



Educational Materials

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



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

Summary

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*](#) (often called the *2016 Climate and Health Assessment*), participants are tasked with describing the impacts of changing climatic conditions on human health with emphasis on vulnerable populations and patients. Participants apply systems thinking to create a visual model of the various health implications arising from climate change, linking specific climate drivers to health impacts through evidence-based causal pathways. Participants apply knowledge gained from the *2016 Climate and Health Assessment* and a set of clinical case studies to make connections to their own practice and are then prompted to consider the co-benefits of climate mitigation and to identify and evaluate adaptation strategies that are protective of human health. To connect with the larger community of climate and health practice, participants are invited to explore local, state or regional data and the US Climate Resilience Toolkit to understand existing climate adaptation and mitigation strategies and engage with local efforts to implement interventions.

Audience

This module is intended for students in the field of Public Health. Additionally, this module is intended for public health professionals interested in learning about the health impacts of climate change. Instructors may be professional educators or informed health professionals, or health professions students interested in sharing knowledge with teams, students and peers.

Settings

This module is a versatile tool that can be implemented in various educational and professional settings such as:

- Medical and public health school applied science curriculum
- Medical and public school special interest group meetings or elective opportunities
- Professional "brown bag" style meetings
- Professional conferences

Learning Objectives

By the end of this module, participants will be able to:

- Classify and discuss the meteorological variables that are affected by climate change.
- Describe the impacts of climate change on human health via evidence-based causal pathways with an emphasis on identification of vulnerable communities and patients.
- Identify specific impacts on vulnerable individuals and communities and changes in public health practice and health care systems that may prevent or buffer adverse health outcomes.
- Describe the health co-benefits of climate change mitigation and strategies to engage patients and communities in making health-protective changes.
- Locate local, state or regional data related to climate and access relevant resources to implement local adaptation and mitigation plans.

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Instructional Time Needed

Engagement	15-20 minutes
Exploration	20-30 minutes
Explanation	20-30 minutes
Elaboration	10-15 minutes
Evaluation	Amount of time will vary depending on evaluation option selected

Key Words and Phrases

adaptation	exposure pathway	particulate matter
air quality	extreme heat event	precipitation
climate change	food-related infection	susceptibility
climate driver	health intervention	systems thinking
co-benefit(s)	health outcome	vector-borne infection
drought	mitigation	vulnerable populations
environmental hazard	ozone	water-related infection

Educational Philosophy

This module follows the **5E instructional model** to promote participant discovery and learning about the complex interactions between climate change, the environment and human health. The philosophy of the model draws on participants' existing knowledge, beliefs, and skills while guiding participants to 'direct their own explorations' through exploration of data and interactive materials.

Alignment to Relevant Frameworks

Climate Literacy

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

Public Health Education

Relevant standards and competencies described by the [Association of Schools and Programs of Public Health](#) include:

- Describe the direct and indirect human, ecological and safety effects of major environmental and occupational agents.
- Describe genetic, physiologic and psychosocial factors that affect susceptibility to adverse health outcomes following exposure to environmental hazards.
- Specify approaches for assessing, preventing and controlling environmental hazards that pose risks to human health and safety.
- Discuss various risk management and risk communication approaches in relation to issues of environmental justice and equality.

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Series Information

This document is part of a series of educational models on climate and health. Additional versions in the series include:

- *A Student Exploration of the Impacts of Climate Change on Human Health in the United States*
- *A Student Exploration of the Global Impacts of Climate Change on Human Health*
- *A Clinical Health Care Student Exploration of the Impacts of Climate Change on Human Health in the United States*
- *A Clinical Health Care Student Exploration of the Global Impacts of Climate Change on Human Health*
- *A Student Exploration of the Impacts of Climate Change on Human Health & Vector-borne Disease*



The original version of the educational materials for United States high school students was prepared by Dana Brown Haine, MS, University of North Carolina, under temporary assignment to NIEHS through the Intergovernmental Personnel Act (IPA) Mobility Program. Additional versions for international, clinical and public health students were developed by Juliana Betbeze, Leann Kuehn, Betsy Galluzzo, Kimberly Hill, Cecilia Sorensen, and Mariana Surillo. Dr. Sorensen also provided the case studies accompanying the educational materials for graduate and professional students. Materials were generously reviewed by educators and professionals around the country.

