Endeavor

STEM Teaching Certificate Project

They're BACK!

A lesson on albedo and the de-extinction of the Woolly Mammoth.

Grades 11-12

AP Environmental Science/AP Biology

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BIG IDEAS

One of the key concepts covered in AP Environmental Science is that of albedo. Students often have a difficult time understanding albedo in addition to the positive feedback loop that has resulting with declining albedo due to climate change. In a cross-over between AP Environmental Science and AP Biology, the de-extinction of the Woolly Mammoth will be discussed as a possible solution to increasing albedo in the arctic regions.

In this lesson which consists of five parts spanning over five 40-minute periods, students will be first be shown an illustration of a Woolly Mammoth in the arctic as their anchoring phenomena in the *Engage* portion of this 5E lesson. Woolly Mammoths are a recognizable animal, though when they existed and how earth differed from today, is not as well known. Students will be asked to identify the Woolly Mammoth, as well as take educated guesses as to when the animal existed and how the planet looked during its time. This may not take a full, 40-minute period, and teachers are welcome to move on to the *Explore* section, which will take longer than 40 minutes.

During the *Explore* portion of this lesson, students will be introduced to the concept of albedo, and how it differs among the major terrestrial biomes. By watching a video, students will learn of how a positive feedback loop now exists in regards to declining albedo and climate change. Students will answer questions on a worksheet during the videos, with students working together in teams to create their own renditions of the positive feedback loop that is occurring with climate change and declining albedo.

In the *Explain* portion of the lesson, students will be given data to the approximate albedo that exists in various biomes (by percentage of reflection) and asked to color in a world map to visually see the differing amounts of albedo. Students will also be asked to graph the data as a bar graph. Using both the map and the bar graph, students will then be asked to look for any patterns and make observations in regards to what biomes have the highest albedo versus the lowest and why. Students will then access NEO NASA Earth Observations website to compare albedo to another parameter recorded by NASA and make any observations.

During the *Elaborate* section of the lesson, students will read an article in regards to scientists working towards de-extinction of the Woolly Mammoth and how such a feat could help increase albedo in the arctic. Students will answer questions directly from the article as well as questions from their own knowledge of genetics and how de-extinction could be achieved.

In the final *Evaluate* section of this lesson, students will re-visit the positive feedback loop that was introduced to them in the *Explore* section. Students will then work together in groups to create a new feedback loop that includes their original positive feedback of snow/ice melt, as well as a branching loop as to what may occur with the introduction of Woolly Mammoths in the arctic/tundra region.

This lesson includes technology, science and literacy. Lessons may be conducted in sequence or separately, per the discretion of the educator. This lesson is written using the 5E's.

Approximate Time for each part of the lesson
(Total time: six 40-minute periods)

Engage
Anchoring Phenomena: Woolly Mammoth Image provided on Google Slides (NOTE: Image credits given in speaker notes, to avoid identification of the Woolly Mammoth)
Discussion Question provided on the Google Slide.
20 minutes
(Teachers may begin the *Explore* section of the lesson at the conclusion of the *Engage* discussion)

Explore
In part one, students will watch a video, ClimateBits: Albedo pertaining to albedo and answer questions on their worksheet. Students will then watch the video, NASA: This World is Black and White and answer the questions in part two of the worksheet. In part three, students will create

their rendition of the positive feedback loop that is occurring between snow/ice melt and climate change.
One 40-minute Period
(Please note: This may take more than 40 minutes. It is recommended that teachers begin this portion of the lesson after the discussion portion in the Engage section).

Explain
Students will use albedo values for various terrestrial biomes and color in a world map in a given worksheet. Students will also use this same information to create a bar graph. Students will then access NEO NASA Earth Observations website to compare albedo with another set of parameters (student choice).
Two 40-minute Periods

Elaborate
Students will read the article, "Are Woolly Mammoths a Solution to the Hairy Problem of Climate Change." Students will answer questions pertaining to the article on a worksheet and discuss with their classmates.
One 40-minute Period

Evaluate
Students will work in groups of two to three to re-create their positive feedback loop in regards to snow/ice melt, but with the introduction of the Woolly Mammoth. Students will use their worksheet to then go on a gallery walk and evaluate the manner in which their peers depicted their new feedback loops. A class discussion as to which renditions were successful and wich were unsuccesful in depicting the changes brought on by the reintroduction of the Woolly Mammoth can follow.
One 40-minute Period

Vocabulary/Key Terms covered in this lesson:

Albedo
Reflectivity
Climate Change
Arctic/Tundra
CRISPR
Genetic Engineering
Feedback Loop
Negative Feedback Loop
Positive Feedback Loop

Worksheets, articles and additional materials have been provided through live links throughout this lesson. Printable documents have been linked to a shared Google Drive.

Link to Google Drive: They're Back! Albedo and Woolly Mammoth Lesson

EDUCATION STANDARDS

NGSS Science Standards Grades 9-12

4-ESS2-2: *Analyze and interpret data from maps to describe patterns of Earth's features.*

HS-ESS3-5: *Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.*

LS2.C*: Ecosystem Dynamics, Functioning, and Resilience*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Constructing Explanations and Designing Solutions *Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.* • Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1)	**ESS3.D: Global Climate Change** • Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** • Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.	**Stability and Change** • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. • Feedback (negative or positive) can stabilize or destabilize a system. **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Common Core State Standards:
New York has adopted NGSS for the Science Common Core standards (as of 2016).

Math: *Not applicable*

ELA: READING STANDARDS FOR LITERACY IN SCIENCE AND TECHNICAL SUBJECTS 11-12
Craft and Structure
RST4: Determine the meaning of symbols, key terms, and other content-specific words and phrases as they are used in scientific or technical sources.
Integration of Knowledge and Ideas

RST7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. *(HS-ESS3-5)*

ITEEA Standards: *Not applicable*

Other Standards

AP Environmental Science Standards

Unit 4: Earth Systems and Resources
4.7 Solar Radiation and Earth's Seasons

ENG-2.A Explain how the sun's energy affects the Earth's surface.

