Mathematics

The Plantwatch program engages students as active participants in the collection and analysis of scientific data. It provides an opportunity for students to practice using their observation skills and to make accurate records, as well as to report findings in a scientific manner. Scientists must be able to portray their information in graphs that are easy for others to understand. The skills listed below all involve mathematics and are transferrable to other fields of study.

Skills Used in Plantwatch:

- measuring temperature
- addition
- subtraction
- division
- graphing
- calculating averages
- linear measurement
- data management
- latitude and longitude calculations

overview:

After being exposed to a certain amount of heat, a spring wildflower will bloom. The concept of growing degree summation (GDS) provides a way to add up how much warmth, or how many heat units, a plant has been exposed to as winter changes to spring and temperatures increase. Some people refer to these units as "growing degree-days." Although growth in wild plants probably begins as soon as temperatures are above zero, we will use 5°C as a base temperature (the minimum temperature at which growth starts)[1]. This temperature is the standard used in agriculture.

MATHEMATICS
activity one

EYEWIRE

Growing Degree Summation (GDS)

skills

Addition, division, graphing, use of Centigrade temperature scale

materials

daily newspaper with temperature records, if available

graph paper

calculator (optional)

preparation

Review this activity (Mathematics Activity 1, *Growing Degree Summation*)

explore/investigate

1. Calculate the growing degree summation (GDS) for a spring day. This can be done using temperatures published in a local newspaper, and some simple math.

   Graph average daily temperatures to see how temperatures fluctuate over a short period of time (i.e. week, month).

   See the following page for Background Information.

2. Calculate the accumulated GDS for the first bloom of your observed plants. Use your daily GDS calculations from #1 above, to determine accumulated GDS.

   See page the following page for Background Information.

[1] Note: The calculation is done using Centigrade degrees.

ALL WORDS HIGHLIGHTED IN BLUE CAN BE FOUND IN THE GLOSSARY (APPENDIX 1).

background information

How to calculate GDS for a spring day

In your area, determine in which spring month the daily high temperatures generally start to exceed 10°C. Start your daily calculations on the first of that month. If you are observing plants in a city, the daily high and low temperatures are generally published in daily newspapers. Use the confirmed temperatures listed for the previous day.

Determine the daily average (mean) temperature in a location by adding the daytime high (usually occurs in day) and the daytime low temperature (occurs at night) and dividing by 2. Then subtract 5 degrees to determine the GDS (heat units) for that day. If the weather was cool and the average temperature was less than 5°C, then that day had no GDS and does not count in your GDS calculations. (Do not add a negative GDS in your calculations; simply count these as zero GDS.)

Example

High or maximum temperature	15°C
Low or minimum temperature	3°C
Average temperature	15°C + 3°C = 18°C ÷ 2 = 9°C
Degree summation above 5°C	9°C- 5°C = 4 GDS on this date

The daily average temperatures can be graphed as in the graph of invented data on the bottom of this page. Note that on May 9 and May 21 the average temperature was below zero.

Calculate the accumulated GDS for first bloom of your observed plant(s):

The accumulated GDS will tell students how much heat it takes that year for a particular plant to flower.

Example

If there were 70 GDS for the location charted below up to May 1, and the plant first flowered on the evening of May 3, what was the total GDS (heat units) needed for first flowering?

Answer:	GDS
heat units from days before May 1 (i.e., April):	70
plus GDS above 5°C on May 1:	5
plus GDS above 5°C on May 2:	4
plus GDS above 5°C on May 3:	7
Total GDS:	**86**

Question: The plant was in full bloom late on May 7th. What was the total GDS needed to reach full flowering?

Growing degree-days for the month of May

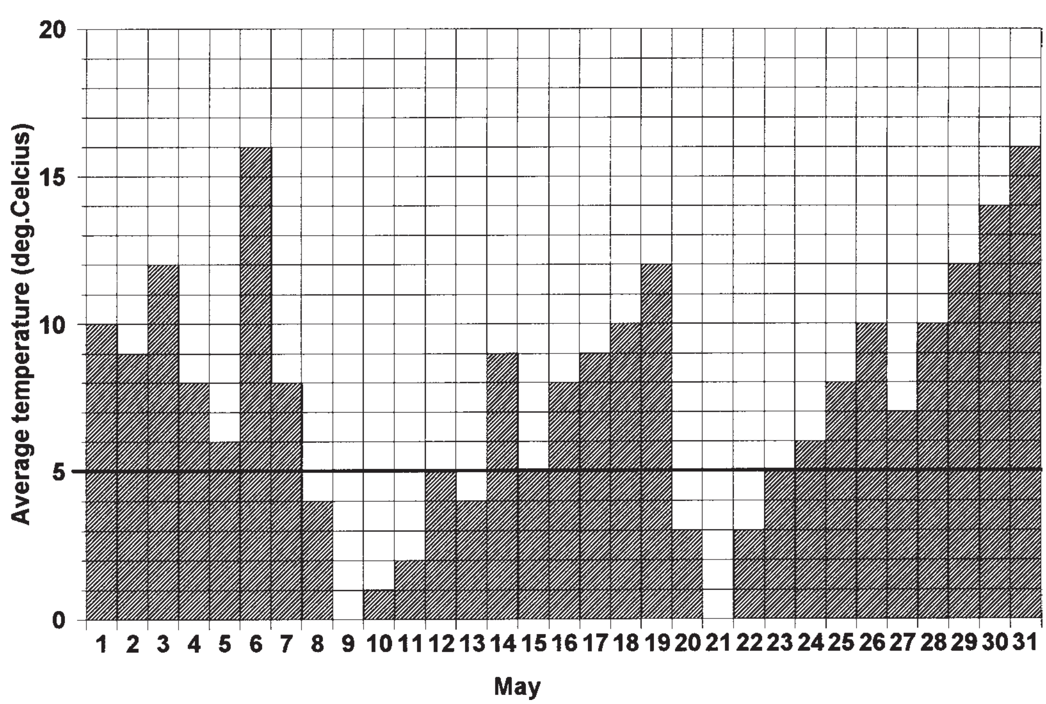
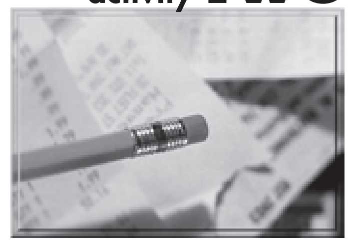


