Research Based Curricu<u>la</u>





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University Guidance

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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

your ability to refer to what others have said in your answer, and credit them for their ideas

referencing

your ability to go above and beyond the school curriculum to new areas of knowledge

deep dive

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

source analysis

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 Japanese Knotweed



Japanese Knotweed, a plant species native to Eastern Asia, once prized in the West for its beauty, is now an invasive nightmare across Europe and North America. In Japan, it is a pioneer species, and often the first coloniser of volcanoes. Following its introduction to the UK in the mid-nineteenth century as an ornamental plant, a lack of competition and pests, combined with its rapid early growth, allowed Japanese Knotweed to spread.

Japanese knotweed is now cited as one of the world's 100 worst invasive species, causing crop losses, damage to infrastructure, and erosion of ecosystem services. Its impact in the United Kingdom is primarily socio-economic, due to public fear and reduction of house prices (see Resource 2), whereas the North American perspective views Japanese knotweed as an environmental threat to native species.

This invasive weed is primarily controlled with an herbicide called glyphosate. However, despite glyphosate being the most effective treatment we have for this plant, it still takes up to three years of repeated spraying with herbicide to bring it under control. Additionally, glyphosate is under review in Europe due to new evidence linking it to health and safety concerns and suggesting it may be carcinogenic.

My project aims to use a 'chemical biology' approach to develop new biochemical solutions for the control of Japanese knotweed. Laboratory-based studies will identify bioactive compounds that interfere directly with the normal growth or metabolism of actively growing knotweed. A knotweed bioassay will be developed to allow the screening of very small quantities of compounds in a controlled environment. Compounds of interest will be further examined to determine their efficacy and mode of action. Identified compounds of interest will be examined in planta in a controlled environment and through glasshouse studies. Additionally, the reasons for the limited efficacy of conventional herbicides against knotweed, and the factors which allow such rapid growth of R. japonica and other related species, will also be considered.

The topics within this pack will include:

The Balance of Life

Science in Society

Biocontrol

Glyphosate Translocation and Transportation in Plants

Chemical Linkages

Infrared

Introduction to Subject Natural Sciences at University





To me studying Natural Sciences at university felt like starting two separate subjects, which eventually amalgamated into one. In first year, chemistry and biology were taught very separately and all aspects including physical chemistry were covered. I think that this breath gave me a good grounding for the rest of my studies and allowed me to understand the wider context. I found my course increasingly interesting later in my degree. Although the modules were still taught separately by either the chemistry or biology departments, the content was beginning to overlap. In chemistry, we were beginning to learn the mechanistic explanation for processes which I had previously learnt about in biology, and my understanding was deepening to a molecular level. For example, we covered the chemical reactions responsible for, antibiotic resistance, DNA transcription and translation, and the citric acid cycle. I enjoyed the applications provided by biology, and the justifications provided by the chemistry.

One of the things which drew me to a degree in Natural sciences, was how I thought it would allow me to keep my options open for a wide range of career paths.

So, what can you do with a natural sciences degree? One option is to directly use the degree content with a position as a Researcher, Laboratory Technician, Secondary School Teacher, Conservation Officer, Forensics, Medical Sales Representative etc.

A science degree develops a range of skills which are desirable in many career paths. These include:

- Ability to research, evaluate, critically interpret and analyse information
- Communication in written, verbal and presentational forms
- Ability to work methodically & accurately
- Decision making and ability to self-manage

Introduction to Subject Natural Sciences at University



Careers in which a science degree may prove useful through the analytical skills developed include: Professional Allied to Medicine, Librarian, Accountant, Production Manager, Information Scientist, Database Administrator, Operational Researcher, Technical author, Patent Examiner, Scientific Journalist, Publishing, and the Food and Drink Industry.

It is also important to remember that there are many graduate jobs open to graduates of any discipline, including science, such as the Civil Service, Police Force, Management Consultancy, Retail Management, Community Education, Banking & Finance, etc.

Good luck!

Claire Holden

Meet the PhD Researcher Claire Holden





I always knew that I enjoyed science, but when it came time to choose my A levels I was unsure what my future career goals should be. I decided to keep my options open and I chose Biology, Chemistry, Physics and Maths.

In 2012, I arrived at Durham University enthusiastic to begin studying Natural Sciences. I put together my module choices in a half and half split between Biology and Chemistry. As my course went on, I found that I enjoyed the overlap between these areas the most. The detailed insight that chemistry can give to explain biological questions has always been an area which excites me.

I completed my master's research project as part of my integrated masters at Durham University. This was on a completely different area to my current area of study! I was looking at the effect of synthetic analogues of retinoic acid, a derivative of vitamin A, on skin cells. The compounds I was using were fluorescent and I got to use a very expensive microscope which allowed me to view the compound inside the skin cells, and other areas of the cell through the use of fluorescent stains. The retinoid project was very collaborative. There was a large research group spanning the Biology, Chemistry, and Physics departments, and involving a company too. I really enjoyed that there were so many people to bounce ideas off, and that our findings fed into each other's projects. I even got my name on a paper, as I was investigating the biological effect of the compounds that a Chemistry PhD student was making.

Meet the PhD Researcher Claire Holden



I would say that my current PhD project is collaborative too, but in a very different way. I am the only person in my plants and crops group here in Lancaster studying Japanese knotweed, but I still work with lots of different people. I have regular meetings with my industry sponsor, Phlorum, my supervisors, the other PhD students in my lab, and another sponsor I have called the Centre for Global Eco-Innovation. One of the things that amazes me about doing a PhD is how much you can learn from someone who appears to be doing something very different to you. For example, as you will see in Resource 6, I am using a technique called ATR-FTIR. For this, I again have to use some very expensive equipment, which the University of Central Lancashire kindly lets me borrow. I was shown how to use this equipment and analyse the data by the other students there who are using ATR-FTIR for the diagnosis of ovarian cancer – a million miles away from Japanese knotweed!

A-Level Subjects
Undergraduate

Biology, Chemistry, Mathematics and Physics

Durham University, MSci Natural Sciences (Biology, Chemistry)

Postgraduate Lancaster University, PhD in Japanese knotweed.

Glossary



Term	Definition				
Abiotic	Physical rather than biological; not derived from living organisms.				
Allelochemical	A chemical produced by a living organism that exerts a detrimental physiological effect on individuals of another species when released into the environment.				
Bioassay	A bioassay is an analytical method to determine concentration or potency of a substance by its effect on living cells or tissues.				
Biocontrol	A method of controlling pests such as insects, mites, weeds and plant diseases using other organisms. It relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role.				
Biodiversity	The variety of plant and animal life in the world or in a particular habitat, a high level of which is usually considered to be important and desirable.				
Bio-spectroscopy	Spectroscopic examination of specimens of living tissue				
Biotic	Relating to or resulting from living organisms.				
Decomposition	Decomposition is the process by which organic substances are broken down into a more simple organic matter. The process is a part of the nutrient cycle and is essential for recycling the finite matter that occupies physical space in the biosphere.				
Detoxify	Detoxification is the physiological removal of toxic substances from a living organism				
Ecosystem	A biological community of interacting organisms and their physical environment.				
Eradication	The complete destruction of something.				
Fauna	The animals of a particular region, habitat, or geological period.				
Flora	The plants of a particular region, habitat, or geological period.				

Glossary



Term	Definition				
Glyphosate	A herbicide often used for the treatment of Japanese knotweed				
Habitat	Type of natural environment in which a particular species of organism lives. A species' habitat is those places where it can find food, shelter, protection and mates for reproduction.				
Herbicide	A substance that is toxic to plants, used to destroy unwanted vegetation				
Infrared spectroscopy	A type of absorption spectroscopy that uses the interaction of infrared radiation with matter, which can be used to identify and study chemicals.				
Inter-specific	Existing or occurring between different species.				
Intra-specific	Produced, occurring, or existing within a species or between individuals of a single species.				
Invasive	An invasive species is a species that is not native to a specific location (an introduced species), and that has a tendency to spread to a degree believed to cause damage to the environment, human economy or human health.				
Isotope	Variants of a particular chemical element that differ in neutron number, but not atomic number.				
Mass spectrometry	An analytical technique that ionizes chemical species and sorts the ions based on their mass-to-charge ratio i.e. measures masses.				
Mycorrhiza or mycorrhizal fungi	A symbiotic association between a fungus and a plant. The term mycorrhiza refers to the role of the fungus in the plant's rhizosphere, its root system.				
Niche	The match of a specie to its specific role and position in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' niche includes all of its interactions with the biotic and abiotic factors of its environment.				
Ornamental plant	Ornamental plants are plants that are grown for decorative purposes in gardens and landscape design projects, as houseplants, cut flowers and specimen display.				
Phloem	The living tissue that transports the soluble organic compounds made during photosynthesis.				