Unit 9: Global Change
9.5 Global Climate Change

STB-4.F Explain how changes in climate, both short- and long term, impact ecosystems.

AP Biology Science Standards

Unit 6: Biotechnology
IST-1.P Explain the use of genetic engineering techniques in analyzing or manipulating DNA.

NGSS Engineering and Technology Standards Grades 9-12

HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:

Constructing Explanations and Designing Solutions *Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.* ● *Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)*	***ETS1.A: Defining and Delimiting Engineering Problems*** ● *Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)*	***Connections to Engineering, Technology, and Applications of Science*** ***Influence of Science, Engineering, and Technology on Society and the Natural World*** ● *New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)*

MEASURABLE STUDENT LEARNING OBJECTIVES

Students will be able to define “Albedo.”

Students will be able to interpret albedo data in reference to terrestrial biomes.

Students will be able to graph albedo in reference to terrestrial biomes.

Students will be able to define “feedback loop.”

Students will be able to create a positive feedback loop in regards to ice/snow melt.

Students will be able to read and interpret an article in relation to the de-extinction of the Woolly Mammoth.

Students will be able to interpret, create and analyze new positive feedback loops in relation to snow/ice melt and the reintroduction of Woolly Mammoths.

MATERIALS NEEDED

Computer with internet accessibility

Markers/Colored Pencils

11x17 paper or poster paper

Pen/Pencil

ENGAGING CONTEXT/PHENOMENON

The phenomena for this lesson will a Google Slide image of a Woolly Mammoth. Students will enter the room with the image alongside questions for them to answer. Students will engage in a discussion of Woolly Mammoths, when they existed, the environment in which they existed, and the possibilities of bring back these organisms.

DATA INTEGRATION

Students will be collecting data from NEO NASA Earth Observations in relation to albedo during various months and years as well as a student-chosen set of parameters. Students will also be gathering data from watching Youtube videos provided through myNASAdata as well as working in groups and critiquing one another's work.

NEO NASA Earth Observations
myNASAdata
Youtube Video: Climatebits:Albedo
Youtube Video: NASA: The World is Black and White
Article: Are Woolly Mammoths a Solution to the Hairy Problem of Climate Change?

TEACHER BACKGROUND KNOWLEDGE

Teachers should be familiar with albedo, interpreting albedo values (from zero to one) and what terrestrial biomes have the highest and lowest albedo values. Teachers should be familiar with feedback loops and the differences between positive and negative feedback loops. Knowledge of the snow/ice melt positive feedback loop should also be known as well as the increasing affects climate change is having on this loop.

What climate change is as well as how it is related to increased CO_2 emissions and global warming will be needed knowledge so as to explain the effects of the positive feedback loop in snow/ice melt.

Teachers should also be familiar with the modern techniques for de-extinction involving CRISPR. It should be noted that this lesson does not go into detail into the methods of de-extinction, however the overall techniques should be understood in order to foster higher-level discussions amongst students.

Teachers should also access all websites prior to the lesson in order to ensure that any school filters are not blocking the websites.

DIFFERENTIATION OF INSTRUCTION

The phenomena for this lesson include a visual representation of a Woolly Mammoth provided on a Google Slide. If students are visually impaired, the teacher can describe or have another student describe what is being seen on the screen. If students are hearing impaired, the questions have been written out on the slide and teachers can also opt to print the slide for the student.

Students will need to be able to manipulate materials the *Explore* and *Evaluate* portions of the lesson, in which they will be designing and drawing their own feedback loops. If students require any aid in this manner (whether it be physical or mental) students can be paired up to compensate.

Students that struggle with reading comprehension may also be paired with other members. There is one article and one website that require reading. Teachers may elect to read the articles out loud to the class rather than having the students read the articles. Teachers may also wish to summarize the articles rather than having students read the articles in its entirety.

The *Explain* portion of this lesson require individual internet accessibility. The *Explore* portion also requires internet accessibility, but may be done as a class activity rather than individually. If any student requires aid in using the internet, students may wish to be paired.

REAL-WORLD CONNECTIONS FOR STUDENTS

Students are constantly being bombarded by the media in regards to climate change. Understanding how climate change is having additional effects on the planet, especially the areas of the poles, is important to understanding how the world, as a whole, is changing.

Links for this discussion can be found here:

- An article by the United Nations in regards to melting permafrost and why it is important to understand it as well as combat it.

- An article by the National Snow and Ice Data Center in regards to why the arctic is so sensitive to climate change and why we should care.

- An article by Quanta Magazine in regards to the controversies that de-extinction entails.

INTEGRATION POSSIBLE MISCONCEPTIONS

Students have misconceptions about albedo, often thinking that a higher albedo means that there is more absorption. Students should be reminded that the number 0 – 1 represent percentages, and that if something is 100% reflective, nothing is absorbed.

Another misconception is that of feedback loops. Often students believe a positive feedback loop means something good is occurring, whereas a negative feedback loop refers to something bad occurring. Rather, when teaching positive and negative feedback loops, it should be pointed out that the positive and negative refer to the overall outcome of the loops. In the case of snow/ice melt, because *more* ice and snow is melting, it is a positive feedback loop.

Due to such moves as *Jurassic World*, students also have misconceptions about the de-extinction of organisms. Such misconceptions often occur due to a lack of knowledge. To understand de-extinction and the pros and cons, students should have a basic understanding of genetics. Using the articles, it can be pointed out that de-extinction of organisms such as dinosaurs would be nearly impossible to occur, due to a lack of preserved DNA. It should also be pointed out that DNA does degrade, and that even bringing back the Woolly Mammoth will result in the creation of a hybrid rather than the original species.

