Research
Based
Curricula

How do plants fight against diseases and pests?

Key Stage 4 Biology

2019

BROUGHT TO YOU BY RBC ACCESS ED

Contents

Part 1: Introduction

Part 2: Resources

Part 3: Advice and Guidance

For Pupils
Welcome

To get into the best universities, you must demonstrate that you are intellectually curious, and will make the most of the wonderful academic opportunities available to you.

One of the best ways of demonstrating this, is by going above and beyond what is taught in school and studying something that is not on the curriculum.

This resource will give you exactly such an opportunity. You will have something interesting to write about in your application to university, something interesting to talk about in a university interview, and open whole new areas of study you might be interested in!

You will develop valuable academic skills as you go, that we have marked out with gold badges (see the next page on university skills). As you work through the resource you can look out for these badges so that you can explain which skills you have developed and what you did to demonstrate them. Developing these skills will help you get university ready!

If you have any questions while you are using the resources in this pack, you can contact your teacher or email us directly at schools@access-ed.ngo.

Good luck with your journey to higher education!

For Pupils
University Skills

To complete this resource, you will have to demonstrate impressive academic skills. When universities are looking for new students, they will want young people who can study independently and go above and beyond the curriculum. All of these skills that you will see here will demonstrate your abilities as a university student – while you're still at school!

Every time you have to look something up, or write up a reference you are showing that you can work independently. Every time that you complete a challenging problem or write an answer to a difficult question, you might demonstrate your ability to think logically or build an argument. Every time that you evaluate the sources or data that you are presented with, you are showing that you can "dive deep" into an unfamiliar topic and learn from it.

Here are the skills that you will develop in this course:

independent research	your ability to work on your own and find answers online or in other books
creativity	your ability to create something original and express your ideas
problem solving	your ability to apply what you know to new problems
building an argument	your ability to logically express yourself
providing evidence	your ability to refer to sources that back up your opinions/ ideas
academic referencing	your ability to refer to what others have said in your answer, and credit them for their ideas
deep dive	your ability to go above and beyond the school curriculum to new areas of knowledge
source analysis	your ability to evaluate sources (e.g. for bias, origin, purpose)
data interpretation	your ability to discuss the implications of what the numbers show
active reading	your ability to engage with what you are reading by highlighting and annotating

For Teachers
RBC Guide

Programme Aims

The Research-Based Curriculum aims to support student attainment and university progression by providing classroom resources about cutting-edge research at local universities. The resources are designed to:

- ✓ promote intellectual curiosity through exposure to academic research
- ✓ stretch and challenge students to think deeply about content that may be beyond the confines of the curriculum
- ✓ develop core academic skills, including critical thinking, metacognition, and written and verbal communication
- ✓ inform students about how subjects are studied at university, and provide information, advice and guidance on pursuing subjects at undergraduate level

Content

The programme represents a unique collaboration between universities and schools. Trained by AccessEd, PhD Researchers use their subject expertise to create rich resources that help bring new discoveries and debates to students.

The Research-Based Curriculum offers ten modules suitable for either KS4 or KS5 study. The modules span a range of disciplines, including EBacc and A-level subjects, as well as degree subjects like biochemistry. Each module includes six hours of teaching content, supported by student packs, teacher notes and slides. All modules are available online and free of charge for teachers at select schools.

Delivery

Resources are designed to be used flexibly by teachers. The resources can be completed by students individually or in groups, in or out of the classroom.

For Teachers
RBC Guide

Here are five examples of delivery options:

Extra-Curricular Subject Enrichment Clubs

The resources can be completed in small groups (4-8 pupils) across a series of weekly lunch clubs or after-school clubs. Groups can reflect on their learning by presenting a talk or poster on the subject matter at the end of the course.

University Access Workshops

The resources can be used by students to explore subjects that they are interested in studying at university. This can inform their decision making with regards to university degree courses, and allow students to write more effective personal statements by including reflections on the Research-Based Curriculum.

Research Challenge

The resources can be used to ignite curiosity in new topics and encourage independent research. Schools could hold a research challenge across a class or year group to submit a piece of work based on the resources. Pupils could submit individually or in small groups, with a final celebration event.

Summer Project

Resource packs can function as 'transition' projects over the summer, serving as an introduction to the next level of study between KS3 and KS4, or KS4 and KS5. Students could present their reflections on the experience in a journal.

Evidence

The Research-Based Curricula programme builds on the University Learning in Schools programme (ULiS), which was successfully delivered and evaluated through the London Schools Excellence Fund in 2015. The project was designed in a collaboration between Achievement for All and The Brilliant Club, the latter of which is the sister organisation of AccessEd. ULiS resulted in the design and dissemination of 15 schemes of work based on PhD research for teachers and pupils at Key Stage 3. The project was evaluated by LKMCo. Overall, pupils made higher than expected progress and felt more engaged with the subject content. The full evaluation can be found here: ULiS Evaluation.

Questions?

For more information contact hello@access-ed.ngo

Introduction to Topic
Plant defence

A quarter of crop loss in the world is due to damage caused by plant pests. Pests are defined as any organism on or in a plant which is unwanted and causes decrease in either quality, quantity or both. We need to solve these problems especially in the light of a growing human population across the world.

One of the ways in which scientists have tried to protect crop plants in the last 70 years has been by using agrochemicals: chemicals used in the farming industry which are intended to either kill the insect, fungus, bacteria or virus causing the disease or eating the crop.

The topics within this pack will include:

Plant pathogens and pests

How plants respond to attack

Plant tissues and their function

Plant defences

Protecting plants

Methods to assess how well pesticides work

Farmers have two choices in the ways that they apply chemicals and both have positive and negatives. 1. Applying chemicals to the soil so that the plant can take them up into the root system and around the circulatory system of the plant. 2. Spraying the plant leaves or fruit itself to keep the chemical on the surface, or to try and get the chemical through the surface and into the plant system to give it better overall defence.

Chemicals applied to the soil are non-targeted and rely on the roots taking up the chemical. Another problem with this approach is that the chemicals may harm soil organisms, and potentially run into the groundwater system and into streams and rivers damaging aquatic organisms.

Spraying chemicals directly onto leaves is more targeted, but the spray droplets might evaporate or may run off with rainfall and enter the soil. Farmers also need to consider the number of days before the crop will be harvested, because if the plant has not broken down these chemicals they may enter the food chain and be damaging to human health.

I am interested in how droplets behave on the leaf surface. What happens next? Does the droplet evaporate or does the leaf take in the chemical by absorption? If so, how much of the applied chemical does it take in? Does this depend on the type of chemical you are using?

Introduction to Topic
Plant defence

Where does it go inside the plant and how does it work to reduce or kill the target organisms?

My research concerns using biologically derived additives with chemicals which help them stick to, stay on, or go in the leaf so there is less waste and less chemical loss to environment. Use of these additives, called adjuvants, mean that less water is needed and chemicals are better able to work or get to where they need to be.

I am interested in using these additives with chemicals but I also believe in the idea that for the environment's sake we should be moving away from using chemicals in farming all together. People want to buy more organic food now and there are increasing social worries that chemicals stay inside the plant, move into different organisms in the food chain and cause health problems in humans.

The final stages of the project will look at how we can use helpful bacteria/fungi to populate our leaf which aid in stopping the damaging or pathogenic bacteria/fungi from increasing in population and destroying the plant. The idea of out-competing or using organisms that may secrete chemicals that may kill the other kind of organism is a safer way of defending our crops.

Researchers in Plant biology want to understand these micro-organisms so that we can make sure they do the job in plant protection as best they can. We need to think of ways to help stop them drying out or getting lost in the environment or being killed by UV from sunlight. Therefore we need to research natural additives which may help a micro-organism stay wet for longer, not dry out and allow it to pass into the leaf quicker so it is no longer exposed to the harsh environment, such as direct sunlight. By testing natural additives we can try to move away from using chemicals in farming and aim to have success just by using organic methods.

Introduction to Subject Biology at University

Biology is the study of living organisms, varying from the very small - micro-organisms, such as bacteria and fungi - up to the very large - animals and plant kingdoms. It encompasses a wide range of topics such as the health of humans and animals (medicine and veterinary medicine), to the study of plants and their development and diseases (important for food and the farming industry).

Studying Biology at university gives you the opportunity to experience a good overview of all different organisms, how they live, move, breathe, how they fight off (or cause) diseases, how they have evolved and become adapted to do certain jobs. You then have the option in your second year to choose if you want to focus more specifically on one area and become more of an expert in whichever area you are most interested in.

If you are interested in being a doctor or solving life-threatening diseases like cancer or diabetes you might decide to focus on human biology. If you are interested in how the smallest cells on Earth came to be here, how we might use them in medicine or food, or how we can kill them, then Microbiology would suit you well. If you are interested in how plants grow, how we might stop diseases and how we might improve crops to grow in places they normally wouldn't and how we might produce enough healthy crops to feed the world, Plant Biology is for you!

Plants are interesting because they are stuck in one place and have to survive despite changes in temperature, from frost to extreme heat. In hot countries they are bombarded with very high levels of light beaming on them throughout the day and often have to try and grow in soils lacking in water and nutrients. Plants have to try to come up with ways to stop insects and herbivorous animals from eating them, and all of the bacteria and fungi which want to live on them or in them. They have to tell the difference between day and night to be able to photosynthesise and they have an important role of supplying the world with enough oxygen to breathe.

Introduction to Subject Biology at University

And of course as producers, they synthesise the carbohydrates, vitamins and minerals for the health of the food chain.

With climate change creating more extreme climates and more diseases targeting crops, we need to learn as much as we can about plant biology to be able to predict how we can get more quantity and quality food from the crops we grow. This is where a degree in Biology with a specialism in plant biology can really help to improve farming around the world so that we can grow as much food as possible to support the nearly 8 billion people on planet Earth.

Scientists in space have even been successfully able to grow plants in spaceships to support the astronauts who work up there and if humans ever manage to live on other planets, scientists will need to understand plants enough to be able to try and grow plants in an environment with no soil, no water, no atmosphere and no gravity. This is an interesting branch of plant science research which is beginning now and will continue into the future!

I hope that from studying these six resources on plant biology will open you up to the world and experiences of a plant and to think about whether a career in plant research might be interesting for you. The pack includes the types of diseases and organisms that cause them, the problem that feeding organisms cause to a plant, the structure of plant cells, tissues and how transport in plants works. We will then move to look at how we might use chemicals and helpful organisms to fight off diseases in plants and how research today is moving towards trying to use these chemicals, finding out how they move into plants, how quickly and where they go once inside the plant.

Meet the PhD Researcher Kellie Smith

I studied Biology, Geography, English Language and Psychology for my A levels and chose these because they were the subjects I enjoyed the most and they were the ones I thought I was the best at. When I finished my A levels in 2009, I then went to visit the University of Leeds, which was the closest city to where I grew up and at this point I still hadn't decided whether I wanted to do Psychology or Biology.

After comparing the different courses and thinking about what type of job I could see myself doing, I decided on a degree in Biological sciences, which is a branch of Biology which focuses more on cells, molecules and the genetics of living organisms. It also allowed me the option to specialise in a particular topic and I chose plant biology.

During my degree I applied for some extra funding which I had to attend an interview in Cambridge for. I was lucky enough to perform well at the interview and get the extra money. I used this money to work at the John Innes Centre, which is the best funded plant research institute in U.K. This allowed me to get excited about doing research into plants.

A-Level Subjects	Biology, Geography, Psychology, English Language
Undergraduate	Biological sciences
Postgraduate	Masters by Research: Plant and crop science

Glossary

Term	Definition
Pests	unwanted animals or insects which eat plants and cause damage.
Pathogens	bacteria, fungi, nematodes or viruses which cause disease in plants.
Hosts	Plant in which a pathogen or pest is damage or disease.
Narrow/broad host range	Ability to cause damage to one or a few/many different plant types.
Spores	Fungal dispersal structure.
Dispersal	Movement of a disease-causing organism from an affected plant to a non-affected plant.
Stylet	The needle-like aphid feeding mouthpart.
Photosynthesis	The conversion of CO_2 and water to carbohydrate and H_2O using sunlight by plants/algae.
Objective lens	lens pointing at the object on a microscope. Normally found x20, x40, x100.
Organelle	sub-compartment within a cell carrying out a particular function.
Chlorophyll	Molecule which absorbs red and blue light and reflects green light.
Rigid	fixed in place, unable to move.
Penetration peg	The fungal structure which is first to enter into a plant host.