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At-a-glance Summary

This module follows the **5E instructional model** to promote participant discovery and learning about the complex interactions between climate change, the environment, and human health. The 5E model is based on the following steps: engage, explore, explain, elaborate and evaluate. Students will build on existing knowledge and develop new ideas as they progress through the module.

Teaching Strategies

Engage

Participants are prompted to consider the human health impacts of climate driven changes in temperature and precipitation, specifically in regard to their patient populations and healthcare systems. Data visualizations are used to facilitate student engagement and to help the teacher informally assess participants' pre-existing knowledge.

Explore

Participants are assigned a reading from the 2016 CHA 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. Participants consider their patient populations and the populations relevant to their specialty. Participants can also be tasked with exploring data at a local, regional, or national level.

Explain

Using knowledge gained in section 2 (explore) participants work in small groups or as a class to create and present a visual model to convey the complex ways that climate change affects health. The facilitator's actions center on ensuring participant explanations are accurate, addressing misinformation, and clarifying points of confusion. Facilitator introduces systems thinking and emphasizes interactions of Earth's spheres and ecosystems.

Elaborate

Facilitator introduces concept that climate change mitigation strategies confer co-benefits to human health and concept that adaptation strategies reduce negative health impacts. Participants identify specific impacts on vulnerable individuals and communities and explore changes in public health practice that could be advanced to may prevent adverse outcomes within the focus of their assigned topic.

Evaluation (Assessment Strategies)

- **Option 1:** Task participants with thoroughly evaluating at least one adaptation strategy from an economic, social and environmental perspective, creating an effective public health message that accurately reflects the risks, identifying relevant stake holders and developing an implementation plan.
- **Option 2:** Task participants 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 or local healthcare institutions using online resources and geoscience data.
- **Option 3:** Task participants with designing a health intervention to combat a specific health outcome that is relevant to their local community, patient population, state or region of the country.

Extend

Participants could extend their learning by either working to implement a resilience project in their community or by advocating for their adaptation strategy or project through civic engagement with policymakers and stakeholders.

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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 US Global Change Research Program released a report called [The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment](#), which is an evidence-based analysis that significantly advances what we know about the impacts of climate change on human health.

The 2016 report builds upon the chapter on human health in the [2014 National Climate Assessment](#), and provides a foundation for the health chapter in the recent [2018 National Climate Assessment](#). 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 worldwide.** 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 attempts to mitigate the negative health consequences of climate change, it will be important to take 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 participants consider the numerous health effects of a changing climate, it is important that they also be tasked with identifying links to clinical or public health practice and **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 not be able to reverse the change in climate that has already occurred but can reduce future impacts. **Adaptation strategies** help minimize the negative impacts of climate change. An example of an adaptation strategy is a heat wave early warning system that helps protect vulnerable populations from the health effects of heat waves.

Through changes in societal and public health 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. Many strategies will provide **co-benefits**, simultaneously reducing the negative effects of climate change while also reducing illness and death. An example of adaptation strategies that provide health benefits, include resilience of health care facilities, integrated early warning and vector control systems for infectious diseases, and enhanced waste water treatment facilities to manage increased flooding events. However, it is also possible that some mitigation strategies may introduce unanticipated potential for human harm.

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Facilitator Preparation

1. Participants should be introduced to the general concept of climate change and to the human activities influencing greenhouse gas emissions prior to or at the start of this module. This module is appropriate for professional students in health-related fields (public health, medicine, nursing) and can be used to enhance curricular and core competency objectives (see Alignment to Relevant Frameworks section above) including: application of epidemiologic and environmental evidence to clinical practice and understanding the population-level determinants of health on the health status and health care of individuals and populations. This module is also appropriate for professionals in the setting of a journal-club style or focus-group setting.
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 participants should read only their chapter or their chapter along with brochures for the remaining chapters.
4. You will assign one group of participants for each chapter you have chosen; determine how many participants will be in each group and print one copy of the reading for each participant. 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 the following links.