LESSON PROCEDURE

5E Engage Explore Explain Elaborate Evaluate	**Engage: Anchoring Phenomena** ***Google Slide of Woolly Mammoth with Questions*** **Google Slide Image** **Approximately 20 min**
Engage **Anchoring Phenomena:** Woolly Mammoth Google Slide Image with Questions (Google Slide Image)	**Procedure:** 1. As students enter the classroom, have the Google Slide image of the Woolly Mammoth be projected on to the board. (Google Slide Image) a. Allow students to discuss amongst themselves as they settle into the class. b. Click on the image and project the questions on to the slide. c. Ask students to read the questions and write down their answers. d. Discuss the answers with the students, ensuring all understand that Woolly Mammoths *did* exist when humans were on earth but that their environment was very different. 2. Have students move on to the *Explore* section of the lesson. 3. NOTE: This anchoring phenomena will not take an entire 40-minute period. It is strongly suggested that at the completion of the discussion about Woolly Mammoths, that the lesson move on to the *Explore* section. **Modifications** If students are visually impaired, the teacher can read out loud the questions for the students. If there is a student who is hearing impaired, the student can follow along on the slide or have a printed copy of the slide. **Standards Addressed** **ELA: READING STANDARDS FOR LITERACY IN SCIENCE AND TECHNICAL SUBJECTS 11-12** **Integration of Knowledge and Ideas**

	RST7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** (HS-LS2-7) ***HS-ESS3-5:*** *Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.* **Formative/Summative Assessments** During this portion of the lesson, the background knowledge of the students is being assessed. Woolly Mammoths are recognizable animals, but often students are lacking in information about the animals. Answers to the four Google Slide questions can be written on the board, so that students hear and see the answers. Discussion as to how the environment of the planet has changed should be encouraged. If students bring up the topic of de-extinction (a possibility, depending on the students' knowledge), encourage the idea that the environment that the Woolly Mammoth's once existed in no long exists. This not only includes local habitat, but also the climate and plants that existed at that time. **Resources** Google Slide Image
5E **Engage** **Explore** **Explain** **Elaborate** **Evaluate**	**Explore** **What is Albedo? Learning about Albedo and Feedback Loops** **Explore: Albedo Student Worksheet** **Approximately 60 min** **(20 additional minutes from Engage)**

Explore

What is Albedo? Exploring Albedo and Feedback Loops

Students will learn about albedo by watching a video. Students will also explore what a feedback loop is as well as draw their own positive feedback loop.

Explore: Albedo Worksheet

Youtube Video: Climatebits:Albedo

Youtube Video: NASA: The World is Black and White

Procedure:

Learning about Albedo and Feedback Loops.

NOTE: The following procedure is for showing the videos to students as a class. This activity can also be done in smaller groups or individually utilizing student devices.

1. Hand out the Explore: Albedo Worksheet to students.
2. Show the Youtube Video, Climatebits: Alebedo to students.
3. Be sure to pause the video when specific questions are being asked on the worksheet, to ensure students have the answers.
4. Once the video is completed, discussion of the answers to the questions may proceed.
5. Once Part 1 has been completed, show the students the Youtube Video, NASA: The World is Black and White.
6. Pause the video so that students may complete questions.
7. Discuss answers with students, placing emphasis on the differences between negative and positive feedback.
8. Have students work individually or in pairs to complete the last part of the worksheet, in which students depict their own positive feedback loop in regards to ice and snow melt and climate change.

Modifications

Students may need to access a computer with internet access if teachers choose for students to view the videos on student devices. Teachers should ensure that the website is not blocked by any district or school firewalls.

Students who may need additional help in working with a computer should be paired with those that can work with computers without hindrance.

Students who are visually impaired should have a student work with them to read the type out loud and describe the images.

Standards Addressed

AP Environmental Science Standards

Unit 4: Earth Systems and Resources
4.7 Solar Radiation and Earth's Seasons

ENG-2.A Explain how the sun's energy affects the Earth's surface.

Unit 9: Global Change
9.5 Global Climate Change

STB-4.F Explain how changes in climate, both short- and long term, impact ecosystems.

4-ESS2-2: *Analyze and interpret data from maps to describe patterns of Earth's features.*

HS-ESS3-5: *Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.*

LS2.C*: Ecosystem Dynamics, Functioning, and Resilience*

NGSS Engineering and Technology Standards Grades 9-12

HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Formative/Summative Assessments

Students are to complete the 16 questions that encompass parts 1 and 2 in their Explore: Albedo Worksheet. Students are also to draw their own version of a positive feedback loop in regards to climate change and snow/ice melt.

Resources

Computer with internet access

Explore: Albedo Worksheet Student Worksheet

5E Engage Explore Explain Elaborate Evaluate	**Explain** **Albedo and Terrestrial Biomes** **Explain: Albedo and Biomes Student Worksheet** **Approximately 80 min** **(Two 40-minute periods)**
Explain Students are to color in a world map in regards to various albedo values and terrestrial biomes. Students are to graph the various albedo values versus the type of biome. Students are to complete questions in regards to albedo and biomes by utilizing the NEO NASA Earth Observations website and their worksheet. NEO NASA Earth Observations website Explore: Albedo and Biomes Worksheet	**Procedure:** 1. Students should be handed the Explain: Albedo and Biomes worksheet. 2. Working individually, students should be instructed to go to the end of their worksheet, which contains a world map and albedo values for terrestrial biomes. a. Using the given key, students are to color in a world map showing the differing albedo values throughout the various biomes. b. Upon completion of the map, students should then graph the data on the provided worksheet. 3. Part 2 of the worksheet has students using the NEO NASA Earth Observations website to make observations as well as choose their own set of data to compare to that of albedo values. 4. Instruct students to move on to Part 2 once the map is completed and a graph has been drawn. NOTE: The albedo values provided are the median of the range that exists for various terrestrial biomes. **Modifications** Students that struggle with coloring or are color-blind may work with others to ensure the activity is completed. If computer assistance is needed for answers, students with either hearing or visual impairment should be partnered with other students to aid them in using the computer.

