AIT in the Classroom

The Green Mile to School

Think Globally, Act Locally

Small Steps Mean Smaller Footprints

A series of lessons designed for science classrooms as a companion to the documentary *An Inconvenient Truth*

Thank you for downloading these curriculum materials and using them in your classroom. We are excited to offer this resource to you and hope that you find them valuable and easy-to-use.

We realize that teachers are under incredible pressure and severe time constraints. As a result, we've made sure that each of our lesson activities is aligned with curriculum standards you are asked to meet in your classroom. The lessons included in this download are designed for high school science classrooms such as Earth Science, Environmental Science, and Physics, but the materials can also be used in Civics classes, middle school science classes and offer Service Learning opportunities as well.

Don't forget to read and post to the AIT blog, located at http://www.participate.net/educators. We are eager to hear about your classroom experiences and your feedback on the lessons.

TIER I LESSON:

The Green Mile to School

Big Ideas:

The lesson is designed to accomplish these major goals:

1. Students will critically discuss the global warming issue.
2. Students will investigate and discuss the relationship between greenhouse gas emissions and global warming.
3. Students will make informed decisions involving science and society.

Audience:

Grades 9-12

Note: This lesson is most effective when students have already seen the film: *An Inconvenient Truth*. If they have not, and time does not permit for the entire film, it is suggested that you show the segments listed in the Class Time section of this lesson plan.

Lesson Overview:

In this lesson, students will learn that greenhouse gas (GHG) emissions are not all the same. They will investigate the type and severity of emissions released by different countries, states, industries, and cars. This assignment will challenge students to estimate the impact of each factor on greenhouse gas emissions. They will also examine their own personal activities and find ways to help reduce the damage.

Objectives:

- Understand why the relative impact on global warming may vary depending on where you live, what car you drive, how many miles you drive, and how you live your life.
- Understand how both government and corporate policy impact individual choices and vice versa.
- Represent data illustrating differences in greenhouse gas emissions at various scales.
- Calculate the relationship between gas mileage and carbon dioxide emissions in various automobiles.
- Construct a concept map illustrating the relationships among government policies, individual behaviors, and global warming.
- Evaluate multiple ways in which emissions of greenhouse gases can be reduced in the local community.

National Standards Addressed:

This lesson addresses the following National Science Education Standards:

Content Standard A

As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry.
- Understandings about scientific inquiry.

Content Standard F

As a result of activities in grades 9-12, all students should develop an understanding of

- Personal health

- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Fundamental concepts and principles that underlie this standard include:

- Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change.

Risks and Benefits:

- Students should understand the risks associated with:
  - natural hazards (e.g., fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions)
  - chemical hazards (e.g., pollutants in air, water, soil, and food)
  - biological hazards (e.g., pollen, viruses, bacteria, and parasites)
  - social hazards (e.g., occupational safety and transportation)
  - personal hazards (e.g., smoking, dieting, and drinking)
- Individuals can use a systematic approach to thinking critically about risks and benefits. One example is to apply probability estimates to risks and compare them with estimated personal and social benefits.

Materials Needed:

- Data sources (see Additional Resources section below) detailing GHG emission standards at the International, National, State, Local, and Individual levels
- Various automobile dealership pamphlets containing information about gas mileage
- Computer with Internet access
- Calculator
- Notecards (for Concept Map creation)
- Copies of Reproducible #1
- Copies of Reproducible #2 (optional)
- Reproducible #3 (optional)
- Copies of Reproducible #4 (optional research extension)

Teacher Prep Time:

30 minutes *(does not include previewing the film)*

Class Time:

Video: 90 minutes to view entire film: *An Inconvenient Truth*
or
20 minutes to review these sections from the film: Chapter 28, *Balancing the Economy*; Chapter 30, *The Solutions Are in Our Hands*; Chapter 31, *Are We Capable of Doing Great Things?*

Activity: 90 minutes (Additional time outside of class may be required for research.)

Desired Outcomes:

After completing this lesson, students will recognize the relationship among international, national, state, and local policy decisions; corporate decisions; personal decisions; greenhouse gas emissions; and global warming.

Students will work in pairs and later in groups. Be prepared to move desks around in your classroom.

Reproducibles:

This lesson contains several reproducibles. These will provide content for the lesson as well as information for the teacher when planning the lesson and student evaluation.

Background:

Before beginning this lesson:

- Preview the film: *An Inconvenient Truth*
- Seek out media sources for the latest information regarding automobile emissions and global warming.
- Gather data on the amount of GHGs emitted by various countries, states, and automobiles. For example, information on cars should include data on green cars, hybrids, SUVs, economy models, and new prototypes. See Additional Resources for websites.
- Ask students to rank the amount of GHG emissions that various countries, states, and automobiles produce. Also ask them what resources they could use to find the amount of carbon dioxide produced by each.
- Have students calculate the amount of carbon dioxide they generate each year by taking one of these online quizzes:
  - o http://www.climatecrisis.net/takeaction/carboncalculator/
  - o http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html
- Ask students to discuss the number of miles the average citizen travels in various countries and states. Discuss urban sprawl, carpooling, public transit, carpool (or High Occupancy Vehicle [HOV]) lanes, and other variables that influence the number of miles traveled and how that affects GHG emissions.

Lesson Steps:

Part 1: Anticipatory set

1. Ask students how they got to school and how far they traveled.
2. Ask students whether they are aware of any global patterns that seem to be linked to temperature increases. Students may be aware of a few of these.
3. Allow students to pair up and share their beliefs on the hazards of global warming and the urgent need for remedial action. <u>Tally these results and keep for later.</u>
4. Ask students to brainstorm ways that GHG emissions might be reduced. It is quite possible that this list will lack depth and breadth of knowledge. <u>Keep this list to show students later.</u>

Teacher's Notes:

Part 2: Building knowledge through a consideration of scale

1. Ask students to read **Reproducible # 1: SPATIAL PERSPECTIVE - What we see depends on where we are.**
2. Lead a discussion concerning the scale of global warming. For example, ask students to share their thoughts on how government policies (international, national, state, and local) either contribute to or help to reduce the problem of global warming. Be sure to also ask students to explain why some nations, states, and cities/regions contribute more GHGs than others.
3. Next, connect the discussion to the role of environmental and special interest groups in contributing to or solving global warming.
4. Finally, ask students about their personal impact on global warming. This can include the distance traveled to school and after-school activities, the types and the number of cars in their households, the products they purchase, etc. Have students share the results of their earlier assignment in the Background section to calculate their CO_2 emissions.
5. Divide the class into the following small groups:
    a. Continents
    b. Nations
    c. States
    d. Regions of the state/province where they live
    e. Automobile manufacturers
6. Assign each group member a research topic from among the following categories. Each group member will share this information within his or her group.
    - Economy
    - Lifestyle (e.g., extent of consumerism, numbers of automobiles per household, miles traveled)
    - Urban vs. Suburban—To what extent does this influence the number of miles driven?
    - Fuel efficiency
    - The automobile manufacturers group will want to seek out information on other topics such as: target audience, environmental record, miles per gallon, extent to which their cars are made of recycled materials, and whether they offer hybrid or alternative fuel models.

*Be sure to ask the groups to find information that is representative of the whole range of cases within their assigned category. For example, the Continents group should consider information on all seven continents. The Nations group should discuss information on several different countries from several different regions of the world—some industrialized, some moderately industrialized, and some developing. An excellent web-based application that may be helpful for the Continents and Nations groups is: http://www.breathingearth.net. Automobile manufacturers should consider

Teacher's Notes:

makers of sport utility vehicles, hybrid cars, economy cars, gas-hogs, "green" machines, and some of the new prototype cars. In addition, they should consider the role of public transportation.

7. At the conclusion of the group discussion, have one representative from each group briefly present the group's findings. In particular, ask the representative to share the reasons why disparities exist among the individual cases within his or her assigned category.
8. At the conclusion of the presentations, revisit the questions asked in Part I above (Anticipatory set) and tally the results:
    - Will students still get to school in the same way? Why or why not?
    - Can they list ways to reduce GHGs?
    - Do they believe that global warming is an urgent problem? Why or why not?
    - Do Americans travel the same number of miles as citizens from other regions of the world? Does a citizen of California drive as many miles as a citizen of Montana? Why?
    - Can they suggest ways to reduce the number of miles traveled by citizens of various parts of the country and the world?
9. Share with the class the differences between the first tallies and the second tallies.

Assessment:

Note: The assimilation of new concepts often requires time and rigorous mediating activity to help us to refine our learning. The use of concept maps as an assessment tool should provide both. The sequence not only provides ample time for assimilation, but also includes student interaction before, during, and after the unit.

1. Students create an individual pre-concept map that exhibits the cause-and-effect correlation of automobiles, consumer behavior, and government policies (all levels) on global warming.
2. Students share, compare, and discuss their concept maps to create a collaborative map within their assigned groups.
3. Students pursue individual activities and research.
4. Students conclude by creating a final, individualized post concept map as a summative assessment.

To further explain concept maps, you may wish to provide students with a copy of **Reproducible # 2: What Is a Concept Map?**

You may want to use **Reproducible # 3: Concept Map Rubric** to evaluate students' work.

Share this lesson with other teachers in your school:

- a driver's education teacher may reinforce fuel consumption facts
- an art teacher may discuss spatial perspective in his or her classroom

Academic Extensions/Modifications:

There are many variables that affect fuel consumption besides "city and highway" driving. Students interested in the engineering aspects of fuel efficiency may investigate the influence of:

- Frontal area design (i.e., wind resistance or aerodynamic design)
- Spoilers and other wind impeders, such as large side-view mirrors
- Optional equipment such as air conditioners and other electronically powered options
- Tire inflation

Other contributors to fuel consumption:

- Road composition (e.g., concrete, asphalt, gravel, dirt, etc.)
- Road condition (e.g., dry, wet, icy, snowy, etc.)
- Incline (Mileage decreases with every degree of upslope.)
- Weight (e.g., 150 lbs per person; cargo such as luggage, golf clubs, etc.)
- Special equipment such as heavy duty A/Cs, HD axles, or larger fuel tanks (Add 6 lbs of weight per gal.)
- Outside temperature

Enrichment—a Research Option:

1. If time allows, ask students to conduct more thorough research. Provide students with the two-page rubric for science presentation (Student and Self-evaluation), and discuss expectations and concerns. See **Reproducible # 4: Science Presentation Evaluation Rubric.**
2. Each group should be prepared to offer and defend reasons for the differences in GHG emissions within its assigned category. For example, India has a much larger population than the United States, but its residents generally live a more agrarian lifestyle that is less dependent upon fossil fuels. Europe is more urban than Africa. A North American citizen drives more miles to work and consumes more goods that require global transport, etc. *You may distribute various data source handouts for analysis, data representation, synthesis, and presentation by students.
3. When all groups are ready, have each group present its findings to the rest of the class. Use **Reproducible # 4: Science Presentation Evaluation Rubric** for students to evaluate the presentations. Also provide the self-evaluation form for each group to complete.
4. After the groups have presented, ask students to discuss the following:
   - What are the global warming connections among automobile usage, consumer behavior, and government policies?
   - What are some possible ways to reduce emissions (e.g., carpooling, high occupancy vehicle

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lanes, alternative fuels, hybrid cars, riding a bike, walking, etc.)?

- Based on the data presented, which car would they purchase? Why?
- Which car has the least environmental impact? Ask students to be sure to consider other variables besides carbon dioxide emissions and gas mileage.
- Should the government get involved in creating policies? Why or why not?
- How has the introduction of more fuel-efficient cars affected the oil and automotive industries?
- How can each person impact policy?

Additional Resources:

Data sources for greenhouse gas emissions

International emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/EmissionsInternational.html

National GHG emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html

State and local emissions:
http://yosemite.epa.gov/OAR/globalwarming.nsf/content/EmissionsLocal.html

Individual GHG emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/emissionsindividual.html

EPA GHG emission calculator:
http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html

EPA Climate Change Site: http://yosemite.epa.gov/oar/globalwarming.nsf/content/index.html

The Weather Channel's *Planet in Change* Curriculum:
http://admin.www.weatherclassroom.com/upload/materials/Planet_in_Change_new.pdf

ClimateCrisis.Net (The companion website to the film: *An Inconvenient Truth*):
http://www.climatecrisis.net/

To calculate the quantity of carbon dioxide you generate each year, visit:
http://www.climatecrisis.net/takeaction/carboncalculator/

For information on fuel economy, emissions, etc., including ratings on various car types, visit:
http://www.fueleconomy.gov
and
http://www.weather.com/activities/driving/greenvehicle/?from=drivfl

Mauna Loa Carbon Dioxide data:
http://www.smate.wwu.edu/teched/co-2.html

Breathing Earth (This website displays carbon dioxide emissions for every country on earth):
http://www.breathingearth.net/

SPATIAL PERSPECTIVE What we see depends on where we are.

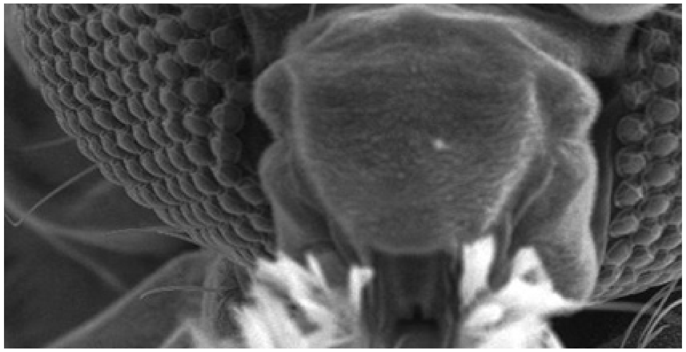
Movie producers often use the idea of spatial perspective when making movies. One method used is called "POV" – or Point Of View. This means that the camera (and the audience) will see a scene just as one of the actors sees it. If there are ten actors in a scene, there are ten possible different POVs. Other spatial perspective methods relate to the distance from the subject in the scene. There is a far shot, medium close-up, close-up, an extreme close-up, and an establishing shot. An establishing shot is an initial reference shot used to frame the setting of the scene. For example, an establishing shot may show the outside of a court house where a trial will be held in the upcoming scene.

The same principles apply in science. Your understanding of a subject will often depend on your point of view and how close or far you are from that subject. For instance, have you ever seen a photo that you thought was a moonscape with valleys and craters, and then found out that you were looking at a magnified picture of skin? The lighting and extra close-up of an electron microscope made the pores look like the pockmarked surface of the moon. Or, perhaps you were looking at what appeared to be beautiful flower petals waving in the breeze, and the camera backed up to reveal a terrifying-looking creature. But wait — it's only a closeup of a mosquito! (See photos at right.) It's all about perspective. Distance, angles, lighting, and position all affect your perception of the image.

A global perspective

Spatial perspective takes on an added dimension when applied to the subject of global warming. It's hard to know what you are looking at until you step away and see the bigger picture.

Many people do not understand the real threat of global warming because they are standing in the wrong place. To fully grasp the danger, they need an "establishing shot." They have to take a step back and a step up from where they are. The neighborhood may look the same, but if they can see the entire planet and the damage that has been done in the last one hundred years, the changes that have occurred will be very clear. Global warming is not about point of view. It's about survival.



Photos courtesy of the Centers for Disease Control and Prevention/Janice Carr

What Is a Concept Map?

Concept maps are graphical representations that show relationships among information. Major concepts are linked by words that describe their relationship. These maps can help you organize and enhance your knowledge on any topic, as well as measure your learning progress; they reveal previous knowledge and deficits in knowledge. Improper links or wrong connections can show a teacher exactly which concepts you are having trouble understanding.

Concept maps may be drawn or built using note cards. This building process allows you to arrange and rearrange the layout of your concept maps before deciding on a final version. You can present your concept maps to the class, each presentation serving as a way to teach classmates about a different aspect of the topic at hand. Concept maps may also be used as an assessment tool.

