



Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States

Climate Change | A Human Health Perspective

A Student Exploration of the Impacts of Climate Change on Human Health in the United States

Summary

This module follows the **5E instructional model** to promote student discovery and learning about the complex interactions between climate change, the environment and human health. Using content from the US Global Change Research Program’s 2016 report, *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (CHA, 2016), students are prompted to describe the impacts of changing climatic conditions on human health with emphasis on vulnerable populations and apply systems thinking to create a visual model of the various health implications arising from climate change. Students also consider the benefits of climate mitigation on human health and are thus introduced to the concept of co-benefits. Students are invited to identify and evaluate adaptation strategies that are protective of human health. To provide a solutions focus to the module, a culminating activity is offered that enables students to engage with local, state or regional data and the US Climate Resilience Toolkit to evaluate climate adaptation and mitigation strategies and, if desired, plan a resilience building project to address a climate change related human health impact relevant to their local community.

Grade Level

Grades 9-12, with options for differentiation provided

Learning Objectives

By the end of this module, students should be able to:

- Describe the climatic conditions that are changing in response to a warming climate.
- Describe the impacts of these changing climatic conditions on human health with emphasis on vulnerable populations.
- Demonstrate understanding of the complexities of the climate change-health effect system through construction of a visual model.
- Describe the health co-benefits of climate change mitigation.
- Describe and evaluate adaptation strategies that are protective of human health.

Instructional Time Needed

Engagement	15-20 minutes
Exploration	20-30 minutes, can be completed either in class or as homework, can also be extended to include time for independent research
Explanation	20-30 minutes
Elaboration	10-15 minutes
Evaluation	Amount of time will vary depending on evaluation option selected

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Key Words and Phrases

adaptation	exposure pathway	mortality
air quality	extreme heat	ozone
allergies	extreme weather	particulate matter
asthma	flooding	precipitation
cause and effect	food-related infection	susceptibility
climate change	health outcome	systems thinking
climate driver	human health	vector-borne infection
co-benefit(s)	mental health and well-being	vulnerable populations
drought	mitigation	water-related infection
environmental hazard	morbidity	5E instructional model
environmental condition		

Alignment to the Framework for K-12 Science Education

This module promotes three dimensional learning as described in the National Resource Council's *A Framework for K-12 Science Education* (see *Resources* section). The *Next Generation Science Standards* (NGSS) also informed module development with relevant Performance Expectations identified in the summary provided in the supplemental materials. This module, if successfully completed, integrates multiple science and engineering practices, disciplinary core ideas, and cross cutting concepts for both earth and life science.

Alignment to the Climate Literacy Framework

This module, if successfully completed, addresses the following essential principles of climate science as outlined in *Climate Literacy: The Essential Principles of Climate Science*:

Principle 3a: Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish.

Principle 3c: Changes in climate conditions can affect the health and function of ecosystems and the survival of entire species.

Principle 7e: Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new areas with favorable climate conditions. Infectious diseases and certain species will be able to invade areas that they did not previously inhabit.

Principle 7f: Human health and mortality rates will be affected to different degrees in specific regions of the world as a result of climate change. Although cold-related deaths are predicted to decrease, other risks are predicted to rise. The incidence and geographical range of climate-sensitive infectious diseases—such as malaria, dengue fever, and tick-borne diseases—will increase. Drought-reduced crop yields, degraded air and water quality, and increased hazards in coastal and low-lying areas will contribute to unhealthy conditions, particularly for the most vulnerable populations.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Authors

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Student completes the graphic organizer as he reads the two page brochure about climate impacts on water-related illness from the 2016 Climate and Health Assessment.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



At-a-glance Summary

This module follows the **5E instructional model** to promote student discovery and learning about the complex interactions between climate change, the environment and human health.

Teaching Strategies	Assessment Strategies (Evaluation)
<p>Engage Students are prompted to consider the human health impacts of a changing climate in response to temperature and precipitation data visualizations to pique their interest and for the teacher to informally assess students' pre-existing knowledge.</p> <p>Explore Students are assigned a reading (CHA, 2016) on a particular climate effect (e.g., extreme heat) and create a visual model that depicts the climate change (driver), exposure pathway(s) and health outcomes. Students consider relevant vulnerable populations. Students can also be tasked with exploring data from their state or region.</p> <p>Explain Students present their visual model to the class and together the class constructs a larger visual model to convey the complex ways climate influences health. The teacher's actions center on ensuring student explanations are accurate, addressing misinformation, and clarifying points of confusion. Teacher introduces systems thinking and emphasizes interactions of Earth's spheres.</p> <p>Elaborate Teacher introduces concept that climate change mitigation strategies confer co-benefits to human health and concept that adaptation strategies reduce negative health impacts. Students are tasked with identifying personal (individual) and societal (collective) solutions that could be advanced to address the negative health outcome(s) that were the focus of their assigned topic.</p>	<p>Option 1: Students write a concluding paragraph for their assigned chapter of the 2016 <i>Climate and Health Assessment</i> that describes relevant health co-benefits of climate mitigation efforts and describes adaptation strategies that could be implemented to protect human health in light of climate change.</p> <p>Option 2: Students evaluate at least one adaptation strategy from an economic, social and environmental perspective and present their analysis either in writing or as an in class presentation that could include development of a poster, brochure, infographic, video, etc.</p> <p>Option 3: Students design a solution to combat a specific health outcome that is relevant to their local community, state or region of the country.</p> <p>Option 4: Students develop a resilience building project to address a climate threat that pertains to a specific health outcome relevant to their local community, state or region of the country. Students are prompted to use the US Climate Resilience Tool Kit and other relevant geoscience data to investigate their assigned climate effect, find geoscience data to support their findings, identify vulnerable populations, investigate and evaluate options for adaptation or mitigation and make a recommendation.</p> <p>Extend Students could extend their learning by either working to implement their resilience project in their school or community (if applicable) or by advocating for their adaptation strategy or resilience building project through civic engagement with relevant policymakers (students could partner with a US Government/Civics class).</p>

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Background

Much of the discussion around climate change has focused on the physical and chemical processes associated with climate change and the resulting environmental effects, such as extreme temperatures and melting glaciers. More recently the discussion has expanded to include impacts on human health.

In April 2016, the Obama Administration released a new report called *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (CHA, 2016), which significantly advances what we know about the impacts of climate change on public health, and the confidence with which we know it. The report is available online at <https://health2016.globalchange.gov/>. The 2016 report builds upon the chapter on human health in the 2014 *National Climate Assessment* that is also available online at <http://nca2014.globalchange.gov/report/sectors/human-health>. Developed over three years by approximately one hundred experts in climate-change science and public health – including representatives from the Environmental Protection Agency, the Department of Health and Human Services, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the Department of Agriculture, and U.S. Geological Survey, the Department of Defense, and the Department of Veteran’s Affairs – the 2016 report reinforces that climate change is a significant threat to the health of the American people not just in the future but right now. **As the climate continues to change, the risks to human health will grow, exacerbating existing health threats and creating new public health challenges, and impacting more people in more places.** Chapter 9 of this report is devoted to “populations of concern” which describes a number of **vulnerable populations** that will experience “disproportionate, multiple, and complex risks to their health and well-being in response to climate change.” Depending on the specific health threat, vulnerable populations may include children, pregnant women, the elderly, outdoor workers, low income groups, some communities of color, indigenous peoples, immigrants, persons with disabilities and persons with pre-existing or chronic medical conditions. As the public health system prepares for climate related human health impacts, it will be important to take relevant vulnerable populations into account locally, regionally and globally.

