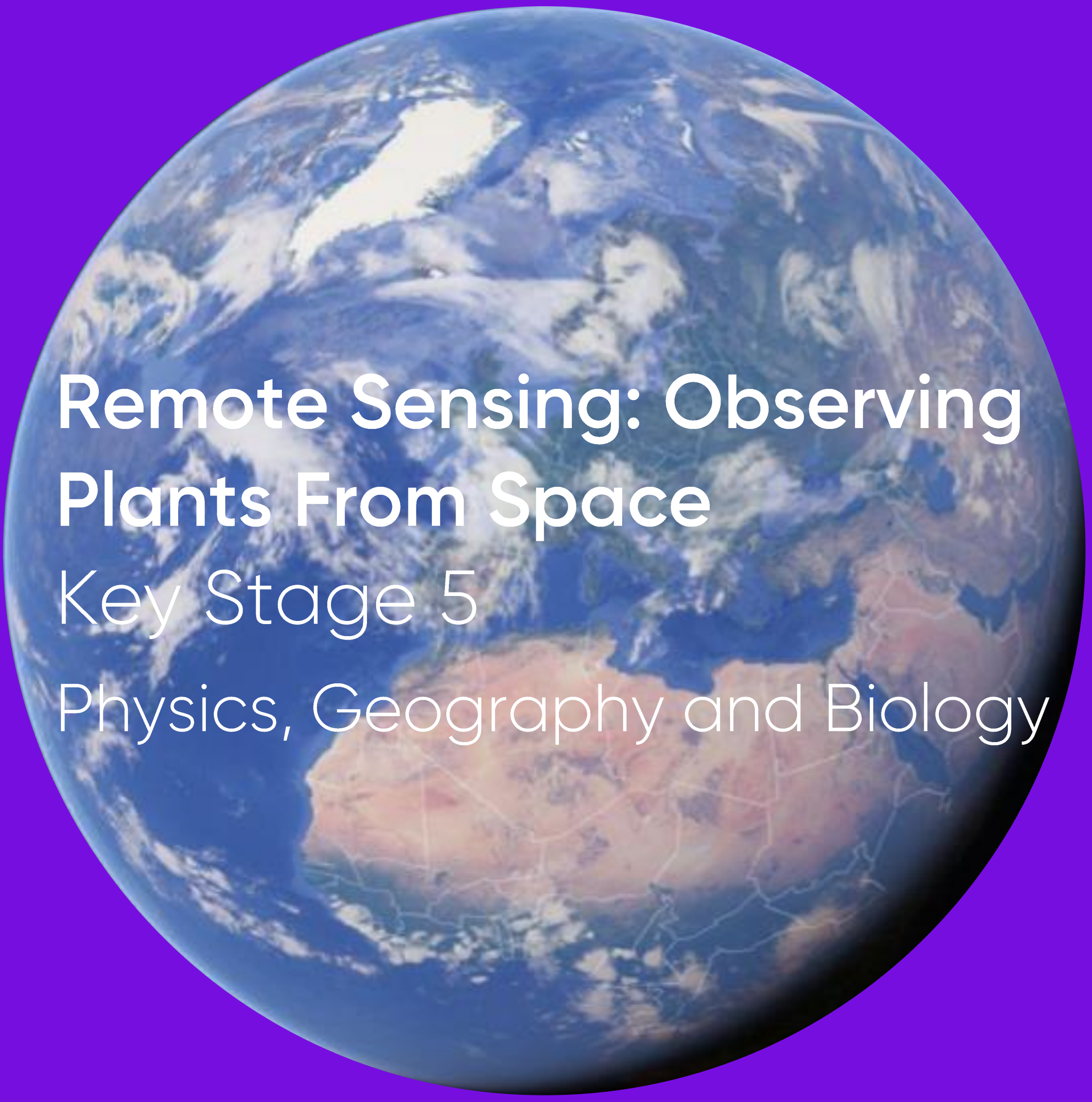
Research
Based
Curricula



Remote Sensing: Observing Plants From Space

Key Stage 5

Physics, Geography and Biology

2020

BROUGHT TO YOU BY RBC ACCESS ED

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For Students
Getting Started

RBC means Research-Based Curriculum,. Each RBC coursebook is written by a PhD student at a university about their cutting edge research.

Why complete an independent 'RBC' study pack?

RBC courses are challenge courses to sharpen your skills and resilience: finishing a RBC course is a major accomplishment to add to your academic CV. To get into the university, you must demonstrate that you are intellectually curious, and will make the most of the academic opportunities available to you. Completing a pack will allow you to gain invaluable experience to write about in your university application..

It allows you to:

✓ Build your subject experience to mention in your UCAS Personal Statement
✓ Sharpen your academic skills
✓ Experience what it's like to study beyond school and at university
✓ Better understand what you enjoy and don't
✓ Improve your overall subject understanding ahead of final exams

For Students
Getting Started

What's in this booklet?

Your RBC booklet is a pack of resources containing:

- ✓ More about how and why study this subject
- ✓ Six 'resources' each as a lesson with activities
- ✓ A final assignment to gauge learning
- ✓ Extra guidance throughout about the university skills you are building
- ✓ End notes on extra resources and where to find more information

Who should complete this pack?

Anyone interested in improving their academic skills or understanding what they should do at university. *This pack is especially great for anyone interested in studying* ***Sciences,*** *particularly* **Physics, Biology and Geography**, *and want to understand how they link.*

Even if you are unsure of where your interest in these subjects can take you, by completing this pack you will have a clearer idea of the variety of subjects that link to one another.

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 Students
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!

Skills you will build for university:

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

Where can this subject take me?

Pathways

Studying Biology or Psychology can open the doors to many degrees and careers. It intersects with microbiology, chemistry, physiology, and sociology. Whatever interests you is likely to relate to biology in some way. See a snapshot of where studying Biology and Psychology can take you.

'Transferrable skills' from Geography to a career:

- Research ability
- IT skills
- Teamwork
- Problem solving
- Analytical and critical ability
- Communication skills through presenting, writing and debating
- Time management
- Creativity
- IT and computer literacy

'Transferrable skills' from Physics to a career:

- Problem solving
- Reasoning
- Numeracy
- Practical skills
- Research and data analysis
- Communication
- Team Working
- Time management and organisation
- Information Technology literacy

What are some are the 'interdisciplinary' subjects in this course?

Interdisciplinary is a term you will hear used by higher education institutions. It's also how many professionals and academics in the real-world operate: they use multiple subjects, or disciplines, to achieve their work.

By thinking about which subjects you like, alongside maths, it can help you choose a career pathway later.

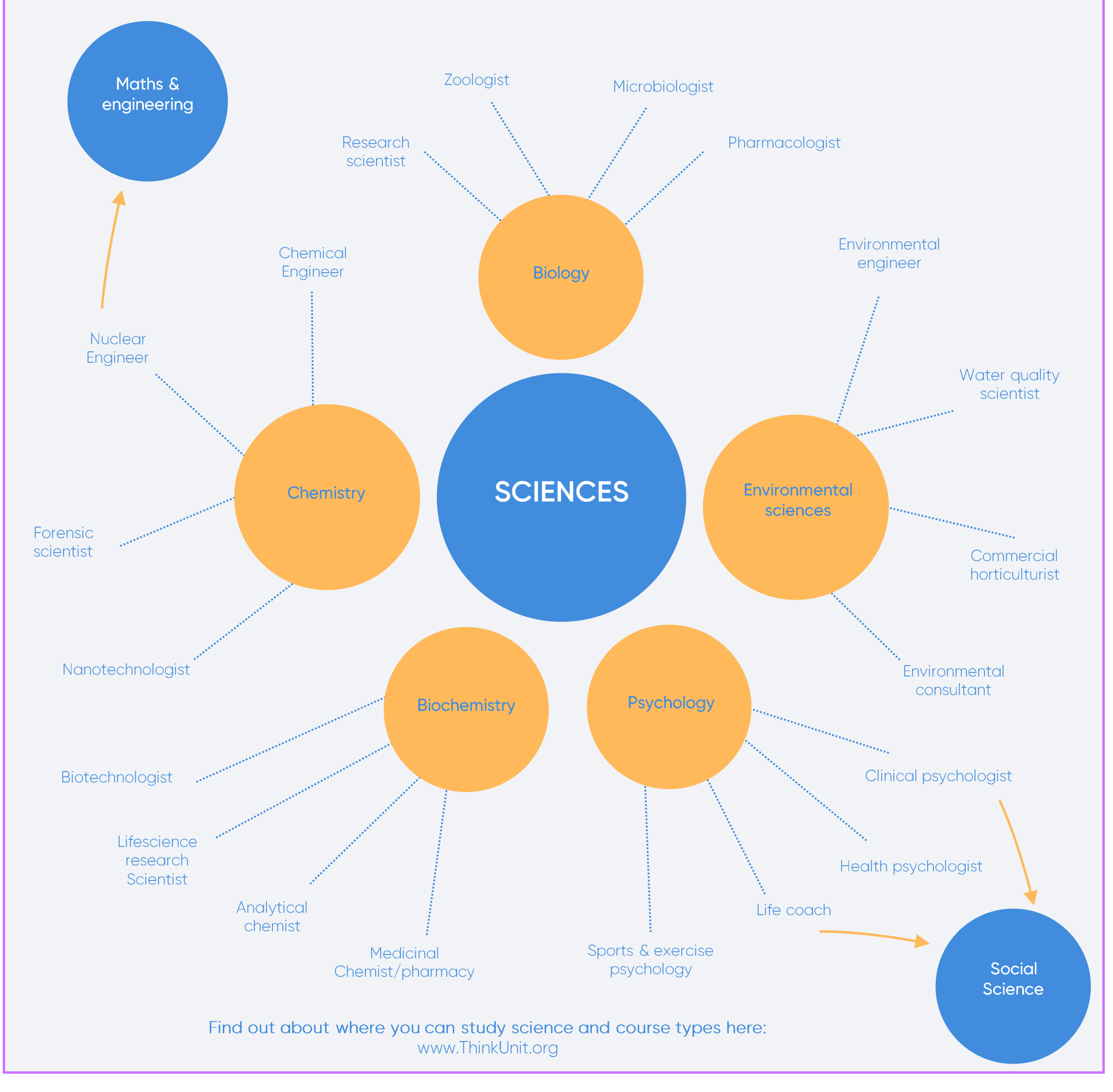
Read more about subject selection and careers pathways:

https://targetjobs.co.uk
https://www.prospects.ac.uk
https://thinkuni.org/

Subject map: Sciences

A degree in Sciences gives Students access to a large number of career choices. Many students who study sciences go on to pursue their Master's degree in Science. However, a significant portion of them also start looking out for jobs in the field of Cancer research, Stem Cell technology and other positions in this space.

Did you know? Being a scientist of any kind can open up may doors within any industries, from managing projects to labs to health policy teams with governments!

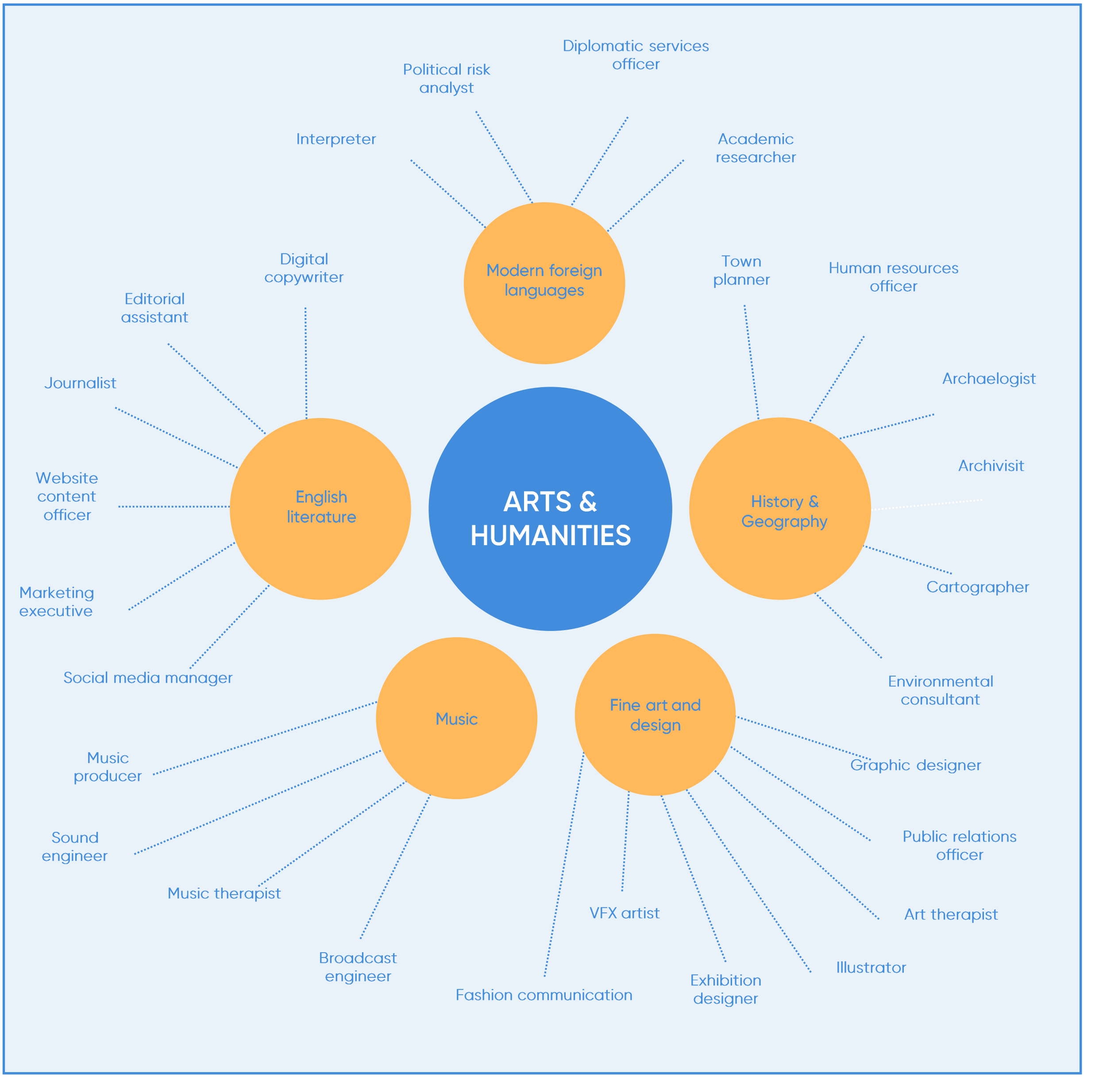


Find out about where you can study science and course types here:
www.ThinkUnit.org

Find our about Science-related careers here:
PROSPECTS: https://www.prospects.ac.uk
TARGET JOBS: https://targetjobs.co.uk

Subject map: Arts and Humanities

Arts as a subject choice is quite popular with students, and it doesn't just mean visual arts like painting or design. These subjects often complement one another and around 24.7% of students with an Arts degree go on to do a Masters' degree in a subject that is within the broad field of Arts and Humanities. Furthermore, a lot of these students get jobs in Marketing, PR and sales.



Find our about Science-related careers here:
PROSPECTS: https://www.prospects.ac.uk
TARGET JOBS: https://targetjobs.co.uk

For Teachers RBC Guide

Learner 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.

Using the RBC pack

These 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
Using the RBC packs

Extra-Curricular Subject Enrichment Clubs

Here are five examples of delivery options:

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.

Why offer these?

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 Studying Natural Sciences at University

The topics within this pack will include:

An introduction to earth observation

The electromagnetic spectrum and satellite vision

Image processing and the creation of vegetation indices

I studied 'Natural Sciences' at undergraduate level. This is a very broad subject which includes elements of biology, chemistry, physics, geography and environmental science. The nice thing about this broad approach is that it gives you a solid grounding throughout the sciences and allows you to pick more specialist courses from across different subjects. For example I took biology modules related to whole organisms (plants and animals) but had very few classes on biochemistry (the cellular level processes). I learnt how our global cycles are affected by a combination of living organisms and physical oceanic and geological processes. I also did courses on collecting data from the field and identifying plants and insects.

Having completed two undergraduate degrees, one in the arts and the other in science, I found that the methods of learning in these two areas are very different. In science there is a lot of information to absorb and understand before you can start applying what you know to real life situations. I would say that in this way, the creative side of science comes later, when you start looking at your own projects. With a subject like Fine Art, you start making straight away and learn your craft by doing. So if you are a creative person, some patience is required at science undergraduate in order to carefully learn all the basic stuff well.

An important tip when studying is to try to contextualise what you are learning so it doesn't remain simply theoretical. Go on as many field trips as you can and perhaps volunteer your time to a charity working in your area of interest. This will also help you to understand where you might want to go in the future.

Introduction to Research

This particular area of research falls under 'Environmental Science' which is a branch of geography. It looks at how images captured by satellites and other instruments can be used to understand what is happening to plants on the surface of the earth. I am particularly interested in how we can monitor changes in biodiversity (the number and frequency of living organisms) and the health of communities. This work is really important as we are currently undergoing a huge loss in species diversity which is entirely caused by human activities. What long term impact this will have on our planets health and human survival is yet to be fully determined, my work being just a tiny piece of this puzzle.

