How to make a glow-in-the-dark pet

Key Stage 4 Programme

Pupil Name

Handbook Designed by Dr Stutchbury

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1	12/12/18	13:00-16:00	University of Manchester
2	8/01/19	15:00-16:00	Science
3	15/01/19	15:00-16:00	Science
4	22/01/19	15:00-16:00	Science
5	29/01/19	15:00-16:00	Science
6 (Feedback)	12/02/19	15:00-16:00	Science
7 (Feedback)	19/03/19	15:00-16:00	Science

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Baseline assessment	8/01/19
Tutorial 2	What is Green Fluorescent Protein (GFP) and how was it discovered?	15/01/19
Tutorial 3	Applications of genetic engineering	22/01/19
Tutorial 4	Pros and cons of genetic engineering	29/01/19
Tutorial 5	Final assignment (Draft and presentations due on first date, final essay due on second date)	12/02/19 and 01/03/19

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on **Friday 1st March**	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	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

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	Dr Stutchbury		
Title of Assignment			
Name of Pupil			
Name of School	Essa Academy		
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

Enter feedback here

Critical Evaluation/Problem Solving

Enter feedback here

Structure and Presentation

Enter feedback here

Resilience Comment

Enter feedback here

Contents

Course Rationale *6*
Mark Scheme *7*
Final Assignment Success Criteria *9*
Subject Vocabulary *10*
Knowledge Organiser *11*
Tutorial 1 — What are we made of? *12*
Activity 1 — Blame the parents! 13
Activity 2 — What is a gene? 13
Activity 3 — Finding genes that fit 14
Activity 4 — Choosing your favourite genes 15
Tutorial glossary 15
Notes 16
Homework – Baseline Assessment 17
Tutorial 2 – Glow-in-the-dark animals *20*
Activity 1 – Watts the point? 21
Activity 2 – Bioluminescence and fluorescence 22
Activity 3 – Light painting 24
Tutorial glossary 24
Notes 25
Homework 26
Tutorial 3 – How to make a glow-in-the-dark pet *28*
Activity 1 – Paws for thought 29
Activity 2 – It's not too hard, don't be purr-plexed 30
Activity 3 – Making insulin inside bacteria 32
Tutorial glossary 33
Notes 33
Homework 34
Tutorial 4 – Turning the lights on in the lab *36*
Activity 1 – Understanding the code of life 37
Activity 2 – Using light to reveal the answers 38
Tutorial glossary 39
Notes 40
Homework 41
Tutorial 5 – How far is too far? *43*
Activity 1 – Applications of genetic engineering 44
Activity 2 – How far is too far? 44
Activity 3 – How to write and reference a scientific essay 45

Tutorial glossary 46
Notes 46
Homework – Final assignment 47
Tutorial 6 – Feedback tutorial ***48***
Peer feedback – Presentations 48
Self-reflection 49
Tutorial 7 – Feedback tutorial ***50***
Reflecting on Uni Pathways 51
Appendix 1 – Referencing correctly ***52***
Appendix 2 – An Introduction to GFP ***54***
Appendix 3 – Examples of genetic engineering ***56***
Appendix 4 – Pros and cons of genetic engineering in plants ***58***
Appendix 5 – Pros and cons of genetic engineering in humans ***59***

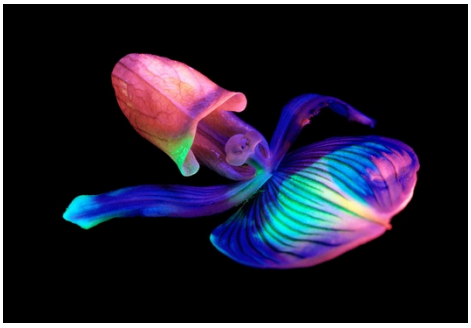
Course Rationale

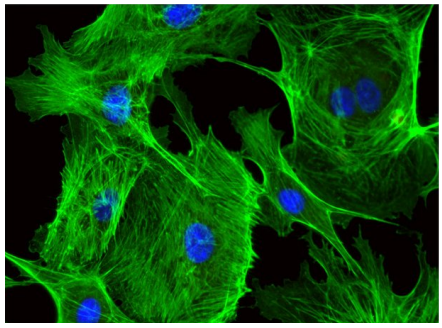
Over the past 100 years, our understanding of life on this planet has increased at a mind-boggling rate. At the heart of these discoveries is a single molecule. DNA.

DNA is known as the 'molecule of life'. It contains all of your genes - the instructions that make you, you. Your genes make your hair straight or curly. They make your eyes blue or brown. They help to determine your likes and dislikes. So, I guess if you support Man City, it's not *completely* your fault. Your genes deserve some of the blame.

The study of DNA and how it controls these characteristics is called genetics. As our understanding of genetics has increased over the years, we are now able to insert genes from one organism into another, a process known as genetic engineering. In this course you will learn how this is useful for humans and, yes, I will teach you how you could make a pet that glows in the dark!

We will also look at the ethical implications that surround this topic. Should we be able to do this? At what point should we stop? Have we already gone too far?





The course will be taught in the style of university tutorials and the final assignment will be similar to the work you would be set at university. You will learn how to prepare a scientific presentation and deliver this to the group at a mini conference, as well as how to write and reference a scientific essay, based on what you have learnt in the course.

The overall aims of the course are:

- To understand what genetic engineering is and how it can benefit humans
- To evaluate the arguments for and against genetic engineering
- Develop transferable skills of critical analysis, presenting, scientific writing and debate
- Experience university-style teaching to give you an idea of what it would be like to progress into further education

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

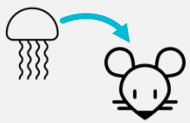
Final Assignment Success Criteria

The Brilliant Club Mark Scheme Skills	Examples of success criteria to include in the final assessment guidance
Knowledge and understanding	Include the key words from the glossary and demonstrate that you understand them by explaining what they mean and how they relate to the topic. Explain the sources that you have drawn on and how they relate to your work. Remember to reference sources correctly.
Research and Evidence	Include research findings from a wide range of sources. You should be discovering some sources yourself from the independent work that you do outside of tutorials.
Developing an argument	Give reasons and evidence to back up the points that you make. You might find the PEE structure helpful: • Point – make the key point clearly • Evidence – explain the evidence for the point • Explanation – explain why your point is relevant and important Make links to other topic areas that you have not discussed in tutorials.
Critical evaluation	Explain whether the evidence that you are discussing is valuable and significant and explain your reasoning. Select relevant research evidence to back up your thinking Comment on how reliable sources are and if they have any limitations.
Structure and presentation	Organise your ideas in paragraphs with a logical structure Include an introduction that clearly outlines what the assignment will contain. Include a conclusion that summarises all the key points clearly. Make sure that you have referenced everything correctly.
Language and style	Make sure that your spelling, grammar and punctuation are accurate. Use a formal writing style that is appropriate for an academic essay.

