Can networks solve everything?

Key Stage 4 Programme

Pupil Name	
Handbook Designed by	Dr D Buxton

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1	26/11/2018	14:00-15:00	Cambridge University
2	09/01/2019	15:20-16:20	Purple Hub
3	16/01/2019	15:20-16:20	Purple Hub
4	23/01/2019	15:20-16:20	Purple Hub
5	30/01/2019	15:20-16:20	Purple Hub
6 (Feedback)	13/02/2019	15:20-16:20	Purple Hub
7 (Feedback)	20/03/2019	15:20-16:20	Purple Hub

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Baseline assignment: networks in real-life	07/12/2018
Tutorial 2	Worksheet 2 & adjacency matrix	14/01/2019
Tutorial 3	Worksheet 3 & node centrality	21/01/2019
Tutorial 4	Worksheet 4 & design a network	28/01/2019
Tutorial 5	Final assignment	11/02/2019 (01/03/2019)

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on 01/03/2019	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Uni Pathways – Pupil Feedback Report

Grade	Marks	Guidance
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of RIS teacher			
Title of Assignment			
Name of Pupil			
Name of School			
ORIGINAL MARK / 100		FINAL MARK / 100	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Knowledge and Understanding

Critical Evaluation/Problem Solving

Structure and Presentation

Resilience Comment

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Course Rationale

We know a lot about the world. We are good at identifying things, giving them a label and describing what they are, or what they do. Our understanding of how all these things communicate, however, is still lacking. A good example is the brain – neuroscientists can list a whole host of words for different brain regions, but would struggle to explain with any certainty how these areas of the brain communicate and how that may have an effect on disease, for example.

Networks could serve as the solution to this problem. They provide us with a mathematical way of describing the relationships between units such as objects, places and people. Furthermore, we can analyse networks to ascertain which units are most important, based on their communications.

During this course, we will explore the world of networks and discover their utility in a wide variety of settings. We will first learn what components are required to make a network, and then build on this knowledge by discussing how these components can change depending on what we are observing (from football tactics, to friendship circles, to the structure of your DNA!). Finally, we will discover how to analyse networks and therefore prove that this method is a useful problem-solving tool, rather than just a nice way to display data!

In your final assignment, you will review the characteristics of networks and have the opportunity to create and analyse your own network. You will also develop key transferrable skills such as analytical thinking, scientific writing and collaboration. These skills will not only improve your abilities as a scientist, but will also give you a taste of university-style assignments, which will give you a head-start in your continuing path through education.

Course Objectives

The overarching objectives of this course on networks are:

- to understand what a network is,
- to be able to explain the different types of network,
- to apply knowledge in order to draw a network visually and mathematically,
- to analyse networks and evaluate key features,
- to collect data and create/analyse your own network.

Mark Scheme

Skills	1st (70-100)	2:1 (60-69)	2:2 (50-59)
Knowledge and Understanding	• All content included is relevant to the general topic and to the specific question/title • Good understanding of all the relevant topics. • Scientific terms are defined and used accurately throughout • Clear justification on how the content included is related to the specific issues that are the focus of the assignment	• Most of the content included is relevant to the general topic and to the specific question/title • Good understanding of most the relevant topics • Scientific terms are used accurately but not always clearly defined. • Adequate justification on how the content included is related to the specific issues that are the focus of the assignment	• Some of the content included is relevant to the general topic and to the specific question/title • Good understanding on some of the relevant topics but occasional confusion on others. • Scientific terms are used mostly accurately with occasional confusion and often not defined. • Some justification on how the content included is related to the specific issues that are the focus of the assignment
Critical Evaluation/Problem solving	• Moved beyond description to an assessment of the value or significance of what is described • Evaluative points are consistently explicit/systematic/reasoned/justified • Effective critiques on the reliability of sources provided • Consistently demonstrate clear, analytical and logical steps to solving problems	• Mostly description but some assessment of the value or significance of what is described • Evaluative points are mostly explicit/systematic/reasoned/justified • Some evidence of critiques on the reliability of sources provided • Some examples of solving problems but not consistently clear, analytical and logical	• Only description with minimal assessment of the value or significance of what is described • Evaluative points are at times explicit/systematic/reasoned/justified • Limited evidence of critiques on the reliability of sources provided • Demonstrate clear steps to solving problems but not consistently analytical or logical

Structure and Presentation	• Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment • The introduction clearly outlines how the essay/report will deal with the issues • The conclusion summarises all the main points clearly and concisely • All calculations, formulas and methods are clearly structured, clear to follow and correct • Tables and graphs are effectively constructed including appropriate headings, units and scales. • All sources are referenced correctly in an agreed format	• Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment • The introduction adequately describes how the essay/report will deal with the issues • The conclusion summarises most of the main points clearly • Calculations, formulas and methods are mostly structured, clear to follow and correct • Most tables and graphs are well constructed • Most sources are referenced correctly in an agreed format	• Ideas are presented in paragraphs and arranged in a structure • The introduction mentions how the essay/report will deal with the issues • The conclusion summarises some of the main points clearly • Calculations, formulas and methods are not always structured, clear to follow and correct. • Some tables and graphs are well constructed but contains some errors • Some sources are referenced correctly in the agreed format with occasional errors

Glossary of Keywords

This is for reference throughout this set of tutorials. You are encouraged to try and define them in your own words or practice their use in a sentence. There are some empty rows for you to add words as you see fit.