Glossary

Term	Definition
Secrete	A cell makes a molecule and exports it out of the cell.
Receptors	Proteins which are membrane-bound and recognise chemical signals from outside the cell.
Immune system	Attempts from the host to fight off or provide resistance to a disease.
Senescence	Discoloration of plants as they die.
Programmed cell death	When a plant dies in a controlled manner.
Toxic molecules	Molecules that cause death to an organism.
Tissues	Collections of cells with a common function.
Organs	Collections of tissue types to make an organ with a specialised function.
Specialised cells	Cells which are adapted to a specific function.
Flaccid	Limp and lacking water.
Transpiration stream	The pull of water from the roots up the stem to the leaves via the xylem.
Tuber	A swollen part of the root which stores energy.
Susceptibility	The ability of a plant to be defenceless or to not have the correct defences to fight off a pest/pathogen. You may see symptoms in a susceptible plant.

Glossary

Term	Definition
Resistance (plant)	A high level of defence statergy(ies) in a plant which makes a pest/pathogen not able to damage it.
Glandular	Cell(s) which can secrete chemicals.
Mimicry	Copying or resembling a feature of another organism.
Semi-permeable membrane	Allows some molecules to pass such as water via osmosis, whilst restricting other molecules due to their nature or size.
Plant protection	Modifying a farming practice to help plant health. (Use of chemicals or biological control)
Commodities	A commodity crop is not eaten but produced as it is useful for or demanded by humans.
Agrochemical sprays	A chemical used (sprayed) in agriculture, normally pesticides or fertilisers.
Outcompete	Do better in a competing successful. Plants compete for light, space, water, nutrients.
Pesticides	A substance used to deter or kill organisms which act as plant pests.
Adjuvants	A substance added to an agrochemical spray to help it better reach its target/work better.
Resistance (Insect)	Ability to avoid being effected/killed by something.
Osmosis	Movement of water molecules and dissolved molecules through a semi-permeable membrane.
Organic farming	Use of farming techniques without adding any chemicals.

Glossary

Term	Definition
Biological control	Use of live organisms to control/kill a plant pest. Predator/prey relationships or micro-organisms.
Pathogenic bacteria / fungi	Bacteria or Fungi that cause disease to the plant are called pathogenic.
Biopesticides	Live microorganisms which can be sprayed as a treatment against plant pests.
Hydrophobic	Water hating, or oil loving. Repels water molecules and is attracted to oils and lipid molecules.
Hydrophilic	Water loving, or oil hating. Attracts to water molecules and is repelled by oils and lipids.
Fluorescent molecule	A molecule which absorbs one wavelength and reflects another to give a colour.

Resource One Overview

Topic	Plant pathogens and pests
GCSE Modules	Detection and identification of plant diseases, fungal diseases.
Objectives	After completing this resource, you should be able to: ✓ describe pests that target plants ✓ describe symptoms and causes of plant disease. ✓ explain think about how diseases might spread. ✓ explain how pests are adapted to cause disease.
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

Resource One
Data Source

Section A

Powdery mildew

Active Reading

Powdery mildew is a pathogen which targets many crop plants and causes disease in salad crops like cucumbers and tomatoes, fruits such as grapes, cereal crops such as wheat and barley and crops high in protein such as beans, peas. Powdery mildew has a wide range of host plants because it can live on crops from multiple plant families. The disease is caused by a fungus which is spread by wind and settles on plant surfaces as a dusty, white coverage over leaves, fruit and seeds.

As a fungus, powdery mildew typically reproduce by making a dispersal structure called spores. Fungal spores are dispersed via wind or insects/bird feet and spores can survive over winter in soil. Over-wintering fungal spores can germinate the following year, normally in spring, when the temperature warms up (above 12◦C) and in humid conditions when there is moisture in the air. When spores germinate in soil, any plants which may be planted here can become diseased during that season. Fungus on infected crops which are touching healthy crops can easily be transferred to the new host to spread the disease further. Nearby crops can also quickly be affected as wind carries the fungal spores from one host plant to another.

Plant growth is affected as there is less surface area of leaves available to capture sunlight for photosynthesis. Fruit and seeds covered in powdery mildew start to degenerate and turn yellow through to brown as they die off and lose their nutritional value. 40% of cereal from cereal crops is lost due to powdery mildew attack and is no longer edible or profitable for farmers to sell at market.

Figure 1

Powdery mildew

Resource One
Data Source

Section B

Aphids

Aphids are insect pests, which feed on the sugary components of a plant. They have a mouthpiece called a stylet, which is used to stab into the plant tissue to access the sugar made by photosynthesis. Aphids can stab into the leaf to get at the veins in the leaf carrying sugary sap, or they can stab into the stem itself to tap into the phloem, the plant sugar transport system between roots and leaves. They are sucking insects, which cause damage by this feeding habit and suck out nutrients from the plant.

Different species of aphid attack different plants, some attack only one type of plant and therefore have a narrow host range but many have a broad host range, which means they can attack many different plant families including fruit trees, cabbage family crops like Brussel sprouts and broccoli, lettuce, pepper, onion, and many others. Unfortunately, this means that if different plants are grown close together, aphids can move between them and attack several plant families and become a real problem for farmers, which is the reason why we call them pests.

Aphids can be green, pink, white, grey or black and may be camouflaged so that they cannot be seen on their host; they also hide under leaves and in curled parts of the plant, hiding inside fruits, leaves or stems. Some aphids have wings and are very small and light so they can be blown around by the wind easily and can travel long distances to reach new target crops. They also detect the colours yellow and green to be able to recognise when they are landing on a potential plant.

Figure 2

Aphids

Resource One
Data Source

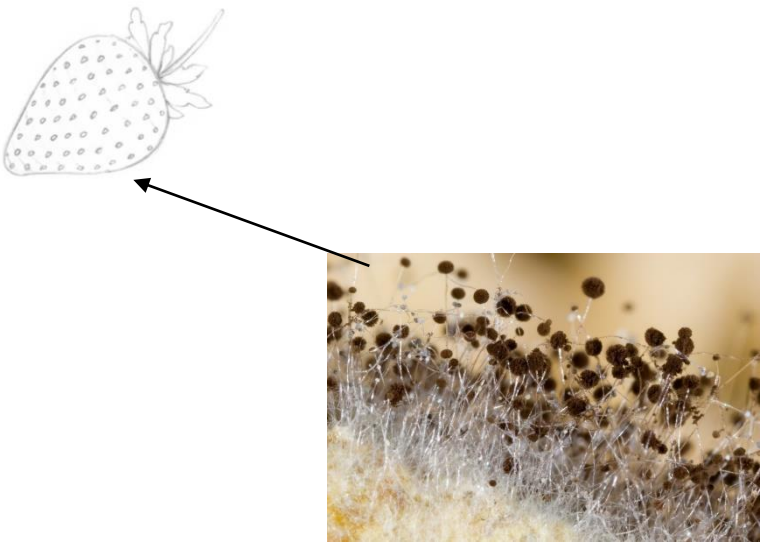
They reproduce very quickly and build up large populations, which become difficult to control without damaging the crop itself. They cause damage due to the stabbing of their stylets but they are also major carriers of diseases such as viruses, which, during feeding, are directly introduced into the plant's circulatory system, and can quickly lead to plant death. During feeding, aphids secrete a honeydew on the plant surface, which looks similar to mould and may attract other pests such as ants. Plants, which have been attacked by aphids, produce lower quality food, which may look damaged and mouldy. Ladybirds are above aphids in the food chain so increasing habitats for ladybirds in the growing area could be a possible way to control aphid populations.

Resource One Activities

Activities

Below is a picture of powdery mildew producing spores.

1. Draw some of the fruit and vegetables around it that are susceptible to powdery mildew. One has been done for you.



2. True or false.

Powdery mildew:

a. Spreads by spores - _____

b. Are carrier of viruses - _____

c. Attack only cucumber plants - _____

d. Lives inside the plant - _____

e. Effect the plant's ability to do photosynthesis - _____

Aphids:

f. Are carried to different plants by water in the soil - _____

g. Live inside the plant - _____

h. Are a problem all over the world - _____

i. Effect the plant's ability to do photosynthesis - _____

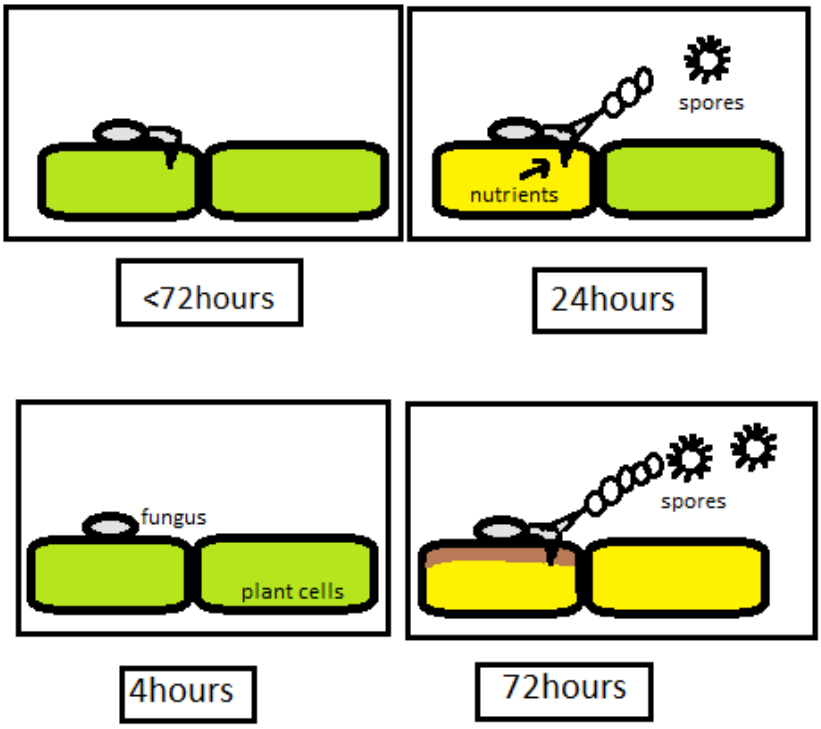
j. Introduce other pests to the damaged plant - _____

Resource One Activities

Activities

3. What adaptations do aphids have that make them a successful plant pest? Think about what features they have to be able to recognise plants, cause damage to plants, spread to new plants and to enable themselves to survive.

4. Below is a diagram of the powdery mildew infection process. The images and times are in the wrong order. See if you arrange them to make an accurate story board of the infection.



5. Describe what is happening in your storyboard at each time point. You might want to think about what the fungus is doing and what its effects are on its plant host. Include why you think that fungi make spores.