You will see when working through this pack that although the objectives of my research lie firmly in the realm of environmental science, the technology of satellite image capture are based on physical principles (ie they could be part of a physics school syllabus). Understanding how light interacts with plants also requires an understanding of photosynthesis, plant development and plant taxonomy (naming plant species), which are all core biological subjects. When you get more involved in a scientific area, it's amazing how multi-disciplinary it can be and how many different skills you will need to master.

Working with the environment and studying living entities is fascinating and also humbling. We live in an amazing place and as scientists, I believe we should be doing all we can to apply our knowledge and skills to environmental protection.

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Meet the PhD Researcher Rachael Thornley

I have taken a very unusual pathway to studying a PhD in earth observation. When I was at school I loved the arts and actually took my first undergraduate degree in Fine Art at Middlesex University in London where I focused on photography and video making (lens based media). After finishing my degree I worked for several years in film and television. Later, I became disillusioned with the media and decided that I wanted to do something positive to help the environment. I felt (and still do) that this is the most pressing issue of our time! With this in mind, I did an apprenticeship with the National Trust, a UK land conservation charity. Following this, I worked for various non-government agencies managing land in the UK and abroad for biodiversity. During this time I did a part time distance learning degree with the Open University in Natural Sciences, which led onto a masters degree in Ecology at Imperial College London. Now I am studying full time towards a PhD at Reading University.

I hope you followed my story ok! You never stop learning in life - I still feel I have plenty of new things I would like to discover. Don't think about your A-level and degree choices as the be all and end all of your education. You change as you get older and so do your interests.

A-Level Subjects	English Literature, Art and Design, Politics and Government, Theology
Undergraduate	Fine Art (BA) and Natural Sciences (BSc)
Postgraduate	Ecology, Evolution and Conservation (MSc), Environmental Science (PhD)

Glossary

Term	Definition
Earth observation	The process of collecting data using satellites
Remote sensing	As earth observation but can also involve
Sentinel 2	The European space agency satellite system
Landsat	The longest running satellite system owned by NASA
Scanner systems	One of the ways remote sensing instruments capture data line by line
CCD systems	One of the ways remote sensing instruments capture data whole areas are captured at once.
Spectral bands	Areas of the electromagnetic spectrum where data is captured.
Image resolution	The quality or detail of an image. Resolution can be spectral, spatial or temporal.
Light attenuation	Processes that reflect, refract or absorb light.
Atmospheric windows	Areas of the electromagnetic spectrum where light
Photosynthesis	The process by which plants obtain organic carbon from light and atmospheric carbon dioxide.
Calvin cycle	A part of photosynthesis occurring at the cellular and molecular level by which energy and organic carbon is produced.
Rods	The radiance sensitive parts of the human eye.
Cones	The wavelength (colour) sensitive parts of the human eye.
Spectral signatures	The characteristic way that some surfaces reflect light in different parts of the electromagnetic spectrum.
True colour images	Colour composite images with three channels that represent how the human eye would see a scene.
False colour images	Colour composite images with three channels where wavelengths other than red, green and blue are attributed to the three channels.
Digital numbers	The numeric representation of an image on a pixel by pixel basis.
NDVI	The Normalised Difference Vegetation Index – a way of measuring photosynthesis.
Biodiversity	The number of species within a given area and their relative abundances
Simpson's diversity index	A measure with values from 0-1 that estimates the number of species and their relative abundances in a sample.
Spectral variation hypothesis (SVH)	The concept that high levels of spectral variation in a given area is correlated with high levels of species diversity.

Resource One Overview

Topic	An introduction to earth observation
A-level Modules	Physics: The Use of satellites
Objectives	By the end of this resource, you will be able to: ✓ An overview of the main satellites and their owners ✓ Details on who might use this data and what for.
Instructions	1. Read the resources 2. Answer the questions 3. Explore one or more of the extra resources

Resource One
Data Source

Section A

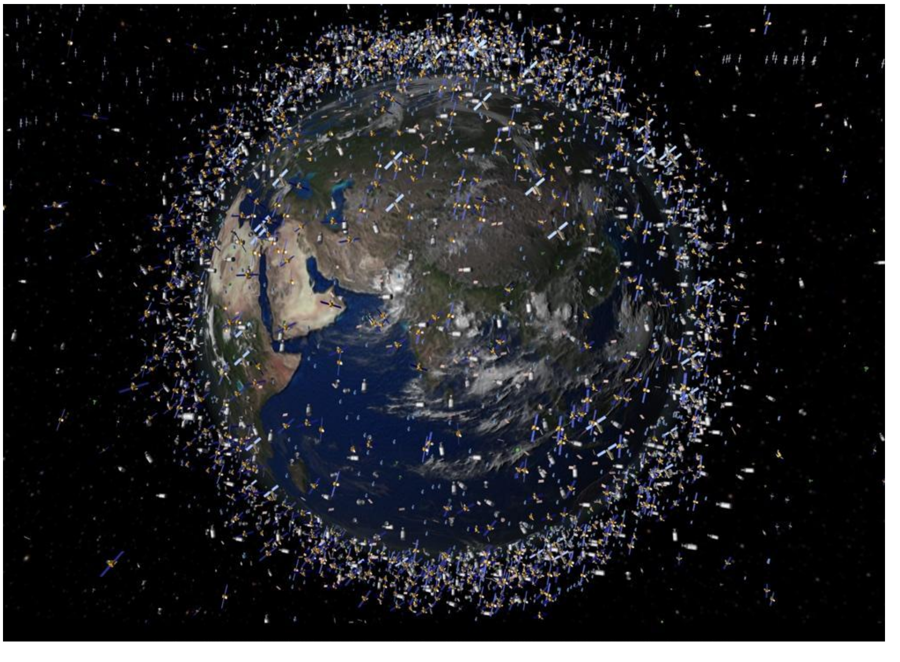
What is a satellite?

Did you know there are almost two thousand operational satellites in orbit around our planet, and many more that are in operational (also known as space junk). The first ever satellite was called Sputnik and was launched by the Russians in 1957. It was only the size of a beach ball and triggered a space race between the USA and the USSR for space dominance. Today, satellites are used for many purposes; for example, communications, navigation, monitoring weather and space activity. The type of satellite we are interested in for this booklet are those that undertake 'Earth Observation', that is, those that capture photographic images of the surface of the earth. Collecting data using satellite platforms is also referred to as 'remote sensing', although we can also do remote sensing from planes and other smaller aerial vehicles.

Figure 1

An artist's representation of the amount of space debris circulating in Earth's orbit. The problem is becoming greater as satellite technology becomes cheaper to access. In 2017 alone, 453 objects were sent into space.

Active Reading



(image source: https://www.pixalytics.com/sats-orbiting-the-earth-2018/)

Resource One
Data Source

You are probably aware of the satellite mode on you google maps app or on the web page. These images are sourced from the North American national Earth Observation satellite program called 'Landsat', the biggest and most expensive satellite mission to date. The European Space Agency (ESA) also run a group of satellites called Sentinel. Both Landsat and Sentinel are very important programs as they record global information all year round which is free to the end–user (that is, anyone who wants to download the data). There are many privately run satellites in earth's orbit from which data must be purchased, often at high costs. However there can be advantages to this imagery over what Landsat and Sentinel can offer, such as more detailed images or more frequent image capture.

Table 1

Some of the largest and most useful satellite constellations and their creators. You may wish to refer back to this table later in the materials if you get confused with the satellite names.

Name of satellite program	Creator / owner	Time in space	Free for us to use on demand
Landsat	US government/ NASA	1976 – now	Yes
Sentinel	European space agency	2013 – now	Yes
MODIS	US government/ NASA	2000 – now	Yes
SPOT	Private company called 'Spot Image' based in France	1986 – now	No
IKONOS	Private company called 'Lockheed Martin Space Systems'	2000 – 2015	No
Hyperion (EO-1)	US government/ NASA	2000 – 2017	Yes

Resource One Data Source

Section B

Who uses this data?

Read this university level text book definition of remote sensing:

Remote sensing is "...the art, science, and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring and interpreting imagery and digital representations of energy patterns derived from non-contact sensor systems." (Jenson 2005).

The first thing we can draw from this definition is the huge range of skills that contribute to the field. You can be a physicist or engineer who is involved in the design of the instruments, or a visually talented geographer who is very good at displaying data as images. The second important point is that the purpose of earth observation is to collect reliable data about the earth's surface, not merely pretty pictures. We can do this by observing energy patterns.

The information we obtain from earth observation is very important to environmental scientists, in particular those that study plants on global or regional scales. Space located sensors allows us to map the presence and absence of plants; to detect vegetation types; to monitor the amount of photosynthesis occurring on the surface of the planet and the way the seasons may be changing as a result of climate change.

These measurements can used in themselves or be loaded into complex mathematical formulas which determine the amount of atmospheric gases and the impact of vegetation on the global climate. These mathematical formulas are known as 'climate models' and their aim is to help us to understand and predict the complex interaction of events that produce our weather and climate.

Resource One Activities

Activities

Active Learning

1. What is an interchangeable term we can use instead of Earth Observation?

2. Who are some of the main users of Earth Observation data?

3. Using the information provided in table 1, choose the most suitable satellite for the following situation: A conservation charity with limited funds wishes to carry out a long -term study looking at forest destruction in the tropics during the period 1980 to 2000.

4. Name four different ways that we can use earth observation to monitor plant life on the surface of our planet.

5. Think about your local areas and the local parks or other green spaces. Write a question that a scientist could try to answer about the distribution of plants in your area using satellites.

Resource One
Further Reading

Explore

Independent Research

- Using a computer with access to the internet – go to this web page www.google.com/maps. Use the satellite tab located at the bottom left hand side of the screen. You are now viewing satellite imagery yourself. Zoom right out so you can see the whole globe. You can spin the globe and go anywhere on the earth's surface. Explore some different parts of the world. Notice the distribution of vegetation on Earth (the green bits).
- Watch these time-lapse videos of the earth from space created by an astronaut called Alexander Gerst. https://www.youtube.com/watch?v=lNwWOul4i9Y
- Read this article from the science magazine 'nature' on the problems caused by space junk: https://www.nature.com/articles/d41586-018-06170-1

Resource Two Overview

Topic	Imaging the earth
A-level Modules	Physics: Transmission media
Objectives	By the end of this resource, you will be able to: ✓ Understand the history of earth observation ✓ Provide an overview of the main technologies behind satellites ✓ Students should grasp the ideas of image resolution.
Instructions	1. Read the resource 2. Answer the questions 3. Take some time to look at some real satellite images online

Resource Two
Data Source

Section A

Image capture

The very first photographs were created in the early 19th century using plates with photo-sensitive chemicals applied to them. Not long after people realised the advantages of being able to look at the ground from above and take photos. This was the first 'remote sensing' work. The first and second world wars were major impetuses for the development of cameras as both sides wished to spy on the enemy and understand the location of airbases and other infrastructure. After the wars, the technology was applied to mapping the world using aerial survey.

Figure 1

On the left, aerial war photography with a film camera mounted on a plane; on the right a very early aerial photo of a German city, Cologne.

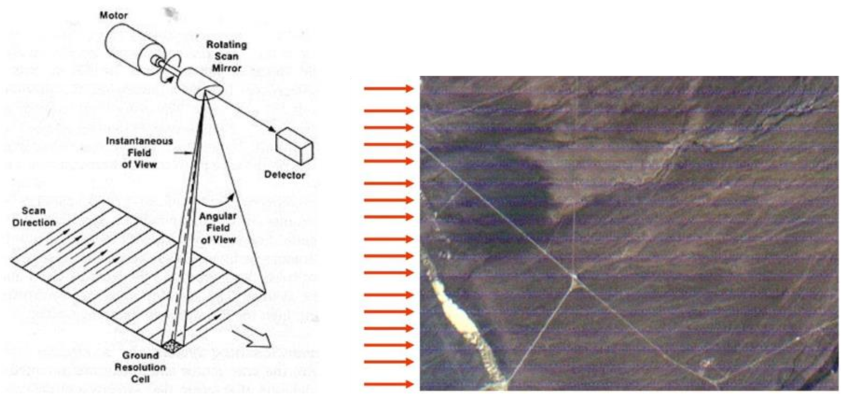
Active Reading

Cameras today are unlike the ones used in the early part of remote sensing. They are digital (not analogue using film). On board satellites there are two kinds of sensor, scanning radiometers (also known as whisk-broom) and Charge Coupled Devices (CCDs also known as push-broom). Scanning radiometers move backwards and forwards and create lines of data. They use a set of mirrors to split the suns' signal into different parts, which we refer to as bands. The width of the image is called the 'swath'. Different sensors are able to capture data with different swath sizes. This can be well demonstrated when looking at figure 2. It shows a slightly faulty image produced by Landsat, where the scanner has not captured the image data properly, leaving gaps shown by the funny coloured lines. You can see how the instrument works by going backwards and forwards across the scene.

Resource Two
Data Source

Figure 2

A scanner system that captures images piecemeal in a series of stripes. The faulty image shows the direction of the scan.

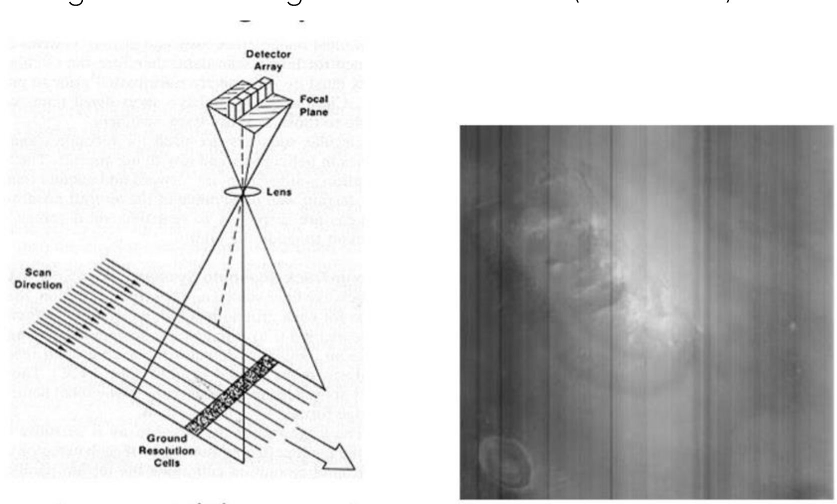


Active Reading

In contrast, CCDs sense a whole area of the surface simultaneously. These are more modern instruments and are similar to those ones found in your phone camera. There are advantages and disadvantages of the two technologies. CCDs are small, have no moving parts (so are less energy demanding) and are much cheaper. They also produce more detailed images. The only problem with them is that the data they produce can be less reliable as the surface of the CCD has thousands of light sensitive sensors that require checking and constant calibration. For this reason scanners are still being used in the larger satellite missions (see table 1).

Figure 3

A CCD system: the image below demonstrates a fault. This time the stripes are vertical reflecting the direction of the scan.



Resource Two
Data Source

Section B

When can we observe the earth?

Figure 4

The earth in partial shadow and in thick cloud.

(Sourced from https://earthobservatory.nasa.gov/images/36019/earth-viewed-by-apollo-8)

Look at this image of the earth. Which parts of this image do you think are suitable for earth observation and which are not? The main point you should have thought of is that we need the sun to be shining on the earth in order to obtain information about the surface. So areas of the globe such as the poles can only be observed in the summer (the poles in mid-winter are in continuous darkness). Also, the sun's light cannot pass directly through clouds, so where there is cloud cover it is also not possible to obtain information. Because the light sources are not controlled, earth observation systems discussed here are called 'passive remote sensing'; we are passively reliant on the sun's rays reaching the earth's surface in order to use them. There exist also active systems called Radar or lidar but these are not covered here (if you are interested in these types of remote sensing see the extra resources section).