Standards Addressed

AP Environmental Science Standards

Unit 4: Earth Systems and Resources
4.7 Solar Radiation and Earth's Seasons

ENG-2.A Explain how the sun's energy affects the Earth's surface.

Unit 9: Global Change
9.5 Global Climate Change

STB-4.F Explain how changes in climate, both short- and long term, impact ecosystems.

4-ESS2-2: *Analyze and interpret data from maps to describe patterns of Earth's features.*

HS-ESS3-5: *Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.*

ELA: READING STANDARDS FOR LITERACY IN SCIENCE AND TECHNICAL SUBJECTS 11-12
Craft and Structure

Integration of Knowledge and Ideas
RST7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Formative/Summative Assessments

Students will be completing a world map, graph and questions in regards to the NEO NASA Earth Observations website.

Resources

NEO NASA Earth Observations website

Explore: Albedo and Biomes Worksheet

	Computers with internet connection (either individual or in groups)
5E **Engage** **Explore** **Explain** **Elaborate** **Evaluate**	**Elaborate** **De-extinction of the Woolly Mammoth** **Elaborate: Woolly Mammoth Student Worksheet** **Approximately 80 min (two class periods)**
Elaborate Students will read an article in regards to the de-extinction of the Woolly Mammoth and answer questions. Elaborate: Woolly Mammoth	**Procedure:** 1. Students are to be handed out the student worksheet. 2. Students are to work individually, reading the article at the end of the worksheet and answers the questions pertaining to the article. 3. Once completed, students are encouraged to share the pros and cons they found (and thought of) in regards to de-extinction. 4. Students should also be encouraged to discuss whether introduction of the Woolly Mammoth back in the artic/tundra would result in raising albedo values. **Modifications** If any student requires aid in using the internet, students may wish to be paired. Students with impairment that may prevent them from reading and reading comprehension may also be paired. **Standards Addressed** **AP Environmental Science Standards** **Unit 9: Global Change** **9.5** Global Climate Change **STB-4.F** Explain how changes in climate, both short- and long term, impact ecosystems. **AP Biology Science Standards** **Unit 6: Biotechnology** **IST-1.P** Explain the use of genetic engineering techniques in analyzing or manipulating DNA.

	NGSS Engineering and Technology Standards Grades 9-12 ***HS-ETS1-3*** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. **ELA: READING STANDARDS FOR LITERACY IN SCIENCE AND TECHNICAL SUBJECTS 11-12** *Craft and Structure* **Integration of Knowledge and Ideas** **RST7:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **Formative/Summative Assessments** Students will use their reading comprehension skills to answer questions in regards to an article. Students will also discuss the pros and cons of de-extinction and the reintroduction of the Woolly Mammoth with their peers. **Resources** Elaborate: Woolly Mammoth Student Worksheet Computers with internet connection (either individual or in groups)
5E **Engage** **Explore** **Explain** **Elaborate** **Evaluate**	**Evaluate** **Redesigning a Positive Feedback Loop** **Evaluate: Feedback Loops Student Worksheet** **Approximately 40 min**
Evaluate Students will create a new version of their snow/ice melt positive feedback loops, but with the	**Procedure:** 1. Students should be broken into groups containing 2-3 individuals. 2. Students should receive the following materials: a. 11x17 paper or poster paper b. Markers/colored pencils

introduction of the Woolly Mammoth. Students will then go on a gallery walk and observe how other students chose to modify their positive feedback loops. Evaluate: Feedback Loop Student Worksheet	c. Pencils 3. Students should be instructed that they will be given 20 minutes to re-design their positive feedback loops for snow/ice melt to include the reintroduction of Woolly Mammoths. 4. Once completed, students should receive the Feedback Loop Student Worksheet. 5. As individuals (or in groups), students are to view and critique their peers on their redesigns of their feedback loops. 6. A class discussion can complete the lesson, asking students which feedback loops were successful in demonstrating the addition of Woolly Mammoths and what made them successful. What feedback loops were unsuccessful? Why? **Modifications** Students that struggle with coloring/drawing or are color-blind may work with others to ensure the activity is completed. Students that are fearful of presentations should stand with their classmates, standing behind a desk or chair to help with their anxiety when presenting. **Standards Addressed** ***NGSS Engineering and Technology Standards Grades 9-12*** ***HS-ETS1-3*** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. **ELA: READING STANDARDS FOR LITERACY IN SCIENCE AND TECHNICAL SUBJECTS 11-12** *Craft and Structure* **Integration of Knowledge and Ideas** **RST7:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. **HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

	Formative/Summative Assessments Teachers may collect the individual evaluations of the students to make a determination of a grade for each presentation. **Resources** Evaluate: Feedback Loop Student Worksheet

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Discussion Questions

1. What animal is being represented in the illustration?
2. How many years ago do you think this animal roamed the earth?
3. What type of habitat do you think this animal lived in?
4. How do you think earth differed in its climate during this time?

SPHERES OF THE EARTH: CRYOSPHERE

Albedo

Objective:

- Students will be able to define albedo.
- Students will be able to state the range in which albedo is calculated, and state what an albedo of 0.1 versus an albedo of 0.8 means in regards to reflectivity.
- Students will be able to draw/illustrate and explain the positive feedback loop that currently exists between declining albedo and climate change.

Part 1 - What is Albedo?

Procedure:

1. Watch the video "ClimateBits: Albedo" provided by myNASAdata. This may be shown as a class or individually on individual student devices.
2. While watching the video answer the questions listed below.
    a. NOTE: Some sections may need to be paused or rewound in order to obtain the answer.

