

Annenberg Media
Professional Development Course

The Habitable Planet

A Systems Approach to Environmental Science

**Produced by the Harvard-Smithsonian Center for Astrophysics in association
with the Harvard University Center for the Environment.**

The Habitable Planet

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in association with the Harvard University Center for the Environment.

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Table of Contents

Introduction

About the Course	1
Course Components	6
About the On-Site Activities	9
Materials	10
About the Contributors	14

Unit 1. Many Planets, One Earth	19
Unit 2. Atmosphere	31
Unit 3. Oceans	43
Unit 4. Ecosystems	53
Unit 5. Human Population Dynamics	65
Unit 6. Risk, Exposure, and Health	87
Unit 7. Agriculture	97
Unit 8. Water Resources	109
Unit 9. Biodiversity Decline	119
Unit 10. Energy Challenges	131
Unit 11. Atmospheric Pollution	145
Unit 12. Earth's Changing Climate	155
Unit 13. Looking Forward: Our Global Experiment	167

Appendix

Further Reading	181
Credits	185

About the Course

Course Overview

Earth is probably unique in the solar system, if not in the universe, because it is a platform that can support complex life forms. Conditions on Earth (temperatures, atmosphere, availability of minerals essential to life) are all maintained by a series of global cycles that link geological systems (plate tectonics, weathering, ocean, and atmospheric transport) with the diverse forms of life (particularly bacteria) that are present in almost every available niche.

The course will begin by asking “What makes Earth unique among planets?” We will then go on to answer that question through the first four units, which provide a background for understanding and discussing the natural functioning of the different Earth systems: geophysical systems, the atmosphere, the oceans, and, finally, natural ecosystems. The next two units (“Human Population Dynamics” and “Risk, Exposure, and Health”) introduce humans as part of the overall ecosystem and look at what is needed to sustain human life. These are followed by a series of units that each deal with the effects of human actions on different natural systems: land use, air and water pollution, biodiversity decline, the extraction of resources, and finally, global issues such as climate change. The final unit looks toward the future and discusses in scientific terms what can be predicted, given current trends, as well as what might be expected if humans act in concert to mitigate their impact on the planetary system.

Accompanying each unit are video case studies that describe current, on-going research programs. Together, these case studies represent a fair cross section of the current “state of the art” in environmental science research. Designed to provoke curiosity and give a human face to many of the issues raised in the units, these videos will motivate and stimulate viewers to explore the themes through further readings and discussion. Five interactive web simulations will also reinforce the concepts we introduce, as well as teach about modeling environmental systems by providing opportunities to manipulate and experiment with natural systems.

Unit Descriptions

Unit 1. Many Planets, One Earth

While astronomers have discovered dozens of planets orbiting other stars and space probes have explored the edges of our solar system, so far no place in the universe we have discovered is suitable for complex life—except Earth. In this introduction to the course, examine the physical description of our planet, its history, and the unique characteristics that make it habitable.

Video 1. Many Planets, One Earth

The early Earth was a much different planet than the one we know today. Ancient rocks provide evidence of the emergence of oxygen in the atmosphere and the deep freeze of a Snowball Earth. Can these clues help explain the rise of complex animal life?

Andrew Knoll and Paul Hoffman, Harvard University

Unit 2. Atmosphere

Earth’s atmosphere is one of the critical systems that make life possible on our planet. Together with the oceans, the atmosphere shapes Earth’s climate and weather patterns, transporting heat from the tropics to the poles. But Earth’s climate is not static. How does the atmosphere control climate? Learn how heat transport in the atmosphere contributes to the planet’s habitability.

About the Course

Video 2. Atmosphere

The atmosphere makes the earth habitable. Heat trapping gases allow for ecosystems to flourish. Weather patterns, including hurricanes, help to regulate global climate. How might human emissions of greenhouse gases affect the balance of these natural systems?

Pieter Tans, Global Monitoring Division, NOAA
Kerry Emanuel, Massachusetts Institute of Technology

Unit 3. Oceans

The oceans cover three quarters of Earth's surface, and large scale ocean circulation plays an important role in regulating temperature and weather patterns on land. Even so, much of the deep ocean remains unexplored. Learn about a microscopic phytoplankton that contributes almost 25 percent of Earth's photosynthesis and that scientists discovered only a few years ago.

Video 3. Oceans

Ocean systems operate on a wide range of scales. Every few years, El Niño affects weather across the globe. On the small scale, tiny photosynthetic organisms near the ocean surface live and die over a 24-hour cycle. How do ocean systems regulate themselves and thus help maintain the planet's habitability?

Mark Cane, Lamont Doherty Earth Observatory, Columbia University
Penny Chisholm, Massachusetts Institute of Technology

Unit 4. Ecosystems

How living things interact with each other and how they participate in fluxes of matter and energy are key to understanding both abundance (why there are so many of a species) and diversity (why there are so many different species). See how ecologists study these factors to predict how ecosystems will change over time and how habitats might respond to human interactions.