This report describes **seven categories of human health impacts** (chapters 2-8) ranging from heat-related illness and death to vector-borne disease to cardiovascular and respiratory illness and disease. As students consider the numerous health effects of a changing climate, it is important that they also be tasked with identifying **adaptation and mitigation strategies** that can be implemented to protect human health with respect to climate change. Mitigation strategies reduce the amount of CO₂ being added to the atmosphere and include deployment of alternative energy sources such as solar and wind power. Current mitigation strategies will likely not be able to reverse the change in climate that has already occurred. At present, our ability to mitigate the magnitude of the climate change that will occur over the next 100 years is limited by the current makeup of the atmosphere, as well as by what we can prevent from entering and what we are able to remove from the atmosphere in the future. Adaptation strategies help people adjust to climate change impacts such as worsened air quality.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



An example of adaptation strategy would be to improve public transportation and encourage alternative transportation options such as bicycling and walking to reduce vehicle emissions that are harmful to human health.

Through these changes in human activities and practices, we may be able to limit the magnitude of changes to the planet's climate and thus reduce the negative impacts to human health. Although it is possible that some mitigation strategies may exacerbate known human health stressors or introduce unanticipated potential for human harm, many strategies will provide **co-benefits**, simultaneously reducing the negative effects of climate change while also reducing illness and death. Furthermore, these co-benefits may have an even greater impact on vulnerable populations.

Teacher Preparation

1. Students should be introduced to the general concept of climate change and to the human activities influencing climate through greenhouse gas emissions prior to conducting this module. This module is appropriate for both earth and life science courses and can be used to either introduce or reinforce the specific climatic changes (e.g., increased precipitation) that are occurring in response to warming.
2. Read the [Executive Summary](#) of the 2016 *Climate and Health Assessment* and/or review the online report and decide whether you want to cover all seven categories of climate impacts on health (chapters 2-8) or focus on select chapters. The table provided on page 5 of the Executive Summary shows specific examples of climate impacts on human health and can be useful as you plan your instruction. Notice the table categorizes seven climate impacts along with one more climate drivers (specific climatic changes), exposure pathways, and health outcomes.
3. Decide whether students will read a brief ½ page chapter summary, the two-page brochure or the entire chapter based on the reading level of students and/or the extent to which you want students to conduct background reading for this exercise. This is an opportunity for students to cultivate their literacy skills.
4. You will assign one group of students for each chapter you have chosen; determine how many students will be in each group and print one copy of the reading for each student. The ½ page chapter summaries are included in the supplementary materials for this module while the other readings will need to be downloaded as pdfs from <https://health2016.globalchange.gov/downloads> or by clicking on the relevant hyperlinks.

Chapter 2: Temperature-related Death and Illness

[Brochure](#) or [Chapter](#)

Chapter 3: Air Quality Impacts

[Brochure](#) or [Chapter](#)

Chapter 4: Extreme Events

[Brochure](#) or [Chapter](#)

Chapter 5: Vector-Borne Diseases

[Brochure](#) or [Chapter](#)

Chapter 6: Water-Related Illness

[Brochure](#) or [Chapter](#)

Chapter 7: Food Safety, Nutrition, and Distribution

[Brochure](#) or [Chapter](#)

Chapter 8: Mental Health and Well-Being

[Brochure](#) or [Chapter](#)

Depending on your instructional goals and/or the amount of time dedicated to student reading, you may choose to have students also read Chapter 9: Populations of Concern [Brochure](#) or [Chapter](#)

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Option for low-level readers

If you have the time to work with students as they develop their literacy skills, prepare to assign each student either the ½ page or the two page summary for a particular chapter(s) and provide them with one or more close reading strategies to use as they work through the text. Provide ample time for them to conduct this reading assignment and for you to review the text as a class – emphasizing vocabulary terms and key concepts. Students could also be placed in mixed-ability groups and tasked with reading the text, highlighting unfamiliar words and concepts before summarizing as a group.

5. Prepare for the Step 6 of *Engagement Activity* by visiting the US Climate Resilience Toolkit's Climate Explorer Tool (see *Resources* section) and entering your zip code or county name. Here you will have access to county level temperature and precipitation data spanning from 1950-2004 (actual data) and 2005-2090 (projected) for which you can invite students to consider human health impacts under two different greenhouse emissions scenarios. **A default data visualization related to extreme precipitation is provided on Teacher PPT slide 4 to accompany the cause-effect model on flooding presented on slide 7 in light of the historic flooding that occurred in Louisiana in August 2016.** If you choose to use a different visualization replace the content on *slide 4* with your selected visualization and modify the cause-effect model on *slide 7* if needed (see Supplemental materials).

To identify other relevant climate-sensitive health outcomes for your state or region the following resources may be useful:

- *What Climate Change Means for Your State*: facts sheets from the EPA that include a section on human health (<https://www3.epa.gov/climatechange/impacts/state-impact-factsheets.html>)
 - Regional chapters from the 2014 National Climate Assessment (<http://nca2014.globalchange.gov/report#section-1948>)
 - Alternatively, students could be tasked with conducting independent research to investigate relevant climate-sensitive health outcomes for their state or region and to find a corresponding data visualization that can be used in Step 6 of the *Engagement Activity*.
6. Familiarize yourself with this entire lesson plan; review the accompanying PowerPoint slide set and update if needed to tailor it to your instructional goals and/or your region.
 7. Assemble required materials (see *Materials section* below).
 8. Prepare a section of the room (whiteboard (recommended), chalkboard or blank wall) for students to display and organize their visual model of how climate change impacts human health.
 - a. Write the following headings on signs that could be a piece of colored paper, or, if using a white board or chalk board, colored markers or colored chalk, respectively, can be used instead of colored paper. Place the signs on the wall/space in this order from left to right: Climate Driver (green); exposure pathway (blue); Health Outcome (red). These signs will guide students as they place their work on the wall in these categories (also see photo on page 11).

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Materials

Computer with MS Office Software (including PowerPoint)
PowerPoint slide set that accompanies this module (see *Supplemental materials*)
Projector

Engagement

- PowerPoint slide set
- [Optional] blank index cards

Exploration

- Print copies of the graphic organizer “worksheet” (provided on page 10), one per student
- [Optional] colored highlighters or colored pencils (green, orange, blue, red) for reading
- Print one copy of the selected reading for each student. The ½ page chapter summaries are included in supplemental materials while the other readings will need to be downloaded as pdfs.