Part 1 Questions

1. Define **Albedo**

2. Why is albedo important in regards to the average temperature of the planet?

3. What feature of the planet has the highest albedo and therefore is the most important in reflecting the sun's energy?

4. Watch the image of the planet showing the weekly solar radiation that is reflected.
   Name TWO sources that are lighter in color and have caused more solar energy to be reflected:

   A. _____

   B. _____

5. As you watch the video, you will notice the albedo shifting from the south pole to the north pole. What do you think is causing this shift?

   _____

   _____

6. How are humans disrupting the albedo of the planet? Give one example.

   _____

   _____

7. What is the range in which albedo is measured?

   _____

8. What types of biomes have the highest albedo?

   _____

Part 2 – Feedback Loops

Procedure:

1. Watch the video "NASA: The World is Black and White" provided by myNASAdata. This may be shown as a class or individually on individual student devices.
2. While watching the video answer the questions listed below.
    b. NOTE: Some sections may need to be paused or rewound in order to obtain the answer.

Part 2 Questions

1. In what temperatures do the black daisies thrive?

2. As a consequence of the increased black daisies, what occurs to the overall planet's temperature? What causes this change?

3. Why is there a shift to the white daisies now thriving?

4. As a consequence of the increased white daisies, what occurs to the incoming solar radiation?

5. State whether the following would have a **high** albedo or a **low** albedo. Express your numbers as 0 being 0% and 1 being 100%:

    a. White daisies: _____

    b. Black daisies: _____

    c. Mirror planet: _____

    d. Perfectly black planet: _____

    e. Water world: _____

6. What variables could cause the fluctuations to differ between the white daisy reflection and the black daisy absorbance? Name two:

    a. _____

    b. _____

7. Define **Negative Feedback Loop**:

_____

_____

8. Define **positive feedback loop:**

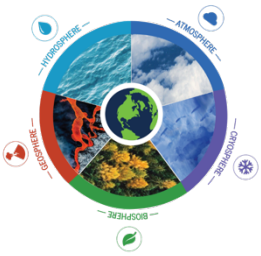
_____

_____

Part 3 – Drawing a Feedback Loop

Procedure:

1. After watching the video "NASA: The World is Black and White" provided by myNASAdata, partner with one or two people.
2. In the space below, draw a **positive feedback loop** in regards to snow/ice at the poles. **Highlight** the area that is being influenced by climate change.



SPHERES OF THE EARTH: CRYOSPHERE

Albedo & Biomes

Objective:

- Students will be able to identify how albedo differs throughout the planet.
- Students will be able to graph the various albedo values in comparison to terrestrial biomes.
- Students will be able to make comparisons between albedo and other global factors, such as temperature, UV, etc.

Part 1 – Albedo of Biomes Map & Graph

Procedure:

1. Using the data provided on the Albedo Biome Map, color the world map depicting the various albedo that exists throughout the planet. Albedo values are listed for specific terrestrial biomes. Note that darker colors will have a lower albedo (less reflectivity) and lighter colors will have a higher albedo (more reflectivity).
2. Using the same albedo values, construct a bar graph.
    a. NOTE: Albedo values are a range. The numbers given are the median of that range. Ranges of albedo values are sourced from PennState/NASA (see citations).

Part 2 – Albedo versus other sources (Making comparisons)

Procedure & Questions:

1. Click on the live link to access the website NEO NASA Earth Observations.
    a. Go to the top and click “Energy”
    b. Click on “Albedo”
    c. Albedo data is not available for specific months. Scroll to “March 2023” to see a full view of the map and the various values of albedo.

    What do darker colors on the map indicate?

    _____

    What do lighter colors on the map indicate?

    _____

What parts of the world have the highest albedo in March 2023?

What parts of the world have the lowest albedo in March 2023?

---

d. Open a new window on your browser. You will be viewing two maps at the same time.
e. Keep one window at “March 2023” and select the second window to “August 2023”.

What parts of the world have the highest albedo in August 2023?

Why do you think there is such a significant difference between March 2023 and August 2023?

---

f. Keep one window at “March 2023”
g. In the second window (the current August 2023) Select the year “2000”.
h. Select “March 2000”.
i. Have the two browser windows side-by-side to make comparisons.

What observations can you see between March 2023 and March 2000?

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j. Repeat steps f – i, but for August 2000 and August 2023.

What observations can you see between August 2023 and August 2000?

---

k. You will now choose another factor to compare to albedo. You have many choices – Atmosphere (ex: cloud cover), Energy (ex: global temp), Land (ex: primary productivity), Life (ex: vegetative index), and Ocean (ex: Chlorophyll concentration).
    i. Each drop-down has many choices. You will need to choose ONE.
    ii. You are making a comparison between March 2000 and your additional factor. You are then repeating this for August 2023.
    iii. You are making a comparison between March 2023 and your additional Factor. You are then repeating this for August 202.

2. Complete the data chart below of your observations between your factor and albedo.

What factor are you comparing to albedo? _____

PLEASE NOTE: You are to use ONE factor to compare to the March 2000 Albedo and March 2023 albedo as well as the August 2000 and August 2023 albedo.

Why did you choose this specific factor?

_____

_____

What do you think you may observe when comparing this factor to albedo?

_____

_____

Observations	
March 2000 Albedo Vs New Factor: _____	
March 2023 Albedo Vs New Factor: _____	

Did you see any patterns between your factor and albedo?

_____

_____

Were there any differences between March 2000 and March 2023 when compared to your factor?

