# Bacterial Factories

## Key Stage 3 Programme

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|---|---|
| Pupil Name | |
| Handbook Designed by | Dr Newnham |

# Timetable and Assignment Submission

## Timetable – Tutorials

| Tutorial | Date | Time | Location |
|---|---|---|---|
| 1 | 12/12/18 | 1.00 - 4.00 | Kings College London |
| 2 | 10/01/19 | 3.15 – 4.15 | |
| 3 | 17/01/19 | 3.15 – 4.15 | |
| 4 | 24/01/19 | 3.15 – 4.15 | |
| 5 | 31/01/19 | 3.15 – 4.15 | |
| 6 (Feedback) | 14/02/19 | 3.15 – 4.15 | |
| 7 (Feedback) | 18-21/03/19 | | |

## Timetable – Homework Assignments

| Homework Assignment | Description | Due Date |
|---|---|---|
| Tutorial 1 | How do bacteria eat? | 07/01/19 |
| Tutorial 2 | Caging chemicals | 14/01/19 |
| Tutorial 3 | Modelling a molecule | 21/01/19 |
| Tutorial 4 | The story of genetic engineering | 28/01/19 |
| Tutorial 5 | Bacterial Factories: The application of BMCs in biotechnology | 01/03/19 |

## Assignment Submission – Lateness and Plagiarism

| Lateness | |
|---|---|
| Submission after midnight on 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 | | | |
| 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**

*Enter feedback here*

**Critical Evaluation/Problem Solving**

*Enter feedback here*

**Structure and Presentation**

*Enter feedback here*

**Resilience Comment**

*Enter feedback here*

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# Course Rationale

Bacteria are simple organisms that carry out many important functions, for example aiding in digestion and absorption of food molecules in our gut. Around 25% of bacteria produce protein cages that encapsulate enzymes essential for their metabolism. These protein cages are called Bacterial MicroCompartments, or BMCs, the most studied of these BMCs is the carboxysome (figure 1) that contains the enzyme RuBisCO (ribulose-1,5-bisphophate carboxylase/oxygenase). RuBisCO is vital for carbon fixation and photosynthetic processes that occur in some bacteria (specifically cyanobacteria). The carboxysome plays a role in improving the efficiency of the enzyme and therefore the pathway. There is also evidence that suggests that some BMCs are required to act as a barrier and protection mechanism in cells by encapsulating enzymes and their products that could be of harm to other cellular functions.