Subject Vocabulary

Word	Definition	In your own words
DNA	The molecule that genes are made from. Found in the nucleus and contains all the instructions for the cell to function.	
Nucleus	The 'brain' or 'control centre' of the cell.	
Gene	A piece of DNA that carries the instructions, or code, to make a certain protein.	
Protein	A molecule that carries out most of the processes for a cell to function. Different proteins determine different characteristics e.g. eye colour.	
Bioluminescence	Light produced by an organism. Happens due to a chemical reaction.	
Fluorescence	Light reflected by a molecule so it appears as a bright colour. Light must be shone on the molecule for this to happen.	
Green Fluorescent Protein (GFP)	A protein found in jellyfish that is naturally fluorescent. Appears bright green when light is shone on it.	
Cell	The smallest unit of life. The building blocks of all living things.	
Genetic engineering	The process of taking a gene from one organism and inserting it into another.	
Vector	A 'vehicle' used to take pieces of DNA and insert it into other cells.	
Plasmid	A small, circular piece of DNA that is often used as a vector in genetic engineering.	
Restriction enzyme	An enzyme used in genetic engineering that cuts a gene out of a piece of DNA.	

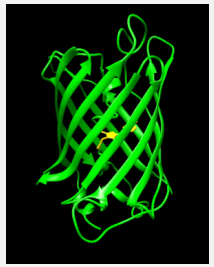
Knowledge Organiser

Key ideas	
	Some animals can produce light. They do this in two ways – bioluminescence and fluorescence.
	Bioluminescence is caused by a chemical reaction. It converts chemical energy into light energy.
	Fluorescence is caused by molecules that reflect light. It requires light to occur.
	Bioluminescence and fluorescence are characteristics controlled by genes, which are made from DNA.
	Genes carry instructions to make different proteins, which control almost every characteristic of an organism. The study of genes is called genetics.
	Genes for from one organism can be inserted into another to give it new characteristics. This is called genetic engineering.
	There are many ethical implications surrounding genetic engineering. It can be extremely beneficial to humans but many people think it's unnatural and shouldn't be allowed.

Green Fluorescent Protein (GFP)

GFP is a fluorescent protein that was discovered in jellyfish in the 1960s. When U.V. light (e.g. from the sun) shines on it, it reflects it and can be seen with a bright green colour.

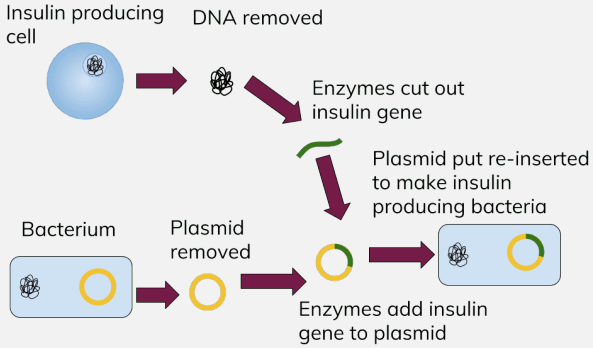
Scientists discovered the gene that makes GFP and used genetic engineering to make other molecules in a cell bright green, so they can be seen with a microscope. It has also been inserted into animals to make them green!



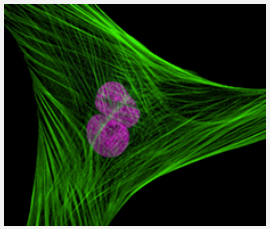
Genetic engineering

The process where a gene for a certain characteristic is removed from one organism and inserted into another.

A vector, such as a plasmid, is required to deliver the gene into the new organism, just like a postman.



Applications of genetic



Molecular research

Crop production

Medicine production

Fluorescent pets!

Tutorial 1 – What are we made of?

What is the purpose of Tutorial 1?

This tutorial will get you thinking about who you are and how you came to be that way.

What colour are your eyes? Are you tall? Do you have a short temper?

We will begin to understand where these characteristics come from and how they are passed on. We will then start to think about different animals and the characteristics that help them survive.

By the end of this tutorial, you should be able to:

- Describe characteristics that can be passed from parents to offspring
- Give a definition for a gene
- Explain why beneficial genes are more likely to be passed on

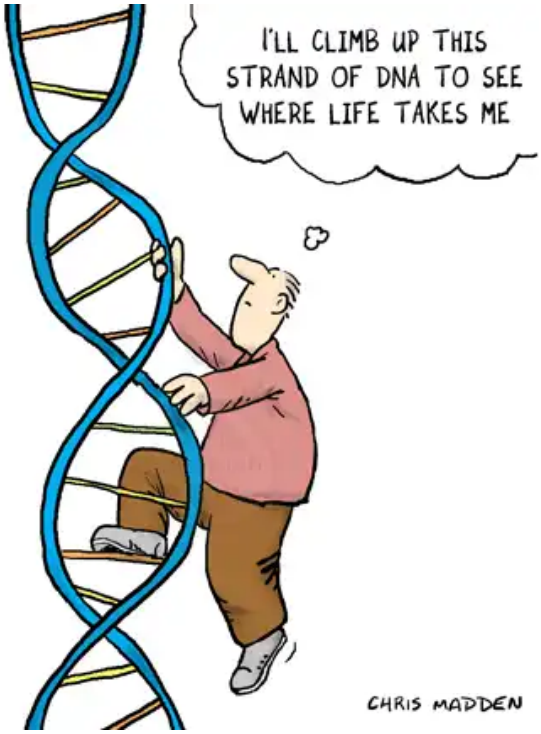
Activity 1 – Blame the parents!

In the space below, write down any ways that people can be similar to their parents

Activity 2 – What is a gene?

Follow the instructions for the activity. Afterwards, write the definition of a gene below:

A gene is



Activity 3 – Finding genes that fit

In pairs, answer your question and write your ideas in the box

PAIR 1
What characteristics will be beneficial for a predator?

PAIR 2
What characteristics will be beneficial for a prey?

PAIR 3
What characteristics will be beneficial for attracting a mate?

PREDATOR	PREY	ATTRACTING A MATE

Activity 4 – Choosing your favourite genes

Discuss in pairs:

Why are beneficial genes more likely to be passed on to the offspring?

Be prepared to share your answer

Tutorial glossary

Use this space to write down any words you have learned today

Word	Definition	In a sentence

Notes

Homework – Baseline Assessment

Think of a trait from an animal that you think would make a good superhuman. Write 300 words to answer the following questions:

- **What advantage does this trait give to the animal and how could this benefit a human?**

- **Do you think it's ethically acceptable to change a human's DNA to give them these characteristics?**

I'm interested to hear your ideas and opinions about these questions, just remember to PEE!