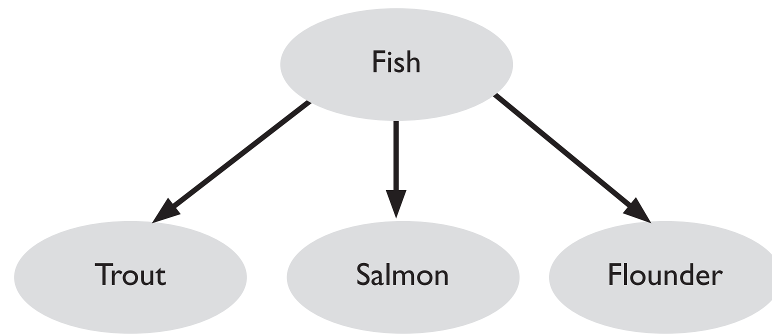
Concept Map Resources: To view some examples of concept maps, concept mapping software, and instructions for use, refer to the following websites:

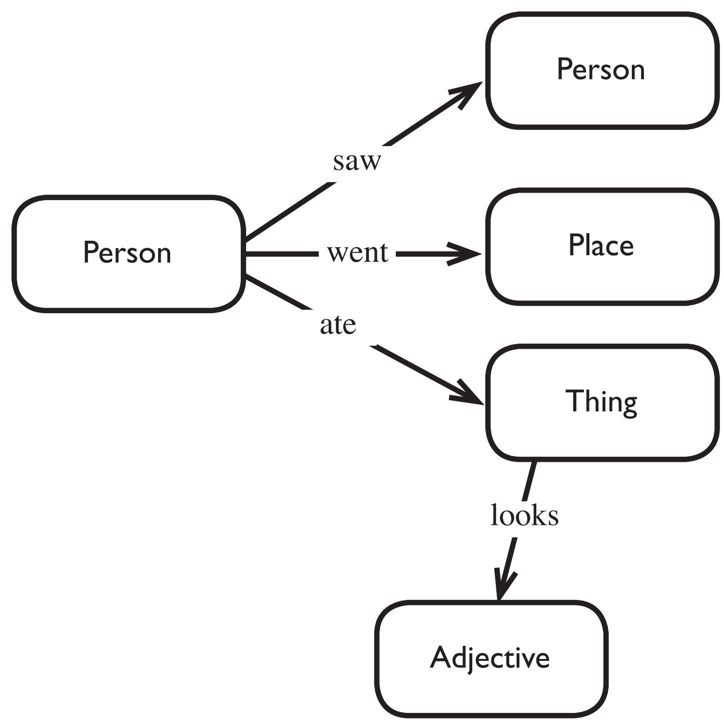
http://www.graphic.org/concept.html

http://www.flaguide.org/cat/minutepapers/conmap7.php

http://cmap.ihmc.us/

http://www.socialresearchmethods.net/kb/conmap.htm





Concept Map Rubric

Alternative Concept Map Scoring Rubric

*Developed by Robert Corbin and Angelique Seifert

Bloom's Higher/Lower Order Thinking	**Points**
Knowledge and Comprehension	1
Application and Analysis	2
Synthesis and Evaluation (Attitude)	3
Ausubel's Cognitive Learning Theory after Novak and Gowin, 1984 Relationships of Linkage and Reasoning Indicators	
Hierarchical (Scored for overall extent; 1 point for each identified level)	H1 – H5
Differentiation (Scored for the overall extent of refinement and/or specificity and explanation of response)	D1 – D5
Cross Concept Linkage (Each individual response between concepts)	C1

The purpose of a concept map is to measure changes in a student's cognitive framework. Generally speaking, students will receive overall higher scores for responses reflecting higher order thinking.

Scoring for Bloom's Scale of Higher and Lower Thinking:
When scoring an answer, consider each of the three categories (Knowledge and Comprehension, Application and Analysis, and Synthesis and Evaluation), and score accordingly. Therefore, each answer is scored and there is a wide range of total number of points that could be accrued.

Scoring for Ausubel's Cognitive Learning Theory:
This aspect of the scoring rubric utilizes three of Ausubel's ideas concerning cognitive frameworks, hierarchy, differentiation, and cross concept linkage.

- Hierarchy – When scoring for the extent of hierarchical placement of responses, look for an overall trend from general to more specific concepts, and assign one hierarchical point value for the total map. For example, if you can identify four distinct levels of hierarchy, assign a score of H4.
- Differentiation – When scoring for the extent of differentiation, look for specific responses that indicate a refinement of knowledge concerning each concept depicted. For example, if a concept is explained in specific detail, the score may be a D4 or a D5.
- Cross Concept Linkage – When scoring for cross concept linkage, look for lines that connect concept to concept, or drawn additions to the map. Score each line or drawn addition.

Science Presentation Evaluation Rubric

Assignment:	
Student Name:	**Score:**

This analytic rubric is used to verify specific tasks performed during a student presentation. If the task has been completed, all points are awarded. No points are awarded if the task is not complete.

Category	Scoring Criteria	Points	Student Evaluation	Teacher Evaluation
Organization ***15 points***	The type of presentation is appropriate for the audience.	**5**		
	Information is presented in a logical sequence.	**5**		
	Presentation appropriately cites two references or more.	**5**		
Content ***35 points***	Introduction piques interest and establishes the speaker's credibility.	**5**		
	Scientific terms are defined	**10**		
	Presentation is accurate.	**10**		
	There is a logical summary of the presentation.	**10**		
Presentation, ***Oral or Other*** ***50 points***	*Oral* Good eye contact is maintained with audience. *Other* Presentation is visually interesting.	**10**		
	Oral Speaker's voice is clear and audible. *Other* Presentation can be viewed easily from anywhere in the room.	**10**		
	Oral Speaker uses appropriate body language. *Other* Presentation is artistically pleasing but not distracting.	**5**		
	Oral Correct pronunciation of words and proper use of language. *Other* Grammar and punctuation are correct.	**5**		
	Oral A visual aid is used for support. *Other* Presentation properly cites author(s).	**5**		
	It is clear that the presentation has been practiced and that it is based on results from reliable sources.	**10**		
	Presentation meets time restrictions.	**5**		
Score	**Total Points**	**100**		

Self-evaluation

Evaluate your group's performance honestly by selecting the appropriate rating.					
	Criteria		Complete	Partial	Not at All
Presenter	Preparation	The presentation is well thought out and thoroughly prepared.			
	Posture	Posture is appropriate throughout the presentation.			
	Eye contact	Good eye contact is maintained with the audience.			
	Language	Language and pronunciation are used properly.			
	Vocal	Uses a clear voice, easily heard at the back of the room.			
Content	Logic & flow	Sequential outline; connects results from the experiment.			
	Length	Stayed within the assigned time requirement.			
Speaker Support Materials	Visual aids	At least one well-prepared visual aid representing gathered data is properly labeled and used for support.			
	Viewability	Easily viewed from a distance			
	Artistic merit	Artistically pleasing without being distracting			
	Grammar	Good writing skills and punctuation			

TIER 2 LESSON:

Think Globally, Act Locally

Big Ideas:

The lesson is designed to accomplish these major goals. Students will:

1. Locate primary source documents and analyze them for bias.
2. Make informed decisions involving science and society.
3. Prepare cogent presentations with support materials (e.g., tables, graphs, PowerPoint presentations, or other products) in order to clarify their positions in a community meeting.

Audience:

Grades 9-12

Note: This lesson is most effective when students have already seen the film: *An Inconvenient Truth*. If they have not, and time does not permit for the entire film, it is suggested that you show the segments listed in the Class Time section of this lesson plan.

Lesson Overview:

Only two industrialized nations have chosen NOT to ratify the Kyoto Protocol: the United States and Australia. However, in the absence of a Federal agreement, several U.S. cities have chosen to adopt the provisions of the Kyoto Protocol on their own. In this lesson, students will research the history of the Kyoto Protocol, the implications of the treaty, and the reasons many local governments have chosen to support it. Students will then determine which communities in their state, if any, have "ratified" Kyoto and will interview local politicians on their reasons for supporting or not supporting "ratification." Finally, upon completing these investigations, students will role-play key officials from various countries in order to present the official government positions on whether to support the Protocol. City Council members, County Commissioners, Mayors, School Board members, parents, community activists, and others may be invited as audience members.

Objectives:

- Locate, analyze, discuss, and evaluate sources describing the Kyoto Protocol and global warming.
- Develop competencies associated with "public work" through data gathering, teamwork, public speaking, problem-solving, and civic participation.
- Role-play the positions of several stakeholders on the issue of global warming.
- Analyze global warming and associated problems from international, national, and local perspectives.
- Learn how to solve complex scientific problems through the workings of a local democracy in a creative, constructive manner.

National Standards Addressed:

This lesson addresses the following National Science Education Standards:

Content Standard A

As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry.
- Understandings about scientific inquiry.

Teacher Prep Time:

30 minutes *(does not include previewing the film)*

Class Time:

Video: 90 minutes to view entire film: *An Inconvenient Truth*

or

20 minutes to review these sections from the film: Chapter 3, *Basic Science of Global Warming*; Chapter 4, *Global Warming Cartoon*; Chapter 6, *CO_2 Measure Since 1958*; Chapter 9: *CO_2 Levels Back 650,000 Years*; Chapter 26, *Is There A Controversy?*; Chapter 27, *Science Fraud*; Chapter 28, *Balancing the Economy and Environment*; Chapter 29, *City By City*

Activity: Four 90-minute or six 60-minute class periods (Additional time outside of class may be required for research.)

Content Standard F

As a result of activities in grades 9-12, all students should develop an understanding of

- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Fundamental concepts and principles that underlie this standard include:

- Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change.

Risks and Benefits:

- Students should understand the risks associated with:
    - natural hazards (e.g., fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions)
    - chemical hazards (e.g., pollutants in air, water, soil, and food)
    - biological hazards (e.g., pollen, viruses, bacteria, and parasites)
    - social hazards (e.g., occupational safety and transportation)
    - personal hazards (e.g., smoking, dieting, and drinking).
- Individuals can use a systematic approach to thinking critically about risks and benefits. One example is to apply probability estimates to risks and compare them with estimated personal and social benefits.

Materials Needed:

- Data sources that document greenhouse gas (GHG) emissions at the international, national, state, local, and individual levels (see Additional Resources section)
- Masking tape (optional)
- Flags from the United States, China, India, United Kingdom, Russia, and Japan (optional)
- Computers with Internet access
- Calculators
- Copies of Reproducible #1
- Copies of Reproducible #2

Desired Outcomes:

After completing this lesson, students will understand how to apply scientific and democratic principles in concert to affect positive environmental and societal change. Every American can deconstruct power structures and established societal codes in order to achieve justice through democratic participation.

- Copies of Reproducible #3
- Copies of Reproducible #4
- Copies of Reproducible #5
- Prizes (e.g., trophies or ribbons) for the highest scoring presentation team (optional)

Reproducibles:

This lesson contains reproducibles that provide data about emissions and global warming. They may be used as handouts if time prevents students from finding their own data. Additional reproducibles are provided for assessment of presentations and concept maps.

Background:

Before beginning this lesson, preview the film: *An Inconvenient Truth*. In addition, seek out media sources for the latest information regarding the Kyoto Protocol and global warming. Because this lesson includes discussions, role plays, and research assignments, you should also either ask your students to review the following sources or use them to prepare a list of reference materials for your students:

- The EPA's Global Warming website:
  http://yosemite.epa.gov/oar/globalwarming.nsf/content/index.html
- School library for print (e.g., books, magazines, and reports) and audio-visual materials that address the Kyoto Protocol, environmental forecasts, recommended solutions, and socio/political/economic positions
- The public library for all of the above
- The public information department websites of your city and state for brochures, reports, charts, action plans, and projections on air quality

This list should be as complete as possible so that students will get a sense of the diversity of views on this topic. Assemble and organize printouts and copies of photos, data, and articles that your students can use. Since they will be role-playing public officials and spokespersons with different perspectives, the students will need to sort through the materials to isolate and organize data that supports their individual roles. Many of these resources (Internet and print) will also have a list of connecting links and publications that will give students even more research opportunities.

Lesson Steps:

Preparation:

Plan ahead: Invite judges to sit in on Day 4 of the lesson. Ask representatives from the community to attend. One way to give more importance to this activity is to ask a full range of other staff members

Teacher's Notes:

Suggestion:
Use masking tape to define national borders and hang flags.

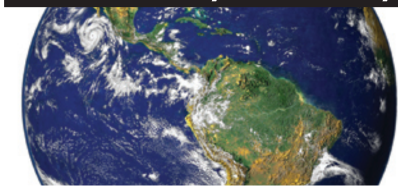
or community members to serve as judges and let your students know they are coming. For example, a judging panel with a civics person, speech person, environmental science person, and an art teacher would give a full range critique.

Day 1: Getting your heads into it

1. As a take-home assignment, ask students to investigate local air quality and global warming policies. If possible, interview local, regional, or state officials to identify regulations, policies, or initiatives related to global warming.
2. Lead a discussion on what students learned about local air quality policy. In particular, ask students:
   - Does the local government consider global warming and air quality to be the same issue or not?
   - Do government officials believe their community is doing enough with respect to air quality and global warming?
3. Ask students why different areas of the country have different air quality challenges, policies, and perspectives. (Sample answers: population, weather patterns, state regulations, proximity or density of industry, etc.)
4. Pass out or ask students to research and assemble articles, photos, charts, and data on the Kyoto Protocol; local and regional global warming initiatives; and local air quality. Ask the class to review them thoroughly to identify trends.
5. Explain that this is a week-long activity and that students will be addressing environmental issues on both global and local scales.
6. Distribute and read **Reproducible # 1: Six Countries and Their Positions on the Kyoto Treaty** to the class. Explain that this document will be the foundation for discussion, research, and resulting reports.
7. Divide the class into six groups and assign each group to represent one of the following countries*:
   a. United States
   b. European Union
   c. China
   d. Russia
   e. Japan
   f. India

   Ask the students from each *country* to sit together in a designated section of the room.

   *As an alternative, you may assign students to represent decision-makers on a local level.



Teacher's Notes:

For example:

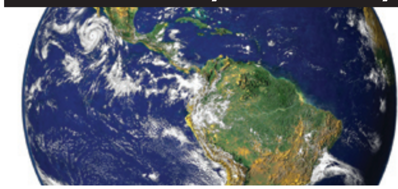
a. Business leader from the energy sector
b. Business leader from the manufacturing sector
c. Farmer
d. Medical professional
e. Mayor or Governor
f. Representative from the EPA

8. Ask a few of the following thought-starter questions:
    - Is the current global warming just part of a normal cycle? Why?
    - Who can we turn to for the most reliable information?
    - Can we trust new, sophisticated scientific technology, such as computer modeling, that says our environment is in trouble?
    - What will happen if the technology is right?
    - What will happen if the technology is wrong?
    - What corrective actions (if any) make the most sense? Why?
    - What are the differences between the terms CO_2 *emissions*, *GHGs,* and *ozone depletion*?
9. Ask students what they know about the Kyoto Protocol. This may take some prodding, so it will be beneficial to have a list of thought-starters ready.
    - Where is Kyoto?
    - What was the Kyoto meeting about?
    - Why is that important?
    - Who is participating? Why?
    - Who is not participating? Why?
10. Ask students to define the environmental responsibilities and conflicting values of citizens who come from different countries and cultures. Here are some thought-starters for this discussion:
    - In many countries people rely on wood for their cooking needs as well as for warmth. This consumes valuable timber and produces harmful GHG emissions. This is bad, but uncooked food can lead to disease, and people die when there's not enough heat. Which is worse? What is the answer?
    - Is there a difference between the environmental damages from GHG emissions in a developed country versus the GHG damages in undeveloped countries? Explain the difference.

Write some of these thought-starters on the board to encourage students to keep thinking about them.

- Which is more excusable: deforestation for agricultural/forestry production in a developed country or deforestation for/by farmers in a developing country that uses the land and trees for survival?
- Are businesses from less developed countries that cut down forests for export or businesses from developed countries that demand the timber more environmentally responsible? What about governments that engage in this sort of exchange?
- As developing countries continue to progress, vehicles, residences, and industries that rely on fossil fuels for heat and power contribute more and more GHGs. Should they slow down their rate of progress? Should they be asked to reduce emissions of GHGs?
- Several industrialized countries have instituted a carbon tax. Some people have suggested that these countries should institute carbon credits. What are carbon taxes and carbon credits? Do you think they should be employed by developed countries?
- There are healthcare, medical well-being, and social costs associated with burning fossil fuels. Some would argue that these are external costs and that the industrialized world, particularly the United States, does not pay for them. What are external costs and who pays for them?
- Several models of fuel-efficient automobiles are available to the average consumer in the developed world. Why are there so few on the road?
- What is permafrost? What effect can the melting of the permafrost have on your (role play) country?
- What impact would rising sea levels have on your (role play) country? What about shoreline housing?
- What are coral reefs? How and why are they changing? How will that affect your assigned country? What will it do to sea creatures?
- What is the Larsen-B ice shelf? Is this question relevant to your country?
- How do the rates of destruction of forests and the rates of drought compare with previous history?

11. Pass out **Reproducible #2: Signatories to the Kyoto Protocol: June 2005** and **Reproducible #3: The Kyoto Protocol - Some FAQs and QSAs.**
12. Ask each *country* to formulate a preliminary one-sentence statement about its initial position on the Kyoto Protocol/CO_2 emissions issue.
13. Ask students to consider carefully how their position may be influenced by their region or country's industry, commerce, and population growth rate, etc.
14. Assign students out of class research: Ask group members to find the following information about



Review the schedule for the week-long activity and highlight the critical deadlines.

their assigned country or locality.

- type of government
- urban/rural demographics
- population and rate of growth
- economic resources and GDP
- reliance on import or export
- lifestyles of its citizens
- GHG emissions from transportation and industry
- growth or deterioration of forestlands and farmlands
- environmental protection strategies/policy
- names and titles of the policymakers who oversee the following in their assigned country or region:

  government oversight
  transportation
  industry
  economy
  farms and forests
  environment and land protection
  urban development

15. After conducting the preliminary research, members of each nation, region, or locality should caucus, discuss, and organize their findings in order to present the real position of the country they represent.
16. Preview of Day 2
    a. Describe the role plays, research procedures, reports and presentations, and the debate preparation.
    b. Explain that each student will assume a role and become a spokesperson or advocate for the assigned office and the country or region.