Resource One
Further Reading

Explore

Further reading:

- introduction to controlling plant pests.

https://www.bbc.com/bitesize/guides/zsf82hv/revision/4

- more information on the Biology of aphids and killing them.

http://www.biology-resources.com/aphid-01.html

- Black rose spot, a different type of fungal pathogen, and how to kill it.

https://www.rhs.org.uk/advice/profile?pid=270

- Mealy bugs – another type of sucking insect which effects plants.

https://www.rhs.org.uk/advice/profile?PID=201

- information about tobacco mosaic virus, a type of virus which causes disease in plants.

https://www.bspp.org.uk/downloads/education/BSPP_TMV_Info.pdf

- video about xanthomonas, a devastating bacteria which is destroying bananas in Africa.

https://www.bing.com/videos/search?q=xanthomonas+in+banana&&view=detail&mid=4B3E47ABAB6D476704FB4B3E47ABAB6D476704FB&&FORM=VDRVRV

Resource Two Overview

Topic	How plants respond to attack
GCSE Modules	Eukaryotes and prokaryotes, plant and animal cells, microscopy

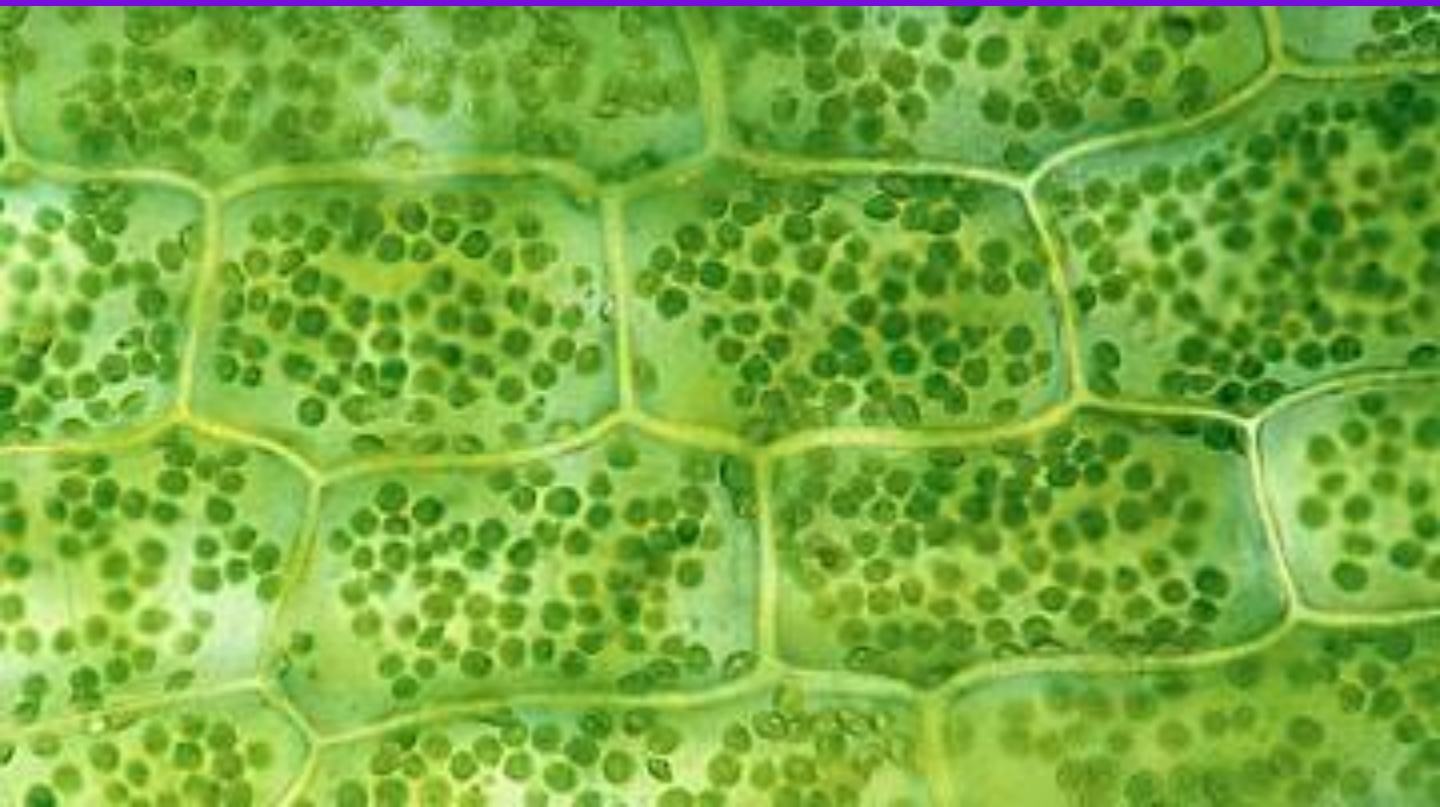
Objectives

After completing this resource, you should be able to:

- ✓ Recognize plant cells under a microscope
- ✓ Recall the organelles that make up a plant cell and what functions they have.
- ✓ Explain how pests and pathogens attack a plant host and how a plant cell generates an immune response

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading



Resource Two
Data Source

Section A

Plant cells

Active Reading

Plants are made up or plant cells. Figure 3 shows leaf cells packed together as seen under a microscope. The cells have fixed shapes and are packed together in lines (called files) which tessellate without overlap. This is quite different to animal cells which are free to move around and vary in their shapes and positions. If you look at the surface of a leaf with a school microscope, you would see the outline of plan cells, marked out by the cell wall, but you would struggle to see finer detail. Plants are eukaryotic organisms because their cells contain a nucleus and they also have organelles which carry out particular jobs. To be able to see the nucleus and organelles you would need to use a higher objective lens or a more powerful microscope.

Figure 3

Plant cells

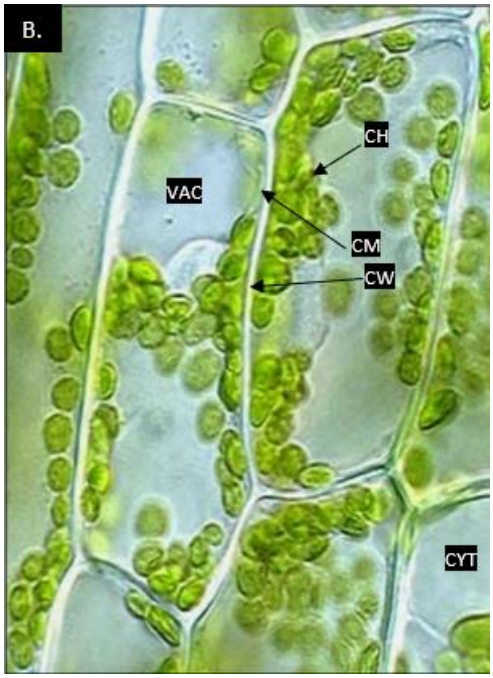
Figure 4 shows the leaf cells using a higher objective lens. The most obvious organelle visible is the spherical green chloroplasts (CH). Chloroplasts are gren because they contain chlorophyll which absorb red and blue light but reflect green light. Chloroplasts carry out photosynthesis in the plant and are therefore not found in animal cells. The cell walls (CW) are also not found in animal cells and mark out the edges of the plant cells. The cell wall is made of tough

Resource Two
Data Source

cellulose which gives the cells their rigid shapes and allow the cells to contain a high amount of water without bursting. Similar to animal cells, plant cells have a nucleus containing DNA, a cell membrane (CM) to control what enters and leaves the cell, mitochondria to respire, the cytoplasm (CYT) where chemical reactions happen and ribosomes and endoplasmic reticulum which make proteins and fats. Unlike animal cells, plants contain a vacuole (VAC) which is a large central storage compartment separate to the cytoplasm.

Figure 4

Plant cells in detail



Section C

Plant cells and disease

When micro-organisms like the fungus, powdery mildew land on plant cells and penetrate into them they have to pass through barriers including the cell wall and cell membrane. When an aphid uses its stylet to pierce and feed inside cells, it also penetrates through the cell wall and causes cell damage. The cell wall acts as a physical barrier which protects the plant but the penetration peg structure of the fungus or the stylet mouthpart of an aphid can get through some types of plant cells. To get through the cell wall and cell membrane the pest or pathogen wounds the plant cells and leaves them open to other diseases/infections in the same way as in human open skin cuts.

Resource Two
Data Source

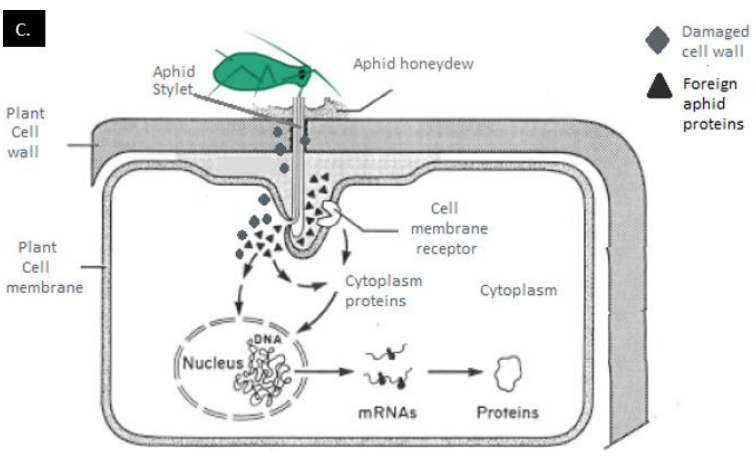
Disease causing organisms can secrete enzymes such as cellulase to breakdown and damage the cellulose plant cell wall. Some organisms can secrete proteins which attach to receptors in the plant cell membrane and trick the plant into letting them inside the cell and then either cause further cell damage or activate the plant cell immune system.

Proteins in the plant cell membrane and cytoplasm can detect when its cell wall has been damaged and plant cells may make more carbohydrates to try rebuild the wounded cell wall. The nucleus of the plant cell can respond quickly by transcribing new genes which are then translated into active proteins to try to fight off the attack. Plant cells may also make and secrete hormones to signal to other cells about the attack, or the cells under attack may make enzymes or release toxic molecules from the vacuole to try to kill the attacking organism.

The chloroplasts and other organelles start to break down and burst open as the plant cells die. The breakdown of chlorophyll in the chloroplasts means that plant cells lose their ability to photosynthesise and lose their green colour and start to undergo the process of senescence, changing colour through to yellow and brown (think of a banana ripening). This colour change is a marker of cell death and scientists think that plants breakdown the compartments in their cells so that the micro-organisms can no longer survive inside them or use the cell for their own gain. This type of plant cell death is called programmed cell death.

Figure 5

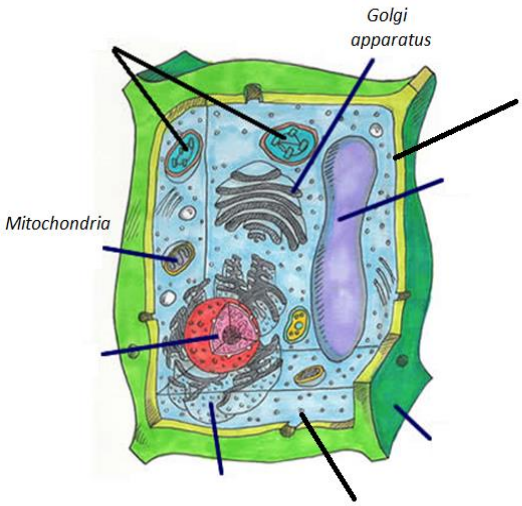
Plant cells and disease



Resource Two Activities

Activities

1. Below is a diagram of a plant cell. Try to fill in the remaining seven unlabelled structures and organelles of the plant cell.



Nucleus *Cell membrane* *Cell wall*

Chloroplasts *Ribosome* *Endoplasmic reticulum*

Vacuole

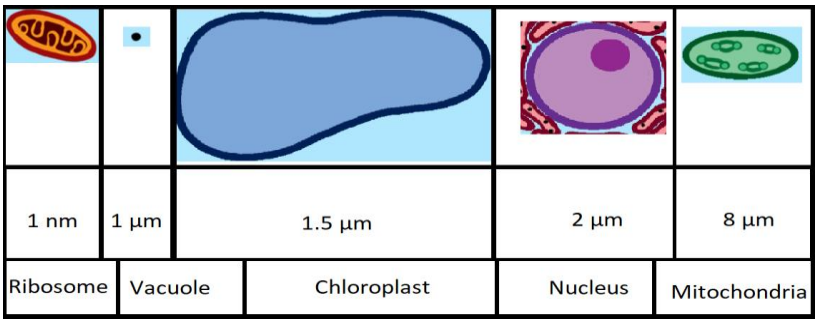
2. Match the organelles to their functions. One has been done for you.

Cell wall	Translates RNA into proteins.
Cell membrane	Site for Photosynthesis. Absorbs light energy to make chemical energy by making carbohydrates.
Cytoplasm	Contains stored chemicals and toxic compounds and releases them when the cell needs them.
Nucleus	Selective membrane which contains receptors and controls what molecules enter and leave the cell.
Chloroplasts	Maintains cell shape, gives strength and ability to hold water. Physical barrier against pathogens.
Vacuole	Contains DNA. Releases genes which encode for antibacterial proteins during pathogen attack.
Ribosomes	Contains proteins which do reactions such as enzymes and other signalling molecules.

Resource Two Activities

Activities

3. It is an important skill in Biology to be able to measure the sizes of cells and structures within them as seen in a microscope. Size and appearance of organelles are two ways we can tell them apart. Arrange and label the following plant organelle names, pictures and sizes from smallest to largest. Remember: 1mm is 1000 times bigger than 1µm. 1µm is 1000 times bigger than 1nm.



4. Using figure 4, explain why you can see plant chloroplasts in a light microscope but cannot see the mitochondria despite them being similar sizes.

5. Use the equation below to work out the actual size of a plant cell. The plant cell in a photograph measures 1.2 mm across. If the magnification in the photograph is x100, what is the actual size of the plant cell?