- **P**oint – make the key point clearly
- **E**vidence – explain the evidence for the point
- **E**xplanation – explain why your point is relevant and important

Organise your writing into paragraphs:

- Include an introduction stating the trait you have chosen
- **Explain** why this would make a good superhuman
- **Justify** whether you think this is acceptable
- **Summarise** your key points in a conclusion

Tutorial 2 – Glow-in-the-dark animals

What is the purpose of Tutorial 2?

This tutorial will focus on two characteristics that are beneficial to several animals – bioluminescence and fluorescence. They actually glow in the dark!

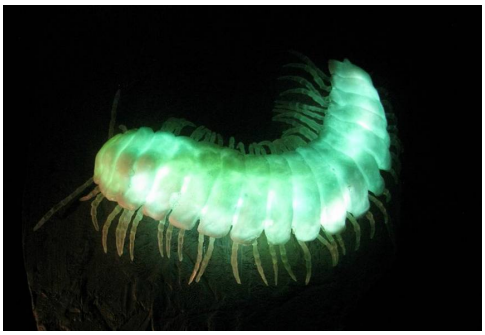
We will cover what these terms mean, what benefits they give to the animal and then have a go at 'painting' with light.

By the end of this tutorial, you should be able to:

- Give definitions for bioluminescence and fluorescence
- Explain how each characteristic is controlled
- Describe the advantages that these characteristics can give to the animal

Activity 1 – Watts the point?

Discuss the following questions in pairs and write your ideas in the boxes below



Why might bioluminescence be beneficial?

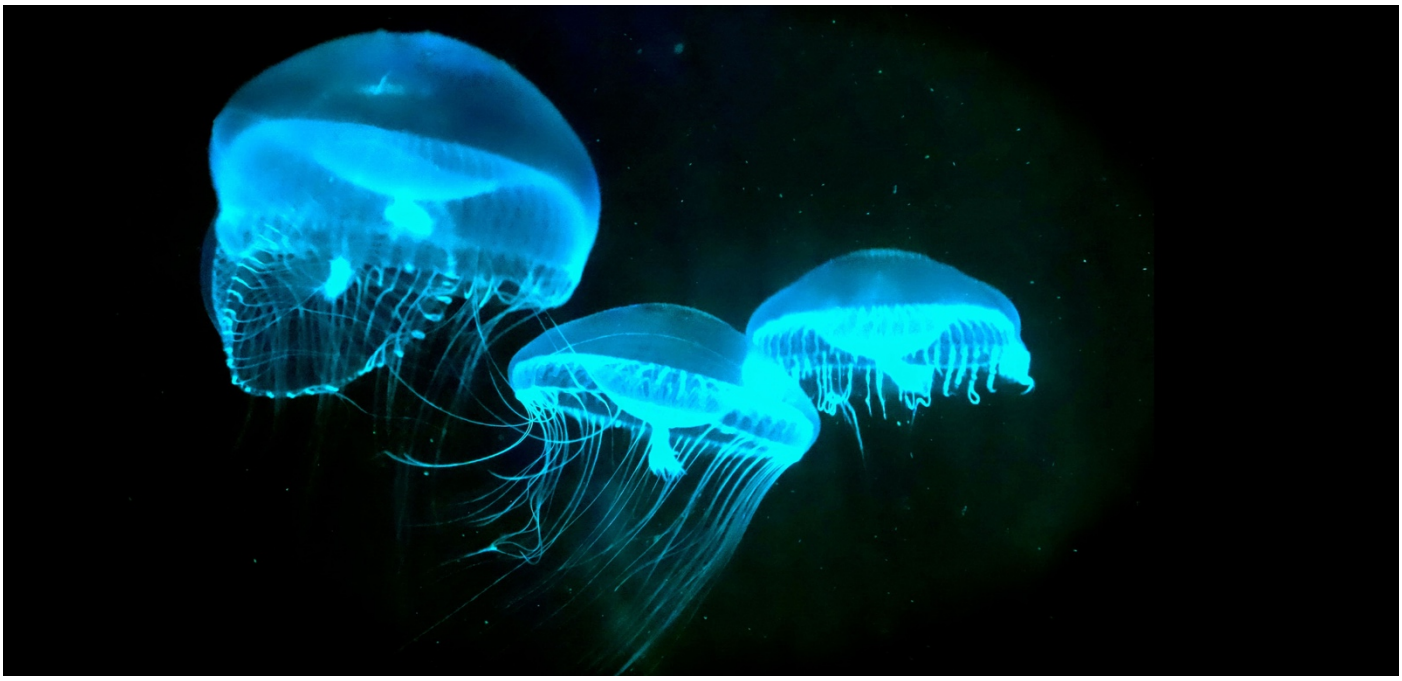
What makes an animal bioluminescent?

Activity 2 – Bioluminescence and fluorescence

Watch the videos and use the space below to take notes

In your own words, describe bioluminescence

In your own words, describe fluorescence



In pairs, discuss the following question and write down your ideas:

How might an animal use bioluminescence and fluorescence together to glow even brighter?

Activity 3 – Light painting

'Paint' a picture using light and a camera. Stick your picture in the space below

Tutorial glossary

Use this space to write down any words you have learned today

Word	Definition	In a sentence

Notes

Homework

Read Appendix 2. Write 200-300 words to answer the following question:

What is Green Fluorescent Protein (GFP) and how was it discovered?

Key points to include:

- What is GFP?
- Who discovered GFP?
- What did they do to discover it?
- Why is it important?

Tutorial 3 – How to make a glow-in-the-dark pet

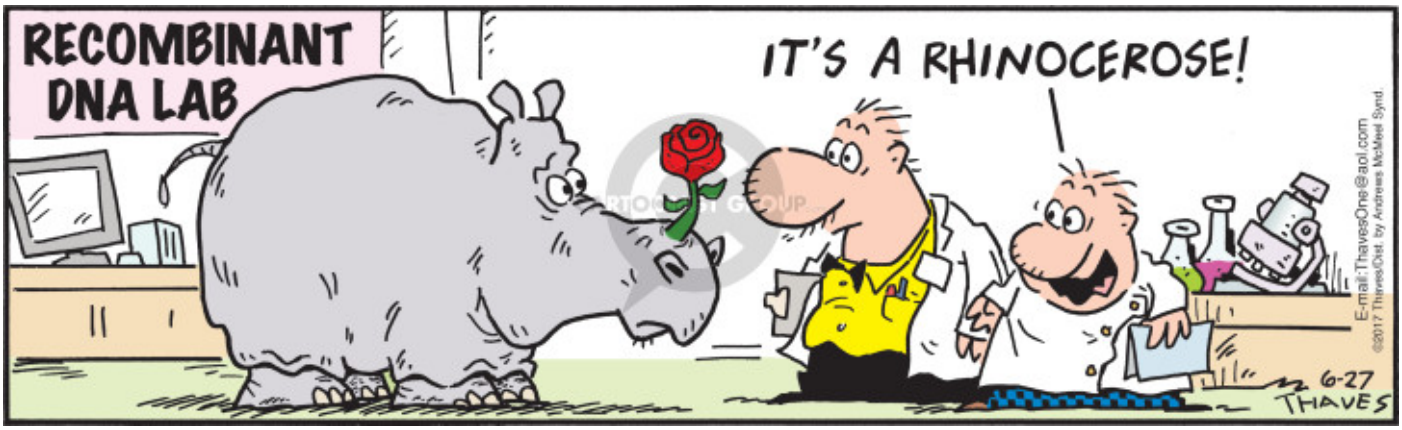
What is the purpose of Tutorial 3?