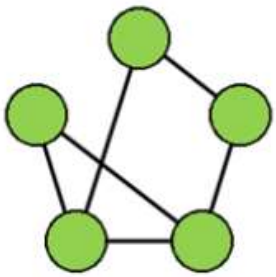
Word	Definition	In your own words/In a sentence
Network	The arrangement of a set of objects that share connections if there exists a common trait or relationship.	
Node	An object in the network, typically represented by a small circle.	
Edge	A line that connects a pair of nodes in the network.	
Adjacent	A term used to identify whether a pair of nodes are connected by an edge.	
Path	A unique sequence of edges (travelling through unique nodes) that connect one node to another.	
Degree	The total number of edges that are directly connected to a node.	
Directed edge	A line that connects one node to another in a single direction, typically represented by an arrow.	
In-degree	The total number of directed edges that point directly towards a node.	
Out-degree	The total number of directed edges that point away from a node.	
Weighted edge	A labelled line that connects a pair of nodes in the network. The label is a number that shows the strength of a connection.	
Weighted degree	The total sum of the weighted edges that are connected to a node.	
Adjacency matrix	A square grid of numbers that describes (in a mathematical way) whether each pair of nodes is adjacent or not.	

Centrality	A method to identify the most important/influential node(s) in a network.	

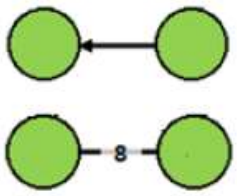
Knowledge Organiser

Can Networks Solve Everything?

Key concepts



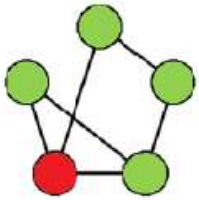
A **network** is a collection of **nodes** and **edges**. Nodes can be **disconnected**, but edges must **connect** to a node at either end.



Networks can have **direction** and/or **weights**, depending on what they are describing.

$$\begin{bmatrix} 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$

Networks can be written as an **adjacency matrix**, which describes, in **grid form**, connections between nodes.



The **importance** of nodes in a network is measured using **centrality** scores.

Important Vocabulary

Network	The arrangement of a set of objects that share connections if there exists a common trait or relationship.
Node	An object in the network, typically represented by a small circle.
Edge	A line that connects a pair of nodes in the network.
Adjacent	A term used to identify whether a pair of nodes are connected by an edge.
Path	A unique sequence of edges (travelling through unique nodes) that connect one node to another.
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Adjacency matrix	A square grid of numbers that describes (in a mathematical way) whether each pair of nodes is adjacent or not.
Centrality	A method to identify the most important/influential node(s) in a network.

Learning objectives knowledge structure

Tutorial 1
- Networks and keywords
  - Nodes
  - Edges

Tutorial 2
- Types of network
  - Directed
  - Weighted

Tutorial 3
- Mathematical interpretation
  - Adjacency matrix

Tutorial 4
- Analysing networks
  - Centrality

Tutorial 5
- Real-life networks
- Academic writing
  - Structure
  - Referencing

Final Assignment
- Report & creating/analysing own network

Tutorial 1 – Networks, Nodes and Edges

Figure 1: A network representation of the world map.
Link: https://www.tibco.com/blog/2016/03/15/welcome-the-newest-member-of-the-tibco-bpm-family-tibco-nimbus-maps/

What is the Purpose of Tutorial 1?

- To identify the two key components of a network
- To explain the difference between a node and edge
- To be able to draw a network when given prior information

Activity 1: Connect the Dots

Connect the dots on the image below by drawing lines between consecutive numbers.

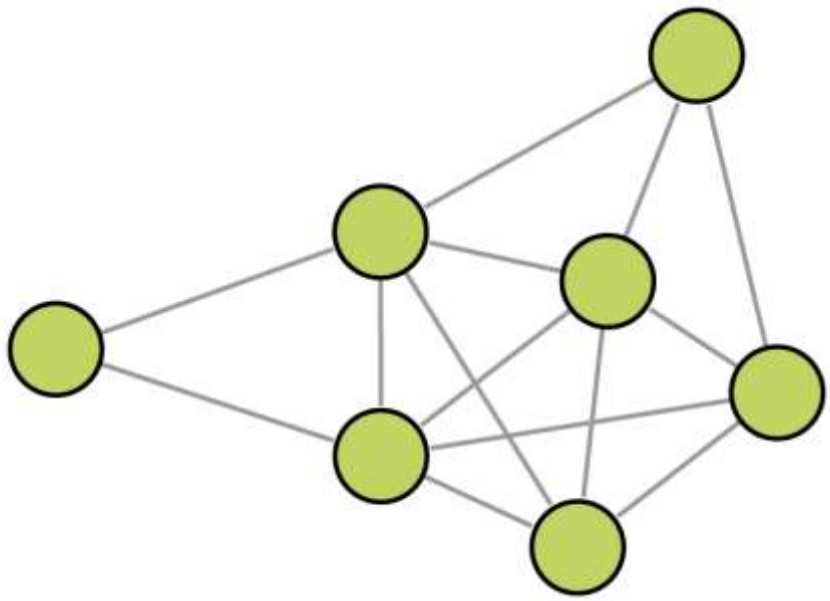
Is this a network?

What are the similarities between this and a network?

What are the differences?

Activity 2: Which is which?

From the image below, identify a node, an edge and a network. Use the definitions you have written down to help you.



How many nodes are there?

How many edges are there?

Give examples of what the nodes and edges could be. One example has already been given.

Airports	connected by	flight paths
	connected by	
	connected by	
	connected by	
	connected by	
	connected by	

Activity 3: Story Time

Read the extract below.