   Actual size = measured size/magnification

   Actual size = _____ mm

6. Using picture 5 and the text, state five actions a plant cell might do when it recognises it has been eaten by an insect pest or is being attacked by a disease-causing pathogen. Try to include which organelles are involved and what the plant hopes to achieve by these actions.

Resource Two
Further Reading

Explore

- activities to complete about plant cells and their organelles:

https://www.footprints-science.co.uk/index.php?type=Plant%20and%20animal%20cells&section=Section2&info=3

- history of plant disease and how pathogens effect plants:

https://www.britannica.com/science/plant-disease

- How to make your own model plant cell.

https://sciencing.com/make-plant-cell-model-stepbystep-7724993.html

- Look under a microscope at plant cell slides, you can make your own out of an onion, or by cutting a thin slice of a stem and putting it flat on a microscope slide. Try to draw the cells and work out the sizes of the cells you can see using the equation given above using the known magnification on your microscope.

Resource Three Overview

Topic

Plant tissues and their function

GCSE Modules

Cell specialisation, Principles of organisation, Plant tissues, Plant organ system.

Objectives

After completing this resource, you should be able to:

- ✓ recap how tissues are organised to make up the leaf organ.
- ✓ explain how stomata controls water status of the plant.
- ✓ recap xylem and phloem as tissues of the stem.
- ✓ explain how aphids cause damage to the leaf tissue layers.

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading

Resource Three
Data Source

Section A

Plant tissues

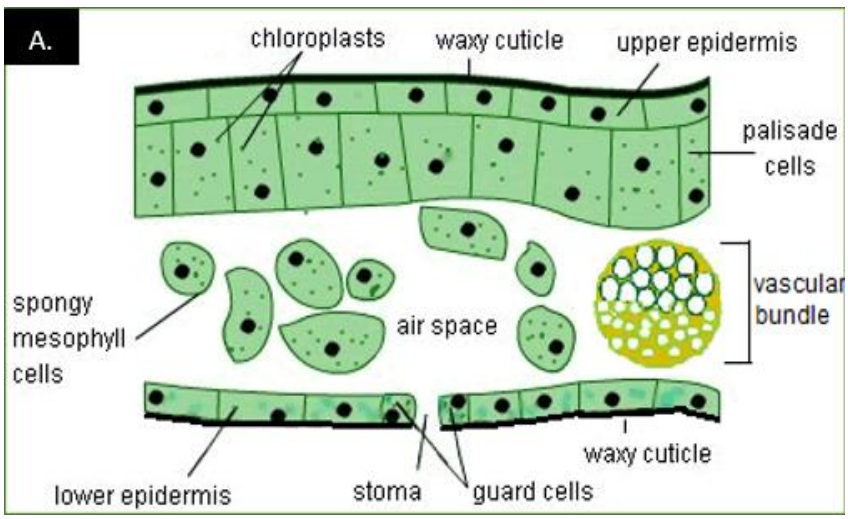
Cells are packed together to form layers. Plant cells may become specialised cells to adapt them for a given function depending on where they are located in the plant. Cells with a common function are grouped together to form tissues. The leaf is an organ made up of several leaf tissue types which are all in some way adapted for photosynthesis, which is the main job of the green leaves of a plant.

On the top and bottom outer surface of a leaf is a waxy cuticle. This is not a layer of cells but a layer of wax which is made by the upper and lower epidermis and secreted to form a new layer. The cuticle wax is waterproof and keeps the water inside the plant, it is also reflective, so it allows light to pass through into the leaf to reach the cells. As it is the outermost layer of the leaf it is the first boundary that insects and pathogens come into contact with and is considered to be a protective layer for the plant. Some plants have waxy surfaces which are slippery so insects may fall off.

The upper and lower epidermis are found on the upper and lower parts of the leaf beneath the secreted wax cuticle. These are the layers you would see if you looked at either of the top or bottom surface of a leaf under a microscope. The two epidermal layers form a barrier to stop pathogen entry on either side of the leaf but again still allow light to pass through for photosynthesis.

Figure 6

Plant cells and tissues

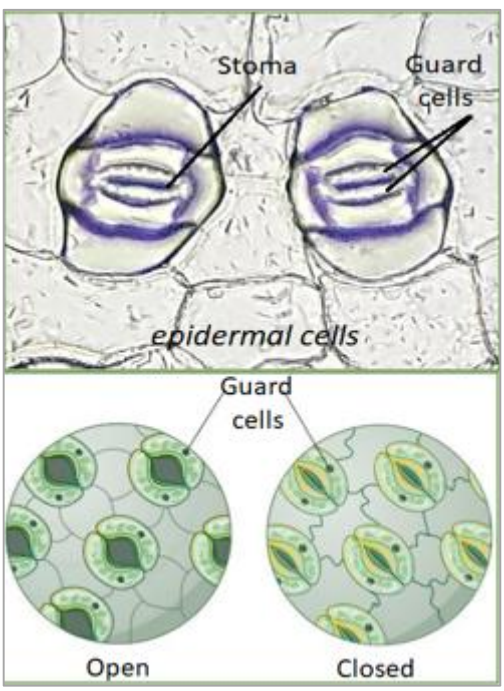


Resource Three
Data Source

Both the upper and lower epidermis contain stomata (singular – stoma) which are small holes which allow CO2 and O2 in and out of the leaf. The lower epidermis has many more stomata than the upper surface and the stomata are surrounded by two guard cells which are specialised cells shaped like kidney beans. The level of water in the guard cells (called turgor) determines whether the guard cells are stretched (full of water which opens the hole) or flaccid (closes the hole). The cell wall of guard cells are thicker on the inside restricting the movement at the stoma and when full of water the outer walls bend outwards because the cell wall is thinner and more flexible. The stomata are used by plants to control the amount of water lost as water vapour to the environment which also drives more water up the stem to the leaves, from the roots. When plants experience drought and the guard cells are flaccid the holes remain closed to conserve water. In the day when plants are photosynthesising the holes are open to allow for gas exchange, and they close at night when there is no light available for photosynthesis.

Figure 7

Stomata



Resource Three
Data Source

Deep Dive

On the top surface, underneath the upper epidermis are the palisade mesophyll cells. These are stacked upright in a single layer and packed full of chloroplasts to maximize photosynthesis. These cells are positioned to capture the most light and contain more chloroplasts in their cells to convert CO2 to carbohydrates.

In the centre of the leaf are the spongy mesophyll cells which are packed loosely to allow more surface area for CO2 to move into cells and O2 produced by photosynthesis to move out. The air spaces allow gas to flow out of the stomata and into the atmosphere. The centre of the leaf contains vascular tissue composed of xylem and phloem. The vasculature of the leaf ensures that the leaf receives water and nutrients from the roots via the stem, and that the sugars made by the leaf are transported to other tissues of the plant.

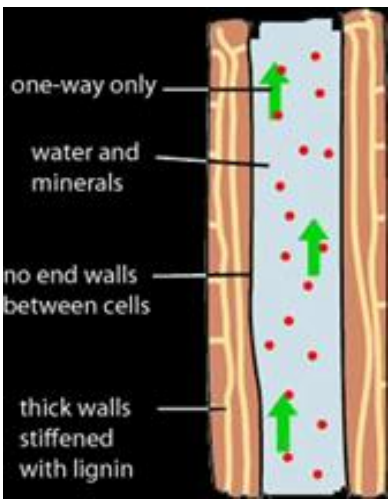
Section B

Xylem and phloem

The stem is an organ specialised for transport. It is made up of xylem and phloem vascular tissue. Xylem vessels transport water and absorbed minerals via the transpiration stream from the roots up the stem and into the veins of the leaf. Transport through the xylem is considered to be one directional starting at the roots and providing a water source to photosynthetic tissue such as leaves. Xylem vessels are slotted on top of each other to form a tube with the ends of walls removed to form a continuous channel. They are adapted to carry large amounts of water and when mature are dead cells.

Figure 8

Xylem



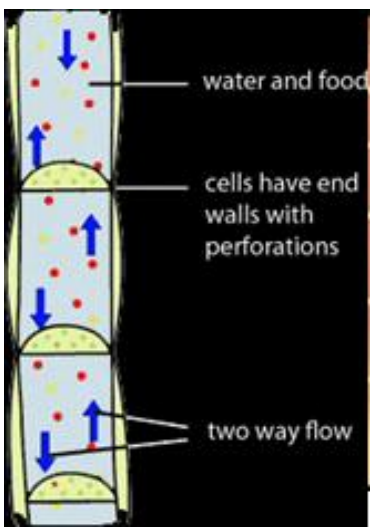
Resource Three
Data Source

Xylem vessels do not contain a nucleus so that they have more cytoplasmic space available to carry water. Like other plant cells they have a primary cell wall, but xylem tissue also has an extra layer called the secondary cell wall. The secondary cell wall is composed of lignin which provides extra thickening and mechanical strength to the stem which has to both support the whole plant upright and has the pressure of carrying large amounts of water. Lignin is what gives tree bark the brown appearance and in trees secondary cell walls are added every year to give the rings which can be seen on a tree stump.

Phloem is arranged next to the xylem and runs inside the stem. Phloem tissue transports dissolved sugars, amino acids and hormones around the plant. Sugars made by the leaf must be transported to other areas of the plant, which may not photosynthesise but still require energy. The plant may also need to transport sugar and amino acids to new leaves, which are growing and not yet able to photosynthesise. Therefore, phloem tissue moves molecules in both directions, both down to the roots and up to new leaves and flowers. This process is called translocation, movement of molecules from where they are made to another tissue, where they are needed for growth and repair. Phloem tissue is living, the cells contain nuclei and have walls between each stacked cell which have holes like a sieve to allow selected molecules to move between cells.

Figure 9

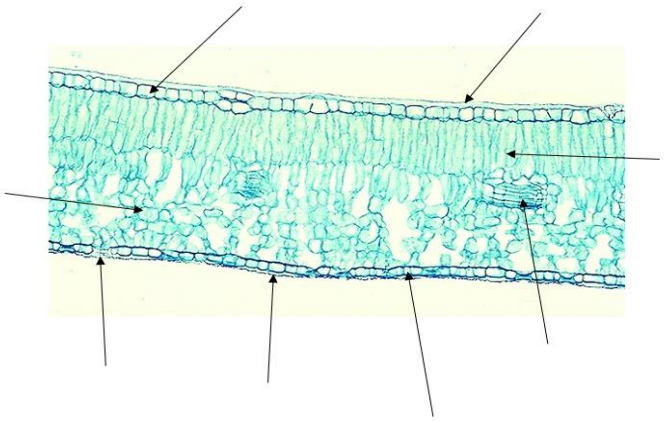
Phloem



Resource Three Activities

Activities

1. Identify and label the cell types and structures in this thin slice through a real leaf.

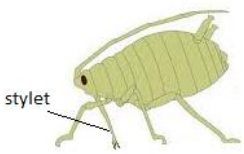


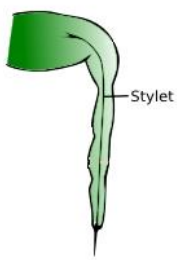
2. Explain the functions of each tissue type and how each of the following tissue types are adapted for their functions:

    - Waxy cuticle –
    - Upper epidermis –
    - Guard cells –
    - Palisade mesophyll cells –
    - Spongy mesophyll cells –

3. Use figure 6 and the text to draw a diagram of the leaf with its different layers using a pencil. Leave some space at the top of your drawing as you will be adding to it.

4. An aphid is a pest which uses its stylet mouthpiece to penetrate a leaf and navigate to the phloem to feed on sugar (see resource 1) . Below is an aphid and an image of its needle-like stylet. Draw an aphid on the surface of your leaf. Draw where its stylet would need to stab into and where it would need to go. Think about the different cell layers it needs to penetrate. You may need to rub out some of your drawing to make way for the insect's stylet.





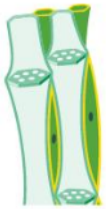
Resource Three Activities

Activities

4. Fill in the gaps in the text below about the xylem and phloem tissues in the stem.

Xylem

The _____ carries water and _____ from the _____ to the leaves and is described as being _____. The water flows via the _____ stream. The cell walls are toughened by _____ and the vessels are _____ and _____ to water.



