Name: _____

Phet Glacier Lab

First, let's do some research on what glaciers are and the types of landforms they will create. Open your computer up and answer the following questions, finding the answers using the internet. Good search techniques dictate that you search for clues while adding the word glacier in the search phrase. Bullet points are instructions. Bolded sections are for your information.

- **Write your answers in a different color, bold or a different font.**

1. In your own words describe the difference between a glacier and an iceberg.
2. What is the relationship between temperature and glacier size?
3. What is the relationship between snowfall amount and glacier size?
4. What causes a glacier to grow or recede?
5. Describe how a hanging valley is formed. Add a picture of a hanging valley.
6. Describe how a u-shaped valley is formed. Add a picture of a U-shaped valley.
7. Describe how an arete is formed. Add a picture of an arete.
8. Describe how a horn is formed. Add a picture of a horn.
9. Describe how a cirque is formed. Add a picture of a cirque.

Now that we found out what landforms are created by glaciers, we need to discover where all of that weathered rock goes. We know that glaciers move rocks downhill, but when the glacier melts it deposits those rocks. Below are some questions pertaining to landforms that demonstrate evidence of the deposition processes of glaciers.

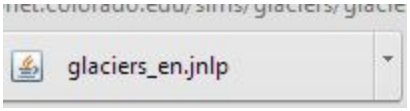
10. Define glacial till.
11. Describe what a moraine is how it is formed. Add a picture of a moraine.
12. Describe what an outwash plain is and how it is formed. Add a picture of an outwash plain.
13. Describe what a drumlin is how it is formed. Add a picture of a drumlin.

14. Describe what an esker is and how it is formed.

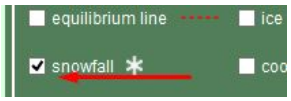
Below is a thought provoking question. With your partner or group discuss it and answer it.

15. Why would glaciers be described as the “Most Erosive Force in Nature”.

Now that you have some understanding of the landforms that weathering, erosion and deposition of glaciers create, you are going to have an opportunity to explore the processes behind glacial erosion.

- Open this URL in a different tab on your browser. http://phet.colorado.edu/en/simulation/glaciers . Click the “play button.” 
- Click the downloaded file at the bottom of your browser. 

- Click on the “Advanced” tab. 

- Turn off the “snowfall” effect. 

- Play with simulation for about 5 minutes to get to know all of the features. You can grab the bear to move down the mountain. Make the glacier grow and shrink. If your glacier ever disappears hit the “Reset All” button. Play with all of the different tools to find out what they do and the data they can give. 

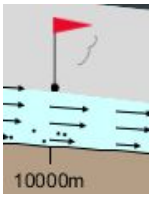
- Turn on the “equilibrium line.” This line indicates the boundary where the freezing meets the melting of the glacier. Change some of the factors and describe what happens to the equilibrium line and what happens to the glacier. 

- Change your units of measure to “Metric”

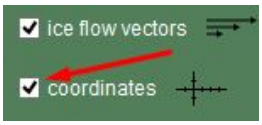
16. What do you think would happen to the glacier if the average annual snowfall increases meters/year?
17. If the temperature changed, hypothesize what two things could change in the glacier?
18. Decrease the temperature and increase the snowfall. Explain what happens to the equilibrium line.
19. With those same settings from #18, explain what the glacier did in terms of advancing or retreating.
20. With those same settings from #18, explain what happened to the thickness of the glacier.

Now set the temperature and snowfall to an amount that creates a decent sized glacier. Press the “Steady State” button and Pause the motion of the glacier.

- **Drill several vertical holes through the glacier.**

21. Before pressing the play button, explain what you **think** will happen to the holes when you press the play button.
22. Now press the play button. Look what happens to the holes. What do you think is causing this reaction?
23. Turn on the "Ice Flow Vectors." A flow vector is nothing more than an arrow representing the speed and direction of the glacier. Explain why the ice flow vectors are larger on the top of the glacier compared to the bottom.  