> Jane Smith called Gary Jones to ask whether he and his family would like to visit for a meal. Gary accepted, and asked his wife, Paula Jones, to bring a bottle of wine from the cupboard as a gift.
>
> Later that evening, the Jones family arrived at the Smith residence. Paula told her daughter, Sarah, to check if her classmate Zara Smith had completed her homework for class the following day. Sarah found Zara and they had a chat comparing answers for their homework assignment.
>
> At the dinner table, Zara complimented Paula on her choice of earrings. Paula thanked Zara and turned to Jane to tell her where she bought the earrings from.
>
> After finishing the meal, Gary and Paula's son, Robert, asked his father if he could be excused from the table. Gary accepted, whilst Robert quietly explained to his mother (Paula) why he needed to be excused.

Suppose this extract was describing a network. What could the nodes be and what would represent edges connecting them?

In the space below, draw this network.

Is it possible to categorise the nodes into distinct groups? If so, what could these groups be?

Baseline Assignment

Write a short summary (maximum 400 words) on what a network is and how they are applied to real-life scenarios. The format is preferably a Word document (this work may be useful for your final assignment) but can also be submitted in writing. If you use any websites as research for your summary, include the links after your writing. There is space below to make notes.

You will be assessed on the quality of your written communication. Marks will be given for good spelling, punctuation and grammar, as well as the correct use of technical terms.

Tutorial 2 – Types of Networks

Figure 2: A 'one way' road sign in the United Kingdom.
Link: http://www.yourvalleynews.co.uk/travel/one-way-traffic-system-not-viable/

What is the Purpose of Tutorial 2?

- To explain the difference between a directed and undirected network
- To explain the difference between a weighted and unweighted network
- To solve the shortest path problem for small networks with directed and/or weighted edges

Activity 1: The Wiki Game

Who is the best at the Wiki game?

Here are the rules:

- On a computer, everyone starts with the same Wikipedia page open
- You will all be given the same destination page
- You must navigate your way to the destination page using **ONLY** links from your current Wikipedia page
- The person that arrives at the destination page in the **FEWEST** number of clicks (not the quickest time!) wins
- You cannot go back or visit a page that you have already been to

Whilst playing the game, write a list (below) of the pages you visit before reaching the destination page.

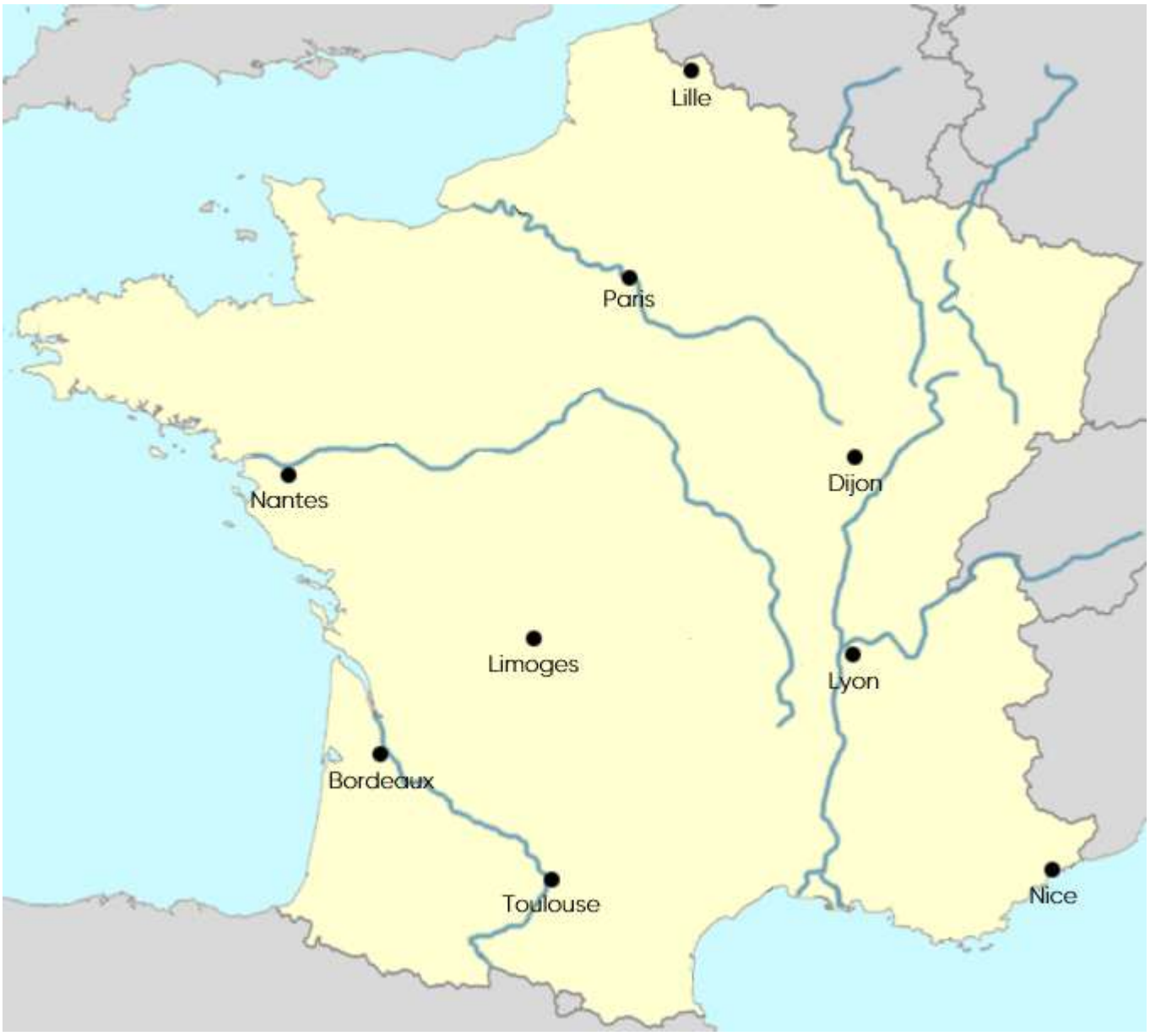
Starting Page: Nobel Peace Prize	11.
1.	12.
2.	13.
3.	14.
4.	15.
5.	16.
6.	17.
7.	18.
8.	19.
9.	20.
10.	Destination Page: Unicorn

Consider that this game was a network. If the nodes are Wiki pages, what are the edges?