This tutorial covers the process of genetic engineering. We will look at what is meant be this term and how it can be used to insert desirable characteristics from one organism into another.

By the end of this tutorial, you should be able to:

- Define the term genetic engineering
- Describe the process of genetic engineering
- Explain a way that genetic engineering can be used to benefit humans

Activity 1 – Paws for thought



Based on everything we have covered, how would you make a fluorescent pet?
Write your ideas in the box below

After the discussion, briefly describe genetic engineering

Activity 2 – It's not too hard, don't be purr-plexed

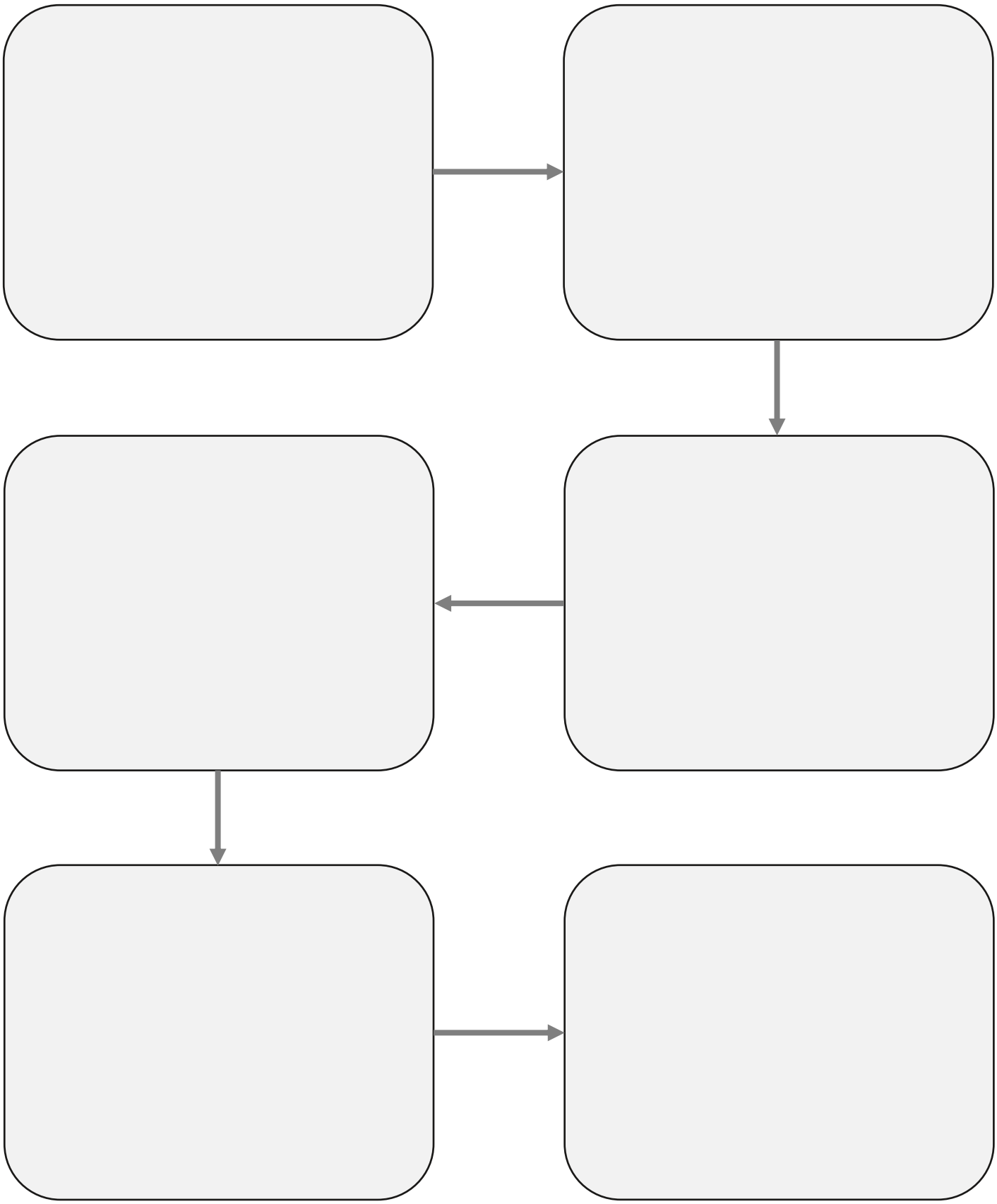
Using the materials provided, create a set of instructions for how to carry out genetic engineering. Use the space below to note down your ideas. Try to use the keywords in your ideas.

