Topic 2. Plant Health

2.1 Abiotic Factors

To maximise plant growth there are several factors that growers must carefully balance to promote best growing conditions. These factors fall under two categories: biotic and abiotic.

Biotic factors (living)	**Abiotic factors** (non-living)
• Competition from other plants • Pests • Pathogens (diseases) (These are discussed in topic 2.2)	• Temperature • Moisture • Relative humidity • Light intensity • Wind • Oxygen availability • Nutrient availability

Acer japonicum emergent foliage damaged by frost on March 20th 2020.

Horticulturalists have limited control of abiotic factors outdoors, but can work toward mitigating factors limiting to growth, ensuring plants perform at their best for the locality they're growing in. These are explored below:

Temperature:

- **Low temperatures can be limiting to the rate of plant growth** and freezing/frost can be very harmful to plants in active growth.
- **Plants grow slowly in cool temperatures**, and cool spring or summer weather will delay flowering in ornamental and edible species. This can be problematic, for example in *Fragaria* × *ananassa* (strawberry) the first harvests will be delayed if the weather remains cool.
    - Some growers place mobile **cold frames** over plants, or **horticultural fleece**, to create a **warmer microclimate**, mitigating cool weather somewhat.
- Freezing temperatures leading to **frost, particularly late frosts, can be devastating to horticulturalists and growers**. Spring flowers on fruiting trees, e.g. *Malus* 'Bramley's Seedling' (apple) or *Prunus domestica* 'Victoria' (plum) are damaged by frost and these **trees can suffer significant fruit loss because of cold springs**.
    - **Growers can limit frost damage by only growing later flowering fruiting trees** if they're in a cold area, such as the later flowering *Malus* 'Laxton's Royalty'; it's important to ensure compatible trees are flowering at the same time. On a small scale, horticultural fleece can be used to cover small trees, such as restricted forms i.e. cordons, fans, espalier or step-overs; it's not normally practical to fleece larger trees. Spraying plants with fine droplets of water in the evening can protect them from frost due to water's high specific heat capacity – essentially the surface water droplets slow the rate of flower cooling and can keep light frosts from damaging flowers.
- Winter flowering *Camellia japonica* can suffer flower damage in cold snaps, as can spring flowering *Magnolia* species and cultivars. These flowers are browned by frost.
    - It's not normally practical to try and prevent frost damage, and affected flowers are best picked off the plants. More flowers will usually follow on *Camellia japonica* but if frost damages *Magnolia* in full bloom it can ruin the display for that year, making them a high risk plant, especially with potentially greater extremes of weather as a result of climate change.

Magnolia cv. flowers damaged by frost and snow, April 12th 2021.

2.2 Biotic Factors:

Biotic factors include **competition** from other **plants**, **pests**, and **pathogens**. This section will explain the impact on plant health of each of these factors and how horticulturalists can minimise them.

Some key definitions:

- **Pest**: an organism that resides in a place where it is not wanted – this includes all forms of life, including plants (weeds) and animals. It's convention to call pest plants 'weeds' and pest animals 'pests'.
- **Weed**: a plant that is growing in the wrong place, according to the gardener.
- **Pathogen**: a microorganism that causes disease. Plant pathogens are most commonly fungi, bacteria and viruses.
- **Cultural control**: managing plant collections to reduce likelihood of pests or pathogens affecting individuals in a detrimental way.
- **Physical control**: mechanical eradication of a pest or pathogen, e.g. hand weeding *Taraxicum officinale* (dandelion) plants from a garden border.
- **Biological control**: use of a living organism that predates or parasitises a pest, e.g. ladybirds and their larvae consuming aphids.
- **Chemical control**: use of a synthetic product to kill a pest, pathogen or weeds.
- **Pesticide**: any chemical substance used to control pests, including herbicides, insecticides, fungicides and algaecides:
  - **Herbicide**: a chemical substance that is used to kill plants.
    - **Selective herbicide**: only kills a certain type of plant, e.g. lawn herbicides only kill eudicotyledonous plants, they do not kill monocotyledonous plants (i.e. lawn grasses).
  - **Insecticide**: a chemical substance that kills insects.
  - **Fungicides**: a chemical substance that kills fungi.
  - **Algaecide**: a chemical substance that kills algae.