Fig. 4
A sample chart of average daily temperatures in a month

overview:

To get a good idea of this year's bloom times in your area, it is best to observe several plants of your selected species. Bloom times vary between individual plants, and it is most accurate to report an average or mean of these flowering dates. In this exercise you can create a Julian calendar and use the Julian dates to easily average your dates. Report this average to Plantwatch!

MATHEMATICS
activity **two**



DYNAMIC GRAPHICS

Calculating Averages

skills

Addition, Division

materials

Paper/pencils or computer with a spreadsheet program

explore/investigate

1. Calculate an average first flowering date for plants that all flowered during one month.
2. Calculate the average date of a flowering stage (for example, first flowering) for plants, using a Julian calendar.
3. Report your calculations when you send Plantwatch your results!

   When reporting bloom dates, students should put the average date of the same plant species under the *Comments* section on the Data Form (e.g.,"The average date of flowering for our five lilacs was May 31.")

background information

Calculate an average flowering date...

1. **For plants that all flower during one month**

   If the observed plants all flower during one month, your students can find an average using the days of the month. For example, supposing there are five "first flowering" dates in May.

   The calculation is done as follows:

   May (15+16+16+17+19) / 5 = 16.6.

   This number is rounded off and May 17 is reported as the average first flowering date.

2. **Using a Julian calendar**

   To easily calculate the average date of a flowering stage (for example, first flowering) for plants, the **Julian calendar** is often used. Have your students create their own Julian calendar for this year.

   In the Julian calendar, each day of the year has a number, starting as follows:

   January 1 =Julian day 1

   February 1= day 32

   March 1= day 60

   December 31= day 365

   This way of calculating dates is very useful when the dates to be averaged span two months. For example, April 29, May 2 and May 3 converted to Julian dates make averaging a simple mathematical problem. In a leap year (e.g., 1996, 2000, 2004), when we have an extra day, February 29, you need to alter the calendar so that March 1= day 61, and so on, up to December 31= day 366.

   Determine the Julian day for each of your plants' first flowering date that you recorded. Find the average of these numbers by adding them together and dividing by the number of dates added. Refer back to your Julian calendar to determine the month and day of this average Julian date.

Example: If the class observed five common purple lilacs in the year 2000 (a leap year), with first flowering dates of May 28, 30 and 31, and June 2, then the Julian day calculation would be as follows:

May 28 = Julian day 149

May 30 = Julian day 151

May 31 = Julian day 152

June 2 = Julian day 154

June 2 = Julian day 154

Total of Julian dates: (149 + 151 + 151 + 154 + 154) = 760 divided by 5 days = day 152. Therefore, May 31 is the average first flowering date for these five common purple lilac shrubs.

overview:

Use your own data or Plantwatch data posted on the Internet to produce graphs and maps of temperatures and bloom dates. Interpret graphs of bloom data from Nova Scotia, Canada, and Sucany, Slovakia.

MATHEMATICS
activity **three**

EYEWIRE

Graphing and Mapping

skills

- **Data management (students find Plantwatch and weather data on the web, and organize and map data)**
- **Graphing (students interpret provided graphs, or graphs and maps on the web)**

materials

graph paper or computer, Internet access

explore/investigate

1. Make your own graphs and maps (see page 3-32)
2. Interpreting graphs (see page 3-33)
3. Reading a graph (see page 3-34)

1. Make your own graphs and maps

A. **Growing degree summation** — See Mathematics Activity 1 (page 3-27) which includes graphing average daily temperatures.

B. **Flowering dates** — For each Plantwatch species that your students observed create a graph with calendar date and Julian date (see Mathematics Activity 2, page 3-29) on the x axis and plant number on the y axis. You can graph both first and full bloom on the same graph by using different symbols.

