Albedo

FINALIST
Environmental Film Festival in the Nation's Capital
2021

OFFICIAL SELECTION
Wildlife Conservation Film Festival
2021

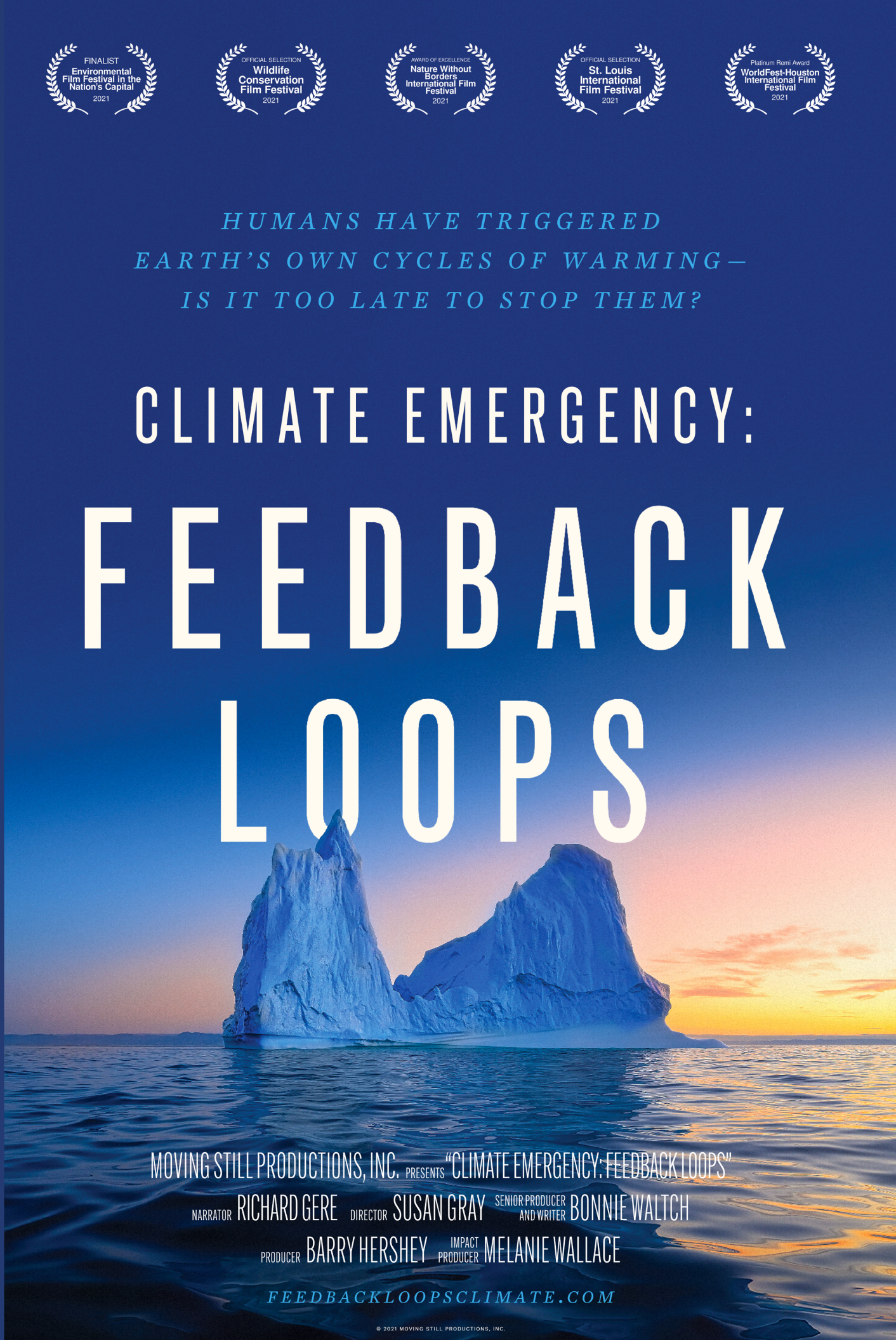
AWARD OF EXCELLENCE
Nature Without Borders International Film Festival
2021

OFFICIAL SELECTION
St. Louis International Film Festival
2021

Platinum Remi Award
WorldFest-Houston International Film Festival
2021

HUMANS HAVE TRIGGERED EARTH'S OWN CYCLES OF WARMING— IS IT TOO LATE TO STOP THEM?

CLIMATE EMERGENCY: FEEDBACK LOOPS



MOVING STILL PRODUCTIONS, INC. PRESENTS "CLIMATE EMERGENCY: FEEDBACK LOOPS"

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FEEDBACKLOOPSCLIMATE.COM

JOURNEYS IN FILM™
educating for global understanding

About *Journeys in Film*

Journeys in Film is a 501(c)(3) nonprofit organization that amplifies the storytelling power of film to educate the most visually literate generation in history. We believe that teaching with film has the power to help educate our next generation with a richer understanding of the diverse and complex world in which we live.

We transform entertainment media into educational media by designing and publishing cost-free, educational resources for teachers to accompany carefully chosen feature films and documentaries while meeting mandated standards in all core subjects. Selected films are used as springboards for lesson plans in subjects like math, science, language arts, social studies and more. Our resources support various learning styles, promote literacy, transport students around the globe, and foster learning that meets core academic objectives.

In addition to general subject areas, Journeys in Film's programs engage students in meaningful examinations of human rights, poverty and hunger, stereotyping and racism, environmental issues, global health, immigration, and gender roles. Our teaching methods are successful in broadening perspectives, teaching for global competency, encouraging empathy, and building new paradigms for best practices in education. We seek to inspire educators, school administrators, community members and home-schooling parents to use our innovative curriculum to capture the imagination and curiosity of their students.

We also develop discussion guides for films that don't necessarily lend themselves to academic standards but cover topics and themes that are valuable for classroom discussions and in other settings, such as after school clubs, community screenings, and college classes.