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 participant reading, you may choose to have participants also read Chapter 9: Populations of Concern [Brochure](#) or [Chapter](#). Facilitators interested in learning more before preparing the lesson may find resources in the appendix.

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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 participants to consider human health impacts under two different greenhouse emissions scenarios. **A default data visualization related to extreme precipitation is provided on Facilitator 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).

Explore More: Case Studies for Students and Health Professionals

In addition to the examples throughout this text, a graduate level supplement featuring detailed clinical care and public health case studies of climate and health impacts is available [here](#).

Before starting a lesson, instructors are encouraged to explore the case studies and select those that best apply to the field of expertise for your audience. Alternatively, students can explore case studies on their own.

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

- EPA: Climate Impacts on Human Health
- Regional and health-related chapters from the 2018 National Climate Assessment

[Factsheets](#)

[Report](#)

Alternatively, participants could be tasked with conducting independent research to investigate relevant climate-sensitive health outcomes for their state, region, or patient population 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 participants 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 participants as they place their work on the wall in these categories (also see photo on page 14).

Materials (Note: these materials may be substituted as needed depending on resources)

Computer with MS Office Software (including PowerPoint).

PowerPoint slide set that accompanies this module (see Supplemental materials) Projector.

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Engagement

- PowerPoint slide set
- [Optional] Blank index cards

Exploration

- Print copies of the graphic organizer “worksheet” (provided on page 12), one per participant.
- [Optional] colored highlighters or colored pencils (green, orange, blue, red) for reading.
- Print one copy of the selected reading for each participant. 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

[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](#)

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 participant in the group) of blank systems diagram (see PPT slide 14).
- Print one copy of the corresponding “clinical case studies” for each topic for each participant in each group.

Elaboration

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

Evaluation

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

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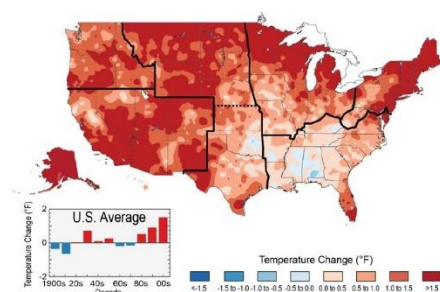
Procedure

Engagement

This short exercise is intended to quickly and informally assess participants' 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 participants' lives. This activity also introduces participants to the terminology that will be used in the exploration and explanation phases of this module.

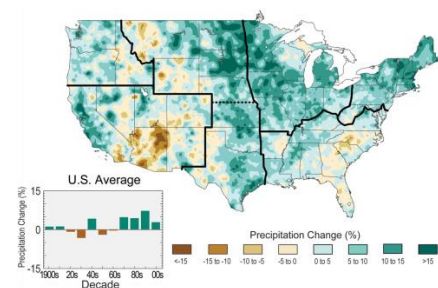
Part I | Exploring prior knowledge

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 participants to name specific examples of climatic change (e.g., increased air temperature) to assess their pre-existing content knowledge. This query invites participants 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 participants' answers.
3. Project figures from the 2014 National Climate Assessment that depict observed changes in temperature and precipitation for the nation (*Facilitator 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'i.

RIGHT: The colors on the map show annual total precipitation changes for 1991-2012 compared to the changes from 1901-1960.



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, participants could be asked to interpret each figure in writing or aloud with a partner.
5. Next, ask participants 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 participants' answers.