Key words

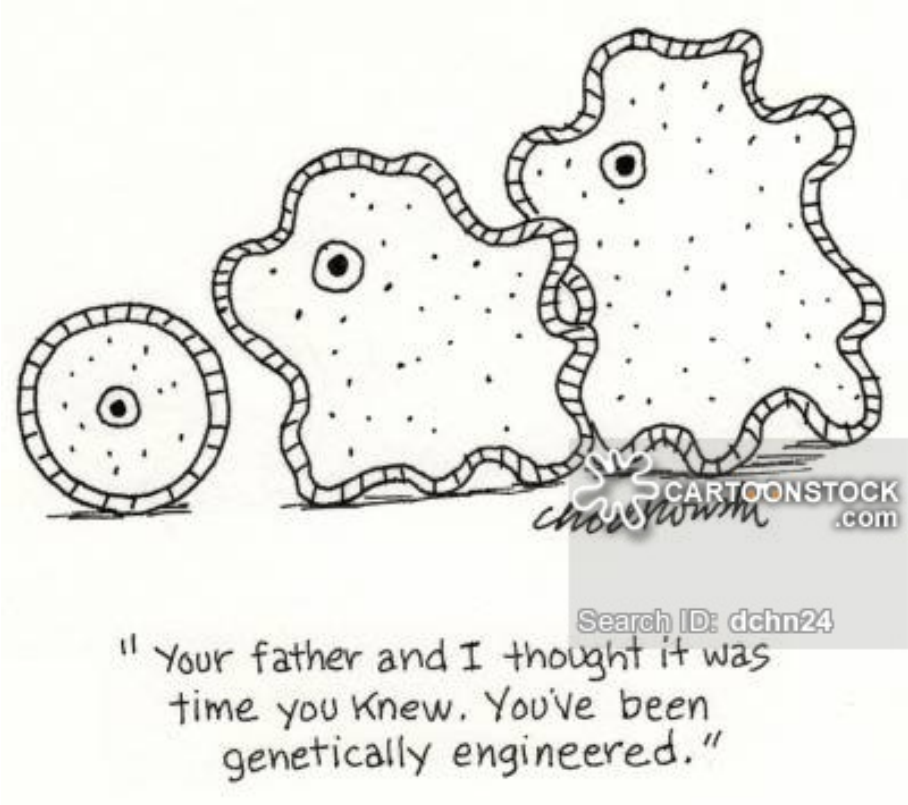
Gene – A small section of DNA that codes for a specific characteristic
Chromosome – A long piece of DNA that contains thousands of genes
Plasmid – A circular piece of DNA that can be inserted into a bacterial cell
Restriction enzyme – An enzyme that cuts DNA at a specific place
DNA ligase – An enzyme that sticks 2 ends of DNA together
Vector – Something that carries a gene from one organism to another

The genetic engineering process

Fill in the flowchart with text and diagrams to explain each step



Activity 3 – Making insulin inside bacteria



Describe how you would genetically engineer bacteria to produce human insulin. Use the words 'gene', 'enzyme' and 'vector' in your answer.

Tutorial glossary

Use this space to write down any words you have learned today

Word	Definition	In a sentence

Notes

Homework

Appendix 3 gives five examples of genetic engineering. Use the information to answer the following questions, you should write 200-300 words in total.

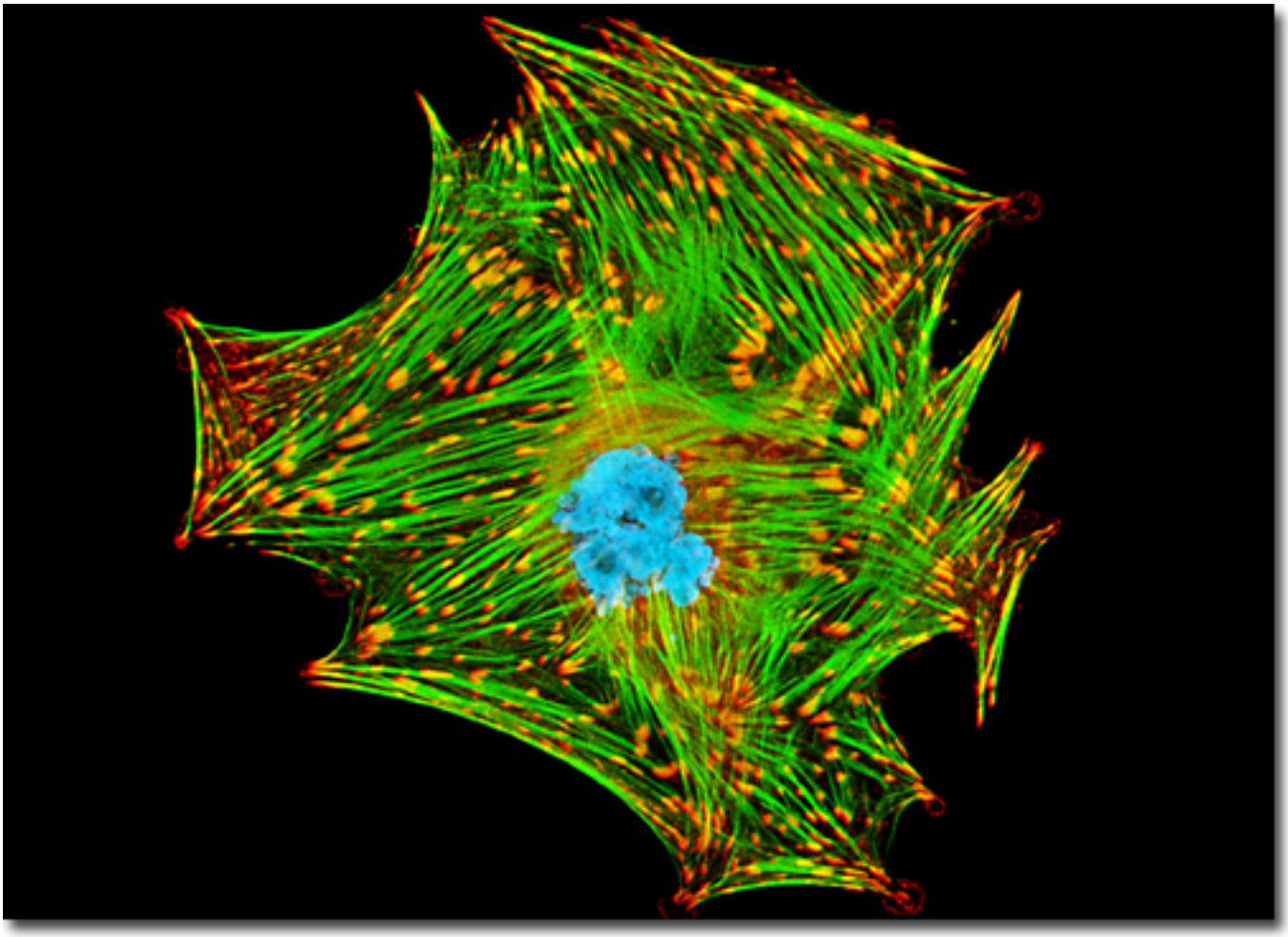
Which application of genetic engineering do you think has the potential to provide the most benefit to humans? Why?

Do you think that all of the applications covered are all ethically acceptable? Explain your answer.

Key points to include:

- Introduce your chosen application of genetic engineering
- What are the key benefits it can offer to humans? (remember to PEE!)
- Is it ethically acceptable?
- Do you think any of the applications covered not ethically acceptable? Explain your answer

Tutorial 4 – Turning the lights on in the lab



What is the purpose of Tutorial 4?

This tutorial links the last two together, explaining how fluorescent proteins are used in a lab to study cells. We will look how scientists use genetic engineering and fluorescence to understand cellular processes at the molecular level – that's about as small as they get!