Chapter 2: Temperature-related Death and Illness

Chapter 3: Air Quality Impacts

Chapter 4: Extreme Events

Chapter 5: Vector-Borne Diseases

Chapter 6: Water-Related Illness

Chapter 7: Food Safety, Nutrition, and Distribution

Chapter 8: Mental Health and Well-Being

[Brochure](#) or [Chapter](#)

Explanation

- Colored dry erase markers if using whiteboard for display of visual model
- Colored chalk if using chalkboard for display of visual model
- If using blank wall for display of visual model:
 - Colored (green, blue, red/orange) ¼ sheets of paper, index cards or Post-it notes
 - Masking tape to attach the colored paper to the wall (if not using Post-it notes) and for showing connections between items on the visual model
- [Optional] 1 copy (per student in the group) of blank systems diagram (see *PPT slide 11*)

Elaboration

- No special materials aside from PowerPoint slide set are needed for this activity.

Evaluation

- [Optional] Computers with internet access, one per student or student group.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



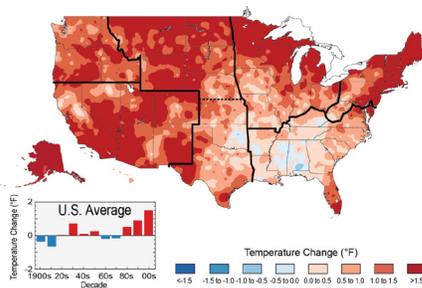
Procedure

Engagement

This short exercise is intended to quickly and informally assess students' pre-existing knowledge of how climate impacts human health and pique their interest in expanding their knowledge. The use of national and/or regional data visualizations provides relevance to students' lives. This activity also introduces students to the terminology that will be used in the exploration and explanation phases of this module.

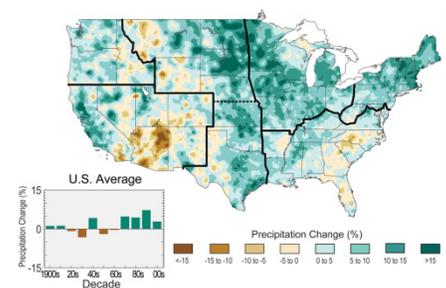
Part I | Exploring prior knowledge

1. Draw a "T" chart on the board or large easel; label the left hand column of the chart "examples of climatic change" and label the right hand column "human health effects."
2. Ask students to name specific examples of climatic change (e.g., increased air temperature) to assess their pre-existing content knowledge. This query invites students to list specific ways the climate is changing (temperature, precipitation, extreme weather, etc.). Record their responses in the left-hand column of the T chart; do not worry about right or wrong answers, just record students' answers.
3. Project figures from the 2014 National Climate Assessment that depict *observed* changes in temperature and precipitation for the nation (*Teacher PPT slides 2 and 3*). Alternatively, you may choose to project visualizations from your region of the country or for the entire globe; state and regional data visualizations for temperature and/or precipitation can be created in the US Climate Resilience Toolkit's Climate Explorer Tool while global data visualizations are available through NOAA's Global Temperature and Precipitation Maps online tool (see *Resources* section).



LEFT: THE COLORS ON THE MAP SHOW TEMPERATURE CHANGES OVER THE PAST 22 YEARS (1991-2012) COMPARED TO THE 1901-1960 AVERAGE FOR THE CONTIGUOUS U.S., AND TO THE 1951-1980 AVERAGE FOR ALASKA AND HAWAII.

RIGHT: THE COLORS ON THE MAP SHOW ANNUAL TOTAL PRECIPITATION CHANGES FOR 1991-2012 COMPARED TO THE 1901-



4. As a class, interpret each figure noting regions that are becoming cooler/warmer and drier/wetter and discuss the observed climate changes for your state and region of the country. Alternatively, students could be asked to interpret each figure in writing or aloud with a partner.
5. Next, ask students to list specific impact(s) of 1) a warming climate on human health; 2) a wetter climate on human health; and 3) a drier climate on human health. Record their responses in the right-hand column of the T chart aligned with any relevant climatic changes listed in the left-hand column; do not worry about right or wrong answers, just record students' answers.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Alternative: Ask students to construct their own T charts on 4x6 notecards; cards could be collected as a pre-assessment. If done anonymously, students could swap cards and share recorded answers aloud as teacher constructs a T chart for the class at the front of the room.

Part II | Creating a visual model of cause and effect

- Project *slide 4* of the data visualization you selected in step 5 of the *Teacher Preparation Section* to the class and ask students to observe and interpret the visualization either individually or with a partner. If referencing a current event (e.g., a recent flooding), adding one or more photos will enhance the relevance of this topic.
- As a class, summarize the data visualization and tell the students that the class is going to construct a **visual model** to show the connection between a specific climate change (*default example: heavy precipitation*) and a specific human health effect (*default example: water contamination*). This modeling activity will introduce students to the terminology that will be used in the exploration and explanation phases of this module.
- In order to create this visual model, use the template provided on *slide 5* as a prompt as you ask students to respond to the following questions:

Flooding & Human Health	
Data Visualization: Number of days with rainfall above 1 inch in 2090; risk of flooding	
What is the specific climate change , also called the climate driver, which is referenced by this data visualization?	Heavy precipitation
What is/are the environmental condition(s) that arise in response to this specific climate change? <i>These conditions can either create(s) or exacerbate(s) an environmental hazard.</i>	Flooding
What is the environmental hazard being examined? <i>An environmental hazard is what will directly lead to a negative health outcome. Together, the environmental condition(s) and the hazard(s) comprise the exposure pathway.</i>	Exposure to contaminated floodwaters
What is/are the health effect(s) that might arise from exposure to the environmental hazard? <i>Health outcomes refer to the specific impacts of the hazard on human health.</i>	Water-borne illness

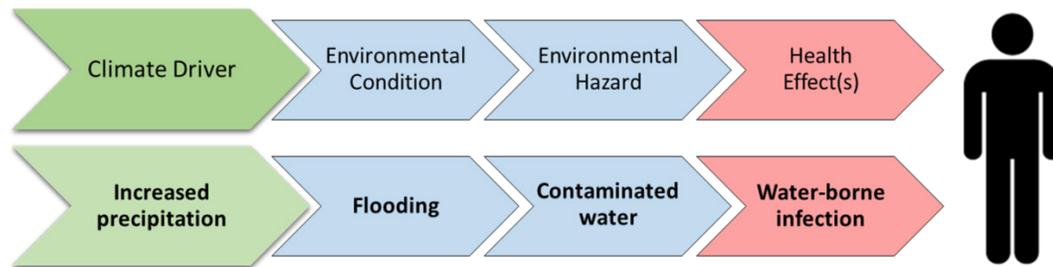
- Together, this information can be used by the class to construct a **visual model of this cause-effect mechanism using the template provided** (see *slides 5-7*).

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Visual Model | Cause and Effect | Flooding & Human Health



10. Point out to students that flooding can be both an environmental condition and a hazard if high waters leads to an injury or drowning. Ask students if they can think of other human health hazards that might arise from flooding (e.g., growth of mold and mildew after water subsides). *Slide 12* shows other hazards that can arise from flooding.