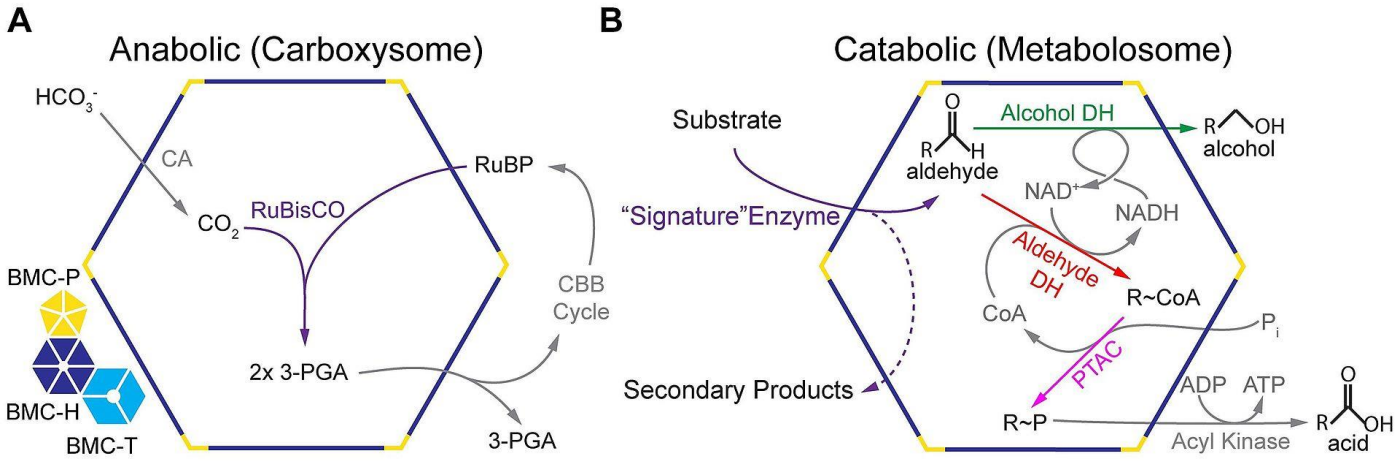


**Figure 1: A simplified diagram of the function for known BMCs.** (A) Carboxysome. (B) Metabolosome. Reactions in grey are surrounding reactions related to the BMC pathway. BMC shell protein are depicted on the left: blue, BMC-H; cyan, BMC-T; yellow, BMC-P. 3-PGA = 3-phosphoglycerate, and RuBP,= ribulose 1,5-bisphosphate.

Genetic engineering is an important tool in biotechnology. It allows us to adapt, alter and create proteins with new and improved functions. The technique is being applied to research and industrial processes from fuel production, disease prevention and drug development. It could lead to numerous important and useful scientific breakthroughs.

BMCs contain multiple different proteins, from structural components to functional enzymes in important metabolic pathways. In this project we will look at what, how and why we might genetically engineer individual or multiple proteins from a BMC. We will identify individual proteins or even whole pathways that are incorporated into BMC cages, look at the possible targets for genetic engineering and applications in biotechnology.

## Course Objectives

The overarching objectives of this project on bacterial microcompartments are:

- To understand BMC roles in the function of bacteria
- To have a good knowledge of BMC structure and composition
- Explain how BMCs (proteins) can be adapted for new/improved functions
- To identify the potential and uses of BMCs or their components in biotechnological applications

# 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<br>• Good understanding of all the relevant topics.<br>• Scientific terms are defined and used accurately throughout<br>• 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<br>• Good understanding of most the relevant topics<br>• Scientific terms are used accurately but not always clearly defined.<br>• 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<br>• Good understanding on some of the relevant topics but occasional confusion on others.<br>• Scientific terms are used mostly accurately with occasional confusion and often not defined.<br>• 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<br>• Evaluative points are consistently explicit/systematic/reasoned/justified<br>• Effective critiques on the reliability of sources provided<br>• Consistently demonstrate clear, analytical and logical steps to solving problems | • Mostly description but some assessment of the value or significance of what is described<br>• Evaluative points are mostly explicit/systematic/reasoned/justified<br>• Some evidence of critiques on the reliability of sources provided<br>• 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<br>• Evaluative points are at times explicit/systematic/reasoned/justified<br>• Limited evidence of critiques on the reliability of sources provided<br>• 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<br><br>• The introduction clearly outlines how the essay/report will deal with the issues<br><br>• The conclusion summarises all the main points clearly and concisely<br><br>• All calculations, formulas and methods are clearly structured, clear to follow and correct<br><br>• Tables and graphs are effectively constructed including appropriate headings, units and scales.<br><br>• 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<br><br>• The introduction adequately describes how the essay/report will deal with the issues<br><br>• The conclusion summarises most of the main points clearly<br><br>• Calculations, formulas and methods are mostly structured, clear to follow and correct<br><br>• Most tables and graphs are well constructed<br><br>• Most sources are referenced correctly in an agreed format | • Ideas are presented in paragraphs and arranged in a structure<br><br>• The introduction mentions how the essay/report will deal with the issues<br><br>• The conclusion summarises some of the main points clearly<br><br>• Calculations, formulas and methods are not always structured, clear to follow and correct.<br><br>• Some tables and graphs are well constructed but contains some errors<br><br>• Some sources are referenced correctly in the agreed format with occasional errors |