By the end of this tutorial, you should be able to:

- Understand that genes code for proteins
- Describe how genetic engineering is used to fluorescently label proteins
- Explain how this technique can help scientists work out the function of different proteins in the cell

Activity 1 – Understanding the code of life

Describe the relationship between genes and proteins

Activity 2 – Using light to reveal the answers

You have discovered a new protein and want to know what it does. You decide to use genetic engineering to 'stick' Green Fluorescent Protein (GFP) to the protein and see where it goes in the cell.

You have a plasmid that contains the gene you are interested in.

In pairs, describe how you would use genetic engineering to 'stick' GFP to the protein you are interested in and see it in a cell.

Use this space to write down your ideas.

Based on the image you have taken, where in the cell is your protein?

Given its location, what do you think your protein might do?

Tutorial glossary

Use this space to write down any words you have learned today

Word	Definition	In a sentence

Notes

Homework

Many people believe that genetic engineering is extremely beneficial for humanity. Others argue that scientists are 'playing God' and that we have already gone too far.

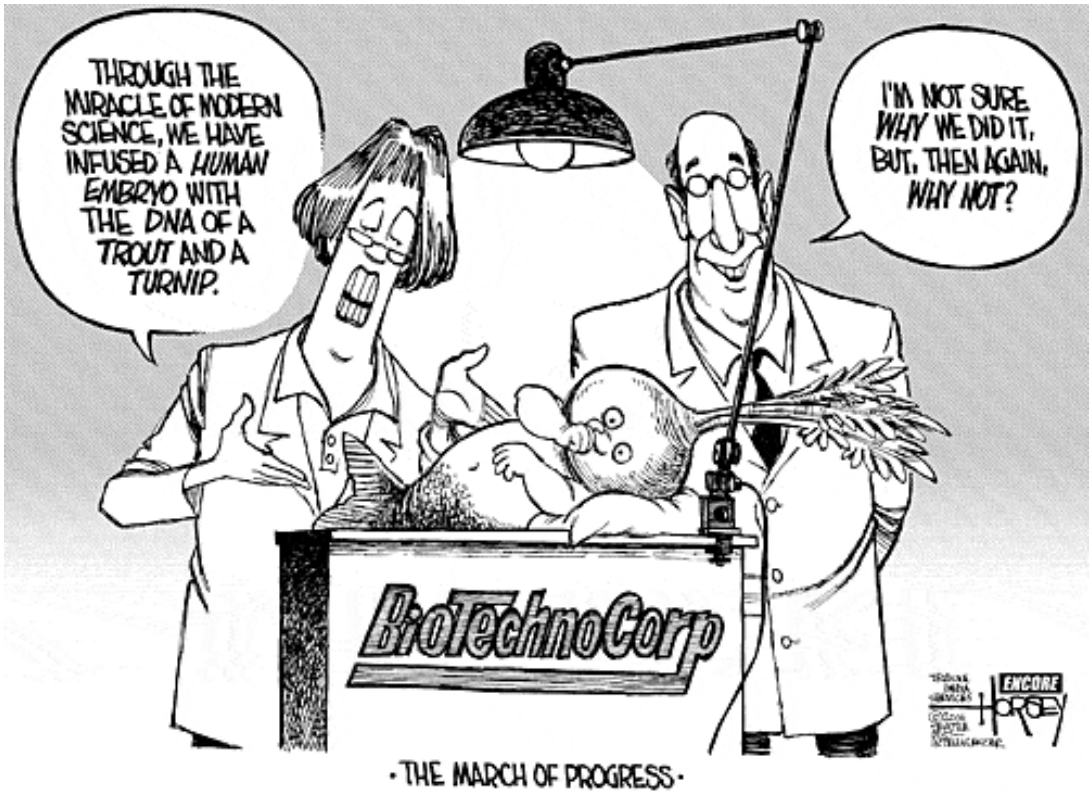
To prepare for next week's debate, research the key arguments that support your position on genetic engineering (for or against). Summarise the key points that you would like to raise in the debate.

Appendix 4 and Appendix 5 contain some useful information, but I also encourage you to do your own independent research.

Key points to include:

- State a point that is for or against genetic engineering
- Include a piece of evidence that supports the argument
- Justify why the evidence allows you to say that genetic engineering is a good/bad thing

Tutorial 5 – How far is too far?



What is the purpose of Tutorial 5?

Throughout this tutorial series we have looked at the process of genetic engineering and how it can be used to benefit research. However, this is a very controversial topic and it's important to see both sides of the argument.

Is it OK to change an organism's DNA? Does it give scientists too much power? Have we already gone too far?

By the end of this tutorial, you should be able to:

- Describe several applications of genetic engineering
- Explain the concerns surrounding genetic engineering
- Evaluate the arguments for and against its use

Activity 1 – Applications of genetic engineering

After the discussion, write down three applications of genetic engineering

Activity 2 – How far is too far?

After the discussion, summarise the key arguments for and against genetic engineering

FOR	AGAINST

Activity 3 – How to write and reference a scientific essay

Read the examples and highlight the things that make them good and bad.
Write a set of instructions about how to write a scientific essay.

Tutorial glossary

Use this space to write down any words you have learned today

Word	Definition	In a sentence

Notes

Homework – Final assignment

Write 2-3 pages (approx. 1000 words) to answer the question:

Should scientists be able to use genetic engineering or has it gone too far?

Support your argument with examples.

The assignment will be broken down into two parts:

<u>Part 1 (30% of final grade – due 12th February in Tutorial 6)</u>

Prepare a 5-minute presentation to summarise how you plan to write the essay. You will deliver this to the group in Tutorial 6.

Your presentations should:

- **Describe the way you have answered the question**
- **Talk about the key sources you used from your research**
- **Explain why you have chosen your answer to the question**

Extra things to think about:

- **Engage the audience – maybe ask them a question to get them thinking**
- **Follow a logical structure – it should have a beginning, middle and end**
- **Show off with your knowledge of the subject!**
    - Be the teacher!
    - Use key words
    - Show evidence of independent research
    - What's the most interesting thing you have read?

<u>Part 2 (70% of final grade – due Friday 1st March)</u>

Your final 2-3 page essay.

Your scientific essay should cover:

- What is genetic engineering?
- How does it work?
- Examples of how it can benefit humans
- Concerns about the technology and why people think it has gone too far
- Your answer to the question, based on the evidence you have presented
- Use the paragraph starters from Tutorial 5 to help you with the structure

Page 9 of this booklet has more information about how to write your essay.

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To present the first draft of your essay
- To receive feedback on your presentation
- To receive feedback on the structure and content of my essay

Peer feedback – Presentations

My partner is: _____

One thing I liked is…

One thing to improve is…

One idea I would like to steal is…

Self-reflection

One thing I have done well is...

One thing I can do to improve is...