Teaching tip! To help students distinguish between an environmental condition(s) and hazard, provide some familiar examples that might arise as a result of thunderstorm:

Environmental condition: Heavy rain → **Hazard:** Slippery roads

Environmental condition: High winds → **Hazard:** Downed trees

Environmental condition: Drought → **Hazard:** Wildfire

11. To conclude this engagement activity, tell the students that they are going to work as a class to create a visual model of the various health outcomes arising from climate change as described in the *2016 Climate and Health Assessment* using the same strategy.

Exploration

This activity invites students to develop their literacy skills by reading content from the 2016 Climate and Health Assessment. Student reading materials have been prepared exclusively for this activity although for advanced students you may choose to ask them to read the two-page brochure or the entire chapter for their assigned climate impact. A graphic organizer is provided that can be used to guide students as they construct a visual model that will ultimately be shared with the class in order to construct a larger model that will convey the complex climate and health system during the explanation activity.

1. For each chapter of the assessment you plan to investigate, assign 3-4 students per chapter and distribute copies of the assigned reading to each group member.
2. Either in class or as a homework assignment, ask students to complete their reading assignment and either individually or in their group complete one or more rows of the graphic organizer provided on page 10 to summarize the climate and health impacts and vulnerable populations identified in their reading. Time permitting, you may also choose to ask students to read [Chapter 9](#) to learn more about the vulnerable populations identified in their assigned reading. *This is an opportunity for your students to cultivate their literacy skills – ask students to practice close reading and highlight and look up any words or concepts that are unfamiliar.*

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



3. Next, task students with completing one or more rows of their graphic organizer. In general, students seem to find it easier to identify a hazard first and then work backwards to identify the underlying environmental condition(s) that creates the hazard and then the ultimate climate driver (s) that is responsible for producing the environmental condition(s). To complete a row, students list the specific health effects for each hazard identified and then list any vulnerable populations that are more susceptible to experiencing negative health outcomes in reaction to the hazard cited. **In some cases it may be difficult to differentiate the environmental condition(s) from the environmental hazard. For example, increased temperature can be a change in climate, an environmental impact and an environmental hazard. Under heat-related morbidity and mortality high heat/temperatures is the hazard, but under cardiovascular disease and stroke high temperature conditions contribute to an increase in other hazards such as ozone and particulate matter. Students may need guidance in this area; the Answer Key (see page 17) may assist you with that guidance.*
4. Depending on your instructional goals, students could be tasked with conducting additional research on their assigned chapter to investigate this topic from a local or regional perspective.
5. Tell each group that during the next phase of the activity (explanation phase), they will present their visual models to the class (some groups may have more than one model to present). Each group should identify one student who will present the model(s) aloud to the class while the other students in the group contribute to the model by writing and/or placing their model components on the board/wall.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States

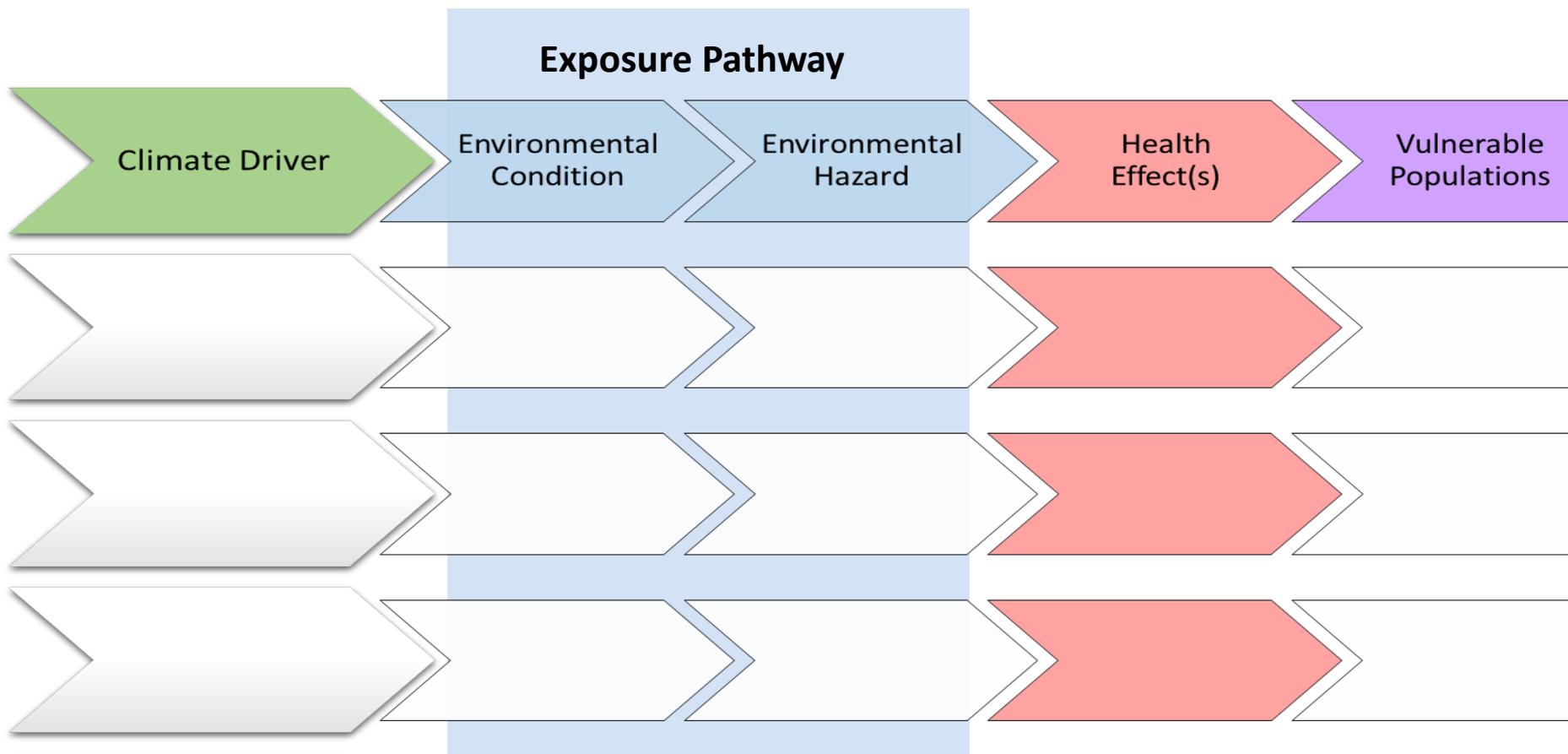


Climate Change and Human Health

Assigned Chapter: _____

NAME: _____

As you read, identify the environmental condition(s) that produce the environmental hazard(s) cited and then identify the underlying climate driver(s) (e.g., increased precipitation). For each hazard, list the health effect(s) and the most vulnerable people/groups. **Not all rows may need to be completed.**



It may be difficult to distinguish the environmental condition from the environmental hazard. For example, increased temperatures can be a change in climate, an environmental impact and an environmental hazard! An environmental hazard is what will directly lead to a negative health outcome.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Explanation

During this activity, students have the opportunity to explain their visual model(s) to the class as a larger model is being constructed that will convey the complex climate and health system. The teacher's actions center on ensuring student explanations are accurate, addressing misinformation, and clarifying points of confusion. During the debrief, the teacher introduces systems thinking and emphasizes interactions of Earth's spheres (atmosphere, biosphere, hydrosphere, lithosphere).