Competition:

Plants compete with each other for light, nutrients and water (abiotic factors). In most habitats, plants grow close to one another and are fighting a constant battle for these abiotic factors, as well as battling pests and pathogens. In a garden, competition from other plants is controlled by the gardener.

Competition comes from :

- **Intended garden plants** that are **growing bigger** and **compete with surrounding plants for space**. This happens when gardeners plant vigorous plants near ones that can't compete, e.g. *Geranium* 'Orion' planted near *Erigeron karvinskianus*. Whilst both are suitable for sunny sites, the rapidly spreading geranium will grow much larger than the *Erigeron* and soon smother it, outcompeting it for light, water and nutrients, eventually killing it. The same occurs when woody plants grow larger and their branches start shading out previously sun-drenched spaces below. Over time this can reduce flowering and vigour in sun-requiring plants, e.g. *Paeonia lactiflora* (peony).
- **Spontaneous plants: weeds**. Weeds compete for the aforementioned abiotic factors, and can also play **host to pests and pathogens** that affect intended garden plants. For example, *Senecio vulgaris* (common goundsel) is host to rust disease, which can affect other garden plants.
  - There is a less commonly discussed side to **weeds, the positives**. They also play **host to natural predators**, cover bare ground to **reduce soil erosion** and **shade the soil**, reducing evaporative losses. They host a range of species, **improving garden biodiversity** – for example, *Urtica dioica* (nettles) leaves are consumed by peacock and red admiral butterfly caterpillars. Deep rooted plants such as *Taraxicum officinale* (dandelion) **extract nutrients from deep in the soil**, bringing them to the surface levels when their leaves decompose. Modern thinking is to consider whether a spontaneous plant is really a weed, or is welcomed. Some 'weeds' are actually self-seeded garden plants. *Nigella damascena* (love-in-a-mist) self-seeds readily into sunny spots and many gardeners allow them to grow; they offer nectar to pollinators and their seeds are forage for birds and other animals.

- **Biennials**: few biennial plants are considered weeds – many are welcomed as self-sown desired plants, such as *Myosotis sylvatica* (forget-me-not) and *Digitalis purpurea* (foxglove). Like ephemerals and annuals, they only spread via seed.
- All ephemerals, annuals and biennials produce copious seeds and typically have evolved effective ways to disperse their seeds (see topic 5: plant science 2).
- **Perennial** weeds often pose the greatest problems to gardeners, especially well-established colonies. Depending on their **organs of perennation** (the storage organ they survive the dormant season with), they are either spreading or do not spread: (note – adaptations listed below are detailed in topic 5: plant science 2).
    - **Non-spreading** perennial weeds include those with **tap roots**, for example *Taracum officinale* (dandelion) and *Rumex obtusifolius* (dock). These grow each year from the same location, where the plant originally germinated from a seed. They only naturally spread via seed, but can also sprout from severed root sections as a result of gardening activities.
    - **Spreading** perennial weeds are numerous and have a variety of methods of **colonising new areas**. Nearly all disperse seeds, but it's the vegetative spread that makes them so difficult to eradicate. Spreading perennial weeds, like many garden plants, spread either via underground or surface rhizomes, stolons, root suckers, tip-layering or bulbils. Some examples:
        - **Rhizomes** (underground stems): *Calystegia sepium* (hedge bindweed), *Aegopodium podagraria* (ground elder), *Elymus repens* (couch grass), *Equisetum arvense* (mares tail), *Reynoutria japonica* (Japanese knotweed).
        - **Root suckers** (where adventitious buds on roots initiate into new shoots): *Rhus typhina* (stag horn's sumac), *Rubus spectabilis* (salmonberry), *Symphoricarpus albus* (snowberry).
        - **Stolons** (arching overground, leafless stems that grow plantlets at their tips): *Trifolium repens* (white clover), *Ranunculus repens* (creeping buttercup), *Fragaria vesca* (alpine strawberry).
        - **Tip-layering** (where regular, leafy stems can form plantlets at their tips): *Rubus fruticosus* (blackberry).
        - **Bulbils** (where tiny bulbs are produced from axillary buds on a stem or in place of a flower): *Allium paradoxum* (few-flowered leek).
    - **Rhizomatous** and **suckering** weeds are especially problematic because **underground** parts of the weeds persist year-on-year, allowing new shoots and roots to develop. Even small sections of rhizome or suckering root can send up a new shoot. This makes total removal very difficult, even after digging as much out of the soil as possible. Rhizomes and roots are often in the top 30 – 50cm of soil, though they can run much deeper, making them extremely difficult to fully remove.