Video 4. Ecosystems

The abundance of diversity in tropical rainforests is astounding. How can so many species co-exist when they are competing for the same resources? And in North America, why did removing just one species change the distribution of plants and animals up and down the food web?

Stuart J. Davies, Smithsonian Tropical Research Institute
Robert Crabtree, Yellowstone Ecological Research Center

Unit 5. Human Population Dynamics

How does human population growth and decline influence economic and social well-being? Does urbanization pose an environmental problem for humans or a pathway to better living conditions? Given current birthrates, what are the obstacles to preserving open space for future generations? Discover the ways that demographers approach these questions and more through the study of population dynamics.

Video 5. Human Population Dynamics

The human population of our planet now exceeds 6.5 billion and is rising. Much of this growth is projected for the most environmentally fragile regions of the world. Will studying the history of the world's population growth help predict the Earth's "carrying capacity"?

Martha Farnsworth Riche, U.S. Census Bureau
Deborah Balk, Baruch College, City University of New York

About the Course

Unit 6. Risk, Exposure, and Health

Humans' exposures to chemicals through pollutants and the food supply have been linked to health risks. What are the general classes of environmental agents that harm health, how do they enter the body, and how do they damage cells once they are present? Learn how dangers are assessed, exposures reduced, and the risks to human health managed.

Video 6. Risk, Exposure, and Health

In order to survive, we require food, air, and water— all of which are contaminated to some extent by man-made pollutants. We are exposed to these products all our lives, even before birth. How are these exposures impacting health, and what can be done to reduce these risks?

Howard Hu, Harvard School of Public Health
Robin Whyatt, Columbia University

Unit 7. Agriculture

The Earth's population will peak at 10 billion or more this century, but the amount of new agricultural land that can be brought into production is limited. In countries around the world, efforts to feed a growing population are leading to the intensification of agriculture—growing ever higher yields of food and products from lower inputs of land, water, and labor. Learn about physiological and environmental factors that limit crop growth, and visit places where agricultural research is helping farmers maximize their harvests and at the same time reduce environmental damage.

Video 7. Agriculture

Will world population outrun food resources? The green revolution of the 20th century multiplied crop yields, in part through increasing inputs of pesticides and fertilizers. How can farmers reduce their use of agricultural chemicals and still produce enough food?

Peter Kenmore, United Nations Food and Agriculture Organization
Pamela Matson, Stanford University

Unit 8. Water Resources

Rivers, lakes, and underground aquifers supply fresh water for industry, irrigation, drinking, and sanitation, but diversion, over-use, and pollution threaten irreplaceable water resources in many parts of the globe. This unit describes the world's major water reserves. See how scientists are grappling with the problems posed by water extraction, salinization, pollution, and water-related diseases.

Video 8. Water Resources

While essential to the lives of humans and animals, freshwater only accounts for 6 percent of the world's water supply. Over-use and agricultural pollution threaten water resources around the globe. How can we provide the water needed for cities and crops while ensuring the survival of the ecosystems that depend on natural water supplies?

Thomas Maddock, University of Arizona
Wendy Graham, University of Florida

About the Course

Unit 9. Biodiversity Decline

While biologists are still trying to learn how many species exist on Earth, a broad trend is clear: extinctions are occurring today at an exceptionally high rate. This unit examines how scientists define and measure biodiversity and how biodiversity is distributed geographically around the globe. Discover the important connection between biodiversity and the stability of ecosystems.

Video 9. Biodiversity Decline

Species are being lost at an extremely rapid rate in rainforests and coral reefs. With so many species yet to be discovered, scientists struggle to keep ahead of the bulldozers on land and the “rise of slime” in the sea. How can we protect the biodiversity of these vulnerable ecosystems?

William Laurance, Smithsonian Tropical Research Institute
Jeremy Jackson, Smithsonian Tropical Research Institute, Scripps Institute

Unit 10. Energy Challenges

Industrialized nations rely on vast quantities of readily available energy to power their economies and produce goods and services. As populations increase and citizens demand better standards of living, global energy consumption will continue to rise, accompanied by ever-higher demands for non-fuel mineral resources such as iron and steel. Learn about future technologies that can produce ample supplies of energy without some of the environmental costs linked to current energy resources.

Video 10. Energy Challenges

Global energy use increases by the day. Polluting the atmosphere with ever more carbon dioxide is not a viable solution for our future energy needs. What new technologies will help provide the energy we need without pushing the concentrations of CO₂ to dangerous levels?