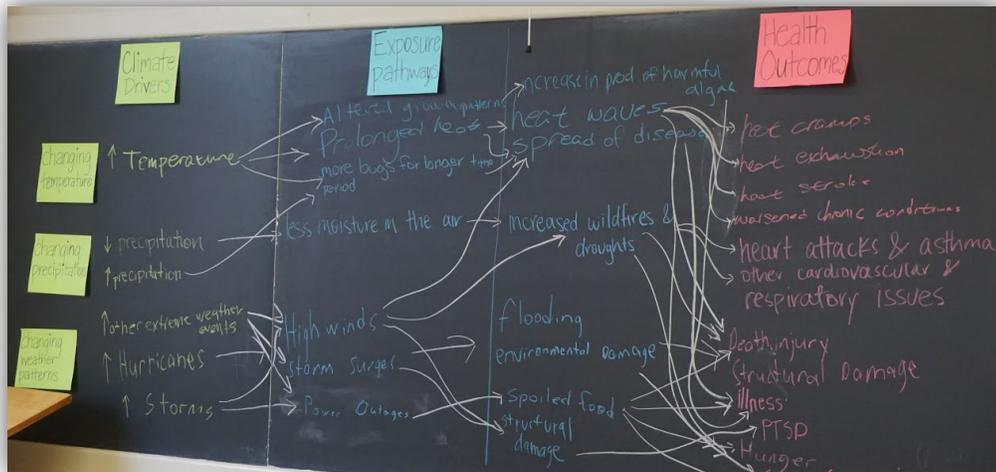
1. Tell the class they are going to combine their models to create a larger visual model to illustrate the complexity of the climate and health system. One at a time, invite each group to come to the board/wall space you have identified and describe their visual model(s) aloud for each health outcome identified in their chapter as they place their model on the board/wall. For each health outcome identified, students should also mention any vulnerable populations to the class.
 - Students will either write their words on the board or place their post-it notes/cards in the appropriate location and connect the words using a marker, chalk or tape.
 - Students should note where one environmental condition (e.g. flooding) influences other health outcomes by adding arrows to the model.
 - If a change in climate or environmental condition is already represented on the board/wall, students should use the term that is already there and connect that term to the new information they are adding to the board.
 - **As a facilitator, prompt students to consider the terms that have already been placed on the board and make new connections using markers or even new terms when possible.** For example: Drought will not only cause an increase in wildfires but can also lead to crop failures resulting in a shortage of food, higher food prices and a likely increase in cases of malnutrition and hunger.

Teaching tip: Ask students to fill in a blank copy of the systems diagram provided on *PPT slide 11* (1 copy per student) to stay on task while others are presenting.

2. As the facilitator, it is important to check if the climate driver → environmental condition → environmental hazard → health outcome sequence identified is correct/logical and clearly depicted on the wall before inviting the next group to the board/wall.
3. Students will begin to see overlapping themes from the placement of the cards and connecting arrows. For example, flooding results in more than one environmental hazard (see *slide 12*) which, in turn, results in several potential health effects.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



4. The visual model created by the entire class might look chaotic, but it gives students an opportunity to see, both visually and intellectually, the complexity of the interactions between the environment and human health. They can see that one event leading to a change in climate (an increase in temperature) can result in many different environmental conditions (increase in heat index, longer growing season, drought) which in turn can generate many different environmental hazards (prolonged exposure to heat, longer pollen season, water scarcity) which in turn can result in many different potential health effects (heat related morbidity and mortality, increased incidence of asthma and allergies). It is a complex system. *NOTE: A systems diagram is provided for the teacher's reference showing these connections - see PPT slide 13.*

Systems-thinking Debrief

The goal of this activity is to create a visual representation of a complex system from the simple “cause-effect” models each group constructed. By building the larger model and answering the guiding questions provided below, students will begin to see the complex interconnected nature of our environment and its impact on human health, as well as the need to simplify in order to study and better understand the individual aspects of the system as well as their connections to each other.

5. Introduce systems thinking by asking the following questions:
- Is the climate change-human health system depicted here a simple or complex system?
Complex system –one environmental condition can lead to multiple hazards and multiple health outcomes; multiple climate drivers can interact to produce an environmental condition.
 - Is the climate change and human health system a physical system? A chemical system? A biological system?
Earth's processes and its living inhabitants are systems within systems. The climate change and human health system is composed of physical, chemical, and biological systems that interact with each other and all interact to influence human health.
 - Are there any smaller (sub) systems within the climate-health system?

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Yes, each sphere represents a system, together the systems make up the larger climate and health system. The human body is also a relevant system and this is a good opportunity to emphasize that for each health outcome some individuals are going to be more vulnerable to climate impacts than others. Susceptibility can be influenced by factors such as age, genetic make-up, and socio-economic status. Chapter 9 of the 2016 Climate and Health assessment provides more information on vulnerable populations with key findings that 1) vulnerability varies over time and is place-specific; 2) health impacts vary with age and life stage; 3) social determinants of health interact with climate factors to affect health risks.

- What is the value of a systems thinking approach to understanding the impact of climate on human health? (e.g., how does knowing about the bigger system help with the study of a smaller system, in this case the human body?)

*Student answers may vary. Look for logical answers. Answers may include statements such as it helps identify potential variables/influences on the system; if you are not aware of the larger system you may reach erroneous conclusions or encounter unintended consequences. Taking a systems thinking approach can also be used to identify how communities (including schools) and the public health system will need to adapt to protect public health in response to a changing climate. **You may want to use this as an opportunity to discuss how the diagram on the board relates to career interests of students; for example, there will be a need for informed public health professionals and adequate public health infrastructure along with informed city and regional planners and school administrators who can prepare schools and communities for these challenges and protect public health.***

6. Refer to the visual model depicted on the classroom wall and ask students to consider the environmental condition for a single climate impact such as flooding (also see slide 12) and all of the potential health effects associated with it. *As the facilitator, you may choose to use a different colored marker or tape to denote the numerous health effects that can arise as a result of a single health threat such as flooding.*
7. Next, you will prompt the class to consider how scientists study the climate and health system; suggested questions are provided below but you may come up with your own questions depending on what you want to emphasize:
 - Why do you think scientists study one part of a bigger system (e.g., incidence of malaria in areas of drought)?
Student answers may vary. Look for logical answers. Answers may include simple statements like “to make it easier.” For example there are many things that could be studied with respect to drought – weather patterns, occurrence, length of time, quality of water supplies, amount of water supplies, increase or decrease in specific pests, use of chemicals as a result of certain pests, etc. There is too much to look at if you tried to do it all. Thus, in order to study or understand a complex systems it needs to be simplified. Simplifying a system can include looking at one part of the system, at a simple “cause and effect” level, or manipulating a variable within the system (experimentation).
 - What do you think are the challenges for a scientist trying to study a smaller part of a bigger system? Consider the parts of a system and its boundaries.
Student answers may vary. Look for logical answers. Answers may include

Educational Materials

A Student Exploration of the Impacts of Climate Change
on Human Health in the United States



statements like: defining the boundaries (i.e. where do you stop? How much do you include in the study?) of the system; identifying and controlling for variables; keeping track of what enters and leaves the system; accurately identifying actions and reactions.