Based on my current plan, my essay will

- Follow a logical structure with a clear introduction and conclusion ☐
- Present arguments for and against genetic engineering ☐
- Answer the question ☐
- Reference my sources of information ☐

Based on my feedback, I will improve my essay by:

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.

Appendix 2 – An Introduction to GFP

Adapted from original article by Timothy King and Paul May

An introduction to GFP

GFP stands for green fluorescent protein and is, imaginatively, a protein that fluoresces green in the presence of UV light. It has found its use in all areas of cellular biology and advances have reached the point where it is the focus of works of art, such as a pet rabbit called Alba, whose fur glowed green under UV light. In November 2008, three men, Osamu Shimomura, Martin Chalfie and Roger Tsien, were awarded the Nobel Prize in chemistry, "for the discovery and development of green fluorescent protein". So, what makes this such a versatile and important molecule?

A history of GFP

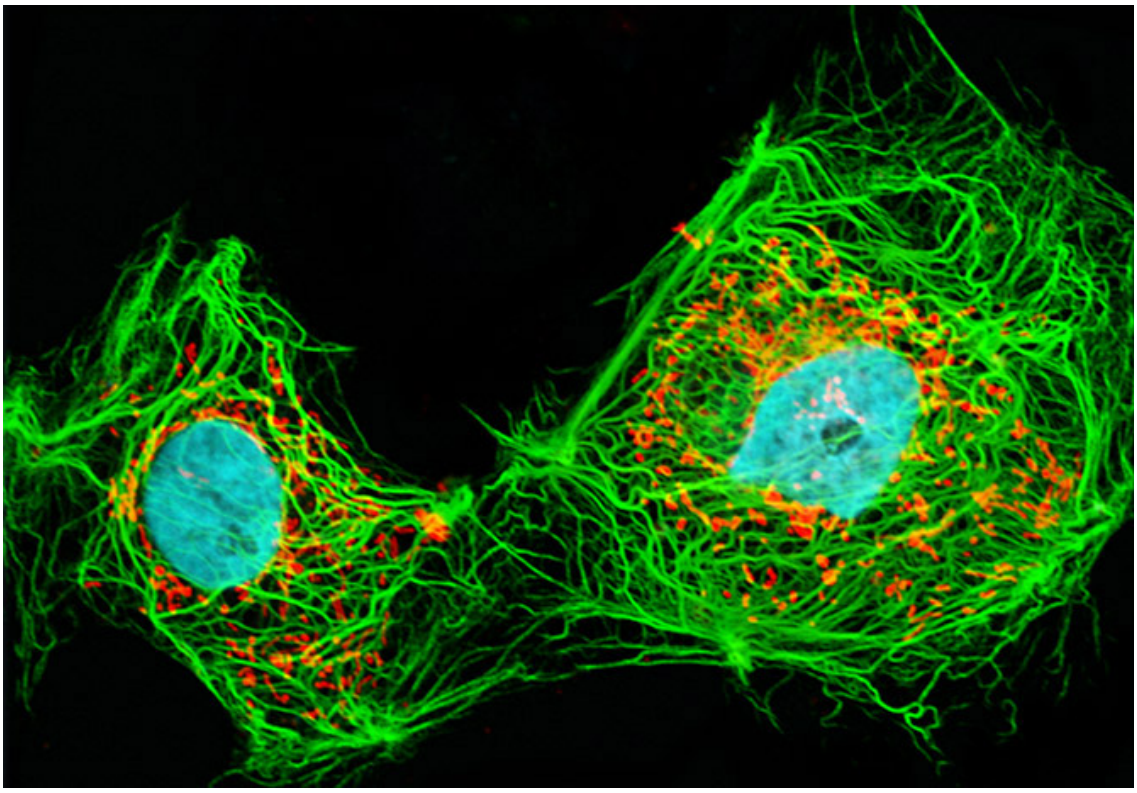
Osamu Shimomura is the starting point for GFP. As a young boy, he was only miles from the atomic bomb that landed on Nagasaki, close enough to be temporarily blinded by the explosion. In 1960, Osamu Shimomura moved from Japan to work at Princeton University and here he worked in a research group studying the jellyfish Aequorea victoria. The project he was working on involved bioluminescence, the edges of the skirt, or umbrella, of this species of jellyfish emitting a green light. So, along with two colleagues from the university he went to the Pacific Ocean. The three scientists collected specimens of the jellyfish, from which they removed a 5 mm-thick ring from around the skirt, responsible for the glow observed. Somewhat gruesomely, these rings were crushed to remove the liquid parts and forced through cheese-cloth to separate the material they wanted from the solid that made up the jellyfish.

The crushed rings, or "squeezate" as it was referred to in the original paper, was purified to produce just over 5 mg of glowing substance, though this proved not be the green light observed, but possessed a blue glow instead, originating from a protein named Aequorin. In the purification process another, discarded, protein was found that did possess this green fluorescence, but was practically ignored as it only emitted the distinctive green light when irradiated with blue or UV light. In 1962 the results of the work were published, with only a minor mention of the fluorescing green protein. Realising the potential of the green fluorescing protein, Shimomura shifted his focus, and over the next 17 years continued to work on the jellyfish.

In 1992, the gene for GFP was eventually coded by Douglas Prasher, genes and DNA, in general, being the blueprints from which proteins are synthesised. This was a significant breakthrough and led to a race to be the first research team to successfully express the gene in and organisms. The first person to manage this was Martin Chalfie and in 1994 published the results of this work. Chalfie succeeded in inserting the gene for GFP into the bacteria *E. coli*, which then fluoresce with a green light in the presence of UV radiation. Since then, GFP has been used for thousands of different applications, and improvements have been made to the properties of the protein by mutations in the gene, creating brighter variants, as well as multiple different colours. As well as this, GFP and GFP variants have been found in dozens of different marine species, from sea anemones to sea pansies, which produce their own light, to corals that possess no bioluminescence, but have the ability to fluoresce. And the natural varieties do not just stop at green, with almost all imaginable colours having been found.

Why is GFP important?

So why is this important? Well this means that organisms, other than those in which GFP naturally occurs, can be genetically engineered to have a gene that produces GFP and it will still work without multiple other genes being implanted. When Chalfie first made glowing green E. coli, it opened wide the possibilities for looking inside a living cell for the first time.



Appendix 3 – Examples of genetic engineering

Enviropig

The Enviropig, or "Frankenswine," as critics call it, is a pig that's been genetically altered to better digest and process phosphorus. Pig manure is high in phytate, a form of phosphorus, so when farmers use the manure as fertilizer, the chemical enters the watershed and causes algae blooms that deplete oxygen in the water and kill marine life.

So scientists added an E. Coli bacteria and mouse DNA to a pig embryo. This modification decreases a pig's phosphorous output by as much as 70 percent – making the pig more environmentally friendly.