What is different about the edges in this network?
(HINT: One of the rules may help)

Activity 2: A Map of France

Using a ruler, connect all the French cities with edges.



Which of the cities is closest to Nice? How could you prove it?

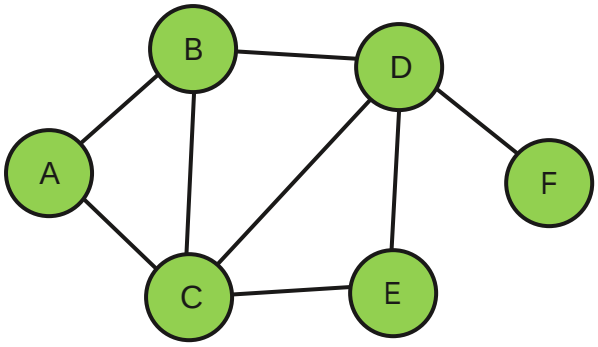
If every 1 cm on this map scaled to 200 km, label each edge with distances between cities (round to the nearest 100 km).

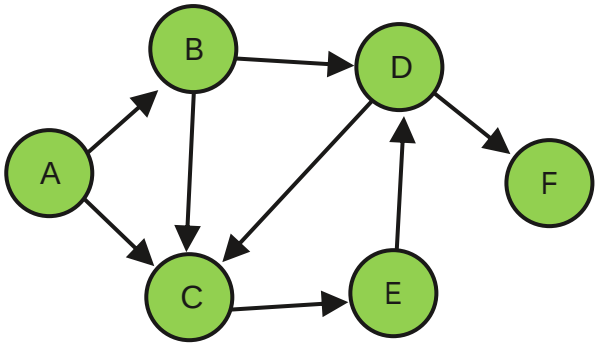
Tick the box of the shortest route:

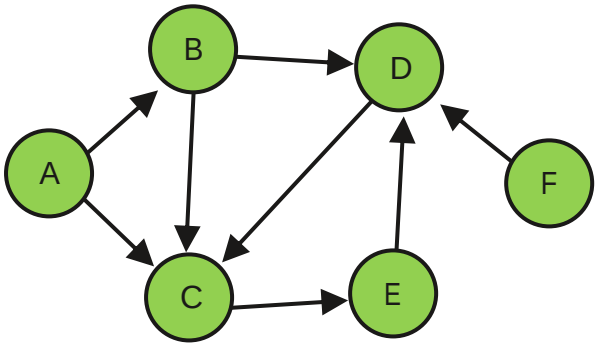
1. Nantes -> Bordeaux -> Lyon -> Nice ☐
2. Toulouse -> Limoges -> Lille -> Lyon ☐
3. Nice -> Nantes -> Toulouse -> Bordeaux ☐

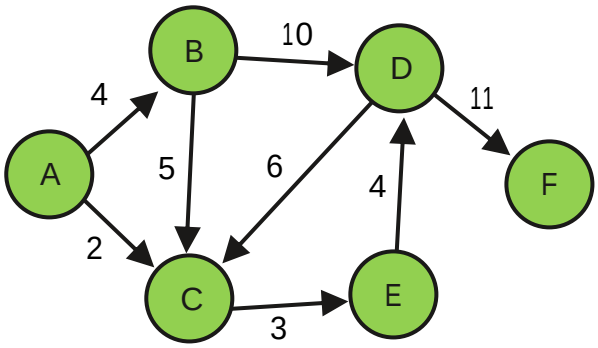
Activity 3: The Shortest Path Problem

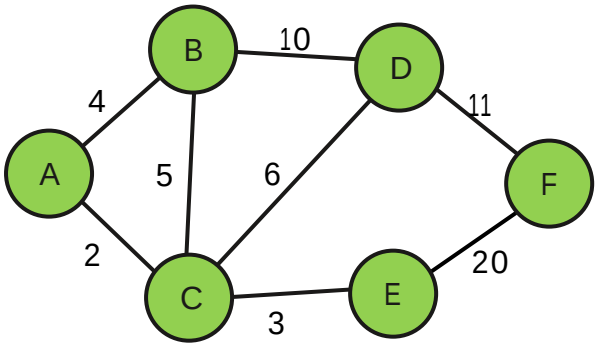
With the networks below, firstly identify whether they are directed, weighted, both or neither. Secondly, in each case, find the shortest path between node A and node F.

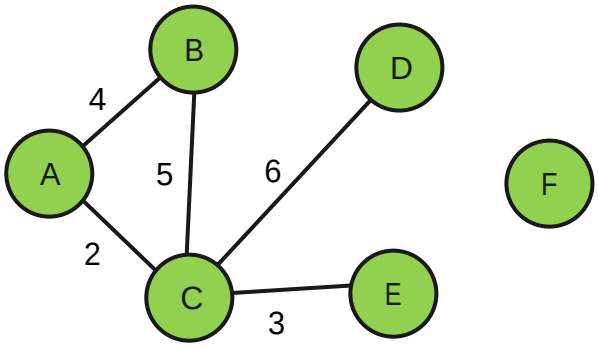












Homework 2

- Complete **Homework 2 Worksheet**, which contains problems on types of networks.
- Write a small summary (~250 words) about the **adjacency matrix** (we will discuss this in the next tutorial).