Neeraj Gupta, Battelle Memorial Institute and Department of Energy
Andy Aden, National Renewable Energy Laboratory

Unit 11. Atmospheric Pollution

Air pollution is a global issue, with emissions from East Asia impacting the day-to-day air quality of cities in North America. At the same time, greenhouse gases such as carbon dioxide and methane are changing the climate, while other man-made compounds destroy the ozone layer at high latitudes. Discover how pollutants released from smokestacks and tailpipes undergo a complex chemistry that transforms them into dangerous toxins—with widespread detrimental effects on human health.

Video 11. Atmospheric Pollution

Once released, air pollution reacts chemically to form even more dangerous secondary pollutants. And these travel: nitrogen oxides from Asia affect the long-term health of Californians. How do we use what we can learn about air pollution transport to better control its impact?

Charles Kolb, Aerodyne Research, Inc.
Luisa Molina, Massachusetts Institute of Technology

About the Course

Unit 12. Earth's Changing Climate

For the first time in the history of our species, humans are now impacting the habitability of Earth on a planetary scale. Fossil fuel combustion has increased concentrations of greenhouse gases to levels that no human has yet experienced while, at the same time, studies have shown Earth's past climate to be an exquisitely sensitive system subject to dramatic shifts over timescales of a few decades. In this unit, examine the science behind global climate change and explore its possible impact on natural ecosystems and human societies.

Video 12. Earth's Changing Climate

Tropical glaciers are the world's thermometers; their melting is a signal that human activities are warming the planet. Will natural ecosystems be able to absorb enough additional carbon dioxide from the atmosphere to mitigate the full impact of human-induced greenhouse gas emissions?

Lonnie Thompson, The Ohio State University
Chris Field, Stanford University

Unit 13. Looking Forward: Our Global Experiment

Emerging technologies offer potential solutions to environmental problems. Over the long-term, human ingenuity may ensure the survival not only of our own species but of the complex ecosystems that enhance the quality of human life. In this unit, examine the wide range of efforts now underway to mitigate the worst effects of man-made environmental change, looking toward those that will have a positive impact on the future of our habitable planet.

Video 13. Looking Forward: Our Global Experiment

Earth's essential systems are being stressed in many ways. There are many tipping points in the environment, beyond which there could be serious consequences. Will human ingenuity, resiliency, and cooperation save us from the worst outcomes of our global experiment?

John Holdren, Harvard University
Daniel Pauly, University of British Columbia
Ann Pringle, Harvard University
Daniel Schrag, Harvard University
E.O. Wilson, Harvard University

Course Components

On Site Activities

The Habitable Planet Professional Development Guide is intended to provide structure, resources, and activities for use in teacher professional development. The course consists of thirteen two-and-a-half hour sessions, each of which includes pre- and post-viewing group activities and discussions that complement the half-hour video. Each session addresses specific content from that unit's video and text and has a consistent structure that includes key content questions, activities, and resources for extending personal understanding and teaching the unit topic.

Background (Pre-Workshop)

Prior to arriving at the on-site session, participants should read the background sections of the assigned unit. Participants will also have completed the between-session assignment from the previous session.

Introduction

The introduction to each unit is a short summary and overview of the entire unit. The major themes of the unit are identified.

Essential Questions

The essential questions section contains several key questions that address the unit topic. The questions are intended as advanced organizers to start you thinking about the specific unit topic. They are global in nature and attempt to focus your attention on the big picture when reading the text, watching the video, and conducting on-line simulations. For example, in Unit One, "Many Planets, One Earth," an essential question is, "How does evidence of the deep past inform us about today's ecological conditions?" In the text and video, you will read, see, and hear about the use of fossils and geologic formations to explain the extensive climate changes that have helped create the abundance and diversity of life on Earth.

The Content

The content section of each unit guide contains a brief summary of the text and video for the unit that focuses on key science concepts. Each video focuses on two distinguished research scientists who describe their work as it relates to the unit topic. The videos present interdisciplinary subjects and diverse methodological relationships in unique ecological settings.

Learning Goals

Learning goals are presented as potential outcomes for participants in The Habitable Planet professional development workshops. For each unit, we present three types of expected science education outcomes, including knowledge, skills, and dispositions. Many of the goals are directly related to national standards in science education. Knowledge refers to specific science content. Skills refer to science process skills, such as experimental techniques, evaluation of results, and outcomes and communication. Dispositions refer to attitudes and values related to science and the specific research findings.

Key Concepts

Key concepts are listed to focus the learner on specific ideas that are presented in the text and video. In many cases, the key concepts correspond to specific sections of the unit text.

Misconceptions

Each unit includes a section on misconceptions related to the unit topic. Misconception research indicates that these commonsense but incorrect explanations of the world interfere with new learning. We want you to be aware of these ideas for your own personal learning and to consider them as you prepare lessons for your students. In most cases, we have identified a misconception, suggested why it may be prevalent, and explained the scientifically accepted understanding.