_____

_____

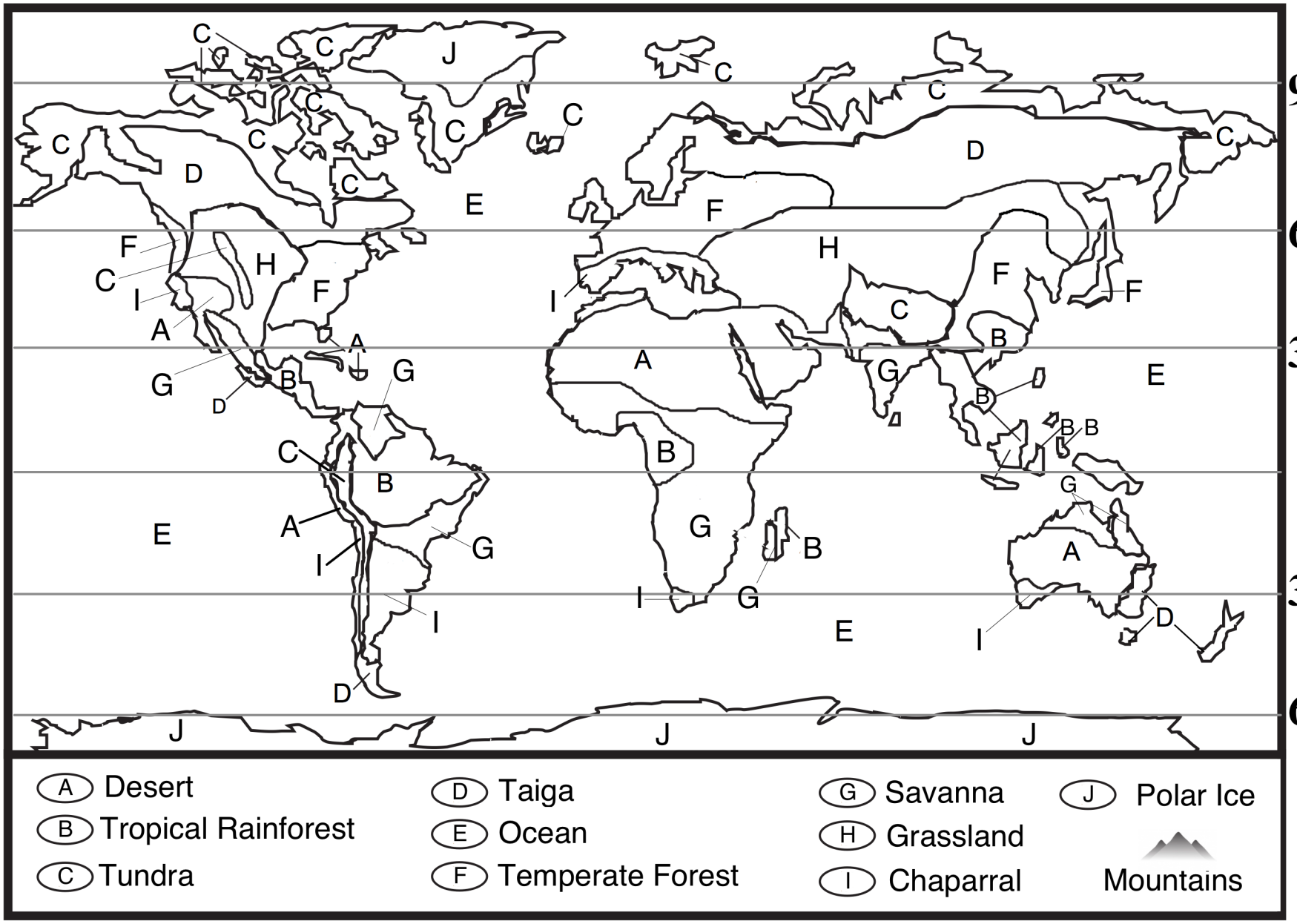
Repeat this process for August 2000 and August 2023.

Observations	
August 2000 Albedo Vs New Factor: _____	
August 2023 Albedo Vs New Factor: _____	

Did you see any patterns between your factor and albedo?

Were there any differences between August 2000 and August 2023 when compared to your factor?