Journeys in Film is a 501(c)(3) nonprofit organization.

Why use this program?

In an age when literacy means familiarity with images as much as text and a screen has become a new kind of page, 21st-century students are more connected to media than any previous generation.

This offers educators unprecedented opportunities to engage students in learning about a variety of subjects and issues of global significance. Films, television, documentaries, and other media platforms can provide an immediate, immersive window to a better understanding of the world and matters affecting all of us.

We teach our students literature that originated from all around the world, but we tend to forget that what often spurs the imagination is both visual and auditory. Films evoke emotion and can liven up the classroom, bringing energy to a course. We believe in the power of films to open our minds, inspire us to learn more, provide a bridge to better understanding the major issues of 21st-century concern, and compel us to make a difference.

When properly used, films can be a powerful educational tool in developing critical thinking skills and exposure to different perspectives. Students travel through these characters and their stories: They drink tea with an Iranian family in *Children of Heaven*, play soccer in a Tibetan monastery in *The Cup*, find themselves in the conflict between urban grandson and rural grandmother in South Korea in *The Way Home*, and watch the ways modernity challenges Maori traditions in New Zealand in *Whale Rider.* Journeys in Film brings outstanding and socially relevant documentaries to the classroom that teach about a broad range of social issues in real-life settings, such as famine-stricken and war-torn Somalia, a maximum-security prison in Alabama, and a World War II concentration camp near Prague. They explore complex and important topics like race and gender. Students tour an African school with a Nobel Prize–winning teenager in *He Named Me Malala* and experience the transformative power of music in *The Music of Strangers: Yo-Yo Ma & the Silk Road Ensemble* and *Landfill Harmonic*.

Our hope is that this generation of youth will contribute to the betterment of humankind through kindness and understanding, together with scientific knowledge to help solve some of the world's most pressing issues.

Our goal is to create relevant and engaging curricula and programming around media that encourage cross-cultural understanding, empathy, and knowledge of the people and environments around the world. We aim to prepare today's youth to live and work as globally informed, media- literate, and competent citizens.

Why We Must Act Now

"We're reaching the stage in the heating of the earth when fundamental systems are disrupted: the jet stream, the Gulf Stream, even the way the planet reflects and absorbs sunlight. As these five films will make clear to to all who view them, we are kicking off feedback loops beyond our ability to control—once we've melted the Arctic no one has a plan for refreezing it; the great forest fires pour ever more carbon into an already overloaded atmosphere. We've run out of margin—we must act now to stop the burning of fossil fuel that lies at the bottom of this cascading crisis."

—Bill McKibben, author, environmentalist, and co-founder of anti-carbon campaign group *350.org*

"The global average temperature continues to set new records. Extreme heat waves and intense droughts now affect much of the globe, damaging agriculture and facilitating wildfires. Simultaneously some regions are experiencing extreme storms, precipitation, and flooding. These specific changes were anticipated by some scientists 40 years ago, but the changes were not supposed to happen until 2100 or later. Why now? The direct warming has melted reflective ice and snow and released additional heat trapping gases from permafrost and other lands. These feedbacks have amplified the warming and disrupted the climate decades to a century sooner than anticipated. We can unwind this accelerating downward spiral by rapidly reducing heat trapping gases and by allowing more forests and other natural systems that are already removing 31% of our annual emissions each year to accumulate additional carbon out of the atmosphere. This will eventually slow global warming and diminish the feedbacks, facilitating the return to a more benign climate. The feedback loop videos identify four major feedbacks and clearly demonstrate how they interact to accelerate further warming and increase the resulting climate change consequences."

— William Moomaw, Professor Emeritus, The Fletcher School, Tufts University
Lead author of the Nobel Prize-winning Intergovernmental Panel on Climate Change

Introducing *Climate Emergency: Feedback Loops*

The five short films of *Climate Emergency: Feedback Loops* were released in 2021, a year after one of the hottest years on record. In 2020, the Earth experienced a range of extreme weather that may have finally caught the attention of policy-makers:

- A Siberian heat wave set temperature records in excess of 100 degrees Fahrenheit within the Arctic Circle.
- Wildfires ravaged the western United States and Australia.
- The Atlantic hurricane season, with an extraordinary 30 named storms, caused over $46 billion in damages to property.
- The area of Arctic sea ice was at a record low.
- Super Typhoon Goni hit the Philippines with sustained winds of 195 miles per hour.
- Monsoon flooding in China destroyed or damaged 1.4 million homes and businesses.

Extreme as these events were, scientists are even more worried about the Earth's natural feedback loops that have the potential to create even more disastrous weather events. According to an article in *Scientific American,* "…catastrophic climate change could render a significant portion of the Earth uninhabitable consequent to continued high emissions, self-reinforcing climate feedback loops and looming tipping points."[1]

What is a feedback loop? Feedback loops are a continuous system in which a change in one (or more) parts of the system act to influence the rest of the system, either positively (increasing the effects of the system) or negatively (decreasing the effects of the system). A positive feedback loop is a circular chain of events that can amplify a change within a system. In a negative feedback loop, series of events dampen the change within the system, helping make it more stable.

1 https://www.scientificamerican.com/article/the-climate-emergency-2020-in-review/

The five films of *Climate Emergency: Feedback Loops* use stunning video, interviews with leading climate scientists, and thoughtful narration by Richard Gere to educate the viewer on key feedback loops greatly accelerating climate change. The "Introduction" film drives home the point that human activity is increasing global warming and leading to climate change. It explains the concept of feedback loops and shows briefly how this concept applies to forests, atmosphere, permafrost, and albedo.

"Forests" explains that the world's trees have long served as a "carbon sink," removing carbon dioxide from the air, storing carbon in wood, leaves, branches, and trees' soils, and in turn releasing water vapor and oxygen. The shrinking of forests, due to human activities like logging and clearing areas for agriculture, means that less carbon is captured and global temperatures increase.