Day 2: Taking on the roles

1. Review Day 1 activities; answer questions.
2. Offer the following discussion questions:

   Which of the following produce harmful GHGs? What kind of GHGs do they emit?

   - forest fires
   - livestock
   - homes heated with solar panels
   - dead fish on the shore
   - sand storms
   - sail boats

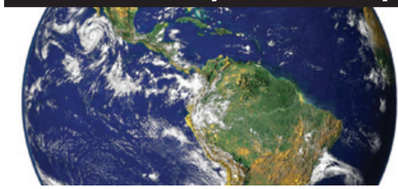
Teacher's Notes:

- homes heated with electricity
- homes heated with natural gas
- rice paddies
- cars, trucks, and buses
- sawmills
- slaughterhouses
- volcanic eruptions
- swamps
- garbage dumps and landfills
- hurricanes and tornadoes
- automotive paint shops
- oil spills
- car assembly plants
- crop dusters

3. Instruct students to assume the roles of the identified policymakers or citizens. Ask the students to have an internal caucus within their assigned country or locality with the goal of formulating a united position on the Kyoto Protocol. In other words, the students should use the positions and experience of their real-life counterparts as they build a platform for their country's or locality's position on the Kyoto Protocol.
4. Ask a representative from each group to present its position at an international conference. It would be best to have that one person take on the role of the actual person who speaks on behalf of the area of the country or locality to which he or she is assigned.
5. Instruct each policymaker to write a bullet-point summary and a rationale for his or her position on the Kyoto Protocol with the help of teammates. Students can use information from the teacher and research from Days 1 and 2 to formulate these talking points. You may wish to distribute **Reproducible #4: ClimateCrisis.net Information** for this step.
6. Direct the team to review the preliminary statement they made on Day 1 to see how accurate their perceptions were.
7. Each team should synthesize the bullet points from all team members and decide on a firm position that will help them prepare for the presentation on Day 3.
8. Review and Preview of Day 3
    a. Review the activities and findings of the day and answer any questions. Make suggestions for further research or idea development.
    b. Preview Day 3. Students will prepare presentation boards/PowerPoint slideshows as visual aids for their country's presentation.

Day 3: Pulling it all together

1. Review work from Days 1 and 2.
2. Discussion question: What was the biggest surprise you found in your research and/or caucus with your group?
3. Discuss the presentations that will be prepared in class today. Provide tips on how to make an interesting, convincing presentation. Show samples if possible. If some of the students will be using PowerPoint, review the format and some samples of good and bad work. Provide students



Teacher's Notes:

with a copy of **Reproducible # 5: Presentation Evaluation Rubric**.

4. Ask each country to choose a coordinator who will take the lead in organizing and designing.
5. Ask each group to create an outline for its presentation and design the boards, screens, or visuals that will support their speaker(s).
6. When their materials are ready, each country or locality will decide whether one person will make the presentation or whether all or most of the group will be involved.
7. Students will then rehearse (and critique themselves) internally and make necessary changes.
8. Review and Preview of Day 4
    a. Review the work of all the countries or localities and make suggestions for last-minute improvements.
    b. Preview the Day 4 activities.

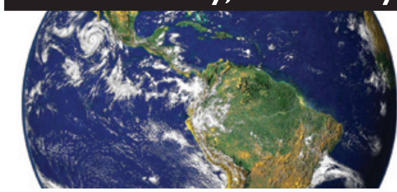
Day 4: The Summit - presenting the case

1. Preview the presentation format.
2. Introduce the judges. To determine the order of presentation, have the team leaders draw numbers.
3. Presentations
    a. Each country will be given 10-15 minutes to present, followed by 2-5 minutes for a Q&A session.
    b. The rest of the class period will be open discussion and/or critique by the teacher or judges.
4. Use **Reproducible # 5: Presentation Evaluation Rubric** for the judging. Each presentation will be judged on depth of knowledge, organization, structure, presenters' skills, and visual support. The winning nation should receive trophies or ribbons, and perhaps an opportunity to make its presentation before the entire student body.

Day 5: Compromise Position Extension

If there is time for a fifth day for this activity, the class can use its new-found knowledge to form a combined position paper regarding the United States', their region's, or the local stance for or against the Kyoto Protocol. Arriving at a compromise position will require diplomacy as well as knowledge and conviction. It will also require the close oversight and wisdom of the teacher.

When the document is finished, it can be printed on manuscript paper and posted on the school bulletin board and/or sent to decision makers. Copies can also be attached to a press release. The release can be sent to newspaper editors and feature writers, or the public service director of radio and television stations. It can also be sent to special interest groups like the local chapter of the



Sierra Club, the Chamber of Commerce, etc. Many of these groups will follow up with phone calls and letters wanting more details or even interviews with the students or teachers. The process will show the students how media contacts are developed and can be used to call attention to their cause. It will give the students a sense of community interaction and will elevate the project above the normal school assignment.

Additional Resources:

Data sources for greenhouse gas emissions

International emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/EmissionsInternational.html

National GHG emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html

State and local emissions:
http://yosemite.epa.gov/OAR/globalwarming.nsf/content/EmissionsLocal.html

Individual GHG emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/emissionsindividual.html

EPA GHG emission calculator:
http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html

EPA Global Warming Site:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/index.html

The Weather Channel's *Planet in Change* Curriculum:
http://admin.www.weatherclassroom.com/upload/materials/Planet_in_Change_new.pdf

ClimateCrisis.Net (The companion website to the film: *An Inconvenient Truth*):
http://www.climatecrisis.net/

U.S. Mayor's Climate Protection Agreement
http://www.seattle.gov/mayor/climate/default.htm#who

Chicago Climate Exchange
http://www.chicagoclimatex.com

California Air Resource Board
http://www.arb.ca.gov

Six Countries and Their Positions on the Kyoto Treaty

THE LEGAL PROCESS LEADING TO THE KYOTO PROTOCOLS

1988	1992	1994	1995	1997	1998	2001	2005
Intergovernmental Panel on Climate Change established. Environmental concerns growing. UN General Assembly held first debate on climate change; adopted 43/53 on the "Protection of the global climate for present and future generations of mankind (IPCC)."	UN Framework Convention on Climate Change (UNFCC) opened for signing at the Earth Summit in Rio de Janeiro. Also referred to as the UN Conference on Environment and Development (UNCED).	Convention came into force March 21. 186 governments are party to the convention; it is close to achieving universal membership.	In March and April, the Berlin Conference of the Parties (COP) sought to determine the commitments required by industrialized countries.	These talks led to the Kyoto Protocol being adopted on December 11. 87 countries signed the Protocol.	Talks to determine the Protocol's rulebook were discussed in November in Buenos Aires and later in Bonn in July 2001.	After much more negotiation in Marrakech during October and November, the rulebook for the Protocol was agreed upon; these became known as the Marrakech Accords.	On February 16, the Kyoto Protocol finally came into effect 90 days after Russia ratified it.

Timetable source: http://globalgophers.com/articles/kyoto-protocol.htm

THE BIG SIX

United States

- The treaty called for 55% global reduction of carbon dioxide, based on 1990 levels.
- The United States is responsible for more than one-third (36%) of the entire world's CO_2 emissions – far more than any other country.
- As one of the original signatories of the Kyoto treaty, the United States agreed to reduce emissions by 6% from its 1990 levels.
- In 2001 President George W. Bush refused to ratify the treaty, citing these reasons:
  - The US economy could suffer an estimated $400 billion in losses as a result of emissions restrictions on industry and transportation, and the US could lose almost 5 million jobs.
  - Many developing nations that have extremely high emissions are not bound by the emissions limits set in the treaty.
- Since pulling out of the treaty, U.S. emissions have increased 15% above 1990 levels—21% above our initial objective.
- However, several recent events may foreshadow a change in the US position:
  - America's unique political structure gives each of the 50 states the autonomy to legislate Kyoto-like reforms on their own. Environmental leaders in some states are already promoting legislation that supports the objectives of the Kyoto Treaty.
  - The California Air Resources Board has set tough emissions standards and is well known for its strict emissions regulations.
  - The Chicago Climate Exchange is a group of North American municipalities, companies and organizations that have agreed to reduce their emissions over the next several years.
  - Massachusetts, New York, and New Hampshire are creating emission reduction and trading systems.
- The recent 2006 elections have placed many in office who are sympathetic to environmental and global warming issues. This may lead to revisions in the US position on Kyoto.

European Union

- The European Union (EU) became a strong proponent of the treaty and has insisted that every provision be enforced.
- Many European countries were offended by the US rejection of the treaty. This may have motivated them to ratify the treaty in spite of its flaws and their own differences.
- Although other nations have been willing to make necessary changes and, in some cases, forgive nations that failed to meet standards, the EU has opposed any such compromise.
- The EU was initially hesitant about giving credits for maintaining forests which store carbon in what are termed "carbon sinks."
- Despite its strong statements of commitment to the ideals of the treaty, the EU greenhouse gas emissions are only 2.9% lower than 1990 levels.

China

- In 2004, just two years after ratifying the Kyoto Protocol, China backed up its commitment by announcing plans to generate 10% of its power from renewable sources by 2010.
- There are still a number of concerns about China's dedication to the ideals of the Kyoto Protocol.
    - China's status as a *developing country* even though it has the world's largest population and a rapidly expanding economy.
    - *Developing country* status exempts China from mandatory emission reduction objectives.
    - The exemption is a problem for China as it is the world's largest coal producer. Its oil consumption has doubled in 20 years.
    - China does not show signs of complying with any requests for reductions in GHG emissions.
    - China is using a combination of CDM (Clean Development Mechanism) and CER (Certified Emissions Reductions) benefits to enlist foreign support for economic development projects, to promote its own contribution to global climate change, and to help reduce of acid rain.

Russia

- Russia's support was a critical factor in the acceptance of Kyoto and the targeted 55% reduction in greenhouse gas emissions.
- However, subsequent developments have raised questions about Russia's motives.
    - Some suspect that Russia used its support of Kyoto as leverage to open the door to membership in the WTO.
    - Since Russia's industrial output has dropped significantly since 1990, it now could gain billions of dollars through *emissions trading*.
    - *Emissions trading* allows Russia to sell its unused emissions to other signatory countries that emit more than the protocol allows.
    - Some feel that this practice defeats the purpose of setting GHG limits.

Japan

- Even though it is a leading member of the Kyoto Protocol, Japan was initially reluctant to ratify the treaty when the United States refused to sign.
- Its ratification in June 2002 was important because:
    - Japan accounts for 8% of global GHG emissions.
    - Japan promised to reduce emissions by 6% of the published 1990 levels.
- Unfortunately, by 2002 Japan's GHG emissions had actually increased by 11% over its 1990 levels.
- This setback has not deterred Japan from advocating clean air technology or from manufacturing cars with hybrid technology.

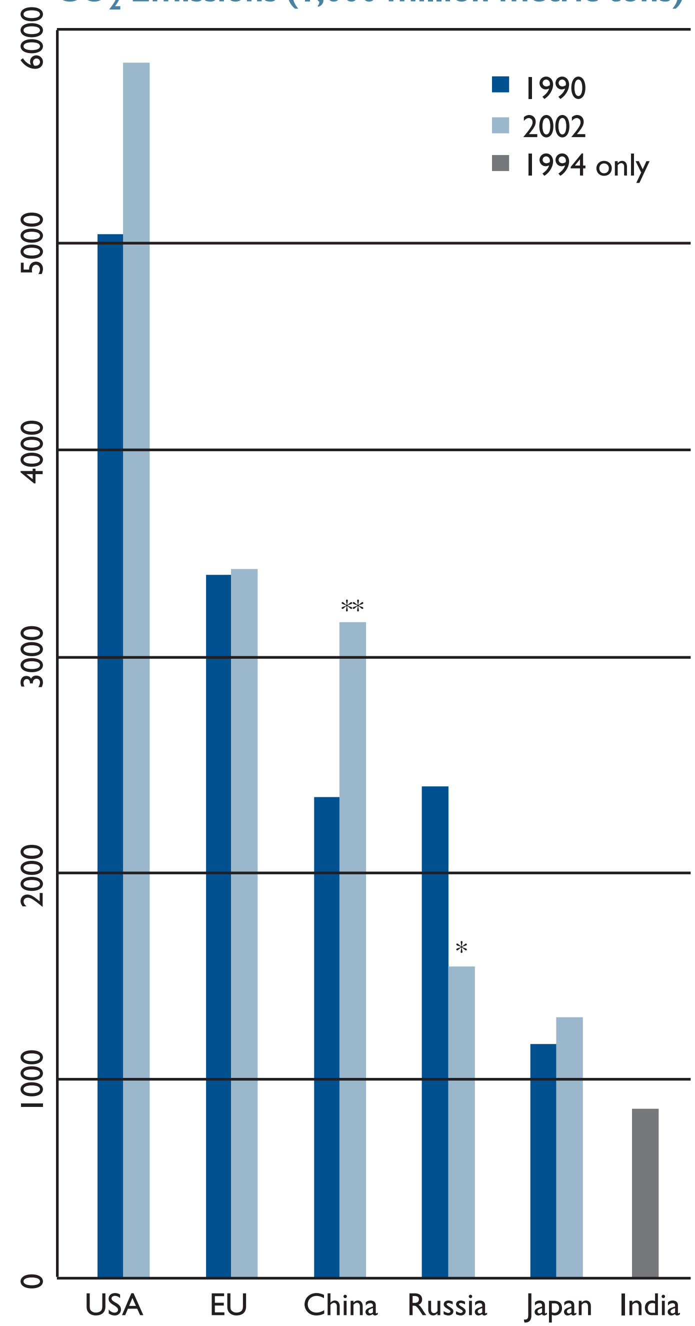
India

- India ratified the treaty in 2002 because its representatives recognized the impact that its population (1 billion) has on global warming.
- Like China, India gained *developing nation* status and thus avoided reduction quotas.
- India has only submitted one emissions report (in 1994). The data from that year showed a 50% increase in emissions.
- India's prime minister maintains that per-capita emission rates of developing countries are a fraction of those of developed nations.

Additional Thoughts

- The responses and actions of India and China demonstrate that *developing nation* status will need to be addressed in the future. Their actions also lend some credence to the US rationale for not signing the treaty.
- No matter how dedicated the Kyoto supporters are, there is no quick-fix solution to climate change. Carbon dioxide that is in the atmosphere will be there for several generations.
- It will take a long-term, global effort and massive changes in energy usage to undo the damage.
- The Kyoto Protocol is not the ultimate solution. It is a necessary first step in that process.

CO_2 Emissions (1,000 million metric tons)



*1999, **2001 (both China figures include Hong Kong)
Sources: UNFCCC (China figures from IEA)

Sources:
http://news.bbc.co.uk/2/hi/science/nature/3143798.stm
http://www.wikipedia.org (various articles)

Signatories to the Kyoto Protocol: June 2005

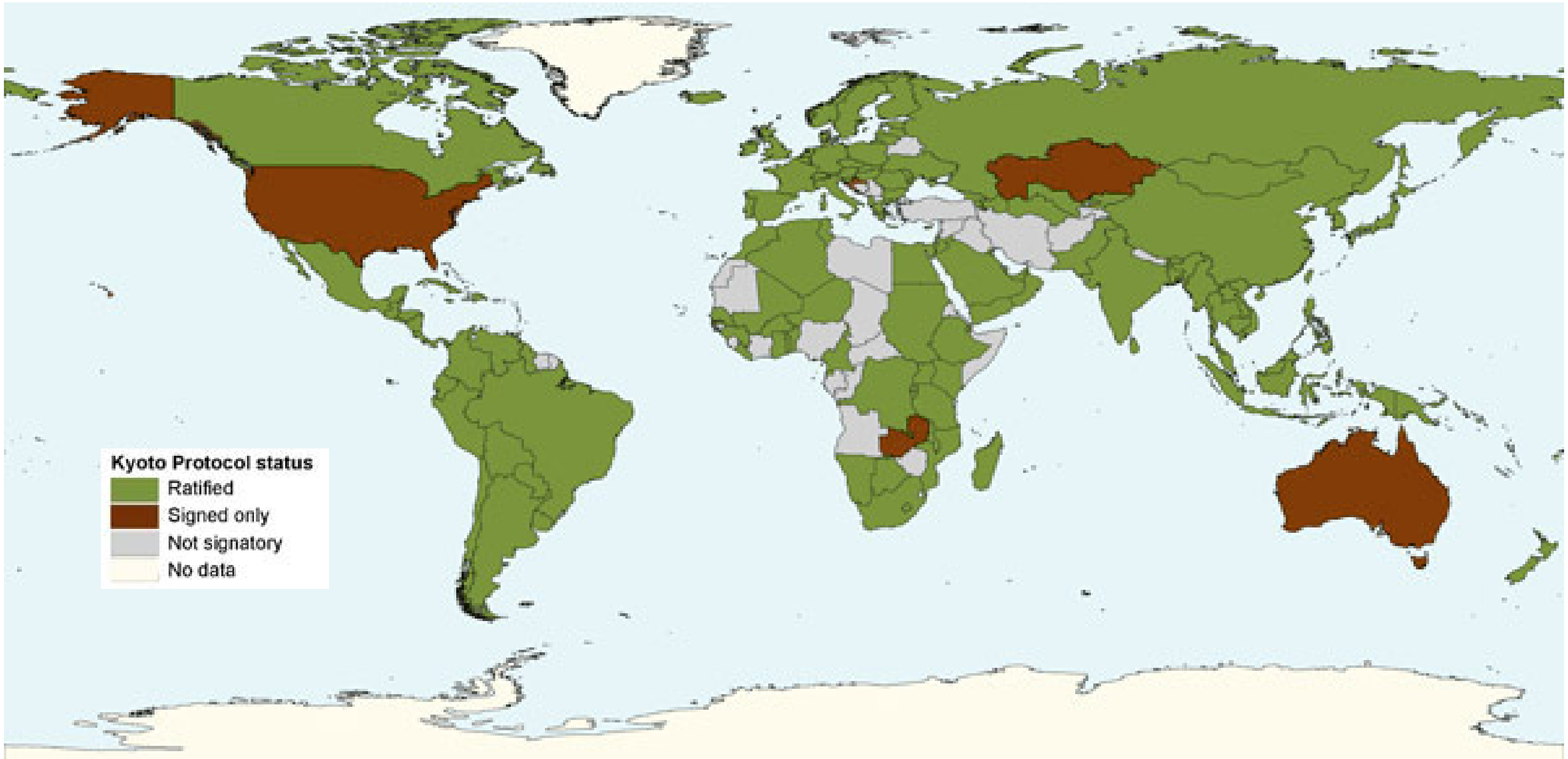


Image credit: World Resources Institute, 2005

Source: http://earthtrends.wri.org/text/climate-atmosphere/map-504.html

This map shows the countries that have ratified or signed the Kyoto Protocol as of June 2005.