Resource Two
Data Source

Section C

Image quality – image resolution

Table 1

Image resolution data of some of the most important satellite missions

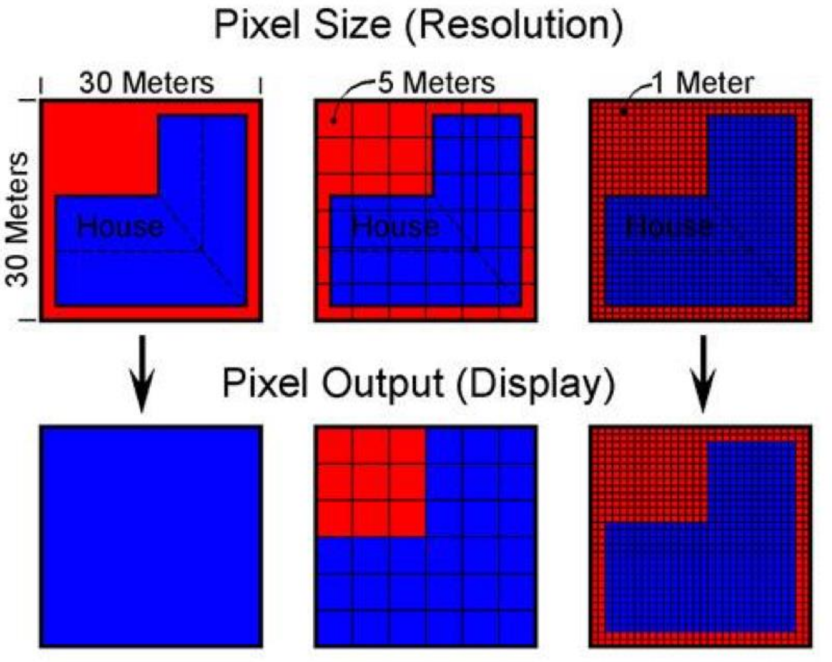
Instrument	Sensor type	Spectral resolution	Number of channels (or bands)	Spatial resolution (best)	Temporal resolution
Landsat - 8	scanner	Visible and near-infra-red	6	30 x 30 m	16 day revisit
Sentinel - 2	scanner	Visible and near-infra-red	13	10 x 10 m	6 day revisit
MODIS	scanner	Visible, near-infra-red, Short wave infra-red	36	250 x 250 m	1-2 day revisit
SPOT	CCD	Visible and near-infra-red	4	6 x 6 m	26 day revisit
IKONOS	CCD	Visible and near-infra-red	4	4 x 4 m	16 day revisit
Hyperion	CCD	Visible, near-infra-red, Short wave infra-red	220	30 x 30 m	16 day revisit

Images captured by satellites have different qualities, which can be summarised by the term 'resolution'. There are three main types of resolution; spatial, temporal and spectral. The table below gives you an overview of the resolution provided by 6 major satellites. The spatial resolution refers to the size of the image pixels relative to the ground area the sensor is capturing. You will know that all photographs have a pixel resolution, as when you zoom in too much they go pixelated or appear blurry. The image below shows the same scene (a house) but taken by different satellite sensors. The house measures about 30 x 30 m. The left hand side of the diagram shows how Landsat would capture the house (in one pixel). The middle example is similar to a satellite like IKONOS or SPOT. The final example on the right shows how a very high resolution device would show the house. There is no such satellite data widely available but in the future it is likely there will be. However detail is not always a good thing as very large images are difficult to deal with in terms of computer memory and processing power. The ideal resolution is related to the application.

Resource Two
Data Source

Figure 5

Diagram of how a house might be represented by satellite sensors of differing spatial resolution



(sourced from: https://www.satimagingcorp.com/services/resources/characterization-of-satellite-remote-sensing-systems/)

Active Reading

Temporal resolution, is referred to in remote sensing as 'revisit time'. This is because the satellite is circulating the globe suspended in orbit (it has a set path that it follows). There are different kinds of orbits which determine how often the satellite will collect data from a particular place on the earth's surface. Some satellite systems are actually composed of a pair of satellites in order to double the revisit time (like Sentinel 2).

Spectral resolution is a measure of how much of the electromagnetic spectrum can be captured by the sensor and therefore how many bands or channels it has. This is very important for research based activities concerning vegetation.

Resource Two
Data Source

Section D

Multi-spectral and hyperspectral data

The satellites listed in table 1 are mostly able to capture images that we describe as 'multi-spectral'. More recently devices have been developed that are called' hyperspectral'. The differences between these two types of instruments are illustrated in figure 6. The hyperspectral device gives us much more information about the nature of the earth's surface and so in many ways allows us to work more accurately. However hyperspectral data can only be captured with the use of CCD type sensors. It also has an issue called poor ' signal to noise ratio'. There is only a certain amount of light available from the sun and this has to be split in many different directions to produce a hyperspectral image. This process negatively affects the quality of the signal.

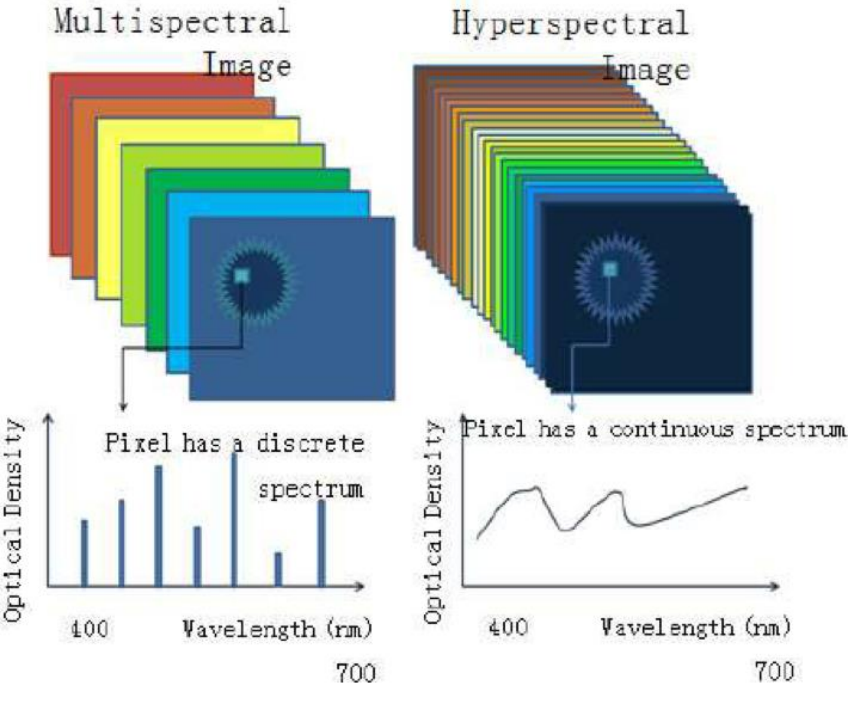


Figure 6

Multispectral bands record larger chunks of light whereas hyperspectral devices collect data in smaller chunks. Multi-spectral data is also called 'discrete' (meaning disconnected or discontinuous); hyperspectral data is called continuous (meaning connected). Image sourced from:

https://www.researchgate.net/publication/281067356_Early_detection_of_melanoma_using_multispectral_imaging_and_artificial_intelligence_techniques

Resource Two Activities

Activities

Active Learning

1. If we wanted to build a data set of images to survey a large area of the globe as often as possible, looking at table 1 which satellite would we use? Do you think we would actually get images this frequently? What would likely prevent use from obtaining this temporal resolution?

2. If you saw a satellite image with strange white lines running horizontally, what type of instrument is very likely to have produced this image? How do you know this? Can you explain what has probably caused the lines?

3. Write a short paragraph describing the pros and cons of the six satellite missions we have mentioned in this module.

4. Look at the 6 images below. If the last image (the most pixelated) shows a 30 m resolution, what is the likely resolution of the other images in the sequence? Match the images with the given values accordingly. Annotate the numbers of following illustration:

2 m resolution	1 m resolution
10 m resolution	30 m resolution
5 m resolution	20 m resolution

5. How can you discriminate between a multi-spectral and a hyper-spectral image?

Resource Two
Further Reading

Explore

Independent Research

- For more information about the difference between passive and active sensors explore the link below: https://earthdata.nasa.gov/learn/remote-sensors
- Read more about satellite orbits using this link: https://www.nrcan.gc.ca/maps-tools-publications/satellite-imagery-air-photos/remote-sensing-tutorials/satellites-sensors/satellite-characteristics-orbits-and-swaths/9283

Resource Three Overview

Topic

The electromagnetic spectrum and satellite vision

A-level module

Physics: The nature of electromagnetic waves

Physics: Wave particle duality

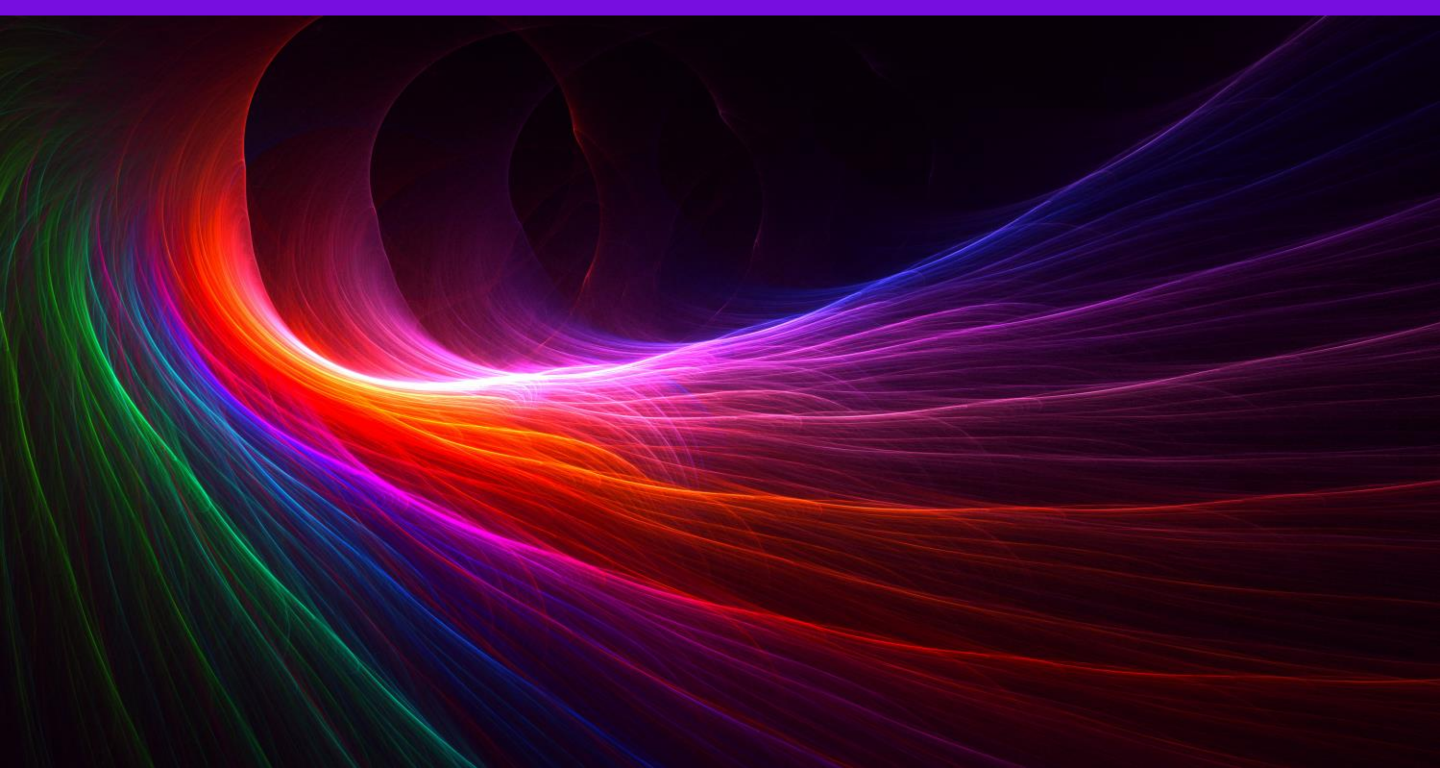
Objectives

After completing this resource, you should be able to:

- ✓ What is light and how can we measure it
- ✓ Introduction to the electromagnetic spectrum and human/non-human vision
- ✓ How satellites see objects and light attenuation

Instructions

1. Read the resource
2. Answer the questions
3. Explore the extra resources



Resource Three
Data Source

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Section A

What is light?

Active Reading

Light is a complex and until recently a poorly understood component of our universe. It is also one of the scientific subjects that has been studied for the longest. The ancient Greeks (c. 400 BC) carried out experiments to discover how light worked. They realised even then that white light is made up of many different colours. They also understood how light is reflected, refracted and diffused, phenomenon that we refer to in remote sensing as light 'attenuation'.

Much later, in the 17th century, opposing theories of the behaviour of light developed. Christiaan Huygens carried out experiments that suggested light was composed of waves whereas, Sir Issac Newton claimed that light was made up of tiny particles. It was not until the 20th century that Albert Einstein discovered the existence of the photon allowing the conflicting theories to start to be resolved. Photons have very strange behaviours that allow them to possess the dual properties of waves and particles. When propagating, light behaves like waves, when interacting with energy, light behaves like particles

We can classify light in terms of wavelength; the size of the wave. Coloured light has wavelengths between about 400 and 720 nm (nm stands for nanometer and is 1 billionth of a meter).

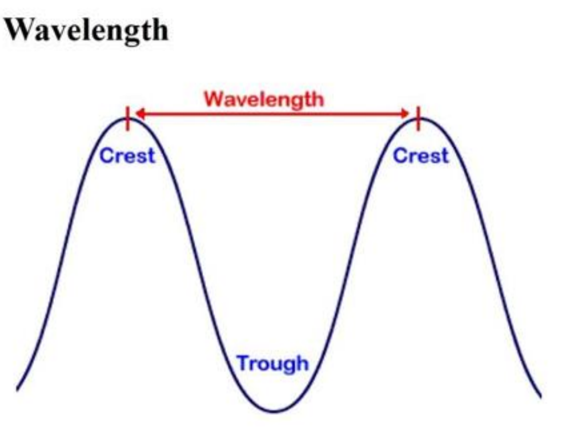

Figure 1

The wavelength of light is the distance between two crests or two troughs. Light waves are so tiny we can't see them but we can infer their form by their interaction with matter.

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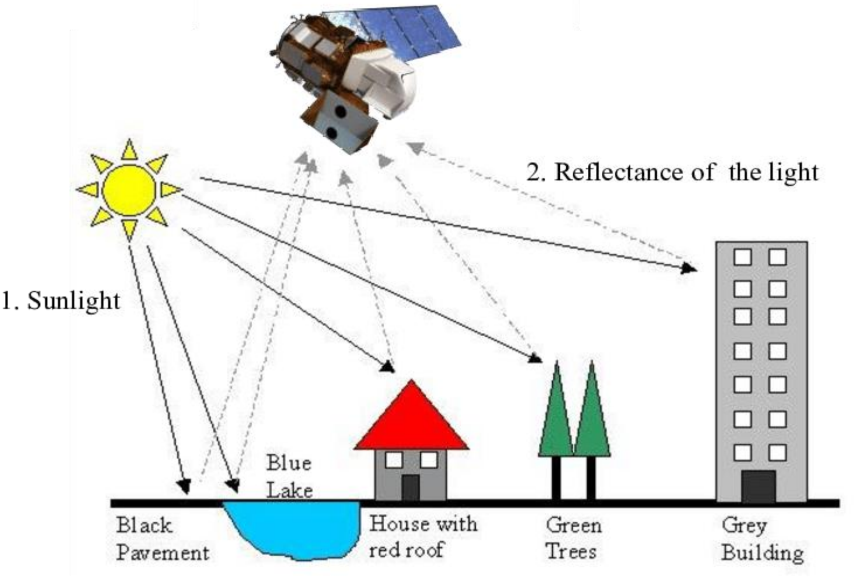
We can also describe light in terms of the number or frequency of waves per unit time. In this module we will refer to types of light in terms of wavelength but it is useful when looking at other resources to understand that it can also be described in this other way.

You might wonder why remote sensing scientists care about the theory of light. Well, light is interacting with matter on its way from the sun to the surface of the earth and back to our satellite sensors. These interactions affect the energy of light and the signal we receive. If we know enough about the journey of the light we are interested in we can begin to understand the nature of the matter we are studying.

Figure 2

Some examples of the journey of light from its source, the sun to satellite sensors



(Taken from the paper 'An Efficient Algorithm for Earth Surface Interpretation from Satellite Imagery')

Resource Three
Data Source

Section B

How do eyes work?

Mounted on satellites are light sensitive instruments. Like our eyes these instruments are able to detect signals from the visible part of the electromagnetic spectrum, the blue, green and red parts, but they are also able to pick up signals from outside the visual range. You can see from the diagram below, that the visible part of the spectrum is very small compared to the other parts.

Figure 3

The electromagnetic spectrum.

Active Reading

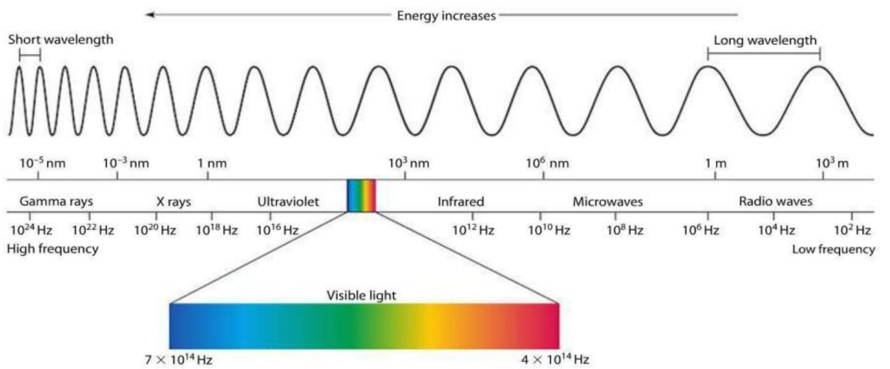


Image sourced from: https://www.miniphysics.com/electromagnetic-spectrum_25.html

We live our entire lives responding to stimuli located in this very small part of the spectrum but objects around us are also reflecting (and absorbing) wavelengths in other parts of the spectrum. Some organisms have different kinds of light perceiving organs that respond to these other wavelengths. Below are two images of a flower from a UK plant called Wood Anemone. The left image shows how we humans see the flower head (white), the right hand side is how bees see the flower – completely differently! This is because bees have evolved receptors in the ultra-violet part of the spectrum and they can see the petals reflecting wavelengths in this part of the spectrum.

