



## Buds, Leaves, and Global Warming – the Harvard Forest Project

Initial Experiment at Brookline  
High School, MA

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Biology 2 Honor

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# Introduction to Trees

Leaf Lab – a tour around the schoolyard

Purpose: Identify trees – compare observations and samples with field guides



## Background Readings:

1. *Spring Forward* by Daniel Grossman explains mismatch: ex. Great tits, winter moth caterpillars, oak leaf budburst.

MANY PLANT SPECIES around Oxford, England, bloomed earlier in the 1990s than they did from the 1954 to 1990 mean. Among the most dramatic changes was in *Lonicera album*, also known as the white dead nettle. First flowering was January 23, compared with March 18.

As temperatures rise sooner in spring, interdependent species in many ecosystems are shifting dangerously out of sync

# Spring Forward

By Daniel Grossman

## Background Readings:

### 2. *Leaf-out Dates Highlight a Changing Climate* by Catherine Polgar and Richard Primack (*HFP resource*)

What is the connection between global warming and phenological events of tree species?





# Harvard Forest Project

The start of the Buds project was the “Introduction to Phenology” powerpoint presentation.

Harvard Forest Project

# INTRODUCTION TO PHENOLOGY



# Phenology

- Phenology is the study of the timing of natural events. (Center of Biodiversity, University of Wisconsin)
- Phenology is the study of recurring biological phenomena and their relationship to weather. (Ohio State Univ)
- *Phenology* is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate. (Wikipedia)

# Phenology -



What are examples of some biological events?



# Phenology -

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What are examples of some biological events?

Examples include:

- ▣ migrations
- ▣ budding
- ▣ sap flow
- ▣ hibernation
- ▣ leaf out

# Purpose of Study

- Why do scientists want to record data about phenological events?
  - ▣ Record responses to global change, make predictions.
  - ▣ Monitor mass/ energy interactions.
  - ▣ Leaf-out and leaf senescence influence cloud formation.
  - ▣ Understand effect on our food supply.

# Climate Change

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- Based on our reading of *Spring Forward*, what are some ways that climate change can affect phenological events?

# Climate Change

For our Engage: Ecology Unit -

- *Inconvenient Truth* video
- Climate Change webquest
- Additional readings including the Diversity of Life book by E.O. Wilson and *Global Weirding* chapter from Hot, Flat, and Crowded by Thomas L. Friedman.
- Jigsaw presentation: each group will be assigned a chapter from the report Confronting Climate Change in the U.S. Northeast, prepared by the Northeast Climate Impacts Assessment Synthesis Team.

# Harvard Forest Project

## Harvard Forest Schoolyard Research

- Dr. John O'Keefe, Ph.D. (Forest Ecologist)
- Pamela Snow (Program Coodinator)
- You will contribute to a long-term field study run by Harvard Forest by collecting data on leaf senescence and bud burst/ leaf out.
- Go to Dr. O'Keefe's PDF to view his data.

# Harvard Forest Project

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## Long-Term Questions for Study:

- How long is the growing season in our schoolyard?
- How might the length of the growing season relate to climate?



# Harvard Forest Project

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This year we will answer our Field Study Questions:

- When does the growing season for trees in our schoolyard end this autumn?
- When does the new growing season begin in the Spring?

# Field Study at BHS overview

- At least 4 field site visits in the Fall to collect data on leaf color change and senescence.
- At least 4 field site visits in the Spring to collect data on bud burst and leaf development.
- Submit data to Harvard Forest.
- Analyze data to answer our Questions.