# Subject Vocabulary

| Word | Definition | In a sentence |
|---|---|---|
| Amino acid | Building block of a protein | |
| Anabolic | Build up molecules | |
| Bacteria (multiple) / Bacterium (singular) | Microscopic single-celled organisms with a simple internal structure | |
| Bacterial microcompartment | Protein cage that contains part of a metabolic pathway, e.g. carboxysome or metabolosome | |
| Biofuel | A fuel that comes from a biological process | |
| Bioinformatics | Using computational methods to study protein and genetics | |
| Biotechnology | Manipulation of a biological process for an industrial purpose | |
| Carbon fixation | The use of carbon in living organism, e.g. photosynthesis | |
| Carbon Source | The molecule that supplies an organism with carbon, for energy | |
| Catabolic | Breakdown molecules | |
| Channelling (of a pathway / substrate) | Restricting flow of substrates / products in a metabolic pathway, usually to improve efficiency | |
| Compartmentalisation / Encapsulation | Enclosing a molecule inside a cellular structure | |
| Cyanobacteria | A group of bacteria that carry out photosynthesis | |
| Enzyme | A protein that speeds up a specific chemical process | |
| Eukaryote | An organism with complex cellular structures | |

| | | |
|---|---|---|
| Gene | Small section of DNA that codes for a specific protein | |
| Genetic engineering | Adding/removing/altering genes | |
| Hexamer (protein) | A molecule (protein) made up of 6 structural subunits | |
| Metabolic Pathway | A sequence of chemical reactions occurring inside a living organism | |
| Metabolism | Chemical process required for life | |
| Metabolites | Chemicals produced and needed in metabolism | |
| Operon | Multiple related genes grouped together | |
| Pentamer | A molecule (protein) made up of 5 structural subunits | |
| Peptide | Small functional section of a protein | |
| Photosynthesis | The process that uses sunlight to produce glucose from carbon dioxide and water | |
| Polyhedral | Description of an 3D object that has multiple faces made up of polygons (>3 sides) | |
| Prokaryote | An organism with simple cellular structures | |
| Protein | A molecule with a structural and functional role in a cell | |
| Protein Domain | A part of a protein that can exist and function on its own | |
| Selectively Permeable | Allows certain molecules to pass through | |
| Shell protein | The proteins forming the sides of the bacterial microcompartment | |

| | | |
|---|---|---|
| Substrate | The substance that an enzyme acts upon | |
| Targeted/targeting | Refers to a protein with the ability to be directed to a specific place in cell | |
| Trimer | A molecule (protein) made up of 3 structural subunits | |
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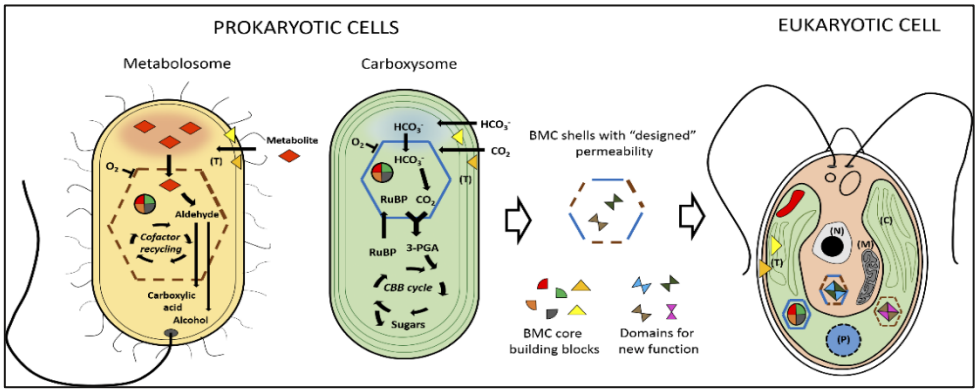
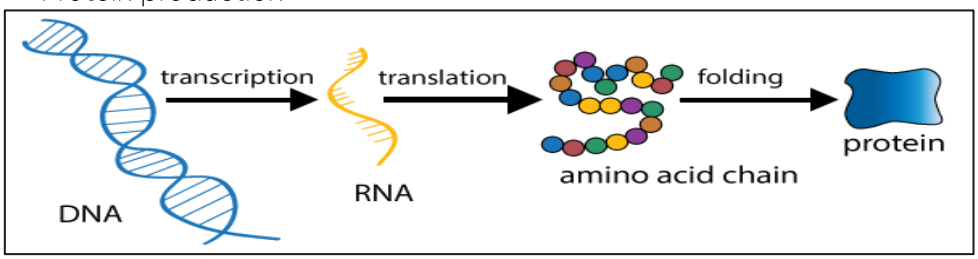
# Knowledge Organiser