Resource Three
Data Source

Figure 4

Wood anemone flower as seen by humans (left) and bees (right).

sourced from: forums.canadiancontent.net/showthread.php?t=66080

The structure of the human eye is made up of two different types of light sensitive mechanisms: the rods which are sensitive to radiation (brightness) and the cones, sensitive to coloured light in the red, green and blue regions (figure 5). The reason that we can see even in very low light conditions is due to the rods. However at night you will notice you don't see in colour, this is because the cones are not active at these light levels.

Figure 5

Diagram of the tissue at the back of the human eye with the position of rods and cones explained.

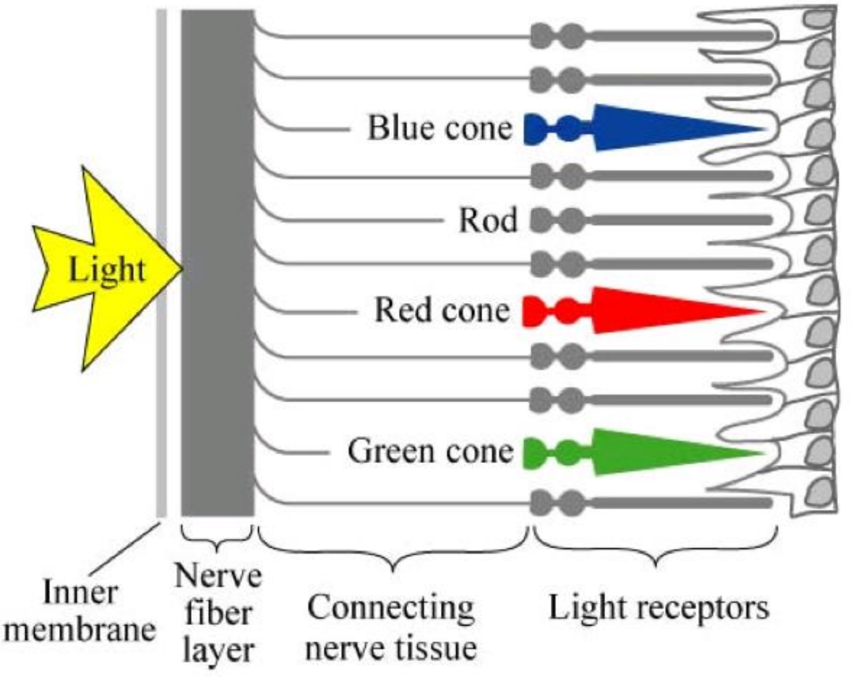


Image sourced from https://www.sas.upenn.edu/~ksundeen/spec%20project%20stuff/Eyes%20and%20Spectrometers.html

Resource Three
Data Source

Figure 6 shows which parts of the light are being absorbed by the rods and cones. These lines are called 'response curves' and are often used in remote sensing studies to illustrate the sensitivity of an instrument to certain regions of light. The higher the curve at a certain wavelength, the more energy it absorbs at that point in the spectra. You can see that the red and green curves are more closely related in terms of the wavelengths of light they absorb compared to the blue.

Figure 6

Absorption curves of the colour and radiance cells in the human eye, showing which parts of the electromagnetic spectrum they are sensitive to.

Active Reading

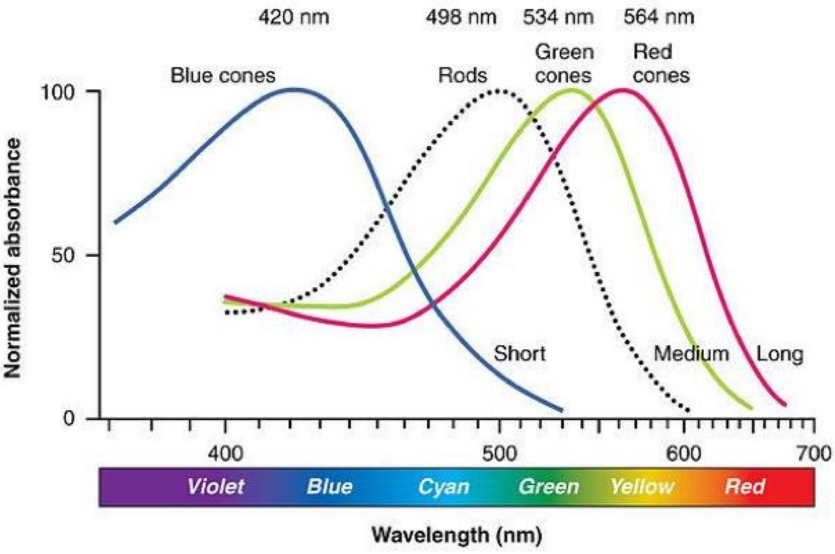


Image sourced from: https://en.wikipedia.org/wiki/Photoreceptor_cell

Section B

How do eyes work?

Before light reaches the surface of the planet it has to pass through about 80km of atmosphere and back again to reach the sensor. That's 160km of air; a lot can happen on that journey. You might think that air contains very little of substance to interact with light but actually the atmosphere contains lots of gases and particles that cause light to change in terms of its energy balance. One of the simplest examples of scattering can be seen in the photograph below. Can you think what it may be?

Resource Three
Data Source

Figure 7

Why does the sky appear blue to us?

The sky only appears blue to us as in the upper atmosphere there are gases that scatter incoming light. The name for this phenomenon is 'Raleigh scattering'. Without this type of scattering we would not be able to see into shadows; they would just be a black patch. In the lower part of the atmosphere (0-5km) another type of scattering occurs called Mie scattering. This is caused by water vapour (water molecules), dust and other particles that reflect light in many different directions. Light scattering actually adds radiance to the signal picked up by the satellite. As you might imagine this will affect the signal passed to the blue channel.

Resource Three Data Source

To add further complexity to the situation, there are also gases in the atmosphere that absorb incoming and outgoing radiation. In figure 8 we can see some commonly occurring atmospheric gases and their absorption curves. The black bit represents the part of the electromagnetic spectrum where the gases absorb light strongly. In these areas light gets attenuated strongly. The bottom curve represents the cumulation of all the gases in the atmosphere and something called the atmospheric windows (the parts of the spectrum where gases absorb light the least). 0.3 – 0.7 micrometers is the visible region. You can see there is hardly any black curve there. Why do you think that as earth observation scientists we focus on these windows and build sensors to capture data in these regions of the spectra? It's because only at these places can we be confident that we are measuring what is occurring on the planets' surface and not the concentration of gases in the atmosphere instead.

Active Reading

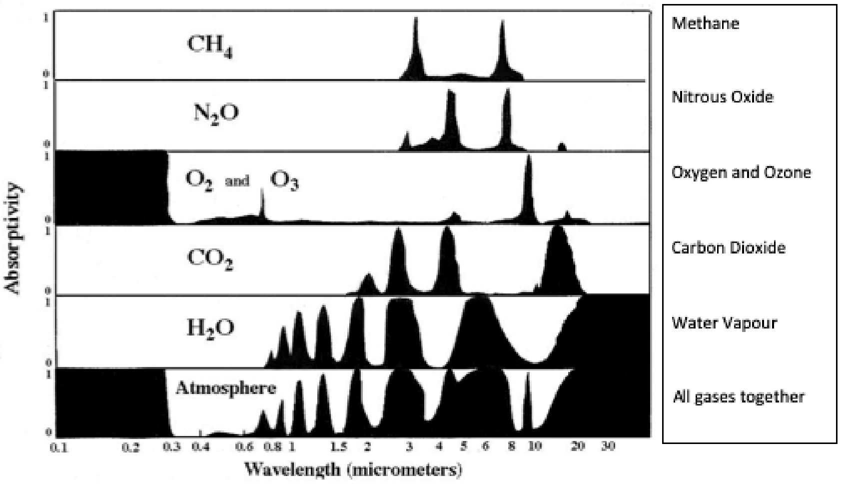


Figure 8

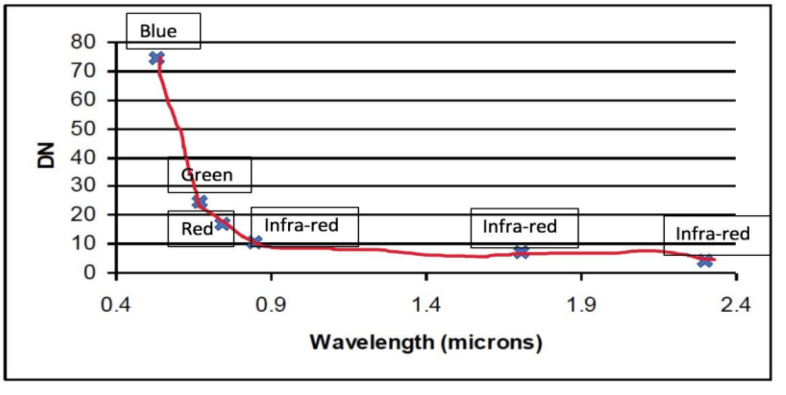
Absorption of light waves in our atmosphere by different gases. Here micrometers is used to measure the wavelengths instead of nanometers (one micrometer = one thousand nanometers).

Resource Three Activities

Activities

Active Learning

1. Categorize each of the following wavelengths according to the part of the spectrum they broadly belong to:
    a. 1m
    b. 500nm
    c. 1nm
2. Describe the two light detectors present in the human eye. Make a parallel between their function and what happens in remote sensing.
3. Below is a value curve taken from the Landsat satellite of a surface: clear water. Using the information from this module, can you speculate on why the blue channel might not be representative of the reflectance at the earth's surface?



4. Imagine you have the responsibility (and money) to build your own satellite, using figure 8 as a reference, describe which parts of the electromagnetic spectrum you would use and which would you avoid?
5. O3 or ozone gas strongly prevents the sun's radiance from passing to the satellite sensor. Although this creates a problem for earth observation scientists (we can't collect data in these wavelengths), why do you think this is a good thing for life generally on earth? (If you are stuck go to this link for more information: https://en.wikipedia.org/wiki/Ozone_depletion)

Resource Three
Further Reading

Explore

Independent Research

- Watch this video that describes using cartoons the dual nature of light: https://youtu.be/mlaVHxUSiNk

- Read this web page about how different animals see the world: https://www.momtastic.com/webecoist/2009/01/14/animal-vision-color-detection-and-color-blindness/

- If you love the physics side of this module and would like to delve deeper into equations here is a really nice overview: https://labo.obs-mip.fr/multitemp/radiometric-quantities-irradiance-radiance-reflectance/

Resource Four Overview

Topic	Plant – light interactions
A-level Modules	Biology: Energy transfers in and between organisms Geography: The carbon cycle
Objectives	After completing this resource, you should be able to: ✓ Help students to understand the main processes behind photosynthesis ✓ Understanding why plants appear certain colours to us ✓ Grasp the basics of plant light absorption in the red and blue parts of the spectrum and reflectance in the near infra-red. ✓ Apply these concepts to remote sensing technologies
Instructions	1. Read the resource 2. Answer the questions 3. Explore the extra resources

Resource Four
Data Source

Section A

How does photosynthesis actually work?

Active Reading

Plants and the process of photosynthesis is the basis of most food chains. About three billion years ago unicellular organisms evolved the ability to convert the atmospheric gas carbon dioxide into something called organic carbon, the building blocks of life. These organisms were the ancestors of modern day plants, and they started a chain of events that dramatically altered the composition of the earth's atmosphere and the kind of organisms that would be able to survive here.

One of the outcomes of this transfer of carbon from the atmospheric reserve to the biological reserve was the production of the gas oxygen. The name of this process is the 'Calvin Cycle'. You may have seen the equation below that shows chemically how this process works.

Figure 15

The Calvin cycle and light interactions. This process is complex and still not fully understood by science. It represents one of the major steps of evolution on our planet.

$$6CO_2 + 6H_2O + e \Rightarrow C_6H_{12}O_6 + 6O_2 + e$$

carbon dioxide + water + absorbed EM radiation => glucose + oxygen + reflected EM radiation

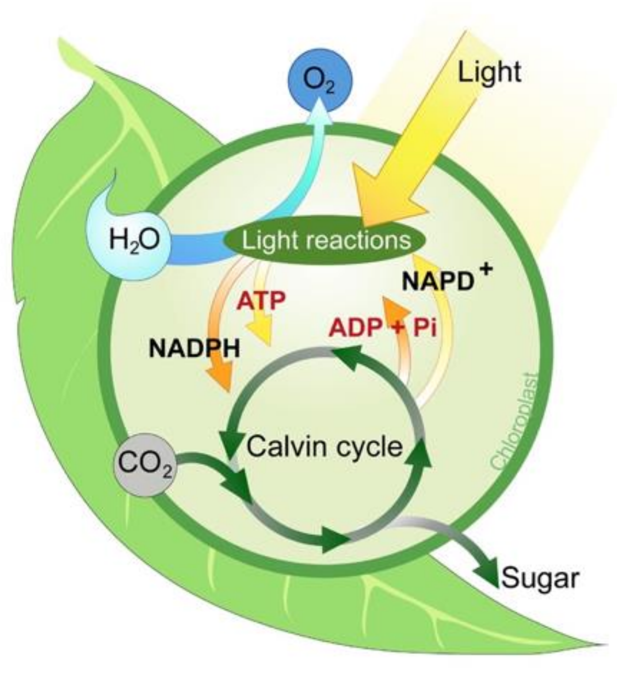


Image sourced from: http://www.hcrowder.com/photosynthesis.html

Resource Four
Data Source

Section B

Why are leaves mostly green?

A chemical compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths. This is why we 'see' green. It's actually the part of the electromagnetic spectrum that plants don't want so much. They want the blue and red light as they use these wavelengths to power their growth. Leaves appear "greenest" to us in the summer, when chlorophyll content is at its maximum. In autumn, there is less chlorophyll in the leaves, so there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear red or yellow. The internal structure of healthy leaves act as excellent diffuse reflectors of near-infrared wavelengths. If our eyes were sensitive to near-infrared, trees would appear extremely bright to us when in leaf.

Section C

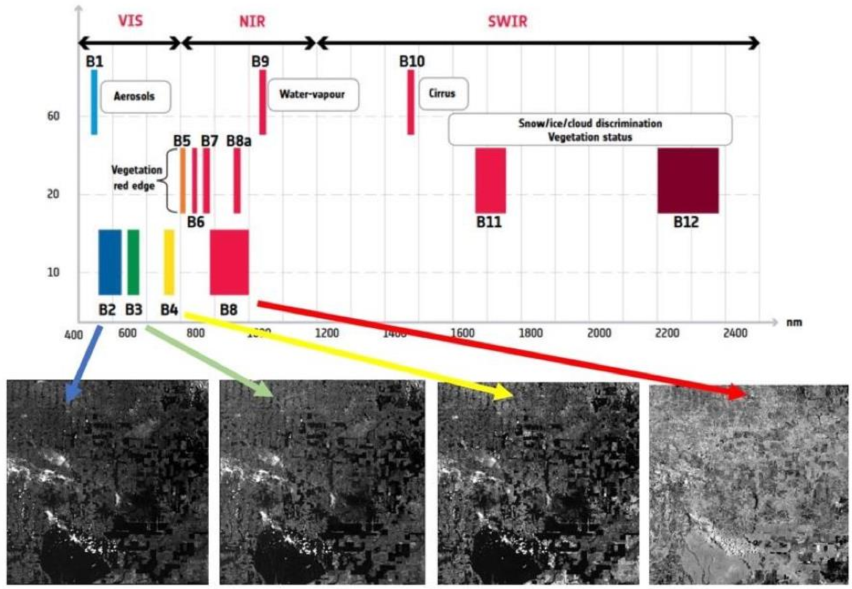
How can we use remote sensing to see photosynthesis?

In remote sensing we take advantage of the intense absorption of the red and blue light to visualise and quantify the amount of photosynthesis occurring. Green light is reflected by chloroplasts that are located on the outer part of the leaf, called the palisade. Light in the infra-red part of the spectrum is strongly reflected by parts of the leaf under the surface called the spongy mesophyll. Figure 2 shows four of the bands captured by Sentinel-2. The scene is a part of the rainforest in Brazil. Most of the scene is made up of vegetation. Can you see how similar the blue, green and red bands are? The infra-red band is really showing us something different. Reflectance values are very high in this band.