# Tree Identification

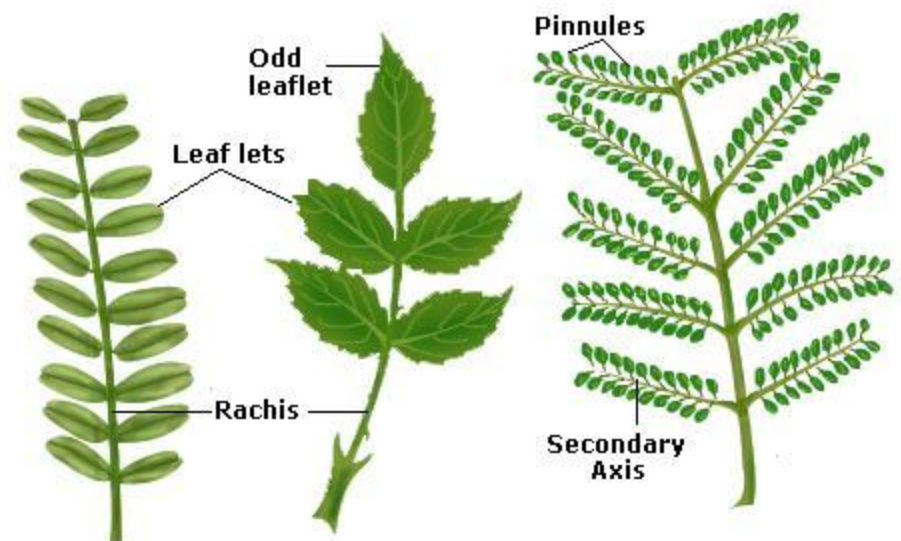
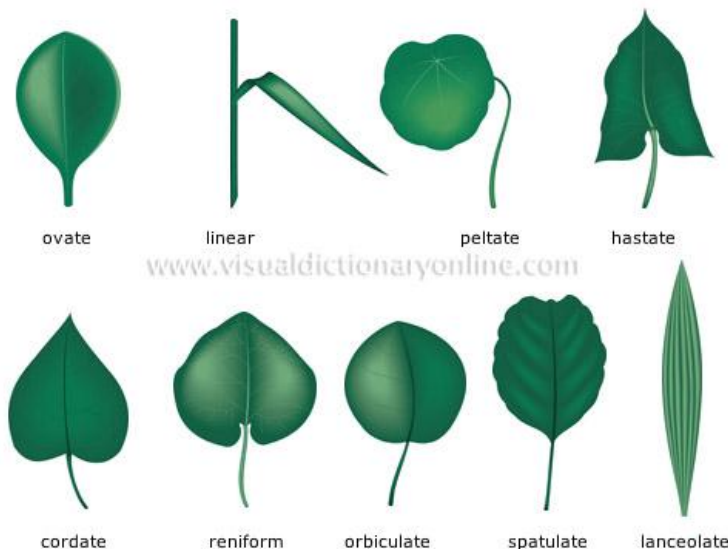
- You have had practice identifying trees through our Leaf Lab.
- opposite or alternate
  - ▣ maples, ashes, dogwoods – MAD – are opposite, most others are alternate



# Tree Identification

## □ simple or compound

- simple leaves have a bud at the base or stem/ petiole
- compound leaves are made up of leaflets: ashes, hickories, walnut, butternut, and sumacs



# Site Set Up

- Native, deciduous trees
- 2 branches per tree
- at least 6 leaves per branch (do not include the terminal leaf/ cluster at tip)
- 1 student pair per branch

# Tree & Branch Flagging

- Use flagging “tape” to label your tree.
  - Write the tree number on the tape – 1, 2, 3, or 4
  - Flag the branches.
  - Write the branch letter (ex. A, B) on the tape.
  - Tie the tape around the branch just after the 6<sup>th</sup> leaf.



# Harvard Forest Protocol – Dr. O’Keefe

- When choosing and labeling leaves/buds do **not** use the terminal/tip leaf/bud, but start counting at the next leaf from the tip as #1, then the next as #2, etc.
- On opposite leaved trees #1 and #2 will be paired **across** from each other. If there is a side branch on your main branch before you reach #6, use the tip bud on the side branch as the next # and continue using buds down the side branch until you reach #6 or, if necessary, return to leaves on the main branch. (Note, you do use the tip bud on side branches, just not on the main branch.)

# Data Collection

- Your team will record data on the Autumn Student Data Sheet.
  - ▣ Initial data collection: measure your leaves at points of greatest width and greatest length.
  - ▣ Record the fraction of each leaf that is **not** green and if the leaf has fallen or not.
  - ▣ Record the fraction of the leaves on the whole tree that are **not** green.
- Your team will complete an accurate sketch of the 6 leaves as they are arranged on the branch. Label your leaves on the diagram (1, 2, 3, etc).