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Part II | *Creating a visual model of cause and effect*

- Project *slide 4* of the data visualization you selected in step 5 of the *Facilitator Preparation Section* to the class and ask participants 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 participants that the class is going to construct a **visual model** to show the connection between a specific meteorological variable affected by climate change (*default example: heavy precipitation*) and a specific human health effect (*default example: water contamination*). This modeling activity will introduce participants 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 participants to respond to the following questions:

Flooding & Human Health	
What is the climate driver , also called specific climate change, 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?	Water-borne illness

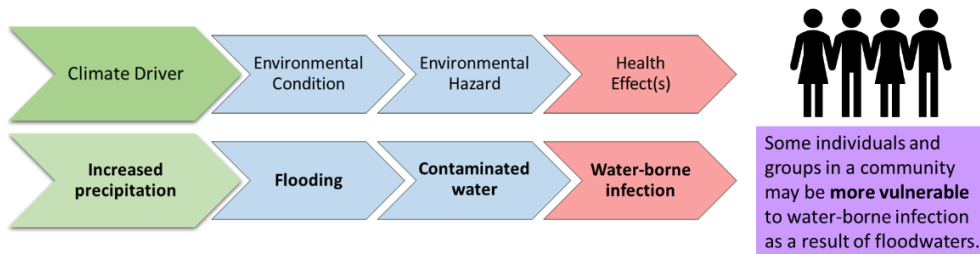
- Together, this information can be used by the class to construct a **visual model of this cause-effect mechanism using the template provided** (see *slides 5-7*).

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Visual Model | Cause and Effect | Flooding & Human Health



10. Point out to participants that flooding can be both an environmental condition and a hazard if high waters leads to an injury or drowning. Ask participants if they can think of other human health hazards that might arise from flooding (e.g., growth of mold and mildew after water subsides; affecting current access to healthcare facilities). Slide 15 shows other hazards that can arise from flooding.

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

Environmental condition: Heavy rain and flooding → **Hazard:** Slippery roads, contaminated water

Environmental condition: High winds → **Hazard:** Downed trees and power lines, power outages

11. To conclude this engagement activity, tell the participants 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

1. For each chapter of the assessment you plan to investigate, assign 1-4 participants per chapter and distribute copies of the assigned reading to each group member (*2016 Climate and Health Assessment* chapters and corresponding clinical case studies).
2. Ask participants 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 participants to read [Chapter 9](#) to learn more about the vulnerable populations identified in their assigned reading.
3. Next, task participants with completing one or more rows of their graphic organizer. To complete a row, participants 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 the clinical implications of the health threat (clinical medicine students/practitioners).
4. Depending on your instructional goals, participants 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 participant who will present the model(s) aloud to the class while the other participants in the group contribute to the model by writing and/or placing their model components on the board/wall.

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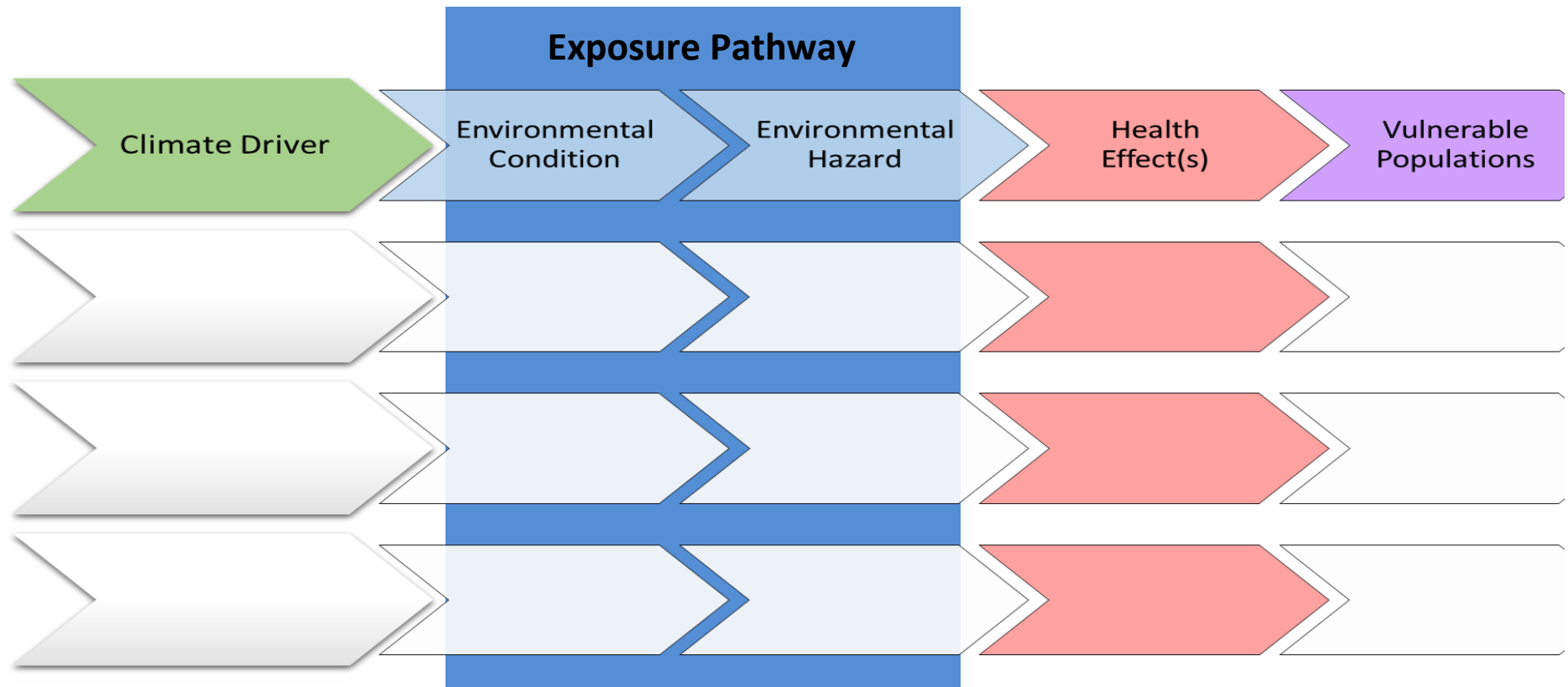