Course Components

Getting Ready (On-Site)

In preparation for watching the video, you will engage in forty-five minutes of investigation through activity and discussion. Typically, we present three activities that the facilitator of the group will lead. Activity One and Activity Two are consistent throughout the entire course, while Activity Three changes to fit the specific unit topic.

Activity One: Assessing Prior Knowledge, Questions, and Related Experiences

Assessing learners' prior knowledge is considered one of the most important factors in meaningful learning because the knowledge that the learner brings to the topic will influence any new learning. At the start of each session, the facilitator will distribute three index cards to each participant. On the first card, participants should indicate something they know to be true about the unit topic. On the second card, each participant should write one question he or she has about the specific unit topic. On the third card, each person should describe a direct experience related to the unit topic.

For example in Unit 12, "Global Climate Change," a participant might write:

Climate change is occurring faster than ever.

What causes climate change?

It seems the winters are warmer with less snow.

When the participants have completed their three cards, the group tapes the cards onto the wall or blackboard, grouping similar ideas, questions, and experiences. Statements, questions, and experiences may be grouped in a variety of idiosyncratic ways. Participants should look for relationships and discuss similarities and differences. They should begin to see patterns of understandings and experiences. The group can use chalk, markers, or tape to indicate logical groupings and relationships between ideas. Participants may add or delete cards. They can move cards around. Some of the most interesting aspects of this activity are associated with the dynamic interaction of participants. Often cross-links between various groups of ideas indicate very creative associations and relationships. The group can return to this wall diagram after viewing the video to discuss their original ideas and add new ones.

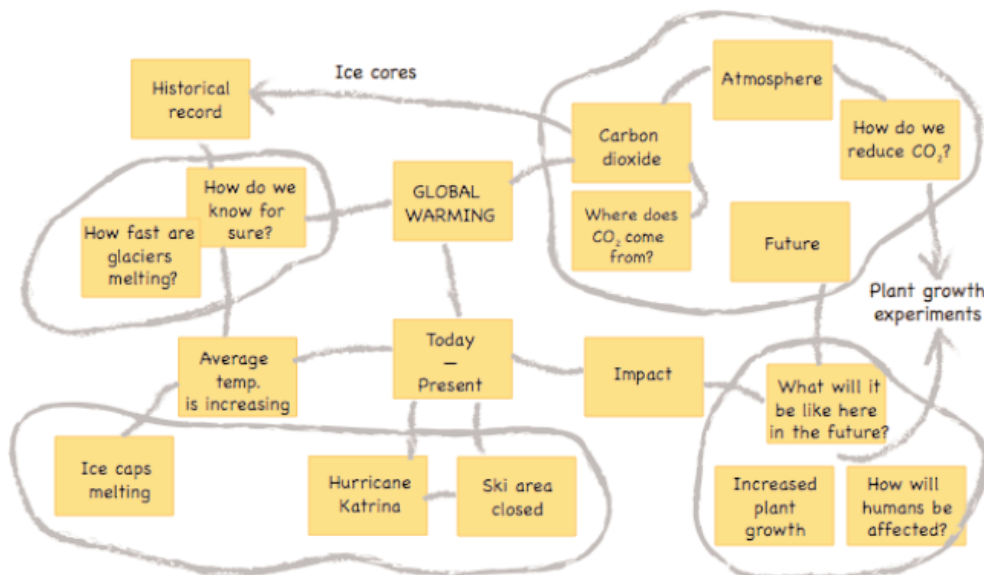


Figure A. This example from Unit 12, "Earth's Changing Climate," illustrates a potential outcome of Activity One: Assessing Prior Understanding. Consider the individual cards and how they might be grouped. This is only one possibility for their organization. Each week the goal is that the participants will reflect on their personal understandings, questions, and experiences and share them in a way that creates dynamic interactions.

Course Components

Activity Two: Current Events and Editorial Cartoons

Participants share an article or cartoon that they have found related to the week's topic. Newspapers, magazines, and the Internet can provide many popular perspectives on topics related to The Habitable Planet. Each participant should be asked to read aloud the headline of his or her article. The facilitator should ask a few people to summarize their articles, asking for comments from others with related articles. As the group discusses the articles, a participant should record a list of key concepts.

Activity Three: Pre-Video Demonstration or Activity

The third activity before the viewing of the video is typically a demonstration, discussion, or online simulation related to the unit topic. In most cases, the facilitator will need to set up the demonstration before the group arrives and have it ready for viewing and discussion by the participants. The objective is to illustrate related science concepts and discuss key ideas and various perspectives as they relate to the video. An example of this approach is the greenhouse demonstration in Unit 12. Although a very simple activity, this demonstration clearly indicates how light energy is captured and thus causes temperature increase. Participants will discuss how this can happen in natural settings, which leads into the Unit 12 video on global climate change. When an activity involves using The Habitable Planet Interactive Labs, the facilitator will ensure that, at a minimum, a single computer with Internet access is available for the group. Participants will use the simulation to control variables, predict outcomes, and visualize results.