# Field Notes

Record field notes (from Dr. O'Keefe's Protocol) on the back of the Autumn Student Data Sheet

- Whole tree sketch & general observations
- Tree characteristics:
  - ▣ leaf shape, edges and vein pattern, bud shape, twig smell and bark characteristics
  - ▣ record these on the first day and if there are any changes
- Climate:
  - ▣ temperature, cloud cover, precipitation, wildlife observations, any unusual conditions or recent events such as a strong windstorm or frost/freeze
  - ▣ record these for each data collection time







**Autumn Student Data Sheet**

December 2007

Name: \_\_\_\_\_ Date: \_\_\_\_\_  
 Teacher: \_\_\_\_\_ School: \_\_\_\_\_

Tree Number: ____ Branch letter ____	Please measure leaves only once at beginning of season.					
Tree Species: _____	Leaf 1	Leaf 2	Leaf 3	Leaf 4	Leaf 5	Leaf 6
Leaf Length (cm.)						
Leaf Width (cm.)						

Put a check mark in the correct column below to show Leaf Color and Leaf Drop

Leaf #	Fraction/ Percent of Leaf Color (not green)				Leaf Drop 0-not fallen 1- fallen
	0 - 25%	26 - 50%	51 - 75%	76 - 100%	
					
1					
2					
3					
4					
5					
6					
<b>Whole Tree</b>					N/A

<b>Total number of study leaves observed per branch</b> (fallen and not fallen)	
<b>Total number of leaves fallen</b>	

**Teacher note:** Remember that the branch total above must be added with branch totals from all branches on the same tree to get the total number of leaves dropped per tree to submit to Harvard Forest to post online.

**Optional Field Notes:**

Weather Notes:

Animal/ Plant notes:

# Climate Change

- ◆ Concurrent to the HFP, students did a variety of work related to climate change:
  - ◆ readings
  - ◆ virtual field trip
  - ◆ video
  - ◆ Northeastern Climate Change project.
- ◆ Goal for next year – to reduce amount of class time spent on Climate Change background.

# Virtual Field Trip

- <https://sites.google.com/site/vftclimatechange/Home>

Home Updated Sep 13, 2011 3:08 AM



## VFT - climate change

Search this site

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## Home

### Virtual Field Trip: Climate Change and the Effect on Populations.

Through this on-line activity, you will learn about climate change and the effect it has on population size and biodiversity. You should take brief notes on the readings and answer the questions on a separate piece of paper. Read the directions thoroughly before clicking on the link to visit the next website.

You can navigate through this site by using the links at the bottom of each page or through the side bar on the left.





# Video

- ◉ An Inconvenient Truth

From director Davis Guggenheim, *An Inconvenient Truth* is a passionate and inspirational look at former Vice President Al Gore's fervent crusade to halt global warming's deadly progress by exposing the myths and misconceptions that surround it. In this intimate portrait of Gore and his "travelling global warming show," Gore comes across as never before in the media - funny, engaging, open and intent on alerting citizens to this "planetary emergency" before it's too late.

Interspersed with the bracing facts and future predictions is the story of Gore's personal journey: from an idealistic college student who first saw a massive environmental crisis looming; to a young Senator facing a harrowing family tragedy that altered his perspective; to the man who almost became President but instead returned to the most important cause of his life. With an emphasis on hope, *An Inconvenient Truth* ultimately shows us that global warming is no longer a political issue but rather, the biggest moral challenge facing our civilization today.

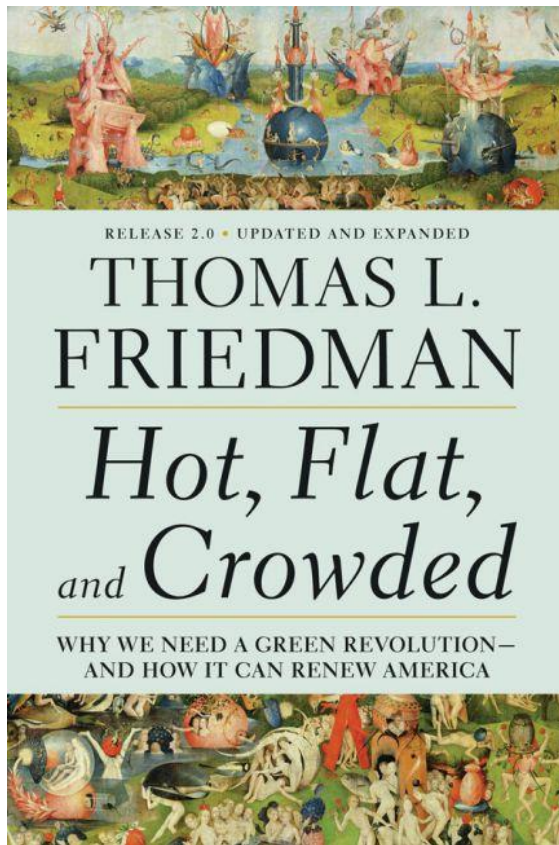
After having its U.S. debut at the 2006 Sundance Film Festival and international premiere at Cannes, *An Inconvenient Truth* opened to rave reviews and enthusiastic audiences everywhere. A smash hit, the film went on to win Academy Awards® for Best Documentary feature and Best Song. It also became a global phenomenon, one of the highest grossing documentaries of all time with a worldwide audience estimated at 5 million people.