Phloem

The _____ carries sugars and _____ acids around the plant. The process of moving food substances around the plant is called _____. Phloem vessels are _____ and move substances from tissues which make it called the _____ to tissues that need it, called the _____.

Sink, phloem, dead, living, amino, impermeable, roots, lignin, translocation, minerals, transpiration, source, xylem, uni- directional.

Resource Three
Further Reading

Explore

Independent research

Take a daffodil or white chrysanthemum flower. Place it on a cutting tile and use a scalpel to cut down the middle of the stem longitudinally until you are about 10cm from where the flower starts. (You will need a teacher with you for safety reasons). Stand each half of the stem in a test tube in a rack and secure it with a clamp stand/elastic band. Get two different food colourings (blue and red work well). A type called Kopykake works the best. Add a small amount of colouring to water in each test tube. Observe the flower for the next 24 hours. You will see how the water moves from the bottom of the stem up the xylem to dye the flowers.

- how leaves are adapted for different climates.

https://www.mrgscience.com/yr9-topic-5-plant-structure-and-photosynthesis.html

- revision on xylem and phloem.

https://www.bbc.com/bitesize/guides/zps82hv/revision/1

- quiz about xylem and phloem.

https://www.educationquizzes.com/gcse/biology/unit-3-xylem-and-phloem/

- further information about phloem cells.

https://moodle.beverleyhigh.net/mod/resource/view.php?id=6100

- video about transport in plants

https://www.stem.org.uk/resources/elibrary/resource/35131/plant-transport

Resource Four Overview

Topic	Plant defence
GCSE Modules	Cell specialisation. Plant tissues. Communicable diseases. Detection and identification of plant diseases. Plant defence responses.
Objectives	After completing this resource, you should be able to: ✓ recognise that pathogens and pests have their own methods to avoid or deal with plant defences ✓ recognise that plants have different susceptibility to different pests and pathogens. ✓ recognise that symptoms can be visible and we can measure them to tell us how badly a plant has been affected by a disease.
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

Resource Four
Data Source

Section A

Pathogens and pests

Pathogens can directly cause damage or enter a plant through a wound on the plant surface. Pests like insects or larger herbivores such as grazing sheep, goats and cows also eat plants and plants have many types of defences to repel them or kill these types of organisms.

Figure 10

Pathogen and pest examples

Section B

Physical barriers

You have already learnt about some of the physical barriers that plants have to protect against attack.

Deep Dive

- The cuticle is the waxy outer layer which is thickened in some exotic plants both to help with less water loss through transpiration and to provide a thicker covering against insects.
- The cell wall made of cellulose is another obstacle for the challenging pathogen to pass. In trees, the xylem tissue of the stem secretes a secondary cell wall made of tough material called lignin. These thickened cell walls make the bark of the tree, which is added to each year to form rings and gives the trees more added layers of protection against insects and pathogens.
- The cell membrane around the epidermal cells facing the outside of a leaf also limits what can come in and out of the cells by forming a selective membrane.
- The stomata of leaves can be controlled by the plant when water is plentiful or scarce, by changing the amount of water in guard cells, which changes their shapes and consequently, the hole in between the cells widens or shrinks. Plants can also close their stomata when pathogens are detected, to stop them from using the holes as a gateway to penetrate into the cells below.

Resource Four
Data Source

Some exotic plants such as the pitcher plant or venus fly traps have extreme ways to control insects and actually prey on them so are called carnivorous plants. Pitcher plants attract insects with sweet-smelling nectars, trapping them in their very thick, waxy cuticle and then letting them fall into a sack full of digestive fluid to be degraded.

Plants have specific structures or modified cells which aid them in defence. Some plants have hairs on the surface of leaves called trichomes which are extensions of the epidermal cells which can be made up of a single cell or a collection of cells which are specialised for insect and pathogen defence. The trichome barrier looks like a furry layer made up of stiff hairs which forms a physical barrier for small organisms such as fungi and flies which cannot get through it.

Figure 11

Trichomes visible on a plant

Trichomes can also be glandular, which means they are able to produce and secrete chemicals. Trichomes of the tomato plant can produce sticky substances which can trap organisms. Some other plants can make toxic substances to repel organisms. Some chemicals made by the trichome, once ingested by an organism can slow their growth or stop the next phase of their lifecycle, making them weaker, less able to further attack the plant and more likely to become diseased or eaten by an organism which preys on them. Plants are also able to recognise when a pathogen is attacking them and can make new leaves with more trichomes on them for more defence.

Resource Four
Data Source

Nettles are another example of a plant which contain trichomes on their leaves and stems. When nettles sense movement the tip of the trichome easily falls away to reveal a needle structure which can penetrate into a nearby organism or herbivore and release weakly acidic chemicals to cause a sting. This is a good example of a plant defence strategy which also repels the human hand.

Other modified structures which provide physical defence include spines and thorns. Thorns are found on the stems of roses and are sharp and stab larger herbivores. Spines are modified leaves and are characteristic needle-like features of cacti. Leaves can also have sharp, pointy edges, for example the holly bush leaves or the aloe vera plant which has teeth-like edges along the margins of the leaves.

Figure 12

Teeth-like edges on a plant

Section C

Chemical defences

Some plants make chemicals which have properties that aid them in defence. Tomato plants for example make compounds which you can smell and these gases act as a deterrent for some organisms. Some plants make strong smelling compounds when the tissue has been damaged such as through feeding or wounding, this signals to other plants there has been an attack. Onion plants make strong-smelling compounds when damaged which irritates the attacking organism (in the case of humans, it makes our eyes water).

Resource Four
Data Source

Some plants make toxic compounds which repel insects and effect the insect nerve system. Chrysanthemum flowers make a chemical called pyrethin which deter insects and has been extracted and used to make agrochemical sprays to warn off insect pests. There are some plant chemicals which cause severe vomiting and are poisonous to pets or humans such as nightshade or hemlock. Plants such as aloe vera can make antiseptic compounds, which can kill potential pathogenic bacteria and viruses. Plants can also make antimicrobial proteins which can kill bacteria and fungi by entering into their cell membranes and causing their cells to burst.

Section D

Sensory defences

Movement can trigger some of a plant's armoury. In venus fly traps, the trichomes on the inside of the traps 'feel' the insect movement and triggers a closing mechanism. In the nettle example, the movement caused the loose end of the trichomes to expose the sharp needle.

Plants can use colourful flowers and sweet-smelling nectar to attract pollinators. They also use chemicals to attract predators which eat the prey organism feeding on the plant. Ladybirds can be attracted by a plant through the release of gases during an aphid attack to bring ladybirds to the plant to control the aphid population.

The passionflower has natural patterned, pigmented spots on its leaves which look like butterfly eggs. This adaptation deceives butterflies into thinking they have already laid their eggs on the leaf which deters them from laying their eggs 'again' and prevents all their newborn larvae feeding on the leaf material. This strategy of plant defence is called mimicry.

Figure 13

Mimicry in the passionflower

Resource Four Activities

Activities

1. Draw your own picture of a 'Super plant' which has been mutated to include as many defences on it as you can think of. Make sure you label the parts of your plant that help defend it and include how each part helps it fight off insects/animals or micro-organisms.

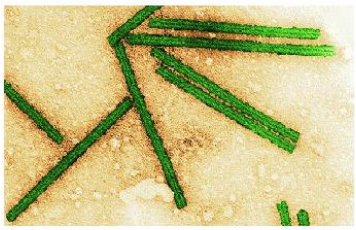
2. Give 3 examples of chemical defences that plants have developed against pests/pathogens and herbivores.

3. Just as plants have developed strategies to defend against pathogens and pests, pathogens and pests have their own defences. Match up the images and labels below to the disease-causing pathogen or pest. There are also some statements about the plant defence and some statements about how the organisms get around the defence. Try to match these up to the appropriate organism.

Tiny pathogens which cannot pass through the cuticle, cell wall or membrane.

Small enough to penetrate through stomata

Prefer to probe stylet into smooth leaves



Bacteria & Fungi

Aphids

Viruses

Secrete compounds which force the stomata to stay open or prevent the plant closing them.

Avoid leaves with trichomes or hide on the underside of leaves

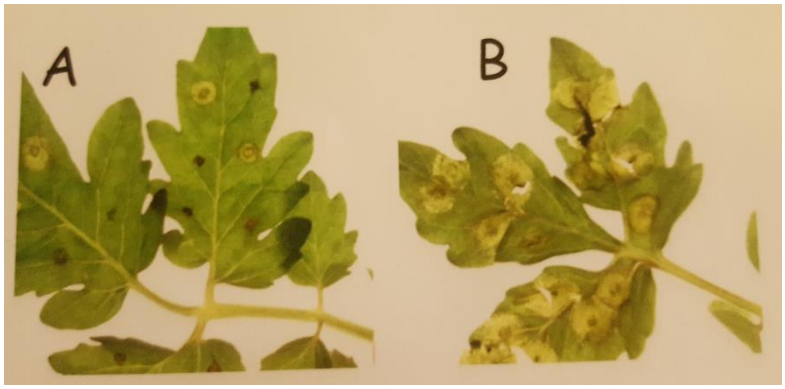
Are carried into the plant by insect saliva and wounds

Resource Four Activities

Activities

4. Spot the difference between the two leaves below.

5. The images A and B below show leaves from two different species of tomato plants which have been infected with a fungus called Botrytis for 48 hours. Botrytis causes yellow and brown lesions on the leaf surface. The lesions are shown by the arrows.



a. Use a ruler to measure the diameter of the lesions (the length across the width of the lesion). Measure the diameter of any 3 lesions on each of the leaves and calculate the average lesion diameter for each plant.

b. The plant leaf on the left (A) is more resistant to the disease-causing organism. Suggest a reason why this plant might be more resistant?

c. The plant leaf on the right is more susceptible to the disease-causing organism. How do we know this and why do you think this may be?

Resource Four
Further Reading

Explore

- Very good video outlining methods of plant defence.

https://www.youtube.com/watch?v=Hja0SLs2kus

- Video which goes into more detail about chemical defences.

https://www.youtube.com/watch?v=ZRxVjuVR4YM

- news article giving more information and depth about pathogen defences. It is not expected that you understand all of this article at GCSE level.

http://www.global-engage.com/agricultural-biotechnology/stomata-and-wounds-constant-dilemma-pathogen-infection/

- news article giving more information about plant defences and pathogens. It is not expected that you understand all of this article at GCSE level.

https://phys.org/news/2018-12-news-hormone.html

- Practical experiment: plant adaptations and how nettles sting.

http://www.saps.org.uk/secondary/teaching-resources/869-investigating-leaf-adaptations-why-do-nettles-sting

Resource Five Overview

Topic	Protecting plants
A-Level Modules	Plant tissues, Plant organ system, Communicable diseases, Factors affecting farming, Farming techniques
Objectives	After completing this resource, you should be able to: ✓ appreciate that climate change might affect health of food and commodity crops. ✓ understand the nomenclature for different pesticides is based on the type of organism it targets. ✓ understand the use of chemicals in the farming industries and some of the positives and negatives. ✓ appreciate the inefficiency of spraying chemicals and the role of adjuvants to help. ✓ give examples of biological control methods in organic farming.
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

Resource Five
Data Source

Section A

Plant protection

Deep Dive

Plant protection is the modification of farming techniques to try to improve plant health, particularly of crop plants needed for food including: fruit, vegetables, salad and cereals or commodities such as cotton, coffee. As the world population is increasing, there are more people to feed and less land available to do it. As climate change causes more unpredictable weather, we are starting to see more droughts due to less rainfall at some times, more flooding due to high rainfall at other times and generally higher temperatures causing heatwaves for longer. It is expected that food crops will be negatively affected by these changes and scientists are working very hard to work on ways that we can produce more food with less land and less water.

Increasing global temperatures means that we may face more issues of pathogens and pests in the future. Fungi require high temperature and wet conditions to reproduce and make spores to spread disease. Aphids are killed off by frost periods and without this, would continue to reproduce quickly and damage more crops for longer. Pests and pathogens might also start to become successful in areas which they weren't previously found as the conditions were previously unsuitable.

Growing food crops is already problematic as disease can spread quickly when the same plant type is grown close together on a piece of land or if a pest/pathogen finds its way into a greenhouse. Many of our food crops are also not well adapted to cope with pests and pathogens and don't have the correct defences to fight them off. Currently, on average about 35% of total food crops which could help feed the population is lost due to pests and disease.

