A Bee in Maths:
Animal behaviour & Complex Systems

Key Stage 4 Programme

Pupil Name	
Handbook Designed by	Richard Pearce

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6 (Feedback)			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on _____.	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

The Brilliant Club KS4 Programme – Pupil Feedback Report

Grade	Marks (%)	What this means
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

Name of PhD Tutor			
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:

Learning Feedback Comment 1 - *Key Learning Priority*	
What you did in relation to this Key Learning Priority *Feedback*	How you could improve in the future *Feedback*
Learning Feedback Comment 2 - *Key Learning Priority*	
What you did in relation to this Key Learning Priority *Feedback*	How you could improve in the future *Feedback*
Learning Feedback Comment 3 - *Key Learning Priority*	
What you did in relation to this Key Learning Priority *Feedback*	How you could improve in the future *Feedback*
Resilience Comment	
How you showed learning resilience during the course *Feedback*	How you could build learning resilience in the future *Feedback*

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Course Rationale

This course aims to explore how and why animals behave in the ways they do, both as individuals and as part of a group. This is a growing area of research in both biology and mathematics, which shows how these two subjects can be used together.

Discovering how animals behave and interact increases our knowledge in many areas of science, such as animal conservation, animal movement, epidemiology, biomimicry, and complex systems. For example, Learning about how honeybees find food can help with their conservation and therefore improve the pollination of the crops that we rely on for our food.

Complex systems are present all around us, especially in nature (e.g. the human brain), and they consist of many interacting parts. These interactions are often quite simple, but what emerges is often unpredictable (i.e. the whole is greater than the sum of its parts). The combination of mathematics and science can help us to understand how these complex systems work.

The course consists of the following:

- An introduction to some of the different types of animal behaviour, including several examples.
- It aims to increase understanding of what a scientific research paper is and how they are written, including how conclusions are made from the data collected.
- It explores what a complex system is, including several examples found in nature.
- Students will develop their research, presentation, and critical thinking skills.

Mark Scheme Table

	Skills	1st (70–100)	2:1 (60–69)	2:2 (50–59)
Subject knowledge	Knowledge and Understanding	• All content included is relevant to the specific question • 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 specific question • 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 specific question • 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 thinking	Research and Evidence	○ Inclusion of rich sources of research findings as evidence for the claims/ideas ○ Use evidence to support claims/ideas, consistently clearly and convincingly ○ Evidence of further reading beyond materials provided which were used in an appropriate context ○ Appropriate assumptions/ conclusions are reached	○ Inclusion of adequate sources of research findings as evidence for the claims/ideas ○ Use evidence/ calculations to support claims/ideas, mostly clearly and convincingly ○ Evidence of further reading beyond materials provided ○ The assumptions/ conclusions that are reached are mostly appropriate	○ Inclusion of some sources of research findings, data, quotations or other sourced material as evidence for the claims/ideas ○ Use evidence/ calculations to support claims/ ○ assertions/ideas, at times clearly and convincingly ○ Limited evidence of further reading beyond materials provided ○ There is an attempt to make assumptions/conclus ions
	Developing an Argument	• Argument/proof exceptionally well-developed and well-justified • Makes links effectively between subjects that have not previously been associated • Uses concepts from the tutorials in an unfamiliar context, and does so accurately and	• Argument/proof clear and well-developed and position justified • Some evidence of linking subjects that have not previously been associated • Use some concepts from the tutorials in an unfamiliar context, but not always accurate	• Argument/proof clear but not well-developed or justified • Limited evidence of linking subjects that have not previously been associated • Limited use of concepts from the tutorials in other contexts • Some analysis of