Resource Four
Data Source

Figure 2

Sentinel data bands in the blue, green, red and infra-red parts of the spectrum (B2, B3, B4 and B8). The bands are represented in grayscale. Dark parts have low values and light parts high values. B8, represented in pink, is the infra-red band and has very high values as leaves reflect light strongly at these wavelengths. (Note: each satellite has different band numbers assigned to each part of the spectrum; for example B1 on Landsat is blue whereas blue is B2 on Sentinel – this is because Landsat doesn't have a UV band but Sentinel does).



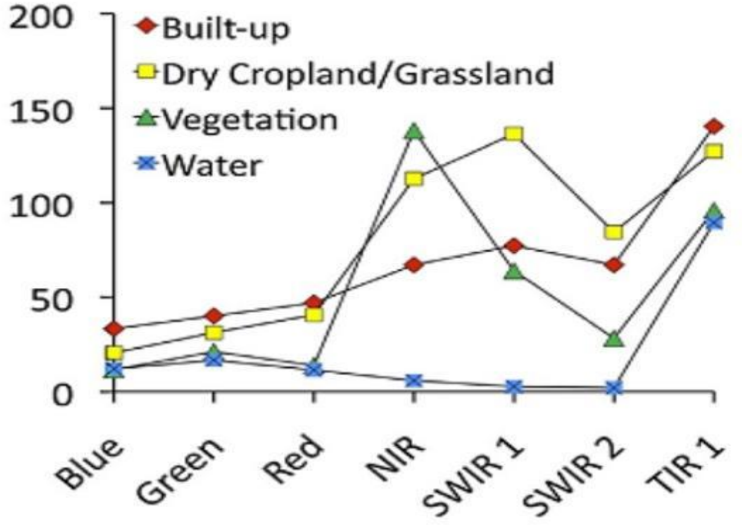
Because we know that plants have a very particular behaviour in regards to their reflection of light, we say in remote sensing that they have a distinct signature. Other types of land surface such as rocks, water and buildings also have their own signatures. It is by mapping these signature values on our satellite scenes that we are able to quantify (put into numbers) how much vegetation is present.

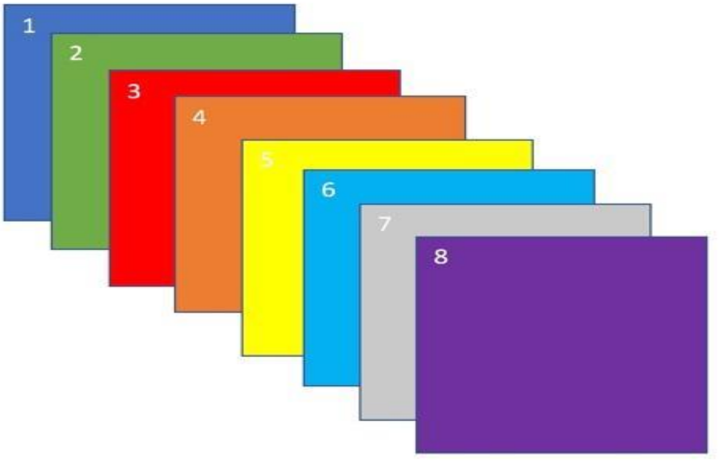
In remote sensing we make a plot of each pixel in an image to show how each spectral band is responding. Look at figure 3. Can you see how three very different land surfaces are reflecting light in the 8 bands. Vegetation has a very distinctive low part of the curve in the visual part of the spectrum (bands 1, 2, 3). Then it jumps up in band 4 (the near infra-red or NIR), dropping down again in bands 5, 6 and 7 (Short wave infra-red SWIR). This dramatic jump up between the red and infra-red is called the 'red-edge' by remote sensing scientists. The other surfaces lack these specific characteristics, however they have their own curve shape, which can be used in other areas of remote sensing research.

Resource Four
Data Source

Figure 3

Spectral reflectance curves of four surfaces, buildings, cropland, green vegetation and water, as recorded by the Landsat satellite.



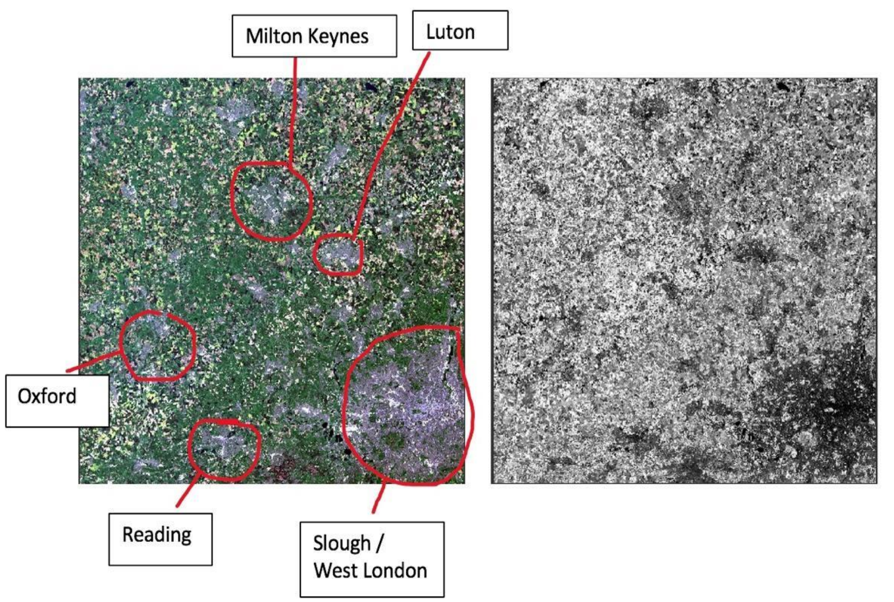


Resource Four Activities

Activities

Active Learning

1. What three things are required to fuel photosynthesis?
2. Draw your own diagram summarising the carbon cycle, showing the plant and atmospheric reserves and the inputs and outputs.
3. The Sentinel image below is of the area of the UK around the town of Reading with the urban centres labelled. It is 100km x 100km. What band is this image on the right likely to represent?



4. How do Sentinel and Landsat band designations differ in the visual part of the spectrum?
5. Summarise in a few sentences how vegetation is spectrally different from other common land surfaces.

Resource Four
Further Reading

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Explore

Independent Research

- Explore the history and evolution of photosynthesis using this link: http://www.plantphysiol.org/content/154/2/434
- Use the spectral characteristics viewer to explore the spectral signature of various land surfaces. https://landsat.usgs.gov/spectral-characteristics-viewer
- Find out about how human modification of vegetation is affecting the weather and climate: https://climate.ncsu.edu/edu/Vegetation

Resource Five Overview

Topic

Image processing and the creation of vegetation indices.

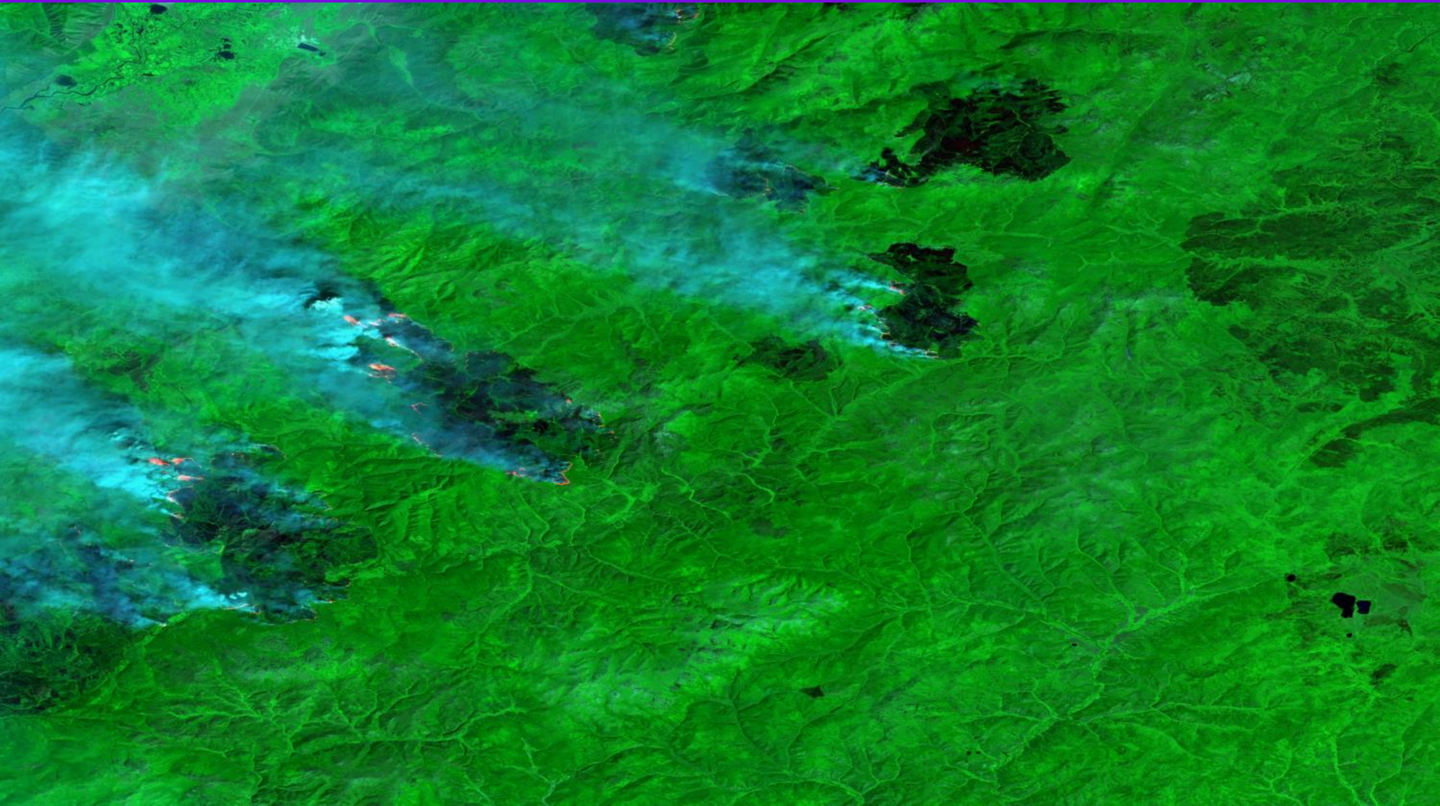
Objectives

After completing this resource, you should be able to:

- ✓ Understanding the difference between true colour and false colour images
- ✓ Familiarisation with the concept of colour assignment for communication of data.
- ✓ Grasp that images are actually made up of digital numbers
- ✓ Understand how vegetation indices can simplify our representation of vegetation.

Instructions

1. Read the resource
2. Answer the questions
3. Look through the extra resources



Resource Five
Data Source

Section A

True colour and false colour images

Remotely sensed data is usually displayed using the red-green-blue (RGB) colour coordinate system. This system is based on the additive colour theory and the three primary colours: red, green and blue. The human eye can only detect red, green and blue (visible light) without the aid of enhancements. Satellites can collect data in other bands but we can only interpret these bands by transforming them into colours we can see. When we view satellite images on google maps for example they are displayed as something called 'a true colour image'; a combination of red, green and blue bands. However, satellites collect data in other wavelengths that we cannot see with the naked eye. In order to visualise these other wavelengths we can create 'false colour' images which need some training to understand. Figure 1 contrasts these types of images.

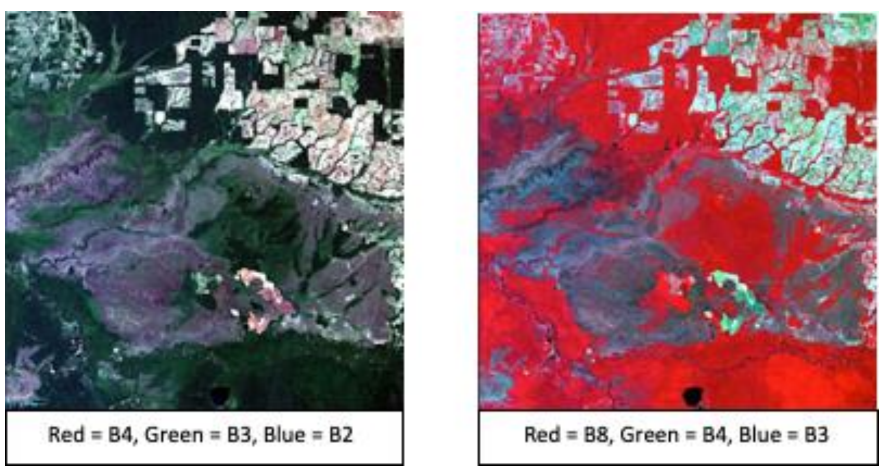


Figure 1

A Sentinel sourced true colour image (left) made up of red, green and blue channels and a false colour image (right) made up of green, red and infra-red channels. The images show Brazilian rainforest conversion to palm oil plantation. This concept is arguably communicated better using the false colour composite (it is clearer on this image where the virgin forest is (red) compared to bare soil (grey) and new palm oil plantations (white/green)) however we need some training to understand this image.

The way we produce digital images both on a computer screen and in print is by combining three channels, that produce red, green and blue. All the other different colours we see are due to different combinations and intensities of these three primary colours. People who work with satellite images use computer programmes called 'image processing software' to manipulate colour in images.

Resource Five
Data Source

Figure 2

A representation of a dandelion using true colour and false colour assignment.

Active Reading

Figure 2 is a representation of how left, a human sees a dandelion flower and right how a bee sees the flower. A bee has vision receptors sensitive to light in the green, blue and ultra-violet part of the spectrum (it can't see red like we can). This may seem a bit confusing as the flower on the right is red, so how can that be how a bee sees?

The person who has created this image has simply chosen red to represent how the centre of the flower appears to a bee. It would be actually impossible to fully show a human how a bee sees as we just don't have the right type of eyes. What we can do is create a representation of a bee's experience. The important message that the image conveys is that the centre of the flower is very attractive to the bee as this is where the pollen is. Similarly, when we are processing imagery from space, we can assign colours to areas of interest to illustrate the points we are trying to make.

Resource Five
Data Source

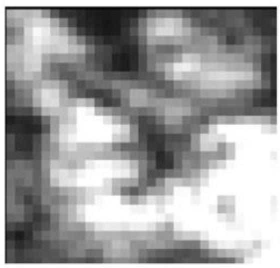
Section B

Digital numbers

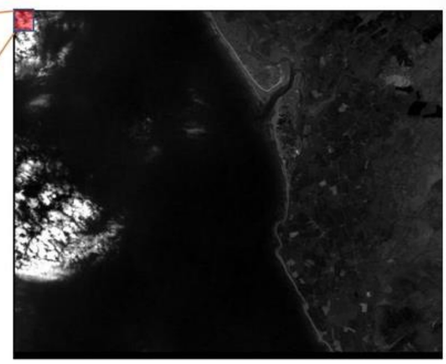
An important thing to grasp is that digital images are made up of numbers. To demonstrate how this works look at figure 3. Firstly we have a greyscale representation of band 2 of a Landsat image. If we zoom in to the top left hand corner we can see the pixels. Each of these pixels is represented by a value shown by the table.

Figure 3

Each pixel in each band has a number associated with it. We can compute values based on these numbers.



Row	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	175	182	181	188	166	132	111	104	99	98	94	93	94	101
1	161	170	189	200	196	175	151	124	101	100	94	93	97	104
2	144	163	197	212	203	192	172	146	117	105	102	95	96	106
3	154	167	191	205	199	194	189	172	151	125	113	103	105	107
4	176	180	192	201	193	189	188	179	176	147	125	118	111	102
5	180	181	195	199	174	162	163	161	154	128	120	115	102	99
6	171	175	187	193	164	143	134	143	148	135	127	111	100	99
7	155	175	183	176	161	146	130	129	143	148	144	130	132	136
8	135	151	160	171	180	176	163	137	124	131	139	138	151	151
9	122	145	152	181	203	196	171	144	132	119	115	120	133	153
10	130	141	143	176	200	201	176	175	191	182	140	118	122	144
11	114	120	119	146	177	184	183	201	227	216	181	166	150	142
12	94	100	101	111	140	165	184	192	223	235	221	203	177	160
13	106	107	99	103	130	170	195	201	229	250	245	231	206	190



Section B

Digital numbers

An alternative approach to representing vegetation in images comes from the creation of indices. Instead of looking at the values of many bands and deciding which three we would like to use in an image (remember we only have three channels on our computer screen or printer), we can process a number of the bands mathematically to produce a digital number image representing in summary the data we are interested in. The most famous and widely used of these indices is called the NDVI (The Normalised Difference Vegetation Index). It is calculated using the red and infra-red bands of an image using the following equation:

Resource Five
Data Source

Section B

Digital numbers

Data Interpretation

$$\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$

What we are doing in essence is taking the information in two bands and summarising it into a single band. The method takes advantage of the big difference in reflectance in the red and infra-red parts of the spectrum. It is calculated as an index in order that its values are 'bounded'. The maximum possible value is +1 and the maximum negative value is -1. Because of this we can then compare different images and land classes.