Figure 14

Lost crops

Resource Five
Data Source

Section B

Chemicals

One method which has been used by farmers for the last 70 years is the use of agrochemical sprays. These are chemicals which inhibit or kill insects, fungal, bacterial or viral pathogens or kill other plants (weeds) which grow faster and outcompete our crops of interest. These different chemicals are grouped according to what they kill for example: insecticide, fungicide, bactericide, insecticide, virucide and herbicide all use the root word from the organism they target and use the suffix -cide which means to kill. The group of all these chemicals together are called pesticides as they kill one plant pest or another.

Pesticide sprays are sprayed either on the soil or onto the plant leaves. When spraying the soil the pesticide needs to be dissolved in water so that it is soluble and taken up by the plant roots and transported to the rest of the plant. If the pathogen or insect is damaging the leaves this is a slow process to get the chemical to where it needs to be in large enough amounts to be able to work. An additional problem is that useful micro-organisms or insects such as worms in the soil may be killed by the pesticide sprays. Spraying the leaves can be more beneficial if the pest or pathogen targets the leaves, if there is limited water in the area or the chemical is not soluble in water. Spraying the leaves has its own problems, one of the main ones being that plants naturally have defences such as the waxy cuticle, cell walls and cell membranes to limit which chemicals can move in so it is not easy to get chemicals into the leaves without understanding more about the types of chemicals that plant leaves absorb and which they allow to penetrate through them.

Spraying crops is a very wasteful process. Many droplets from the spray are vapourised into water vapour and don't reach the target leaf/soil. Some of the droplets may run off the leaf or be carried by wind and be lost to the environment. On a wet day when leaves are already wet, the spray droplets cannot stick to the leaf and run off more easily. Harsh chemicals lost to the environment may end up in water sources and damage aquatic organisms or they may accumulate in soils and kill soil organisms.

Resource Five
Data Source

Section C

Adjuvants

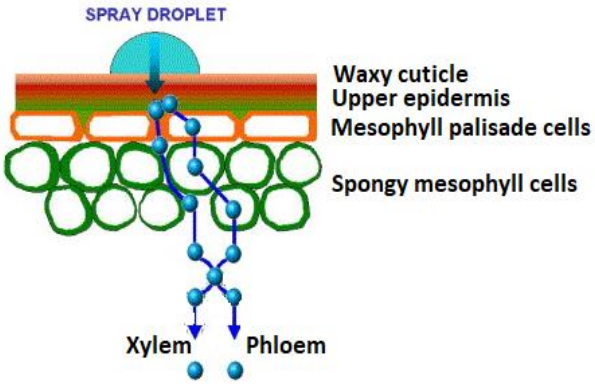
One way to make the spraying process more efficient is to use adjuvants with pesticides. Adjuvants are additives which help the pesticide reach its target location so that it can work better at killing the target pest. If powdery mildew is on the leaves, then the fungicide needs to be in contact with the fungus on the leaf so a farmer might need to use an adjuvant which helps the fungicide stick to and spread over the leaf to give high surface area of coverage. Glycerol is a good example because it is very thick and sticky and retains water well.

Aphids poke in their stylet and feed from the phloem so in this case a farmer might use an insecticide spray with an adjuvant to help it penetrate into the leaf quickly and get into the phloem of the leaf and stem and to kill aphids as they feed from the phloem sap.

To understand absorption and penetration we need to understand how chemicals behave on the leaf. Do they get absorbed quickly or slowly, in large amounts or small amounts? Do they through the cuticle or do they come in through areas of the leaf near to stomata? We also need to know how transport around the plant works. Is the chemical soluble enough in water to be able to be transported with water in the plant cells via osmosis? Finally, we need to know how quickly all of this happens and how well it helps with plant protection against attacking pests and pathogens.

Figure 15

Spray droplet on a leaf



Resource Five
Data Source

Section D

Biological control

Another way that organic farmers might try to control a pest or pathogen infection is to use other live organisms. Organic farming is defined as using methods of farming which don't use any chemicals. This way of farming is becoming more popular especially because pests and pathogens can develop resistance to chemicals which means they are able to avoid being killed by them.

Using natural predators is one way of biological control. Aphids are eaten by ladybirds so by planting plants nearby that are a habitat for ladybirds, the predator/prey relationship can be used to lower the population of aphids. Farmers can also use micro-organisms as a method of biological control. Different species of a bacteria called Bacillus which are harmless to plants, make natural toxic compounds which can kill feeding insects like butterfly and moth larvae so the products made by Bacillus can save plants under attack. Certain types of fungi are also able to reduce moth pests on crops. A fungus called Trichoderma is safe to plants but releases toxic compounds to kill pathogenic fungi harming the plant.

The biggest problem of using biological organisms as a leaf spray to help with pest and pathogen problems is that the micro-organisms need to be kept alive. The micro-organisms can be damaged on the leaf in times of high temperatures and UV light which dry out and damage the cells, so they no longer work. New research is focusing on adjuvants which come from nature that can be added to biological organisms which help them retain moisture or protect them from UV light.

Figure 16

Ladybirds as a form of biological control

Resource Five Activities

Activities

1. How might climate change negatively influence plant health?

2. Match up the following organisms which cause problems for food crops with their labels and the type of pesticide that farmers would use to kill them.

Aphids

Japanese knotweed

Powdery mildew

Slug

Tobacco mosaic virus

Xanthamonas

Herbicide

Virucide

Molluscicide

Bactericide

Fungicide

Insecticide

3. Describe how chemical droplets from a spray bottle: a. get to the leaf and b. get into the phloem. Include the different tissue types of the leaf to describe this process.

4. Why would a farmer decide not to spray infected plants with a chemical spray on a wet and windy day?

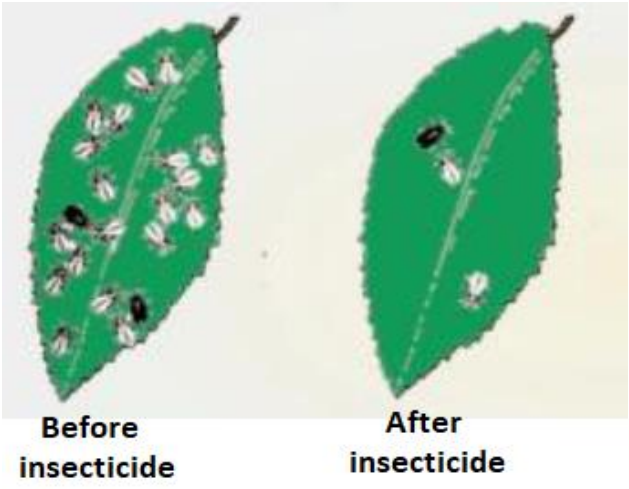
5. What is the purpose of using an adjuvant?

6. What is biological control of plant protection? Give examples in your answer.

Resource Five Activities

Activities

7. Below is an image of a leaf before and 24hours after insecticide spray treatment.



a. How many black insects are on the leaf before and after treatment?

b. How many white insects are there on the leaf before and after treatment?

c. Which insect species did this insecticide control the best and how do you know this?

d. Suggest a reason why some of the insects have not been killed by the treatment?

e. What other methods might a farmer use to try and kill the remainder of the insects?

Resource Five
Further Reading

Explore

- History of using agrochemicals in farming

https://agrochemicals.iupac.org/index.php?option=com_sobi2&sobi2Task=sobi2Details&catid=3&sobi2Id=31

- Recent news article detailing new types of garden pests in the U.K and Europe.

https://www.telegraph.co.uk/news/2019/01/17/gardeners-warned-never-before-seen-pest-covers-trees-unsightly/

- Extension activity: Make a poster and choose one of the following insects as a case study: caterpillars, vine weevil, thrips, gall mites, carrot root fly. Include a picture of your pest, where it lives, what its life cycle is, how it causes damage/disease, what plant it effects, what predators eat it, how farmers try to get rid of it and any other interesting information you can find about your pest.

Resource Six Overview

Topic	Methods to assess how well a pesticide/adjuvant works
GCSE Modules	Detection and identification of plant diseases

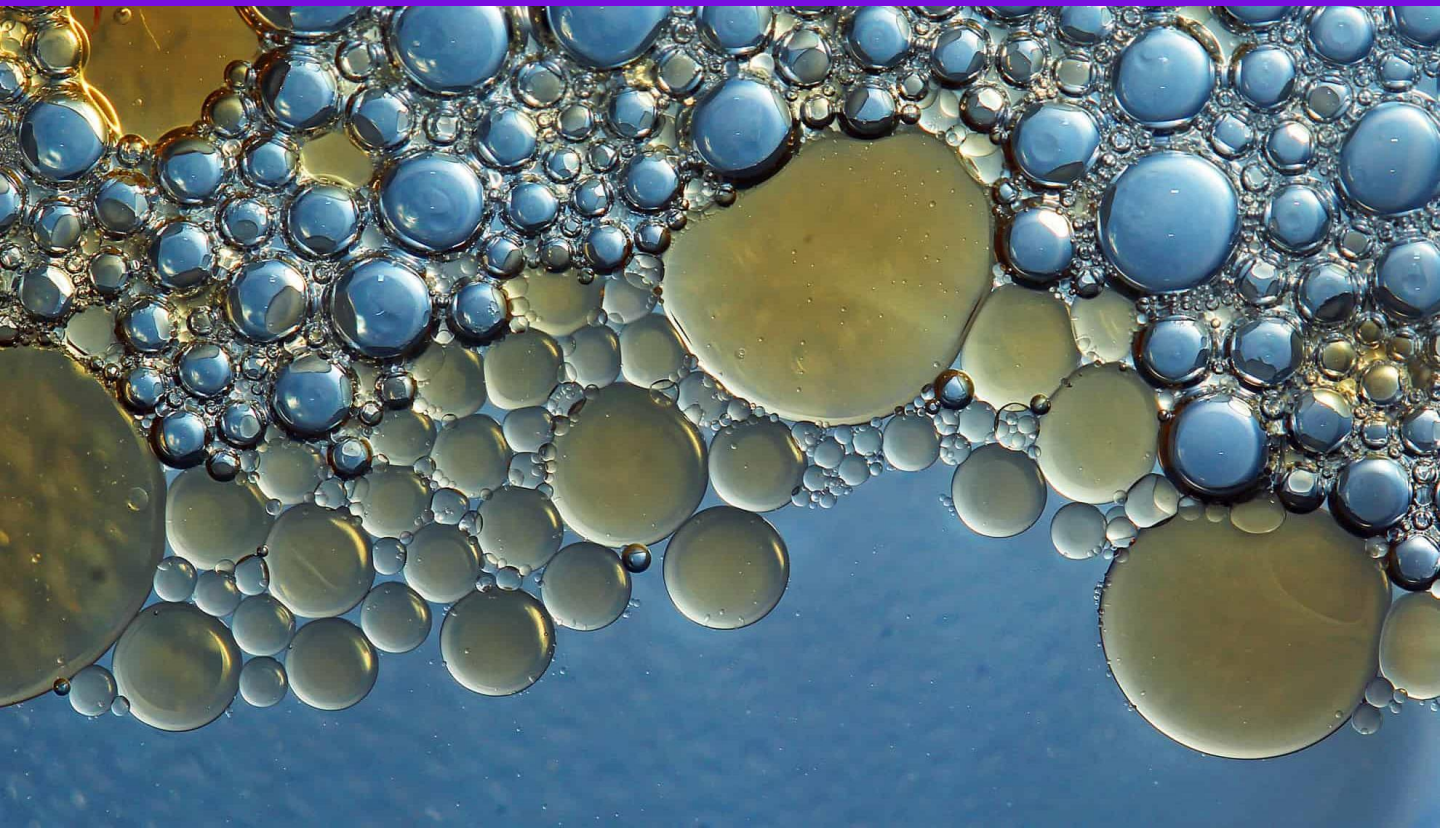
Objectives

After completing this resource, you should be able to:

- ✓ Understand that adjuvants are specific to the type of pesticide and infestation on the crop.
- ✓ Understand the use of thermal cameras and droplet drying time as a measure of time pesticides/adjuvants spend on the surface of the leaf.
- ✓ Understand the limitations of these techniques and why fluorescent molecules tell us more.
- ✓ Reinforce the idea of using insect counts and measuring damage on the leaf to tell us how well a pesticide treatment worked.