In the video "Permafrost," the viewer learns that this area of frozen ground, which covers about a quarter of the Northern Hemisphere, stores massive amounts of carbon underground. As it begins to thaw, microscopic animals are waking and feeding on frozen vegetation and animals and then releasing more gases into the atmosphere, creating additional warming.

"Atmosphere" deals with warming that is altering the Earth's weather pattern and making extreme weather events more common. Even the jet stream is being affected, resulting in warmer weather moving north and stalling for longer periods of time, with consequent changes in rainfall patterns and flooding.

"Albedo" refers to the ability of Arctic ice to reflect the sun's rays and temper their warming effect. However, the volume of ice is decreasing; it has shrunk 75% in the past forty years,

and consequently the albedo effect has diminished. The Arctic may soon be ice-free in the summer.

Taken together, these five short films make the case that time is running out to prevent catastrophic climate change, change that could result in the extinction of whole species and drastically affect human societies. Unless we demand and implement dramatic changes, the Earth will reach a "tipping point" from which there is no return.

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Climate Emergency: The Albedo Effect

Enduring Understandings

- Natural systems are interdependent.
- All life on Earth depends on and affects the climate.
- The sun is the primary source of energy for climate systems on Earth.
- The climate of Earth is regulated by complex interactions between systems.
- The climate of Earth is shaped by natural and human-made processes.
- Climate change impacts all human communities.
- The actions of human communities impact the climate of Earth.
- Climate change will have consequences for all Earth systems.

Essential Questions

- What are feedback loops?
- How do positive and negative feedback loops differ?
- What role do feedback loops play in the environment?
- How do feedback loops relate to the climate of Earth?
- Is the climate of Earth changing?
- What evidence do we have that the climate of Earth is changing?
- What contributes to climate change?
- What is the albedo effect?
- How does the albedo effect relate to climate feedback systems on Earth?
- How does the reflectivity of different surfaces affect the amount of energy they absorb?
- How does the melting of Arctic ice affect albedo?
- How does the melting of Arctic ice impact the climate of Earth?

Notes to the Teacher

In this lesson, students learn about the albedo effect and the decreasing ability of the Arctic region to act as a mirror reflecting the sun's rays. They also study how global warming causes the melting of sea ice and land ice at the poles, making the sea level rise and threatening millions of people along global coastlines. The activities in this lesson have been designed for use as individual modules or tiered instruction with each new lesson component building upon the last. A review of the activities prior to delivery is highly suggested to best determine the class time needed for each one and appropriately plan for materials acquisition. While the suggested lesson duration is between three and six one-hour periods, the activities can easily be modified based on time available or the point in the course curriculum where the lesson can best be integrated.

This lesson assumes students have some background on the fundamentals of climate change, the concept of a carbon footprint, and the role of greenhouse gases in climate change. The following resources may be helpful in the event review material is necessary:

- Climate Change: https://youtu.be/dcBXmj1nMTQ
- Climate Change Quiz: https://climate.nasa.gov/quizzes/global-temp-quiz/
- Greenhouse Gases: https://youtu.be/lrst59O9Q1Q

Please note that all suggested video links in this lesson can be displayed on a projector or shared with students for use on individual devices, depending on the classroom technology available.

Part l of this lesson investigates the concept of feedback loops while exploring the unique types and elements of these regulatory cycles which permit Earth's systems to adjust in response to changing conditions. A full set of copies of **Handout 1: Thinking About Systems** is recommended for each class; blank paper and colored pencils/markers may also be necessary. A computer with Internet access and a projector will be useful in showing the TED-Ed video about feedback loops in Step 4, the link for which can be found at https://youtu.be/inVZoI1AkC8.

Handout 1: Thinking About Systems can be completed as an in-class activity or assigned as homework if time is limited. It is also important to note that some or all of this part of the lesson can be assigned prior to Parts 2 and 3, depending on the knowledge level of the class and time available. In the event the concept of environmental feedback loops has already been covered in the course curriculum, feel free to skip ahead to Part 2 of the lesson.

In Part 2 of this lesson, students learn about the albedo effect and the impact of a shifting albedo in response to a changing climate. They will study the relationship between melting sea ice and climate change, thinking critically about the consequences of a lower albedo relative to the future of our planet. A full set of copies of **Handout 2: How Does the Albedo Effect Work**? is recommended for each class; index cards and colored pencils/markers may also be necessary. A computer with Internet access and a projector will be useful in showing the *Climate Emergency: Feedback Loops* film Albedo in Step 5, the link for which can be found at https://feedbackloopsclimate.com/albedo/. **Handout 2: How Does the Albedo Effect Work?** can also be completed as a homework assignment depending on the time available.

In Part 3 of this lesson, students will explore the science behind the albedo effect. They will develop and test hypotheses about the relationship between the albedo and temperature of a system, designing experimental models which reflect how changes in surface reflectivity can impact Earth's climate trends. A full set of copies of **Handout 3: Turn Up the Heat—Investigating the Albedo Effect** is needed for each class, as are the items on the laboratory supply list detailed in the **Materials** section below. It is important to note that each group will need 2 clear containers, such as plastic to-go cartons, plastic cups, jars, or beakers. While standard, non-mercury thermometers are recommended for this activity, wearable/adhesive thermometers or digital temperature sensors would also work. While a number of things can be used as the light source, please note that the distance between the dual container setups and light source should be the same for all groups. (30–40 cm is recommended).

The assorted materials the teacher will need to provide for the investigation in Part 3 should be a collection of substances of different colors and textures designed to represent different types of surfaces on Earth. Examples could include salt/sugar/cotton (snow), soil/gravel (land), ice (sea ice), different foliage types (vegetation), or water (water bodies). The idea here is for groups to have choice surrounding the design of their container setups. This part of the lesson also assumes that students are familiar with experimental design basics and hypothesis testing. Prior experience with plotting data on an X-Y coordinate graph will also be helpful.