Ratifying countries are green. Those that have signed but not ratified are dark brown. Those that have neither signed nor ratified are grey.

For more information regarding the Kyoto Protocol, see
http://unfccc.int/essential_background/kyoto_protocol/items/2830.php

The Kyoto Protocol – Some FAQs and QSAs
(Frequently Asked Questions and Quick Short Answers)

FAQ: *How many Kyoto treaties are there? And why is it called a Protocol?*

QSA: There is only really one treaty, but representatives of the world met six more times to discuss and negotiate terms of the Kyoto Protocol between 1997 and 2006. The word protocol means the first draft of a treaty. Technically, the Kyoto Protocol is now called the Kyoto Treaty. For an excellent graphic representing the timeline for the Kyoto Protocol, visit: http://maps.grida.no/go/download/mode/plain/f/kyoto_protocol_timeline_and_history.png

FAQ: *What was the most important objective of the original treaty?*

QSA: In 1997, the Kyoto Treaty asked all signatories to reduce greenhouse gas emissions by 5.2 percent in 10 years. The objective was short-sighted.

FAQ: *What did that objective lack?*

QSA: That objective only dealt with reducing current and future emission levels. It offered no solutions for the gases that are already in the atmosphere and will continue to be a problem for the next century or so.

FAQ: *Is any organization dealing with the issue of those gases?*

QSA: Yes and no. The Intergovernmental Panel on Climate Change has stated that it will take a 60 percent reduction to make any progress. Many believe that this is both logistically and politically too difficult to implement. The panel's report can be seen at: http://www.grida.no/climate/ipcc_tar/wg1/005.htm

FAQ: *Doesn't the practice of trading emissions credits defeat the overall purpose of setting reduction goals?*

QSA: It seems to reward those who emit the most pollutants and then make deals for credits that relieve them of any penalty. Unfortunately some of the smaller, less developed countries are not really part of the pollution problem and need all the economic help they can get.

FAQ: *Greenhouse gases seem to be an important part of the Kyoto Protocol. What are they and where do they come from?*

QSA: The term covers a number of familiar chemical compounds, including steam and water vapor. Other greenhouse gases are methane, carbon dioxide, and nitrous oxide. CFCs (chlorofluorocarbons) also belong on this list, but since they are generated only by industrial processes, they have a unique status as the only greenhouse gas that is entirely man-made.

FAQ: *What are CFCs? And where do they come from?*

QSA: The full name—chlorofluorocarbons—identifies the ingredients of CFCs as chlorine, fluorine, and carbon compounds. For many years, CFCs have been found in aerosols and air conditioners. Recent legislation has made them less common, but the CFCs released over the years will continue to be a long-term factor in the greenhouse effect.

The entire Kyoto Protocol document can be found on the following website: http://unfccc.int/resource/docs/convkp/kpeng.html

ClimateCrisis.net Information

WHAT IS GLOBAL WARMING?

Carbon dioxide and other gases warm the surface of the planet naturally by trapping solar heat in the atmosphere. This is a good thing because it keeps our planet habitable. However, by burning fossil fuels such as coal, gas, and oil, and clearing forests we have dramatically increased the amount of carbon dioxide in the Earth's atmosphere and temperatures are rising.

The vast majority of scientists agree that global warming is real, it's already happening, and that it is the result of our activities and not a natural occurrence.[1] The evidence is overwhelming and undeniable.

We're already seeing changes. Glaciers are melting, plants and animals are being forced from their habitats, and the number of severe storms and droughts is increasing.

The number of Category 4 and 5 hurricanes has almost doubled in the last 30 years.[2]

Malaria has spread to higher altitudes in places like the Colombian Andes, 7,000 feet above sea level.[3]

The flow of ice from glaciers in Greenland has more than doubled over the past decade.[4]

At least 279 species of plants and animals are already responding to global warming, moving closer to the poles.[5]

If the warming continues, we can expect catastrophic consequences.

Deaths from global warming will double in just 25 years—to 300,000 people a year.[6]

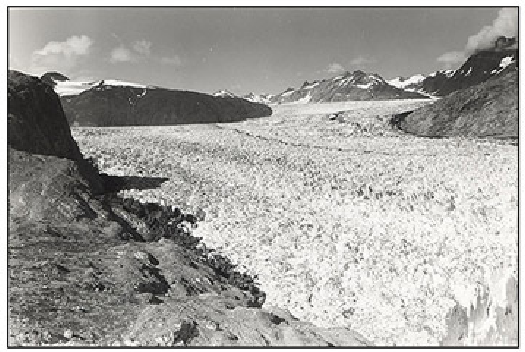
Global sea levels could rise by more than 20 feet with the loss of shelf ice in Greenland and Antarctica, devastating coastal areas worldwide.[7]

Heat waves will be more frequent and more intense.

Droughts and wildfires will occur more often.

The Arctic Ocean could be ice free in summer by 2050.[8]

More than a million species worldwide could be driven to extinction by 2050.[9]




On the left is a photograph of Muir Glacier taken on August 13, 1941, by glaciologist William O. Field; on the right, a photograph taken from the same vantage on August 31, 2004, by geologist Bruce F. Molnia of the United States Geological Survey (USGS).

Image Credit: National Snow and Ice Data Center, W. O. Field, B. F. Molnia

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[1] According to the Intergovernmental Panel on Climate Change (IPCC), this era of global warming "is unlikely to be entirely natural in origin" and "the balance of evidence suggests a discernible human influence of the global climate."

[2] Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. Nature 436: 686-688.

[3] World Health Organization

[4] Krabill, W., E. Hanna, P. Huybrechts, W. Abdalati, J. Cappelen, B. Csatho, E. Frefick, S. Manizade, C. Martin, J, Sonntag, R. Swift, R. Thomas and J. Yungel. 2004. Greenland Ice Sheet: Increased coastal thinning. Geophysical Research Letters 31.

[5] Nature.

[6] World Health Organization

[7] Washington Post, "Debate on Climate Shifts to Issue of Irreparable Change," Juliet Eilperin, January 29, 2006, Page A1.

[8] Arctic Climate Impact Assessment. 2004. Impacts of a Warming Arctic. Cambridge, UK: Cambridge University Press. Also quoted in Time Magazine, Vicious Cycles, Missy Adams, March 26, 2006.

[9] Time Magazine, Feeling the Heat, David Bjerklie, March 26, 2006.

Presentation Evaluation Rubric

Assignment:				
Student Name:		**Score:**		
This analytic rubric is used to verify specific tasks performed during a student presentation. If the task has been completed, all points are awarded. No points are awarded if the task is not complete.				
Category	**Scoring Criteria**	**Points**	**Student Evaluation**	**Teacher Evaluation**
Organization *15 points*	The type of presentation is appropriate for the audience.	**5**		
	Information is presented in a logical sequence.	**5**		
	Presentation appropriately cites two references or more.	**5**		
Content *35 points*	Introduction piques interest and establishes the speaker's credibility.	**5**		
	Scientific terms are defined.	**10**		
	Presentation is accurate.	**10**		
	There is a logical summary of the presentation.	**10**		
Presentation, *Oral* or *Other* *50 points*	*Oral* Good eye contact is maintained with audience. *Other* Presentation is visually interesting.	**10**		
	Oral Speaker's voice is clear and audible. *Other* Presentation can be viewed easily from anywhere in the room.	**10**		
	Oral Speaker uses appropriate body language. *Other* Presentation is artistically pleasing but not distracting.	**5**		
	Oral Correct pronunciation of words and proper use of language. *Other* Grammar and punctuation are correct.	**5**		
	Oral A visual aid is used for support. *Other* Presentation properly cites author(s).	**5**		
	It is clear that the presentation has been practiced and that it is based on results from reliable sources.	**10**		
	Presentation meets time restrictions.	**5**		
Score	**Total Points**	**100**		

Self-evaluation

Evaluate your group's performance honestly by selecting the appropriate rating.					
	Criteria		**Complete**	**Partial**	**Not at All**
Presenter	Preparation	The presentation is well thought out and thoroughly prepared.			
	Posture	Posture is appropriate throughout the presentation.			
	Eye contact	Good eye contact is maintained with the audience.			
	Language	Language and pronunciation are used properly.			
	Vocal	Uses a clear voice, easily heard at the back of the room.			
Content	Logic & flow	Sequential outline; connects results from the experiment.			
	Length	Stayed within the assigned time requirement.			
Speaker Support Materials	Visual aids	At least one well-prepared visual aid representing gathered data is properly labeled and used for support.			
	Viewability	Easily viewed from a distance			
	Artistic merit	Artistically pleasing without being distracting			
	Grammar	Good writing skills and punctuation			

TIER 3 UNIT:

Small Steps Mean Smaller Footprints

Big Ideas:

Students will accomplish these major goals:

Part 1 - Movie Circles

1. Authoritatively discuss major global topics.
2. Engage in critical thinking and reflection as they view, discuss, and respond to films dealing with global change.

Part 2 – Modeling

1. Recognize that biogeochemical cycles influence humanity from the microscopic to the macroscopic.
2. Visualize molecular, trophic, and global models of carbon.
3. Interact with large sets of scientific data to create models of carbon from the molecular level to the global level.
4. Analyze carbon footprints.

Audience:

Grades 9-12

Note: This unit is most effective when students have already seen the film: *An Inconvenient Truth*. If they have not, and time does not permit for the entire film, it is suggested that you show the segments listed in the Class Time section of this lesson plan.

Unit Overview:

To be motivated learners, students must see a direct and immediate impact of their efforts on their own lives and on the community. Students need an effective model to exercise critical thinking, problem solving, and decision making. Providing a step-by-step problem-solving model can be an excellent way to teach students across the curriculum.

This semester-long, project-based unit is based on five tenets:

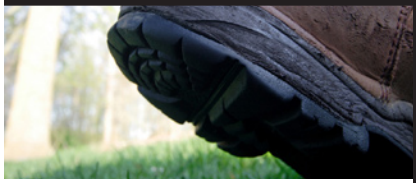
1. Teachers and students must turn to natural phenomena around them to identify problems to be solved. This empowerment helps students realize that they can become actively involved in greater and seemingly more distant issues such as global warming.
2. Teachers and students need learning experiences that let them create their own universes of knowledge rather than assimilating knowledge created by others.
3. Student questions are the major contributors, if not the guides, to the scope of the unit. Students are more receptive when their own learning agendas are considered and incorporated.
4. With this unit, teachers act as guides and co-learners to help students acquire the skills of effective learners and problem solvers. This dynamic enables students to see and feel that they are acting upon the world.
5. Finally, parents, teachers, subject-matter experts, and other contributors are encouraged to take an active role in the classroom, just as students must be allowed to take a more active role in the community.

The Sequence:

Part 1 – Movie Circles

One of the most effective new educational tools is the "Literature Circle." This is simply a classroom adaptation of a "Book Club," in which a group of friends or members of the same social group select a book, read it on their own, and then discuss it in their meetings.

The same approach can be used in the classroom with film—a "Movie Circle." The format allows students to gather different—and often opposing—impressions and insights. Individual students are also able to feel more secure in their opinions by aligning themselves with others who share their impressions. Even students with lower reading, critical-thinking, or presentation skills can participate through this type



of alliance. The experience may even help them improve their overall academic skills.

The Movie Circle will create a more in-depth understanding of *An Inconvenient Truth*. It will also sharpen the students' abilities to examine, evaluate, organize, and defend their opinions.

Perhaps the greatest value of this approach is that the students—not the teacher—determine the scope, depth, and outcomes of the learning process. While this may be only partly true in actuality, the sense of self-determination provides incentive to delve into the topic of global warming with greater intensity than if it were just a reading assignment or book report. This sense of ownership can be further enhanced if each group selects its own name and publishes its report or presentation with that name as the by-line.

Part 2 – Modeling
After discussing the topics of climate change and renewable energies, students will interact with large sets of scientific data in order to create gumdrop, box, and computer models of carbon from the molecular level to the global level. Following this introduction to the topic, student teams will analyze their school's carbon footprint.

Part 3 – Community Problem Solving
To conclude the unit, students will brainstorm a list of the problems associated with global warming, identify which is most important, brainstorm solutions, and then implement those solutions. The series of solutions and recommendations will help to reduce the school's or community's impact on the environment. As a whole, the class will select the best ideas from all teams, and then develop and practice a presentation that will be delivered to a larger, public audience. Teams will also have the option of presenting their findings and their recommendations to their classmates, the community, and to the Future Problem Solving Academic Program.

Objectives:

Part 1 - Movie Circles

- Use viewing skills and strategies to understand and interpret visual media and to research information on global warming.
- Use the general skills and strategies of the reading process while researching global warming.

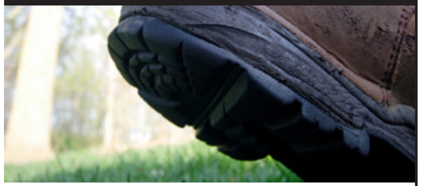
Part 2 – Modeling

- Suggest lifestyle modifications that would decrease the amount of carbon dioxide released into the atmosphere.
- Understand that matter and energy are neither created nor destroyed, but may change forms and locations. Construct gumdrop models to simulate photosynthesis, respiration, and ADP-ATP (adenosine diphosphate - adenosine triphosphate) transfer.
- Create functional, idealized models of geochemical cycles.
- Conduct controlled experiments with computer models in order to predict inputs, rates,

Big Ideas:

Part 3 - Community Problem Solving

1. Develop divergent thinking skills by generating a list of at least 20 challenges, problems, or issues that cause or are caused by global warming at multiple levels (e.g., local, regional, global).
2. Develop convergent thinking skills by selecting one problem from the list whose solution could have the greatest impact on resolving the other problems.
3. Produce divergent solutions to this problem.
4. Create criteria to evaluate the merit of the solutions.
5. Evaluate solutions based on the extent to which they meet the criteria generated in Step 4.
6. Develop a best solution action based on the highest scoring solution.
7. Explain through a written proposal how the problem will be solved.
8. Present their solution in a poster session or other formal arena.
9. Experience a Eureka! moment when realizing that they can solve complicated societal and scientific problems in a creative, constructive manner, through the workings of a local democracy.



Teacher Prep Time:

60 minutes *(does not include previewing the film)*

Class Time:

Part I - Movie Circles:

- 90 minutes to view entire film: *An Inconvenient Truth*
- 180 minutes to participate in the Movie Circle

Part 2 - Modeling:

- Photo gumdrops - one 90-minute class period
- Carbon cycle box models - two or three 90-minute class periods
- Carbon cycle computer models - two 90-minute class periods for activities
- Four 90-minute or six 60-minute class periods for research

Part 3 - Community Problem Solving:

Depending upon the depth, this could take an entire semester or academic year.

outputs, behavior, and human impact on the carbon cycle.

- Research, collect, analyze, organize, and synthesize data in models.
- Hypothesize about, control variables in, and experiment with possible human causes of global warming in a computer model.
- Relate inorganic and organic outputs and inputs to growth, photosynthesis, nutrient cycling, and the carbon cycle.
- Cite the movement and changes of matter and energy that occur in photosynthesis and growth of green plants.
- Describe the nutritive role of food.
- Construct and analyze diagrammatic and graphic quantitative models involving flows and storages in a system showing correct direction and magnitude.