Glossary



Term	Definition				
Phylogeny	The evolutionary development or history of a species or of a taxonomic group of organisms.				
Reynoutria japonica or R. Japonica	The Latin name for Japanese knotweed				
Rhizome	A type of plant stem situated either at the soil surface or underground that contains nodes from which roots and shoots originate. Rhizomes are unique in that they grow perpendicular, permitting new shoots to grow up out of the ground. When separated, each piece of a rhizome is capable of producing a new plant.				
Sinks	The sites in a plant where photo-assimilates are stored or used.				
Soil bulk density	The oven dry weight of a unit volume of soil inclusive of pore spaces is called bulk density. Density = Mass / volume				
Sources	The parts of a plant where net fixation of carbon dioxide occurs				
Stand	The name given to a patch of Japanese knotweed, often consisting of densely packed foliage and lacking in other plant species due to shading by the broad leaves of Japanese knotweed.				
Succession	The process of change in the species structure of an ecological community over time. The time scale can be decades (for example, after a wildfire), or even millions of years after a mass extinction.				
Translocation	The movement of materials from leaves to other tissues throughout the plant				
Xylem	The transport tissue that transports water in plants from the roots to the leaves				

Resource One Overview



Topic The Balance of Life

A-Level Modules Populations in ecosystems

Objectives By the end of this resource, you will be able:

- ✓ To understand how ecosystems are a fine balance, and how populations interact
- ✓ To understand the process of succession
- ✓ To understand how Japanese knotweed can play a part in succession
- ✓ To understand the concept of biodiversity

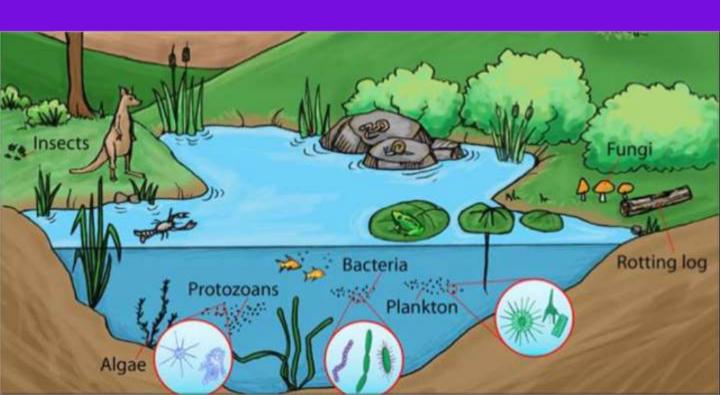
nstructions 1. Read the data source

- 2. Complete the activities
- 3. Explore the further reading

Context Ecosystems and the niche occupied by different species.

Competition between different populations. How changes in abiotic conditions can lead to succession. Methods to

estimate the size of populations.



Resource One Data Source



Section A

What is an ecosystem?

An ecosystem is a biological community of interacting organisms and their physical environment. Like all things in biology, ecosystems are finely balanced, and changing one part will have an impact on the rest. An ecosystem is a dynamic system. Populations of different species form a community. A community and the non-living components of its environment together form an ecosystem. Ecosystems can range in size from the very small to the very large. Within a habitat, a species occupies a niche governed by adaptation to both abiotic and biotic conditions.

Section B

Adaptation and niches

The plant species which I study, Japanese knotweed, is native to Asia. Here it finds its niche as the first plant to colonise volcanoes after volcanic eruptions. Despite fertile soil, volcanic landscapes also present difficulties due to steep slopes, acidity, and the release of sulphur dioxide. In volcanic soil, the levels of available phosphorus, a vital nutrient to plants, can be low due to the reaction of soluble phosphorus to form solid compounds of low solubility.

If the phosphorus is not soluble then it is not available in the soil water and cannot easily be taken up by plant roots. Japanese knotweed has several adaptations which allow it to overcome these difficulties. Japanese knotweed has a high tolerance of sulphur dioxide and can grow across a range of pHs. It has a large underground storage organ system called a rhizome. The system of rhizomes can help stabilize soil, see later section on erosion prevention. The rhizome can spread outwards underneath the soil from the initial site of growth. From this underground network bamboo-like shoots called canes sprout upwards. The patch of Japanese knotweed formed in this manner is referred to as a 'stand'. These stands are often very densely packed with lots of large leaves coming from the canes.

Resource One Data Source



Section C Succession Ecological succession is the name given to a process by which the structure of a biological community evolves over time. There are two types of succession, primary and secondary. Primary succession occurs in harsh areas, where the soil does not lend itself easily to the sustenance of life. Examples of such areas include recent lava flows, newly formed sand dunes, or rocks left from a retreating glacier.

Secondary succession occurs in areas where a small-scale disturbance does not eliminate all life and nutrients from the environment but does cause the removal of a community which previously existed, allowing an opening in a niche for a new species to become established.

Colonisation by pioneer species which is adapted to the harsh conditions, such as Japanese knotweed, allows for primary succession. Primary succession can transform a landscape from a barren environment to climax community. At each stage in succession, certain species may be recognised which change the environment so that it becomes more suitable for other species with different adaptations. The new species may change the environment in such a way that it becomes less suitable for the previous species. Changes that organisms produce in their abiotic environment can result in a less hostile environment and change biodiversity. Conservation of habitats frequently involves management of succession.

Examples of sites where Japanese knotweed has been the first species to colonise recent lava flows include, Mt. Aso, Sakurajima Island, Mt. Nakadake, and Mt. Fuji. In primary successional stands on Mt. Fuji, researchers Tateno and Hirose, found that organic nitrogen, ammonium, and nitrate concentrations were 14, 4, and 2-fold higher, respectively, under R. Japonica stands than in bare soil (Tateno and Hirose 1987). Many early successional species, like R. japonica,

Resource One Data Source

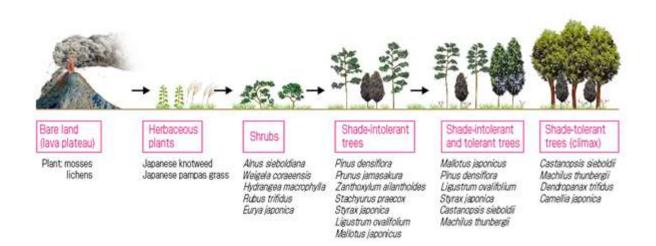


are known to increase soil formative processes, specifically by decreasing soil bulk density and increasing organic matter content, water content, and nutrient levels (Hirose and Tateno 1984). It is for this reason that, in the 1950s to 1970s, Japanese knotweed was used as an indicator species for fertile land.

Japanese knotweed facilitates succession in more ways than the improvement of soil qualities. In Japan, it is observed to exhibit a phenomenon known as 'central die-back', in which the shoot density (number of shoots in a given area) decreases in the centre of the patch, leaving a ring of knotweed with a small clearing in the centre. This is thought to be an intrinsic mechanism rather than any inter- or intraspecific competition. It is thought that the morphology of the older central rhizomes changes to produce fewer shoots than the newer rhizomes which are spread outwards to the sides of the stand. It remains unclear whether the rhizomes in the centre are alive or not, regardless, this clearing provides shelter and protection for seedlings of successor shrubs to grow.

Figure One (below)

Diagram of succession on a Japanese volcanic environment



Resource One Data Source



Section D

Knotweed on the move

Japanese knotweed is thought to have been introduced to Europe in 1849 by Philip Franz Von Siebold, a German physician and botanist in 1849. He travelled to Japan, teaching Western medical practices, and smuggling many species of Japanese flora and fauna into Europe. Siebold sent the plant to the Royal Botanical Gardens at Kew, England 2. Throughout the nineteenth century, Japanese knotweed was widely used as an ornamental. It became popular in the Victorian gardens of Europe. Deemed as the 'most interesting plant', it won a gold medal from the Society of Agriculture and Horticulture at Utrecht, in 18479.

Section E

Invasive species disrupt the native balance

There is a difference between an invasive species and an introduced species, and that is the damage caused. Japanese knotweed is a very fast-growing plant, and did not evolve alongside the native plants and animals we have here in the UK. Native UK plants must fight for the same resources such as light, water, and nutrients, as Japanese knotweed. Where at least one resource is limited. competition occurs within and between populations for the means of survival. Within a single community, one population is affected by other populations, the biotic factors, in its environment. Populations within communities are also affected by, and in turn affect, the abiotic (physicochemical) factors in an ecosystem. The adaptation mentioned earlier, the underground rhizome system, stores enough energy to allow Japanese knotweed to shoot up very fast early in the season, and shade out competitors with its large leaves.

Additionally, because Japanese knotweed did not evolve in the UK, the herbivorous pests such as caterpillars which target UK plants do not eat Japanese knotweed. Plants produce compounds called 'secondary metabolites' as a form of defence against insects. An example you might be

Resource One Data Source



familiar with is the bitter taste you get when you brew a cup of tea for too long – this bitterness is due to a compound type called tannins, which are produced to ward off hungry insects. Most insects are specially adapted to detoxify the secondary metabolites produced by their target plant species. This relationship is very specific because both insects and plants have evolved together, adapting to survive in their own niches. Most native UK insects cannot detoxify the secondary metabolites produced by Japanese knotweed leaves, and so the plant goes unharmed by native insects, giving it an advantage over the more tasty UK plants.

Figure Two

Dense foliage in a

Japanese knotweed

stand



Section F

Japanese knotweed reduces biodiversity in native populations

Biodiversity is a measure of how many different species live in an ecosystem. Ecosystems with higher biodiversity are more stable as they can easily adjust to changes. If something happens which alters the numbers of one species, there are usually knock-on consequences for other species in the community. Ecosystems with higher biodiversity have fewer species that depend on just one other for food, shelter and maintaining their environment.

Although a beneficial nursery on the exposed lava flows of East Asia, in its invaded habitats Japanese knotweed is considered a negative environmental weed. It is acknowledged to cause major ecological alterations to invaded communities by forming dense stands containing only Japanese knotweed and no other plants, known as mono-specific stands. The densely packed canes and broad leaves exclude the native vegetation (Holzner 1982).

Resource One Data Source



Competition with Japanese knotweed reduces growth of native flora and impacts faunal diversity. The foliage forms a dense canopy which causes a reduction in light levels by >90% at ground level, this restricts the growth of competing vegetation (J. N. Barney, unpublished data). The rhizome releases a series of secondary allelochemical compounds (see Resource 5), which affect the availability of mineral nutrients for native plants. The percentage cover of native vegetation, investigated via a 50 m transect through a R. japonica stand, showed a decrease from 100% where there was no Japanese knotweed, down to 0% within the Japanese knotweed stand. No native vegetation was able to penetrate the densely packed Japanese knotweed stand (Maerz et al 2005). The same research group found that there were fewer green frogs where there was Japanese knotweed. Under stands of R. japonica, the mineral content of the topsoil was significantly higher than under native species, especially in potassium and manganese (Vanderhoeven et al. 2005).