Graphic Organizer

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 condition and an environmental hazard! An environmental hazard is what will directly lead to a negative health outcome.

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Explanation

During this activity, participants 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 facilitator's actions center on ensuring participant explanations are accurate, addressing misinformation, and clarifying points of confusion. During the debrief, the facilitator 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, participants should also mention any vulnerable populations to the class and how this outcome could relate to their patient populations
 - a. Participants 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.
 - b. Participants should note where one environmental condition (e.g. flooding) influences other health outcomes by adding arrows to the model. They should also mention whether the conditions and health outcomes are exacerbating current conditions.
 - c. If a change in climate or environmental condition is already represented on the board/wall, participants should use the term that is already there and connect that term to the new information they are adding to the board.
 - d. **As a facilitator, prompt participants 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.

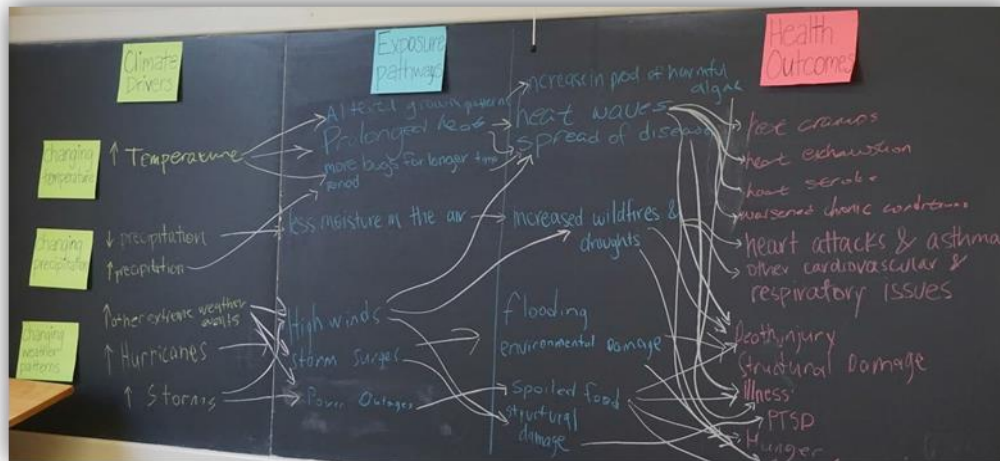
Teaching tip

Ask participants to fill in a blank copy of the systems diagram provided on PPT slide 14 (1 copy per participant) 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. Participants 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 16) which, in turn, results in several potential health effects.