Part 3 – Community Problem Solving

- Use various information sources, including those of a technical nature, to obtain a variety of information on the topics.
- Make effective use of basic life skills in overcoming unexpected challenges.
- Operate effectively within a group to obtain assistance in a community project.
- Use stylistic and rhetorical techniques in writing.
- Learn to pre-write, draft, revise, edit, and publish.
- Read to understand and interpret a variety of texts.
- Use viewing skills to understand and interpret visual media, such as computer models, for research information.
- Understand and learn how to analyze chronological relationships and patterns to forecast trends.
- Understand that when societal challenges are coupled with the scientific enterprise, they often inspire scientific research.
- Understand the relationship among science, technology, society, and the individual.
- Understand the nature and uses of different forms of technology.

National Standards Addressed:

This lesson addresses the following National Science Education Standards:

Content Standard A

As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry.

Small Steps Mean Smaller Footprints

Desired Outcomes:

After completing this unit, students will:

- Deconstruct power structures and established societal codes in order to achieve justice through democratic participation.
- Understand how to apply scientific and democratic principles in concert to affect positive environmental and societal change.
- Recognize differences of viewpoint, opinion, life experience, social injustices, and social responsibility in the community from the local to the global level.
- Consider the input of and mutual benefits for all people at all levels through meaningful dialogue.
- Process differing viewpoints to arrive at consensual societal, cultural, and ecological solutions that benefit all.

- Understandings about scientific inquiry.

Content Standard F

As a result of activities in grades 9-12, all students should develop an understanding of

- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Fundamental concepts and principles that underlie this standard include:

- Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change.

Risks and Benefits:

- Students should understand the risks associated with:
  - natural hazards (e.g., fires, floods, tornadoes, hurricanes, earthquakes, and volcanic eruptions)
  - chemical hazards (e.g., pollutants in air, water, soil, and food)
  - biological hazards (e.g., pollen, viruses, bacteria, and parasites)
  - social hazards (e.g., occupational safety and transportation)
  - personal hazards (e.g., smoking, dieting, and drinking).
- Individuals can use a systematic approach to thinking critically about risks and benefits. One example is to apply probability estimates to risks and compare them with estimated personal and social benefits.

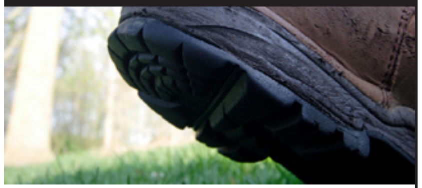
Materials Needed:

Part 1 - Movie Circles

- The film *An Inconvenient Truth*
- Copies of Reproducible # 1
- Copies of Reproducible # 2

Part 2 - Modeling

- 6 bags of various-color gumdrops per class of 30 students
- 6 boxes of toothpicks per class of 30 students



Teacher's Notes:

- Digital camera (optional)
- Copies of Reproducible # 3
- Copies of Reproducible # 4 or Reproducible # 4 (extended)
- Copies of Reproducible # 5
- Copies of Reproducible # 6
- Computer with Internet connection
- Index cards (optional)
- Stella software (optional)

Part 3 - Community Problem Solving

No materials required

Reproducibles:

This unit contains several reproducibles. These will provide content for the lesson as well as information for the teacher when planning the lesson.

Background:

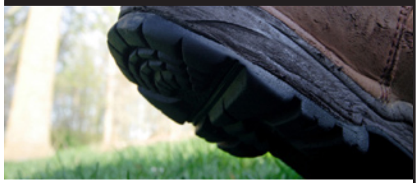
Part 1 - Movie Circles

For this activity, the class will be divided into small groups (5-7 students) called Movie Circles. After all students have seen *An Inconvenient Truth*, students will discuss it in their group meetings. Each group should include as diverse a mix of students as possible, in terms of academic and conversational skills. This format has proven to be an effective instructional strategy that generates greater interest in the subject, more initiative in fulfilling the objectives, and higher levels of comprehension. Because there is minimal intrusion from outside (e.g., the teacher), students in small peer groups feel free to ask questions of each other, listen to opposing viewpoints, explain their own perceptions, and defend their own rationale. The skills developed through this cooperative learning experience will not only help make this a successful assignment, but will also prove invaluable outside the classroom as the students face the complex challenges of careers, daily living, and citizenship.

Part 2 - Modeling

Activity # 1 – Photo gumdrops lab

Students will use gumdrops and toothpicks to create models that will help them analyze glucose synthesis and the free energy of hydrolysis of ATP (adenosine triphosphate). This activity is first in the sequence because it demonstrates the chemical and molecular processes of photosynthesis. It shows how atoms are "cycled" from one form (carbon dioxide in the atmosphere) to another (organic molecules in plant and animal tissues), and then back again through processes such as respiration and decomposition.



Teacher's Notes:

This activity applies the law of conservation of matter and of thermodynamics. Through this device, students will learn that:

- Every element, including carbon, can be traced within cycles and natural processes.
- Energy is transformed and/or transferred from place to place around the earth.
- Carbon moves back and forth from photosynthesis to cellular respiration without being destroyed.
- Energy is transformed continuously from light to chemical to mechanical.

Students will have Eureka! moments that give them a sense of accomplishment and discovery. One such instance will probably occur when they build a glucose model and then disassemble it to represent respiration. In other words, carbon dioxide and water, the outputs of cellular respiration, are required for photosynthesis. Conversely, the outputs of photosynthesis, glucose and oxygen, are required for cellular respiration. The waste products of one process are the resources for the other. The exercise will become a concrete example that matter is neither created nor destroyed; it simply moves around. It also provides an understanding that living things convert glucose into carbon-based substances and that these substances provide energy for all life processes.

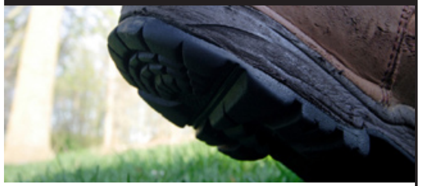
The students will need close supervision at this point to remind them that this realization is not the end game; it is merely an important step in the process.

This activity gives students a platform on which to base the global geochemical carbon cycle. It also shows students that the biosphere and atmosphere are communicating via the carbon dioxide molecule. It will allow them to understand the basis of human perturbations on the system as they progress further into the unit.

In order to pique student interest in structural and functional relationships in the carbon cycle, we utilize a topic to which all teenagers can relate…food! For the last part of this activity we ask students if it is possible to fill up on junk food and be malnourished. This makes students curious about structural and functional relationships in ecosystems. They want to know why some foods are high in nutrients and energy while others are not. They want to know why cows can get nutrients from grass while humans cannot. These questions provide the perfect transition to the next spatial level of our study of geochemical cycles and global warming. They are moving from organism to biogeochemical cycling.

Activity # 2 – Carbon cycle box model

In this activity, students will use "box" models of the carbon cycle to study the effect of emissions on global warming. The boxes will represent places where carbon accumulates (storages or stocks); arrows (flows or fluxes) will indicate the movement of carbon among these boxes. This exercise leads to an understanding that although carbon moves continuously, the rate of movement varies between the atmosphere, lithosphere (i.e., rocks and soil), hydrosphere (i.e., water) and biosphere (i.e., living organisms). Students will find that in some parts of the ecosystem, carbon is recycled rapidly, but in others—such as when shells sink to the bottom of the ocean or when plants become fossil fuels—carbon cycles very slowly. It is important that students understand the concept of rate differentials.



Be prepared to answer the question: If matter cannot be created or destroyed, how can emissions be contributing to global warming?

This activity is very timely, because global warming is an ominous threat as greenhouse gases (GHGs) continue to reach historic levels in the atmosphere. That problem is exacerbated by human activities that alter the rates of these flows or fluxes. When we choose to release much of the carbon stored in fossil fuels, we are drastically altering the quantity of carbon in the atmosphere at a particular time. In ecology, "everything is connected to everything else," which means that changes must occur in other earth systems.

One of the questions that you should be prepared to answer is based on the findings of the previous activity: If matter cannot be created or destroyed, how can emissions be contributing to global warming? This is a perfect opportunity to reinforce the idea of rates. Carbon has been trapped for millennia in fossil fuels. Since the Industrial Revolution, we have been releasing it into the atmosphere at an alarming rate.

Activity # 3 – The short-term carbon cycle

In this activity, students will create computer models that allow them to manipulate variables that cause global warming. To do that, they will need to consult several Internet or library resources. An excellent starting point is the research data on carbon dioxide concentrations in the atmosphere from the Mauna Loa observatory. See **Reproducible # 6: Carbon Model Self-Assessment**. You may wish to allow student interests to determine which aspects of the carbon cycle they choose for study.

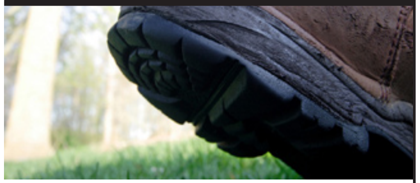
Those who want to study the effects and origins of specific greenhouse gases will find several Internet sites. For instance, there are sites that deal with the effects of carbon fertilization, while others address the bio-pumping of carbon to the ocean bottoms by marine organisms.

If possible, ask students to manipulate deforestation and fossil fuel burning in a computer model to see the effect on carbon dioxide in the atmosphere. This activity develops the ability to run controlled experiments with the global carbon cycle, which is difficult to do in reality. At the conclusion of this activity, you may wish to discuss the utility of computer models and whether they have accurately predicted what has come to pass with respect to temperature increases on Earth.

Part 3 - Community Problem Solving

The culminating exercise provides students with a framework to solve problems associated with global warming. Students need an effective model to exercise critical thinking, problem solving, and decision making. Providing a step-by-step problem-solving model can be an excellent way to teach students across the curriculum. The community problem solving model originated from the work of Dr. Paul Torrance. Dr. Torrance successfully used community problem solving to:

- improve cooperative teamwork
- provide a proven problem-solving model
- increase written and verbal communication skills
- improve research skills
- improve analytical and critical thinking skills
- improve self-directedness and responsibility for learning.



Lesson Steps:

Part 1 - Movie Circles

1. Ask students to view the film: *An Inconvenient Truth.*
2. Allow students to participate in a Movie Circle by assigning student groups to the roles listed below in **Reproducible # 1: Discussion Sheet for Movie Circles**. Allow the students to select from the following chapters:

   Chapter 3: *Basic Science of Global Warming*
   Chapter 4: *Global Warming Cartoon*
   Chapter 6: *CO_2 Measure Since 1958*
   Chapter 9: *CO_2 Levels Back 65,000 Years*
   Chapter 18: *Resistance to Change*
   Chapter 26: *Is There a Controversy?*
   Chapter 27: *Science Fraud*
   Chapter 28: *Balancing the Economy*
   Chapter 29: *City by City*
   Chapter 30: *The Solutions Are in Our Hands*
   Chapter 31: *Are We Capable of Doing Great Things?*
   Chapter 32: *Our Only Home*

3. Allow each member of the Movie Circle to share what he or she learned about the assigned chapter among the other group members.
4. Ask the summarizer from each group to present the group's findings to the remainder of the class.
5. Ask students to share their thoughts on topics such as these:
   a. Does evidence exist on global patterns that seem to be linked to temperature increases? Students may be aware of a few of these.
   b. Are there energy options for the average citizen that do not contribute to global warming?
   c. Would they purchase a hybrid or electric car? Why or why not?
   d. Is global warming an urgent issue in need of remedial action?
6. Have students complete **Reproducible # 2: Movie Circles Self-Assessment Form.**

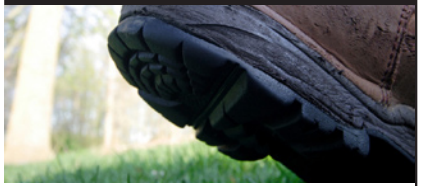
Part 2 - Modeling

Activity #1 - Photo gumdrops lab

Photosynthesis

1. Place the formula for photosynthesis on the board or elsewhere in the room for all students to see: **$6CO_2 + 6H_2O$ yields $C_6H_{12}O_6 + 6O_2$**
2. Provide students with **Reproducible # 3: Photo Gumdrops Questions** to fill out as they proceed through this activity.

Note: Building gumdrop models to simulate the steps of geochemical movement is a difficult task. ADP and ATP (adenosine diphosphate and adenosine triphosphate) are particularly delicate. Therefore, it is helpful to take digital photos through every phase of the activity. The photos will not only help students retrace their steps, but could also be used as visual support for their presentation. This also gives students a physical resource to review to help them retain concepts for later in the sequence.



Teacher's Notes:

3. Tell students that they will be creating models of glucose with gumdrops and toothpicks.

4. Ask students to choose three different colors of gumdrops to represent carbon, hydrogen, and oxygen. *Note*: It may helpful to review the octet rule and the concept of valence electrons.

5. If students are unfamiliar with how to use the Periodic Table, tell them that carbon wants to bond to four other atoms, oxygen to two, and hydrogen to one, and that bonds are represented by toothpicks.

6. Ask students to construct six waters (H_2O) and six carbon dioxides (CO_2) using the rules above. *Note:* Carbon dioxide will require double bonds to satisfy the rule.

7. Ask students to create enough waters and carbon dioxides to construct a molecule of glucose.

8. Ask students to simulate photosynthesis by constructing glucose out of the carbon dioxides and waters. (You may wish to allow students to consult pictures or diagrams of glucose.)

9. Students will have "oxygen" left over after rebuilding a glucose model. They will have the tendency to ignore these or put them back. If you see them doing this, ask them whether oxygen just disappears in nature. When they can't find an answer to that, ask them to re-assemble the glucose model and keep the extra oxygens.

<u>Cellular respiration</u>

1. Ask students to take the glucose molecule apart and use the parts to make six molecules of carbon dioxide and six molecules of water. This represents the opposite reaction to photosynthesis, called cellular respiration.

2. Ask students to lay out all of the gumdrops necessary to construct the formula for cellular respiration. They will need to lay out glucose, carbon dioxide, water, and oxygen molecules.

<u>Drawing the carbon cycle</u>

1. Ask students to draw a model of the carbon cycle that shows the role of photosynthesis and respiration, and identifies transfer and transformation.

2. Ask students to view the carbon cycle as a whole and to identify and discuss strategies that they might employ to reduce the release of carbon dioxide into the atmosphere. Ask them to suggest both policy and individual behavior.

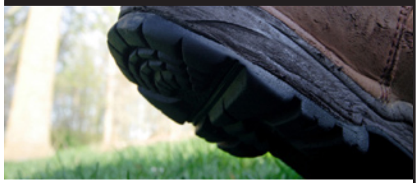
<u>ATP-ADP optional enrichment</u>

1. Ask students to locate diagrams of adenosine diphosphate (ADP) and adenosine triphosphate (ATP).

2. Ask students to gather enough gumdrops to create the five-ring D-ribose, adenine, and the appropriate number of phosphate groups to create ATP.

3. Ask students to use the models to simulate the free energy of hydroysis of ATP.

4. Ask students to create the initial reactants and the final products.

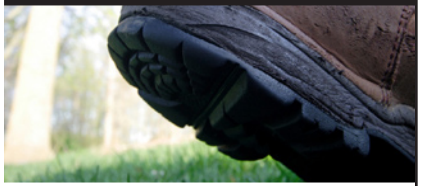


You may wish to provide groups with index cards on which to write arrows and boxes, allowing them to move the cards around to construct their models.

Activity # 2: Carbon cycle box model

1. Tell students that the culminating goal of this activity is for them to draw a carbon cycle box model.
2. Tell students that they will need to work systematically to keep all information organized.
3. Demonstrate how to draw a simple box model. For example, you could draw a seed to a mouse and a mouse to a snake and a snake to an owl.
4. Explain to students that both matter and energy move through this model. Reservoirs or stocks are places where matter or energy accumulate and are represented by boxes. Flows are energy or matter moving from one reservoir to another and are represented by arrows.
5. Emphasize that it is important to pay attention to the direction of the arrows since they indicate where matter and energy are moving to and from.
6. Explain to students that carbon continuously moves among the atmosphere (i.e., air), lithosphere (i.e., the Earth's crust, including rocks and soil), hydrosphere (i.e., the Earth's water, including fresh and saltwater), and biosphere (i.e., living things on land and in water) in what is termed a biogeochemical cycle. It is human alteration of the residence time of carbon that is mostly responsible for global warming.
7. Place 4 to 5 students in each sphere group below:
    - Carbon in the atmosphere
    - Carbon in the lithosphere
    - Carbon in the hydrosphere
    - Carbon in the biosphere
8. Ask students to gather information on the rates at which carbon flows into and out of the sphere to which they have been assigned (i.e., atmo-, litho-, hydro-, and bio-).
9. Ask the students to draw a box with the name of their sphere in the middle of it.
10. Ask them to draw arrows into and out of their box to indicate carbon inputs and outputs that affect their sphere.
11. Ask students to gather together as a group to reconcile connections among their assigned boxes to create an overall model of the carbon cycle. Tell students that they will probably need to create several drafts of their carbon cycle box models and that their models will look different from those of the other groups. This is OK. Explain to students that they will need to think about all of the ways that carbon flows into and out of their particular sphere (i.e., atmo-, litho-, hydro-, and bio-).