Here is a graphical representation with a single pixel of the image in the red and near-infra-red channels. If Red (R) had a value of 0.3 and Infra-red (IR) had a value of 0.1, for this particular pixel we would need to calculate: 0.3 – 0.1 divided by 0.3 + 0.1, which would be 0.2 divided by 0.4. So the NDVI value of this one pixel would be 0.5. If we did this for all the pixels in a whole image we would end up with a single channel image only of NDVI which would be very easy to

$$\text{R} - \text{IR} \div \text{R} + \text{IR}$$

Resource Five Activities

Activities

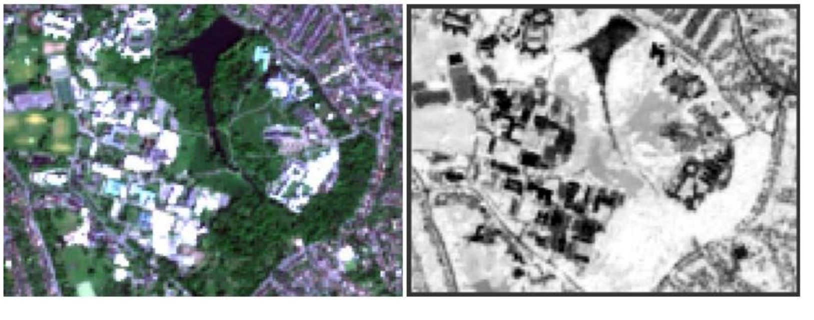
1. Draw a false colour image using red, blue and green of a plant in your house or garden. Try to emphasise the features of the plant using this method. Here is my effort using a pot plant in my greenhouse. I have chosen to colour the green parts in red, the brown parts in blue and the non-biological elements (the pot) in green.

Resource Five Activities

Activities

Active Learning

2. Infra-red cameras and film were first invented by the military to find the enemy under camouflage. This is because infra-red imagery can differentiate between surfaces that are 'green' and surfaces that are vegetation. Below is a map of the University of Reading campus. Below it is a true colour image (left) and an NDVI image (right). The lake is clearly visible on the NDVI image as it has very low values (dark). Find on the map the area to the west of the lake where the sports facilities of the university are based. Next to the tennis area there is a football pitch (this is marked for you on the map). Look carefully at the NDVI image in black and white and find the same area. Can you explain why this football pitch has such low NDVI values?



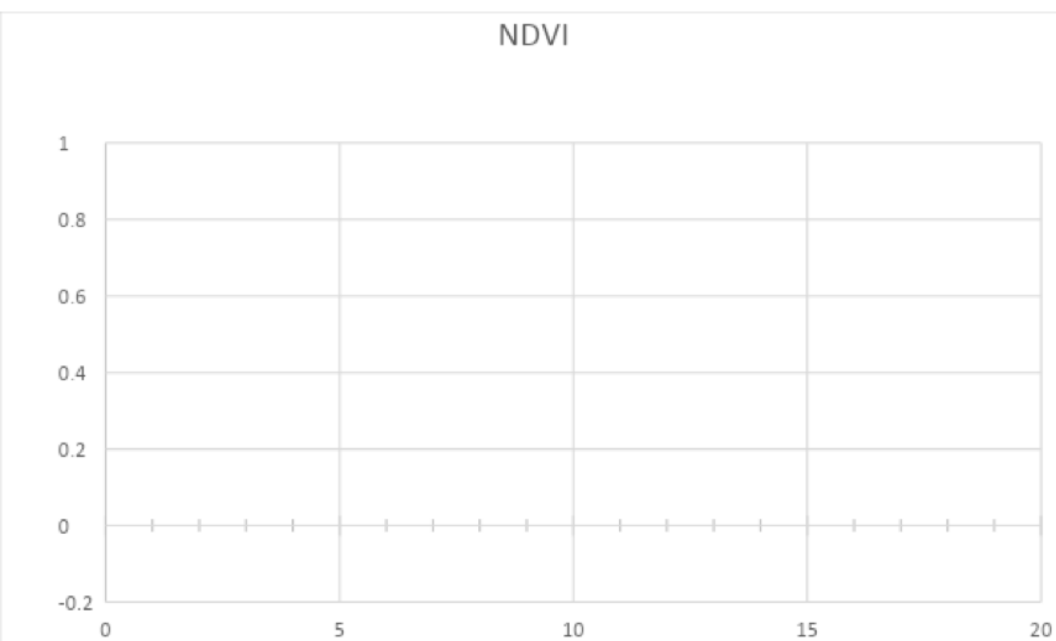
Resource Five Activities

Activities

3. Transform these digital numbers of specific pixels from a Sentinel image into the NDVI (use the equation given in the module materials, you will probably need a calculator).

Sample number	Land class type	B2	B3	B4	B8	NIR - Red	NIR + Red	NDVI
1	Buildings	0.2222	0.2316	0.1104	0.0973			
2	Buildings	0.113	0.0966	0.0571	0.0567			
3	Buildings	0.0713	0.1066	0.115	0.1454			
4	Buildings	0.1988	0.1594	0.1676	0.1733			
5	Buildings	0.2132	0.226	0.1988	0.2125			
6	Water	0.0016	0.0121	0.009	0.0132			
7	Water	0.0074	0.0093	0.0129	0.015			
8	Water	0.0058	0.0076	0.0089	0.0165			
9	Water	0.0089	0.0123	0.0114	0.0156			
10	Water	0.0077	0.0051	0.0126	0.0163			
11	Meadow	0.0242	0.0571	0.0377	0.3415			
12	Meadow	0.019	0.0433	0.0228	0.3405			
13	Meadow	0.017	0.0443	0.0259	0.2972			
14	Meadow	0.0207	0.0488	0.0305	0.3711			
15	Meadow	0.0173	0.0512	0.0281	0.372			
16	Woodland	0.0205	0.0404	0.0546	0.2642			
17	Woodland	0.017	0.0358	0.0514	0.2605			
18	Woodland	0.0227	0.0497	0.0585	0.2912			
19	Woodland	0.0148	0.0361	0.0479	0.2461			
20	Woodland	0.0072	0.032	0.0264	0.1544			

4. Plot your calculated NDVI values onto the graph below. Use a different colour pen for each of the four land classes.



Resource Five Activities

Activities

5. Do you think the data can be grouped into land classes just using the NDVI? Draw circles around the classes/groups you think look possible to classify and label them with the land class.

Resource Five
Further Reading

Explore

Independent Research

- Explore other examples of false colour images on the wiki page: https://en.wikipedia.org/wiki/False_color
- Go to youtube and type in the search bar: 'photoshop for the scientist'. Photoshop is a widely available piece of software for image manipulation. There are a number of tutorials about different ways scientists can manipulate images to describe a quantitative process. Have a quick look at some of them, just to see the kinds of images scientists may want to process. If you would like to try some image manipulation yourself, perhaps you have access to Photoshop software at school. If not there is a free downloadable alternative called 'GIMP'. https://www.gimp.org/

Resource Six
Overview

BROUGHT TO YOU BY RBC ACCESS ED

Topic

Applications of remote sensing to vegetation diversity estimates

GCSE Modules

Geography: Local ecosystems

Biology: Genetics, populations, evolution and ecosystems

Objectives

After completing this resource, you should be able to:

- ✓ Familiarise students with the notion of biodiversity estimation including diversity indices.
- ✓ Gain an overview of indirect and direct measures of diversity using remote sensing.
- ✓ Understand how the spectral variation hypothesis works.
- ✓ Acquire an idea of the potential of direct species mapping.

Instructions

1. Read the resource
2. Answer the questions
3. Explore the extra resources

Resource Six
Data Source

Section A

What is biodiversity?

Biodiversity (short for biological diversity) is a term used to describe the number of taxonomic units (or species) within a given area. Biologists spend a lot of time working in the field to collect data on the number of species present (called species richness) and the number of individuals of that species (species abundance). They use mathematical formulas called biodiversity metrics to summarise this data. One of the most common formulas is called Simpson's diversity index. The measure equals the probability that two entities taken at random from the dataset of interest represent the same type. It is often termed a measure of 'evenness'.

Data Interpretation

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

Where:

D = diversity index (simply a number with no units)

N = total number of organisms of all species found

n = total number of individuals found of the species you are interested in

Here is an example how it works. First you must have the species present in each area (here a 1 x 1m plot) and the number of each individual found. Total the number of individuals for each plot (this is N in the equation).

Species (common name)	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Oxeye daisy	10	5	1	2	0
Common spotted orchid	5	5	10	2	20
Yellow oat grass	7	5	2	6	0
Quaking oat grass	2	5	0	6	0
N (total organisms)	**22**	**20**	**13**	**16**	**20**

Resource Six
Data Source

Next for each value in the table above calculate (n/N)2 (the first cell is filled in with the full calculation).

Then each column in added up and the total is subtracted from one. The index runs from 0 to 1. 0 is obtained when you only have one species (here plot 5). Completely even distribution of individuals (as in plot 2) scores high. It is actually impossible to attain 1 as you would need an infinite number of species!

Species (common name)	Plot 1 $(n/N)^2$	Plot 2	Plot 3	Plot 4	Plot 5
Oxeye daisy	$(10/22)^2$ = 0.20661157	0.0625	0.00591716	0.015625	0
Common spotted orchid	0.05165289	0.0625	0.59171598	0.015625	1
Yellow oat grass	0.10123967	0.0625	0.02366864	0.140625	0
Quaking oat grass	0.00826446	0.0625	0	0.140625	0
Column total	**0.3677686**	**0.25**	**0.62130178**	**0.3125**	**1**
1- total = D	**0.6322314**	**0.75**	**0.37869822**	**0.6875**	**0**

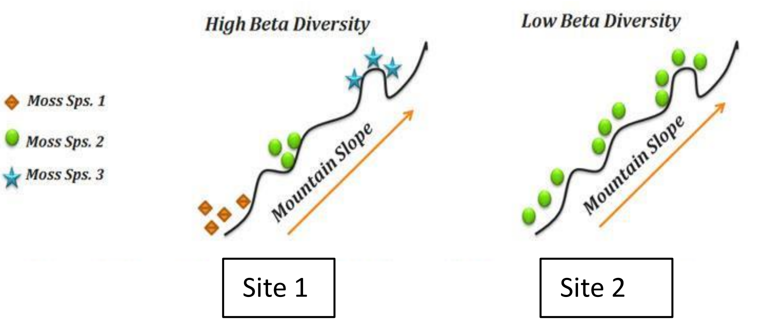
Resource Six
Data Source

Measures of diversity are influenced by spatial scale. The table below summarises the three principle scales and figure 1 illustrates the difference between the scales.

Alpha diversity	Smallest scale or measurement – most likely from a single sample
Beta diversity	Intermediate scale of diversity– links alpha and gamma scales
Gamma diversity	Largest scale of measurement – landscape or regional

Figure 1

Beta diversity of two mountain side habitats. Local samples are shown by dots, stars and squares grouped on the wiggly line. Because they have little difference the local (alpha diversity) in both samples is low. When we compare the samples on a larger scale (the whole mountain-side) we see that beta diversity is higher in site 1 than in site 2.



Active Reading

Biodiversity is not uniformly distributed over the Earth's surface. Some regions have a rich, heterogeneous flora, others are homogeneously covered by only a few plant species. A recurrent pattern is the decrease of the number of animal and plant species from the equator to the poles, as well as from low to high elevation.

Because of human activities we know that biodiversity is in decline in most places of the globe. Preventing further species loss is the aim of those involved with biological conservation. Over the last ten years biologists have become very interested in the idea that we may be able to map biodiversity using satellite images. If properly used, images have the potential to update lists of critically endangered species, to determine suitable areas to look for rare species and to check if management of reserves is being carried out effectively.

Resource Six
Data Source

Section B

Direct and indirect use of remote sensing

Data Interpretation

Remote sensing platforms have the ability currently to look at ecosystem diversity and species diversity, indirectly or directly, dependent on the scale of the pixels used and the organism of interest. One theory is that NDVI measures are correlated with diversity measures: higher NDVI = higher diversity. Figure 1 shows a study of mountain flora where plant richness and NDVI are strongly correlated, with maximum richness being found at elevations of around 1000m. This is an indirect measure of diversity, as we are not actually counting the species but using a ‘proxy’.

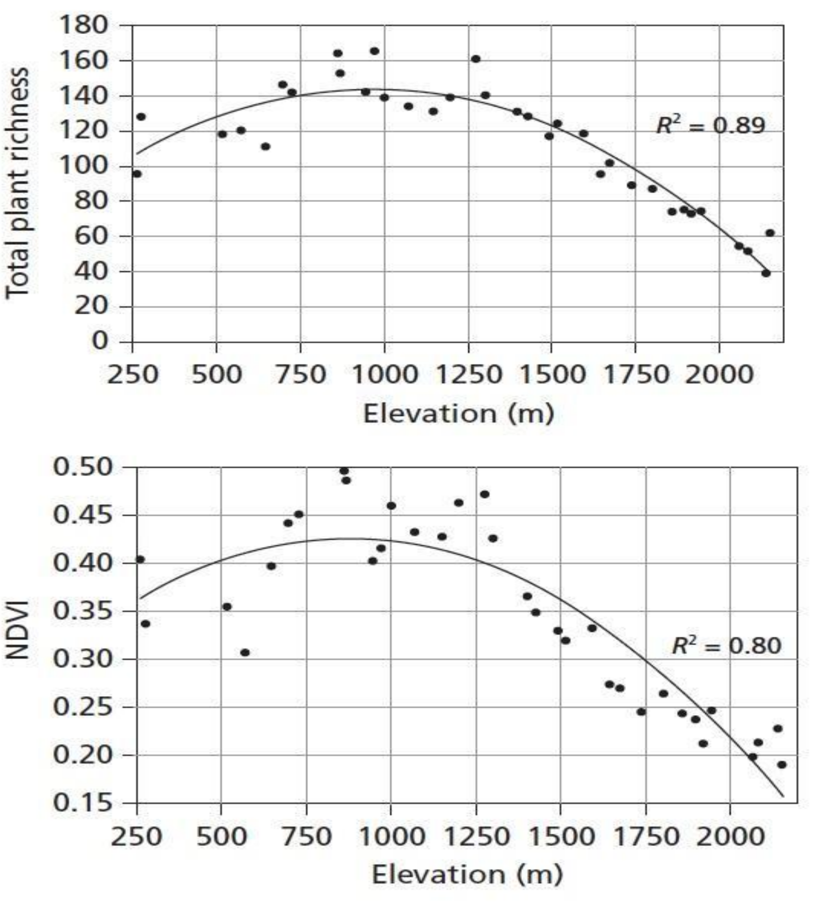


Figure 2

: The richness (number of species of plant) was recorded on a mountain at different elevations. This data was compared with the change in NDVI recorded at the pixel locations.

(Reproduced from Levin et al. 2007)

Resource Six
Data Source

Another popular indirect measure of biodiversity is called the Spectral Variation Hypothesis (SVH). It assumes that the higher the spectral variation of an image, the higher the environmental heterogeneity and hence the diversity of the considered area. Again this measure is scale dependent and is still being tested as to its usefulness in differing contexts. There are several ways that spectral variation can be measured. Most involve something called a 'measure of dispersion'. You may have heard of this idea if you have done some statistics in the past. Basically these are measures of the variation of a sample around the average (the mean). Normally these calculations are carried out on hyperspectral data (you may remember from resource 2 that this data has many channels). We tend to use the co-efficient of variance which can be calculated using this equation:

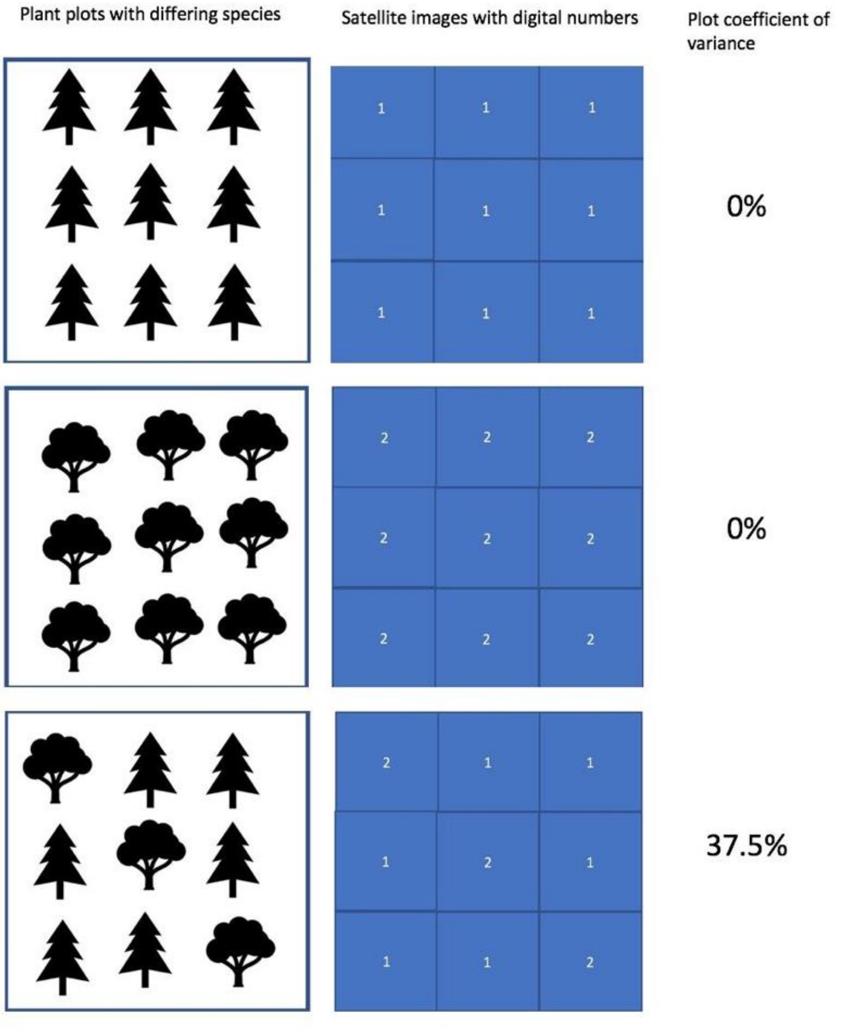
$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

Let's look at an example of how this works using some very simple made-up data from a plant survey with a single band of data. Plots that are mono-culture (only contain one species) have a co-efficient of 0%. This means the sample has no variation; it is all the same. It doesn't matter what this species is (here a conifer or a deciduous tree). If a plot is mixed in species the value of the co-efficient rises. Here the bottom plot has just two species with a co-efficient of 37.5%, a higher dispersion around the average value.