- **Turn on the "Coordinates"**
- **To determine the speed of the glacier, two quantities are needed: distance and time. Pause the glacier to allow accurate measurements. Place a flag on the glacier at a known distance. Now hit play until the flag hits the next number on the grid then hit pause.**
- **Fill in the following table:**



24.	Position of flag in meters	Time in years
Initial Position/time		
Final Position/Time		
Total Distance and Time		

- **To calculate speed you need to know the change in position and the change in time.**
  - **Speed = Δ in position/Δ in time**
  - **Δ means change**

25. What is the speed of the glacier? Speed = (Change in Position)/(Change in Time)

If you haven't noticed, there are many tiny black dots that represent sediment that is being eroded by the glacier.

26. Where did this material come from?
27. Where are the sediments being deposited?

- **Make the glacier retreat up the mountain.**

28. What happens to all the material that moved with the glacier?
29. What is the difference between a Terminal Moraine and a Recessional Moraine?

- **Press the "RESET ALL" button and set the glacier back to its starting location.**
- **Create the largest glacier possible and turn the time up to FAST.**
- **Place a flag at the end of the glacier. Make the glacier completely melt away.**
- **Once this is done pause the simulation and then increase the snowfall to maximum and decrease the temperature to its lowest point.**

30. Before pressing play, take a guess as to how many years you think it will take for the glacier to reach the flag?

- **Press Play**

31. About how many years did it actually take?
32. So, is growing a large glacier a slow natural process or a quick one?
33. Define glacial accumulation.
34. Define glacial ablation.

A glacier budget is a measurement of the rate by how much a glacier will grow or retreat each year. Glacier Budget = Accumulation minus Ablation

- **Create your own unique glacier.**
- **Place a green box, which happens to be a budget-meter, place a budget-meter in three different locations along the glacier.**
- **Using the table record the accumulation, ablation and budget at each point.**

35.	**Accumulation**	**Ablation**	**Budget**
Meter A	Depends where they place the box.	Depends where they place the box.	Depends where they place the box.
Meter B	Depends where they place the box.	Depends where they place the box.	Depends where they place the box.
Meter C	Depends where they place the box.	Depends where they place the box.	Depends where they place the box.

36. What does the data tell you about the glacier's activity? Depending on where they placed their boxes and what their data is, answers will vary. If they have a negative budget somewhere along their glacier it means that their glaciers is shrinking. If the budget is a positive number, that portion of the glacier is growing.

- **Create a very large glacier. Use the ice thickness tool to determine the thickness of the middle of your glacier.**

37. How thick can a typical glacier be?

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Phet Glacier Lab Answer Key

1. In your own words describe the difference between a glacier and an iceberg.
A glacier is a large sheet of ice found on land and an iceberg is part of a glacier that has broken off and is floating in water.

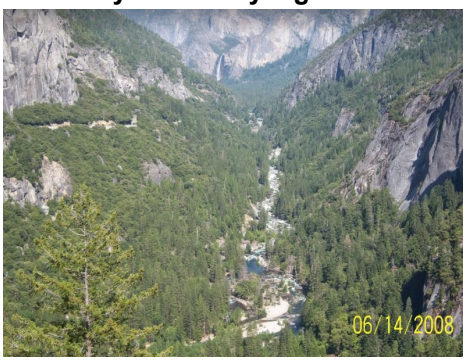
2. What is the relationship between temperature and glacier size?
As the temperature decreases the ice will not shrink and has a possibility to grow in size.

3. What is the relationship between snowfall amount and glacier size?
The more snow that is allowed to fall on a glacier the larger the glacier can get in size.

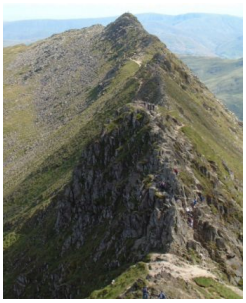
4. What causes a glacier to grow or recede?
An increase in temperature and snowfall and the glacier grows. A decrease in temperature and snowfall will cause a glacier to recede.

5. Describe how a hanging valley is formed. Add a picture of a hanging valley.
Formed when a larger heavier glacier carves a path is intersected by a smaller glacier. The smaller glacier would not have dug so deep and therefore tends to hang over a cliff so to speak. Usually represented by waterfalls where the two glaciers intersected.