Equisetum arvense (field horsetail/mare's tail) rhizome with pale new growth apparent. This weed can sprout from even small sections of rhizome.

Controlling weeds:

There are four main ways to control weeds: **cultural, physical, mechanical and chemical.**

Cultural control:

- Ephemeral, annual, biennial and self-seeded perennial weeds can be reduced by **mulching** the soil with e.g. 5cm of bark. This **blocks light** from reaching the surface, which can trigger germination in most weed species. Mulching is best undertaken in late winter after the previous year's seed dispersal season and before weeds begin germinating. This is not effective on established perennial weeds regrowing from organs of perennation – their stems and leaves will have enough force to push through mulch.

Common generalist pests and their control measures:

Pest and damage:	Control and avoidance measures
Deer: Deer are a problem in more rural areas where they can access gardens. They're **generalist grazers and can quickly devour a large amount of plant material in a short time**. Deer are shy animals and usually graze gardens at night, typically avoiding areas near the house where human activity is common, however when hungry they will graze any part of the garden.	**Cultural:** If the property occupant/s don't want to exclude deer, the only effective option is to **only select plants that are not consumed by deer**, such as *Buddleja davidii* (buddleia), *Choisya spp.* (Mexican orange), *Daphne spp.*, *Hypericum spp.* (rose of Sharon), *Mahonia spp.*, and others. **Physical: a garden perimeter fence of at least 1.8m high is an effective barrier to all species of deer**.
Rabbits: Rabbits are generalist feeders that are more common in rural areas. They **feed at a relatively low height, eating herbaceous material to ground level. They can also eat the bark of young trees in winter**, severely damaging or even killing them by ringbarking. In some locations rabbits might burrow, damaging roots.  A common rabbit.	**Physical:** The most effective barrier method is by **installing a perimeter fence 1.2 – 1.4m high and buried 30cm into the ground, or flared out horizontally by 30cm, just below the ground surface and away from the garden**. This will prevent rabbits burrowing under the fence. **Physical: Young trees in rabbit-prone sites should have a tree guard fitted** (often spiralled plastic) to prevent rabbits damaging the bark.  A plastic rabbit guard around a newly planted, young tree.
Molluscs (slugs and snails) Often considered the most problematic pest in the garden, however **most species of slug and snail are actually beneficial to garden ecosystems**. **Only a small number of mollusc species damage living plants**. Most consume dead plant material, contributing to the natural composting process and are essential to holistic garden health. Those that consume living plant material do so with a rasping mouthpart that makes characteristic **uneven holes in leaves, flowers, stems and roots, along with tell-tale slime trails**. They **tend to target seedlings and developing foliage, stems and flowers** of various plant species. *Lupinus spp., Delphinium spp, Hosta spp.*. and *Dahlia spp.* are all susceptible, as are many other garden plants.	**Cultural:** the best way to **avoid mollusc damage is to avoid growing susceptible plants** and focus control around new, vulnerable plantings. **Recent, susceptible purchases should be hardened off before planting** into the garden, especially in spring as many plants are grown for sale in polytunnels and glasshouses on wholesale nurseries. These plants have less toughened leaves and stems as they're buffered from wind and rain in their protected growing environment and are more attractive to molluscs. **Cultural: plants grown from seed in containers benefit from being planted out when they're a little larger, as young seed-grown plants are more susceptible**. Direct-sown seeds result in plants that are 'grown hard' in outdoor conditions and are less targeted; this is most suitable for hardy annuals such as *Centaurea*