8. Conclude this activity by reiterating that the climate and health system is inherently complex. To better understand the system and assess how climate change is impacting human health it is essential to study its component parts while keeping interconnections in mind. The way scientists think about these interconnections is through the concept of a “system.” **But scientists and policy-makers also need to consider other systems connected to their system of interest as they advocate for strategies that are protective of human health.** For example, there is a push for use of biofuels to reduce our reliance on non-renewable petroleum-based sources. Doing that would solve one set of problems like oil spills and increasing independence from foreign oil, but it may introduce another set of problems in an interconnected system, such as using a food source as a fuel when the world’s population is increasing or the emissions from that alternative fuel may still contribute to air pollution or climate change. These interconnections will be explored further in the next activity.

Elaboration

During this solutions-focused activity, students elaborate on the concepts they have learned and make connections to other related concepts; this activity also promotes critical thinking by asking the students to evaluate solutions.

1. Reinforce to students that greenhouse gas emissions resulting from human activities are driving the climatic changes described in this module. Introduce students to the concept of **climate mitigation** (taking action to reduce or prevent the emissions of greenhouse gases) and prompt students to consider the **health co-benefits** that are conferred by such actions. For example, implementing renewable energy technologies means fewer greenhouse gas emissions and also reduced emissions of particulate matter thus improving air quality which will translate into overall improved cardiopulmonary health. This improved health outcome is an example of a health co-benefit. It should also be emphasized that these health co-benefits may have maximum impact on already vulnerable populations (e.g. those with asthma).
2. Task students with considering how climate mitigation will impact the health outcomes described in their assigned reading. What are the relevant health co-benefits?
3. To further bring a solutions focus to this module, tell students they will identify both personal (individual) and societal (collective) solutions that could be advanced to either prevent or manage the negative health outcome(s) that were the focus of their assigned reading. These solutions can be thought of as **adaptation strategies**. A list of possible adaptation strategies is included for each chapter in the *Answer Key* (page 17).
4. For their assigned chapter, task students with identifying personal and societal adaptation strategies to:
 - a. **Prevent** the negative health outcome(s) from occurring in a changing climate; and/or
 - b. **Promote preparedness/adaptation** so that the negative health outcomes are less severe or occur to a lesser extent than without the intervention.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Alternative: The class could vote on what they consider to be the most relevant human health impact for their community or state and in small groups come up with relevant adaptation strategies.

5. Students could also be asked to investigate local adaptation strategies that are either being planned or implemented to address any health outcomes mentioned in their assigned chapter.

Teaching Tip: Students may find that some strategies could be both a mitigation strategy and an adaptation strategy. For example, an urban forest can reduce greenhouse emissions (mitigation) and it can improve air quality (adaptation).

6. For each adaptation strategy identified have students evaluate the pros and cons of implementation. **Some adaptation strategies may counter mitigation efforts!** For example, building an urban cooling center for people to go to on extreme heat days will be associated with increased greenhouse gas emissions unless the center is powered by renewable energy.
7. Next, invite each group to share one or more of the adaptation strategies they identified to the class.

Evaluation

During this phase, students demonstrate what they have learned by extending their knowledge and practicing their science communication skills.

Depending on the amount of time devoted to assessment of student learning as result of this module, a range of evaluation options is provided and organized from least to most time intensive.

Option 1: Task students with **writing a concluding paragraph** for their assigned chapter of the 2016 *Climate and Health Assessment* that describes relevant health co-benefits of climate mitigation efforts and describes adaptation strategies that could be implemented to protect human health in light of climate change. In their writing students should demonstrate a clear understanding of the distinction between mitigation and adaptation; accurately describe the health co-benefits of mitigation efforts and the vulnerable populations that would especially benefit from these efforts; and describe at least one plausible adaptation strategy while mentioning the pros and cons of implementation.

Sample evaluation rubric

State specific health effect(s) cited in the chapter	10 points
Distinguish between mitigation and adaptation	20 points
Accurately describe health co-benefits of climate mitigation efforts	30 points
Clearly describe at least one adaptation strategy	20 points
Describe pros and cons of implementation of adaptation strategy	20 points

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Option 2: Task students with **thoroughly evaluating at least one adaptation strategy (solution)** they identified during the elaboration activity from an economic, social (including vulnerable populations) and environmental perspective and present their analysis either in writing or as an in class presentation that could include development of a poster, brochure, infographic, video, etc. This could entail evaluation of a local solution to a health outcome cited in their assigned chapter. Students may choose to write a letter to the editor of the local paper or to a policymaker outlining how their community should prepare for a human health outcomes related to their chapter.

Sample evaluation rubric

State specific health effect(s) cited in the chapter	10 points
Clearly describe the adaptation strategy being recommended	20 points
Evaluate strategy from an economic perspective (pros/cons)	20 points
Evaluate strategy from a social perspective (pros/cons)	20 points
Evaluate strategy from an environmental perspective (pros/cons)	20 points
End product clearly communicates information	10 points

Option 3: Task students with **designing a solution** to combat a specific health outcome that is relevant to their local community, state or region of the country. Their design could be described in writing or through a schematic drawing/diagram or they could design a physical prototype through creative reuse of household materials. Students present their design to the class which could be accompanied by a brochure or fact sheet. *Grading rubric is not provided but students should state the specific problem they are trying to solve and clearly describe their solution.*

Option 4: Task students with **developing a resilience building project** (climate adaptation plan) to address a specific climate threat (e.g. flooding) that is relevant to their local community, state or region of the country. Students are prompted to use the US Climate Resilience Tool Kit (<https://toolkit.climate.gov/>) and other relevant geoscience data to investigate their assigned climate threat, support their findings with additional geoscience data (including climate predictions), identify vulnerable populations (check out the Social Vulnerability Index (<http://svi.cdc.gov/map.aspx>)) and investigate and evaluate options for adaptation and make a recommendation. The Tool Kit helps users navigate the steps of developing a resilience building project; while designed for use by communities, this tool kit can guide students through the process of developing a plan to prepare the community for one climate-sensitive health outcome in an effort to simplify the activity. The plan could be outlined in writing and/or through an in-class presentation.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Sample evaluation rubric

Clearly state specific health threat	10 points
Identify vulnerable populations	10 points
Clearly state goal of resilience building project	10 points
Use geoscience data to support need for project	20 points
Clearly describe the adaptation strategies that make up your plan	30 points
Evaluate and prioritize strategies	20 points

Extend

Students could further extend their learning by either working to implement their resilience project in their school or community (if applicable) or by advocating for their adaptation strategy or resilience building project through civic engagement with relevant policymakers (students could partner with a US Government/Civics class).