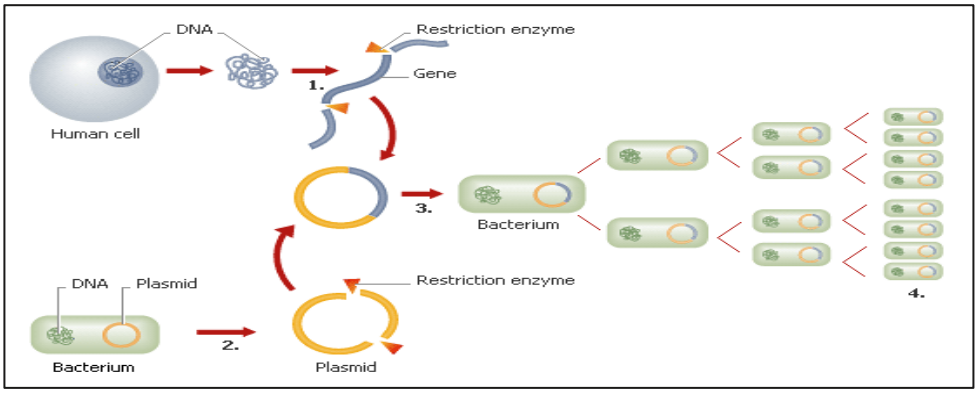
Bacterial microcompartments and their components




Protein production




Genetic engineering




Bacterial microcompartments (BMCs) – protein shells that encapsulate part of a metabolic process. It is formed of multiple proteins all encoded in a genetic operon. The components of most BMCs are:

**Shell proteins** – that form the cage around the functional enzymes - hexamers (BMC-H), trimers (BMC-T), pentamers (BMC-P)

**Targeted enzymes** – metabolic enzymes that contain a peptide that allows them to be compartmentalised/encapsulated.

**Other proteins** – further enzymes not enclosed in the BMC, transporters in the cell and co-enzymes required for metabolic function.

BMC Applications in Biotechnology

**Production** of fuels, drugs and other chemicals

**Improvement** of new and existing metabolic pathways – concentrating pathway enzymes, modification of enzymes adding other components (e.g. co-enzymes)

**Structural** function – shell proteins as scaffolds for cellular activity

| Keyword | Definition | In Use |
|---|---|---|
| Gene | Small section of DNA that codes for a particular protein | |
| Operon | Multiple related genes grouped together | |
| Protein | A molecule with a structural and functional role in a cell | |
| Amino acid | Building block of a protein | |
| Enzyme | A protein that speeds up a specific chemical process | |
| Metabolism | Chemical process required for life | |
| Genetic engineering | Adding/removing/altering genes | |
| Bacterial microcompartments | Protein cage that contains part of a metabolic pathway | |
| Compartmentalisation/encapsulation | Enclosing a molecule inside a cellular structure | |
| Targeted/targeting | Refers to a protein with the ability to be directed to a specific place in cell | |
| Peptide | Small functional section of a protein | |
| Bioinformatics | Using computational methods to study protein and genetics | |
| Biotechnology | Manipulation of a biological process for a purpose | |