Common generalist diseases and their control measures

Disease and damage:	Control and avoidance measures

Grey mould (fungal); aka botrytis.
Botrytis cineria
A **very common** pathogen, **causing rot of soft plant tissues** with a characteristic **grey/brown surface fuzziness**. It's **most prevalent in cool, humid conditions, especially combined with poor air movement**. Common on soft fruit like strawberries, gooseberries, grapes and raspberries, as well as the foliage of lettuce, *Cyclamen*, *Pelargonium* and many other ornamental plants.
It **spreads via spores and is ubiquitous across the UK**. Often living saprophytically (on dead plant material), it can enter and infect living plants via wounds, although it can infect plant tissue even without wounding.
 
Grey mould on a *Cyclamen* cv.
	Cultural:
	• **Avoid susceptible species.**
	• Select **resistant cultivars** of susceptible species, e.g. Strawberry 'Pegasus' has moderate botrytis resistance.
	• **Good air movement** is essential:
	  ○ **pruning to remove congested branches.**
	  ○ **Sterilise tools between plants.**
	  ○ sufficient **spacing** of **plants.**
	  ○ installing **fans** in **glasshouses.**
	  ○ **ventilating glasshouses** when possible.
	Physical:
	Good hygiene will also reduce incidence:
	• Keep **growing spaces like greenhouses free of dead, fallen plant material** that may become damp and host grey mould.
	• **Remove dead and dying leaves and flowers** on susceptible plants, especially in greenhouses.
	• **Check plants on a regular basis** for signs and **remove infected tissue** when seen.
	• Isolate affected potted specimens to reduce spread.
	
	Treatments:
	There are **no chemical controls** available to home gardeners.

Powdery mildew (fungal) This is a group of fungus species that are **very commonly seen on a wide range of host plants**. There are many different species of powdery mildew, each of which have a specific host range; most have similar symptoms. Powdery mildew **develops on dry leaf surfaces**. Commonly affected plants include courgettes and marrows, cucumbers, peas, *Berberis, Phlox,* Roses, *Lonicera*, and many others. **Symptoms include a white, powdery surface spotting which spreads and can eventually cover the whole leaf**. In courgettes, marrows and cucumbers it appears on the oldest leaves first. **Severe infestations lead to stunted growth and unsightly appearance**. - In **annual species** like courgettes it can cause **severe crop losses and premature loss of the plant**. - In **perennial species** it's usually not terminal, but it **impacts negatively on visual appearance and vigour**.	**Cultural:** • Powdery mildew is **best minimised by ensuring susceptible plants are not planted into stressful conditions, good airflow is maintained around plants, and summer drought stress is prevented.** • For example, planting susceptible *Phlox paniculata* into raised beds in a sheltered garden with poor airflow, and allowing the soil to dry in summer, will result in a heavy infestation of powdery mildew. It would be better to **select** a more drought resilient, **mildew-resistant species** instead. **Cultural:** • **Mulch to aid water retention** in the soil. • **Spot water in dry spells**, targeting susceptible plants. • **Prune and tidy to ensure good airflow** around susceptible plants. • **Overhead watering mid-morning during dry weather can reduce powdery mildew**; this will ensure leaves are dry by nightfall, reducing risk of other diseases developing.

Apple canker (fungal)

This disease needs to be carefully controlled in orchards and in gardens apple plants should be routinely inspected. *Sorbus* (mountain ash) and *Pyrus* (pear) can also be infected.