Background Reading:

Book excerpt:

the chapter *Global Weirding* from the book  
Hot, Flat, and Crowded by Thomas L. Friedman



“Doesn't Al Gore  
owe us all a big  
apology?”

p147

# Global Weirding

“After listening to Gore’s compelling argument, I humbly suggested that he write an op-ed piece that would begin like this:

*‘I’m sorry. I am truly sorry. I want to apologize. I completely underestimated global warming. I beg your forgiveness.’”*

p149

# Confronting Climate Change in the U.S. Northeast



## SCIENCE, IMPACTS, AND SOLUTIONS

Prepared by the Northeast Climate Impacts  
Assessment Synthesis Team.

Peter C. Frumhoff

James J. McCarthy

Jerry M. Melillo

Susanne C. Moser

Donald J. Wuebbles

JULY 2007

*A report of the Northeast Climate Impacts Assessment*

HFP  
Resource

# Northeast U.S. Climate Change Project

## Instructions – Presentation on Predicted Local Effects of Climate Change

Question: What are some predictions for how climate change will affect our area?

Main Source: Confronting Climate Change in the U.S. Northeast report. *Please cite any other sources that you use.*

*Work in groups of 2 on a visual presentation (poster or powerpoint) to the class. Your presentation should consist of illustrations/ pictures/ photos/ drawings as well as written points – however, be careful not to fill up your space with paragraphs!*

# Northeast U.S. Climate Change Project

- *Chapter One: Our Changing Northeast Climate*
- *Chapter Two: Coastal Flooding*
- *Chapter Three: Marine Life*
- *Chapter Four: Impacts on Forests*
- *Chapter Five: Impacts on Agriculture*
- *Chapter Seven: Impacts on Human Health*



# Northeast Coastal Flooding

By Cody T. and Sarah K.

# Causes of Coastal Flooding

- \* Direct Cause of Coastal Flooding
  - Intensity of Tropical Storms on the east coast.
  - Frequency in Tropical Storms on average.

# Causes of Coastal Flooding

## Causes of Intensity and Frequency of the Tropical Storms

- Global Warming in water
- allows the water to heat up the storms and feed them energy

# Areas that can be affected

What could Boston ,  
New York City, and  
Atlantic City  
expect in the  
future?

- a coastal flood equivalent to today's 100-year flood every two to four years on average by mid-century
- almost annually by the end of the century.



# Boston flooding

- \* this image shows how the 100-year can cover the city of Boston.
- \* Left bottom show the landmarks that will be covered in water from the flood.



# What affects on infrastructures?

- \* Transportation: T-tunnel entrance is not flood-proof
- \* cost the city roughly \$75million to recover.



# What affects on infrastructures?

- \* A 100-year coastal flood in Boston near the end of this century has the potential to create conditions where sewer lines back up and overflow and storm water drainage is impeded



# What will the results be?

- \* The physical result will be that more and more land sinks.
- \* EVENTUALLY
  - The Northeast cities are densely populated.
  - Flooding in these areas - devastating
  - Cause an “emergency response” (like Katrina)







# Sources

<http://www.wunderground.com/resources/education/gore.asp>

<http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf>

[http://media.sacbee.com/static/weblogs/photos/images/2010/aug10/katrina\\_five\\_sm/katrina\\_five\\_13.jpg](http://media.sacbee.com/static/weblogs/photos/images/2010/aug10/katrina_five_sm/katrina_five_13.jpg)

[http://www.visualfuturist.com/orleans/art/katrina\\_flooded.jpg](http://www.visualfuturist.com/orleans/art/katrina_flooded.jpg)

# Data Collection Results

- What worked well:
  - Going out about once a week.
  - As a class, we entered in our data into the spreadsheet via infocus projector.