		confidently • Content is analysed effectively to support the argument	• Analysis of content to support the argument	content to support the argument
	Critical Evaluation	○ Moved beyond description to an assessment of the value or significance of what is described ○ Evaluative points are reasoned/justified ○ Effective critiques on the reliability of sources provided	○ Mostly description but some assessment of the value or significance of what is described ○ Evaluative points are mostly reasoned/ justified ○ Some evidence of critiques on the reliability of sources provided	○ Only description with minimal assessment of the value or significance of what is described ○ Evaluative points are at times reasoned/ justified ○ Limited evidence of critiques on the reliability of sources provided
Written communication	Structure and Presentation	• Ideas are arranged in a logical structure that is appropriate for the assignment • The introduction clearly outlines the aim of the report • The conclusion summarises all the main points clearly and concisely • Figures, tables and graphs are effectively constructed including appropriate headings, units and scales • All sources are referenced correctly in an agreed format	• Ideas are arranged in a structure that is mostly appropriate for the assignment • The introduction adequately outlines the aim of the report • The conclusion summarises most of the main points clearly • Most figures, tables and graphs are well constructed • Most sources are referenced correctly in an agreed format	• Ideas are arranged in a structure • The introduction mentions the aim of the report • The conclusion summarises some of the main points clearly • Some figures, tables and graphs are well constructed but contains some errors • Some sources are referenced correctly in the agreed format with occasional errors
	Language and Style	○ No spelling, grammar or punctuation errors ○ Writing style consistently clear, appropriate for scientific documents and easy to follow ○ Accurate and consistent use of technical language and vocabulary	○ Minimal spelling, grammar or punctuation errors ○ Writing style mostly clear, appropriate for scientific documents and easy to follow ○ Some attempts of using technical language and vocab alary, but not always accurate	○ Some spelling, grammar or punctuation errors ○ Writing style moderately clear, appropriate for scientific documents and easy to follow ○ Use of simple language and vocabulary effectively but struggles to use technical language

Glossary of Keywords

Word	Definition	Use in a sentence
Anatomy		
Associative learning		
Behaviour		
Biomimicry		
Complex		
Conditioned		
Conservation		
Conspecific		
Discriminate		
Emergent property		
Environment		
Epidemiology		
Innate		

Individual parts		
Instinctive		
Interaction		
Reference		
Research paper		
Scent-mark		
Species		
Stimulus		
System		

Tutorial 1 – Animal Behaviour

What is the Purpose of Tutorial 1?

- An introduction to the study of animal behaviour
- What is an ethologist?
- Different types of learning in animals

Animal Behaviour is the scientific study of the ways in which animals interact with other animals and with their environment.

Animals exhibit a wide range of **instinctive** and **learned** behaviours, which help them to survive.

Animals **communicate** with each other in a variety of ways, using sounds, chemicals, and body language.

An ethologist is a scientist who studies animal behaviour; some famous ethologists include:

> Jane Goodall (1934–present) is a British ethologist who has spent her life studying chimpanzees in Africa. She famously observed that they have distinct **personalities** and are capable of behaviour like hugging and tickling each other. Perhaps her most famous observation was that they are capable of using **tools**.
>
> Nikolaas Tinbergen (1907–1988) was a Dutch ethologist who also won the Nobel Prize. He studied gulls and showed that their chicks **instinctively** knew to peck at red spots on their parents' beaks to encourage them to **regurgitate** food.

Activity: Can you find two more famous ethologists? What are they most famous for?

1. Name:

2. Name:

Video: https://www.ted.com/talks/frans_de_waal_do_animals_have_morals

Make notes on the video:

- What is the main theme of the video?

- Provide examples of this.

Types of behaviour

Behaviour is defined as the response of an animal to a **stimulus**; some responses are **innate** (they are not learned – they are instinctive and happen automatically). A newborn sucking milk from its mother is an example of an innate behaviour.

Other behaviours are **learned**. These are called conditioned behaviours, and there are four types: **classical conditioning**, **operant conditioning**, **imprinting** and **habituation**.

Activity: Fill in the gaps below with the correct type of **learned behaviour**.

- _____ occurs by rewarding or punishing an animal. Teaching a dog to jump through a hoop by giving it treats is operant conditioning (e.g. sniffer dogs to find illegal drugs or bombs).