6. Describe how a u-shaped valley is formed. Add a picture of a U-shaped valley.
The valley formed by a glacier as the glacier weathers and erodes rock downhill between two mountains.



7. Describe how an arete is formed. Add a picture of an arete.
The arete is the mountain ridge found between two valleys, formed by glaciers moving parallel down each valley.



8. Describe how a horn is formed. Add a picture of a horn.
A place where two or more aretes meet.

9. Describe how a cirque is formed. Add a picture of a cirque.
When a glacier carves out a bowl shaped hollow on the side of a mountain.

10. Define glacial till.
The sediment left behind after a glacier melts or the sediment moved to the sides of glaciers as the glacier plows a path down a mountain.

11. Describe what a moraine is how it is formed. Add a picture of a moraine.
Moraines are the glacial till that is left at the end or the sides of glaciers.

12. Describe what an outwash plain is and how it is formed. Add a picture of an outwash plain.
An outwash plain is found at the end, terminus of the glacier. It is the sediment that is eroded from the end of the glacier by meltwater some distance from the terminus.

13. Describe what a drumlin is how it is formed. Add a picture of a drumlin.
A hill made out of glacial till. They tend to be layered which suggests that multiple events happened to add till to the core of the initial drumlin. They look like elongated hills.

14. Describe what an esker is and how it is formed.
A long line of glacial till. Believed to be formed in ice tunnels.

15. Why would glaciers be described as the "Most Erosive Force in Nature".
This answer would vary, but they should mention something about the sizes of glaciers, or that they move large amounts of sediment by plowing through mountains. I accept any intelligent though here.

16. What do you think would happen to the glacier if the average annual snowfall increases meters/year?
Students will discuss this and answer it based on current ideas.

17. If the temperature changed, hypothesize what two things could change in the glacier?
Students will discuss this and answer it based on current ideas.

18. Decrease the temperature and increase the snowfall. Explain what happens to the equilibrium line.
It moves downslope. Increasing snowfall moves equilibrium line closer to the end of the glacier.

19. With those same settings from #18, explain what the glacier did in terms of advancing or retreating.
The glacier advances.

20. With those same settings from #18, explain what happened to the thickness of the glacier.
The glacier got thicker.

21. Before pressing the play button, explain what you **think** will happen to the holes when you press the play button.
Students will take an educated guess on this question.

22. Now press the play button. Look what happens to the holes. What do you think is causing this reaction?
The bottom of the glacier has more friction so it is moving slower than the top of the glacier.

23. Turn on the "Ice Flow Vectors." A flow vector is nothing more than an arrow representing the speed and direction of the glacier. Explain why the ice flow vectors are larger on the top of the glacier compared to the bottom.
The vectors demonstrate that bottom of the glacier does in fact move slower than the top.

24.	Position of flag in meters	Time in years
Initial Position/time	**This will be dependent on where they place the flag.**	**This will be dependent on what year they start the simulation on.**
Final Position/Time	**This will be dependent on where flag ends up.**	**This will be dependent on what year they stop the simulation on.**
Total Distance and Time	**These will depend on cells above.**	**These will depend on cells above.**

25. What is the speed of the glacier? Speed = (Change in Position)/(Change in Time)
Dependent on how much snowfall and the temperature of their simulation.

26. Where did this material come from?
From the edges of mountains as well as breaking rock from below the glacier.

27. Where are the sediments being deposited?
At the end of the glacier.

28. What happens to all the material that moved with the glacier?
It gets deposited along the glaciers path.

29. What is the difference between a Terminal Moraine and a Recessional Moraine?
Terminal moraines are the sediment left at the end of the glacier. Recessional moraines are the sediment left along the path as the glacier retreats.

30. Before pressing play, take a guess as to how many years you think it will take for the glacier to reach the flag?
Students will take a guess so answers will vary.