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- 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, warmer water temperatures) which in turn can generate many different environmental hazards (prolonged exposure to heat, longer pollen season, rapid development of mosquito vectors) which in turn can result in many different potential health effects (heat related morbidity and mortality, increased incidence of asthma and allergies, and vector-borne diseases). It is a complex system. *NOTE: A systems diagram is provided for the teacher's reference showing these connections - see PPT slide 16.*

Systems-thinking

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, participants 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.

- Introduce systems thinking by asking the following questions:

- Are there any smaller (sub) systems within the climate-health system?

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.

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- What is the value of a systems thinking approach to understanding the impact of climate on human health?

Participant answers may vary. 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 system thinking approach can also be used to identify how communities (including schools and healthcare facilities) and the public health system will need to adapt to protect public health in response to a changing climate.

6. Refer to the visual model depicted on the classroom wall and ask participants to consider the environmental condition for a single climate impact such as flooding (also see slide 15) 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. 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.
8. To conclude this section, have each group reflect upon the clinical case studies associated with their climate driver. Invite participants to discuss and share other examples they have encountered in their practice environments – clinical or public health.

Elaboration

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

1. Reinforce to participants that greenhouse gas emissions resulting from human activities are driving the climatic changes described in this module. Introduce participants to the concept of **climate mitigation** (taking action to reduce or prevent the emissions of greenhouse gases) and prompt participants 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

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impact on already vulnerable populations (e.g. those with asthma). Introduce the concept of **adaptation** as a means to prevent adverse health impacts already happening within communities as a result of the current impacts of climate change. *You may display slides 18-23.*

2. Task participants 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 solution focus to this module, tell participants they will identify changes to public health practice 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.
4. For their assigned chapter, task participants with identifying adaptation strategies in the practice of public health 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.
5. Participants 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

Participants 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 participants 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, participants demonstrate what they have learned by extending their knowledge and practicing their science communication skills. Depending on background of the participants and the amount of time devoted to assessment of participant learning, a range of evaluation options is provided.

Option 1: Task participants with thoroughly evaluating at least one adaptation strategy they identified during the elaboration section from an economic, social (including vulnerable populations) and environmental perspective. Task participants with creating an effective public health message that accurately reflects the risks. Next, ask participants to identify relevant stake holders and create actionable steps to implement the adaptation strategy.

Option 2: Task participants 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 or local healthcare

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institutions. Participants are prompted to use the [US Climate Resilience Tool Kit](#) 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](#)) 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 participants 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.

Option 3: Task participants with designing a health intervention to combat a specific health outcome that is relevant to their local community, patient population, 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. Participants present their design to the class which could be accompanied by a brochure or fact sheet.

Extend

Participants could further extend their learning by either working to implement their evaluation project in their community (hospital, university, town/state/region or clinical practice) or by advocating for their adaptation strategy or resilience building project through civic engagement with relevant stakeholders (e.g. American College of Obstetrics and Gynecologists – revising/adapting policy on heat exposure and pregnant women).

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Online resources

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

NASA Global Climate Change: Vital Signs of the Planet
<https://climate.nasa.gov/>

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

Using Media to Enhance Teaching and Learning: What is a model?
<https://serc.carleton.edu/introgeo/models/WhatIsAModel.html>

US Climate Resilience Toolkit | Climate Explorer (Explore maps and graphs of historical and projected climate trends in your local area by entering your zip code.
<https://crt-climate-explorer.nemac.org/>

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

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What Climate Change Means for Your State | Fact Sheets from the EPA

<https://19january2017snapshot.epa.gov/climate-impacts/climate-change-impacts-state.html#:~:text=As%20our%20climate%20changes%2C%20every,water%20supplies%20in%20other%20states.>

WHO UNFCCC Climate and Health Country Profile Project:

<http://www.who.int/globalchange/resources/countries/en/>

Multimedia

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

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

Healthy Futures and QWeCI: Health and Climate Change in Africa

<https://www.youtube.com/watch?v=oYL4Nc-qnKE>

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

<https://vimeo.com/92569617>

Protecting Public Health from Climate-Related Threats: From Science to Practice in the United States, Climate Reality Project