- _____ is where an animal becomes steadily used to a stimulus or situation (e.g. crows response to a scarecrow over time; they become familiar with the scarecrow and no longer fear it).

- _____ is the tendency of young animals to follow the first moving object they see. This is usually the mother. Imprinting usually occurs during a short, but critical, period of a young animal's life (e.g. ducklings following their mother).

- _____ occurs without rewarding or punishing. For example, many dogs will run towards the door to begin their walk when their owner shakes their lead.

  A Russian scientist called **Ivan Pavlov** completed a famous experiment where he observed that his dog produced lots of saliva when he showed it food. Every time he fed his dog, he rang a bell for a short while afterwards. Eventually, just ringing the bell alone was enough to make his dog salivate. It had been conditioned into salivating when it heard the bell - and not just when it saw food.

Homework 1

a. Write about an example of animal behaviour – you can focus on a specific behaviour that occurs for multiple species of animal or you can focus on a specific animal species and the different behaviours they display (remember to include references where appropriate) (**200 words**).

b. Read the abstract of the paper "Bumblebees can discriminate between the scent-marks of conspecifics".

- Highlight any words, phrases, or sentences you do not understand – see if you can find out what they mean.

- Write down in your own words what the paper is about

(**100 words**).

Tutorial 2 – Scent-mark Discrimination in Bumblebees

What is the Purpose of Tutorial 2?

- Bumblebee anatomy
- Read and evaluate a scientific research paper
- Consider the scientific method of studying animal behaviour
- Associative learning in bumblebees

Activity: Label the Bumblebee

Antennae

Wing

Tail

Thorax

Tongue

Head

Pollen basket

Abdomen

Tarsi

Activity: A **scientific research paper** is typically divided into four sections: **introduction**, **materials and methods**, **results**, and **discussion**. For the paper "Bumblebees can discriminate between the scent-marks of conspecifics", state what the purpose of each section is and summarise in the context of the paper:

- Introduction

- Materials and methods

- Results

- Discussion

Fill in the <u>blanks</u> for each of the bullet-points below (missing words are provided below):

- The **introduction** is compiled from reference material and reflects the _____ or _____ that leads you to perform the _____.

- In the final draft the organisation of the **materials and methods** section is coordinated with the **results** section.

- The **results** section presents _____ in nearly chronological order and directs the reader along the same mental paths through the data that you took in _____.

- The **discussion** section provides _____ of the data and discusses the meaning of the _____.

- The use of good **references** throughout the paper gives the work _____ by demonstrating an awareness of previous _____.

  Missing words: results, research, thought processes, interpretation, reasoning, relevant data, credibility, solving the problem, experiments.

Video: https://www.youtube.com/watch?v=B9z8cJXox3Q

What does the video show?

Bumblebees can also **pull strings** and **move a small ball** for a reward (these are further examples of **associative learning**):

How does each video demonstrate associative learning?