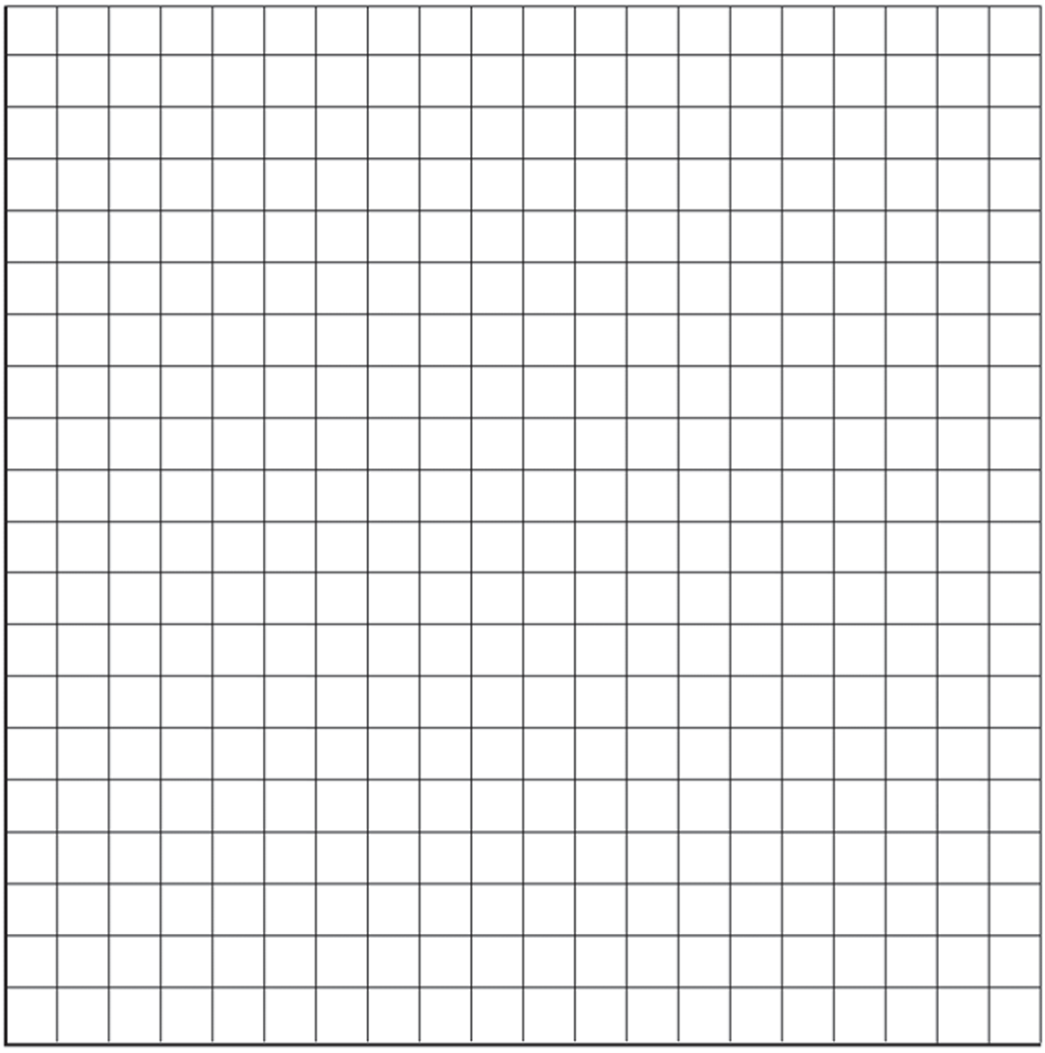
Biome World Map

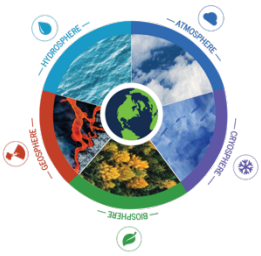


Map created by Rita Thomas
Source: NASA Earth Observatory Website

Albedo of Biomes Graph

1. Use the albedo values on the Albedo World Map to construct a bar graph.
2. What values will you use for as the x-axis? For the y-axis?
3. Be sure to label your axis and title your graph.





SPHERES OF THE EARTH: CRYOSPHERE

The Woolly Mammoth

Objective:

- Students will use CER method to discuss an article in regards to the de-extinction of the Woolly Mammoth.
- Students will discuss the pros and cons to bringing back the Woolly Mammoth and releasing it into the wild.

Procedure:

1. Read the attached article "Are Woolly Mammoths a Solution to the Hairy Problem of Climate Change?" by Jonathan Shipley.
2. Answer the questions below.
3. Prepare for a discussion with the class.

Article Questions:

1. When did Woolly Mammoths last roam earth?

   _____

2. Did humans live at the same time as Woolly Mammoths? What types of humans existed at the same time as Woolly Mammoths?

   _____

   _____

3. Why dd humans hunt Woolly Mammoths?

   _____

4. What company is planning on bringing back the Woolly Mammoth? When do they plan on having this completed?

   _____

5. Where do scientists plan on releasing the Woolly Mammoths? What kind of biome once existed there? What biome exists there now?

   _____

6. What **claim** are scientists making in regards to climate change and the reintroduction of the Woolly Mammoth?

7. From what you have learned so far, the tundra that now exists was once grasslands. The permafrost currently in the tundra is melting – causing the darkened soil to absorb more heat, and therefore melt faster (positive feedback loop). What **evidence** do you now have that would support the claim that grasslands and forests would help decrease this positive feedback loop?

8. What **reasoning** would connect the evidence you presented in question #7 to the scientist's **claim**?

9. Are scientists bringing back a true Woolly Mammoth? Why or why not?

10. There are many scientists who fear bringing back the Woolly Mammoth.
    List below some of the pros and cons to bringing back an animal such as the Woolly Mammoth:

Pros	Cons

Are Woolly Mammoths a Solution to the Hairy Problem of Climate Change?

discovermagazine.com/planet-earth/are-woolly-mammoths-a-solution-to-the-hairy-problem-of-climate-change

Jonathan Shipley

(Credit: Ekaterina Glazkova/Shutterstock)

The last woolly mammoth likely roamed around 4,000 years ago. Modern humans lived alongside the animals for thousands of years — and before that, the Neanderthals used woolly mammoths for almost everything imaginable: food, shelter, tools, art. The world's oldest known musical instrument, a flute, was fashioned from mammoth ivory.

In the very near future, however, humans may cross paths with the extinct beasts once again.

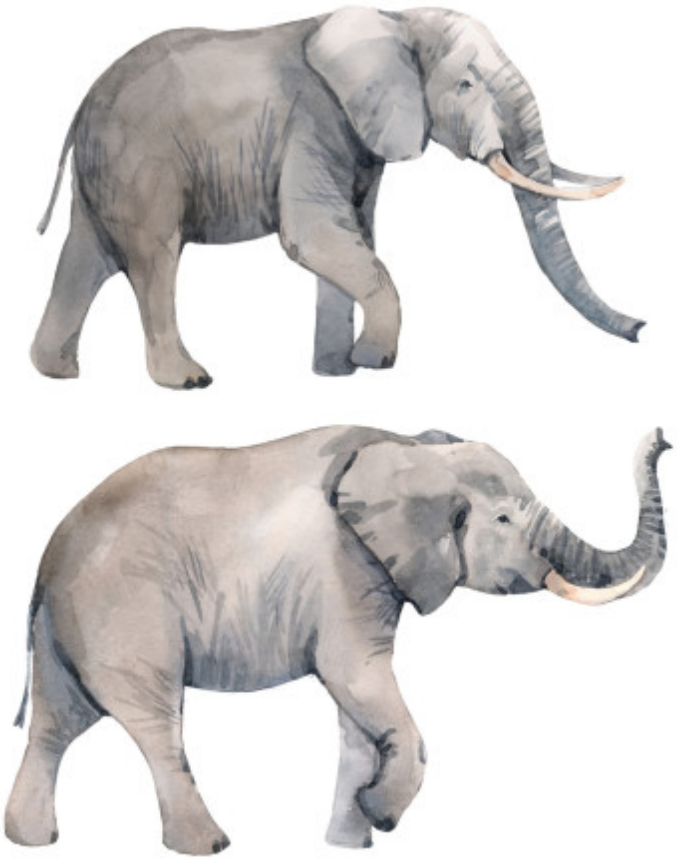
Colossal Biosciences, a Texas-based biotechnology startup, is on the forefront of reintroducing the woolly mammoth to the world — or some version of it. The company expects to create mammoth-elephant hybrid calves by 2027. These animals will be reintroduced at Pleistocene Park, a Russian nature reserve in Siberia, where attempts are being made to recreate the grasslands that flourished during the last ice age.