Activity Four: Watch the Video

In each session, we have provided questions to consider while watching the video. These questions are fairly specific and help focus the viewer's attention on key parts of the video. The facilitator and participants should consider the questions before the start of the video.

Activity Five: Discuss the Video

We have provided questions that are more general and intended to stimulate discussion following the video. These questions focus on analysis or synthesis and ask the participants to compare and contrast the ideas or methodologies the researchers present.

Activity Six: Going Further

This activity includes discussions, experiments, or demonstrations to conduct following the viewing of the video. The activities should be prepared by the facilitator before the professional development workshop session convenes. Each activity is intended to build upon key ideas and extend participants' understanding.

Activity Seven: Return to Essential Questions

Before the conclusion of the session, participants should return to the essential questions posed in the background section of the professional development guide.

Activity Eight: Discuss Classroom Supplementary Activities

In each session, we have provided a number of supplementary activities that can be used in middle and secondary school science classrooms. The facilitator should take a brief amount of time to have participants discuss the activities and how they might be implemented in the classroom.

Between Sessions (Post-Workshop)

These activities should be completed before the group convenes to address the next unit. Assignments prepare the participants for effective participation in the next professional development session.

Next Week's Topic

Each participant should read the entire Online Text for the next unit as well as the misconceptions section in the Background section of the guide.

Course Components

On-Line Simulation

If there is an online Interactive Lab for the next unit, participants should complete the simulation, write a paragraph summary of what they learned, and bring it to the next meeting of the workshop group.

Current Events, Popular Articles, and Cartoons

Each participant should bring a newspaper or magazine headline, article, or editorial cartoon related to the next unit topic.

About the On-Site Activities

Helpful Hints

Included in the materials for each session you will find detailed instructions for the content of your Getting Ready and Going Further activities. The following hints are intended to help you and your colleagues get the most out of these pre- and post-video discussions.

Designate a Facilitator

Each week, one person should be responsible for facilitating the session (or you might select two people—one to facilitate Getting Ready and the other to facilitate Going Further). The facilitator does not need to be the same person(s) each week. We recommend that participants rotate the role of facilitator on a weekly basis.

Review the Site Activities and Bring the Necessary Materials

Be sure to read over the Getting Ready and Going Further sections of your materials before arriving at each workshop. The sessions will be the most productive if you and your colleagues come to the workshops prepared for the discussions. A few of the activities require special materials. The facilitator should be responsible for bringing these when necessary.

Keep an Eye on the Time

Thirty minutes go by very quickly, and it is easy to lose track of the time. You should keep an eye on the clock so that you are able to get through everything within the two-and-a-half hour session. You may want to use a small alarm clock or kitchen timer as a reminder.

Record Your Discussions

We recommend that someone take notes during each Site Discussion or, even better, that you make an audiotape recording of the discussions each week. These notes and/or audiotape can serve as “make-up” materials in case anyone misses a session.

Share Your Discussions on the Internet

The Site Activities are merely a starting point. We encourage you to continue your discussions with participants from other sites through the course email discussion list. Participants can join this list through the course home page on www.learner.org.

Materials

For each session

3 index cards per participant for each session

Unit 1: Many Planets, One Earth

Activity Three: Geologic Time Scale Activity

- One roll of toilet paper (231 sheets or more)
- Felt-tip marker(s), preferably several colors
- Clear tape for repairs

Activity Six: Carbon Cycle and Human Influence

- Three easily acquired, inexpensive, and uniform objects for each participant—e.g., small rocks, pencils, pens, shells, etc.
- Poster board or large pieces of paper labeled as carbon pools, atmosphere, biomass, soil, ocean, fossil fuel deposits, and underground rocks

Unit 2: Atmosphere

Activity Four: Demonstrating the Carbon Cycle

- At least 15 black balloons to represent carbon. One red balloon (equals 48 black balloons) and one white balloon (represents 66,000 black balloons); balloons should be filled with air
- String or tape to attach balloons
- Large index cards identifying the principal carbon reservoirs: Atmosphere; land biomass (plant or animals); ocean; fossil fuel; rock
- Drawing paper and markers

Activity Six: The Effect of Surface Type on Heating

For each group of four participants:

- Six 1-liter bottles
- Six thermometers
- Tape
- White paint and brushes
- Three cups of dark soil
- Three cups of white sand
- Water and dump buckets
- One 150-watt floodlight bulb
- Portable reflector lamp
- Stand to support lamp set-up
- Graph paper

Materials

Unit 3: Oceans

Activity Three: Ocean Currents Demonstration

- Large, shallow watertight container
- Food coloring
- Fan
- Water
- Stopwatch

Activity Six: Stratification of a Water Column

- A watertight column (such as settling tubes, clear PVC, or a very large graduated cylinder)
- 4 small glass vials with screw-on lids
- Fine sand
- Food coloring (optional)
- Water