# Tutorial 1 – Do Bacteria Need to Eat?

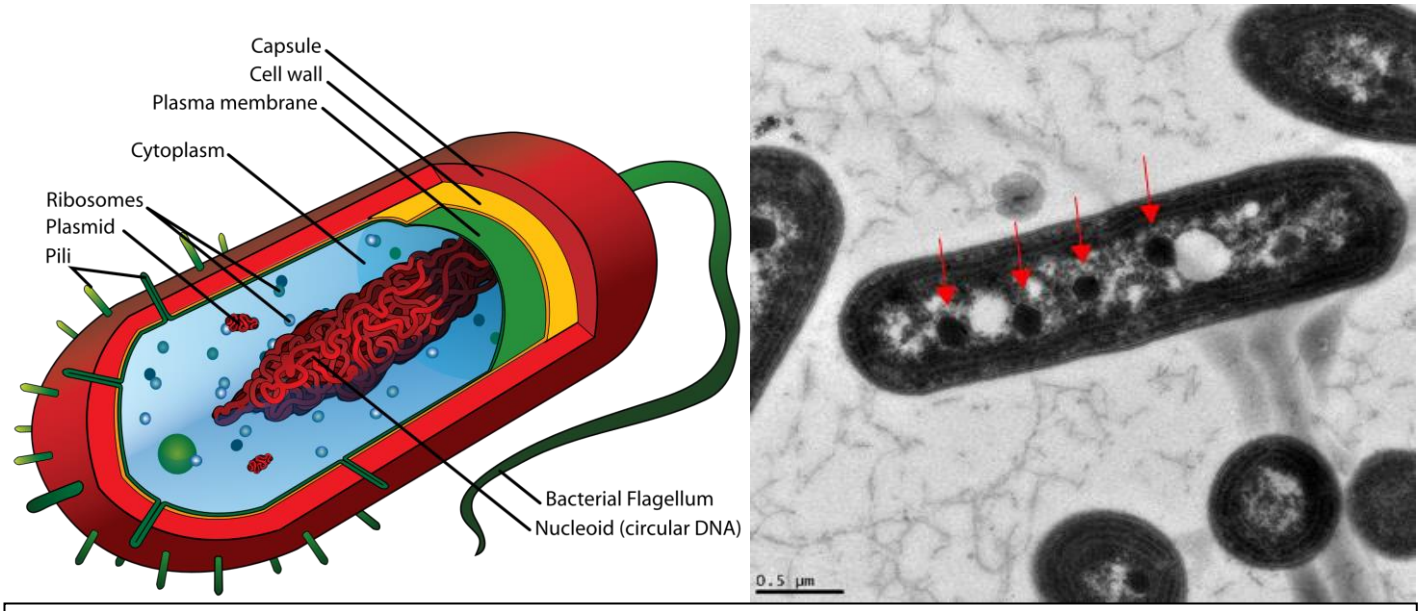



**Figure 2: Bacterial cell.** A) A labelled diagram of a prokaryotic cell and its structure. B) An electron microscope image of a cyanobacteria (*Synechococcus elongatus*) with arrows indicating the subcellular structures, the bacterial microcompartments.

## What is the Purpose of Tutorial 1?

Bacteria are prokaryotes, they have simple internal structures and exist as single celled organisms. They are involved in many different processes and live in diverse environments. Bacteria don't have mouths but do require nutrients (food), like us (eukaryotes). Metabolism is important in all cells, it breaks down nutrients into essential molecules and releases energy. In eukaryotes the cells are well organised with important metabolic processes contained in organelles, however, prokaryotes do not have organelles. Bacteria have developed methods for compartmentalising metabolic pathways, these are called bacterial microcompartments (BMCs)

- Objective 1 – Identify a bacterial cell with its structure and function
- Objective 2 – Describe the role of a bacterial microcompartment
- Objective 3 – Demonstrate knowledge of how bacteria produces energy

## Activity 1 - Roles of Bacteria

Bacteria are often referred to as germs which suggests they are bad, for example making us sick. However, bacteria are involved in many different processes, a lot of these are useful and some important to our health. Can you think of any jobs, both good and bad, that bacteria do?
Brainstorm as many different roles of bacteria - Extension: can you name any bacteria?

| Positive | Negative |
|---|---|
| | |

## Activity 2 – Features of Cells

Prokaryotes have simple internal structures in comparison to the eukaryotes (plant and animals). What are the differences?
Make sketches/notes to show the similarities and differences between bacteria, animal and plant cells.

## Activity 3 – Build a Bacterium

Bacteria have simple structures. Using your knowledge and figure 2, build a bacterial cell with the resources provided.
Add a picture of your design and label it with structures and functions

## Activity 4 – Can bacteria get fat?

Bacteria are living organisms, so like us their metabolism breaks down the nutrients they take in to provide energy. As we know bacteria carry out may different functions and live in diverse environments, this means they have adapted to survive and live on the nutrients available. To adapt they have developed different metabolic processes depending on the environment.
Make notes from our discussion - Note down any keywords/phases, try to include a quick definition in your own words (they may be useful in your assignment)

## Baseline Assignment – How do bacteria eat?

Bacteria like any living organism require essential molecules and energy from a food source. Using the work we have done today and your own research, explain bacterial metabolism. How do bacteria get nutrients and energy from a food source? What food sources do bacteria use? How do bacterial cells organise metabolism, e.g. bacterial microcompartments?