Common Core Standards addressed by this lesson

History/Social Studies

CCSS.ELA-LITERACY.RH.9-10.7
Integrate quantitative or technical analysis (e.g., charts, research data) with qualitative analysis in print or digital text.

CCSS.ELA-LITERACY.RH.9-10.8
Assess the extent to which the reasoning and evidence in a text support the author's claims.

Science and Technical Subjects

CCSS.ELA-LITERACY.RST.9-10.1
Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

CCSS.ELA-LITERACY.RST.9-10.2
Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

CCSS.ELA-LITERACY.RST.9-10.3
Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.5
Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).

CCSS.ELA-LITERACY.RST.9-10.7
Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

CCSS.ELA-LITERACY.RST.9-10.8
Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

CCSS.ELA-LITERACY.RST.9-10.9
Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Writing

CCSS.ELA-LITERACY.WHST.9-10.1.A
Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counter-claims, reasons, and evidence.

CCSS.ELA-LITERACY.WHST.9-10.1.C
Use words, phrases, and clauses to link the major sections of the text, create cohesion, and clarify the relationships between claim(s) and reasons, between reasons and evidence, and between claim(s) and counterclaims.

CCSS.ELA-LITERACY.WHST.9-10.1.D
Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

CCSS.ELA-LITERACY.WHST.9-10.1.E
Provide a concluding statement or section that follows from or supports the argument presented.

CCSS.ELA-LITERACY.WHST.9-10.2.A
Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.

CCSS.ELA-LITERACY.WHST.9-10.2.D
Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

CCSS.ELA-LITERACY.WHST.9-10.2.E
Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.

CCSS.ELA-LITERACY.WHST.9-10.7
Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

CCSS.ELA-LITERACY.WHST.9-10.9
Draw evidence from informational texts to support analysis, reflection, and research.

Duration of Lesson

Three to six one-hour periods

Assessments

Completion of the **Thinking About Systems** analysis activity and index card illustrations
Completion of the **How Does the Albedo Effect Work?** group discussion
Completion of the **Turn Up the Heat—Investigating the Albedo Effect** laboratory investigation and reflection questions
Group discussion
Student presentations

Materials

Writing utensils
Blank 8 ½" x 11" paper
Whiteboard
Whiteboard markers
Computer with Internet access
Projector
Large index cards
Colored pencils or markers
Classroom set of materials for the laboratory investigation in Part 3:

- 2 clear containers per group
- 2 thermometers per group
- cardboard
- scissors
- tape
- markers
- 1 light source with incandescent or heat bulb per group
- timer
- assortment of materials to represent Earth's surfaces (See instructions in Notes to the Teacher above.)

Full class copies of:

Handout 1: Thinking About Systems
Handout 2: How Does the Albedo Effect Work?
Handout 3: Turn Up the Heat—Investigating the Albedo Effect
Teacher Resource 1: Thinking About Systems (Suggested Answers)
Teacher Resource 2: How Does the Albedo Effect Work?

Procedure

Part 1: Feedback Loops 101 (1–2 one-hour periods)

1. Begin by dividing the class into groups of two or three. Ask students to discuss the concept of "cause and effect." Invite each group to think of three examples of cause and effect from their own lives, allowing several minutes for students to share.

2. Invite students to then share examples of cause and effect which are unique to the environment, allowing time for sharing and a short discussion.

3. Explain to students they will have the opportunity to consider some of the advanced cause-and-effect relationships in the environment by exploring the concept of feedback loops. If time permits, invite students with prior knowledge of feedback loops to share what they know.

4. Play the TED-Ed video about feedback loops at https://youtu.be/inVZoI1AkC8. At the end of the video, host a discussion using the following questions and suggested answers as a framework for the conversation. If feedback loops are a new concept for the students, illustrate the examples of positive and negative feedback loops in Questions C and D below as cycles on the board as they are shared. Another suggestion would be for students to do the same.

a. What is a feedback loop? (A response from the environment that relates to the output.)
b. How would you explain the difference between positive and negative feedback loops? (A positive feedback loop is a circular chain of events that can amplify a change within a system. In a negative feedback loop, series of events dampen the change within the system, helping make it more stable.)
c. What is one example of a negative feedback loop from the video? (Predator/prey relationships: Predators eat prey which, in turn, causes a drop in the predator population due to decrease in food access. As the predator population size decreases, the prey population size increases. As the prey population size increases, a greater number are consumed by the predators. In turn, the prey population drops again as the predator population increases.)
d. What is one example of positive feedback loop from the video? (Contribution of organic material to the soil from decomposing plants which, in turn, aids the growth of new plants. Another example would be removing a forest, which makes the land vulnerable to erosion.)
e. Why are positive feedback loops called "positive"? (Because the feedback loop amplifies a particular effect or change from previous conditions.)
f. Can you think of other examples of feedback loops you may have heard about? (While answers here may vary, common responses may also include air conditioning systems, metabolic pathways in the body, the human sweat response, and the human shiver response.)

5. Ask students to work in their same groups to practice their knowledge of feedback loops. Distribute copies of **Handout 1: Thinking About Systems** and blank paper to each student. Review the instructions for the activity and give the groups time to work independently on the prompts. For each environmental system prompt, the students should illustrate the feedback loop as a cycle on the paper provided. They can each work on a complete set or divide the illustrations between members of the group.

6. When groups have finished, invite students to share their responses for each scenario and showcase their illustrations in the form of a class discussion. If time is limited, students can also finish the handout and illustrations as a homework assignment to be discussed as an introduction to Part 2 of the lesson in the next class.

Part 2: The Albedo Effect (1–2 one-hour periods)

1. Begin by asking students to imagine themselves in the middle of the Sahara Desert on the hottest day of the year (potentially 135+ºF). Ask them which combination of garments from the options below would keep them most cool.