Unit 4: Ecosystems

Activity Six: Determination of Species Diversity and Abundance Using Owl Pellet Data

- Copies of Table 4.1 for each participant
- Owl pellets

Unit 5: Human Population Dynamics

Activity Three: Changes in Human Population

- Copies of tables and graphs in Activity Three

Activity Six: Spatial Demographics Activity

- One set of fact sheets for each participant, listing the environmental and natural resources for the seven countries featured in the Interactive Demographics Lab
- A computer and Internet access in order to run the Interactive Demographics Lab

Unit 6: Risk, Exposure, and Health

None

Materials

Unit 7: Agriculture

Activity Three: A Sustainable Agricultural Land-Use Scenario

- A large number of small objects of two different colors, such as small garden decorating stones, marbles, or candies
- Paper bags—one per group

Activity Six: Bioaccumulation

- Oil
- Red dye
- Five 100 ml beakers
- Two 400 ml beakers
- Fishing pole
- 16 test tubes
- Red marker
- 1-liter beaker
- Stirring rods
- Pipettes
- Fish consumption advisories (one per participant)

Unit 8: Water Resources

Activity Three: What is a Watershed?

- Stream table, children's pool, or large plastic container
- Crumpled newspaper
- Saran wrap
- Spray bottle
- Blue colored water
- Clear acetate sheet for each participant
- Erasable markers

Unit 9: Biodiversity Decline

Activity Six: Timber Harvesting Community Role Play

Set of role cards for each group of nine participants

Unit 10: Energy Challenges

None

Materials

Unit 11: Atmospheric Pollution

Activity Three: Tree Leaf Symmetry

- Topographic map of local area of study, areas marked leaves

Activity Six: Discussion of Local and National Air Quality

- A report for air quality in cities in the USA. *Print out the report found at the EPA Web site for the United States, Air Quality Index Report, Metropolitan Statistical Area (MSA) summary type, for the year of 2006 (or later, if available)*
- Reports for the specific location of the group

Unit 12: Earth's Changing Climate

Activity Three: Greenhouse Demonstration

- 2 identical containers
- 2 covers
- Clock
- Light source
- Matches
- Vinegar
- Baking soda
- 2 shallow dishes
- 2 thermometers

Activity Six: Historical Climate Statistics

- Graph paper

Unit 13: Looking Forward: Our Global Experiment

None

About the Contributors

Course Developer

Daniel P. Schrag, Harvard University

Daniel Schrag is professor of Earth and planetary sciences and environmental engineering at Harvard University and the director of the Harvard University Center for the Environment. Schrag studies climate and climate change over the broadest range of Earth history. Schrag received a B.S. from Yale in 1988. He majored in political science and geology, beginning an interest in science and policy that continues to this day. As a graduate student at Berkeley, Schrag was introduced to geochemistry and paleoclimatology through his work developing new methods for reconstructing ancient climates. After receiving his Ph.D. in 1993, Schrag taught at Princeton until 1997, when he moved to Harvard's Department of Earth and Planetary Sciences. In his research, Schrag applies a variety of techniques from analytical chemistry to a wide range of Earth materials including trees, corals, and deep sea sediments, using the data to understand the chemical and physical evolution of the atmosphere and ocean and the relationship to the evolution of life. He has studied the physical circulation of the modern ocean, focusing on El Niño and the tropical Pacific. He has worked on theories for Pleistocene ice-age cycles over the last few hundred thousand years. He helped develop the Snowball Earth hypothesis, proposing that a series of global glaciations occurred between 750 and 580 million years ago that may have contributed to the evolution of multicellular animals. He has also worked on the early climates of Earth and Mars nearly 4 billion years ago. He is currently working with economists and engineers on technological approaches to mitigating future climate change. Among various honors, Schrag was awarded a MacArthur Fellowship in 2000.

Content Developers

Units 1, 12, 13

Daniel P. Schrag (see above)

Unit 2

Steven C. Wofsy, Harvard University

Steven Wofsy is professor of atmospheric and environmental science at Harvard University. His work focuses on the chemical composition of the atmosphere, both regionally and globally, and is motivated by the need for scientific information and analysis to make wise decisions on the future development of the world's resources. His group projects include developing new airborne sensors to make accurate measurements of CO₂, CH₄, CO, and N₂O and devising new analysis and modeling procedures to extract quantitative information about sources, sinks, transformations, and transport of atmospheric trace gases. The long-term goal of these efforts is to understand the factors that regulate atmospheric composition and to help design programs to mitigate undesirable change.