Useful link: https://mathinsight.org/network_introduction

Tutorial 3 – The (Adjacency) Matrix

Figure 3: "The Matrix" from the 1999 film of the same name.
Link: *https://medium.com/@marknutter/the-matrix-plot-that-should-have-been-54bcddc60e2b*

What is the Purpose of Tutorial 3?

- to identify the similarities between a network and its corresponding adjacency matrix
- to create an adjacency matrix when given only an image of a network
- to draw a network when given only an adjacency matrix

Activity 1: Battleships

You have three ships. The lengths of these ships are as follows:

- Ship 1 – 2 squares long
- Ship 2 – 3 squares long
- Ship 3 – 4 squares long

Place your three ships somewhere in the grid below and take it in turns with your partner to try and sink all the battleships! If you get a 'hit', have another go. If you 'miss', it is your partner's turn.

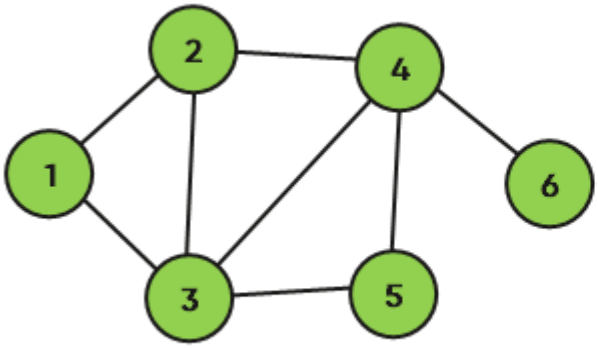
	A	B	C	D	E	F
1						
2						
3						
4						
5						
6						

Using your game of battleships as an example (or otherwise), explain your understanding of a matrix.

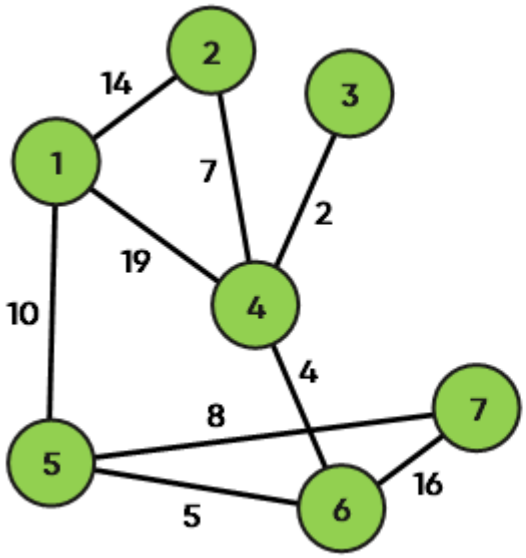
Can you name any other games that use a grid system? What are the similarities and differences between these games and a matrix?

Activity 2: Network to Matrix

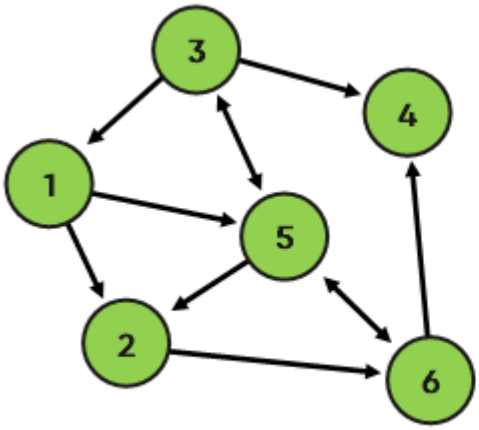
Convert the networks below into adjacency matrix form. Nodes have been numbered for you to make it clearer which row/column to use.



A =



A =



A =

Activity 3: Matrix to Network

Convert the adjacency matrices below into networks. Remember to label each node with numbers. Can you tell which type of network you are drawing (weighted/unweighted, directed/undirected)?

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 & 1 & 0 \end{bmatrix}$$

$$\mathbf{A} = \begin{bmatrix} 0 & 12 & 7 & 4 & 0 & 9 \\ 12 & 0 & 16 & 0 & 20 & 0 \\ 7 & 16 & 0 & 2 & 0 & 0 \\ 4 & 0 & 2 & 0 & 3 & 11 \\ 0 & 20 & 0 & 3 & 0 & 0 \\ 9 & 0 & 0 & 11 & 0 & 0 \end{bmatrix}$$

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 0 \end{bmatrix}$$

Homework 3

- Complete **Homework 3 Worksheet**, which contains problems on converting to and from adjacency matrix form.

- Write a small summary (~250 words) about **node centrality** (we will discuss this in the next tutorial).