C. **Temperatures** — Chart the daily high and low temperatures and calculate the mean temperature.

D. **Use data on the Plantwatch website** — Have students look up the Plantwatch Internet web page. Check under *See your dates here!* for this year's flowering dates, and *Archives* for previous years' data. For each plant species, the data tables list first and full bloom dates, observer name, and observation location (province or state and latitude/longitude). Have your students do the following exercises:

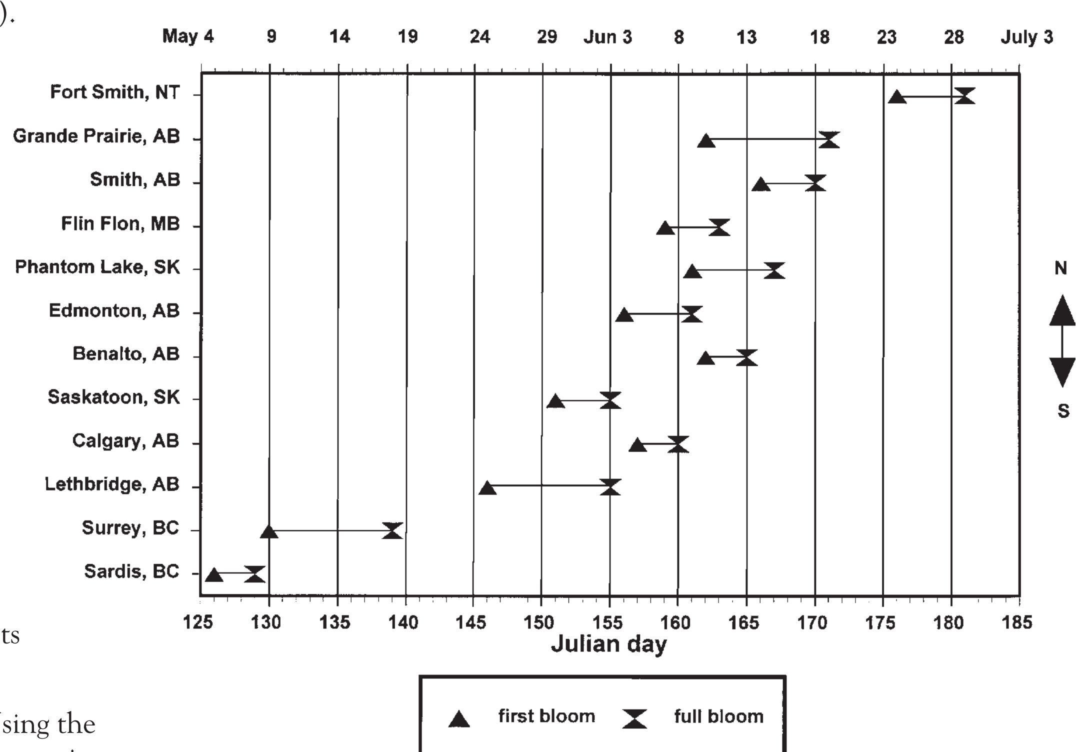
Exercise (i) — Select a plant species, and a bloom stage (first, or full bloom) and using the location information, plot the most recent year's observations as dots on a map.

Exercise (ii) — Using the archived data from previous years, map all available data for your selected plant for your area. Consult the federal weather office website/homepage to see if an early or late spring is predicted for next year. Make a prediction of bloom times for next spring.

Exercise (iii) — Have your students try this exercise using recent data from the Plantwatch website. The following is an example of how flowering dates can be graphed from north to south to see the influence of latitude. This data is from the Plantwatch program, 1996, for common purple lilac. If many dates were received for some areas, a mean date was calculated for graphing. Why might it be that northern areas sometimes have earlier bloom than areas farther south? (Consider the effects of altitude/weather patterns.)

Compare temperature records by seeing the 1961-1990 Canadian climate normals [www.cmc.ec.gc.ca/climate/] for two cities in your province or territory.

Fig. 5 **First and full bloom dates of Common Purple Lilac <u>(Syringa vulgaris)</u> for Western Canada**



based on 1996 Plantwatch data (February 4, 1997)
Devonian Botanic Garden, University of Alberta

2. Interpret Graphs

Nova Scotia student phenology reports, 1910-1923 (an Internet activity)

A. Environment Canada's Ecological Monitoring and Assessment Network (EMAN) has posted a fascinating database of phenology information from eastern Canada in the first quarter of this century. Alexander H. MacKay was secretary for the Botanical Club of Canada, as well as superintendent of Education for Nova Scotia. He coordinated a phenology survey for that province from 1891-1927. Students and teachers recorded the dates when the flowers of many native and cultivated plants were first seen and becoming common. The information for most of the survey including graphs and animations of the "flowering wave" has been posted on the EMAN site. Many of the plants that were surveyed in this early Nova Scotia study are now also used by Plantwatch!

Exercise (i)

- Find the website: www.cciw.ca/MacKay/
- Look at the MacKay data. Select *Common names* to access it.
- Select a base map. Use Nova Scotia (whole province).
- *First seen* means that the first flowering of this plant was observed on the listed date. *Commonly seen* means the flowering of this plant was becoming common on the listed date.