You need to write this in the style of an abstract - a summary of scientific research/literature. It should be no more than 300 words. Use your keywords and phrases from activities above.
Please submit your work as a word document, if possible (you might want to use the information later in the course) Include information on any references/sources you use (Appendix - links, articles, videos). Images can be included (not essential), you should refer to these in the text. Your work must have a title and your name. You will be marked on the quality of your written communication; spelling, punctuation, grammar and use of scientific terminology.

Use the space below for any notes.

# Tutorial 2 – Caging Chemicals

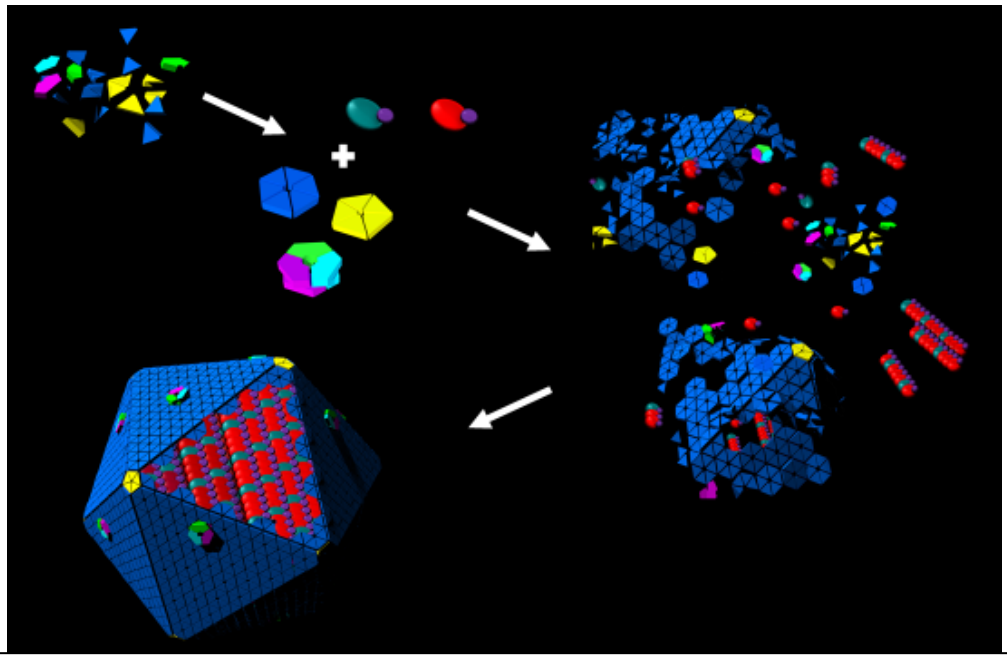


**Figure 3: A diagram representing bacterial microcompartment (BMC) formation.** Showing building blocks forming into a shell containing the machinery for a metabolic pathway.

## What is the Purpose of Tutorial 2?

Bacterial microcompartments (BMCs) are protein shells (cages) that compartmentalise enzymes (machinery) required for a specific metabolic function. In different bacteria different metabolic pathways are compartmentalised. The shells are similar in most BMCs; they are polyhedral structures comprised of multiple different proteins. The metabolic enzymes, that are contained inside BMCs, have specialised regions that target them to the BMC shell and enable its encapsulation.

- Objective 1 – Name the components of a BMC
- Objective 2 – Describe the function of the different parts of the BMC
- Objective 3 – Identify some of the functions of different BMCs

## Activity 1 – Importance of BMCs

BMCs encapsulate specific metabolic pathways. What benefits are there of containing the pathway enzymes and the metabolites (molecules being used or formed)?
Brainstorm the possible reasons for encapsulating a pathway inside a BMC.

## Activity 2 – Identify the parts

A BMC has many different parts. The shell requires multiple different building blocks(proteins) due to its polyhedral shape; hexamers, trimers and pentamers. The encapsulated proteins have specialised regions to allow for targeting the BMC.
List the components and include a description of its structure and function

| Component | Description |
|---|---|
| | |

## Activity 3 – Specific functions of BMCs

Bacteria live in different environments and therefore metabolise different molecules. BMCs differ in structure and enzymes depending on the molecules metabolised.
Read the extract and outline the role of the BMC, you can use diagrams (e.g. figure 1) or words.