- Dark clothing or light clothing?
- Short sleeves or long sleeves?
- Shorts or long pants?

Take a class poll and invite several students to share their thinking.

2. Explain that the more brightly colored clothing with the greatest coverage would do the best job of reflecting the sun's energy away from the body, allowing the body to absorb less heat and therefore cool it more effectively. In this case, the combination of lightly colored long sleeves and long pants would be best.

3. Explain that this concept of surface reflectivity is known as the *albedo effect,* adding that any small change to the color or surface area of systems can impact the amount of totally energy reflected. Explain that, in the case above, the lightly colored, longer clothing would have a *high* albedo. Alternatively, the darker, shorter clothing would have a *low* albedo.

4. Explain to the students that the film they are going to watch explains the concept of albedo through the lens of our planet's climate. Distribute a copy of **Handout 2: How Does the Albedo Effect Work?** to each student and explain they will have time after the film to answer the questions provided. If time permits, ask the students to quietly read through the questions and highlight important words and/or phrases that will help guide their attention as they watch.

5. Play the *Climate Emergency: Feedback Loops* film "Albedo" at https://feedbackloopsclimate.com/albedo/. At the end of the film, ask students the following questions and invite several to share their thoughts.

- Why do you think this film was produced? (Answers here may vary.)
- What is the critical environmental theme of this film? (Shifting albedo due to climate change.)

6. Use the questions on **Handout 2: How Does the Albedo Effect Work?** to guide a class discussion; suggested answers to the questions can be found on **Teacher Resource 2**. For Question 3, invite students to illustrate the feedback loop they detailed as part of their response on a blank sheet of paper. (Note: If time is limited, the entire handout can be assigned as homework for the next class.)

7. Ask the students to consider the following question, inviting several to share their thoughts.

- Do you think a shifting albedo at the hands of a changing climate is a problem for our planet? Why? (Answers here may vary.)

8. Explain that this film is part of an initiative called "Climate Emergency," indicating a dire situation for the health of our planet. Distribute one index card to each student and write the following statement on the board:

> "**The models predict that if we continue the path we're on, that the Arctic will experience very dramatic changes, and those changes will reverberate throughout the system—the human system, the biological system, and the socioeconomic system.**"

9. Explain that this is one of the last lines of the film they just watched. Ask the students to think about how this statement makes them feel. Ask them to write several sentences which capture their thoughts on the index card. (Note: Students should not put their names on the index cards.)

10. Collect the index cards. Mix them up and read several aloud to the class, one at a time. Invite students to raise their hands if they agree with the sentiment on each card. Read as many as time permits.

Part 3: Modeling the Albedo Effect (1–2 one-hour periods)

1. To check for understanding of the concept of albedo, ask students to answer the following questions by holding up one or two fingers to signify their response. Invite questions or discussion where needed. (Answers are in bold text.)

a. Which has a higher albedo: **(1) a snow-covered meadow** or (2) an asphalt parking lot?
b. Which has a lower albedo: **(1) a forest** or (2) an exposed rock outcropping?
c. Which location has a higher albedo: **(1) Alaska** or (2) Europe?
d. Which body of water has a lower albedo: (1) a shallow pond or **(2) a deep ocean**?
e. Which has a higher albedo: **(1) a vegetable garden** or (2) a rainforest?
f. Which has a higher albedo: **(1) a snow-covered field** or (2) a deep, frozen lake?

2. Explain to students they will have the opportunity to explore the concept of the albedo effect by designing their own laboratory investigation. Divide the class into groups of two or three. Distribute a copy of **Handout 3: Turn Up the Heat—Investigating the Albedo Effect** to each student, and allow groups several minutes to read the "Objective" and "Background" sections.

3. Review the lab instructions with the class. Explain that groups will design two different setups to explore the albedo effect, measuring the change in albedo as a function of temperature within the contained systems they create over time. Remind them that their first setup, Setup 1, should reflect a high albedo system and demonstrate the least amount of temperature change as possible during the 20-minute period. Setup 2, conversely, should reflect a low albedo system and demonstrate the greatest amount of temperature change as possible during the 20-minute period. Explain that the materials students choose for their container designs should relate to different surfaces on Earth. For example, students may decide to use salt to represent a snow-covered surface. Water, alternatively, could represent waterbodies such as rivers, lakes, or oceans. The depth of the water is yet another example of a variable to consider. Remind them to think about the relationship of color and texture to the albedo in choosing the materials for their respective setups.

4. Give groups time to review the Procedure, collect their materials, and begin to design their container setups. Remind students they need approval from you for their proposed experimental setups (see Step 5) before proceeding. Remind students to record their data for each setup in the tables provided and to pay close attention to the instructions in Step 10 regarding the construction of their final graphs.

5. When groups have finished their 20-minute period of data collection, they should begin cleaning up and work on their final graphs.

6. Depending on time available, the Reflection Questions on the last page of **Handout 3** can be completed in class or as a homework assignment. Either way, a class discussion using the questions as a framework will be an important part of the reflection for this investigation.

Extension Activities

Extension Activity 1: Game Design

Students could develop board games or activities which demonstrate their understanding of feedback loops and the albedo effect as they relate to the climate of Earth.

Extension Activity 2: Climate Change Impacts

Students could conduct further research on one of the impacts of climate change referenced in the answer to Question 7 of **Handout 2: Exploring the Albedo Effect**. As part of their research, they could detail real-world examples of the impact and design their own awareness campaigns to inspire change within their respective communities. The topics in question are:

- crop reduction
- global increases in food pricing
- erratic weather/increased precipitation
- excessive drought
- sea-level rise
- coastline destruction
- human health concerns
- climate refugees

Extension Activity 3: Carbon Footprint Awareness

Students could calculate their own carbon footprint, research ways of reducing their footprints, and design engagement campaigns to help members of their communities do the same. This digital Carbon Footprint Calculator from the U.S. Environmental Protection Agency may be helpful: https://www3.epa.gov/carbon-footprint-calculator/.