31. About how many years did it actually take?
1500 years.

32. So, is growing a large glacier a slow natural process or a quick one?
Glaciers form relatively slowly.

33. Define glacial accumulation.
The glacier is growing due to snow and ice accumulation.

34. Define glacial ablation.
The glacier is retreating and getting smaller.

35.	**Accumulation**	**Ablation**	**Budget**
Meter A	Depends where they place the box.	Depends where they place the box.	Depends where they place the box.
Meter B	Depends where they place the box.	Depends where they place the box.	Depends where they place the box.
Meter C	Depends where they place the box.	Depends where they place the box.	Depends where they place the box.

36. What does the data tell you about the glacier's activity?
Depending on where they placed their boxes and what their data is, answers will vary. If they have a negative budget somewhere along their glacier it means that their glaciers is shrinking. If the budget is a positive number, that portion of the glacier is growing.

37. How thick can a typical glacier be?
Glaciers are thick as some small mountains. Their numbers may vary but glaciers can get as thick as 1500 feet and thicker.

Phet Glacier Lab

Teacher Insights, Recommendations and Reflection

1. Link to the student Google Doc Version: http://tiny.cc/Glaciers2
2. Time: Two full periods sometimes spilling over into a third. Depending on time and how hard they worked depends whether it is homework or not.
3. Before even considering doing this assignment, you will need to make sure that the computers you are using are capable of running Java. This Phet lab requires java. Hopefully someday they will change it to work without Java.
4. I do let students work in partners to three people in a group. If you prefer having them do it by themselves that is fine and can still be completed in just over 2 days.
5. Understand this this assignment requires students to read the instructions. Those who do complete the assignment without issue and it is pretty self driven. When students say things like “I don’t understand...” it is because they wanted to have it explained.
6. Questions 1-15.
    a. These questions are designed to give students an opportunity to view images of and define glacial landforms.
    b. I allow my students to divide and conquer these questions.
7. Questions 16-20
    a. These questions are designed to get students to understand the relationship between snowfall/temperature and glacier size.
8. Questions 21-23
    a. Students will understand that glaciers move quicker on top than on bottom due to the drag of friction.
    b. Students will expose to vector arrows or at least reinforce the concept of vector arrows.
9. Questions 24-25
    a. These questions will integrate a little math into the assignment, helping them understand the rate of change in regards to speed at which a glacier moves per year.
10. Questions 26-29
    a. Students will understand where glacier get their material from and how terminal and recessional moraines are formed.
11. Questions 30-32
    a. Refers to the idea that glaciers really do form slowly and over many years.
12. Questions 33-36
    a. Students will understand the words ablation and accumulation and how they are used when talking about glaciers.
    b. Students will use a glacial budget meter that demonstrates that accumulation minus ablation will tell a scientist how fast the glacier is growing or shrinking. I talk about this number as being used when scientists talk about climate change and come up with numbers that tell how long it will take before a glacier disappears.
13. Question 37
    a. Students will understand that glaciers are quite tall at their largest sections. Glaciers do contain a lot of ice.
14. After students are finished or on the third day we have a discussion about just the big ideas.
    a. Glaciers grow and shrink due to temperature and snowfall
    b. Glaciers are big eroders
    c. You can calculate the rates of growth and speed.
    d. Glaciers are very large.
    e. There are many different landforms that supply evidence that there was an ice age or periods of large glaciers.
15. When I talk about the different landforms that glaciers make, I use the presentation found at the bottom of section 1 on my website: http://EarthScience.xyz/Glaciers as well as section 2 from the website.
    a. I also show some of these landforms using Google Earth as a whole group discussion. There are many places in the world that have glaciers and their landforms.
16. After we are completely done with discussing glaciers and showing images of what glacial landforms look like, I show the movie “Chasing Ice.” There is a youtube version of it, https://www.youtube.com/watch?v=haZmBxwFa7s that you can try. It is probably pirated so the link might die. I actually bought the video, because the imagery is fantastic. It is definitely politically biased for those who believe that the glaciers will be gone in a few more years and cause widespread destruction, but we have a fun debate after watching the video, which has very compelling evidence in support of destructive climate change. There is an “F” word in it, but I just mute this section. Like always, watch it and get admin approval to show it. I pause the video a lot to discuss many of the landforms that are seen in the video.