  Select *Use first seen* selector.
- **Select the following, one by one:**
  - *Trembling Aspen*, same as our aspen poplar (*Populus tremuloides*)
  - *Lilac*, same as our common purple lilac (*Syringa vulgaris*)
  - *Wild Pear*, same as our saskatoon or serviceberry (*Amelanchier* spp.)
- See the variability in each data set by clicking *Draw a graph.*
- Use the graphs to answer the following question:

Which shows more variability in flowering time (the difference between the earliest and latest flowering date recorded) between years, lilac or wild pear?

Answer: First seen lilac ranges from Julian day 100 in 1906, to day 213 in 1918 (113 days difference), but *first seen* wild pear ranges only from day 102 in 1911, to day 188 in 1923 (86 days difference). Therefore, the lilac shows more variability in flowering time between years than the wild pear.

Exercise (ii)

Use the map to study how the flowering wave moves across Nova Scotia. Select wild pear to study, and the year 1918, day 90 to 200. The map will appear and show an animation of flowering occurring over the weeks of spring. Note that the animation repeats itself.

- Look at the time chart at the map bottom to answer the following questions:

  a) In what part of which month did most wild pear flowering occur in 1918?

  Answer: Mid-May to the end of May

  b) Where does wild pear flowering start, near the south end (Yarmouth area) or the north end (Cape Breton) of Nova Scotia? Does flowering occur first inland, or on the coast? Why might this pattern occur?

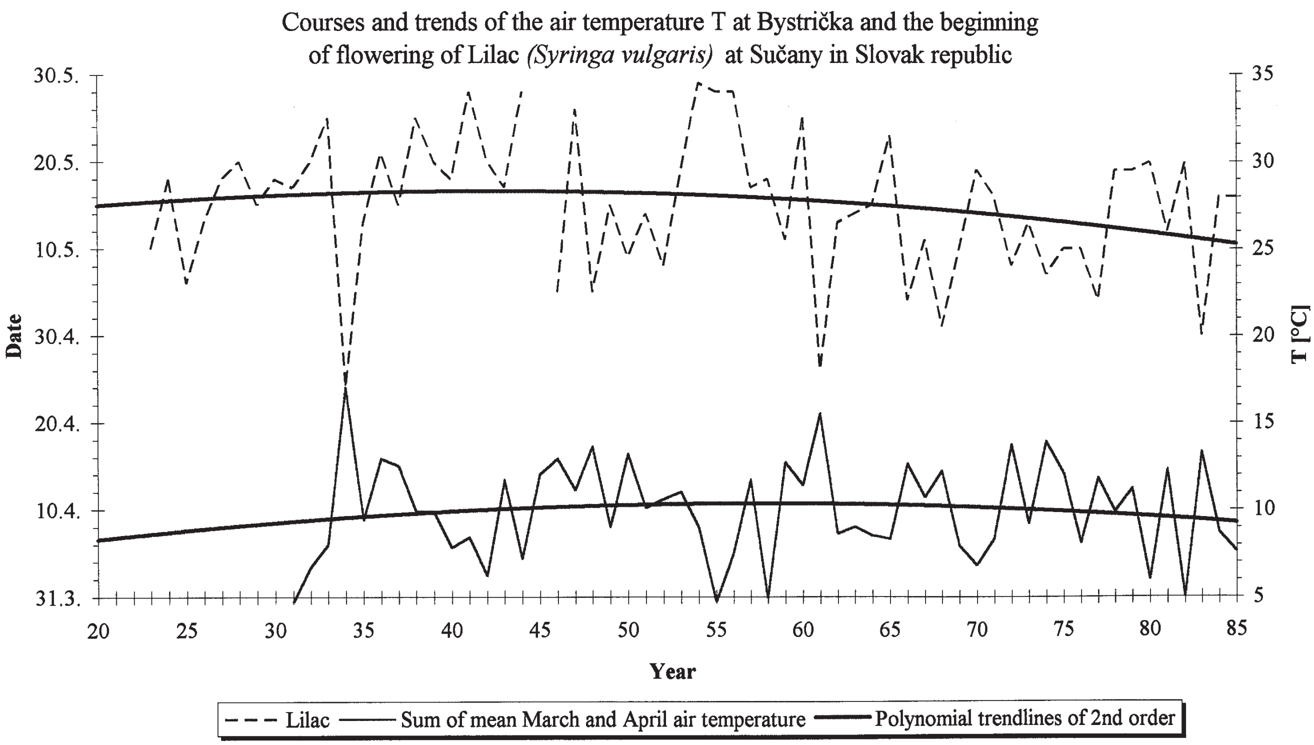
  Answers: Flowering seems to start inland in the south near Yarmouth, moving north and to coastal areas.

  Possible reasons are as follows:
  Southern areas generally warm up earlier than more northerly ones. Coastal areas are likely to receive less sun in spring because fog is created where warm air rides over the cold Labrador Current water. Off Yarmouth, there is an inflow of warm Gulf Stream water and therefore less fog. Also, ocean currents may affect certain coasts more than others.