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Resources

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. 2012. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. National Research Council. Washington, DC: The National Academies Press.
<http://www.nap.edu/>

Climate Change Impacts in the United States: The Third National Climate Assessment. 2014. Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds. U.S. Global Change Research Program, Washington, DC, 841 pp. doi:10.7930/J0Z31WJ2.
<http://nca2014.globalchange.gov/>

Climate Literacy: The Essential Principles of Climate Science. 2009. U.S. Global Change Research Program, Washington, DC, 18 pp.
<http://www.globalchange.gov/browse/reports/climate-literacy-essential-principles-climate-science-high-resolution-booklet>

The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. 2016. Crimmins, A., J. Balbus, J.L. Gamble, C.B. Beard, J.E. Bell, D. Dodgen, R.J. Eisen, N. Fann, M.D. Hawkins, S.C. Herring, L. Jantarasami, D.M. Mills, S. Saha, M.C. Sarofim, J. Trtanj, and L. Ziska, Eds. U.S. Global Change Research Program, Washington, DC, 312 pp. <http://dx.doi.org/10.7930/J0R49NQX>
<https://health2016.globalchange.gov/>

Next Generation Science Standards: For States, By States. 2013. NGSS Lead States. Washington, DC: The National Academies Press.
www.nextgenscience.org/

NOAA's Global Temperature and Precipitation Maps
<http://www.ncdc.noaa.gov/temp-and-precip/global-maps/>

Social Vulnerability Index
<http://svi.cdc.gov/>

US Climate Resilience Toolkit
<https://toolkit.climate.gov/>

US Climate Resilience Toolkit | Climate Explorer
<http://toolkit.climate.gov/climate-explorer2/>
Explore maps and graphs of historical and projected climate trends in your local area by entering your zip code.

What Climate Change Means for Your State | Fact Sheets from the EPA
<https://www3.epa.gov/climatechange/impacts/state-impact-factsheets.html>

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Multimedia

Feeling the Effects of Climate Change, PBS video (13 minute video)

<http://video.pbs.org/video/1939995285>

National Climate Assessment: Health chapter (appx 2 minute video)

<https://vimeo.com/92569617>

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Chapter by Chapter | Graphic Organizer for Reading Comprehension *Answer KEY*

Chapter 2 | Temperature-related Death and Illness | Extreme Heat

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
<p>↑ air temperature</p> <p>-more frequent, elevated air temperature</p> <p>-prolonged heat waves</p> <p>-seasonal timing of events</p>	<p>-elevated air temperatures</p> <p>-combined impact of temperature, humidity, wind, & sunlight</p>	<p>prolonged exposure to extreme heat</p>	<p>heat-related illness and death, including heat cramps, heat exhaustion, heatstroke, and hyperthermia; dehydration; exacerbation of respiratory, cardiac and other illnesses associated with extreme heat; hospital and emergency department visits</p> <p>potential decrease in cold-related deaths, including hypothermia and frostbite</p>	<p>children and the elderly;</p> <p>economically disadvantaged groups; chronically ill; outdoor workers and athletes</p>

Possible adaptation strategies to address extreme heat

Personal: stay hydrated, be aware of heat advisories and adjust work/play time outdoors, etc. **Students may be prompted to identify adaptive behaviors for athletes who participate in school sports during high temperature events.**

Societal: issue heat advisories, offer cooling centers or water play features at parks, adjust shifts of outdoor workers or time of outdoor practices to avoid hottest part of day, construct green roofs, cool roofs, plant street trees, train emergency personnel for heat-related illness, etc. In regards to school sports, students could be prompted to identify actions the athletic department/school administration can take to protect athletes who participate in school sports during high temperature events.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Chapter 3 | Air Quality Impacts

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
↑ temperature + changes in precipitation	longer growing seasons	longer pollen season	↑ allergies/asthma -timing, frequency, severity	children and elderly; asthmatics and people whose immune systems are compromised; economically disadvantaged groups
↑ temperature ↓ humidity	↑ air temperature + UV radiation ↓ cloud cover and rainfall	↑ ground-level ozone	↑ cardiac effort, impairs pulmonary gas exchange, acute myocardial infarction, premature deaths, hospital visits, lost school and work days, acute respiratory symptoms, lung inflammation & scar tissue, chest pain, coughing, throat irritation, congestion, bronchitis, emphysema, asthma	children and elderly; asthmatics and people whose immune systems are compromised
↑ temperature ↓ rain or snow	drought wildfires	dust particulate matter smoke	Respiratory symptoms, allergies, lung damage, premature death, adverse chronic and acute cardiovascular and respiratory health outcomes	children and elderly; asthmatics
↑ temperature ↑ rain or snow	↑ moisture & humidity	↑ molds & airborne allergens	allergies, asthma, respiratory symptoms	children and elderly; asthmatics and people whose immune systems are compromised
↑ heavy precipitation and severe weather events ↑ humidity	↑ indoor humidity and dampness	↑ indoor mold, dust mites, bacteria, and other bio-contamination indoors ↑ indoor volatile organic compounds (VOCs)	asthma and allergy exacerbation	children and elderly; asthmatics and people whose immune systems are compromised

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Possible adaptation strategies

Personal: *limit outdoor exercise near roadways, increase distance from high-traffic roadways, educate self and family about asthma/allergies, reduce personal carbon emissions*

Societal: *provide air conditioning and filtration, education about asthma/allergies, reduce carbon emissions, urban greening; air quality warnings (e.g., ozone alerts)*

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Chapter 4 | Extreme Events

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
↑ precipitation	flooding	flooding, mudslides, slippery roads, debris, loss of infrastructure, contaminated drinking water	traumatic injury and death; drowning; mental health impacts; carbon monoxide poisoning related to power outages; hospitalization; famine; poor water quality; displacement; gastrointestinal illness	coastal populations; persons with disabilities; certain racial/ethnic minority groups; pregnant women and children; low income populations; persons with limited english proficiency
↑ temperature	extreme weather events: hurricanes, tornadoes, severe thunderstorms	wind, flooding, storm surge, power outages	damaged structures can injure or kill people; displacement from homes and/or businesses	pregnant women and children; persons with disabilities; elderly; low income populations
↑ temperature ↓ precipitation	drought	wildfires (smoke); decrease in potable water supplies; decrease in water supplies for agriculture	smoke inhalation; burns; asthma exacerbation; mental health impacts; dehydration; famine; illness from reduced water quality and quantity	asthmatics; low income populations; certain populations of color; pregnant women and children; elderly

Possible adaptation strategies

Personal: respond to evacuation orders and other emergency warnings, pack an emergency preparedness kit or “Go Bag” and develop a family communication plan in advance of extreme events