Additional Resources

Climate Change Basics

NASA Global Climate Change
https://climate.nasa.gov/

How to Talk to Kids About Climate Change
https://www.npr.org/2019/10/22/772266241/how-to-talk-to-your-kids-about-climate-change

EPA Climate Change
https://www.epa.gov/climate-change

Climate Reality Project
https://www.climaterealityproject.org/

EPA: Calculating a Carbon Footprint
https://www3.epa.gov/carbon-footprint-calculator/

Climate Change Data

NASA Climate Change: How Do We Know?
https://climate.nasa.gov/evidence/

NOAA Data Snapshots: Reusable Climate Maps
https://www.climate.gov/maps-data

National Science Foundation: Climate Reanalyzer
https://climatereanalyzer.org/

National Snow & Ice Data Center
https://nsidc.org/

Climate Change Impacts

NASA: The Effects of Climate Change
https://climate.nasa.gov/effects/

World Wildlife Foundation: Effect of Climate Change
https://www.worldwildlife.org/threats/effects-of-climate-change

CDC: Climate Effect on Health
https://www.cdc.gov/climateandhealth/effects/default.htm

Thinking About Systems

Directions: Please read the examples of environmental systems provided in the table below. For each system, state whether it is an example of a positive or negative feedback loop. Then, for each scenario, provide an explanation for your answer in the space below and illustrate the feedback loop as a cycle on the blank paper provided.

Environmental System	Type of Feedback Loop (Positive or Negative)	Explanation
A population of turtles is critically endangered. Because the population has become so small, finding a mate has become a challenge. The number of births has since declined, and the turtle population continues to decrease.		
A native grass species has covered a meadow. Some larger plants and shrubs are present but have grown slowly due to longer roots with less access to water. Because the grass is smaller and has shorter roots, it has more access to water and grows more consistently.		
The warming of Earth's climate has caused an increase in atmospheric water vapor, resulting in more precipitation. More precipitation has caused a shift in the movement of ocean currents, distributing water to new locations on Earth. This, in turn, increases the amount of atmospheric water vapor and precipitation in parts of the world that are typically dry.		
As a population of mountain goats has increased, so has their consumption of food. As a result, increasing food scarcity has led to the starvation and death of some of the population.		
As Earth's climate warms in response to climate change, an increase in water vapor contributes to increased cloud formation. Increased cloud cover can have a cooling effect by reflecting heat from the sun but can also absorb and trap heat from the Earth's surface.		

Thinking About Systems (Suggested Answers)

Environmental System	Type of Feedback Loop (Positive or Negative)	Explanation
A population of turtles is critically endangered. Because the population has become so small, finding a mate has become a challenge. The number of births has since declined, and the turtle population continues to decrease.	Positive	The turtle population decrease due to fewer births will further perpetuate the challenge in mating and producing offspring. This will cause the population to drop further.
A native grass species has covered a meadow. Some larger plants and shrubs are present but have grown slowly due to longer roots with less access to water. Because the grass is smaller and has shorter roots, it has more access to water and grows more consistently.	Negative	Due to consistent water access, the grass would grow at a balanced rate while inhibiting the growth of the larger plant cover. In doing so, the grasses would provide habitat for insects, birds, and small mammals.
The warming of Earth's climate has caused an increase in atmospheric water vapor, resulting in more precipitation. More precipitation has caused a shift in the movement of ocean currents, distributing water to new locations on Earth. This, in turn, increases the amount of atmospheric water vapor and precipitation in parts of the world that are typically dry.	Positive	Increased precipitation in places which are typically less dry could lead to continued changes to the movement of ocean currents and additional precipitation elsewhere. In this case, the cycle of increasingly erratic weather would strengthen over time.
As a population of mountain goats has increased, so has their consumption of food. As a result, increasing food scarcity has led to the starvation and death of some of the population.	Negative	A decrease in population size would give surviving members access to more food while also decreasing food scarcity. The population size would eventually stabilize.
As Earth's climate warms in response to climate change, an increase in water vapor contributes to increased cloud formation. Increased cloud cover can have a cooling effect by reflecting heat from the sun but can also absorb and trap heat from the Earth's surface.	Positive	When heat from the sun is absorbed by the clouds, Earth's temperature will increase. This would increase the amount of atmospheric water vapor, further warming Earth's climate.

Handout 2

***Climate Emergency*: Albedo Lesson**

(Environmental Science, Earth Science)

How Does the Albedo Effect Work?

Instructions: Please answer the following questions to the best of your ability after watching the *Climate Emergency: Feedback Loops* film "Albedo" (https://feedbackloopsclimate.com/albedo/).

1. This film argues that Earth's equilibrium is at risk. What does "equilibrium" mean? Why is the concept of equilibrium used here in reference to Earth?

2. In your own words, how would you describe the albedo effect?

3. What happens when the Earth loses its ability to reflect sunlight? Is this an example of a positive or negative feedback loop? Please explain.

4. Snow and ice reflect a large percentage of the sun's rays. Do snow and ice have a *high* or *low* albedo? Please explain.

5. In the film, Don Perovich from Dartmouth College references the yearly growth and melting of Arctic ice as a natural cycle. He then goes on to say this cycle is changing. What about this yearly cycle is changing?

6. According to the film, heat-trapping gases like carbon dioxide, methane, and nitrous oxide from human-caused greenhouse emissions are responsible for increasing the temperature in the Arctic two to three times faster than anywhere else on the planet. This warming is then amplified by the loss of albedo as the reflective Arctic ice and snow disappear, exposing the dark ocean beneath. Why is this a problem?