3. Reading a Graph

Lilac flowering dates in Slovakia

Flowering in shrubs and trees occurs in response to the air temperatures at the height of their branches. Many countries in Europe have a long history of recording the timing of plant development, with several centuries of data. The following graph of lilac flowering times and temperature was kindly provided by Dr. Olga Braslavska, phenologist for the Slovak Hydrometeorological Institute. (In Canada, we have several phenology data sets going back to the 1890s.)



Explanation of the Graph

The x axis (horizontal axis at bottom) shows the years from 1920 to 1985.
The y axis (vertical line on left of graph) shows the flowering date for common purple lilac (note that 20.4 means the 20th day of the 4th month = April 20th, and 10.5 means May 10th).
The y axis on the right shows the temperature, in degrees Centigrade.
The dotted line shows the annual date when first flowering occurred for common purple lilac in the town of Sucany in Slovakia.
The solid line shows the temperature in degrees Centigrade, calculated as the sum of the mean March and April temperatures.

Questions to ask students:

1. What were the two earliest flowering years?
2. What was the latest flowering year?
3. In these years were the temperatures unusually low or high?
4. How much variation is there between the earliest flowering date and the latest, on this graph?
5. How much does the temperature vary? (Notice that there are fewer years of temperature data.)
6. Does there appear to be a trend over time in the flowering data?
7. Is flowering getting earlier or later? Why might this change be occurring?

Answers:

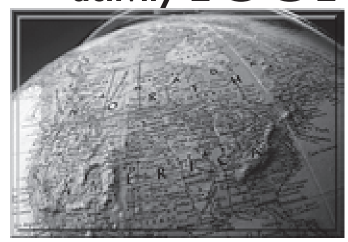
NOTE: If answers are not to appear on student handouts, please cover Answer area before photocopying.

1. *1934 and 1961 are the two earliest flowering years*
2. *1954 is the latest flowering year*
3. *Warmer temperatures match earlier flowering dates*
4. *About 34 days*
5. *The spring temperature (sum of the mean air temperatures for March and April) varies by about 13˚C*
6. *There is a slight trend to earlier bloom since the 1950s. A temperature trend is not so evident.*
7. *Flowering of lilac in Sucany is getting earlier. This change is most likely due to an increase over time in the air temperature before flowering. There is also a global trend to higher temperatures.*

If you want to see more graphs showing trends in flowering times, see the phenology website: <http://www.dow.wau.nl/msa/epn/trends/> for changes seen internationally.

MATHEMATICS

activity **four**

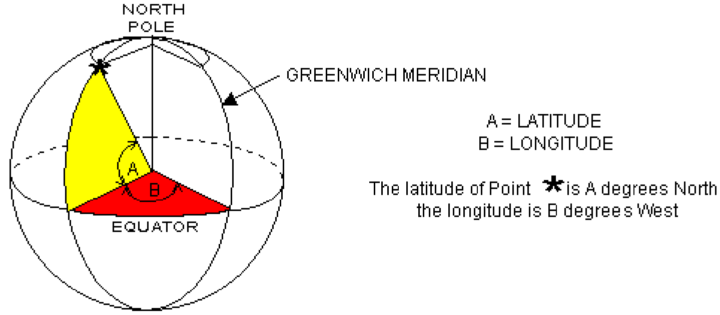


EYEWIRE

Latitude and Longitude:
How to Calculate Your Global Address

In order to use your students' flowering dates, Plantwatch research scientists need to know the location of all the Plantwatch plants in latitude and longitude. If all the plants are within 5 km (3 mi.) and 50 m elevation of one another, one location can be reported for all your students' observations. Using a GPS (Global Positioning System) instrument to determine the location of the plants is a quick method of getting a location.

The following introductory exercise will help your students use a map to determine the precise location of their plants and convert their location in degrees and minutes to decimal form, the form most useful to Plantwatch scientists. This straightforward exercise, which takes 15-30 minutes to complete, is an excellent way to introduce the concepts of latitude and longitude to your students. If you and your students cannot determine the latitude and longitude of the plants, feel free to e-mail us for assistance (plant@ualberta.ca).

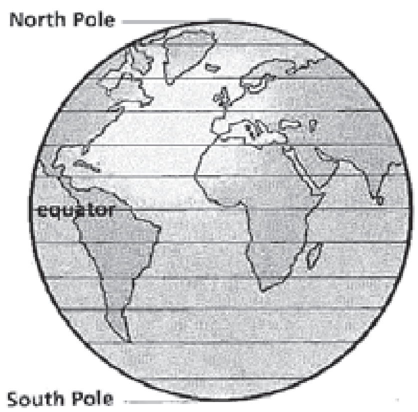


Introduction: What is Latitude and Longitude?

A simple activity, using an orange to represent the Earth, is available at Orange Globe <http://octopus.gma.org/space1/orange.html>.

In the same way that a street and an avenue specify a particular intersection in a city or town, latitude and longitude can be used as grid coordinates to locate any point on Earth. By using degrees and minutes of latitude and longitude, your students can describe the location of their plants within about 1.5 kilometres, or about 1 mile.

LATITUDE



Latitude is the distance north or south of the equator. Latitude lines run east and west along the surface of the earth.