Unit 3

James J. McCarthy, Harvard University

James McCarthy is an Alexander Agassiz Professor of Biological Oceanography and director of Harvard University's Museum of Comparative Zoology. He holds faculty appointments in the Department of Organismic and Evolutionary Biology and the Department of Earth and Planetary Sciences and is the head tutor for degrees in environmental science and public policy. His research interests relate to the regulation of plankton productivity in the sea, in particular the cycling of nitrogen in planktonic ecosystems. He was the founding editor of the American Geophysical Union (AGU) Global Biogeochemical Cycles journal. For the past five years, he has served as co-chair of the Intergovernmental Panel on Climate Change (IPCC), Working Group II, which has responsibilities for assessing impacts of and vulnerabilities to global climate change. He has been elected a fellow of the American Association for the Advancement of Science, a fellow of the American Academy of Arts and Sciences, and a foreign member of the Royal Swedish Academy of Sciences. In 1997, he was the recipient of the New England Aquarium's David B. Stone award for distinguished service to the environment and the community.

About the Contributors

Unit 4

Paul R. Moorcroft, Harvard University

Paul Moorcroft is a professor of biology at Harvard University who specializes in terrestrial ecosystem dynamics. His research investigates how ecological processes affect the structure, composition, and functioning of terrestrial ecosystems at regional to global scales. He has published a book with Mark Lewis on animal movement, entitled *Mechanistic Home Range Models: From Individual Behavior to Large-scale Pattern*.

Unit 5

David E. Bloom, Harvard University

David Bloom is Clarence James Gamble Professor of Economics and Demography and chairman of the Department of Population and International Health at the Harvard School of Public Health. His recent work has focused on the links among population health, demographic change, and economic growth, and on primary, secondary, and higher education in developing countries. He has been on the faculty of the public policy school at Carnegie Mellon University and the economics departments of Harvard University and Columbia University. He is a fellow of the American Academy of Arts and Sciences, where he co-directs the Academy's project on Universal Basic and Secondary Education.

Unit 6

John D. Spengler, Harvard University

John Spengler is the Akira Yamaguchi Professor of Environmental Health and Human Habitation in the Department of Environmental Health at the Harvard School of Public Health. His research activities are directed at the assessment of population exposures to environmental contaminants that occur in homes, offices, and schools, and during transit, as well as in the outdoor environment. Although he is investigating the effects of pollutants of outdoor origin (ozone, acidic particles, PCBs), he is particularly interested in pollutants of indoor origin (fungi, dust mites, nitrogen dioxide, tobacco smoke, radon, and others). He is also investigating ways to promote improved air quality through sustainable development strategies. Dr. Spengler's objective is to construct the framework for linking zoning, purchases and practices, construction and appliance specifications, and pricing and tax strategies to energy and pollution consequences. He believes that the concepts of pollution prevention, environmental cost accounting, risk-reducing based decision making, and life-cycle analysis have to mature from academic concerns to functional activities within the public and private sectors of a market-driven economy.

Unit 7

Noel Michele "Missy" Holbrook, Harvard University

Missy Holbrook is professor of biology and the Charles Bullard Professor of Forestry in the Department of Organismic and Evolutionary Biology at Harvard University. Her research interests include long-distance transport physiology in plants; root physiology: interactions between uptake and growth; water relations associated with flowering and flower production; biomechanics of growth and development; and factors that control uptake and movement of water in tropical trees.

Unit 8

Charles F. Harvey, Massachusetts Institute of Technology

Charles Harvey is the Doherty Associate Professor in Civil and Environmental Engineering at the Massachusetts Institute of Technology. He is a hydrologist concerned with groundwater and the fate and transport of chemicals in the subsurface environment. His research projects include investigations into the arsenic contamination of Bangladesh's water supply, the flux of nutrients in coastal ocean waters, and the fundamental physical and chemical processes that transform pollutants within soils and groundwater.

About the Contributors

Unit 9

Anne Pringle, Harvard University

Anne Pringle is an assistant professor of organismic and evolutionary biology at Harvard University and an associate member at the Broad Institute. Her research explores evolution as it happens in wild populations of fungi. Current work in her laboratory focuses on an introduced symbiont currently expanding its range on the West Coast of North America, cooperation between germinating spores of the genetic model *Neurospora crassa*, and immortality within filamentous fungi.

Unit 10

John P. Holdren, Harvard University

John Holdren is Teresa and John Heinz Professor of Environmental Policy and Director of the Program on Science, Technology, and Public Policy at the Kennedy School, as well as professor in Harvard's Department of Earth and Planetary Sciences. He is also director of the Woods Hole Research Center, chairman of the board of the American Association for the Advancement of Science, and co-chair of the independent, bi-partisan National Commission on Energy Policy. His work has focused on causes and consequences of global environmental change, analysis of energy technologies and policies, ways to reduce the dangers from nuclear weapons and materials, and the interaction of content and process in science and technology policy.