Japanese knotweed invaded sites have an increased abundance of fungi and amoebae, but a decreased abundance of bacteria. Fungi are thought to be favoured by the slowly decomposing knotweed litter and high tannin concentration (Mincheva et al. 2014, Tamura Tharayil 2014, Stefanowicz et al 2016). Some species of fungi can break down the complex organic substances in Japanese knotweed and release them back into the soil, which is important for nutrient recycling (Suseela et al 2016). Knotweeds are non-mycorrhizal plants and negatively impact mycorrhizal fungi (Stefanowicz et al 2016; Zubek et al 2016; Lavoie 2017).

Resource One Activities



Activities

- 1. Describe what is meant by a pioneer species.
- 2. A volcano has erupted in Japan leaving only a bare lava plateau. Different species begin to colonise the bare land, and these change over time. Put the following plant types in chronological order, A-D.

Mature trees
Mosses and lichens
Shrubs
Herbaceous plants (e.g. Japanese knotweed)

- 3. What is the role of ecological succession in a habitat?
- 4. Using the sources, suggest how succession can lead to more complex food webs.
- 5. Using the sources, suggest why biodiversity is important to an ecosystem.
- 6. What adaptations does Japanese knotweed have that make it better able to:

colonise a volcano landscape compete against native UK species?

7. Using your knowledge from your wider course content, design your own experiment to measure the effect of Japanese knotweed stands on species diversity.

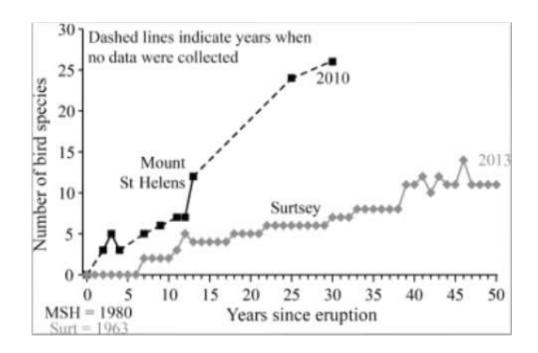
Some possible things which you may want to think about using include: transects, ruler, tape measure, tubs to collect soil, pH meter, light meter etc

Resource One Activities



Activities

8. The following graph shows the change in species diversity over time in two locations, Mount St. Helens and Surtsey. Mount St. Helens is an active stratovolcano located in Skamania County, Washington, USA. St. Helens which erupted in 1980. Surtsey is a volcanic island located off the southern coast of Iceland, which erupted in 1963. Explain what is happening in the graph.



Resource One Further Reading



Explore



- For a short introductory guide to what Japanese knotweed looks like and its associated problems, watch this short video clip: https://www.youtube.com/watch?v=JTWWCjaOdkk
- For more information on Japanese knotweed, see CABI's website:
 https://www.cabi.org/japaneseknotweedalliance/what-is-japanese-knotweed/
- 3. For a recent thorough review on the environmental impacts of Japanese knotweed, see the following paper: Lavoie, Claude. (2017). The impact of invasive knotweed species (*Reynoutria* spp.) on the environment: review and research perspectives. Biological Invasions. 19. 10.1007/s10530-017-1444-y.

Resource Two Overview



Tonic

Science in Society: The Socio-economic impact of Japanese Knotweed

Science in Society

Objectives

By the end of this resource, you will be able:

- ✓ To understand how public image can be informed by scientific reporting, and change scientific goals.
- ✓ To appreciate how difficult it can be to quantify physical, emotional and financial damage by Japanese knotweed, and how this can be reflected with legislation.
- ✓ To understand how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society

Instructions

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

Context

As an invasive species, Japanese knotweed can cause negative impacts in its introduced range. As we have seen from Resource 1, invasive species can disrupt the fine balance of ecosystems, causing environmental damage. However, socio-economic damage can also be caused. Resource 2 explores what this means.





Section A

Japanese Knotweed

Removal

In its invasive range, steps have been taken to prevent the spread of Japanese knotweed, due to both the negative environmental impacts and the social consequences, such as reduced house prices and a legal liability if nothing is done. Control methods include, manual methods (I.e. digging it all up), biological control, and chemical control. Each method has its advantages and drawbacks, and with a combination of techniques, Japanese knotweed can be managed. However, eradication is difficult, and can take several years of repeated treatment. In fact, a recent study of physiochemical control methods over a three-year period found that no control method provided complete eradication. Even the smallest fragment of rhizome left in the soil can lead to regeneration. The prolific growth of shoots can push through the asphalt in pavements, and the rhizomes can penetrate through weaknesses in pavements, walls, land drainage works, and flood defence structures Locadro, 1973).

Section B

Public Perception



As we have seen from Resource 1, Japanese knotweed is not native to the UK and poses an environmental threat. However, Japanese knotweed also poses a socio-economic problem. Negative hysteria surrounding its invasive success has caused ripples of fear in the property market. A house with Japanese knotweed on its land can be valued at a lower price than the same house if it were knotweed-free. Some banks have gone so far as to refuse to lend mortgages on properties plagued by knotweed. The persistent and vigorous growth of Japanese knotweed's underground rhizome system has provoked fear in the public that their homes will be damaged by the plant. This blight on the reputation of Japanese knotweed is a self-fulfilling prophecy, with increased anxiety caused by the plant leading to a more dramatic response from property surveyors, purchasers, and mortgage lenders, in turn causing more reason to worry.



Section C

Economic Impact

Although perhaps misplaced, the implications of this fear and its cost to the UK economy is very real and is estimated, by Williams et al (2011), at £165,609,000 per annum. The breakdown of these costs into country and sector can be seen in Table 1, the data in which was estimated in Williams report based on the figures for 2010.

Table One

Total annual costs of Japanese knotweed (Taken from Table 4.5. of Williams 2011)

Sector	England	Wales	Scotland	GB
Local authorities	£270,000	£66,000	£96,000	£432,000
Research	£319,000	£19,000	£32,000	£370,000
Railways	£1,726,000	£100,000	£174,000	£2,000,000
Roadsides	£3,901,000	£438,000	£757,000	£5,096,000
Riparian	£3,444,000	£469,000	£1,724,000	£5,637,000
House devaluation	£963,000	£56,000	£97,000	£1,116,000
Development	£141,358,000	£7,644,000	£1,508,000	£150,510,000
Householders	£383,000	£23,000	£42,000	£448,000
Total	£152,364,000	£8,815,000	£4,430,000	£165,609,000

The popular property search engine Zoopla advises users that Japanese knotweed on site could reduce a property's value by up to 20%. Williams et all (2011) estimated that the presence of Japanese knotweed increases the loan to value ratio of houses by at least 5%.

Section D Legal Liability

Due to the damage which invasive species can cause to the environment, many of these are regulated by law. Some invasive species are classed as 'Invasive Alien Species for Union Concern'. These species cannot be imported into the country, and there are special licences required for you to grow them. Although in the European Union Japanese knotweed is not classed on the highest level of regulation 'List of Invasive Alien Species for Union Concern', there are still laws in place to prevent it's spread.



Liability means being responsible for something or obligated by law to do something. In this context, land owners are responsible for preventing the spread of Japanese knotweed to other people's property. In the United Kingdom, the Wildlife and Countryside Act (United Kingdom Parliament 1981) made it an offence to actively plant or otherwise cause the species to grow in the wild. A decade later it was classified as controlled waste, meaning it needs to be disposed of at a licenced landfill (United Kingdom Parliament 1990). If you allow Japanese knotweed to spread onto a neighbours' property you have committed a crime under the Anti-Social Behaviour, Crime and Policing Act 2014.

In the United Kingdom, two home owners, Stephen Williams and Robin Waistell, became the first members of the public to receive compensation from Network Rail for allowing Japanese knotweed to spread into their land. In the UK, Japanese knotweed spreads by vegetative reproduction rather than by seed. This means that fragments of rhizome or stem from the Japanese knotweed on Network Rail's land could have started a new patch of Japanese knotweed in the home owner's land. Additionally, rhizomes can spread laterally underground moving outwards and away from the central 'mother' patch, this can form a new 'daughter' patch elsewhere. The connection to a larger rhizome network means that the above-ground shoots can use energy from this larger more established storage organ to grow. Network Rail's treatment of the knotweed was deemed inadequate, unreasonable, and in breach of its duty as a landowner. In July 2018, Network Rail became the first company to be successfully sued for allowing Japanese knotweed to spread onto another person's land. This ruling could set a new precedent for home owners seeking compensation from Network Rail, local authorities, and other major landowners.



Section E

Can science calm the storm?

Trade Bodies such as the Property Care Association are keen to help quench some of the fear surrounding Japanese knotweed, and recent research led by Dr Mark Fennell and Professor Max Wade of AECOM, together with Dr Karen Bacon of the University of Leeds aims to do just this. Stephen Hodgson, chief executive of the PCA, commented on the research saying that

"although the invasive weed is a fast growing and highly invasive species perfectly capable of causing disturbance to areas such as paths, patios, driveways and garden walls, it is an herbaceous perennial, which lacks the potential to cause significant disturbance to normal building foundations."

Following this research, regulations have been changed to allow the plant to grow closer to a house, without posing a risk to the foundations.

Studies like research led by Dr Mark Fennell and Professor Max Wade of AECOM, which give information about the damage caused by Japanese knotweed are important to inform legislation. Punishments for people who allow knotweed to spread onto other people's land need to be appropriate for the level of damage caused. Harder to quantify than the physical damage, however, is the emotional stress caused and the devaluation of property, as these can both fluctuate along with public perception.