Resource Six
Data Source

Figure 3

A diagram of forestry plots and their co-efficient of variation.

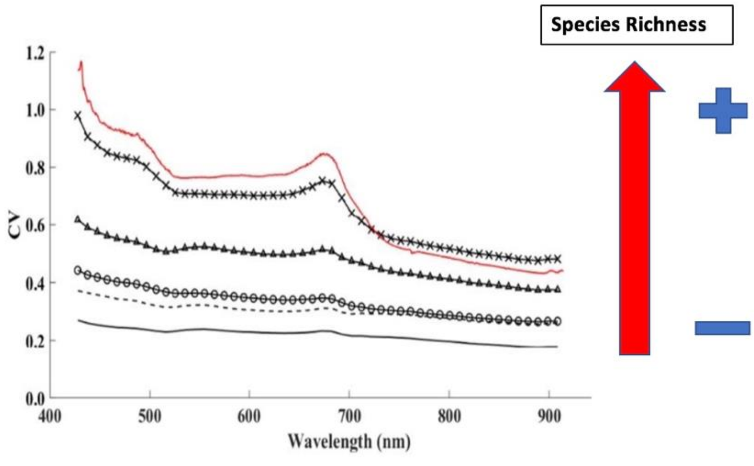


Imagine now that you have many bands recording information across the spectra (hyperspectral data). For each band there will be a measure of dispersion, as shown in figure 3 (we will have the same number of values as bands). We can plot these dispersion values against the wavelength to produce a plot like the one in figure 4. We can see when species richness rises in these grassland plots so does the value of the co-efficient of variance across all the different hyperspectral bands. For example, the bottom line represents a plot with two species and has a co-efficient of variance of about 0.2 (20%).

Resource Six
Data Source

Figure 4

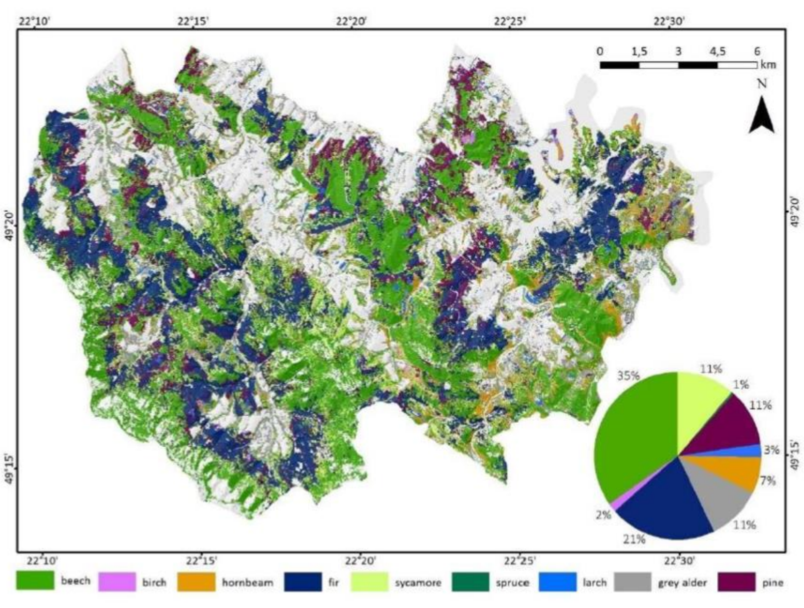
This graph shows the co-efficient of variance plotted against each wavelength. The spectral variation curve is higher when the species richness level of the plot is higher displaying a link between diversity of species and the amount of spectral variation within a given area. (Reproduced from Gholizadeh et al. 2018)



A direct method of diversity estimation is when plant species are big enough to be recorded from space. With the start of the Sentinel mission in 2013, we now have free to download images of a 10 x 10 m pixel size which has begun to make this kind of survey possible. In figure 5, tree species have been mapped for a forest in Poland. These methods are currently limited to species of a certain size; for example large trees.

Figure 5

Sentinel data has made possible the accurate mapping of tree species. This is a distribution map of a parts of the Carpathian mountain forests which allows the area to be understood in terms of species distribution. (Reproduced from Grabska et al. 2019)



Resource Six
Data Source

Vegetation and different vegetation types (species) can have different spectral signatures and temporal variation in their spectral reflectance. The map in figure 5 was put together by use of multi-temporal images captured by Sentinel over a single year. We don't know yet whether all species are possible to map in this way as some species may be spectrally indistinct from other species. If this is the case it will have an negative effect on the reliability of both direct and indirect methods.

Resource Six Activities

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Activities

1. Use the formula given in the table to calculate Simpson's diversity index for the two plant plots below. It is a forestry plot measuring 100 x 100 m. Fill in the answers in table 2. State which plot is the most diverse.

	PLOT 1	PLOT 2
Species name	**Number of individuals**	**Number of individuals**
Oak tree	6	6
Ash tree	14	7
Hazel	8	8
Scots pine	2	1
Hawthorn	1	9
Holly	4	1
N		

	PLOT 1	PLOT 2
Species name	Plot 1 $(n/N)^2$	Plot 2 $(n/N)^2$
Oak tree		
Ash tree		
Hazel		
Scots pine		
Hawthorn		
Holly		
Column total		
1-total = D		

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Resource Six Activities

Activities

Active Learning

2. Describe the difference between alpha, beta and gamma diversity.
3. Thinking of the way that satellites capture data from above the plant canopy and the way the diversity metrics for these plots have been calculated, what is your opinion about the suitability of using this particular approach when we want an exhaustive list of species? (If you need help think about a woodland and the different 'layers' of vegetation that grow there – can we see them all from space?)
4. Look at figure 3: In the bottom plot, if each of the conifer trees were replaced by deciduous trees and vice versa would the value of the coefficient of variation change? Why not?
5. Give a short critique of the indirect and direct methods of diversity estimation considering the technologies we have currently at our disposal.

Resource Six
Further Reading

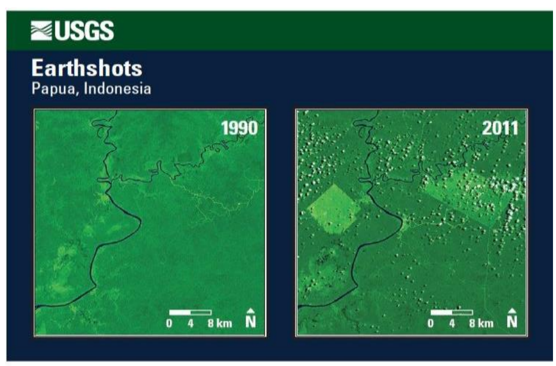
Explore

Independent Research

- Access and read this article about the call to conservationists to agree on useful biodiversity metrics from space: https://www.nature.com/news/environmental-science-agree-on-biodiversity-metrics-to-track-from-space-1.18009

- Go to this link. https://earthshots.usgs.gov/earthshots/. The page is called 'Satellite Images of Environmental Change'. Here navigate to the tab 'Forests' and look at all the examples of how forests are being removed over the globe. View the animations.

- Take part in a discussion with other students over the 'Earthshot' download below sourced from the USA government. Think about the image resolution, the possible uses of the data it represents and the environmental impacts of this kind of vegetation change. For more information try googling the palm oil industry and deforestation.



Papua, Indonesia 1990-2011

Papua is a province of Indonesia, which produces a little over half of the world's palm oil. The palm oil plantations show up clearly in Landsat images as the light green blocks in the middle of the undisturbed rain forest.

Date	Satellite	Bands	Res	Path	Row
Nov. 20, 1990	Landsat 5 TM	7,5,3	30 m	100	65
Apr. 4, 2011	Landsat 5 TM	7,5,3	30 m	100	65

Earthshots: Satellite Images of Environmental Change

The U.S. Geological Survey Earth Resources Observation and Science (EROS) Center archives data from the Landsat satellites (1972–present). Earthshots presents environmental changes using Landsat images.

http://earthshots.usgs.gov

09/13

Final Reflection

Deep Dive

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Your final project for this booklet is to create a presentation for your class, family or teacher on a pressing issue associated with changes in vegetation: conversion of natural forest to agriculture or urban environment. This is best done in power-point or another computer package that allows you to show images easily.

Imagine you are a researcher and you want to explain to a group of normal members of the public how we can study our subject using remote sensing:

The presentation should include slides on each of the following:

1. What natural forest looks like and why these areas are important to conserve. Find some images of forests and the animals and plants that are reliant on the forest type of your choice (these pictures don't have to be from satellites). Tell the audience about your forest: is it tropical or in the UK?
2. Choose a satellite that you would use for your research. Explain to your audience why remote sensing (and your satellite in particular) is a good tool to use for detecting this kind of change. (Think about the different kinds of resolution that we looked at in resource 2).
3. Show we are able to detect vegetation change or replacement using remotely sensed images (think about NDVI – resource 5). See if you can find a satellite image that shows forests being cut down and replaced with crops or buildings.

You will need to carry out some of your own research on the subject and find online remotely sensed images that illustrate it well. If you are interested in sourcing your own images this is possible by working through some of the guidance in the 'deeper look' section following this one. However it is also ok to use found images on the web.

One place to start if you are stuck is to search a term like 'palm oil' in google. Go to the 'image' tab and here you will see lots of things relating to your search. You will need to right click on images and 'save image' to download a copy to your computer. These images can then be inserted into your presentation.

Make your presentation very visual and try to communicate your ideas with pictures. This is one of the main skills in being an earth observation scientist!

A good place to source images and examples is from academic papers. These may be difficult to understand and sometimes require a subscription to access. A good place to access papers for free is google scholar: https://scholar.google.com/

I have provided below a couple of links to papers to get you started.

https://www.sciencedirect.com/science/article/pii/S1110982315000332

https://iopscience.iop.org/article/10.1088/1748-9326/2/4/045022/pdf

Part 3 – Study Skills, Tips & Guidance

This section includes helpful tips to help you complete this pack, as well as improve your study skills for any courses you take next year.

It also includes a few fantastic easy-to-use resources to know what to do next if you are hoping to go to university in the next few years, like UCAS advice and web links to more academic opportunities.

In this section:

University Study Skills:
- ✓ Cornell Notes
- ✓ Key Instruction Words
- ✓ Academic Writing
- ✓ Referencing
- ✓ Evaluating Your Sources

University Guidance:
- ✓ What next?

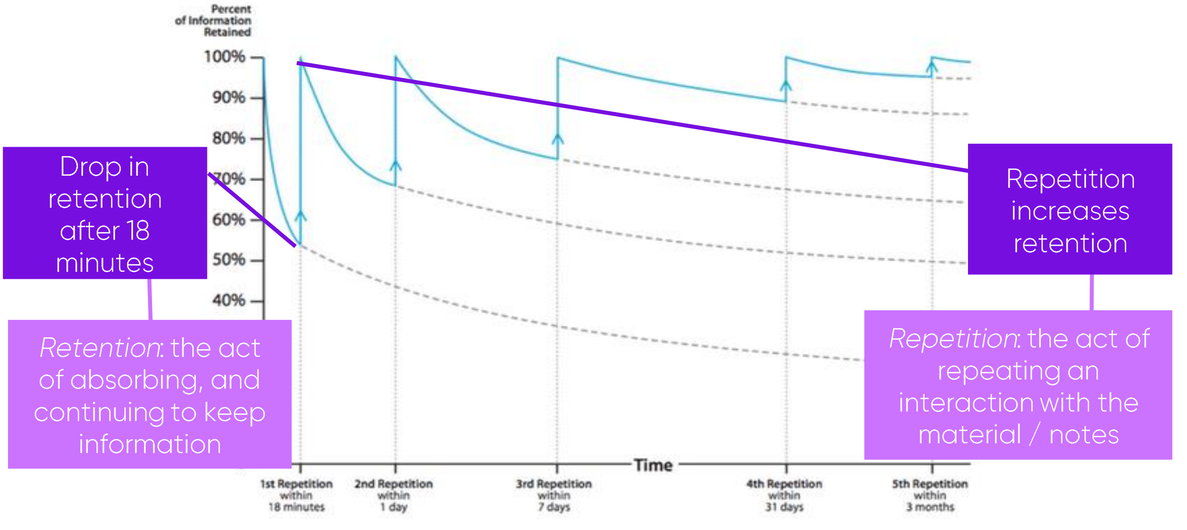
Subject Guidance:
- ✓ More on studying your subject

University Study Skills
Cornell Notes

Why is good note taking important?

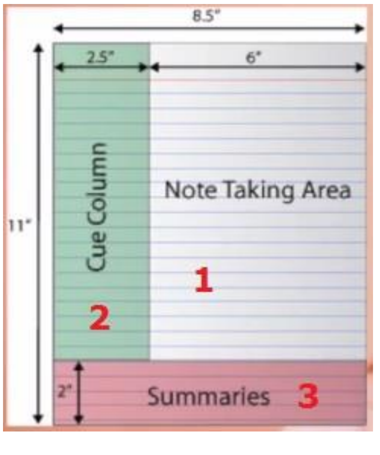
If it feels like you forget new information almost as quickly as you hear it, even if you write it down, that's because we tend to lose almost 40% of new information within the first 24 hours of first reading or hearing it.

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. Create Format: 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 the 'note taking' 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.

University Study Skills
Cornell Notes

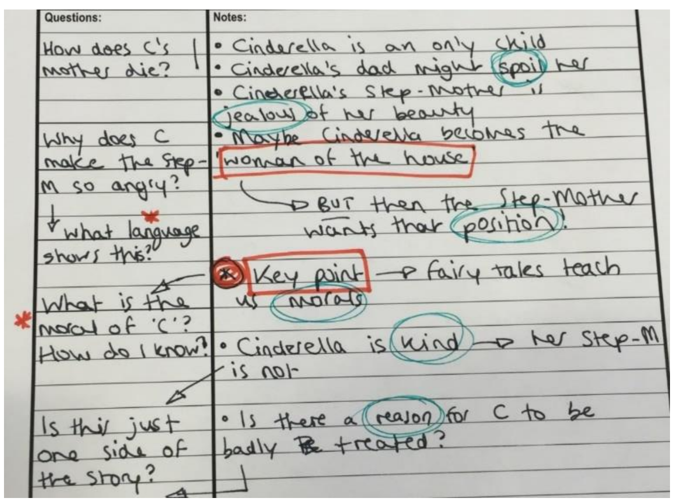
Step 2 Note-Making

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

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

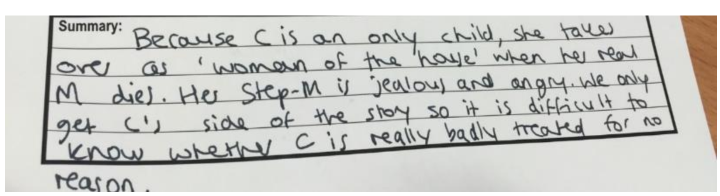
- Which is most important / significant reason for...
- To what extent...
- How does the (data / text / ideas) support the viewpoint?
- How do we know that...

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



Step 3 Note-Interacting

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



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

University Study Skills
Key Instruction Words

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

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

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

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

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

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

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

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

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

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

University Study Skills
Key Instruction Words

Con't

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 Study Skills
Academic Writing

What is academic writing?

'Academic writing' is a specific way of writing when communicating research or discussing an argument/point of view. It has a logical structure, and it uses formal language. There is a particular tone, 'voice' and style to the language. Unlike creative or narrative writing, academic writing will also use different sources of information to support what is being said.