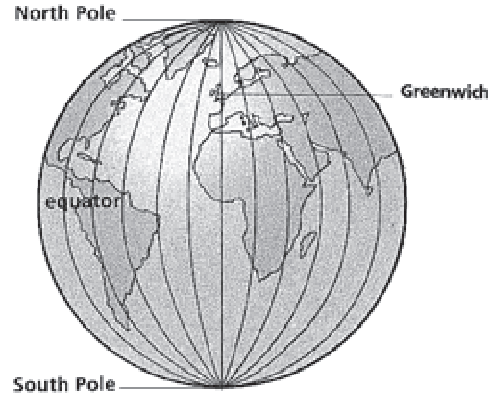
The latitude of a location is expressed as a degree of the angle (A) formed at the centre of the earth by two lines, one drawn from the equator to the earth's centre, and the other drawn from the location to the earth's centre. Thus any point on the equator has a latitude of 0°, and the Poles are at 90 degrees north and south.

Each degree of latitude (also longitude) is divided into 60 equal parts called minutes, and each minute can be further divided into 60 seconds. For Plantwatch, only accuracy to minutes is necessary.

On the surface of earth, one degree of latitude is about 110 kilometers (68 miles). However, because the earth is not quite a perfect sphere, the distances get slightly greater toward the poles, where there is a slight flattening.

LONGITUDE

Longitude lines run north and south along the surface of the earth.



The earth is divided into two parts, or hemispheres, of east and west longitude. Each hemisphere has 180 degrees. The universal standard is to start counting longitude east and west from an imaginary line running through Greenwich (pronounced "gren-itch"), a suburb of London, which is assigned a longitude of 0 degrees.

Mapmakers think of the earth as a huge globe that is divided into 360 equal slices (180 west and 180 east of Greenwich). The lines of longitude between the slices on the outside of the globe are called meridians.

So, meridians are the main lines of longitude on maps. North, South and Central America have longitudes described as west of Greenwich, whereas most of Europe, Russia, India and China are east of Greenwich.

The space between two meridians is greatest at the equator — about 110 kilometers (68 miles). This space narrows as the meridians approach the North and South poles. For example, a degree of longitude at New Orleans, Louisiana, U.S.A., is about 97 kilometers (60 miles) wide, whereas at Winnipeg, Manitoba, Canada, which lies nearer the North Pole, a degree of longitude is less than 72 kilometers (45 miles) wide.

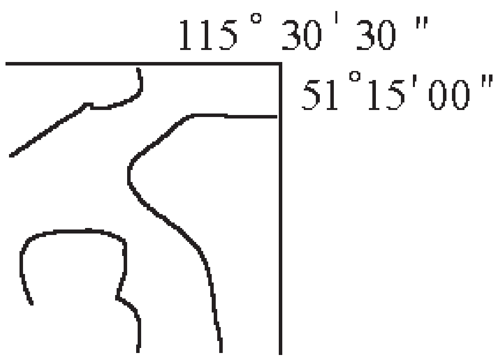
Finding the Latitude and Longitude of a Particular Place

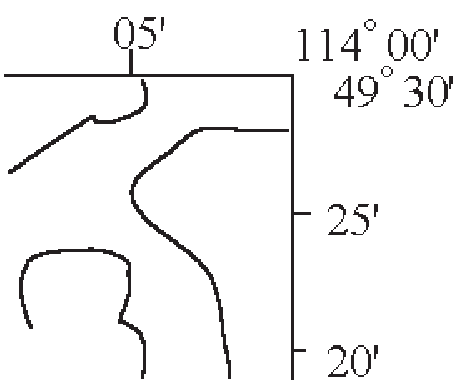
To complete this part of the exercise, your students will need to obtain a detailed map that has latitude and longitude in both degrees and minutes. On a small-scale map (like those found in many atlases, where the scale may be 1:1,000,000), which covers a large area of the Northern Hemisphere, too much detail is lost to provide enough accuracy for this work.

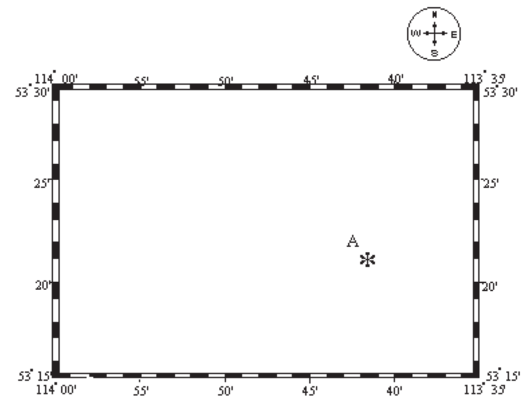
1:50,000 or 1:100,000 maps are available from provincial or federal map offices and private map retailers. See Appendix 2 (Appendix, page 4-6) for the website to locate these offices and businesses. Most universities also maintain an extensive map library.

1. **Have your students see what is already marked on their maps:**

   - On many maps you will find the latitude and longitude in the margin at each corner (see below).
   - These grid coordinates are marked in degrees, minutes and seconds. For instance, a corner may be marked 115° 30' 30" and 51° 15' 00"
   - The figures at the top of the map corner represent longitude (115° 30' 30").
   - The figures below the longitude give the latitude (51°15' 00")
   - If you have a 1:50,000 scale map, your students will probably find points along the border marked in minutes, as illustrated here.
   - The border of the map may look like the map shown below.