Useful link: https://cambridge-intelligence.com/keylines-faqs-social-network-analysis/

Tutorial 4 – Centrality of Nodes

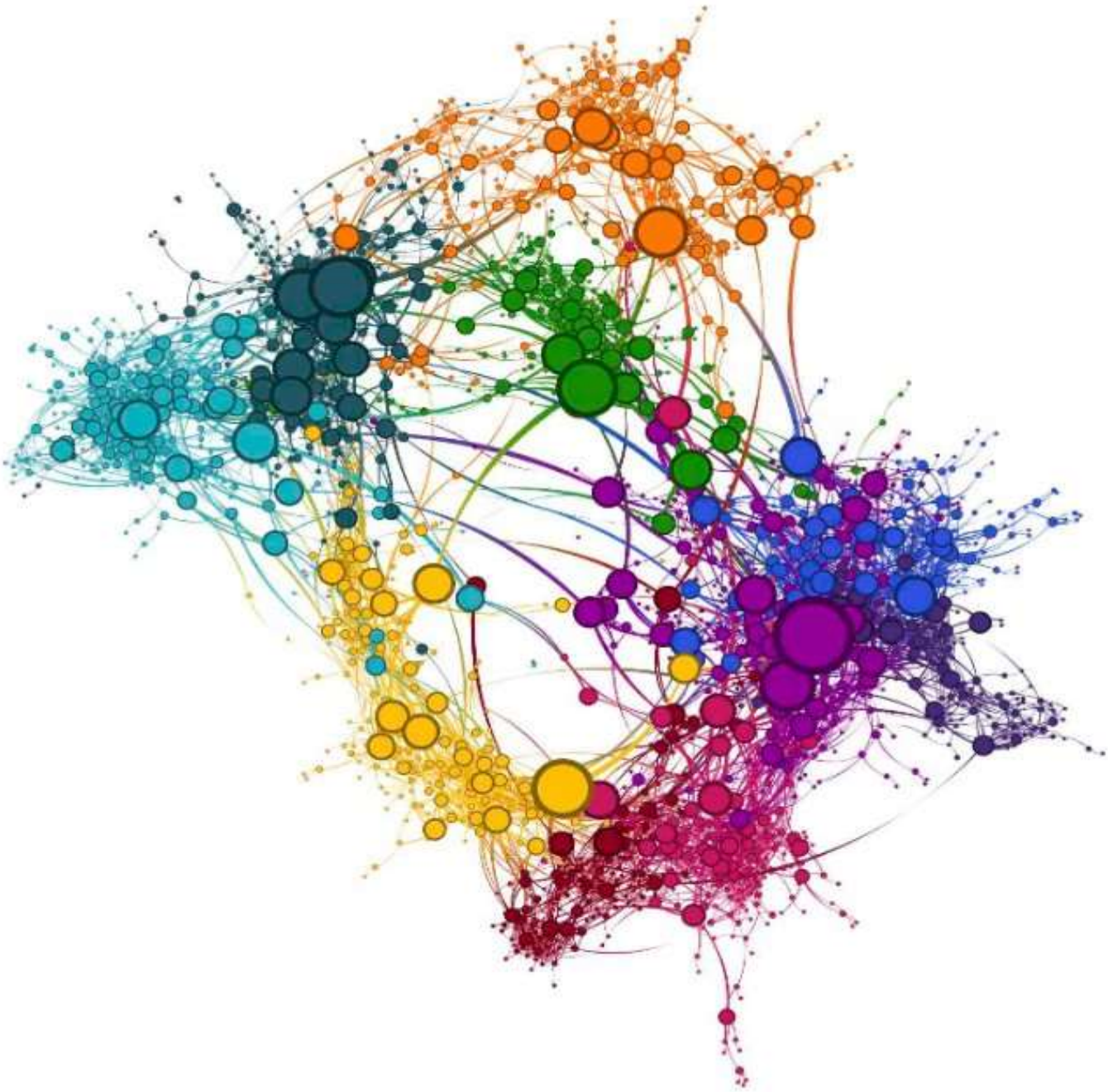


Figure 4: A complex network with node sizes differing, depending on their (betweenness) centrality score.
Link: *https://www.andrew.cmu.edu/user/jiaduoh/418finalproject/*

What is the Purpose of Tutorial 4?

- To explain to impact and context of centrality
- To recall different ways of calculating node centrality
- To perform degree centrality calculations on various networks

Activity 1: Importance

In pairs, you will be assigned one of three members of a football club.

Goalkeeper

Striker

Manager

Discuss with your partner and make a case for why your person is the most important for a football club.

For each member, can you think of a network for which they are the most important node? Think about what the edges could represent and why the person you are looking at would have the highest centrality.

Activity 2: Centrality Measures

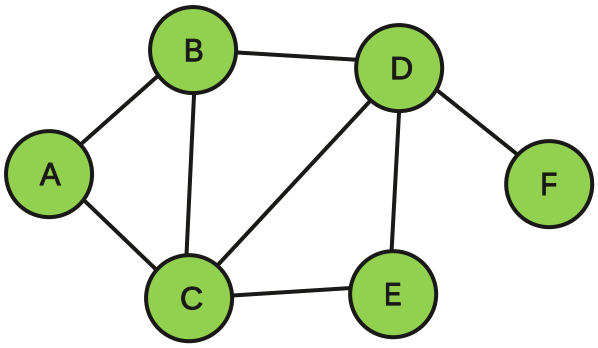
Can you match the centrality measure to its definition?

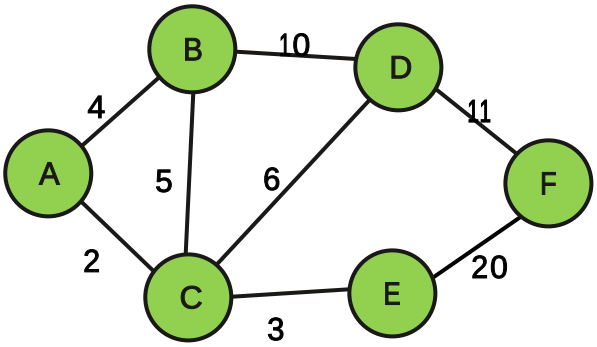
Degree centrality	The number of times the node acts as a bridge along the shortest path between two other nodes. These nodes may not have many edges connecting to them.
Closeness centrality	Counts the number and quality of links to a page to then estimate how important a website is. Used by the Google search engine.
Betweenness centrality	The number of edges that connect to a node. If a network is directed, this can be separated into in-degree and out-degree centrality
Eigenvector centrality	The average length of the shortest path between the node and all others in the network, i.e. how close a node is to everything else.
PageRank centrality	An iterative method that scores nodes based on the importance of their connected neighbours.

