Background information

Phenology is the study of living organisms' response to seasonal and climatic changes in their environment. Seasonal changes include variations in day length or duration of sunlight, precipitation, temperature and other life-controlling factors.

It is the study of recurring biological cycles and their connection to climate. For example, annual bird migrations, insect outbreaks, and salmon spawning are phenological cycles. While these events occur at around the same time each year, their precise timing varies from year to year. This year-to-year variation is called interannual variability.

Every year, as conditions for plant growth improve, a wave of green spreads over the land surface and then retreats as conditions for plant growth decline. The period between this green-up and green-down or senescence is known as the growing season. Some scientists recently found that the growing season has increased in northern latitudes by eight days since the early 1980s. These changes in the length of the growing season may be an indication of global climate change.

Plant green-up is initiated when dormancy (a state of suspended growth and metabolism), is broken by environmental conditions such as longer hours of sunlight and higher temperatures in temperate regions, and rains and cooler temperatures in deserts and semi-arid areas.

As plants begin green-up, leaf chlorophyll absorbs sunlight for photosynthesis.
Growing plants use carbon dioxide from the air for photosynthesis. By removing this greenhouse gas from the atmosphere, plants play a major role in our planet's climate. The pattern of atmospheric carbon dioxide is closely linked to the pattern of global plant green-up.

As plants photosynthesize, they also transpire water from the soil, through the roots and plant stems, and out the leaves into the atmosphere. This affects atmospheric temperature, humidity, and soil moisture. With green-down, plant transpiration of water decreases; plants reduce water loss when their water supply is greatly limited during winters for deciduous plants and during dry spells for desert plants. Therefore, knowing the timing of green-up and green-down is important for understanding the global water cycle.

Scientists also use greenness estimates from satellites to map wild fire danger. High greenness areas represent lower wildfire danger, while low greenness areas represent higher wildfire danger. Scientists studying migrations of animals such as caribou, use greenness maps to help them understand animal population migration patterns.

The various leaf colours we see are due to the physics of sunlight striking pigments in the leaves. Four broad categories of pigments are recognised. Chlorophyll, carotenoids, anthocyanins, and tannins.

During spring and summer, the leaves serve as the principal site for the photosynthetic process in which carbon dioxide and water are transformed the carbohydrates necessary for

tree growth. This food making process takes place in the leaf in numerous cells containing the pigment chlorophyll, which gives the leaf its green colour. As the days get shorter and temperatures get cooler in the autumn, there is a decline in synthesis of new chlorophyll.

The green colour disappears and the rate of photosynthesis declines. The trees become very frugal and even more efficient by pulling nutrients such as nitrogen and phosphorus into twigs and branches to be stored for the winter, further enhancing the loss of chlorophyll.

Along with chlorophyll, leaves also contain yellow or orange carotenoid pigments. This is the same pigment, which gives the carrot its familiar colour. Most of the year these yellowish colours are masked in leaves by the greater amount of green chlorophyll. It is the unmasking of the carotenoids that account for the yellow and golden colours

The anthocyanin pigments responsible for the pink, red and purple leaves are formed by reactions between sugars and other compounds. A mixture of red anthocyanin pigment with yellow carotene often gives a bright orange colour as seen in some species of maples.

GLOBE activities

You will need to start these activities in early Spring before the trees are in leaf, before 'Budburst'. You can find information about when budburst happens locally from your wildlife trust.

Your plant phenology site should be in an area where green-up of native plants is due to climatic factors such as increased temperature or precipitation. Watering and fertilization alter plants ' green--up and green-down cycles, and the data would not be representative of natural vegetation and local climate connections. Buildings absorb solar radiation and shelter sites from wind. Therefore, avoid sites near buildings or where watering or fertilization is done.

To determine if the building is too close, stand at the plant and sight the top of the building through your clinometer. If the angle is greater than 45° the building is too close.

Non-native species, called exotics, have green-up and green-down cycles that may not be tied to the local climate. Often this is because exotics have not evolved to survive in the local climate.