- Video (**string pulling**): https://www.youtube.com/watch?v=gSCr5OxXN1A

- Video (ball moving): https://www.youtube.com/watch?v=exsrX6qsKkA

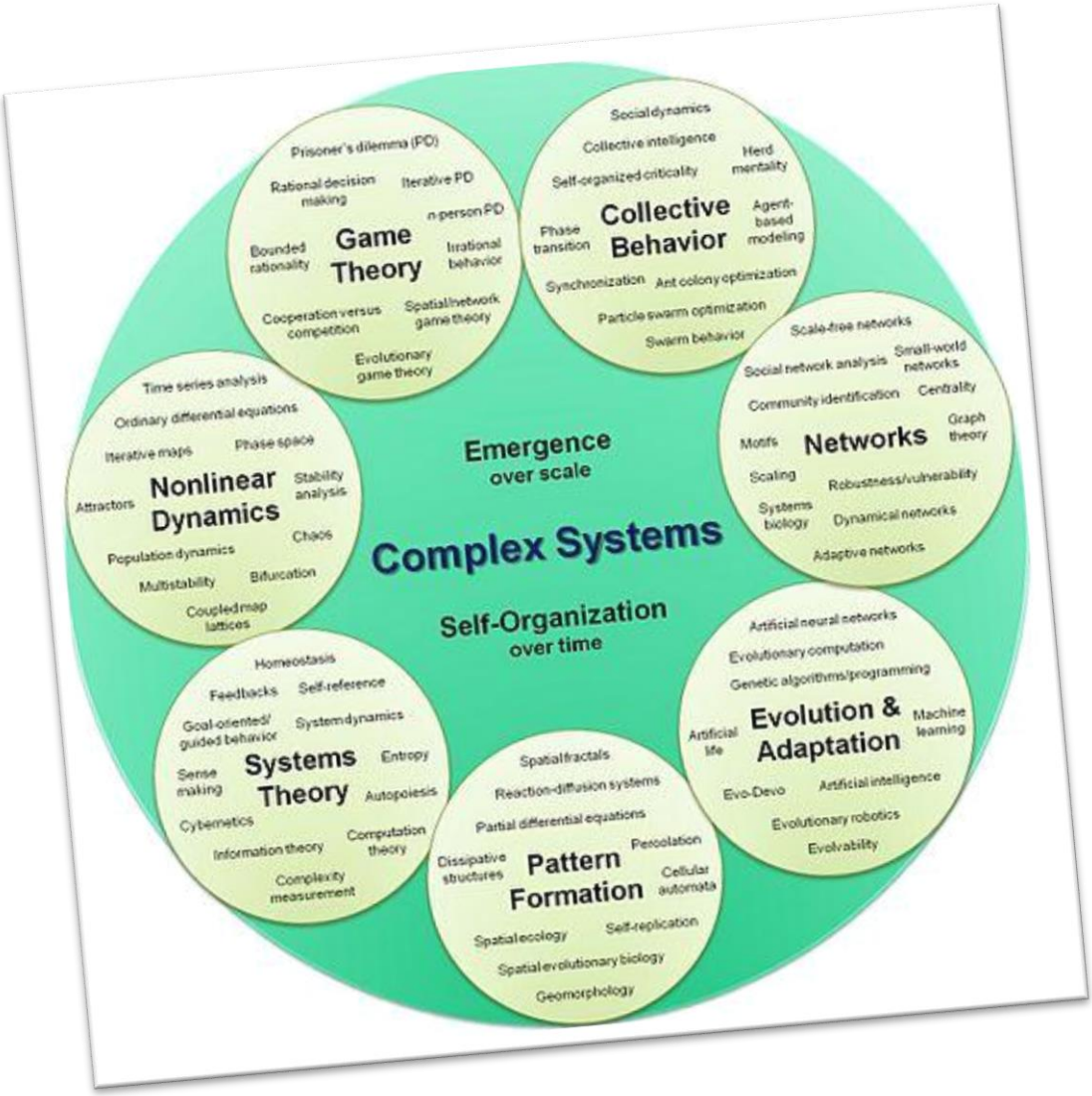
Homework 2

Use your research skills to answer the question below in your own words (remember to include references where appropriate):

What is a complex system?

(200 words)

Tutorial 3 – Complex Systems



What is the Purpose of Tutorial 3?

- To discuss what a complex system is
- Some examples of complex systems
- To think of other possible complex systems

"I think the 21st century will be the century of complexity. We have already discovered the basic laws that govern matter and understand all the normal situations. We don't know how the laws fit together, and what happens under extreme conditions. But I expect we will find a complete unified theory sometime this century. There is no limit to the complexity that we can build using those basic laws."

(Steven Hawking, Physicist)

Complex systems are made up of individual parts that interact, and produce emergent properties.