# Fall Data 11-12

## Harvard LTER Schoolyard - Fall Phenology 2011-2012

**School Name:** Brookline High School, MA BRH  
**Teacher Name:** Jasmine Juo (Jennifer)  
**Grade Number:** 11th-12th grade  
**Class Name:** Biology 2 Honor  
**Site Description:** Brookline High School Campus

School	Teacher	Date	Julian Day	TreelD	Species	Ltotal	Lfallen	Tcolor
BRH	Juo	13-Sep	256	1	BW	6	0	1
BRH	Juo	13-Sep	256	2	RM	12	0	1
BRH	Juo	13-Sep	256	3	PO	12	0	1
BRH	Juo	13-Sep	256	4	RE	12	0	1
BRH	Juo	28-Sep	271	1	BW	6	0	1
BRH	Juo	28-Sep	271	2	RM	12	0	1
BRH	Juo	28-Sep	271	3	PO	12	0	1
BRH	Juo	28-Sep	271	4	RE	12	0	1
BRH	Juo	7-Oct	280	1	BW	6	0	1
BRH	Juo	7-Oct	280	2	RM	12	0	1
BRH	Juo	7-Oct	280	3	PO	12	0	1
BRH	Juo	7-Oct	280	4	RE	12	0	1
BRH	Juo	17-Oct	290	1	BW	6	0	1
BRH	Juo	17-Oct	290	2	RM	12	0	2
BRH	Juo	17-Oct	290	3	PO	12	0	1
BRH	Juo	17-Oct	290	4	RE	12	0	2
BRH	Juo	25-Oct	298	1	BW	6	0	1
BRH	Juo	25-Oct	298	2	RM	12	0 - branch A removed	1
BRH	Juo	25-Oct	298	3	PO	12	0	2
BRH	Juo	25-Oct	298	4	RE	12	0	2
BRH	Juo	31-Oct	304	1	BW	6	0	1
BRH	Juo	31-Oct	304	2	RM	12	0	1
BRH	Juo	31-Oct	304	3	PO	12	0	3
BRH	Juo	31-Oct	304	4	RE	12	0	2
BRH	Juo	7-Nov	311	1	BW	6	0	1
BRH	Juo	7-Nov	311	2	RM	12	0	2
BRH	Juo	7-Nov	311	3	PO	12	0	4
BRH	Juo	7-Nov	311	4	RE	12	0	4
BRH	Juo	15-Nov	319	1	BW	6	6	4
BRH	Juo	15-Nov	319	2	RM	12	6	3
BRH	Juo	15-Nov	319	3	PO	12	3	4
BRH	Juo	15-Nov	319	4	RE	12	12	4
BRH	Juo	28-Nov	332	1	BW	6	6	4
BRH	Juo	28-Nov	332	2	RM	12	6	4
BRH	Juo	28-Nov	332	3	PO	12	12	4
BRH	Juo	28-Nov	332	4	RE	12	12	4