7. Studies suggest that the melting of Arctic sea ice and snow cover on land are responsible for a 40% loss in Earth's reflectivity. Climate model projections suggest that Arctic sea ice will be lost in the summer months altogether by the end of this century. The added contribution of greenhouse gases to the equation may dictate the additional loss of the winter sea ice. Using the film as reference, how might the changing climate of the Arctic relate to temperature elsewhere on Earth?

8. According to the film, we have the technology and knowledge to move toward sources of energy that do not produce heat-trapping gases but we are not making this a priority. Why do you think this is the case?

Teacher Resource 2

***Climate Emergency*: Albedo Lesson**

(Environmental Science, Earth Science)

How Does the Albedo Effect Work? (Suggested answers)

Instructions: Please answer the following questions to the best of your ability after watching the *Climate Emergency: Feedback Loops* film "Albedo" (https://feedbackloopsclimate.com/albedo/).

1. This film argues that Earth's equilibrium is at risk. What does "equilibrium" mean? Why is the concept of equilibrium used here in reference to Earth?

The word equilibrium refers to a state of balance.

2. In your own words, how would you describe the albedo effect?

The albedo effect refers to the ability of a surface to reflect sunlight.

3. What happens when the Earth loses its ability to reflect sunlight? Is this an example of a positive or negative feedback loop? Please explain.

As it loses its ability to reflect sunlight, the climate of Earth warms. Positive feedback loop.

4. Snow and ice reflect a large percentage of the sun's rays. Do snow and ice have a *high* or *low* albedo? Please explain.

Snow and ice have a high albedo due to their light color. The lighter the color of the surface, the larger the percentage of reflection.

5. In the film, Don Perovich from Dartmouth College references the yearly growth and melting of Arctic ice as a natural cycle. He then goes on to say this cycle is changing. What about this yearly cycle is changing?

The timing when different elements of this cycle occur. For example, the ice is melting earlier, the freezing is starting later, the ice coverage decreases every month of the year, etc.

6. According to the film, heat-trapping gases like carbon dioxide, methane, and nitrous oxide from human-caused greenhouse emissions are responsible for increasing the temperature in the Arctic two to three times faster than anywhere else on the planet. This warming is then amplified by the loss of albedo as the reflective Arctic ice and snow disappear, exposing the dark ocean beneath. Why is this a problem?

One of the best natural reflectors (snow) is being replaced by one of the worst (the open ocean). The ocean will absorb the sunlight, heat up, and melt more ice. The continued increase in melting ice will further perpetuate the cycle. As the darker waters warm, they emit carbon dioxide and water vapor and further warming the system.

7. Studies suggest that the melting of Arctic sea ice and snow cover on land are responsible for a 40% loss in Earth's reflectivity. Climate model projections suggest that Arctic sea ice will be lost in the summer months altogether by the end of this century. The added contribution of greenhouse gases to the equation may dictate the additional loss of the winter sea ice. Using the film as reference, how might the changing climate of the Arctic relate to temperature elsewhere on Earth?

Warming patterns in the Arctic may contribute to the movement of warm air around the planet. This could cause crop reduction, global increases in food pricing, erratic weather/increased precipitation, excessive drought, sea-level rise, coastline destruction, human health concerns, climate refugees, etc.

8. According to the film, we have the technology and knowledge to move toward sources of energy that do not produce heat-trapping gases but we are not making this a priority. Why do you think this is the case?

Answers may vary.

Handout 3

***Climate Emergency*: Albedo Lesson**

(Environmental Science, Earth Science)

Turn Up the Heat—Investigating the Albedo Effect

Objective

To develop and test hypotheses about the effect of albedo on the temperature of different surfaces.

Background Information

Albedo generally refers to the amount of energy reflected by a surface. Surfaces on Earth with a higher albedo are bright and reflect more/absorb less of the sun's energy. Surfaces of this nature include ice caps, glaciers, seasonal snow cover, and deserts. Conversely, surfaces with a lower albedo are darker and reflect less/absorb more of the sun's energy. Surfaces of this nature include open water, forests, concrete, and soil. The angle at which the sunlight hits a surface relative to its texture can also affect the albedo of the surface.

Understanding the fate of sunlight arriving to Earth is crucial to how we interpret and respond to our planet's changing climate. For this investigation, you will design two setups to explore the role of albedo in determining the amount of energy absorbed by different surfaces. For each setup, you will measure the change in temperature over a 20-minute period.

Materials

- 2 clear containers with lids
- 2 thermometers
- cardboard
- scissors
- tape
- marker
- light source with incandescent or heat bulb
- timer
- assortment of materials to represent Earth's surfaces (provided by the teacher)

Procedure

1. Using the tape and marker provided, label your containers **Setup 1** and **Setup 2.** Add the initials of your group members to each label.

2. Flip one container upside down and trace its perimeter on the cardboard provided. Do this twice. Cut each shape out. Then, use the scissors to poke a hole in the center of each piece large enough to accommodate a thermometer. Set the cut pieces aside.

3. Design your experimental setups using the materials provided by your teacher to represent different surfaces on Earth. Consider the role of albedo in choosing your materials for each setup.
   a. Setup 1 should reflect a high albedo system and demonstrate the least amount of temperature change as possible during the 20-minute period.
   b. Setup 2 should reflect a low albedo system and demonstrate the greatest amount of temperature change as possible during the 20-minute period.

4. Add the materials you have chosen to each container.

5. In the spaces provided below, (1) create a labeled diagram of each setup and (2) describe the types of surfaces your materials represent. *Hint: Be sure to consider color and texture here!* Your teacher must approve your setup before moving onto the next step.

Setup 1:

Setup 2:

6. For each setup, design a hypothesis predicting what you think will happen to the temperature over the 20-minute period.

a. Hypothesis for **Setup 1:**

b. Hypothesis for **Setup 2:**

7. Position the cardboard cutouts you made in Step 2 on the top of each container, sealing the edges with the tape provided. Insert one thermometer into each hole, ensuring the thermometers are placed in such a way to be easily read through the clear sides of each container.