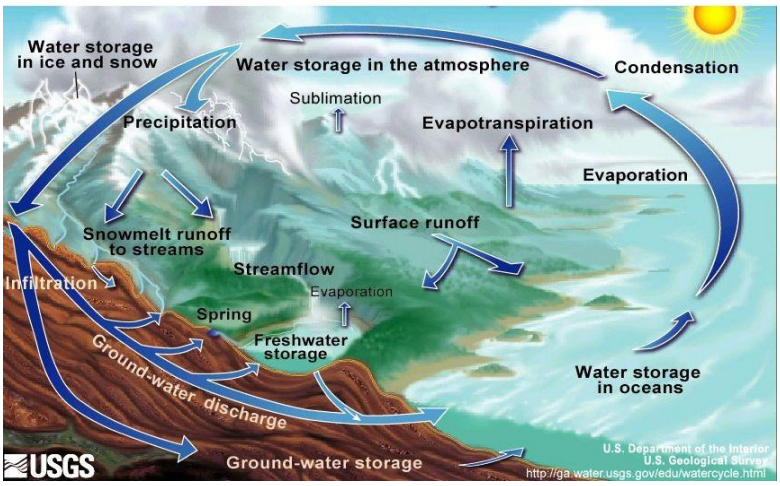
Complex does NOT mean complicated.

Video: https://www.ted.com/talks/eric_berlow_how_complexity_leads_to_simplicity

Notes:

Activity: Below are some examples of complex systems.

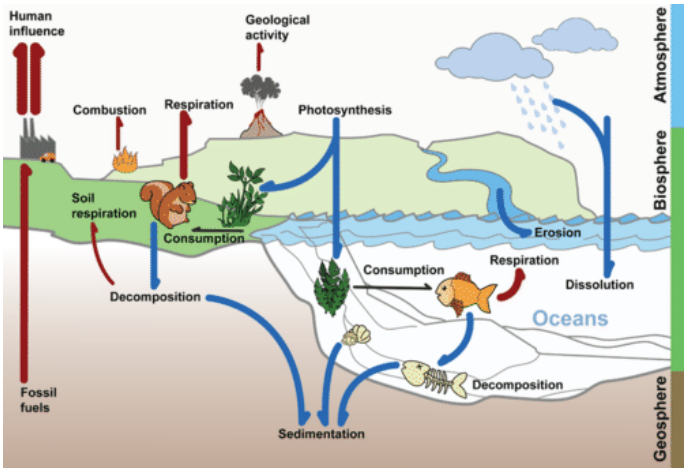
- What are they? *(first one is labelled)*
- Why might they be complex system?
- What do you think are the **individual parts**, **interactions**, and **emergent properties**?



Complex system: The water cycle

Reasons why:

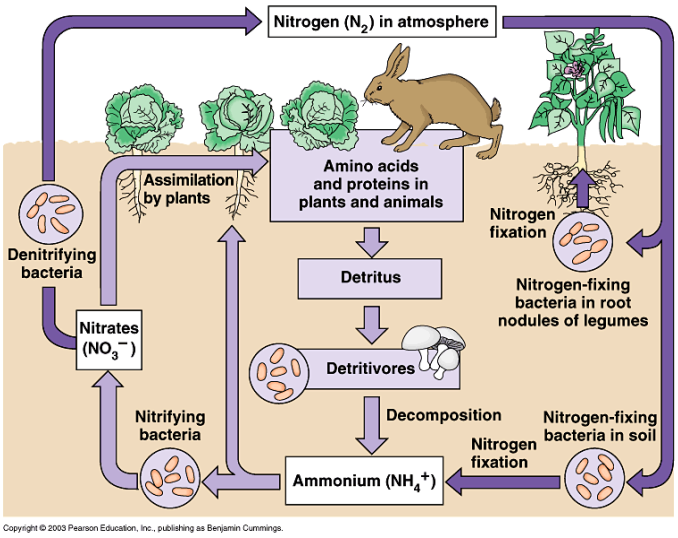
- individual parts:
- interactions:
- emergent properties:



Complex system:

Reasons why:

- individual parts:
- interactions:
- emergent properties:



Complex system:

Reasons why:

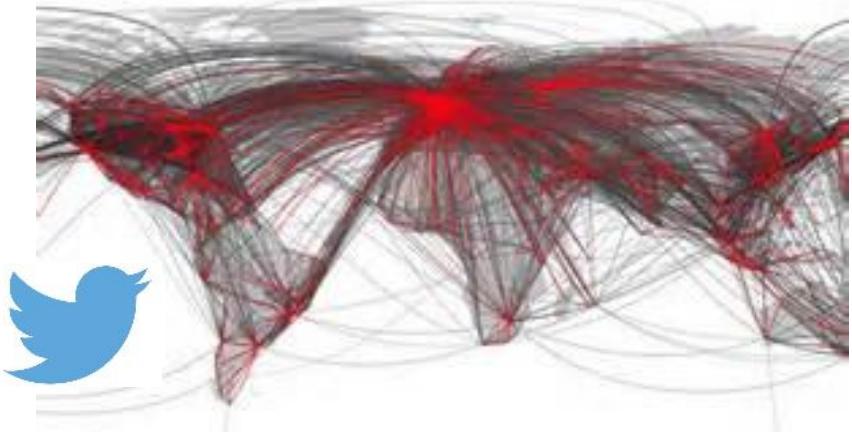
- individual parts:
- interactions:
- emergent properties:

Complex system:

Reasons why:

- individual parts:
- interactions:
- emergent properties:

Video: https://www.ted.com/talks/nicholas_christakis_the_hidden_influence_of_social_networks



Complex system:

Reasons why:

- individual parts:
- interactions:
- emergent properties:

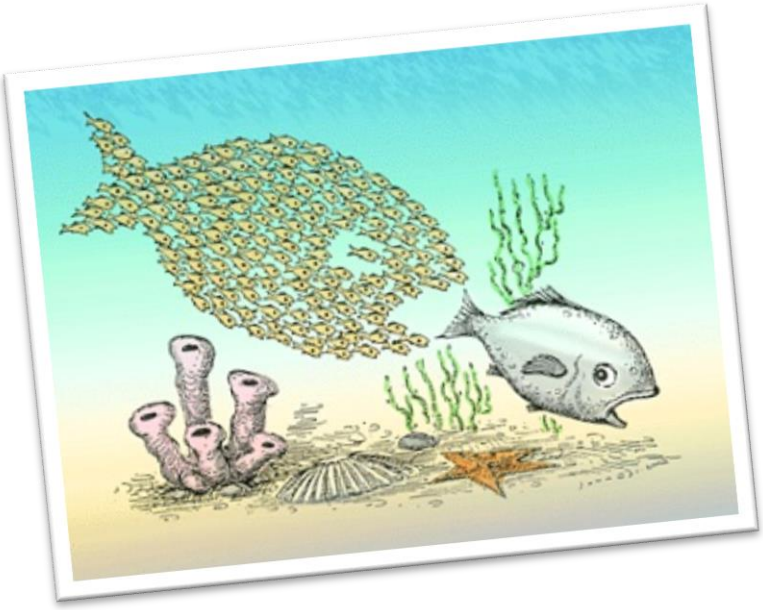
Homework 3

Think of **a complex system** not yet discussed. Describe the complex system and discuss what are its:

- Individual parts?
- Interactions?
- Emergent properties?

(remember to include references where appropriate) (200 words)

Tutorial 4 – Complexity in Nature



What is the Purpose of Tutorial 4?

- We will cover some examples of complex systems in nature
- Gain a deeper understanding of what a complex system is
- Discuss how to prepare for your oral presentation

"Why is geometry often described as 'cold' and 'dry'? One reason lies in its inability to describe the shape of a cloud, a mountain, a coastline, or a tree. Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line... Nature exhibits not simply a higher degree but an altogether different level of complexity"

"Bottomless wonders spring from simple rules, which are repeated without end"

(Benoit Madelbrot, mathematician)

Activity: Below are some examples of **complex systems in nature**

- What are they? *(first one is labelled)*
- Why might they be complex system?
- What do you think are the **individual parts**, **interactions**, and **emergent properties?**