Green-up and green-down detected by satellites are influenced mostly by a few dominant overstory plant species. These will be the species with the largest share of canopy coverage.

If you are using a Quantitative Land Cover Site, you already know the dominant species. If you are using a different site, use the one to three over-story species that are dominant for your region. These over-story plants may be coniferous trees, broadleaf trees, broadleaf shrubs, or grasses. For phenology measurements you should choose a deciduous plant so, if the dominant plant species are all evergreen conifers, use the under-story broadleaf shrubs as your green- up plants. For example, if your study site is 90 percent white pine (a coniferous tree) and 10 percent silver birch (a broad leaf tree),use the silver birch trees as the study plants.

Since a change in plant growing season may be due to a change in climate, students at your school should try to use the same site and the same plant species consistently, year after year.

If lower branches are observed, try to sample them from the edge of the stand of trees or shrubs since branches inside a stand may experience a different microclimate due to shading.

For green-up observations, leaf length is from the leaf base to the leaf tip. Do not include the leaf stem or petiole as part of the leaf length measurement.

Equipment

GPS
Compass
Lengths of bright plastic
Fine permanent marker
Ruler
GLOBE Plant colour guide

Extra activities

Draw a simple line graph and plot the growth of the leaves over the observation period.
Produce a poster showing the growth of the leaves every day.
Make posters to show different trees.

Further investigations

Contact local parks / nature reserves and compare budburst dates with them.
Do the green down activity in Autumn.
Look at the Woodland Trust website.
Work out the height and age of your trees.
Use a tree beater and pooters to find out what minibeasts live in or on your tree. Look at the GLOBE UK website and complete the biodiversity activities
Draw a map of the area and mark on the trees you have studied.
Monitor the weather and see if conditions affect budburst.

Useful contacts and publications

UK phenology network www.phenology.org.uk
A web site supported by The Woodland Trust and the Centre for Ecology & Hydrology, which has set out to monitor, collate, store and evaluate changes to nature's events. Access to UK historic data and the ability to enter data online will both be available. Further enhancements are planned including increasing the amount of historic data available.

Phenology web links www.attra.org/attra-pub/phenology.html
Comprehensive web page of phenology web links. Sequence of Bloom, Floral Calendars, What's in Bloom - Annotated list of phenology related web sites provided by ATTRA (Appropriate Technology Transfer for Rural Areas), the sustainable agriculture information centre funded by USDA.

European Phenology Network www.dow.wau.nl/msa/epn/index.htm
A network to increase the use of phenological data and to stimulate monitoring and research in Europe.

Phenology, the study of nature's cycles of life
www.sws-wis.com/lifecycles/links.html
Links to web sites about the study of cyclic events of nature usually the life cycles of plants and animals in response to seasonal and climatic changes to the environment.

GLOBE curriculum links

Geography Uses fieldwork in a local environment to look at changes due to climatic and human processes. Use of ICT to add global information

Key stage 2	1a-c	2a-f	4a	6e	7a+c

Key Stage 3	1a-d	2a-f	3d+e	4a+b	5a	6d,e,j
	7c+d					

Science Uses data collection to explore changes in plants due to season

Key Stage 2	1.1a+b	1.2a-c, e-l	2.1 a-c	2.3 a+b	2.5e

Key Stage 3	1.1a-c	1.2c-o	2.1b,c+e	2.3a-c	2.5c

ICT Uses computer technology to convey information; to interpret, analyse and check data required for specific purposes. Purposeful use of data-logging equipment.

Key Stage 2	1(a)	1(b)	2(b)	3(a)	4(a-c)

Key Stage 3	1(a)	1(c)	2(b)	3(a)

Mathematics Uses appropriate measuring instruments to observe, record and interpret numbers and scales with a high degree of accuracy. Opportunity for data handling skills.

Key Stage 2	2.1(a-k)	2.2(b,f,k)	2.3(l)	3.4(a,b)	4.1(b-h)	4.2(a-d)

Key Stage 3	2.1(g,h)	2.2(e)	3.4(a)	4.1(a)	4.2(d)	4.3(a-c)