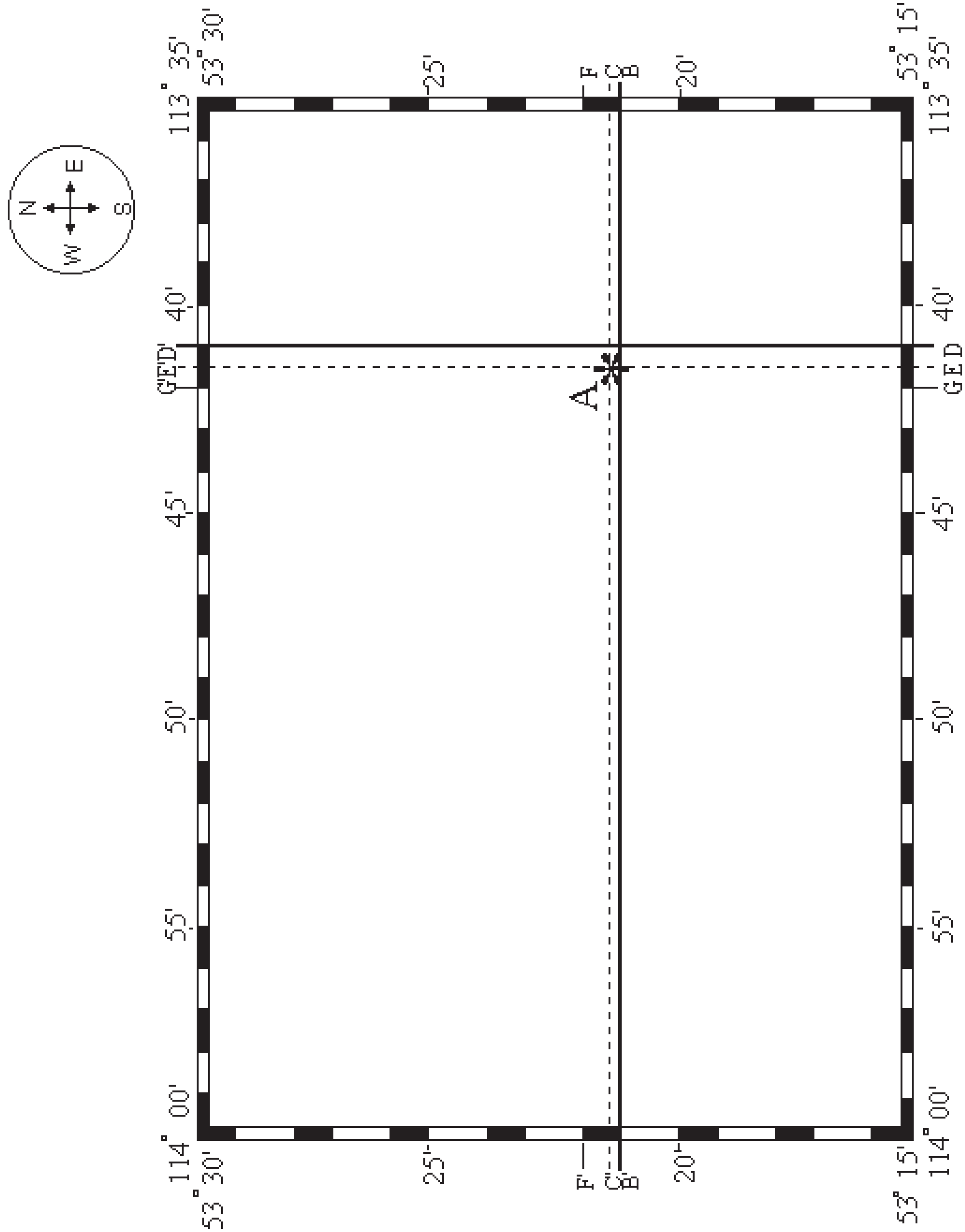
   - Latitude and longitude lines might not exist across your map – if not, have your students put a straight edge across the map and lightly pencil straight lines between the matching border marks (see dotted line within figure on page 3-37).
   - Please remember that

     1 degree = 60 minutes
     1 minute = 60 seconds

     Please note: we made an error in creating this figure: the minutes of latitude should be the same size, i.e., the black and white bars on the sides should be equal lengths. For instance, the bar size for the 19th minute (black bar) should really be the same length as the 20th minute (white bar). Apologies!

2. **Photocopy the following pages for students. Then, using the figure and instructions on the following pages, have your students complete the latitude and longitude exercise.**

   In the right hand column of the instructions page have your students input the measurements from their own maps. Using a 1:50,000 scale map is recommended – on a map of this scale, students will be able to locate their plants precisely.


N
E
S
W
113° 35'
53° 30'
25'
F
C
B
20'
53° 15'
113° 35'
40'
G'E'D'
GED
A
45'
50'
55'
114° 00'
53° 30'
25'
F'
C'
B'
20'
53° 15'
114° 00'

P.S. This exercise looks scary, but it's really easy!