<https://www.youtube.com/watch?v=OtWRw6jE3d0>

World Health Organization: Climate and Health

<https://www.youtube.com/watch?v=HC8eG05cels>

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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 more frequent, elevated air temperature prolonged heat waves seasonal timing of events</p>	<p>elevated air temperatures 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 potential decrease in cold-related deaths, including hypothermia and frostbite</p>	<p>children and the elderly; economically disadvantaged groups; chronically ill; outdoor workers and athletes</p>

Possible adaptation strategies

Public health centered: 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 regard to school sports, participants 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.

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Answer KEY

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
↑ 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

Possible adaptation strategies

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

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Answer KEY

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

Public health centered: 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.

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Answer KEY

Chapter 5 | Vector-Borne Diseases

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
Changes in extreme high and low temperatures	geographic range of disease vectors increases	increased vector-borne disease	spread of vector-borne and zoonotic diseases (e.g. malaria occurring at higher elevations)	persons in close proximity to vector habitat; persons with outdoor occupations; children ages 5-9 and adults ages 55-59; males
↑ temperature and changes in precipitation patterns	↑ vector populations	increased vector-borne disease	spread of malaria, dengue, and other pathogens	persons in close proximity to vector habitat; persons with outdoor occupations; low socioeconomic groups
Extreme events and flooding	↑ vector populations	Increased vector-borne disease	Spread of mosquito borne diseases and leptospirosis	Persons in close proximity to vector habitat; persons with outdoor occupations; low socioeconomic groups
altered weather patterns	drought	↓ some vector populations (e.g. mosquitoes require water)	↓ in some vector-borne diseases in some areas	
↑ temperature	Longer growing season; ↑ pests/vectors;	↑ use of pesticides	neurological diseases, cancer, developmental effects	outdoor occupations; low socioeconomic groups; children, pregnant women, and elderly

Possible adaptation strategies

Public health centered: 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 participants may have heard many of these strategies communicated to people living in and traveling to areas with active Zika virus transmission.

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Answer KEY

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

Public health centered: 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).

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Answer KEY

Chapter 7 | Food Safety and Nutritional Quality

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
altered weather patterns, ↑ temperatures	↑ temperatures and flooding	bacterial pathogens (e.g. salmonella); food spoilage and contamination; disrupted distribution	↑ illness from pathogens that cause vomiting and diarrhea which can result in decreased nutrients in the body; famine	low socioeconomic groups; children, elderly, and pregnant women; indigenous populations; persons with weakened immune systems
↑ CO ₂ levels	direct CO ₂ fertilization effect on plant photosynthesis	stimulate growth and carbohydrate production in some plants = lower levels of protein and essential minerals	negative implications on human dietary nutrition	pregnant women, elderly, and children; persons with weakened immune systems
↑ air temperature	↑ ocean temperature	accumulation of mercury in seafood; introduce contaminants into the food chain	mercury poisoning; seafood-related gastroenteritis	populations that consume diet high in fish; pregnant women, elderly, and children; persons with weakened immune systems
↑ extreme weather events	↑ CO ₂ concentrations	altered incidence and distribution of pests, parasites, and microbes = ↑ in use of pesticides and veterinary drugs	bioaccumulation of pesticides; resistance to pesticides	agricultural workers; pregnant women, elderly, and children; low socioeconomic groups; persons with weakened immune systems
↑ temperature and drought	stress plants, making them more susceptible to mold growth	↑ mold growth and mycotoxin production	illness and death; impaired development in children and immune suppression	children and pregnant women; persons with weakened immune systems; persons with respiratory illnesses
↑ extreme weather events	↑ precipitation and flooding	entry of contaminants into the food chain (e.g. PCBs, organic pollutants, dioxins, pesticides)	illness and death; adverse health effects	children and pregnant women; persons with weakened immune systems

Possible adaptation strategies

Public health centered: 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.

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Answer KEY

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

Public health centered: community engagement, risk messaging and communications; improving access to necessary services for people with mental illness.