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading



Resource Six
Data Source

Section A

Pesticides and adjuvants

Active Reading

Pesticides are used to target pests and pathogens which cause damage or disease to a plant, especially food and commodity crops. These can be sprayed chemicals (pesticides) or sprayed biological organisms which defend the plant, these are called biopesticides. In resource 5 you will have learnt some examples of harmless fungi and bacteria that can be used to fight off pathogenic bacteria and fungi. You will have also been introduced to adjuvants which can be chemicals or biological products which are used to help the sprayed pesticide or biopesticide to reach its target location or function better or for longer. If a farmer wants to spray a biopesticide, a live biological organism, they would use an adjuvant which might help the cells stay alive for longer or stop them drying out. The adjuvant would have to not be harsh enough to kill the cells and would have to be organic if used in organic farming.

Section B

Droplets on a leaf

Different chemicals/biological products behave differently on the leaf surface and some basic Chemistry knowledge is needed to understand the absorption process. The waxy cuticle is the surface on the outside of the leaf and is a thick wax layer. Water cannot easily pass through a layer of wax because wax is a lipid and is hydrophobic (water hating) and water is hydrophilic (water loving). Therefore the wax and water don't mix and form two separate layers.

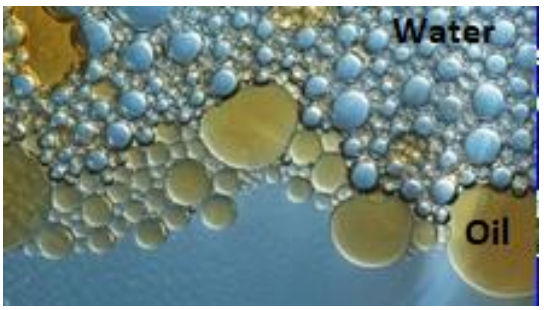


Figure 16

Left: Oil and water separated layers

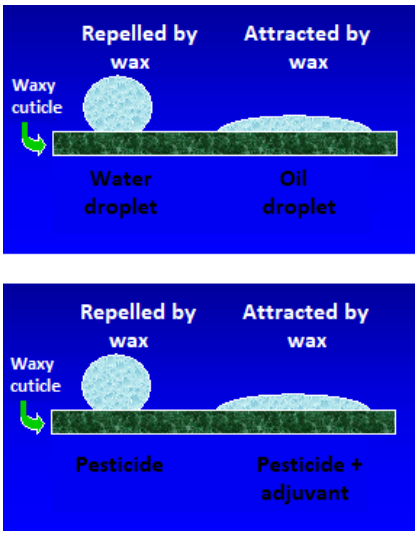
Right: A succulent plant which is adapted for dry conditions. The waxy cuticle layer is even thicker than any food crop and the leaves look wetter for longer

Resource Six
Data Source

The cuticle is designed to keep water in so this is what the plant has become adapted to do. Rain droplets of water stay as a droplet on the surface of the leaf until they evaporate or run off the leaf. Oil/lipid products are absorbed through the waxy cuticle more easily. Therefore if we want the adjuvant/pesticide to get inside the leaf we might use a lipid or oily adjuvant. If we want our pesticide/biopesticide to stay on the leaf for longer we might use an adjuvant which contains water or can take on water from the atmosphere.

Figure 18

Droplet behaviour on a leaf



Section C

Droplet drying time

To understand how well a droplet can get into the plant leaf we need to measure how long the droplet stays on the leaf. This can be done easily with a microscope, by watching the droplet dry and timing how long it takes. We can also use thermal cameras to visualise the droplet on the leaf surface and see how long it takes to become the same temperature as a leaf, an indication that the droplet has disappeared.

Neither of these methods can tell us how much is being absorbed or how much is being evaporated however so we still don't know how much is getting into the leaf. This only tells us the behaviour of the droplets on the leaf cuticle.

Resource Six
Data Source

Figure 19

Observing a drying droplet with a microscope

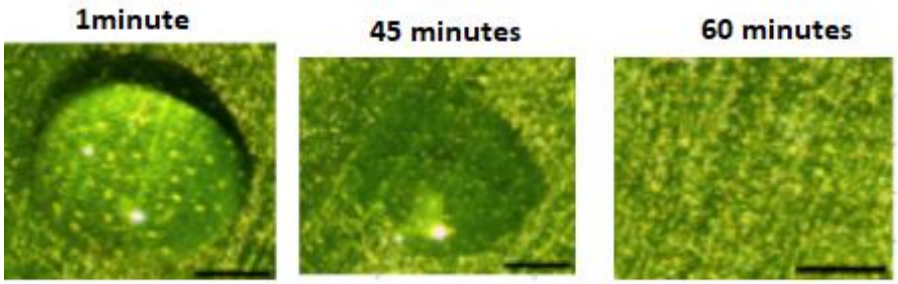
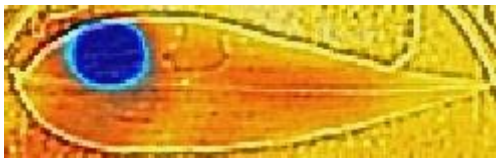


Figure 20

Observing a drying droplet using a thermal camera



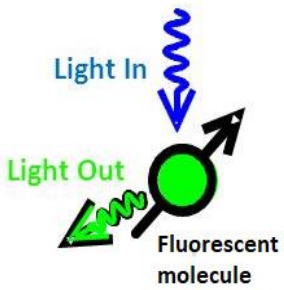
Section C

Droplet drying time

To be able to see how much is inside a leaf we need to use fluorescent molecules as we can't normally see chemicals when they're inside cells. This requires some basic Physics knowledge. To be able to see the pesticides/adjuvants, the pesticide or adjuvant need to either be fluorescent themselves or be used with a dye which is fluorescent. If using a dye it is a good idea to use a dye which doesn't normally go inside cells, and then if it does go inside we can say this is because of the adjuvant that has helped it. A fluorescent molecule is defined as a molecule which absorbs light at one wavelength and emits it at another wavelength giving us a visible colour we can see.

Figure 21

A fluorescent molecule in action

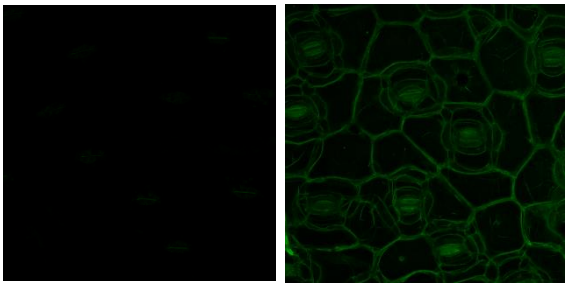


We can use fluorescence to tell us how well products can be absorbed by a leaf. Figure 22 shows the lower epidermis of the leaf. In the leaf on the left it is not fluorescent which means the adjuvant/dye could not pass through to the bottom surface. In the image in the right we can see that the cell walls of all the epidermal cells and the guard cells and

Resource Six
Data Source

Figure 22

Fluorescence study of a leaf



also the stomata all appear fluorescent so the fluorescent molecule must be present at the bottom of the leaf in these areas. The pesticide/adjuvant/dye must have moved from the top of the leaf where it was placed as a droplet, to the bottom of the leaf where it is being visualised here.

Section D

Checking that the pesticide/adjuvant works

The final step is to check if the adjuvant and pesticide help improve plant health and see whether they should be recommended to farmers for certain infestations. This can be done in the lab by spraying leaves with different adjuvant/pesticide products and then putting insects or fungi onto a plant leaf and seeing how many are killed or by measuring how much damage we can see on the leaf. In previous resources in this pack, you have already used these methods when you measured lesions on tomato leaves to compare a fungal infection, and you have counted insects before and after an insecticide treatment to see how successful the treatment was.

Resource Six Activities

Activities

1. What is meant by the terms hydrophobic and hydrophilic?

2. Which boundaries of a plant leaf are hydrophobic?

3. Explain why plants such as aloe vera or a jade plant appear to have wet leaves.

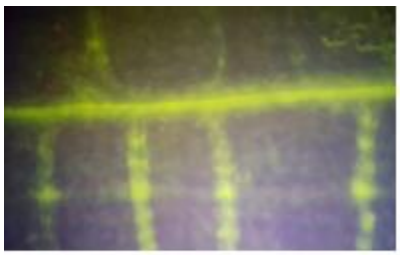
4. What can a thermal camera tell us about a chemical droplet on the leaf surface?

5. If a farmer had a problem with powdery mildew what type of pesticide would you recommend for the problem? Insecticide, fungicide, bactericide, herbicide or virucide?

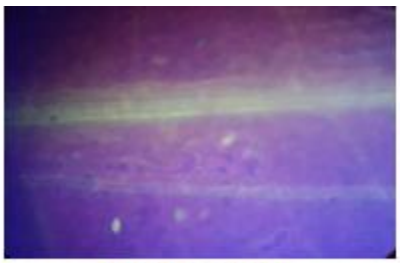
6. What are the limitations of watching droplets with a thermal camera or measuring droplet drying time on a leaf?

7. What advantage does using a fluorescent molecule give?

8. The images below are from the spongy mesophyll tissue of two leaves. You can see the vascular tissue (or veins) made up of the xylem and phloem. The leaves have been treated on the top surface with different adjuvants and a fluorescent dye which is not normally able to penetrate the leaf. The dye appears yellow when viewed with a microscope. Which adjuvant helped the dye penetrate the leaf tissue the best?



Adjuvant B



Adjuvant D

9. If a farmer had an aphid infestation and wanted to use an insecticide to kill the aphids by getting the insecticide into the phloem so that aphids were poisoned when feeding from the plant phloem. Explain which adjuvant, B or D, is best for the farmer to use?

10. How could you check that an insecticide had worked successfully for an aphid infestation?

Resource Six
Further Reading

Explore

- Sygenta is an industrial agrochemical company which has a branch based in the U.K. Take a look at some of the products they make and some of the species of vegetable and cereal crops they sell. Some of these are developed to be grown at different times of the year and have resistance against certain damaging pests/pathogens.

https://www.syngenta.co.uk/

- excellent place for lesson resources and practical ideas specifically for Plant biology in schools.

http://www.saps.org.uk/

- A good website to start learning about growing your plants.

https://www.rhs.org.uk/science

- There is talk that they may be bringing a new Eden project to the Morecambe region in the near future. Read this article to find out more!

https://www.independent.co.uk/news/uk/home-news/morecambe-eden-project-morecambe-bay-mussl-david-harland-cornwall-a8537126.html

This botanical garden in London and others across England inspired me to work in Plant science. Looking around at the amazing plant variety that exists really gets you thinking how wonderful the world of Plants can be and makes you wonder why each plant has evolved the way it has. I recommend visiting as many botanical gardens as you can!

https://www.kew.org/

Resource Six
Further Reading

Explore

Optional practical activities:

1. Take leaves from a succulent plant from your school collection and some other leaf types, maybe collect some from around the school grounds. Use a thin pipette to put the smallest droplets of water that you can on each leaf and time how long they take to disappear (you will probably need at least an hour to do this). On which leaves did the water stay on the longest and on which leaf did it disappear the quickest?

2. You could try adding different food colourings to the water (Kopykake red and blue dyes work well) then add the droplets to the leaves and leave them for 24 hours. After 24 hours you could turn the leaves over and see if you can see any dye from the food dye on the bottom surfaces.

3. Instead of using water use different chemicals to get an idea of which chemicals take longer to dry which is a combination of both evaporation and absorption. Perhaps try water, glycerol and sunflower oil and time how long the droplets take to disappear using a microscope. You could add three different colour dyes to these different chemicals and again after 24hours turn the leaves over and see if they have moved through to the bottom of the leaf. These results will vary with the types of chemicals, dyes and leaves used.

Final Reflection

Deep Dive

BROUGHT TO YOU BY RBC ACCESS ED

Topic Produce a poster about how plants are adapted to defend against pests and pathogens.