	IDENTIFYING LATITUDE for Northern and Western hemispheres	EXAMPLE	INPUT YOUR VALUES HERE
1.	Locate your plant's position on your map and mark it with an asterisk (* — point A on the example map). Draw a horizontal line through this point, parallel to the nearest line of latitude (line C→C' on the example map).	Point A Line C→C'	
2.	Find the nearest latitude point above (north) or below (south) of point C (= point B on the example map)	Point B	
3.	Join B to the same latitude point on the other side of the map (line B-B' on the example map) by drawing a straight line between. On a large map, use a metre stick or a straight edge. Read the latitude of this line in degrees and minutes and note it in the box to the right. Note: (N) means latitude north of the equator. Please remember to tell us if you are North or South of the equator by specifying N or S (all North America is N).	Line B'-B is 53˚ 21' N	____________ ° _______ ' N
4.	Convert the latitude in degrees and minutes to decimal form (see next page). Put the exact latitude of POINT A in decimal form to the nearest minute in the box to the right.	53˚ 21'= 53 + 21/60 = 53 + 0.35 = 53.35	____________ °

	IDENTIFYING LONGITUDE for Northern and Western hemispheres	EXAMPLE	INPUT YOUR VALUES HERE
1.	Find your plant's position on the map and mark it with an asterisk (* — point A on the example map). Draw a vertical line through A and parallel to the nearest line of longitude (line E→E' on the example map).	Point A Line E→E'	
2.	Find the nearest longitude point to the right (east) or to the left (west) of your line (E-E' on the example map). On this map, G or D at the bottom of the map are equally close, so we select D.	Point D	
3.	Join D to the same longitude point D' on the other side of the map. Read this longitude in degrees and minutes and note it in the box to the right. Please remember to tell us if you are in the Western or Eastern hemisphere by specifying W or E (all North America is W).	Line D'-D is 113˚ 41' W	____________ ° _______ ' W
4.	Convert the longitude in degrees and minutes to decimal form (see next page). Put the exact longitude of POINT A, in decimal form, in the box to the right.	113˚ 41' = 113 + 41/60 = 113 + 0.6833 = 113.68˚	____________ °

3. To Check Calculations

There are many references and websites where students may be able to find their locations in degrees and minutes (seconds are usually specified as zero), which is sufficiently accurate for Plantwatch (knowing the location to the nearest minute pinpoints it to a 1.8 x 1.2 km [1.1 x 0.75 miles] area).

Try some of the following websites to check your students' calculations.

- Query Canadian Geographical Names -- search tool provided by Natural Resources Canada

  http://GeoNames.NRCan.gc.ca/english/cgndb.html

  When you get the results of the search, click on the name of place you need to see more information including latitude and longitude.

- The look-up table at

  www.bcca.org/misc/qiblih/latlong.html

  gives latitude and longitude in degrees and minutes of various major cities in

  Canada:
  www.bcca.org/misc/qiblih/latlong_ca.html

  U.S.A.:
  www.bcca.org/misc/qiblih/latlong_us.html

  Other countries:
  www.bcca.org/misc/qiblih/latlong_oc.html

- Students can type the name of their town/city at the following web site to get location information:

  www.astro.ch/atlas/atlquest-eng.html

Congratulations!

Students now can send Plantwatch research scientists their plant locations. They can use the location form on the webpage or put the information on the flowering data sheet (when they are ready to send in their flowering dates).

To convert degrees and minutes to the decimal form

Plantwatch can most easily use your latitude and longitude if it is in decimal form (to two decimal places). To obtain a decimal version of degrees and minutes, you have to convert the minutes, which are normally expressed as a fraction of one degree, into a decimal, and add this figure to the number of degrees. In one degree there are 60 minutes.

Example (using latitude only):

1. Start with degrees and minutes
   53° 21'
2. Divide the minutes by 60
   21 / 60 = 0.35
3. Add decimal minutes to degrees
   53 + 0.35 = 53.35 degrees N latitude

Example

The University of Alberta Devonian Botanic Garden is located about 30 km southwest of the city of Edmonton, Alberta, Canada at 53° 21' N latitude.

1. Start with	2. Convert to decimal form	
53 degrees		= 53.00 degrees
21 minutes	= 21 minutes ÷ 60 minutes	+ 0.35 degrees
N latitude		= 53.35 degrees N latitude

Now, lets do the same for your location

LATITUDE

1. Start with	2. Convert to decimal form	
__________degrees		= ___________degrees
__________minutes	= ______ minutes ÷ 60 minutes	+ ___________degrees
__________latitude[1]		= ___________degrees _____ latitude

LONGITUDE

1. Start with	2. Convert to decimal form	
__________degrees		= ___________degrees
__________minutes	= ______ minutes ÷ 60 minutes	+ ___________degrees
__________longitude[2]		= ___________degrees _____ longitude

[1] Please specify, for the latitude: **N**, if the location is north of the Equator; **S**, if the location is south of the Equator.

[2] Please specify, for the longitude: **E**, if the location is within 180° east of Greenwich; **W**, if the location is within 180° west of Greenwich.