Symptoms start with **dark, dead, sunken bark** that usually starts at a pruning cut or wound, however it can also enter where buds occur on the stems. As the infected sections die, xylem and phloem no longer transport liquids and dissolved minerals, sugars etc. leading to loss of vigour above the canker. **Young branches and twigs, including fruiting spurs, can be girdled leading to death of the part above the canker**. This can happen over the course of a single year.

On larger branches and even sometimes the trunk, canker(s) develop over several years, spreading around the infected limb and reducing vigour of the tree above. **Eventually it can girdle large branches or the trunk, leading to death of large parts of the tree**.

Sometimes fruits can be infected, causing them to rot and fall.

The canker is **spread via spores released into the air from infected areas during winter and spring**. This can be observed as small red fruiting bodies on infected sites. In **summer it can spread via water-dispersed spores from white pustules found at the edges of stem lesions**.

Apple canker on a young branch, which has been girdled and has died.

Cultural:

- **Select more resistant cultivar (no cultivar is completely resistant).**
- **Cultivars with some resistance include 'Cockle Pippin', 'Katy', 'Merton Russet', 'Newton Wonder' and 'Winston'**, though there are many more with resistance.
- Particularly susceptible varieties include 'Cox's Orange Pippin', 'James Grieve' and 'Spartan', as well as several others. These should be avoided.

Physical:

- **Existing apple trees should be inspected carefully for signs of canker and infected stems cut out, pruning back to healthy tissue.**
- **A wound paint should be immediately applied to prevent reinfection.**
- **Cutting tools should be disinfected between cuts.**
- Infected larger branches should be removed if it won't cause significant impact to the canopy.
- Alternatively, on small cankers, a horticultural knife can be used to cut out the canker, removing infected bark and surrounding tissue until signs of the canker are gone.
- **If a tree is very heavily infected, removal should be considered**.

Chemical:

There are **no fungicides available** for home gardeners for use on fungal canker

Apple canker developing on a branch.

Bacterial canker

This **affects *Prunus*** species **such as cherries (including ornamental cherries), plums, apricots, peaches and other closely related plants**.

Symptoms appear in spring, with stems oozing a gummy substance from dark, sunken areas. These infections can spread around the stems, girdling them and causing die-back. Emerging shoots can also be affected, growing as normal in spring but then quickly dying back. **Leaves commonly show 'shotholes' where small circular areas die and fall out of the leaf**, leaving a

Cultural:

- **Varieties with some resistance should be selected** for gardens and orchards. These include the cherries 'Merton Premier', 'Merla' and the plum 'Marjorie's Seedling', amongst others.

Physical:

- **Trees should be inspected in spring and early summer for signs of infection**.

2.3 Legislation and Biosecurity

Legislation

Plant Protection Products Regulations 2012 (PPP):

- Relates to **the use of pesticides in the UK.**
- **Users of professional products must have a certificate** to show they've got suitable knowledge of the chemicals they're using.
- Users of PPP's are required to take **reasonable precautions to protect the environment and human health**.
- Products may not be mixed unless the label/s expressly state it's suitable to do so.
- PPP application must be **confined to the target area**, taking all precautions to do so.
- Take reasonable precautions to ensure that PPP's are **stored, handled** and old packaging is **disposed of** in a way that **does not endanger the environment or human health**. Storage and disposal information can be found on the product label.
- Users of **PPP's must take steps to protect water/aquatic environments.**
- **Minimise use** in specific areas such as:
  - roads, railways and other **surfaces where run-off goes directly into sewage systems or the environment.**
  - **areas used by the public.**
  - **close to conservation areas.**
  - **close to health care facilities.**
  - **areas used by agricultural workers.**
- PPP regulations 2012 also details obligations for sellers and distributors of PPP's to prevent these chemicals posing a danger to the environment or human health.