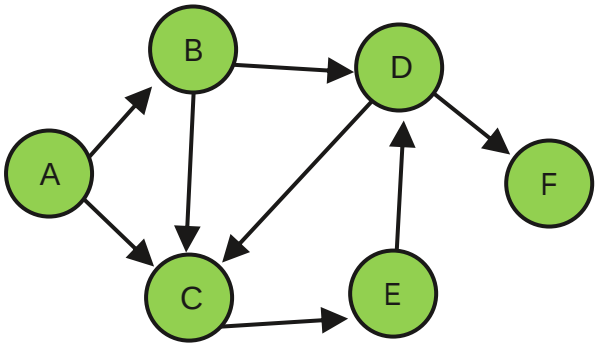
In the space below, describe a possible strength and limitation of two centrality measures.

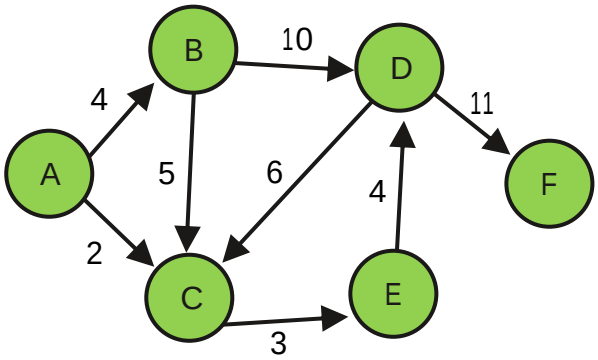
Activity 3: Degree Centrality

For each network, rank nodes A to F in order of importance if using degree centrality (you may need to calculate both in-degree and out-degree, forming two separate lists).









Homework 4

- Complete **Homework 4 Worksheet**, which contains problems on calculating node centralities for various networks.

- Create a small network (between 5 and 10 nodes) based on real-life data (you can collect the data yourself or find some online). Be clear on what your nodes are and how they connect.