Resource Two Activities



Activities

- What socio-economic problems are caused by Japanese knotweed?
- 2. Using table 1, find the following information:
 - a) In 2010, how much money was spent on Japanese knotweed research in Scotland?
 - b) In 2010, how much was spent on Japanese knotweed removal from riparian areas in Wales?
 - c) In 2010, how much money was lost due to the devaluation of houses in England?
 - d) What was the total cost of Japanese knotweed to the UK economy as a whole in 2010?
- 3. How does Japanese knotweed spread in the UK?
- 4. Explain the term 'legal liability' in your own words. Use terminology from the source.
- 5. How justified is the public fear that Japanese knotweed can damage their homes? Explain your answer.
- 6. Discuss the importance of using scientific evidence to inform the public, and decide on legislation. Use examples from the data source to inform your argument.



Resource Two Further Reading



Explore

Scientific Reporting in Mainstream News Sources



Recently, a peer-reviewed paper has been published comparing different treatment techniques to tackle Japanese knotweed. This study was reported in newspapers to inform the general public of the group's findings. Read the original scientific report, and compare with the journalists interpretations from mainstream news sources. Do you agree with the way their conclusions were represented?

Original peer-reviewed paper:

Jones, Daniel & Bruce, Gareth & Street-Perrott, F & Graham, Ian & Abel, Alan & Eastwood, Daniel. (2014). Optimising Physiochemical Japanese Knotweed Control in the UK. 10.6084/m9.figshare.1180114.

https://link.springer.com/article/10.1007/s10530-018-1684-5

Article by two authors of the above paper, Dan Jones and Daniel Eastwood:

https://theconversation.com/weve-found-the-best-way-to-control-japanese-knotweed-95320

News reports:

<u>Daily Mail</u>: 'Japanese knotweed 'cannot be killed off': Scientists fail to destroy the invasive weed after 19 attempts' https://www.dailymail.co.uk/sciencetech/article-5656799/Killer-Japanese-notweed-destroy-UKgardens.html/

<u>Telegraph</u>: 'Japanese knotweed cannot be cured, major study which tried 19 methods finds'

https://www.telegraph.co.uk/news/2018/04/25/japanese-knotweedcannot-

cured-major-study-tried-19-methods-finds/

<u>BBC</u>: 'Knotweed 'cannot be eradicated', Swansea Uni trial shows'

https://www.bbc.co.uk/news/uk-wales-south-west-wales-43882916

Resource Three Overview



Topic Biocontrol

A-Level Modules Populations in ecosystems

Objectives By the end of this resource, you will be able:

- ✓ To define biocontrol
- ✓ To understand how population numbers are controlled in a complete ecosystem
- ✓ To be able to explain the drawbacks of different control methods, chemical and biological, and explain the risks involved.

Instructions 1. Read the data source

- 2. Complete the activities
- 3. Explore the further reading

Context Biological control is a method of controlling pests such as insects, mites, weeds and plant diseases using other

organisms. It relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role. This resource introduces the ongoing research into biocontrol as a method of tackling the

invasive species Japanese knotweed.





Section A

The Biological Control of Japanese knotweed Japanese knotweed is an invasive plant species which can cause environmental and socio-economic damage. There are three main methods for control. One method is to dig up every bit of rhizome, this is known as manual control. Manual control must be very thorough because a new plant can grow from a tiny fragment of rhizome left in the soil. Chemical control is another option which uses herbicides to interfere with the plant's growth. The third option is known as biocontrol. This is still under the research by an organisation called CABI and is not widely used yet. Biocontrol is when one biological organism can cause a reduction in the population of another unwanted organism.

CABI is researching an insect called a psyllid to see if it can control Japanese knotweed. A psyllid is known as a 'sapsucking' insect. The sap refers to the liquid in one of the plant's transportation vessels. Plants have two main transportation systems, the phloem and the xylem, see Resource 4 for more details. The phloem contains a nutrient rich sap which provides the plant with the energy to grow. Some insects piece the phloem vessel and steal the plant's nutrients in order to survive, which damages the plant.

The following information source is an extract from a Science Summary produced by the Environment Agency, explaining what CABI are doing, and why.

Environment Agency

Extract



A sap sucking insect and a fungal disease could form the basis for a highly effective and environmentally friendly way to control an invasive plant known as Japanese knotweed, according to a new study. Funded and managed by a variety of different organisations, including Defra, Welsh Assembly Government, South West Regional Development Agency, the Environment Agency, Network Rail, CABI Bioscience UK and British Waterways, the study investigated the potential for using a safe and sustainable natural pest or pathogen to debilitate knotweed and lessen the current environmental and economic problems associated with it.



Japanese knotweed (Reynoutria japonica) is a large, vigorous weed that is native to Japan, Taiwan and China. It was introduced into the UK in the early 19th century as an ornamental plant, but is now abundant in the wild. It is regarded as a pest in many parts of the country because of its quick growth, which allows it to dominate habitats and exclude other plants. In Japan, the plant is held in check by natural enemies, but these enemies are not naturally found in the UK.

This dense weed also poses a risk to flood management. This is both because it can damage river banks when it dies off in the autumn and because the dead stems can fall into a watercourse, reducing its capacity to carry flood water. In addition, Japanese knotweed can cause damage by growing into concrete or other materials making up flood defences. This all means that land must be cleared completely of the weed prior to building a flood defence scheme, creating huge costs for the Environment Agency.

Current methods for controlling Japanese knotweed involve applying chemicals (herbicides) and physically removing the weed (cutting stems and grazing by cattle). Both methods have major drawbacks. Chemical control can be detrimental to sensitive, non-target plants, while, for complete control, herbicides need to be sprayed repeatedly over a period of years, making this an expensive option. Even then, there is still a potential for the weed to spread. Cutting and cattle grazing do not eradicate the plant, which will continue to grow if grazing stops.

To try to find more effective control methods, a team of scientists looked into the possibility of using biological control methods to limit the growth of Japanese knotweed in the UK. Using living organisms to control pests in this way is known as biological or natural control. The main advantage of this form of control is that, once recognised, an effective natural enemy provides control of the pest indefinitely, without further cost or intervention.



The scientists began by visiting Japan to examine the plant in its native area. They found that Japanese knotweed is much less of a pest in Japan than in the UK, because it is controlled by native natural enemies. So they brought samples of these enemies, including insects and fungi, back to the UK for testing under quarantine.

At the same time, they conducted a literature review on all information relating to Japanese knotweed and its natural enemies, as well as undertaking further studies in Japan.

In the UK, investigations addressed whether the insects and fungi brought back from Japan were specific to Japanese knotweed, to ensure that they wouldn't attack native UK plants. To do this, they first identified 70 UK plant species that are closely-related to Japanese knotweed. These 70 species included all UK species in the same family as the Japanese knotweed. This included ornamental species, rare species and important crops. They then tested these species under quarantine to see whether they were attacked by the natural enemies.

From these tests, the scientists identified a highly specialist sap sucking insect, Aphalara itadori, and a leaf spot fungus, Mycosphaerella polygoni-cuspidati, as potential control agents, with the data suggesting that they would not pose a threat to non-target, native plants.

The scientists are now looking to test these two natural control agents on other native UK plant species. They also intend to conduct more in-depth studies on the interaction between the leafspot fungus and the plants Persicaria vivipara and Polygonum aviculare to establish the extent of its development and reproductive ability. But the scientists are confident that they have found a new method for controlling Japanese knotweed and approval is currently



being sought to release Aphalara itadori. This has been approved by the Advisory Committee for Releases into the Environment and will now undergo a period of public consultation prior to consideration by the Minister for the Environment for approval to release.

This summary relates to information from Science Project [SC010100], reported in detail in the following output(s):-

Science Report: SC010100/SR2 Title: The Biological Control of Japanese knotweed

http://www.cabi.org/japaneseknotweedalliance/Default.aspx?site=139&page=463/

Project manager: Trevor Renals, Ecological Appraisal, South West Region Research Collaborators: Defra, Welsh Assembly Government, South West Regional Development Agency, Environment Agency, Network Rail, British Waterways and CABI Bioscience UK, and coordinated through Cornwall County Council.

http://www.cabi.org/japaneseknotweedalliance/

Further copies of this summary and related report(s) are available from our publications catalogue or our National Customer Contact Centre T: 08708 506506 or E: enquiries@environment-agency.gov.uk. © Environment Agency

Section B

Psyllids

Since the release of this article, the psyllid was favoured over the fungus for further experiments. Permission was granted to release some psyllids into the wild, outside of a contained greenhouse experiment. The best-case scenario for the Japanese knotweed biocontrol program would be to see a steady increase in the psyllid population as they become established, a reduction in the Japanese knotweed population, and no negative impact on native UK wildlife.

The first release of the psyllid in 2010-2013 failed to establish large populations, and a lot of the psyllids did not survive the winter. However, the first release was deliberately cautious and located away from river-ways. Japanese knotweed is known as a riparian plant, meaning that it likes lots of water

Resource Three Data Source



and tends to live near canals and rivers. Therefore, the best conditions for the survival of the psyllid is likely to also be near rivers. Imagine a worst-case scenario for a first release however, and the problems which would be caused if the psyllid population grew out of control, spread across the country, and negatively impacted on UK wildlife. To avoid this, the first release was purposefully designed not to be located in the most favourable habitat for the psyllid and avoided waterways which allow a rapid means of geographical spread.

During the summer of 2015 and 2016 CABI conducted more experiments where they released the psyllids and counted how many survived throughout the season. In 2016, CABI confirmed that the psyllid had managed to overwinter at one southern site. Although there have been problems with getting the psyllid to survive the UK winters, on the upside there has been no observable negative impact on native wildlife to date.