Societal: avoid building in floodplains and coastal areas subject to extreme high tides and sea level rise, provide extreme event plans/coordination, storm preparation and evacuation warnings

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Chapter 5 | Vector-Borne Diseases

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
<i>extreme high and low temperatures</i>	<i>geographic range of disease vectors increases</i>	<i>increased vector-borne disease</i>	<i>spread of vector-borne and zoonotic diseases (e.g. lyme disease expected to spread north as the range of the deer tick increases);</i>	<i>persons in close proximity to vector habitat; persons with outdoor occupations; children ages 5-9 and adults ages 55-59; males</i>
<i>↑ temperature and changes in precipitation patterns</i>	<i>↑ vector populations</i>	<i>increased vector-borne disease</i>	<i>spread of west nile virus and other pathogens</i>	<i>persons in close proximity to vector habitat; persons with outdoor occupations; low socioeconomic groups</i>
<i>altered weather patterns</i>	<i>drought</i>	<i>↓ some vector populations (e.g. mosquitoes require water)</i>	<i>↓ in some vector-borne diseases in some areas</i>	
<i>↑ temperature</i>	<i>Longer growing season; ↑ pests/vectors;</i>	<i>↑ use of pesticides</i>	<i>neurological diseases, cancer, developmental effects</i>	<i>outdoor occupations; low socioeconomic groups; children, pregnant women, and elderly</i>

Possible adaptation strategies

Personal: wear bug repellent, cover skin when outside during peak times of year, check for pests potentially carrying vector-borne diseases after prolonged time outdoors, make use of screens on windows and doors (barriers) and air conditioning to limit exposure to vector-borne pathogens; remove standing water

Societal: educate vulnerable populations on how to limit exposure to vector-borne diseases, provide air conditioned work conditions, vector control and public health practices, change landscape

Note: A discussion of the specific strategies being implemented to reduce exposure to the Zika virus would be timely as students may have heard many of these strategies communicated to people living in and traveling to areas with active Zika virus transmission.

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Chapter 6 | Water-Related Infection

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
↓ precipitation	drought	increased concentration of effluent pathogens in wastewater treatment plants	waterborne pathogens	residents of low income rural areas; small community or private groundwater wells
↑ extreme precipitation	flooding, freshwater runoff, storm surge, changes to coastal salinity	contaminated water supply (pathogens); compromised quality of recreational waters; ↓ shellfish harvesting	vomiting, diarrhea, wound/skin infections; famine and dehydration; infrastructure failure	tribal groups that consume shellfish; populations that use recreational waters (fishing, swimming, boating); children and pregnant women
↑ air temperature	↑ water temperature	↑ pathogenic organisms such as diarrhea-causing vibrio bacteria; ↑ growth of toxic algal blooms; ↑ seafood-related poisonings (e.g. ciguatera)	diarrhea; neurotoxic or respiratory effects from toxic algae	beach goers; remote populations or villages; residents of low income rural areas; children and pregnant women

Possible adaptation strategies

Personal: awareness about raw shellfish consumption and recreating in marine waters with open wounds, informed recreational activities, education of social determinates of health that affect immune status

Societal: public health surveillance system and monitoring; communications between public health officials and state or tribal shellfish resource managers; management decisions regarding shellfish bed closures; public health communication regarding the use of recreational waters after large precipitation events (awareness of swimming restrictions)

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Chapter 7 | Food-Related Infection

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
<i>altered weather patterns, ↑ temperatures</i>	<i>↑ temperatures and flooding</i>	<i>bacterial pathogens (e.g. salmonella); food spoilage and contamination; disrupted distribution</i>	<i>↑ illness from pathogens that cause vomiting and diarrhea which can result in decreased nutrients in the body; famine</i>	<i>low socioeconomic groups; children, elderly, and pregnant women; indigenous populations; persons with weakened immune systems</i>
<i>↑ CO₂ levels</i>	<i>direct CO₂ fertilization effect on plant photosynthesis</i>	<i>stimulate growth and carbohydrate production in some plants = lower levels of protein and essential minerals</i>	<i>negative implications on human dietary nutrition</i>	<i>pregnant women, elderly, and children; persons with weakened immune systems</i>
<i>↑ air temperature</i>	<i>↑ ocean temperature</i>	<i>accumulation of mercury in seafood; introduce contaminants into the food chain</i>	<i>mercury poisoning; seafood-related gastroenteritis</i>	<i>populations that consume diet high in fish; pregnant women, elderly, and children; persons with weakened immune systems</i>
<i>↑ extreme weather events</i>	<i>↑ CO₂ concentrations</i>	<i>altered incidence and distribution of pests, parasites, and microbes = ↑ in use of pesticides and veterinary drugs</i>	<i>bioaccumulation of pesticides; resistance to pesticides</i>	<i>agricultural workers; pregnant women, elderly, and children; low socioeconomic groups; persons with weakened immune systems</i>
<i>↑ temperature and drought</i>	<i>stress plants, making them more susceptible to mold growth</i>	<i>↑ mold growth and mycotoxin production</i>	<i>illness and death; impaired development in children and immune suppression</i>	<i>children and pregnant women; persons with weakened immune systems; persons with respiratory illnesses</i>
<i>↑ extreme weather events</i>	<i>↑ precipitation and flooding</i>	<i>entry of contaminants into the food chain (e.g. PCBs, organic pollutants, dioxins, pesticides)</i>	<i>illness and death; adverse health effects</i>	<i>children and pregnant women; persons with weakened immune systems</i>

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Possible adaptation strategies

Personal: home refrigeration, awareness of food-handling practices and preparation, wash produce before consumption, awareness of outbreaks

Societal: efficacy of practices that safeguard food in the US, standardize food-handling practices and preparation, response to outbreaks, regulate agricultural practices and livestock processing, regulate water quality management, regulate transportation and infrastructure for food distribution

Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health in the United States



Chapter 8 | Mental Health and Well-being

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
<i>altered weather patterns</i>	<i>extreme weather events (hurricanes, wildfires, flooding)</i>	<i>geographic displacement, damage or loss of property, death or injury of loved ones, recovery efforts</i>	<i>anxiety, emotional stress; acute traumatic stress; post-traumatic stress disorder (ptsd); grief; chronic psychological dysfunction; depression, poor concentration, sleep disorders, etc.</i>	<i>children; elderly women (especially pregnant and post-partum women); people with preexisting mental illness; economically disadvantaged and homeless; first responders</i>
<i>altered weather patterns, temperature changes</i>	<i>extreme temperatures</i>	<i>prolonged heat or cold</i>	<i>chronic stress; poor physical and mental health; increased risk of disease or death</i>	<i>people with preexisting mental illness; elderly populations and people taking prescription medications that impair their body's ability to regulate temperature</i>

Possible adaptation strategies

Personal: *acknowledge condition and seek help; provide assistance to family and loved ones; psychological counseling*

Societal: *community engagement, risk messaging and communications; improving access to necessary services for people with mental illness*