John H. Shaw, Harvard University

John Shaw is the Harry C. Dudley Professor of Structural and Economic Geology and Chair of the Department of Earth & Planetary Sciences, Harvard University. Prior to joining the faculty at Harvard, Professor Shaw worked as an exploration and production geologist in the petroleum industry. Shaw directs an active research program that investigates the nature of oil and natural gas deposits in basins throughout the world. His research group works to develop more efficient methods of finding and exploiting these resources, as well as mitigating the environmental impacts of these operations. Professor Shaw's additional research and teaching interests include alternative energies and material resources, as well as the environmental impacts of resource exploitation.

Unit 11

Daniel J. Jacob, Harvard University

Daniel Jacob is a professor of atmospheric chemistry and environmental engineering at Harvard University. The goal of his research is to understand the chemical composition of the atmosphere, its perturbation by human activity, and the implications for climate change and life on Earth. His approaches include global modeling of atmospheric chemistry and climate, aircraft measurement campaigns, satellite data retrievals, and analyses of atmospheric observations.

Professional Development Guide Developers

Michael J. Brody, Montana State University

Michael Brody is an associate professor of education in the College of Education, Health, and Human Development at Montana State University, where he teaches courses in the environment, science education, and educational research at the graduate and undergraduate levels. He received his Ph.D. from Cornell University (1985) in science and environmental education. Brody has worked with teachers throughout the Russian Federation, Morocco, and Thailand and has developed the Ecological Field Studies Program, which connects environmental educators through global networks. He is a research associate of the Museum of the Rockies in Bozeman, Montana, where he helped design the permanent exhibit Landforms/Lifeforms. He is a member of the North American Association for Environmental Education (NAAEE) Research Commission and received the NAAEE Outstanding Contributions to Research Award in 2006. Presently, he is working on the development of Project Archaeology and researching science learning outcomes in both formal and informal settings. Brody is the executive editor of ARexpeditions, an online action research journal for professional educators.

About the Contributors

Warren Tomkiewicz, Plymouth State University

Warren Tomkiewicz is professor of Earth system science and chair of the Environmental Science and Policy Department at Plymouth State University in Plymouth, New Hampshire. He teaches undergraduate courses in Earth system science, environmental science, and ocean studies, and graduate courses in science education. He is also graduate coordinator for the MS and MAT programs in science education. Tomkiewicz has been the recipient of several grants funding professional development institutes, courses, and workshops for science teachers in New Hampshire and Maine. His current research interests include effective teaching and learning strategies in undergraduate Earth system science and environmental science courses. He coordinates an action research project with science teachers on teaching and learning science as inquiry. He received an Ed.D. from Boston University, MS from Northeastern University, and BS from Plymouth State College.

Mary Ann McGarry

Mary Ann McGarry is an associate professor of science education at Plymouth State University in New Hampshire. As an undergraduate at Dartmouth College in 1980, she designed a special major in environmental education and has been pursuing the field ever since, earning a Masters in Earth Sciences and a Doctorate in Science/Environmental Education. After serving as a faculty member on several campuses for the University of Maine System, in 2004 she joined the newly founded Center For The Environment at Plymouth State University (PSU) in New Hampshire, working on a new MS in Environmental Science and Policy degree. She continues to work internationally on environmental stewardship issues, fulfilling a residential fellowship for the Cypriot government, serving as a faculty instructor for the month-long PSU Pakistani Educational Leaders' summer institutes, and leading regular travel study courses for educators within the United States, Costa Rica, and Ecuador. In the fall of 2007, McGarry became the Director of Education for the Hubbard Brook Research Foundation, while remaining a faculty member at PSU.

Penny Juenemann

Penny Juenemann lives with her family in Two Harbors, Minnesota, where she teaches at Two Harbors High School. She received a BS in biology, a BAS in life science teaching, and a BAS in physical science teaching from the University of Minnesota Duluth in 1994. Juenemann started her teaching career at the Fond du Lac Ojibwe School by Cloquet, Minnesota, and in 1997 began teaching in Two Harbors. She received her MS in science education from Montana State University-Bozeman in 2004.

Jessica Krim

Jessica Krim earned her BA in Earth Science Education from the University of Delaware in 1997. She then taught Earth Science and Life Science on the Hopi Reservation in Keams Canyon Arizona and Earth Science in Wilmington, Delaware. In 2003, she returned to school to complete her MA in Physical Science and in 2005 began work on her doctoral degree in Curriculum and Instruction at Montana State University in Bozeman, Montana.

Judith Pyle

Judith Pyle earned a BS in medical technology from Temple University (1979) and an MS in infectious disease from the University of Pennsylvania (1984). She has been teaching honors and AP Biology at Abington High School in Abington, Pennsylvania, for 16 years, has taught at the University of Pennsylvania, and has served as an online adjunct instructor for Montana State University.

Notes