Resource Three Activities



Activities

- 1. Explain biocontrol in your own words.
- 2. Explain in detail why Japanese knotweed is regarded as a 'pest' in the UK.
- 3. List THREE disadvantages of chemical control.
- 4. Why isn't Japanese Knotweed a problem in Japan?
- 5. Which of these are disadvantages of biological pest control? Pick two.
 - a) It reduces the population of the pest without completely removing it
 - b) The control species only eat the pest species
 - c) The control species must come from the same country as the pest species
 - d) Control species may not behave as expected and may become a pest itself.
- 6. Why was it important for the scientists to test the biological control agents on closely related species native to the UK?

Resource Three Activities

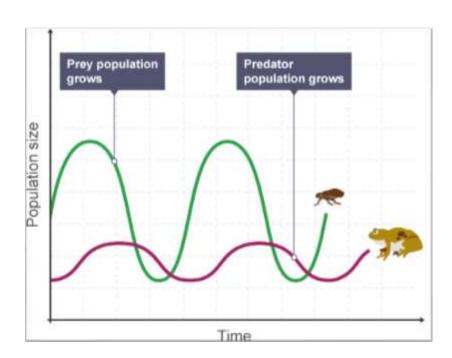


Activities

7. Look at the graph below. This graph depicts a predatorprey relationship. The predator-prey interaction is thought to keep the population of both species in balance. This is the key idea behind biocontrol. In the graph below, the insect is eaten by the frog.



- a) Explain why the two populations fluctuate and suggest how the relationship depicted in the graph can keep both populations in balance.
- b) Explain why the insect population is higher than the frogs
- c) Explain why the frog population peaks after the insect population



Resource Three Further Reading



Explore



For one of the most famous examples of biocontrol, see this short video clip about cane toads. Hawaiian cane toads were introduced to Australia from America, as a biocontrol agent to target cane beetles which were damaging sugar cane crops. They are now an invasive species which poison native Australian wildlife. As you watch, think about why biocontrol agents must be carefully chosen, and what the risks involved are.

√ https://www.youtube.com/watch?v=oYcl0xxU5_s

Resource Four Overview



Topic Glyphosate Translocation and Transportation in Plants

A-Level Modules

Biology: Mass transport in plants

Chemistry: Atomic Structure, Mass numbers and isotopes

Objectives

By the end of this resource, you will be able:

- ✓ To define the phloem and xylem, and the process of mass transport in plants.
- ✓ To explain the use of tracers to investigate translocation in plants
- ✓ To define the meaning of an isotope, and explain how it can be detected using mass spectrometry
- ✓ To understand what a herbicide does

Instructions

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

Context

Japanese knotweed can be treated by a method known as chemical control. Chemical control uses chemical substances called herbicides which are toxic to the weed plants that they target. Herbicides can be sprayed onto the leaves or injected into the stem, In order to understand how herbicides move around the plant, this resource explains the two main plant transportation systems; the phloem and the xylem. Labelling experiments can be used to trace the movement of substances through these systems.



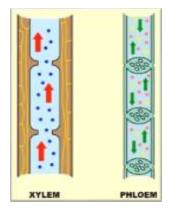


Section A

Plant Transport Systems

Just like us, plants need water and food to survive. Like our circulatory system, there are two main transport systems in plants; the phloem for food, and the xylem for water. The xylem transports water and mineral salts from the roots up to other parts of the plant, whilst the phloem transports sucrose and amino acids between the leaves and other parts of the plant.

The phloem moves food substances from where they are made, known as the sources, and where they are used or stored, known as the sinks. Photosynthesis uses the light energy which lands on the leaves of the plant to form energy-storing sugars, generally referred to as photoassimilates. These energy sources are transported in the phloem to other parts of the plant where they are needed for processes such as:



- growing parts of the plant for immediate use
- storage organs such as bulbs, tubers and rhizomes.
- developing seeds

Transport in the phloem is therefore both up and down the stem. Transport of substances in the phloem is called translocation. The movement of sucrose from mesophyll cells to phloem is active and requires energy from ATP.

Section B
Protein Synthesis

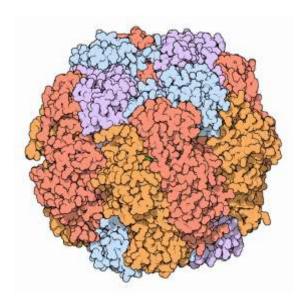
Plants absorb nitrogen from the soil through their roots in the form of nitrate (NO3-) and ammonium (NH4+). Nitrogen is transported from the root to the shoot via the xylem in the form of nitrate, dissolved ammonia and amino acids. Nitrogen is a key component of proteins. The DNA code for a protein remains in the nucleus, but a copy, called mRNA, moves from the nucleus to the organelle known as a ribosome where proteins are synthesised in the cytoplasm. Each sequence of three nitrogenous bases of mRNA that



codifies one amino acid is called a codon. The protein produced depends on the template used, and if this sequence changes a different protein will be made. Carrier molecules bring specific amino acids to add to the growing protein in the correct order. Twenty different kinds of naturally occurring amino acids are converted from the nitrogen taken up into the plant through the roots. Each protein molecule has hundreds, or even thousands, of amino acids joined together in a unique sequence, known as the primary structure. It then folds either into an alpha-helix or a beta-sheet, known as its secondary structure. It is then folded into the correct unique shape, called a tertiary structure. When multiple folded chains of a protein join together they form a quaternary structure.

The overall 3D structure is very important, as it allows the protein to do its job. Proteins perform lots of important functions within cells. For example, proteins called enzymes catalyse reactions within the cell, and proteins called chaperones protect the cell from damaging heavy metals. The process of protein synthesis can be disrupted in plants by chemicals called herbicides, in order to cause damage to the plant.

This is the structure of RuBisCO, a plant protein essential for photosynthesis





Section C Herbicides The growth of unwanted plants can be controlled by the application of chemicals known as herbicides. Herbicides may be selective and species specific, or be non-selective and target a broad-range of plant species. The persistence, or 'residual action' of an herbicide refers to the length of time it remains active in the soil for before degradation into its breakdown products. Herbicides have different uptake methods, for example through the stomata on the leaves or through the roots, as well as different transportation methods once in planta. Some are phloem mobile and some are xylem mobile. The phloem transports photo-assimilates from the leaves to the rest of the plant, however, this translocation can be altered by sink-source relationships. The xylem transports water and solutes, and transpiration drives the flow upwards from the roots to the leaves.



Herbicides all have different mechanisms of action, however, the safest ones for use have plant-specific target domains. Plant-specificity is an important quality for a Japanese knotweed herbicide owing to its usual proximity to water courses, with the preservation of native aquatic life in mind. Japanese knotweed is also found in parks, railway lines, and other public areas where treated-plants could be easily encountered by dogs or children. Plant-specific herbicidal target domains may have mechanisms of action related to function and biosynthesis of chlorophylls, leaf pigments, amino acids, fatty acids and photosynthetic electron transport and other metabolic processes. (Wakabayashi 2002)

Section D
Glyphosate

The herbicide known as 'glyphosate' is an example of an herbicide which works by inhibiting protein synthesis.

Glyphosate, or (N-(phosphonomethyl)glycine), is the most often recommended treatment for Japanese knotweed. This



is a non-persistent herbicide, with both phloem and xylem mobility. It is broad range, and not selective to a specific plant species. Glyphosate has a number of favourable environmental features, such as rapid soil inactivation, degradation to relatively harmless products, and low toxicity to non-plant life. Therefore, it has approval for use near water.



Limited effectiveness - Japanese knotweed can be controlled by glyphosate, however, it often fails to kill it. Environmental factors can render glyphosate less effective. These factors include accumulation of roadway dust (Figueroa 1989), a high concentration of nitrogen in soil (Hunter et al. 1993), and rainfall (Bariuan et al. 1999; Miller et al. 1998). Dusty conditions prevent the glyphosate from entering the plant via its leaf stomata. If it rains soon after application then the rain can simply wash the glyphosate into the soil, where it is broken down by soil microbes.

In high doses glyphosate has been shown effective at killing plants (Dewar et al. 2000). However, in sub-lethal doses, glyphosate affects growth and the partitioning of photoassimilates in many species, but does not kill them (Baur et al. 1977; Coupland and Casely 1975; Geiger et al.1986; Scorza et al. 1984). Changes in aboveground parts of the plant has little effect on Japanese knotweed's secret weapon, its rhizomethe massive underground energy storage organ (Geiger et al. 1986; Haidar et al. 2005).

Sink-source relations are likely to play a large part in the ineffectiveness of glyphosate on Japanese Knotweed. Diversion of herbicide to different sinks, such as growing leaves or flowers, can divert herbicide away from the rhizomes and cause dilution in planta. The time of year when glyphosate is effectively allocated to the rhizome, autumn,



and when the glyphosate is most effective due to an increased rate of protein synthesis, summer, do not coincide. In autumn, the plant is preparing for dormancy and so the levels of protein synthesis are very low and glyphosate is unlikely to kill. The rate of glyphosate allocation to the rhizomes in summer is unlikely to provide a lethal dose. In combination with other herbicides, or regulators of sink-source relationships, glyphosate may be more effective.

In addition to the limited effectiveness of glyphosate on Japanese knotweed there is also a growing demand to find an alternative control solution due to concerns about its safety. Glyphosate has received increased press coverage in Europe recently due to the accumulation of both glyphosate and its degradation product, AMPA, in the environment. Although it has been used widely in agriculture for the past forty years, only recently have chronic low dose effects on animals and humans have been documented. Glyphosate was determined a 'probable carcinogen' by the International Agency for Research on Cancer REF, and has since sparked outrage with many campaigners calling for a ban.

Section E Isotopic labelling As part of my project, I will be using a labelled version of glyphosate to trace its movement around the plant. I will be using a method called isotopic labelling. To understand isotopic labelling, you must first understand what isotopes are.