    Helpful hint: For excellent supporting graphical data, visit the International Panel on Climate Change website at: http://www.ipcc.ch/present/graphics.htm. Particularly useful are the



Prior to *Activity #3*, prepare students for the upcoming activity by helping them make connections among the creation of biomass through photosynthesis (*Activity # 1*), the transfer and/or transformation of carbon through an ecosystem (*Activity # 2*), and Activity 3, where they will be manipulating a carbon cycle computer model.

graphics under the heading, "Climate change 2001 - Synthesis report," and/or http://www.shodor.org/cas/atmcycles.html

If students get stuck or run out of time, you may wish to consider providing copies of **Reproducible # 4: Carbon Cycle Box Model Data**. **Reproducible # 4 (extended)** provides a more extensive study on this data and may be used for more advanced students.

When students have finished their models, ask them to highlight places on the model where humans have altered residence time and affected global warming in both positive and negative ways. Ask students to determine the quantity of carbon created by their school and individually by using one of the following online carbon calculators:

http://www.climatecrisis.net/takeaction/carboncalculator/

http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html

http://www.infinitepower.org/calc_carbon.htm

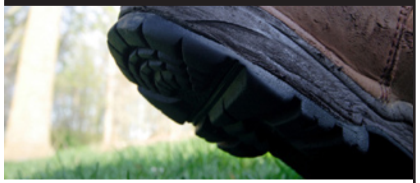
http://www.geic.or.jp/co2-cal/index.html

http://www.nef.org.uk/energyadvice/co2calculator.htm

12. If students do not have Internet access, they may calculate the quantity of carbon dioxide emitted per gallon of gasoline or diesel by using the following conversions: CO_2 emissions from a gallon of gasoline = 2,421 grams x 0.99 x (44/12) = 8,788 grams = 8.8 kg/gallon = 19.4 pounds/gallon. CO_2 emissions from a gallon of diesel = 2,778 grams x 0.99 x (44/12) = 10,084 grams = 10.1 kg/gallon = 22.2 pounds/gallon.
13. Ask students to look at their models in conjunction with the results of the carbon calculators to hypothesize ways that inputs or outputs might be altered to reduce global warming.
14. If possible, ask students to input these changes into the calculators to see the outcomes.

Activity # 3: The short-term carbon cycle

1. Ask students to read **Reproducible # 5: Carbon Cycle Background Information**.
2. If possible, ask students to use the data gathered in *Activity # 2* above to create a computer model of the carbon cycle using Stella software. The diagrams and data found in Reproducible # 4 and # 5 can serve the same purpose.
3. If it is not possible for students to create a model, allow them to manipulate the model of the carbon cycle found at http://www.shodor.org/master/environmental/general/carbon/carbon.html
4. Ask students to predict what will happen as a result of changing one of the variables. For example, what will happen to the quantity of carbon dioxide in the ocean if we decrease the rate of deforestation in the model?
5. Ask students to think about how to design a realistic and appropriate method that allows for the



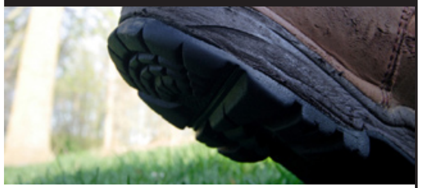
Teacher's Notes:

control of the other variables and collection of sufficient data relevant to their investigation. In other words, they must run a controlled experiment by manipulating only one variable at a time if they want to know the consequences of that manipulation.

6. Ask students to complete **Reproducible # 6: Carbon Model Self-Assessment.**

Part 3 – Community Problem Solving

1. **DIVERGENT THINKING**—Hold a classroom discussion. Ask students to draw upon their experiences in the unit to brainstorm a list of problems that cause or result from global warming. Ask students not to reject or criticize the ideas of others at this point. The goal is to be creative and divergent in thinking.
2. Ask students to write the problems down. The Future Problem Solving Program (http://www.fpsp.org) recommends the following criteria:
   a. Express the problems in terms of what is possible, using the words might or may.
   b. If possible, make references to outside research.
   c. The problems should name specific people or groups who are responsible for the problem. Do not use pronouns.
   d. Problems should draw from a wide variety of categories. For example:
      - business and commerce
      - environment
      - transportation
      - social relationships
      - physical health
      - education
      - technology
      - recreation
      - government and politics
      - ethics and religion
      - arts and aesthetics
      - psychological health
      - basic needs
      - defense
      - economics
      - law and justice
      - communication
      - miscellaneous
3. **CONVERGENT THINKING**—Ask students to select and write down what they feel is the most important problem. The problem should be one that, if solved, would solve many of the other problems identified in Step 2. The Future Problem Solving Program recommends the following:
   - Use one main active verb and include place, topic, and time.
   - Link the underlying problem to global warming.
   - Include purpose.



4. **DIVERGENT THINKING**—Students should brainstorm and write down possible school-based solutions to the problem identified in the previous step. The solutions should include who, what, when, where, why, and how. Try to use the same categories listed in Step 2 above. Again, do not use pronouns. Write the solutions as definite proposals. *For example: School employees will minimize the amount of electricity used in the school by June 2007.*

5. **EVALUATING**—Ask students to develop criteria to judge their solutions. Tell them to determine which five solutions are the best, according to the criteria they established. The Future Problem Solving Program recommends that each criterion question should be one that can be measured in terms of degrees rather than a yes or no answer. For example, use superlatives such as most, least, fewest, etc. This allows students to assign a number between 1 and 5 to indicate the extent to which the proposed solution meets the criterion.

   An example criterion question might be: Which solution has the greatest impact on our school's CO_2 *emissions?*

6. **CONVERGENT THINKING**—Ask students to tally the results for their five best solutions. The one with the highest score is the best solution.

7. **WRITING**—Ask students to write a clear, thorough, and concise description of the best solution. The solution should answer who, what, where, when, why, and how. The solution must also be humane, relevant, effective, creative, possible, and affect the most important problem identified in Step 3.

8. **ACTION**—Ask the students to break the class into committees to address different aspects of the problem. *For example: One group could be in charge of depicting and disseminating the problem and solution artistically; another group might be in charge of writing an article for the school newspaper; another group might create a web page to be used in conjunction with the existing school website; another group might contact local School Board members and decision-makers to arrange a presentation by the students.*

9. Students will present to the school PTA, local county commission, government representatives, etc. As another option, students can write a press release. See the Tier 2 Lesson: Think Globally, Act Locally for information on writing press releases.

10. Enter the Future Problem Solving Program and compete with others in the state.

For more information on the Future Problem Solving Program, including details about its competition, visit: http://www.fpsp.org

Additional Resources:

Data sources for greenhouse gas emissions

International Panel on Climate Change presentations and graphics:
http://www.ipcc.ch/present/graphics.htm

International emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/EmissionsInternational.html

National GHG emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html

State and local emissions:
http://yosemite.epa.gov/OAR/globalwarming.nsf/content/EmissionsLocal.html

Individual GHG emissions:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/emissionsindividual.html

EPA GHG emission calculator: http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ResourceCenterToolsGHGCalculator.html

Additional information on Literature Circles:
Schlick, Noe, K.L. and Johnson, N.J. (1999), *Getting started with literature circles*, Norwood, MA: Christopher-Gordon Publishers

Literature Circles Resource Center:
http://www.litcircles.org/

Other Helpful Sites:

EPA Climate Change Site:
http://yosemite.epa.gov/oar/globalwarming.nsf/content/index.html

The Weather Channel's *Planet in Change* Curriculum
http://admin.www.weatherclassroom.com/upload/materials/Planet_in_Change_new.pdf

The Weather Channel's *The Climate Code with Dr. Heidi Cullen*
http://www.weatherclassroom.com/climatecode.php

Stop Global Warming
http://www.stopglobalwarming.net

ClimateCrisis.Net (The companion website to the film: *An Inconvenient Truth)*
http://www.climatecrisis.net/

Discussion Sheet for Movie Circles

Name: ______________________________ Group: ______________________________

Film: *An Inconvenient Truth* Role: ______________________________ Chapter(s): ______________________________

While you are viewing the film or after you have finished viewing, prepare for the Movie Circle meeting by assuming the identity of one of the strategists below, and then completing and presenting your strategy:

Clarifier: Your job is to find five words or concepts that are important to the chapter, to list and explain each word/concept, and to write down its location in the film.

1. ____________________ ______________________________
2. ____________________ ______________________________
3. ____________________ ______________________________
4. ____________________ ______________________________
5. ____________________ ______________________________

Summarizer: Your job is to prepare a brief summary of your film segment to share with the rest of the class. You want to convey how people are influenced by the various events and how the main conflict contributes to a possible resolution. Be sure to present the essential ideas of the segment.

Key Events: ______________________________

Summary: ______________________________

Questioner: Your job is to develop a list of four questions about this film that your Movie Circle might discuss. Your task is to help circle members discuss the big ideas in the film and share their reactions. Center your questions on the 5 "Ws" + How. Be prepared to show key segments of the film that present the answers. List appropriate segments of the DVD or videotape.

Question 1: ______________________________ Answer: ______________________________

Question 2: ______________________________ Answer: ______________________________

Question 3: ______________________________ Answer: ______________________________

Question 4: ______________________________ Answer: ______________________________

Predictor: Your job is to predict what you think will happen next in this story. After each prediction, defend your reasoning.

Based on what I have seen, I predict that the following events will happen:

1. ______________________________ Why: ______________________________
2. ______________________________ Why: ______________________________
3. ______________________________ Why: ______________________________

Movie Circles Self-Assessment Form

Name: ______________________________ Group: ______________________________

Film: ______________________________ Date Started: ______________________________

My Contribution to Group Discussion

Rate each entry as: 1 - Needs Improvement, 2 - Satisfactory, or 3 - Very Good

Type of Contribution	Rating		
I shared my ideas and offered my suggestions.	1	2	3
I spoke clearly and slowly enough to be understood.	1	2	3
I answered others' questions.	1	2	3
I remained on topic and helped the group stay focused.	1	2	3
I encouraged others to participate.	1	2	3
I disagreed without hurting others' feelings.	1	2	3
I summarized or repeated my ideas when necessary.	1	2	3
I gave reasons for opinions.	1	2	3
I listened courteously and effectively.	1	2	3
I tried to understand and extend the suggestions of others.	1	2	3

My most important contribution to the discussion was:

My plan for improvement is:

Photo Gumdrops Questions

Name: ____

Photosynthesis questions

1. After you made glucose from carbon dioxide, did you have atoms left over? If so, which atoms were they?

2. Are these atoms useful to any other living things? If so, what?

3. Write the formula for photosynthesis.

4. Glucose is an organic molecule with high potential energy, whereas the potential energy in carbon dioxide and water is nil. From where does the energy come in photosynthesis?

5. What law tells us that glucose must get its energy from somewhere—that energy can't come from "nowhere"?

6. Do plants follow the second law of thermodynamics?

7. Why do plants make glucose?

8. Besides carbon dioxide and water, what else do plants need and how do they get it?

9. How do plants influence global warming?

Right now you are using the potential chemical energy stored in your cells to read this question. The process through which organic molecules are broken down to release their potential energy is called cellular respiration.

Cellular respiration questions

1. Compare the formula for cell respiration with the formula for photosynthesis. How are the two reactions related?

2. What are the waste products of cell respiration and are they useful?

3. Why is it appropriate to speak of "burning" food for energy?

4. Which types of organic molecules have the highest potential energy?

5. What are the two purposes of food for animals?

6. Is it possible to fill up on junk food every day but be malnourished? Please explain.

7. Why can't humans use wood or other coarse plant material for food?

ATP-ADP optional enrichment questions

1. Explain the role of pH in the ATP-ADP energy transfer system.

2. What part of the cell helps to maintain the proper amount of energy for metabolic needs?

3. Given that no spontaneous energy transfer is 100% efficient, energy is dissipated as heat in natural processes, and all processes in the universe move toward maximum entropy, how is it that the cell and biosphere exhibit little entropy or disorder?

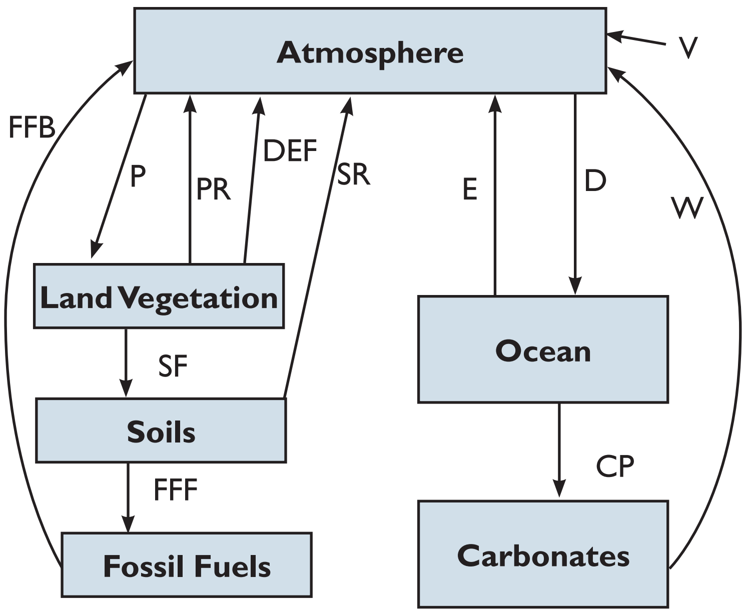
4. The question immediately above implies that cells escape the implications of an important scientific law. What is the law? Do cells escape the law?

Drawing the carbon cycle questions

1. Starting with incoming solar insolation, describe the transfer (i.e., movement without change in form) and transformation (i.e., movement with change in form) of energy and material as it flows through the carbon cycle of an ecosystem. Remember that transfers normally flow through a system and involve a change in location (e.g., movement of organic matter from producer to consumer). Transformations lead to an interaction within a system, which leads to the formation of a new end product and involves a change of states (e.g., energy changes from solar radiation to chemical energy).

2. Take a look at the drawing you made of the carbon cycle. Identify at least four places in the cycle where humans can make changes to reduce global warming.

Carbon Cycle Box Model Data



Source: http://www.colorado.edu/GeolSci/courses/GEOL1070/chap04/chapter4.html

Fluxes (flows):
(in billions of metric tons/year)

Land plants
P: photosynthesis 120
PR: plant respiration 60
SR: soil respiration 60
SF: plants to soils 60
FFF: fossil fuel formation 0.0001
FFB: fossil fuel burning 6
DEF: deforestation 2

Ocean
D: dissolving 107
E: exsolving 103
CP: carbonate formation 4
W: weathering 0.6

Volcanoes
V: 0.1

Notes on fluxes:
—CO_2 increase in the atmosphere:

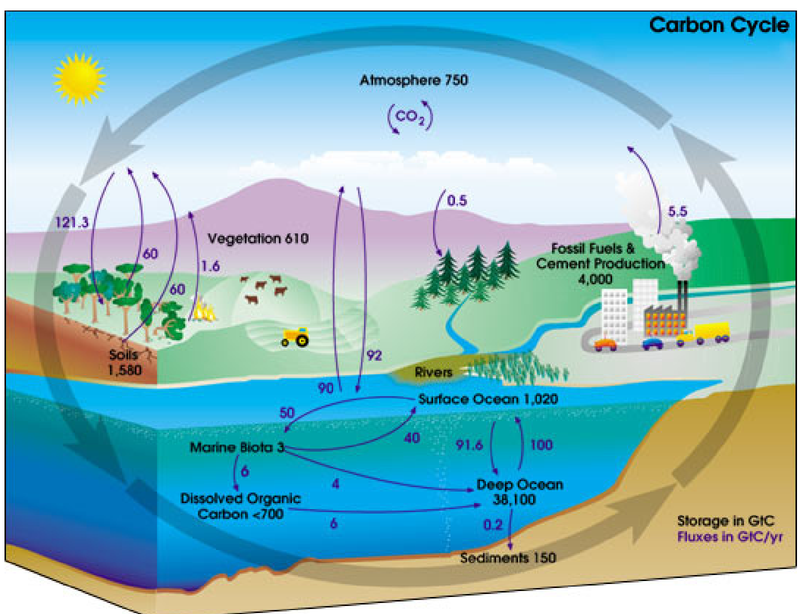
Flux to the atmosphere:
Plant respiration + soil respiration + fossil fuel burning + deforestation + ocean exsolving + weathering...
60+60+6+2+103+0.6 = 231.6 bmt/yr

Flux from the atmosphere:
Plant photosynthesis + ocean dissolving...
120 + 107 = 227 bmt/yr
...difference is buildup of carbon dioxide in the atmosphere of about 4 bmt/yr

Reservoirs: billions of metric tons
Atmosphere: 720
Ocean: 39,000
Carbonates: 100,000,000
Fossil fuels: 4,000
Land plants: 560
Soils: 1500

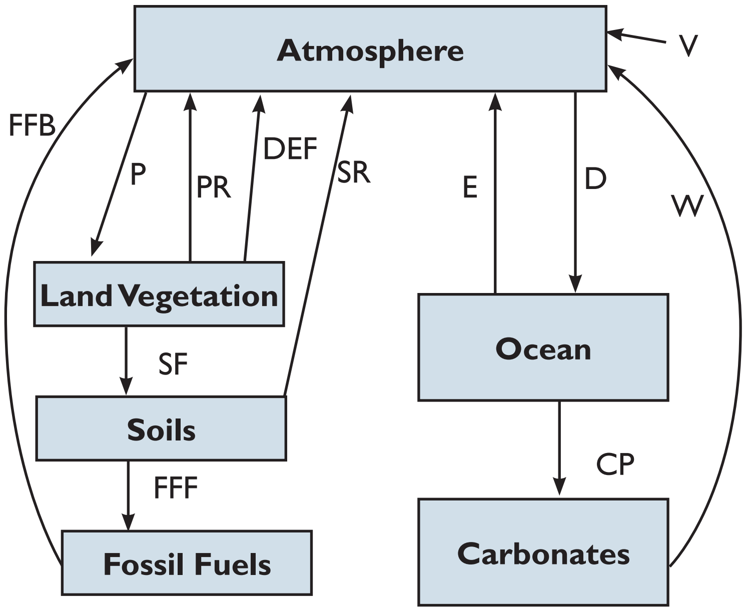
Notes on reservoirs:
—Most carbon is in rocks (carbonates and other sediments).
—Most carbon not in rocks is in the ocean.
—About three times more carbon exists in soils than in land plants.