Colossal describes the hybrids as a vital defender of the earth. According to the company, they will decelerate the melting of arctic permafrost (preventing the emission of greenhouse gases trapped within the permafrost) and revert overshrubbed forests back into natural arctic grasslands, fostering an ecosystem that could maintain its own defenses against climate change. The ultimate goal? Save the world's future by going back in world history.

De-Extinction

Colossal was cofounded last year by Harvard Medical School genetics professor George Church, whose work includes genetic modification of pigs, and tech entrepreneur Ben Lamm. They believe that bringing back the mammoth is radical, but also doable. "We're ushering in a thoughtful wave of restorative biology to de-extinct a species, protect species at risk of extinction and rewild [reintroduce] degraded ecosystems," says Lamm. "This is groundbreaking. We are in control of a science that has the power to reverse and prevent biodiversity loss."

Of course, the company won't be resurrecting the woolly mammoth so much as "de-extincting" woolly mammoth genes to create cold-resistant elephants with all of the core phenotypic traits of the woolly mammoth. Oddly enough, the woolly mammoth shares 99.6% of its DNA with the modern-day Asian elephant. Colossal aims to develop a hybrid species by using CRISPR, a revolutionary gene-editing technology, to bring key mammoth genetic traits into the Asian elephant genome.



The Indian elephant, one of three subspecies of the Asian elephant. (Credit: Anastasia Lembrik/Shutterstock)

Those key traits include a 10-centimeter-thick layer of insulating fat, five different types of shaggy hair and smaller ears to help the hybrid animal tolerate colder weather characteristic of Pleistocene Park. “This gives us the ability to rewild this critical species into a degrading ecosystem to combat the effects of climate change in a disruptive, new way,” Lamm says.

Risks and Rewards

All of this isn’t without risk or controversy. As the character Ian Malcolm famously quotes in Jurassic Park, “Your scientists were so preoccupied with whether or not they could, they didn’t stop to think if they should.” Some other scientists fear the new species will become invasive, affecting native species, communities and ecosystems through competition, browsing and the facilitation of diseases.

It’s also unclear how impactful the mammoths will be in combating climate change. There certainly won’t be many of the animals at the outset, and the gestation period for an elephant is two long years — so calves won’t appear for some time. Additionally, the process of recreating a mammoth is not particularly easy, nor cheap. (The company launched with $15 million in funding from investors, but recently raised another $60 million to speed up its growth.)

Then there are the ethical and moral implications of “resurrecting” the dead. “We’ve worked carefully and diligently on assembling an advisory board of geneticists, bioethicists, scientists and conservationists to foster an ongoing dialogue with industry experts as well as the broader public at large,” says Lamm. While he’s excited about seeing woolly mammoths roam the Arctic tundra again, he’s more excited about creating new tools for conservation.

A recent United Nations report shows that nearly 1 million species risk extinction within the next few decades, particularly if no radical action is taken. Lamm and others believe Colossal’s biotech could even be used to genetically edit these other species, of all types, so that they might be better equipped to deal with the effects of climate change. The company recently partnered with the Vertebrate Genomes Project to genetically preserve the Asian elephant, the African elephant and the Forest elephant through genomic sequencing.

When all is said and done, humans might walk alongside a version of the woolly mammoth once again — straight into a future designed by the scientists of today.

SPHERES OF THE EARTH: CRYOSPHERE

Feedback Loops

Objective:

- Students will be able to answer questions in regards to feedback loops.
- Students will be able to answer questions in regards to the snow/ice positive feedback loop currently occurring.
- Students will be able to create a new positive feedback loop that includes the introduction of Woolly Mammoths.

Procedure:

NOTE: Students should be familiar with feedback loops, the positive feedback loop that exists in snow/ice and the de-extinction of Woolly Mammoths.

1. You will be placed in a team of 2-3 students to complete this activity.
2. Within your group, you are to create a feedback loop, depicting what is occurring with ice/snow in the arctic/tundra region due to climate change, and how the introduction of Woolly Mammoths may change this feedback loop.
3. Be sure your loop is clear, labeled, and easy to understand.
4. Once complete, use the questions below to go on a "gallery walk" and critique the loops created by your peers.
    a. When conducting the gallery walk, think of the following questions for each depiction:
        i. Are the loops depicted easy to understand?
        ii. Do you understand the different aspects of the loop?
        iii. Is it clear what may occur with the introduction of the Woolly Mammoths?
        iv. Is it clear what may occur without the Woolly Mammoths?

Gallery Walk

Names of Students	Positive Aspects	Aspects that needs more work

Names of Students	Positive Aspects	Aspects that needs more work

Names of Students	Positive Aspects	Aspects that needs more work

Names of Students	Positive Aspects	Aspects that needs more work

Names of Students	Positive Aspects	Aspects that needs more work

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