Tutorial 5 – Real-life Networks

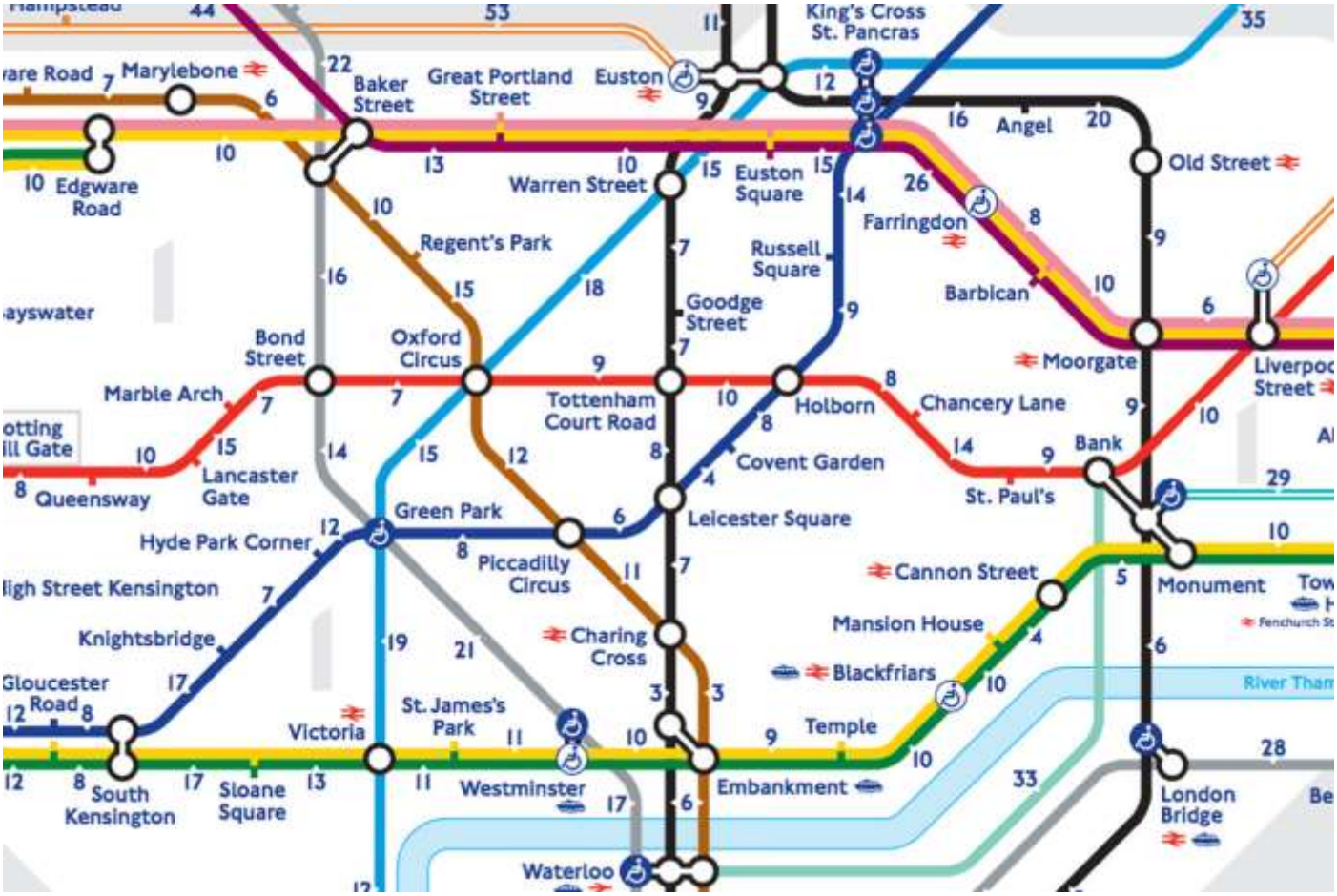


Figure 5: Partial tube map for the London Underground, with walking distances.
Link: https://www.theverge.com/2015/11/11/9712376/london-walk-tube-underground-map

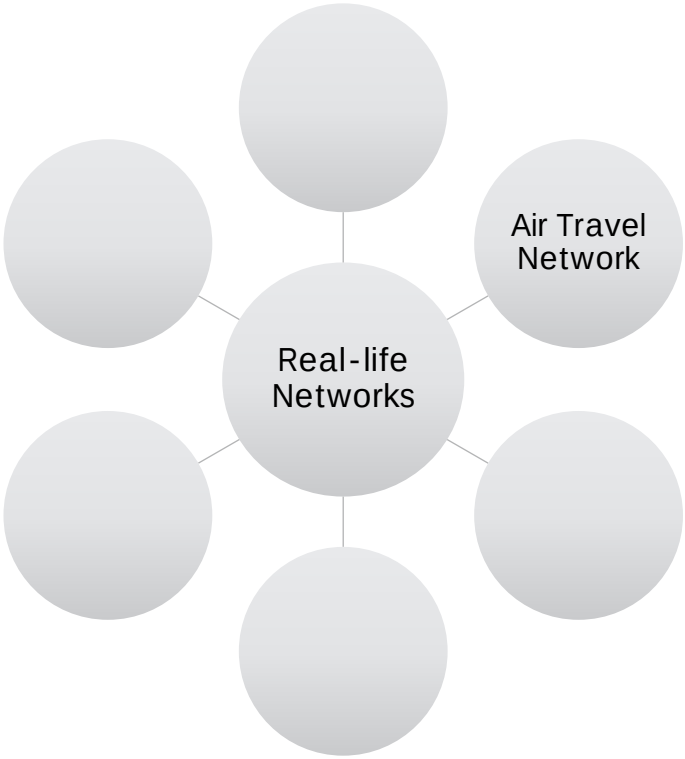
What is the Purpose of Tutorial 5?

- To investigate real-world examples of networks and identify what type of network they are
- To create or use existing data to design your own network
- To demonstrate how to write and reference properly

Activity 1: Discover the Possibilities

During this course, you have been exposed to many examples of real-life networks. Now is your chance to think about and research more examples that peaks your curiosity!

In the space below, write down your initial ideas for real-life networks. Consider what the nodes would be and how edges would connect them. To help you get started, an example has been given in the spider diagram below.



Air Travel Network – Nodes: airports, edges: flight paths. Motivation for research: to find which airport is busiest (has the most inbound and outbound flights) and therefore discover the airport that contributes most to the economy.

Activity 2: Create Your Own

Choose an idea from Activity 1 to create your own network. Is the data easy to find online? Is your network weighted or directed? If you are collecting the data yourself, are you able to do so easily?

Use the space below to sketch your network, collect some data and/or write down some useful links that you have found online.

Activity 3: Writing and Referencing

Use the remaining time in this session to familiarise yourself with how to write and reference correctly, in preparation for your final assignment. Look at Appendix 1 in this workbook for a guide on how to reference and check my feedback from homework assignments for some guidance on your academic writing skills.

Use the space below to take some notes, if needed. This space may be useful for writing down the criteria to succeed for your final assignment.

Final Assignment

What are networks and how are they useful?

Produce a report (between 1,200 and 1,500 words) that answers the above question. Your report should be split into the following sections:

- **Abstract:** A summary of the main points studied during this Uni Pathways course (~250 words);
- **Review:** The largest part of the report: an in-depth description of the main points. It is suggested that you split this into 4 sections – one for each tutorial from 1 to 4 (~600 – 800 words);
- **Conclusions:** A description and analysis of your own network, followed by your evaluation of the strengths and limitations of network analysis (~400 words).

The report should also include an **appendix**, which will contain evidence of your own network (visual representation, adjacency matrix) as well as evidence of calculations for node centrality. You can refer to these in your conclusions section of the report.

Your homework assignments should help to form this document, but make sure that your report is coherent (each section leads into the next). You will be marked on your spelling, punctuation, grammar and the correct use of technical terms.

There is space below to plan your report, if you wish to.

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on final assignment drafts.
- To share examples of best practice with the other pupils in your group.
- To write targets for improving your assignment ready for final submission.

Final assignment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

The success criteria I need to focus on to improve my final assignment are…

Tutorial 7 – Feedback tutorial

What is the Purpose of Tutorial 7?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

My target for future work is…

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
•   •   •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really 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. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

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.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. **A marker in your assignment**: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].
2. **Bibliography**: This is just a list of the references you have used 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.

    a. **Websites** – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

    E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

    b. **Books** – Author, date published, title of book (in italics), pages where the information came from.

    E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

    c. **Articles** – Author, 'title of the article' (with quotation marks), *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', Guardian, 10 July 2014.

Notes

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Can networks solve everything?

Key Stage 4 Programme

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