Video: https://www.youtube.com/watch?v=LU_KD1enR3Q

Complex system: Honeybees (the waggle-dance)

Reasons why:

- individual parts:
- interactions:
- emergent properties:

Video: https://www.youtube.com/watch?v=V-mCuFYfJdI

Complex system:

Reasons why:

- individual parts:
- interactions:
- emergent properties:

Video: https://www.youtube.com/watch?v=Wp3Gau-Aljs

Complex system:

Reasons why:

- individual parts:
- interactions:
- emergent properties:

Video: https://www.youtube.com/watch?v=KasJjuuaCiM

Complex system:

Reasons why:

- individual parts:
- interactions:
- emergent properties:

Video: https://www.youtube.com/watch?v=K8HEDqoTPgk

Complex system:

Reasons why:

- individual parts:
- interactions:
- emergent properties:

Video: https://www.youtube.com/watch?v=N462jZFr13k

Complex system:

Reasons why:

- individual parts:
- interactions:
- emergent properties:

Homework 4

Prepare a **5-8 minute oral presentation** on a **complex system in nature** from the following (different one for each student):

- Ants
- Honeybees
- Bird flocks (e.g. starlings)
- Fish shoals
- Slime moulds
- Sponges

Tips for your presentation:

- **Practise** your presentation and try to stick to the **time limit** (5-8 minutes)
- Don't have too many **slides** (roughly one or two slides per minute)
- Start by **introducing** your topic
- Finish by **summarising** your presentation
- Think of **questions** that you might want to ask someone about their presentation
- Look **online** for further tips

Tutorial 5 – Oral Presentations

What is the Purpose of Tutorial 5?

- Practice at giving oral presentations
- Practice at providing peers with feedback
- Preparation for final assignment

Activity: Each of you will give your **5-8 minute oral presentation** with time for questions afterwards. You will provide **feedback** for your peers (each other) using the form provided.

We will then discuss the final assignment

Homework 5

Final assignment:

- (**40%**) Explain why the following can be considered a complex system (including what the individual parts, the interactions, and the emergent properties might be):
    - A flock of starlings
    - A colony of ants
    - The human brain
    - A slime mould

(150-200 words for each)

- (**60%**) Produce an **A2 poster** (landscape or portrait) on the oral presentation you gave in tutorial 5.

  we will discuss how the poster should look and I will bring in an example, but you should also look online for guidance on how to produce a scientific poster (e.g. http://guides.nyu.edu/posters).

Tutorial 6 – Feedback Tutorial

What is the Purpose of Tutorial 6?

- 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.

Appendix 2 – Using the VLE

VLE username	
VLE password	

Please remember the following key details…

- You are able log into the VLE either through the link on our website (www.thebrilliantclub.org) or going directly to the VLE site at (https://portal.thebrilliantclub.org/sign-in).
- Please update your profile with your full name and email address- this will allow you to retrieve forgotten passwords or usernames
- If you forget your log-in details you can request them to be emailed to you by clicking the link on the VLE home page. (If you are still having problems you can email: schools@thebrilliantclub.org)

What is the VLE?

The VLE is a virtual learning environment for all pupils on Uni Pathways it is used for:

- messaging your tutor
- submitting homework
- submitting your final assignment
- accessing resources for your tutorials
- finding out more information about university and careers

How should I use the VLE?

The VLE is a professional academic environment in which pupils are able to message their PhD Tutor. Here are a few things to consider:

- Ensure you keep a professional tone in the messages you send to your tutors.
- Ensure you always reply to your tutors in a timely manner.
- Thank your tutor for the effort they are putting in to give you your feedback etc.
- Submit all homework to your tutor on time.

IMPORTANT: Final assignment

- When you submit your final assignment, please remember that you need to do so through the 'My Activities' tab and not as an attachment to a message.

Notes

Notes

Notes

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Animal behaviour & Complex Systems

Key Stage 4 Programme

researchersinschools.org