Residence times: years
(all relative to sum of out fluxes)
land plants ~ 5
atmosphere ~ 3
soils ~ 25
fossil fuels ~ 650
oceans ~ 350
carbonates ~ 150 million



http://earthobservatory.nasa.gov/Library/CarbonCycle/Images/carbon_cycle_diagram.jpg

Carbon Cycle Box Model Data



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Notes on fluxes:

—CO_2 increase in the atmosphere:

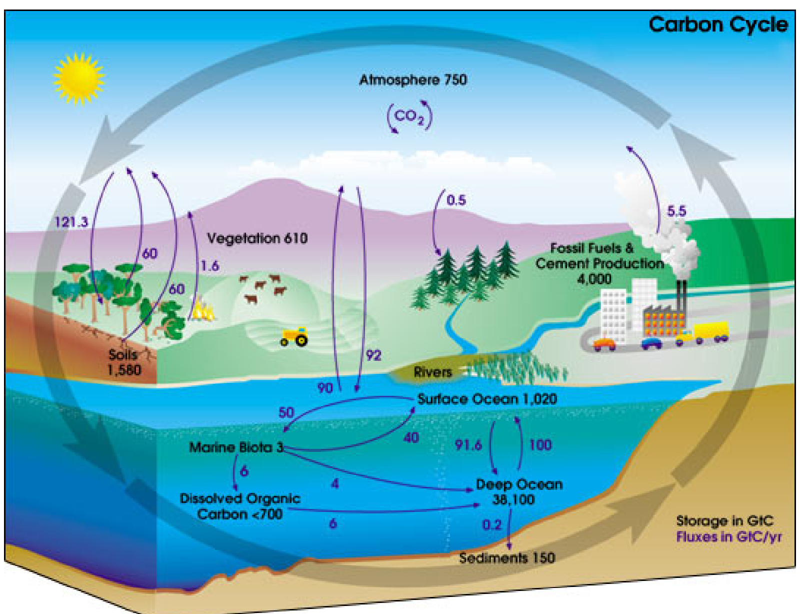
Flux to the atmosphere:
Plant respiration + soil respiration + fossil fuel burning + deforestation + ocean exsolving + weathering...
60+60+6+2+103+0.6 = 231.6 bmt/yr

Flux from the atmosphere:
Plant photosynthesis + ocean dissolving...
120 + 107 = 227 bmt/yr
...difference is buildup of carbon dioxide in the atmosphere of about 4 bmt/yr

More on fluxes...
—Human-caused fluxes are small, but persistent.
—Largest fluxes are between land plants and atmosphere, and the ocean and the atmosphere.
—Flux of carbon out of fossil fuels (FFB) is 60,000 times faster than flux into fossil fuels (FFF).
—Flux to atmosphere from FFB and DEF (6 + 2 bmt/yr) is greater than accumulation of carbon in the atmosphere (about 4 bmt/yr)... this is because the ocean exchange works by diffusion.

Flux by diffusion = k (C air - C ocean)
(**C** is concentration or amount, **k** is a constant)
If (C air - C ocean) goes up, flux goes up.
If (C air - C ocean) goes down, flux goes down.
If (C air - C ocean) reverses, flux reverses.

Even more on fluxes...
—**Photosynthesis** is the basis of life on Earth...
carbon dioxide + water + sunlight = organic material (sugar) + oxygen



http://earthobservatory.nasa.gov/Library/CarbonCycle/Images/carbon_cycle_diagram.jpg

—**Respiration** is the reverse of photosynthesis...
organic material + oxygen =
carbon dioxide + water + energy
Animals and plants respire, releasing energy for other activities...
Decay is also a form of respiration.

Reservoirs: billions of metric tons

Atmosphere: 720
Ocean: 39,000
Carbonates: 100,000,000
Fossil fuels: 4,000
Land plants: 560
Soils: 1500

Notes on reservoirs:
—Most carbon is in rocks (carbonates and other sediments).
—Most carbon not in rocks is in the ocean.
—About three times more carbon exists in soils than in land plants.

Residence times: (years)

(all relative to sum of out fluxes)
land plants ~ 5
atmosphere ~ 3
soils ~ 25
fossil fuels ~ 650
oceans ~ 350
carbonates ~ 150 million

Notes on residence times:
—Some in fluxes are not balanced by out fluxes ...the atmosphere and fossil fuels, for example... so RTs are slightly different (and reservoirs are growing... or shrinking).
—The RT of carbon in the air (mostly carbon dioxide, but some methane) is long enough that the air is well mixed (atmosphere mixes in about one year).
—The RT of soils is the average RT... Some parts cycle very slowly (1000s of years), some parts very rapidly (a few weeks to months... leaves, for example).
—The RT of fossil fuels reflects all FFs suspected to exist... This is a combination of:
- recoverable
- unrecoverable (both physically and economically).

RTs of recoverable FFs:
coal: ~ 350 years
oil: ~ 40 years
natural gas: ~ 60 years

More notes on residence times:
—Ocean RT also reflects the average, which combines the surface water (short RT, few months to years) and deep water (long RT, 200 to 400 years)... Average is weighted toward deep water, since this is most of the water.
—Ocean RT reflects the circulation of the ocean (deep water formation).

Still more on fluxes/residence times:
—Anthropogenic flux (FFB and DEF) to atmosphere ~ 8 bmt/yr, but atmospheric increase is only ~ 4 bmt/yr

Question: Where does the missing 4 bmt/yr go?
Two possibilities: Photosynthesis vs. Ocean uptake
—*Important to know this because the residence times are so different*
Carbon => plants recycles *quickly* (<70 yr) to atmosphere
Carbon => ocean recycles *slowly* (>300 yr) to atmosphere

Carbonate - Silicate Cycle

Long term cycle of the carbon cycle, tied with the rock (silicate) cycle

Time scale for this cycle is **millions to hundreds of millions of years**, so it's not a major concern of humans.

On this time scale, carbon cycling by plants, oceans, and the atmosphere is thought to be in balance (*steady state* or *equilibrium*)... so carbon dioxide levels in the atmosphere are thought to be controlled by weathering rates and rates of volcanic eruptions.

Weathering rates are thought to be controlled by rate of tectonic uplift—more uplift, more weathering, less atmospheric carbon dioxide

May explain the slow decline in atmospheric carbon dioxide from levels of several thousand parts per million (ppm) about 100 million years ago, to 280 ppm in the pre-industrial time.

During this time, the Tibetan Plateau and Rocky Mountain Plateau were raised by tectonic activity.

Also may provide long-term negative feedback to keep carbon dioxide levels from getting too high.

warming —> more evaporation —> rain —> weathering —> carbonate—> removes carbon dioxide from atmosphere —> cooling

Carbon Cycle Background Information

Carbon is unquestionably one of the most important elements on Earth. It is the principal building block for the organic compounds that make up life. Carbon's electron structure gives it a plus 4 charge, which means that it can readily form bonds with itself, leading to a great diversity in the chemical compounds that can be formed around carbon; hence the diversity and complexity of life. Carbon occurs in many other forms and places on Earth; it is a major constituent of limestones, occurring as calcium carbonate; it is dissolved in ocean water and fresh water; and it is present in the atmosphere as carbon dioxide, the second most important greenhouse gas.

The flow of carbon throughout the biosphere, atmosphere, hydrosphere, and geosphere is one of the most complex, interesting, and important of the global cycles. More than any other global cycle, the carbon cycle challenges us to draw together information from biology, chemistry, oceanography, and geology in order to understand how it works and what causes it to change. The major reservoirs for carbon and the processes that move carbon from reservoir to reservoir are shown in Figure 1 at right. We will discuss these processes in more detail below and then we will construct and experiment with various renditions of the carbon cycle, but first, we will explore some of the history of carbon cycle studies.

The global carbon cycle is currently the topic of great interest because of its importance in the global climate system and also because human activities are altering the carbon cycle to a significant degree. The potential effects of human activities on the carbon cycle, and the implications for climate change were first noticed and studied by the Swedish chemist, S. Arrhenius, in 1896. He realized that CO_2 in the atmosphere was an important greenhouse gas and that it was a by-product of burning fossil fuels (coal, gas, oil). He even calculated that a doubling of CO_2 in the atmosphere would lead to a temperature rise of 4-5°C—amazingly close to the current estimates obtained with global, 3-D climate models that run on supercomputers. This early recognition of human perturbations to the carbon cycle and the climatic implications did not raise many eyebrows at the time, but the experiment was just beginning then.

About 60 years later, Roger Revelle, an American oceanographer, pointed out that we

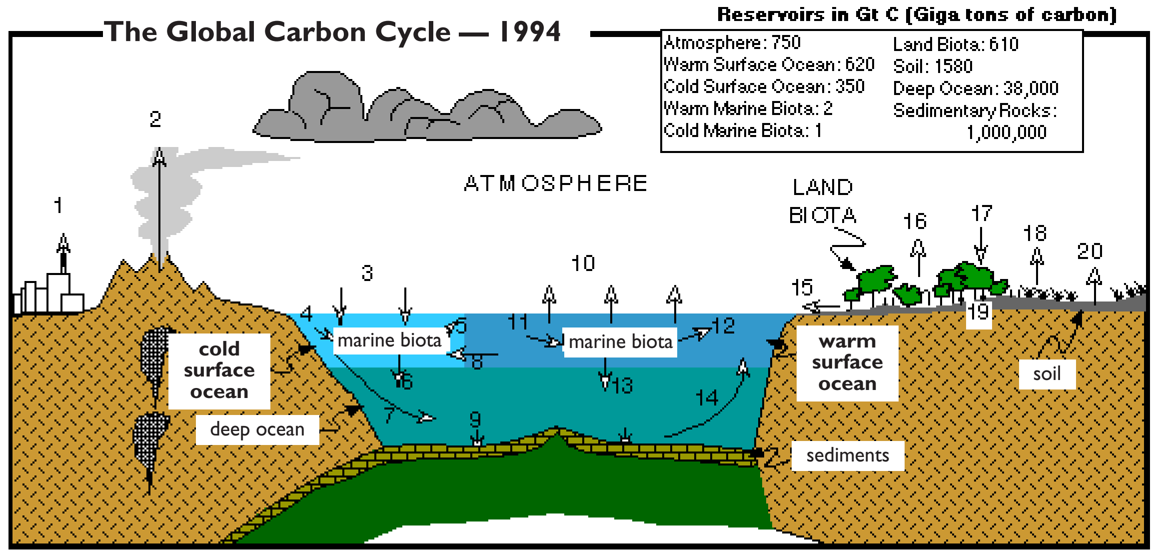


Figure 1: The global carbon cycle, as best estimated, from Siegenthaler and Sarmiento, 1995; Kwon and Schnoor, 1995.

Source: http://www.carleton.edu/departments/geol/DaveSTELLA/Carbon/carbon_intro.htm

Key to Flows:

1) Fossil Fuel Burning — 5 Gt C/yr
2) Volcanic Emissions — 0.6 Gt C/yr
3) Uptake of CO_2 by cold surface waters of the oceans — 90 Gt C/yr
4) Photosynthesis of marine biota in cold surface waters — 8 Gt /C/yr
5) Respiration of living marine biota and rapid recycling of dead biota in cold surface waters — 14 Gt C/yr
6) Sinking of dead marine biota (both organic and inorganic carbon) from cold water into deep water — 4 Gt C/yr
7) Downwelling of cold surface water (mainly near the poles) — 96.2 Gt C/yr
8) Advection (horizontal transfer) from warm to cold surface water — 10 Gt C/yr
9) Sedimentation on sea floor (both organic and inorganic carbon) stores carbon in sedimentary rocks — 0.6 Gt C/yr
10) Release of CO_2 by warm surface waters of the oceans — 90 Gt C/yr
11) Photosynthesis of marine biota in warm surface waters — 32 Gt C/yr
12) Respiration of living marine biota and rapid recycling of dead biota in warm surface waters — 26 Gt C/yr
13) Sinking of dead marine biota (both organic and inorganic carbon) from warm water into deep water — 6 Gt C/yr
14) Upwelling of deep water (at equator and along edges of continents) — 105.6 Gt C/yr
15) River runoff transfers carbon from the land to the sea — 0.6 Gt C/yr (2/3 to warm ocean, 1/3 cold)
16) Deforestation and land clearing releases CO_2 into the atmosphere — 1.5 Gt C/yr
17) Photosynthesis of land biota — 110 Gt C/yr
18) Respiration of land biota — 50 Gt C/yr
19) Litter fall and below-ground loss from plant roots transfers carbon to the soil — 60 Gt C/yr
20) Respiration of microorganisms in the soil releases CO_2 into the atmosphere — 59.4 Gt C/yr

were effectively conducting a giant experiment with our climate system by emitting more and more CO_2 into the atmosphere. One of the problems, he realized, was that we were relatively ignorant about the possible results of this experiment and so he decided that it would be wise to begin monitoring atmospheric concentrations of CO_2. In the late 1950s, Revelle and a colleague, Charles Keeling, began monitoring atmospheric CO_2 at an observatory on Mauna Loa, on the big island of Hawaii. The record from Mauna Loa, shown in Figure 2 below, is a dramatic sign of global change that captured the attention of the whole world because it shows that this "experiment" we are conducting is apparently having a significant effect on the global carbon cycle. The climatological consequences of this change are potentially of great importance to the future of the global population.

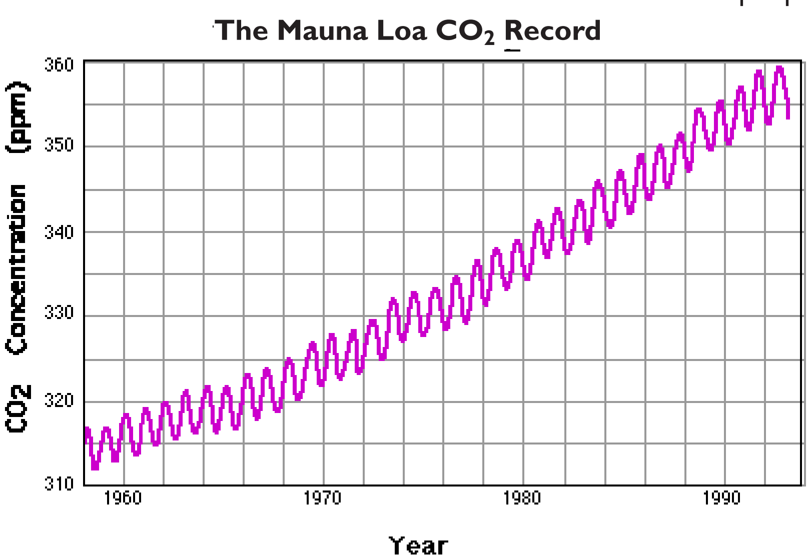


Figure 2: The record of CO_2 measured at Mauna Loa, Hawaii shows seasonal cycles—related to the activity of plants in the Northern Hemisphere—on top of an increasing trend to higher values. The record also shows a subtle increase in the seasonal amplitude over time.

As the Mauna Loa record and others like it from around the world accumulated, a diverse group of scientists began to realize that we really did not know too much about the global carbon cycle that ultimately regulates how much of our emissions stay in the atmosphere. Consider, for instance, the present best estimate of what happens to all of the carbon dioxide emitted to the atmosphere through human activities, summarized in Figure 3 at right.

The primary problem in our understanding of the current state of the global carbon cycle is reflected by the "missing sink"—we do not know where all of the anthropogenic CO_2 is going. We will explore this question of the missing sink in several of the modeling exercises in this handout.