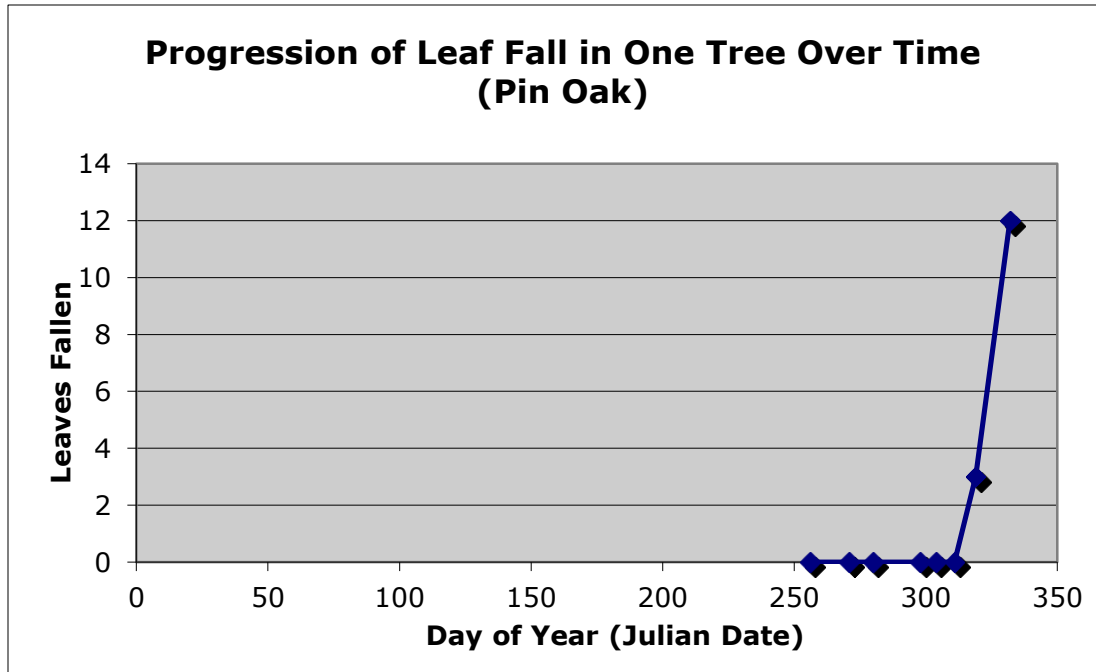
# Data Collection Results

- Room for improvement:
  - Practice with real branches first.
  - Take the time to label the flagging tapes before going out.
  - Double check their identification of the trees early on.



# Data Analysis - Graphing

- For our first attempt (Fall Data):
  - ▣ Work in pairs, explore MS Excel graphing
  - ▣ ARM data – step-by-step demo first



S Greenfield

# Data Analysis - Graphing

- For further graphing exercises, I plan to:
  - Use the MS Excel version(s) on the school laptops to write instructions with screen-shots.
  - Set aside more time to teach graphing in Excel.
  - Survey next year's students about Excel graphing ability and make groups accordingly.



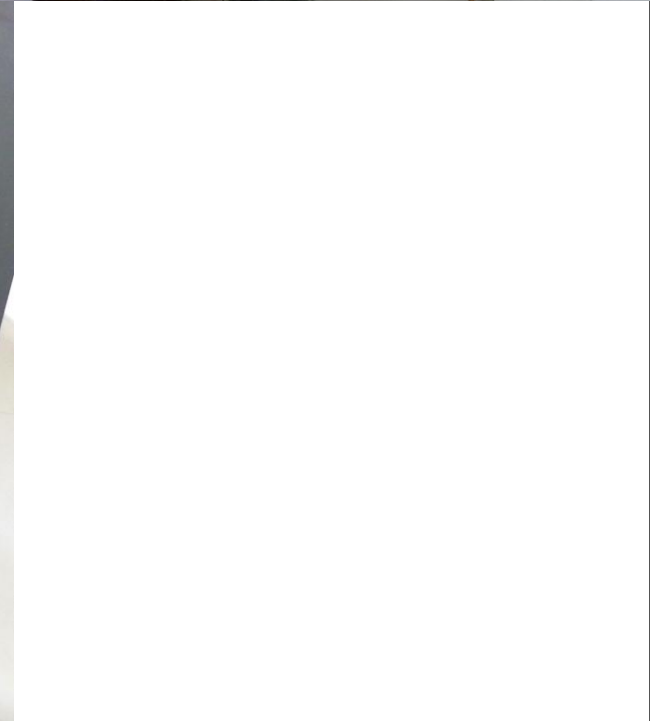


# Spring Data Collection

Budburst & Leaf Out

# Bud Burst Activity

- Interesting bud burst results





# Spring Data Collection

Opportunity to:

- choose “better” branches/ replace a “lost” branch.
- learn about leaf buds vs. flower buds.



# Product: Climate Change Paper

- Students are required to write a research paper based on the Buds project.
- The paper is written in sections over the year.

# Additional changes to consider:

How to better integrate the Buds project into the Bio 2 H curriculum?

- **Animal Behavior** – migration
- **Infectious Disease** – vectors (mosquitos)
- **Molecular Genetics** – control of budburst? Leaf development?