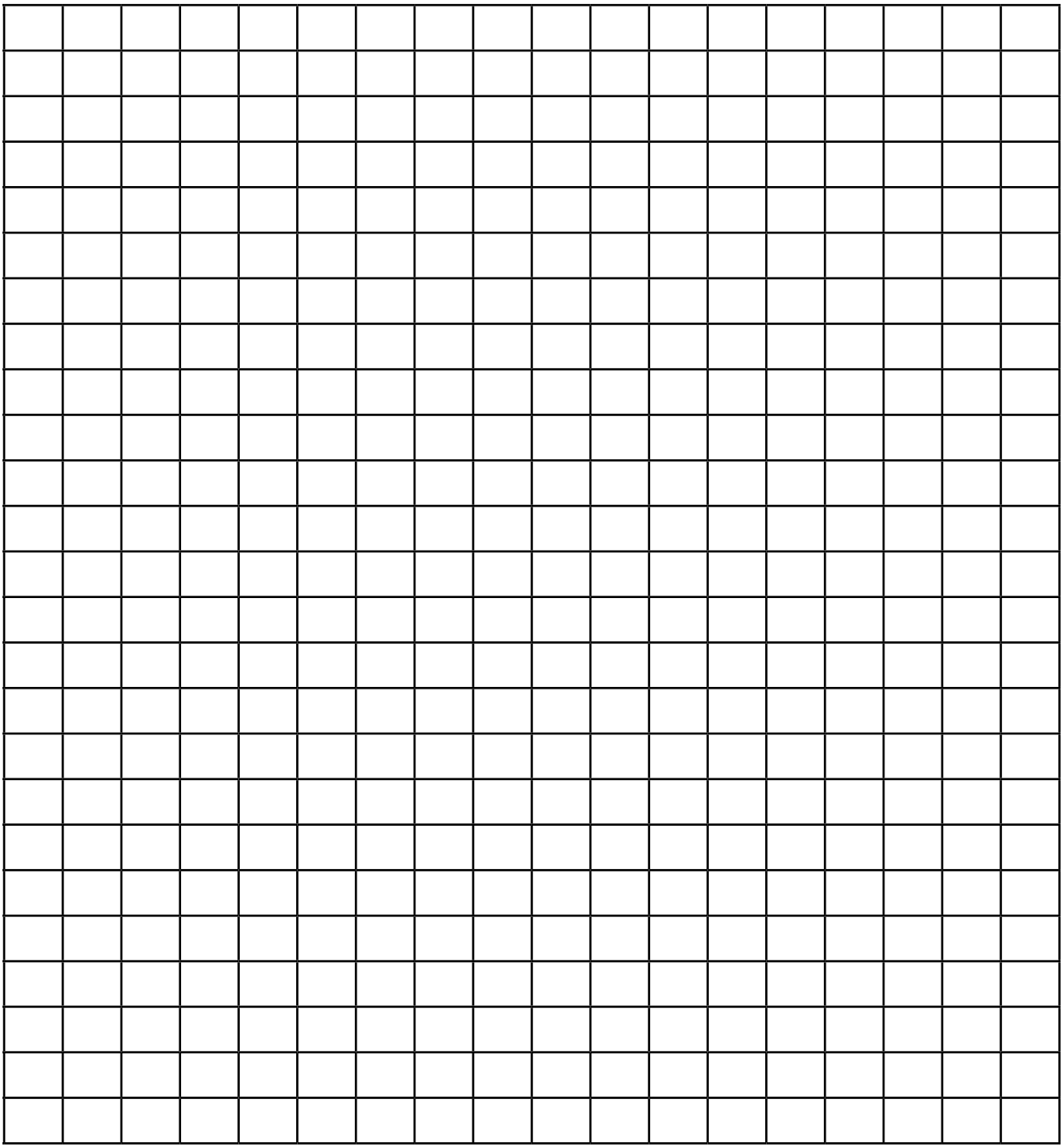
8. Place your containers beneath your light source (do not turn it on yet). Set your timer for 20 minutes. Allow your containers to sit for 60 seconds. Record the temperature for each and enter this number as Time 0 for both setups in the table below.

9. Turn your light source on and begin the time. Record temperature readings for both setups every minute for the 20-minute duration. When time stops, calculate the total change in temperature for each setup and record this value in the space provided at the bottom of each table.

Time (min.)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Setup 1: High Albedo Temperature											
Time (min.)		**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Setup 1: High Albedo Temperature											
Total Change in Temperature											

Time (min.)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Setup 2: High Albedo Temperature											
Time (min.)		**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Setup 2: High Albedo Temperature											
Total Change in Temperature											

10. Graph the temperature data you collected as function of time for **Setup 1** and **Setup 2** below using different colors. Label your axes, including appropriate units of measurement. Include a title and key to distinguish between the lines for each setup.



11. When you are finished, clean up your station and answer the *Reflection Questions* below.

Reflection Questions

1. How did the data you collected compare to your original hypothesis for each setup? Be specific for each.

2. List the materials you used for **Setup 1** and **Setup 2.** Then, describe the type of Earth's surface each material represented.

3. How did the total change in temperature for **Setup 1** compare to **Setup 2**? How would you explain this observation?

4. How does your data for each setup compare to other groups in class? Please be specific.

5. Were any sources of error present in your setups for this investigation? Please explain.

6. If you were to conduct this investigation again, how would you modify **Setup 1** to produce a total change in temperature over the 20-min period that is greater than what was observed here?

7. If you were to conduct this investigation again, how would you modify **Setup 2** to produce a total change in temperature over the 20-min period that is lower than what was observed here?

8. Are the results of this investigation consistent with your prior knowledge of the role of albedo in determining the amount of energy absorbed by different surfaces? Please explain.

9. In what ways did this investigation help improve your understanding of the albedo effect?

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