The importance of present-day changes in the carbon cycle, and the potential implications for climate change became much more apparent when people began to get results from studies of gas bubbles trapped in glacial ice. The bubbles are effectively samples of ancient atmospheres, and we can measure the concentration of CO_2 and other trace gases like methane in these bubbles, and then by counting the annual layers preserved in glacial ice, we can date these atmospheric samples, providing a record of how CO_2 changed over time in the past. Figure 5 (on page 4 of this handout) shows the results of some of the ice core studies, relevant for the recent past —back to the year 900 A.D.

Figure 3: Carbon Cycle Budget for Anthropogenic Effects

Sources:
Fossil Fuel Burning & Cement Production 5.5±0.5 GtC/yr
Forest Burning & Soil Disruption 1.6±1.0 GtC/yr
Total Anthropogenic 7.1±1.1 GtC/yr

Sinks:
Storage in Atmosphere 3.3±0.2 GtC/yr
Oceanic Uptake 2.0±0.8 GtC/yr
Boreal Forest Regrowth 0.5±0.5 GtC/yr
Missing Sink 1.3±1.5 GtC/yr
GtC = Gigatons of carbon = 109 tons
data from IPCC, 1996

The striking feature of these data is that there is an exponential rise in atmospheric CO_2 (and methane, another greenhouse gas) that connects with the more recent Mauna Loa record to produce a rather frightening trend. Also shown in Figure 5 is the record of fossil fuel emissions from around the world, which show a very similar exponential trend. Notice that these two data sets show an exponential rise that seems to begin at about the same time. What does this mean? Does it mean that there is a cause-and-effect relationship between emissions of CO_2 and atmospheric CO_2 levels? Although we should remember that science cannot prove things to be true beyond all doubt, it is highly likely that there is a cause-and-effect relationship—it would be an extremely bizarre coincidence if the observed rise in atmospheric CO_2 and the emissions of CO_2 were unrelated.

It is always worth considering if we can test an hypothesis. Here, the hypothesis is that anthropogenic emissions of CO_2 are the cause of the rise in atmospheric CO_2. Can we test this? The answer is yes; there are in fact several ways of testing this hypothesis. One involves analyzing the ratios of carbon isotopes in CO_2 molecules found in the atmosphere. (A brief aside on carbon isotopes—carbon atoms don't always have the same number of neutrons in them, so they occur with different atomic weights 14, 13, and 12, with ^{12}C making up around 98.9%, ^{13}C making up about 1.1%, radioactive ^{14}C, the radioactive one making up a tiny fraction. ^{12}C and ^{13}C are stable isotopes meaning they do not decay, while ^{14}C has a half-life of 5270 years and is continually being produced when ^{14}N in the atmosphere interacts with high-energy solar radiation.) The CO_2 produced by burning fossil fuels has a much lower ratio of $^{13}C/^{12}C$ than normal atmospheric CO_2. If we were adding new CO_2 that had the same ratio as the rest of the carbon in the atmosphere, the total amount of carbon will increase, but the $^{13}C/^{12}C$ ratio will stay the same; so by adding new with a much lower ratio of $^{13}C/^{12}C$, we are diluting the atmospheric ratio of $^{13}C/^{12}C$.

We therefore predict that if our hypothesis is correct, there should be a decline in the carbon isotope ratio in the atmosphere that should match the history of fossil fuel burning. But in order to test our hypothesis in a meaningful way, we would need to have some record of the carbon isotope ratio of the atmosphere far enough back to understand the significance of recent changes. We can get this information from bubbles of air trapped in glacial ice, and also from tree rings, which of course contain a lot of carbon and preserve a record of the atmosphere at the time they form. As shown in Figure 4 at right, these data do show an exponential decrease beginning at about the same time as the onset of massive fossil fuel burning, so our hypothesis has passed the test, increasing our confidence in it.

Another test takes advantage of the fact that burning fossil fuels consumes an average of 15 oxygen molecules for every 10 molecules of CO_2; this means that we predict a decline in the overall concentration of oxygen in the atmosphere. This turns out to be a very difficult thing to measure, but Ralph Keeling (son of Charles mentioned above) has begun to make measurements and has already observed a decline in oxygen. Thus our hypothesis passes a second test, further increasing our confidence. A final test comes from the fact that the carbon released from burning fossil fuels is essentially devoid of ^{14}C, which has a short (5270 years) half-life; much of the fossil fuel we burn is on the order of 50 to 100 million years old, hence its depletion in ^{14}C. So, if our hypothesis is correct, then there should be a measurable decline in the concentration of ^{14}C in the atmosphere, beginning at about the time when we started to burn fossil fuels to fuel our Industrial Revolution. Indeed, this decline in atmospheric ^{14}C is observed, further strengthening our hypothesis that the rise in atmospheric CO_2 is caused by our burning of fossil fuels.

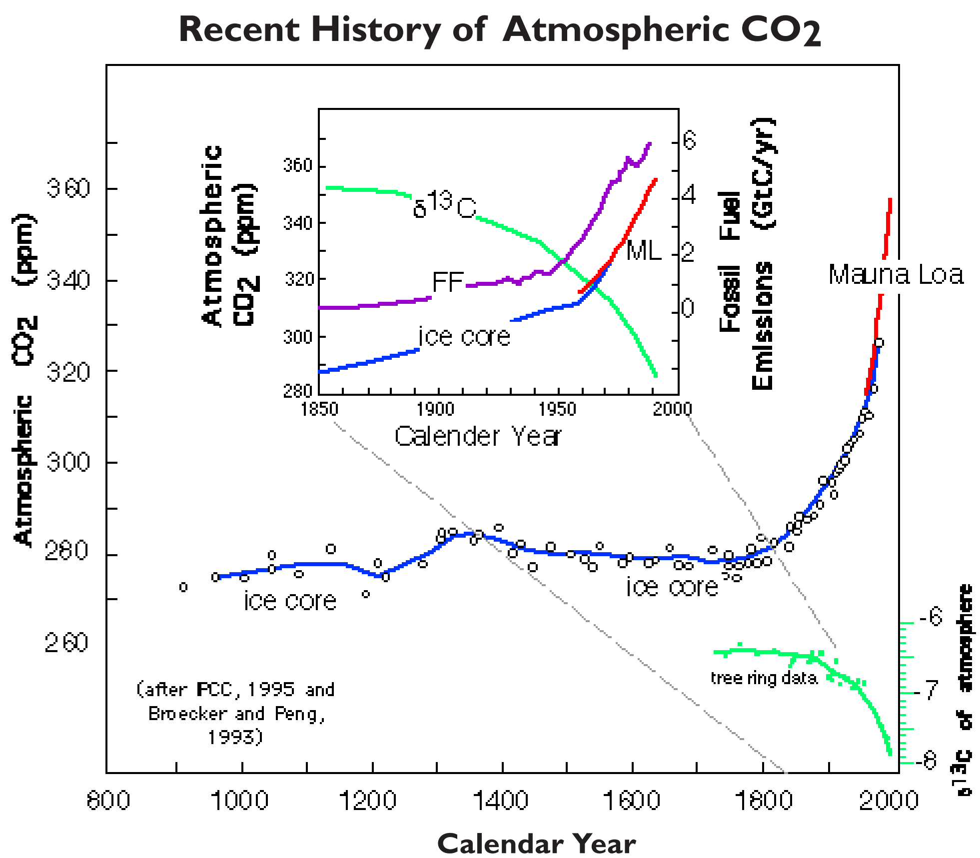


Figure 4: A compilation of data from ice cores and observations from Mauna Loa (yearly averages) shows the recent history of atmospheric carbon dioxide. The exponential growth in atmospheric carbon dioxide coincides with an exponential increase in fossil fuel emissions. Also shown is the changing ratio of carbon isotopes of the atmosphere, which undergoes an exponential decrease as expected from the addition to the atmosphere of carbon dioxide from fossil fuels, which have a much lower isotopic ratio than the atmosphere.

How serious is our modification of the natural carbon cycle? Here, we need a slightly longer perspective from which to view our recent changes, so we return to the records from ice cores and look deeper and further back in time than we did in Figure 4. In addition to providing a record of the past concentration of CO_2 in the atmosphere, the ice cores also give us a temperature record. By studying the ratios of stable isotopes of oxygen that make up the glacial ice, we can estimate the temperature (in the region of the ice) at the time the snow fell (glacial ice is formed by the compression of snow as it gets buried to greater and greater depths). From these data, shown in Figure 5 at right, we can see the natural variations in atmospheric CO_2 and temperature that have occurred over the past 200,000 years (200 kyr).

Looking at this much longer span of time enables us to clearly see that the present CO_2 concentration of the atmosphere is unprecedented in the last 200 Kyr. To find atmospheric CO_2 levels equivalent to the present, we have to go back millions of years. This means that, to the extent that the state of the carbon cycle is closely linked to the condition of the global climate, we are pushing the system toward a climate that has not occurred anytime within the last several million years—not something to be taken lightly.

From this brief look at the record of fossil fuel emissions and atmospheric CO_2 concentrations, it is clear that we have cause for concern about the effects of this global experiment. Because of this concern, there is a tremendous effort underway to better understand the global carbon cycle. We will explore the global carbon cycle by first examining the components and processes involved and then by constructing and experimenting with a variety of models. The first set of models will be relevant to the dynamics of the carbon cycle over a period of several hundred years -- these will enable us to explore a variety of questions about how the system will behave in our lifetimes. The second set of models will provide an introduction to modeling the changes in the isotopic ratios of carbon alluded to earlier. A third model will be relevant for much longer periods of time, allowing us to explore a different set of questions.

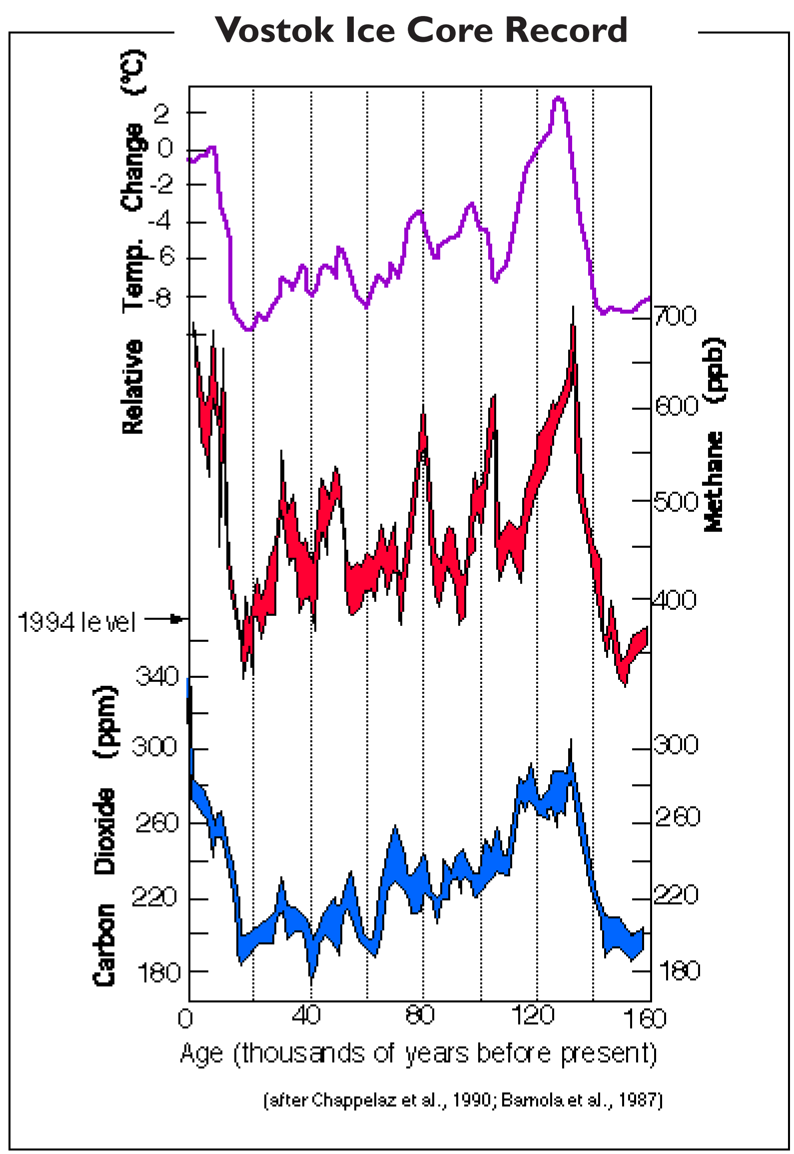


Figure 5: The climate record from the Vostok (Antarctica) ice core shows the natural variations in the atmospheric CO_2 levels associated with the swing between full glacial conditions and interglacial periods such as today. Note the 1994 atmospheric CO_2 level plotted on the left-hand side of the graph; we currently have an unusually high concentration of carbon dioxide. The climatological effects are thus potentially significant.

Carbon Model Self-Assessment

Name: ____

1. What did you learn about your hypothesis/prediction in the carbon model?

2. How did you collect and verify your data?

3. What did you do to control confounding variables in your model?

4. To what extent does your computer model allow you to gather reliable data?

5. Did you find information to support or refute the results you found by manipulating your model?

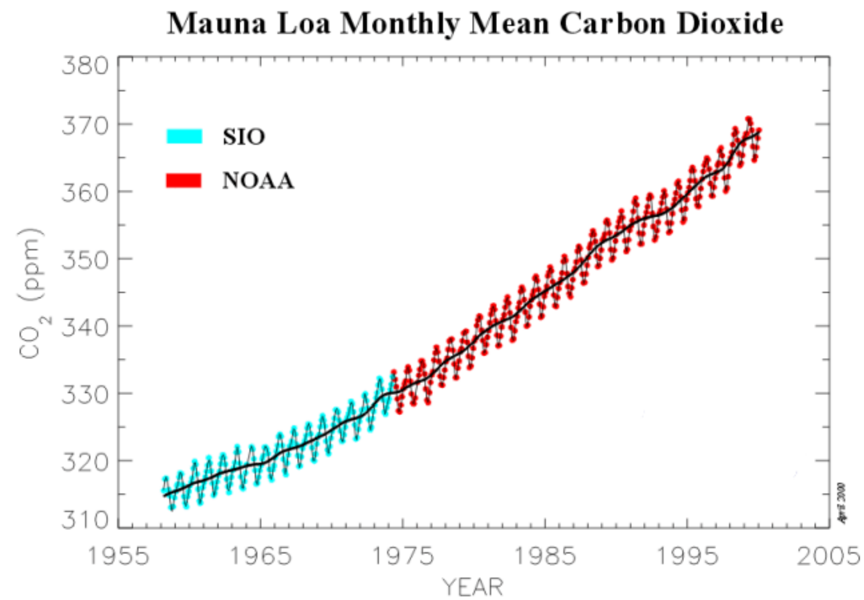
6. What is the biopump stock in the carbon cycle?

7. What is carbon fertilization?

8. Why does carbon dioxide in the atmosphere graphs "zig zag" up and down?

9. Cite evidence that supports the idea that humans are altering the carbon cycle.

10. Based on your experience with the carbon cycle, suggest three policies or human alterations that would help to resolve global warming.



Atmospheric carbon dioxide monthly mean mixing ratios. Data prior to May 1974 are from the Scripps Institution of Oceanography (SIO, blue), data since May 1974 are from the National Oceanic and Atmospheric Administration (NOAA, red). A long-term trend curve is fitted to the monthly mean values. Principal investigators: Dr. Pieter Tans, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6678, ptans@cmdl.noaa.gov, and Dr. Charles D. Keeling, SIO, La Jolla, California, (616) 534-6001, cdkeeling@ucsd.edu.

Source: http://www.mlo.noaa.gov/Projects/GASES/co2graph.htm

About the Curriculum Author:

Robert Corbin is a National Board Certified Science Teacher serving the Charlotte Mecklenburg School System (CMS) as Earth Science Academic Content Coach. He is a founding member of the Bank of America Teaching Fellows and Affiliates program and science facilitator for the National Board Teacher Support Program for CMS. Robert has taught a variety of technology and science courses in a number of public high school, middle school and university settings for about 20 years. He is a Christa McAuliffe Fellow, Duke University Sawyer Fellow, Time Warner Cable All Star Teacher, Ben Craig Award recipient, Omnicron Psi Outstanding Science Teacher, Whitehead Educator of Distinction, and NAGT Outstanding Earth Science Teacher of the Southeastern United States. Robert has received grants and awards from the EPA, NAGT, Bank of America, First Union Bank, Wachovia Bank, Toyota Tapestry Program, International Paper Corporation, Virtual High School Concord Consortium, Noyce Foundation, North Carolina Department of Public Instruction and Christa McAuliffe Foundation. He has written science curriculum for the Weather Channel, Environmental Literacy Council, American Society for the Prevention of Cruelty to Animals, the Duke Talent Identification Program, North Carolina Department of Public Instruction and the Weyerhaeuser Corporation. He has a B.S. in Environmental Science and an I.M.A. in Natural Science Education.

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