e.g. 'PA6 Hand Held Applicators' (various certificates are obtainable, see government website)

i.e. select the most suitable method of control; if a PPP is required, use the least harmful, but effective, option; identify and mitigate any risks, e.g. spraying early in the morning before a garden opens to the public and cordoning off the area + signage until it's safe for public access

e.g. do not spray on windy days to prevent drift of chemical into non-target areas

i.e. use the product that poses least harm to aquatic environments or drinking supply water,
a buffer zone must be in place around water bodies to prevent (as far as is reasonably practical) the PPP entering the water body

Plant Protection Products Regulation 2020:

- **Supplement the 2012 regulations** by requiring **users** of professional PPP's, as well as **importers**, **manufacturers**, **distributors** and **sellers** in Great Britain (England, Scotland, Wales) to **register with the relevant competent authority** (Secretary of State for England, Scottish ministers for Scotland, Welsh ministers for Wales); Northern Ireland has separate legislature for this.
- **Inspections** by the Health and Safety Executive (HSE) **will take place where PPP's are used in a professional capacity** to ensure satisfactory compliance with the law.

2.4 Keeping Plants Healthy

Sustaining healthy plants requires integration of the factors outlined in this section, from biosecurity measures that prevent entry of pest or disease to reducing incidence of outbreaks and quickly managing those that do occur.

Garden Health Plans:

This is a holistic, integrated concept that considers a range of factors as affecting plant health, along with mitigative action. **Garden health plans integrate the widely practiced concept of Integrated Pest Management (IPM)**, which is discussed below.

Garden health plans include the following key concepts:

Key concept	Details	Example
Right plant, right place **(Topic 4.1)**	**Garden sites need to be fully understood** to make **informed planting choices**; gardeners need to know: • Soil type and variations across site • Soil pH across the site • Microclimates: sun/shade, windiness • Topography: slopes, hollows, etc. • Frost pockets • Damper and drier areas • Expected changes as per climate change predictions With this comprehensive understanding, **plants can be selected that are suited to the specific planting location**. Plant acquisitions need to be researched carefully. **Existing plants need to be assessed for their suitability to their current location** and decisions made as to whether the plant might need **transplanting to a more suitable spot, or removal.** **Plants growing in conditions to which they're suited are more vigorous and resistant to pests and pathogens.**	A exposed sunny border on sandy loam: - The border is identified as being liable to dry conditions in summer and rarely waterlogs. Nutrient content is low and the site is exposed to wind. - Existing plantings are analysed and, with knowledge of how plants are performing, autumn transplanting or removal of poorly-performing, disease prone plants is undertaken. - E.g. *Phlox paniculata*, which succumbs heavily to powdery mildew in summer, and *Rosa* 'Harlow Carr', which does not repeat flower well in dry soil, are to be moved to another location in the garden that's more sheltered and doesn't experience such dry soil – improved abiotic conditions should reduce problems they experience. - Plants performing well in the sunny, dry border will be divided and transplanted to replace *Phlox* and *Rosa* plants. *Agapanthus* 'Loch Hope' AGM can be divided and transplanted in the autumn. *Echinacea purpurea* seeds are collected in the autumn and sown immediately, left in a cold frame to stratify over winter. They will be pricked out after germinating and grown on in pots until the following autumn when they'll be planted as larger, more vigorous plants that can compete in the established border.
Maintaining optimum site conditions **(Topic 4.3)**	Site conditions can be managed to ensure they're as optimal as possible for plant health. • **Mulching the soil with organic matter** can improve root conditions. • Mulching **reduces evaporative moisture loss** from the soil, **reducing the rate of soil drying** and therefore reducing plant stress. • **Organic mulches biodegrade, enriching the soil with humus particles that**	A herbaceous border backed with shrubs: - In early spring a 5cm depth of bark mulch is spread under the shrubs to suppress weed germination and improve soil water retention. Mulching after seed dispersal in the autumn is ideal as weed seeds will be covered. - Shrubs are pruned as required – e.g. *Forsythia x intermedia* is pruned immediately after flowering to remove 1/3rd of the oldest