Objectives Include;

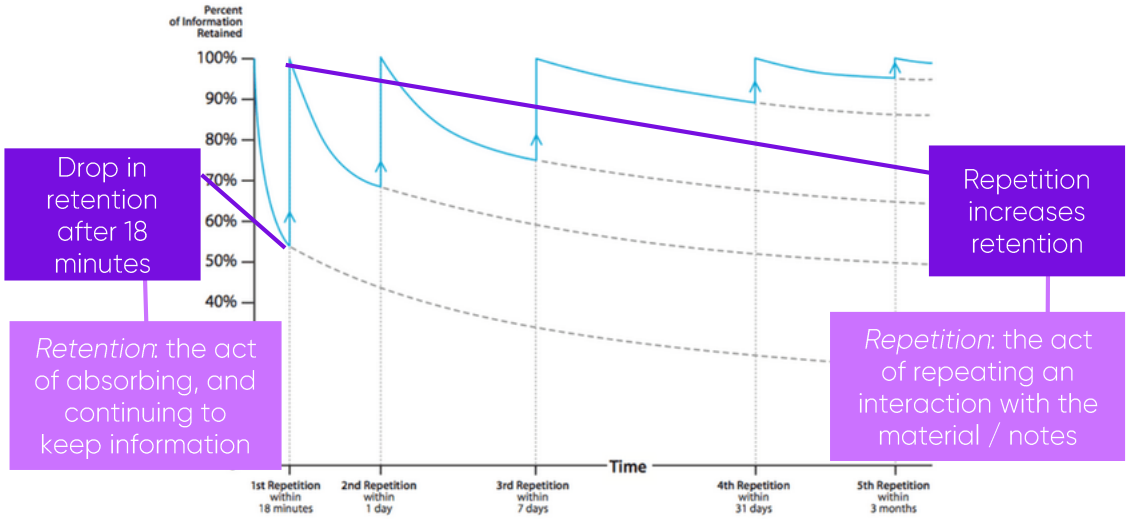
- ✓ examples of pests and pathogens which cause disease or damage to plants.
- ✓ the structure of plant cells and tissues and special protective features of plants.
- ✓ a description of what humans can do to help plant protection.

University Study Skills
Cornell Notes

Why is good note taking important?

If it feels like you forget new information almost as quickly as you hear it, even if you write it down, that's because we tend to lose almost 40% of new information within the first 24 hours of first reading or hearing it.

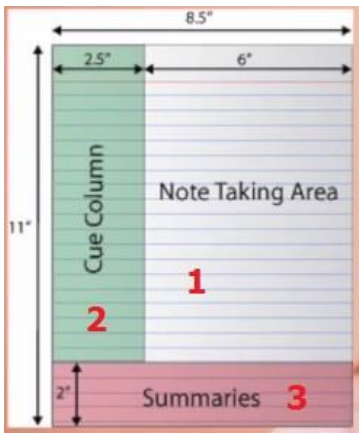
If we take notes effectively, however, we can retain and retrieve almost 100% of the information we receive. Consider this graph on the rate of forgetting with study/repetition:



Learning a new system

The Cornell Note System was developed in the 1950s at the University of Cornell in the USA. The system includes interacting with your notes and is suitable for all subjects. There are three steps to the Cornell Note System.

Step 1: Note-Taking



1. <u>Create Format</u>: Notes are set up in the Cornell Way. This means creating 3 boxes like the ones on the left. You should put your name, date, and topic at the top of the page.

2. <u>Write and Organise</u>: You then take your notes in area on the right side of the page. You should organise these notes by keeping a line or a space between 'chunks' /main ideas of information. You can also use bullet points for lists of information to help organise your notes.

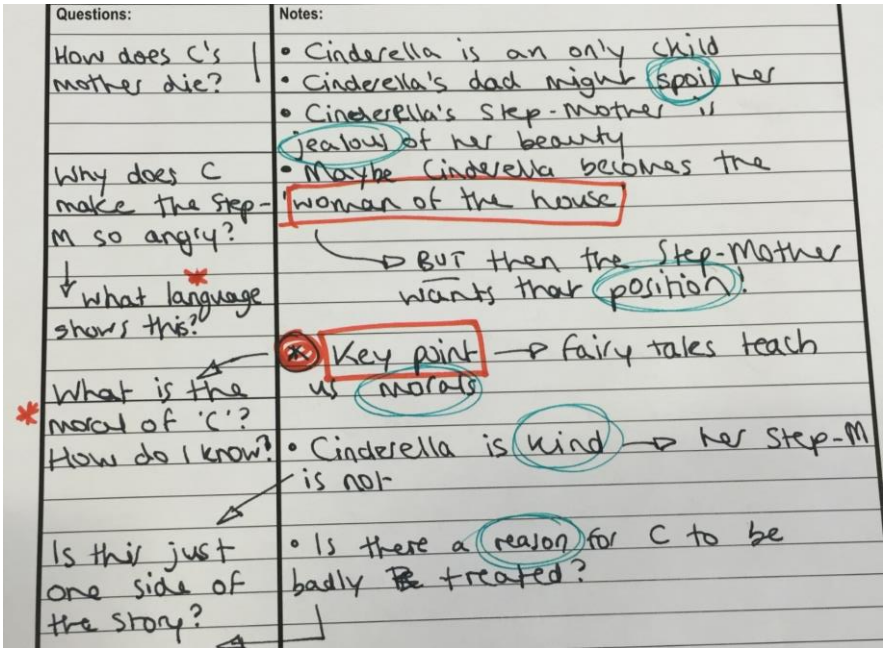
Step 2 Note-Making

1. Revise and Edit Notes: Go back to box 1, the note taking area and spend some time revising and editing. You can do this by: highlighting 'chunks' of information with a number or a colour; circling all key words in a different colour; highlighting main ideas; adding new information in another colour

2. Note Key Idea: Go to box 2 on the left hand side of the page and develop some questions about the main ideas in your notes. The questions should be 'high level'. This means they should encourage you to think deeper about the ideas. Example 'high level' questions would be:

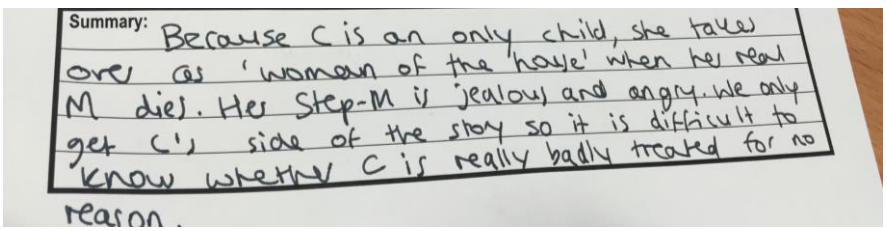
- Which is most important / significant reason for...
- To what extent...
- How does the (data / text / ideas) support the viewpoint?
- How do we know that...

Here is an example of step 1 and step 2 for notes on the story of Cinderella:



Step 3 Note-Interacting

1. Summary: Go to box 3 at the bottom of the page and summarise the main ideas in box 1 and answer the essential questions in box 2.



Give the Cornell Note Taking System a try and see if it works for you!

University Study Skills
Key Instruction Words

These words will often be used when university tutors set you essay questions - it is a good idea to carefully read instruction words before attempting to answer the question.

Analyse – When you analyse something you consider it carefully and in detail in order to understand and explain it. To analyse, identify the main parts or ideas of a subject and examine or interpret the connections between them.

Comment on – When you comment on a subject or the ideas in a subject, you say something that gives your opinion about it or an explanation for it.

Compare – To compare things means to point out the differences or similarities between them. A comparison essay would involve examining qualities/characteristics of a subject and emphasising the similarities and differences.

Contrast – When you contrast two subjects you show how they differ when compared with each other. A contrast essay should emphasise striking differences between two elements.

Compare and contrast – To write a compare and contrast essay you would examine the similarities and differences of two subjects.

Criticise – When you criticise you make judgments about a subject after thinking about it carefully and deeply. Express your judgement with respect to the correctness or merit of the factors under consideration. Give the results of your own analysis and discuss the limitations and contributions of the factors in question. Support your judgement with evidence.

Define – When you define something you show, describe, or state clearly what it is and what it is like, you can also say what its limits are. Do not include details but do include what distinguishes it from the other related things, sometimes by giving examples.

Describe – To describe in an essay requires you to give a detailed account of characteristics, properties or qualities of a subject.

Discuss – To discuss in an essay consider your subject from different points of view. Examine, analyse and present considerations for and against the problem or statement.

University Study Skills
Key Instruction Words

Evaluate – When you evaluate in an essay, decide on your subject's significance, value, or quality after carefully studying its good and bad features. Use authoritative (e.g. from established authors or theorists in the field) and, to some extent, personal appraisal of both contributions and limitations of the subject. Similar to **assess**.

Illustrate – If asked to illustrate in an essay, explain the points that you are making clearly by using examples, diagrams, statistics etc.

Interpret – In an essay that requires you to interpret, you should translate, solve, give examples, or comment upon the subject and evaluate it in terms of your judgement or reaction. Basically, give an explanation of what your subject means. Similar to **explain**.

Justify – When asked to justify a statement in an essay you should provide the reasons and grounds for the conclusions you draw from the statement. Present your evidence in a form that will convince your reader.

Outline – Outlining requires that you explain ideas, plans, or theories in a general way, without giving all the details. Organise and systematically describe the main points or general principles. Use essential supplementary material, but omit minor details.

Prove – When proving a statement, experiment or theory in an essay, you must confirm or verify it. You are expected to evaluate the material and present experimental evidence and/or logical argument.

Relate – To relate two things, you should state or claim the connection or link between them. Show the relationship by emphasising these connections and associations.

Review – When you review, critically examine, analyse and comment on the major points of a subject in an organised manner

University Guidance

Exploring Careers and Study Options

- ✓ Find job descriptions, salaries and hours, routes into different careers, and more at https://www.startprofile.com/
- ✓ Research career and study choices, and see videos of those who have pursued various routes at http://www.careerpilot.org.uk/
- ✓ See videos about what it's like to work in different jobs and for different organisations at https://www.careersbox.co.uk/
- ✓ Find out what different degrees could lead to, how to choose the right course for you, and how to apply for courses and student finance at https://www.prospects.ac.uk/
- ✓ Explore job descriptions and career options, and contact careers advisers at https://nationalcareersservice.direct.gov.uk/
- ✓ Discover which subjects and qualifications (not just A levels) lead to different degrees, and what careers these degrees can lead to, at http://www.russellgroup.ac.uk/media/5457/informed-choices-2016.pdf

Comparing Universities

- ✓ https://www.whatuni.com/
- ✓ http://unistats.direct.gov.uk/
- ✓ https://www.thecompleteuniversityguide.co.uk/
- ✓ Which? Explorer tool – find out your degree options based on your A level and BTEC subjects: https://university.which.co.uk/

UCAS

- ✓ Key dates and deadlines: https://university.which.co.uk/advice/ucas-application/ucas-deadlines-key-application-dates
- ✓ Untangle UCAS terminology at https://www.ucas.com/corporate/about-us/who-we-are/ucas-terms-explained
- ✓ Get advice on writing a UCAS personal statement at https://www.ucas.com/ucas/undergraduate/getting-started/when-apply/how-write-ucas-undergraduate-personal-statement
- ✓ You can also find a template to help you structure a UCAS statement, at https://www.ucas.com/sites/default/files/ucas-personal-statement-worksheet.pdf
- ✓ How to survive Clearing: https://university.which.co.uk/advice/clearing-results-day/the-survivors-guide-to-clearing

Subject Guidance

Biological Science at University

- ✓ Biologists investigate the processes that take place both in and outside all living things.
- ✓ Biologists will need a high level of skill and ability in science and be good at solving problems. Working accurately and having an eye for detail will help you when examining samples under a microscope.
- ✓ You can find out more about different courses and entry requirements by exploring the UCAS Biology Guide online:

https://www.ucas.com/ucas/subject-guide-list/biological-sciences

- ✓ You can find out more about the different careers by exploring the UCAS Biologists Careers online;

https://www.ucas.com/ucas/after-gcses/find-career-ideas/explore-jobs/job-profile/biologist

A Deeper Look Into Plant Science

- ✓ Read: The best funded Plant science institute in the U.K. Have a read about some of the research current Plant biologists are working on in the U.K, including crop research and how to eradicate pests and pathogens.

https://www.jic.ac.uk/

- ✓ Watch: more examples of herbivores and pathogens of plants and plant defences.

https://www.youtube.com/watch?v=0Z40GhiS5oE

- ✓ Listen: podcasts about insect pests of the garden

https://maritimegardening.com/pesky-garden-pests-episode-018/

- ✓ Do: an excellent and inspiring place to visit to see the variety in plants from all across the world

https://www.edenproject.com/

www.researchbasedcurricula.com

www.access-ed.ngo

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