Atoms consist of a nucleus containing sub-atomic particles called protons and neutrons, surrounded by electrons in shells. The specific number of protons determines the type of element an atom is. All atoms of the same element must have the same number of protons, but the numbers of neutrons can vary. Atoms with the same number of protons but a different number of neutrons are called isotopes. Some of these isotopes are radioactive, and some are stable.



Radioactive isotopes can break down releasing energy, and be dangerous to our bodies, so for this reason I will be using stable isotopes of carbon and nitrogen, Glyphosate-2-13C,15N.

There are three naturally occurring isotopes of carbon: 12, 13, and 14.14C is radioactive. 12C and 13C are stable, occurring in a natural proportion of approximately 93:1, so almost all naturally occurring carbon is carbon-12. Nitrogen has two naturally occurring stable isotopes, nitrogen-14, which makes up the vast majority of naturally occurring nitrogen, and nitrogen-15. Therefore, the glyphosate I will be using will be doubly labelled with carbon-13 and nitrogen-15.



Carbon-12 6 protons 6 neutrons



6 protons 7 neutrons



6 protons 8 neutrons

The quantities of the different isotopes can be measured by a method called mass spectrometry and compared to a standard. In analytical chemistry, a standard is a precisely known concentration of an element or a substance, which can be used for calibration. Chemists can measure the mass of atoms and molecules to a high degree of accuracy in a mass spectrometer, so they can work out if the number of neutrons is different. By sampling at different parts of the plant over time, I will be able to use mass spectrometry to see how glyphosate moves around the plant. The understanding of the limitations of glyphosate would redefine the required criteria for a new herbicide, and may elucidate a solution to improve the effectiveness of glyphosate.

Resource Four Activities



Activities 1. Match up the following words with their definitions.

Key Words	Definitions
	A) The sites in a plant where photo-assimilates are
1) Phloem	stored or used.
	B) The movement of materials from leaves to other
2) Xylem	tissues throughout the plant
	C) Variants of a particular chemical element that
3) Isotope	differ in neutron number, but not atomic number.
·	D) The living tissue that transports the soluble organic
4) Herbicide	compounds made during photosynthesis.
	E) The transport tissue that transports water and
5) Translocation	mineral ions in plants from the roots to the leaves.
	F) The parts of a plant where net fixation of carbon
6) Sinks	dioxide occurs.
	G) An analytical technique that ionizes chemical
7) Sources	species and sorts the ions based on their mass-to-
	charge ratio i.e. measures masses.
8) Mass	H) A substance that is toxic to plants, used to destroy
spectrometry	unwanted vegetation.
	univanted regetation.

- 2. What is the function of a ribosome?
 - a) To release energy from glucose
 - b) Involved in protein synthesis
 - c) To build sugars by photosynthesis
- 3. What substance(s) is transported in the xylem?
 - a) Water
 - b) Water and mineral ions
 - c) Sugars and amino acids
- 4. What is the process that transports substances in the phloem?
 - a) Transpiration
 - b) Translocation
 - c) Transcription

Resource Four Activities



Activities

- 5. In which direction are substances transported in the phloem?
 - a) Upwards only
 - b) Downwards only
 - c) Upwards and downwards
- 6. Which tissue transports sugars from the leaves to other parts of the plant including roots for storage?
 - a) Xylem
 - b) Phloem
 - c) Veins
- 7. By which process does water move into a root hair cell?
 - a) Osmosis
 - b) Diffusion
 - c) Active transport
- 8. Suggest an explanation for why translocation in the phloem may be stopped by metabolic inhibitors.



9. The table shows the destination (sink) of translocated carbohydrates in a mature strawberry plant. Suggest an explanation for the percentage of carbohydrate translocated to the strawberries

DESTINATION	% OF TOTAL TRANSLOCATED CARBOHYDRATE
Roots	25
Stem	23
Leaves	14
Strawberry	38

Resource Four Activities



Activities

- 10. Suggest how isotopic carbon could be used to investigate photosynthesis in a plant.
- 11. A complete ring of bark, which includes the phloem but not the xylem, is removed from a woody stem.
- 12. Suggest an explanation for why:
 - a) The tissue above the ring swells but the tissue beneath the ring withers.
 - b) Chemical analysis of the fluid in the swollen tissue shows high concentrations of sugars and other organic solutes, but the tissue beneath the ring is deprived of nutrients.

Resource Four Further Reading



Explore

For a recent article about the growing concern surrounding glyphosate:



https://www.independent.co.uk/life-style/roundup-weed-killer-cancer-lawsuit-wine-beer-alcohol-a8797911.html

Resource Five Overview



Topic Chemical Communication

A-Level Modules Organisms exchange substances with their environment

Objectives By the end of this resource, you will be able:

- ✓ To understand that organisms can communicate with each other through chemical signals
- ✓ To understand that organisms can respond to these chemicals

nstructions 1. Read the data source

- 2. Complete the activities
- 3. Explore the further reading

Context

Humans are constantly communicating with each other, through body language, speech, and social media. From infancy we sing Old MacDonald had a farm, and become familiar with the concept of animals communicating with each other through sounds. However, the communications of the quieter life on the planet, like plants and bacteria, go unnoticed. Chemicals emitted from one organism to another can act as a silent signal, simply to say 'I'm here', alert others of danger, or call for help. Plants are constantly interacting with their environment through these chemical signals.





Section A Introduction

Imagine the smell of freshly cut grass. What comes to mind? Carefree summer days? The primary school playing field? The smell of freshly cut grass is actually a distress signal sent out by the grass after wounding. It is warning other nearby plants to arm themselves ready for attack by insects, triggering them to produce more chemicals in defence.

Plants can use chemical signals to communicate, as well as change their external environment. These chemicals are called allelochemicals. Allelochemicals are one subclass of a group of biochemicals called semiochemicals, which are emitted from one organism to affect the behaviour of another organism. Allelopathy works between different species.

Although this phenomenon is not limited to plants, allelopathy is thought to be the driver of the success of some invasive plant species, and may play a role in weed management. Allelopathic plants interfere with their community through the release of biochemicals. They produce a subset of secondary metabolites, unrequired for their own metabolism, called allelochemicals.

These biochemicals released from allelopathic plants can affect germination, growth, survival, and reproduction of other organisms. Allelopathy is present in many plant communities. The effect of allelochemicals on the target community can be either detrimental, known as negative allelopathy. Indeed, the origin of the term is from the Greek "allelo", meaning 'each other', and "patho" meaning 'suffering'. However, allelopathy can also have a beneficial effect on its target community, known as positive allelopathy. Allelochemicals come in three categories; allomones, kairomones, and synomones. Biotic factors such as nutrient availability and abiotic factors such as temperature and pH have an impact on allelochemical production.



Section B

Negative and Positive effects

Allelochemicals can have both negative and positive effects on both their emitter and the wider community. To differentiate between these, they have been subcategorized into allomones, kairomones, and synomones.

An allomone is a biochemical signal which triggers a response favourable to the emitter but not to the receiver. These are primarily a form of defence.

Kairomones are a subset of allelopathic chemicals which are detrimental to the allelopathic organism but benefit the surrounding community, they are the opposite to an allomone. For example, upon wounding or herbicide treatment, water hyacinth releases a chemical attractant of both a weevil, Necochetina eichhorniae, and a water hyacinth mite, Orthogalumna terebrantis (Messersmith & Adkins, 1995).

Synomones are beneficial to both the emitter and the receiver. Plant volatiles released which attract insects can often be synomones. For example, pollinators are attracted to floral scents, allowing fertilization of plants, and food for the insects. Tomato plants release volatiles which attract species of the Trichogramma genus, which use the tomato pests Hymenopterous as their parasitic hosts. Terpenes released from damaged pine trees act as both synomone and kairomones, as they attract both the pine-feeding beetles and the beetle-targeting pteromalid hymenopterous parasites.





Section C

Transportation Pathways

Allelochemicals are introduced by plants into their environment in a number of ways; foliar leaching, root exudation, residue decomposition, volatilization and debris incorporation into soil (Inderjit & Keating, 1999).

Foliar leaching is when rainwater passes through the canopy and causes chemicals from the leaves to leak out into the environment.

Plant volatiles act as airborne communication signals, for example the triggering of fruit ripening by ethylene, and the attraction of parasitic wasps to ward off pests like caterpillars. Bean plants, Vicia faba, release a volatile, methyl salicylate, which is repellent to aphids but attractive to aphid enemies such as parasitoids.

Evidence of underground signals have also been found. The airbourne aphid-repellent chemical, methyl salicylate, is released by bean plants, Vicia faba, upon attack by aphids. However, other adjacent aphid-free plants can be triggered to produce this repellent, despite being unaffected by aphids, so long as they are connected to the aphid-infected plants via a mycorrhizal mycelial network of fungi (Babikova et al., 2013). This aids both the signal-producing infected plant, by triggering an increase in volatile repellent production in the vicinity, and the signal-receiving aphid-free plant, by warding off an attack pre-emptively. For more about how plants can use the fungal network to communicate, see the BBC article in the further reading.





Section D

How do plants use allelopathy?

Plants use allelopathy to their advantage in a number of ways, including alteration of the soil biochemistry to suit the preferences of the donor plant, defence against insect herbivory, and kin-recognition.



Similarly to quorum sensing in bacteria, plants can recognize their own species using allelochemicals and alter their growth patterns accordingly. In one study using the annual plant, Cakile edentula, Dudley et al found an increased resource allocation to roots when groups of strangers shared a common pot, but not when groups of siblings shared a pot (Dudley & File, 2007). Dudley was also involved in a follow up study of this observed kin-recognition effect. In which a mechanism for the effect was sought. Using Arabidopsis thaliana as a model, this group investigated the role of soluble chemicals in signalling among roots. Young seedlings were treated with liquid media containing exudates from siblings, and strangers (defined as non-siblings) or only their own exudates. The exposure of plants to the root exudates of strangers induced greater lateral root formation than exposure of plants to sibling exudates. Stranger recognition was abolished upon treatment with the an inhibitor of root secretions (Biedrzycki et al., 2010).