Pollution-fighting plants

Scientists at the University of Washington are engineering poplar trees that can clean up contamination sites by absorbing groundwater pollutants through their roots. The plants then break the pollutants down into harmless by-products that are incorporated into their roots, stems and leaves or released into the air.

In laboratory tests, the transgenic plants are able to remove as much as 91 percent of trichloroethylene – the most common groundwater contaminant at U.S. Superfund sites – out of a liquid solution. Regular poplar plants removed just 3 percent of the contaminant.

Venomous cabbage

Scientists have taken the gene that programs poison in scorpion tails and looked for ways to combine it with cabbage. Why would they want to create venomous cabbage? To limit pesticide use while still preventing caterpillars from damaging cabbage crops. These genetically modified cabbages would produce scorpion poison that kills caterpillars when they bite leaves – but the toxin is modified so it isn't harmful to humans.

Web-spinning goats

Strong, flexible spider silk is one of the most valuable materials in nature, and it could be used to make an array of products – from artificial ligaments to parachute cords – if we could just produce it on a commercial scale. In 2000, Nexia Biotechnologies announced it had the answer: a goat that produced spiders' web protein in its milk.

Researchers inserted a spiders' dragline silk gene into the goats' DNA in such a way that the goats would make the silk protein only in their milk. This "silk milk" could then be used to manufacture a web-like material called Biosteel.

Banana vaccines

People may soon be getting vaccinated for diseases like hepatitis B and cholera by simply taking a bite of banana. Researchers have successfully engineered bananas, potatoes, lettuce, carrots and tobacco to produce vaccines, but they say bananas are the ideal production and delivery vehicle.

When an altered form of a virus is injected into a banana sapling, the virus' genetic material quickly becomes a permanent part of the plant's cells. As the plant grows, its cells produce the virus proteins – but not the infectious part of the virus. When people eat a bite of a genetically engineered banana, which is full of virus proteins, their immune systems build up antibodies to fight the disease – just like a traditional vaccine.

Appendix 4 – Pros and cons of genetic engineering in plants

There are many benefits to using genetic engineering. It is used in agriculture to do things such as, improve the yields of important economic crops, and provide insect or pest resistance. It is also used in the medical field to create insulin, which can be used for treating diabetes. But, as with most new technology, it also carries potential risks.

Benefits of genetic engineering

- Genetic modification is a faster and more efficient way of getting the same results as selective breeding.
- Improve crop yields or crop quality, which is important in developing countries. This may help reduce hunger around the world.
- Introduce herbicide resistance, which results in less herbicides being used, as weeds are quickly and selectively killed.
- Insect and pest resistance can be developed and inserted into the plants. The plant produces toxins, which would discourage insects from eating the crop.
- Sterile insects could be created such as a mosquito. They would breed, which would lead to infertile offspring. This may help with spread of diseases, such as malaria, dengue fever and the Zika virus.

Risks of genetic engineering

- Transfer of the selected gene into other species. What benefits one plant may harm another.
- Some people believe it is not ethical to interfere with nature in this way. Also, GM crop seeds are often more expensive and so people in developing countries cannot afford them.
- GM crops could be harmful, for example toxins from the crops have been detected in some people's blood.
- GM crops could cause allergic reactions in people.
- Pollen produced by the plants could be toxic and harm insects that transfer it between plants.

Appendix 5 – Pros and cons of genetic engineering in humans

There are really good reasons why we should – and shouldn't – genetically engineer human embryos

Original article by Tanya Lewis, Business Inside UK, 2015

A powerful tool that lets scientists modify DNA with extreme precision could be used to genetically engineer the human species.

Here are some of the main arguments that were made for and against human gene editing:

Why we should allow it

Gene editing could prevent deadly genetic diseases.

One of the most tantalizing reasons to edit human embryos is the potential to prevent devastating genetic diseases like cystic fibrosis or Huntington's disease. These are caused by mutations in a single gene, so if you could fix that gene, the baby would be born healthy.

In April, Chinese researchers announced they had modified human embryos in order to cure a fatal blood disorder known as beta thalassemia. The embryos were not viable, meaning they could not survive to birth, but it could be a preview of what's to come.

For many parents whose children suffer from genetic diseases, gene editing is a compelling prospect.

Sarah Gray of the American Association of Tissue Banks was one of those who spoke up at the meeting. Her son died of a fatal genetic disease six days after he was born, after suffering terrible seizures. As Sharon Begley reported in STAT, Gray told the attendees, "If you have the skills and the knowledge to eliminate these diseases, then frickin' do it!"

In addition to diseases with a relatively straightforward cause, gene editing could also be used, in principle, to modify genes that lower the risk of contracting or developing diseases like HIV/AIDS. However, it's not that easy – the same gene that makes people resistant to HIV also makes them more likely to die of West Nile virus.

Finally, beyond preventing diseases, the ability to edit embryos opens up an exciting new means for understanding our basic biology. For example, it could be used to study how a fertilized egg develops into a baby.

Why we shouldn't allow it

However, like any new medical therapy, gene editing poses safety and ethical concerns.

Although the Chinese experiment showed the technique could be used in human embryos, it also caused a number of unintended, "off-target" effects on some parts of the genome. These changes could lead to other genetic complications, some of which could be fatal.

"In my opinion, the data is not there to say it is safe or reliable," Joy Larsen Haidle, president of the National Society of Genetic Counselors, told Business Insider previously. Furthermore, "do we risk causing a different problem we didn't anticipate?"

The technology is improving, but scientists will need to do many more studies before it can be proven safe. After all, the broader field of gene therapy suffered some high-profile tragedies including the deaths of several patients.

Safety aside, many experts argue the use of gene editing to correct genetic defects is unnecessary. Doctors can already screen out many of these diseases before a pregnancy, thanks to *in vitro* fertilization and pre-implantation genetic screening.

New York Times columnist and science writer Carl Zimmer told Business Insider previously, "I haven't seen anybody give a legitimate medical reason [for using gene edfiting in human embryos] that couldn't be achieved through other means."

If we do allow gene editing, some worry that it could lead to the creation of "designer babies" whose DNA has been carefully selected to enhance their appearance, intelligence, or other traits that are not medically necessary.

These enhancements may also be unevenly distributed among the population, leading to a society of genetic haves and have-nots.

This also opens the door to another potentially scary idea of trying to "improve" the human race by controlling genetics and reproduction.

Given all of these concerns, many people advocate the "precautionary principle" — the idea that a new product or process which could have controversial or unknown effects should be avoided.

Given the pace at which this technology has been developing, we are likely to be having many more these discussions in the years to come.

Notes

Notes

Notes

UNI PATHWAYS

How to make a glow-in-the-dark pet

Key Stage 4 Programme

researchersinschools.org