The language of academic writing: do's and don'ts

- Do use words you know the meaning of and are confident using, it doesn't have to be complicated to be clear!
- Do not use contractions; don't, can't, doesn't, it'd. Do write out fully; do not, cannot, does not, it would.
- Do not use colloquialisms- this is 'writing as you speak'. Examples include misuse of the words 'literally' or 'basically', common phrases, such 'like chalk and cheese'.
- Do not use slang or jargon. For example, 'awks', 'lit', 'woke'.

Expressing your opinion in academic writing

In academic writing, it is best practice to express an opinion without writing in the first person, which can often be challenging. Always bear in mind that your work should read like a voice that is guided by the evidence and not basic personal intuition.

Therefore, rather than saying 'In my opinion, this proves that', you can express the outcome of your reasoning in other ways:

- 'This indicates that…';
- 'The aforementioned problems in Smith's argument reveal that…';
- 'Such weaknesses ultimately mean that…', and so on.

Signposting

Signposting guides your reader through different sections of your writing. It lets those who read your writing know what is being discussed and why, and when your piece is shifting from one part to another. This is crucial to for clear communication with your audience.

Signposting stems for a paragraph which expands upon a previous idea	Signposting stems for a paragraph which offers a contrasting view
Building on from the idea that … (mention previous idea), this section illustrates that … (introduce your new idea).	However, another angle on this debate suggests that … (introduce your contrasting idea)
To further understand the role of …(your topic or your previous idea) this section explores the idea that … (introduce your new idea)	In contrast to evidence which presents the view that … (mention your previous idea) an alternative perspective illustrates that …
Another line of thought on … (your topic or your previous idea) demonstrates that …	However, not all research shows that … (mention your previous idea). Some evidence agrees that …

University Study Skills
Referencing

What is a reference or referencing?

A reference is just a note in your assignment that tells your reader where particular ideas, information or opinions that you have used from another source has come from. It can be done through 'citations' or a 'bibliography'.

When you get to university, you will need to include references in the assignments that you write. As well as being academic good practice, referencing is very important, because it will help you to avoid plagiarism.

Plagiarism is when you take someone else's work or ideas and pass them off as your own. **Whether plagiarism is deliberate or accidental, the consequences can be severe.** You must be careful to reference your sources correctly.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

University Study Skills
Referencing

Is it a source worth citing?

Question your sources before referencing using these tips:

Currency: the timelines of the information

- When was it published or posted? Has it been revised or updated? Does your topic require current information, or will older sources work as well?

Relevancy: the importance of the information for your needs

- Does the information relate to your topic or answer your question? Who is the intended audience? Have you looked at a variety of sources?

Authority: the source of the information

- Who is the author/publisher/source/sponsor? What are the author's credentials? Is the author qualified to write on the topic?

Accuracy: the reliability and correctness of the source

- Is the information supported by evidence? Has the information been reviewed or refereed? Can you verify whether it is a personal or professional source? Are there errors?

Purpose: the reason the information exists

- Does the author make the intensions/ purpose clear? Is the information fact opinion or propaganda? Are there are biases? Does the viewpoint appear objective?

University Study Skills
Referencing

How do I reference?

- There are a number of different ways of referencing, but most universities use what is called the Harvard Referencing Style. Speak with your tutor about which style they want you to use, because the most important thing is you remain consistent!

- The two main aspects of referencing you need to be aware of are:

1. In-text citations

- These are used when directly quoting a source. They are located in the body of the work, after you have referred to your source in your writing. They contain the surname of the author of the source and the year it was published in brackets.
    - E.g. *Daisy describes her hopes for her infant daughter, stating "I hope she'll be a fool—that's the best thing a girl can be in this world, a beautiful little fool."* *(Fitzgerald, 2004).*

2. Bibliography

- This is a list of all the sources you have referenced in your assignment. In the bibliography, you list your references by the numbers you have used and include as much information as you have about the reference. The list below gives what should be included for different sources.

- Websites – Author (if possible), *title of the web page*, 'Available at:' website address, [Accessed: date you accessed it].
    - E.g. *'How did so many soldiers survive the trenches?'*, Available at: http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [Accessed: 11 July 2019].

- Books – Author surname, author first initial, (year published), *title of book*, publisher
    - E.g. Dubner S. and Levitt, S., (2007) *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything*, Penguin Books

- Articles – Author, *'title of the article'*, where the article comes from (newspaper, journal etc.), date of the article.
    - E.g. Maev Kennedy, *'The lights to go out across the UK to mark First World War's centenary'*, The Guardian Newspaper, 10 July 2014.

University Study Skills
Evaluating your sources

Knowing about the different types of sources and what makes them worth using is important for academic work.

When doing research you will come across a lot of information from different types of sources. How do you decide which source to use? From newspaper articles to books to tweets, this provides a brief description of each type of source, and breaks down the factors to consider when selecting a source.

Tweets

A platform for millions of very short messages on a variety of topics.

Blogs

Blogs (e.g. Tumbler) are an avenue for sharing both developed and unpublished ideas and interests with a niche community.

Youtube

A collection of millions of educational, inspirational, eye-opening and entertaining videos.

Newspaper

A reporting and recording of cultural and political happenings that keeps the general public informed. Opinions and public commentaries can also be included.

Journals

A collection of analytics reports that outline the objectives, background, methods, results and limitations of new research written for and by scholars in a niche field.

Academic book

The information presented is supported by clearly identified sources. Sometimes each chapter has a different author.

Encyclopaedia

Books or online – giving information on many different subjects. Some are intended as an entry point into research, some provide detailed information and onwards references.

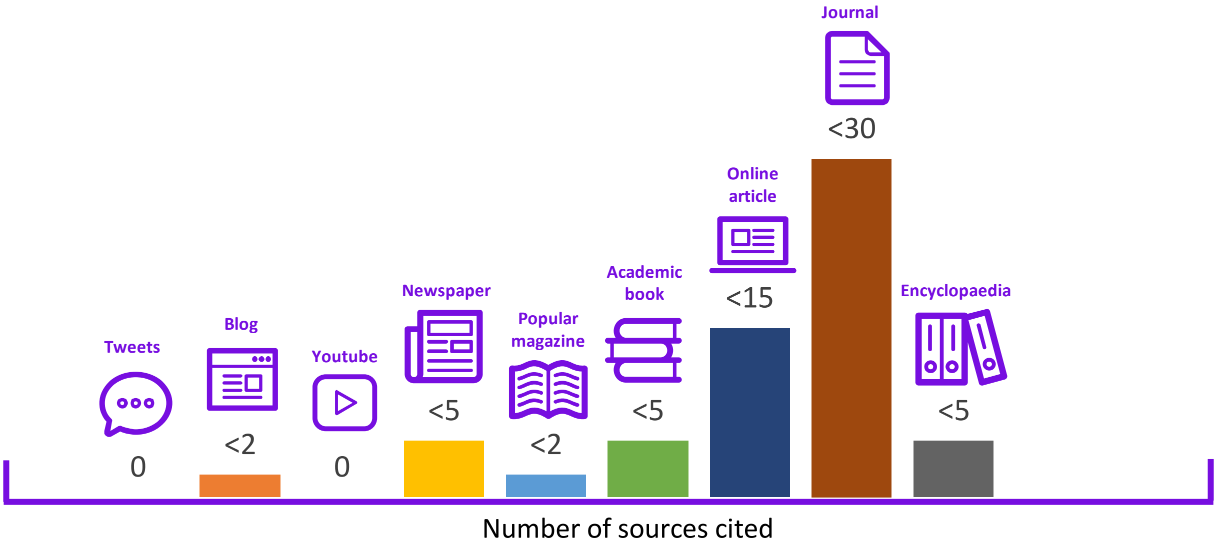
Popular magazine

A glossy compilation of stories with unique themes intended for specific interests.

University Study Skills
Evaluating your sources

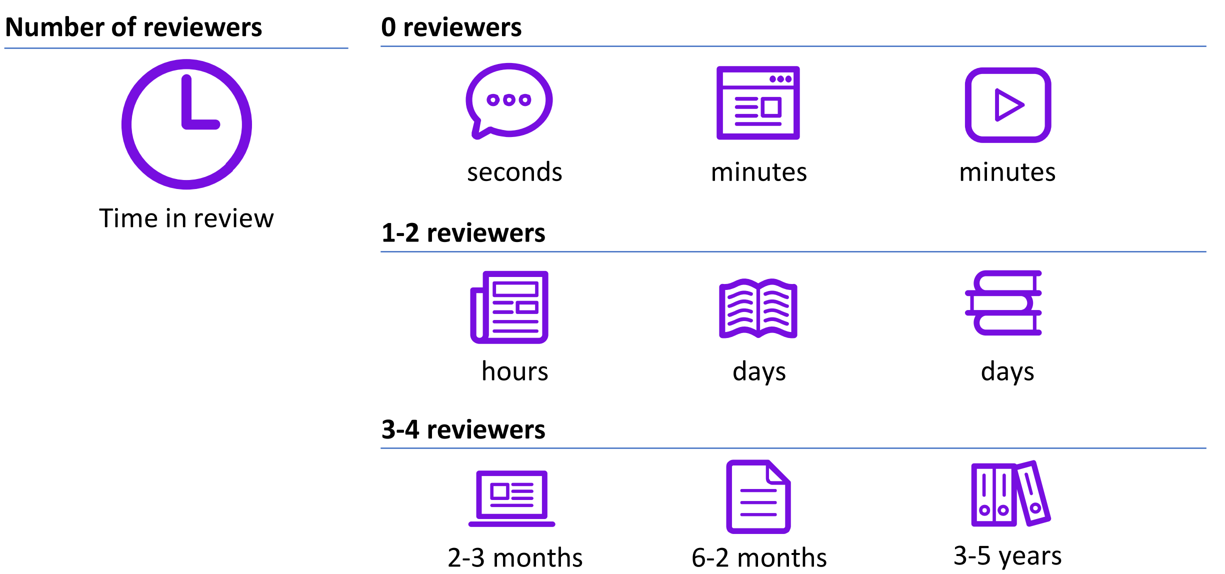
Number of outside sources

When an author used many outside sources into their writing, they demonstrate familiarity with ideas beyond their own. As more unique viewpoints are pulled into a source, it becomes more comprehensive and reliable. This shows the typical number of outside sources used in each publication.



Degree of review before a source is published

Two factors contribute to the amount of inspection that a source receives before it might be published: the number of reviewers fact-checking the written ideas, and the total time spent by reviewers as they fact-check. The more people involved in the review process and the longer the review process takes, the more credible the source is likely to be.



University Guidance
What next?

University Ready!

BROUGHT TO YOU BY RBC ACCESS ED

University Guidance

Different people go to university for different reasons. You might have a particular job in mind or just want to study a subject you are passionate about. Whatever your motivations, going to university can help improve your career prospects, as well as develop your confidence, independence and academic skills.

Choosing a course and university

Choosing the right course to study is an important decision so make sure you take time to research the different options available to you. Here are some top tips:

- ✓ You don't have to choose a course which you have already studied, there are lots of courses which don't require prior knowledge of the subject. You can apply skills gained from school studies to a new field.
- ✓ The same subject can be taught very differently depending on the course and university you choose. Take a look at university websites to find out more about the course content, teaching styles and assessment types.
- ✓ When choosing a university, think about what other factors are important to you. Do you want to study at a campus university or be based in a city centre? What accommodation options are there? Does the university have facilities for any extracurricular activities you're involved in?
- ✓ To research your options, have a look at university prospectuses and websites, as well as seeing if there are opportunities to speak to current students who can give you a real insight in to what life is like there.

Insight into: University of Reading

University of Reading

The author of this coursebook attends the University of Reading.

The University of Reading runs a large number of sessions to help find out more about the process of applying to university as well as taster sessions and Open Online Courses in a number of different subjects. To find out more, visit: www.reading.ac.uk/virtual-events.

Chat to current University of Reading students via Unibuddy and get their views on what university life is like!

University Guidance
What next?

Exploring Careers and Subject 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

Use our platform ThinkUni.org to take a short quiz about your preferences and interests to find out which universities might be a great fit for you.

Other popular resources:

- ✓ https://www.ucas.com/
- ✓ https://www.whatuni.com/
- ✓ http://unistats.direct.gov.uk/
- ✓ https://www.thecompleteuniversityguide.co.uk/
- ✓ https://www.opendays.com/

University Guidance
What next?

UCAS and the university application process

All applications for UK degree programmes are made through UCAS. There is lots of information on the UCAS website to guide you through the process and what you need to do at each stage.

Apply

- Applications **open in September** the year before you plan to start university.
- You can apply for up to **five courses.**
- The deadline for most courses is **15 January**, though there is an earlier deadline of **15 October** for Oxford and Cambridge, medicine, veterinary medicine/science and dentistry.

Decisions

- Some courses may require an interview, portfolio or admissions test in addition to UCAS application. Check individual university websites details.
- Check UCAS Track which will be updated with decisions from the universities you have applied for and to see your deadline for replying to any offers.
- You should choose a firm (or first) choice university and an insurance choice. If you already have your exam results or a university thinks your application is particularly strong, you might receive an **unconditional offer**.

Results

- If you're holding a conditional offer then you will need to wait until you receive your exam results to have your place confirmed.
- Clearing & Adjustment allows you to apply to courses which still have vacancies if you didn't meet the conditions of your offer, have changed your mind about what or where you want to study, or have met and exceeded the conditions of your offer and would like to look at alternate options.

Personal statements

A really important part of your application is the personal statement. The personal statement gives you the opportunity to tell universities why they should offer you a place.

Here a few top tips for making your personal statement stand out:

- You can only submit one personal statement so it's important that you are consistent in your course choices. Make sure you have done your research to show your understanding of the subject area and passion for it.
- Start by brainstorming all your skills, experience and attributes. Once you have everything written down, you can begin to be selective – you only have 47 lines so won't be able to include everything.
- The ABC method: action, benefit and course can be a useful way to help demonstrate your relevant experience and how it applies to the course you're applying for.

University Guidance
What next?

Personal Statement do's and don'ts

Read the tips below from real life professors and admissions staff in university Biology and Psychology departments, on the 'do's' and 'don'ts' of what to include in your personal statement:

Physics

- Tell us why you wish to study Physics. Are there any topics you have studied that have interested you and topics that you are looking forward to studying?
- What drives your interest in Physics; has there been any relevant news/current affairs or new research which have made you wish to learn more about physics?
- How will gaining a Physics degree might help you in your career aspirations?
- Try to demonstrate a wider understanding of the subject through reading or attending events/lectures. Add any university experience that you have gained through summer schools/ day visits; talk about what you got out of the experience.

Geography

- Tell us which aspects of Geography you are interested in
- Are there any issues that you feel strongly about and why? There is always plenty in the news or maybe from personal experience.
- Show you are engaged with the subject. For example, are you involved with any community or conservation groups? What have you learnt from being involved?
- Demonstrate your global and national knowledge. Where have you been, what have you read, what have you learnt?
- Relevant work experience or voluntary work shows that you have passion/ drive.

Further useful resources

Be sure you know what you'll need to do to apply to university in the UK:

✓ Key dates and deadlines: www.access-ed.ngo/timelines-for-applying-to-university

✓ Get tutor advice on writing a UCAS personal statement at www.access-ed.ngo/writing-your-ucas-personal-statement

✓ An easy template to start practising your personal statement: https://www.ucas.com/sites/default/files/ucas-personal-statement-worksheet.pdf

✓ Untangle UCAS terminology at https://www.ucas.com/corporate/about-us/who-we-are/ucas-terms-explained

✓ Discover more about the application process including when to apply and how to fill in your application on the UCAS website.

✓ Read more useful advice about what to include in your personal statement on UCAS, the Complete University Guide and The Student Room.

✓ Attend one of our virtual sessions to find out more about applying and personal statements.

Subject Guidance

A Deeper Look Into Physics

✓ 'Read'
Look at this link on different uses of remote sensing technologies present and future:

https://gisgeography.com/100-earth-remote-sensing-applications-uses/

✓ 'Watch'

Watch this short video on how researchers are using remote sensing technologies to help
https://www.youtube.com/watch?v=EvfYj4OB1sw
There is a series currently available on BBC iPlayer all about watching the earth from space – look at the programme website and watch the clips here.
https://www.bbc.co.uk/programmes/p072n2zr
This clip is especially relevant to the 'final reflection' part of this booklet:
https://www.bbc.co.uk/programmes/p0775l4c
If you have a TV license you can also watch the full programmes through the BBC iPlayer.

✓ 'Do'
The best way to learn more about earth observation is to source your own images. This can be a bit tricky so I have provided some tips on how to start below.
Images can be downloaded from the websites below (be careful when downloading as the images are quite large so first make sure you have space on your computer for them).
You can download some images from this link that are already processed to demonstrate as aspect of land use change:
https://remotesensing.usgs.gov/gallery/image_collections?img:790:3
Sentinel data: the vegetation sensor we have been using here is called Sentinel 2. You need to create a log in to actually download images. All you need for this is your email address.
https://scihub.copernicus.eu/dhus/#/home
Here you can download images from the Landsat missions as well as many other missions.
https://earthexplorer.usgs.gov/

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