Allelopathy can aid succession

Allelopathy has been suggested to have a role in succession (Jackson and Willemsen 1976, Quinn 1974, Gant and Clebsch 1975). Native to Asia, Japanese knotweed is a pioneer species on volcanic sites. Japanese knotweed is thought to allow succession by making the post eruption environment more favorable to other species, for more on this see Resource 1.

In primary successional stands on Mt. Fuji, researchers Tateno and Hirose, found that organic nitrogen, ammonium, and nitrate concentrations were 14, 4, and 2-fold higher,



respectively, under R. japonica stands than in bare soil (Tateno and Hirose 1987). Many early successional species, like R. japonica, are known to increase soil formative processes, specifically by decreasing soil bulk density and increasing organic matter content, water content, and nutrient levels (Hirose and Tateno 1984).

Allelopathy can aid the invasive success of weeds

Japanese knotweed releases allelochemicals which can inhibit the growth of other plants. Plants which themselves produce phytotoxic compounds are also susceptible to develop resistance to allelochemicals to prevent autotoxicity through detoxification mechanisms (Inderjit and Duke, 2003). This has implications for restoration of contaminated land, suggesting that some species which are allelopathic themselves will be less susceptible to the Japanese knotweed residues left in soil.

Section E

Quorum Sensing in

Bacteria

The phenomenon of plants talking to each other through chemical signals, even via fungal networks, extends further to bacteria, which use a similar phenomenon called quorum sensing to communicate.

One example of quorum sensing is exhibited in the Hawaiian bobtail squid, Euprymna scolopes. This squid is just 3 cm in length and dwells in the shallow moonlit waters off Hawaii. Rather than casting a shadow over the light of the night's sky and scaring its prey, the squid has light organs to mimic the light of the moon, and allow it to hunt at night. The light comes from a marine bacterium, V. fischeri, which live in the light organ of the squid. The production of light is called bioluminescence. This species of bacteria can also live freely and float around the sea like plankton. When the density of



the bacteria is low, it would be a waste of energy for the bacterium to produce such a small quantity of light. However, in the light organ of the squid, where the density of bacteria is high enough that the light produced would be clearly seen, the bioluminescence is switched on. How do the bacteria know the density of bacteria of their own species surrounding them? Much like the kin-recognition observed by plants, bacteria release chemical signals to talk to each other.



Resource Five Activities

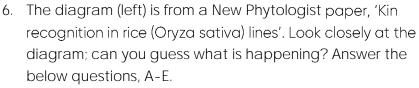


Activities



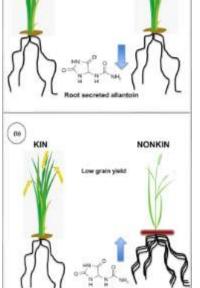


- 2. Give an example of a transportation pathway which might be taken by a plant allelochemical.
- 3. Japanese knotweed releases allelochemicals into the soil. What do these chemicals do?
- 4. A bean plant, Vicia faba, is attacked by an aphid. The aphid sucks the sugar-containing sap from the bean plant's phloem. How might the bean plant respond? Explain why this response would help the bean plant. Suggest how the growth of the bean plant may be affected.
- 5. Ethene, also known as ethylene, is a volatile organic compound. Suggest how it may be used commercially for bananas.





- b) How do the rice plants respond differently when they recognise kin compared to a non-kin stranger?
- c) What effect does all anton in have on the roots of the non-kin plant?
- d) How might the above effect be detrimental to the non-kin plant?
- e) How might this benefit the kin-rice plants?



Link to full paper:

https://nph.onlinelibrary.wiley.com/doi/full/10.1111/nph.15296 Yang, Xue-Fang & Li, Lei-Lei & Xu, You & Kong, Chui-Hua. (2018). Kin recognition in rice (Oryza sativa) lines. New Phytologist. 220. 10.1111/nph.15296.

Resource Five Further Reading



Explore

Watch this TED-ed video



https://www.youtube.com/watch?v=xOXSqy05EO0

Read this BBC article

http://www.bbc.co.uk/earth/story/20141111-plants-have-a-hidden-internet

Watch this YouTube video

https://www.youtube.com/watch?v=1pLfkWTbym4

Resource Six Overview



Topic Information from Infrared

A-Level Modules Infrared spectroscopy

Objectives By the end of this resource, you will be able to understand:

✓ Bonds in a molecule absorb infrared radiation at characteristic wavenumbers.

✓ How 'fingerprinting' allows identification of a molecule by comparison of spectra

✓ How infrared spectroscopy can be applied to biology

tructions 1. Read the data source

2. Complete the activities

3. Explore the further reading

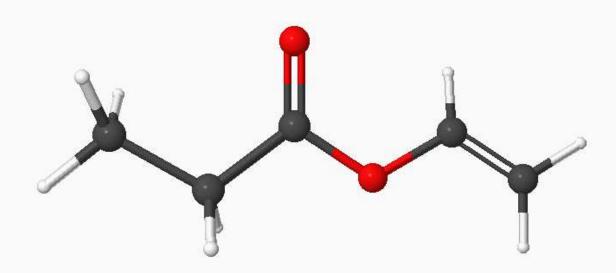
Context When infrared light interacts with molecules, it causes them

to change their vibrations. The bonds within the molecule bend and stretch in different ways. This resource explores how we can use the interaction between infrared light and

molecules to find out more information about

different samples. The use of infrared light in this way is

known as infrared spectroscopy.





Infrared spectroscopy is a technique used to identify different functional groups in a molecule. It is usually used by chemists to help identify a single molecule in a very pure sample. However, it can also be applied to more complex biological systems.

Section A

Molecular vibrations

Two atoms in a covalent bond are held together because both nuclei are attracted to the same pair of electrons. The two nuclei can vibrate backwards and forwards - towards and away from each other - around an average position. There are two basic modes of vibration – 'stretching' and 'bending'. Each bond vibrates at a different frequency. Vibration frequencies are affected by atom size, bond length and bond strength. Stronger bonds and lighter atoms vibrate faster.

Section B

Infra-red spectroscopy

In infrared spectroscopy, the energy from infrared light is absorbed by molecules in a sample, causing changes to their molecular vibrations. For a particular covalent bond in a molecule, only a particular set of vibrational frequencies is possible. Suppose a bond is vibrating at a frequency v1 and its next available frequency is v2; then, if radiation with a frequency (v2 - v1) is incident on the compound containing this bond, some of the radiation is absorbed and the bond vibrates at the higher frequency.

Determination of the frequencies in the infrared region which are absorbed by a compound gives information about the types of bonds which are present. The frequencies at which the energy was absorbed can be shown in an absorbance diagram, known as an infrared spectrum, which covers a range of frequencies, from around 4000 cm-1 to 500 cm-1. The patterns produced in the spectra by IR absorptions are complex and only a few bond types can be identified, such as carbonyl groups C=O, and hydroxyl (alcohol) groups O-H.



Regions of the IR-spectrum

The Y axis of an IR spectrum is percentage transmission, and the X axis is wavenumber measured in cm-1.

Bonds	to hydrogen	Triple bonds	Double bonds	Single bonds
	O-H N-H C-H	C≘C C≡N	C=C C=O	C-O C-F C-Cl
4000	300	0	2000	500 1000

Section C

The Fingerprint Region

The right-hand side of the diagram, from about 1500 to 500 cm-1, is known as the fingerprint region. This fingerprint region is too chaotic to pick out much information by eye. However, the fingerprint region is unique for each molecule and can be used for identification of specific molecules using pre-interpreted spectra from a database.

Section D

Intensity of absorption

IR spectroscopy gives information about the stretching and bending of bonds, particularly the kind of unsymmetrical bonds found in functional groups such as OH, C=O, NH2, and NO2. The intensity of an IR absorption increases with an increasing dipole moment as the bond is stretched. If two atoms in a bond have a very different electronegativity, then the bond will have a greater dipole moment, which will change more when it is stretched. This is why the intensity of absorption is higher for C=O functional group compared with a C-H bond. The oxygen atom is more electronegative than the carbon atom, and so holds a disproportionate amount of the electron density at that end of the bond. Hydrogen bonding can increase the width of the peaks, so O-H of alcohols are easily spotted by their broad peaks in the range 3230 – 3550 cm-1.



Section E

Application to Biosciences

As part of your exams, you will be asked to identify functional groups from the main regions of an example IR spectrum. This is something which organic chemists do frequently, as it helps them to check if they have made the right molecule. In organic synthesis chemistry, the aim is often to produce a pure sample containing only one type of compound.

In contrast, in biological systems, there are a multitude of molecules all mixed together. Imagine taking a spectrum of a cell in your own body and trying to interpret the vibrations caused by all the bonds in your DNA, the proteins in your enzymes, and the lipids in your cell membranes, all bending and stretching at once. Luckily, computer programs and coding can be used to apply maths to the spectra from complex samples.

A specific type of infrared spectroscopy called ATR-FTIR can be used to solve biological questions. ATR stands for Attenuated Total Reflectance, which is a type of sampling technique involving the passage of infrared light through a crystal. FTIR stands for Fourier Transform Infrared Spectroscopy. A Fourier transform is a mathematical process used to convert the raw data into the actual spectrum.

Rather than using the main spectrum to pick out functional groups, the computer plays spot the difference with the messy fingerprint region. Because of the individuality of the fingerprint region, minute changes in spectra can be seen. For example, the difference between the average spectra taken from a set of healthy cells can be compared to the average spectra from a set of ovarian cancer cells. Once the computer is trained to recognise the difference between healthy and cancerous cells, it can be used for patient diagnosis. This is an example of machine learning, where the computer uses a known fraction of a dataset to assign the rest of the data.



I am applying this technique to phylogenetics, the study of the evolutionary history and relationships among individuals or groups of organisms (e.g. species, or populations). Phylogenetics is traditionally worked out by looking at heritable traits, such as DNA sequences. The more similar two species are, the more closely related they are likely to be. I use ATR-FTIR and a mathematical analysis called hierarchical clustering to form linkage maps, similar to those achieved with genetic data. Unlike genetic analysis, ATR-FTIR does not require any long-winded sample preparation, DNA extraction, or sample destruction.



Activities Question 1

Bonds in a molecule infrared radiation at characteristic
wavenumbers. This causes a change to their molecular
Strong bonds vibrate than weak bonds. Chemists use
IR spectroscopy to identify thein a molecule.
'' allows identification of a molecule by comparison of
spectra.

Question 2

Give me an example of how IR spectroscopy can be applied to Chemistry or Biology.

Question 3

Using the information in the following table, why does the bond C-Br vibrate more slowly than C-Cl?

ELEMENT	ELECTRONEGATIVITY	ATOMIC MASS/ U	BOND ENERGY OF C-X BOND/ KG MOL ⁻¹
CHLORINE	3.16	35.453	428
BROMINE	2.96	79.904	362

Question 4

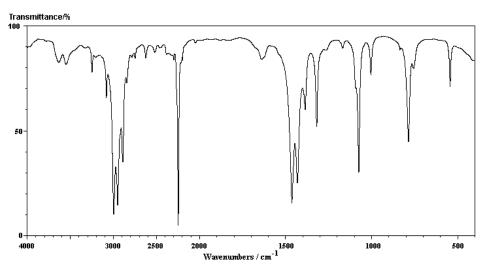


Using the infrared absorption data on the next page, match up the spectra A-D with the following molecules:

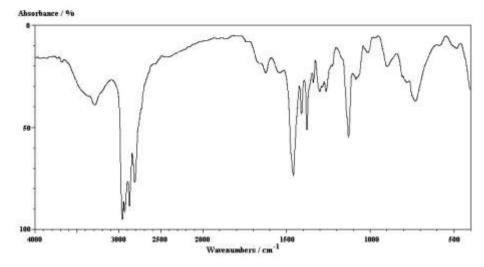
- 1. Butanal, CH3CH2CH2CH(=O)
- 2. Propionitrile, CH3CH2C≡N
- 3. Dodecane, CH3(CH2)10CH3
- 4. Dipropyl amine, (CH3CH2CH2)2NH



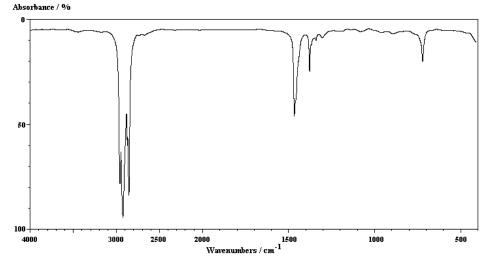




Spectrum B

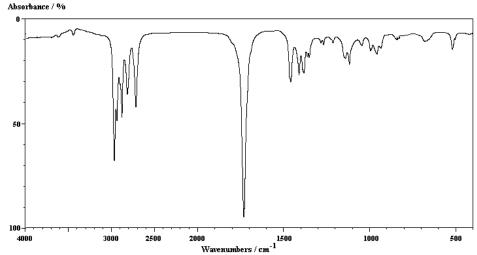


Spectrum C





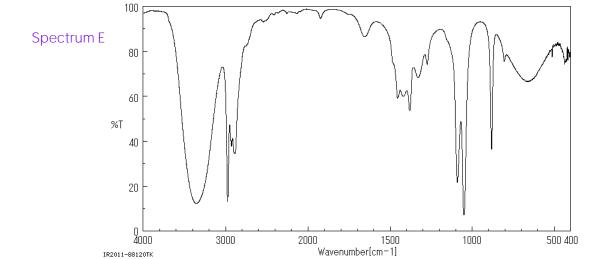




Question 5

Using the absorption table below, identify one feature of the infrared spectrum below (Spectrum E) of a pure sample of X that may be used to confirm that X is an alcohol.

	Infrared absorption data
	<u> </u>
Bond	Wavenumber/ cm ⁻¹
N-H (amines)	3300 – 3500
O-H (alcohols)	3230 – 3550
C-H	2850 – 3300
O-H (acids)	2500 – 3000
C≣N	2220 – 2260
C=O	1680 – 1750
C=C	1620 – 1680
C-O	1000 – 1300
C-C	750 – 1100





Question 6

The 'greenhouse effect' is a process that occurs when gases in Earth's atmosphere trap the Sun's heat. The greenhouse effect of a given gas is dependent on its concentration in the atmosphere and its ability to absorb infrared radiation. Using the table below, argue which of these three gases are greenhouse gases.

GAS	ABBREVIATION	BOND TYPE
Carbon Dioxide	CO ₂	C=O
Water	H ₂ O	O-H
Methane	CH ₄	C-H

Resource Six Further Reading



Explore

Watch this short video to hear more about bio-spectroscopy and its applications within research



https://www.youtube.com/watch?v=lhRNhv70WTA

Final Reflection





Topic Japanese knotweed in the UK

Objectives

Japanese knotweed is an interesting plant in its own right; it can help the transformation of barren volcanic landscapes into lush forests filled with life, it can send out chemicals to change its environment, it can reproduce by itself using its rhizome system and grow super-fast.

In the UK, a lack of natural predators to control this species has allowed it to grow so well that it is receiving some bad press. How much damage it is really causing is a question very hard to quantify. The Japanese knotweed removal industry, solicitors, and homeowners alike are all undecided on how much physical, emotional, and financial damage this controversial plant can inflict.

Instructions

Create a poster outlining the reasons why Japanese knotweed has become an invasive species in the UK, and how the problem may be addressed.

Your response may include:

- 1. What a balanced ecosystem is
- 2. How species are usually controlled by predation
- 3. The difference between an introduced species and an invasive species damage caused including environmental, emotional, financial, and physical
- 4. Control measures such as biological and chemical

Final Reflection





Explore Read

Read this article about the new study relating to the damage caused by Japanese knotweed.

https://theconversation.com/japanese-knotweed-is-no-more-of-a-threat-to-buildings-than-other-plants-new-study-99580

Watch

If you want to identify Japanese knotweed in your local area, watch Paul Beckett of Phlorum explain how in this useful video:

https://www.youtube.com/watch?v=MPqVLn_i2nY

Japanese knotweed is most commonly found by watercourses and railways. Take a walk down your local canal and see if you can spot any.

Listen

Skip to 19:40 into this podcast for a deeper look into the Network Rail case.

https://www.bbc.co.uk/sounds/play/b0b7fj36

This podcast contains interviews with the people who were affected when Network Rail allowed Japanese knotweed to spread onto their property. It touches on the idea of trying to quantify damage, particularly in the absence of any physical destruction.

Do

Volunteer with a local environmental group to target invasive species in your area.

If you are currently completing a Gold Duke of Edinburgh Award, consider a residential with the National Trust. I did this for mine and had a fun week meeting new people, conducting bat emergence surveys, and pulling up unwanted plants around the beautiful Culzean Castle.

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University Study Skills Cornell Notes

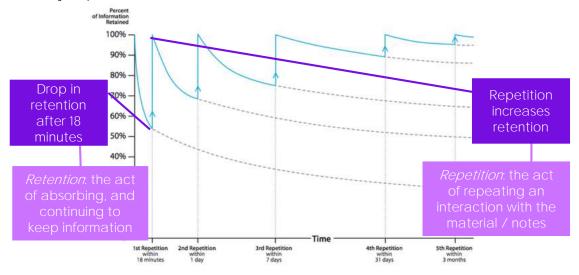




Why is good note taking important?

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.

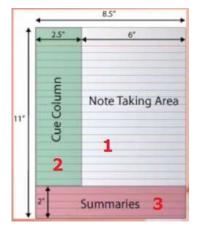
If we take notes effectively, however, we can retain and retrieve almost 100% of the information we receive. Consider this graph on the rate of forgetting with study/repetition:



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. Write and Organise: 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

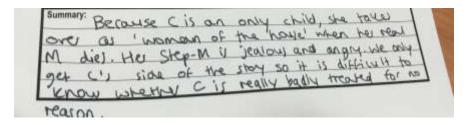
- 1. Revise and Edit Notes: Go back to box 1, the note taking area and spend some time revising and editing. You can do this by: highlighting 'chunks' of information with a number or a colour; circling all key words in a different colour; highlighting main ideas; adding new information in another colour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

Questions:	Notes:
How does C's	· Cinderella's dad might spoil has
	· Cinacella's Step-Mother is
why does c make the ste	p- maybe cinderely becomes the
w so orbid;	
shows this?	ge wants that position!
- X	- 8 Key point - & fairy tales touch
What is the	W (WOLD)
How go I KLO	is not sup- m
Is this just	· 1) there a reason for C to be
one side of	
the stony?	

Step 3 Note-Interacting

1. <u>Summary</u>: 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-quide-to-clearing

Subject Guidance



Natural Sciences at University



- ✓ Biochemists investigate the chemical processes that take place inside all living things.
- ✓ Biochemists 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 Biochemists Careers online: https://www.ucas.com/ucas/after-gcses/find-career-ideas/explore-jobs/job-profile/biochemist

A Deeper Look Into Natural Sciences

- ✓ Listen: http://www.bbcearth.com/Podcast
- ✓ Listen: https://www.nature.com/nature/articles?type=nature-podcast/.
- ✓ Read: https://www.newscientist.com/section/news/
- ✓ Read: https://theconversation.com/uk/



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