## Homework – Application of BMCs

You have a section of text describing an application of a BMC or one of its proteins. The exert from a scientific article gives a lot of detail, go through the text and pick out the key points. Can you write a short paragraph (summary) to describe the key points to the group?
Read the text and summarise the information.

# Tutorial 3 – Translating the code

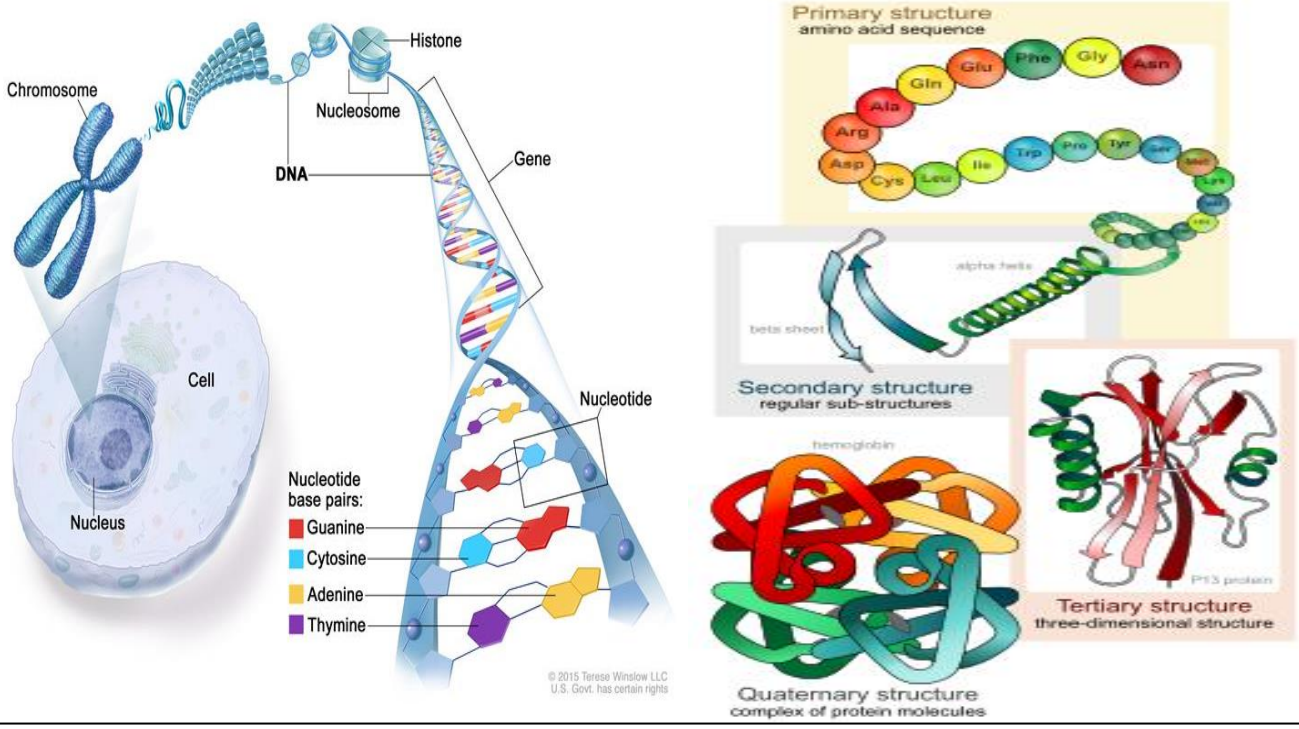



**Figure 4: Diagrams of DNA and protein.** A) DNA molecule – showing double helix structure, gene and organisation into a chromosome. B) Protein molecule – showing amino acid chain folding into overall structure.

## What is the Purpose of Tutorial 3?

Deoxyribonucleic acid (DNA) is a very important molecule that supplies the code (instructions) for every protein (machinery) made in a living organism. Proteins are molecules that are made by cells to carry out a range of functions from structural - the shell of the BMC, signalling – in and outside the cell, to metabolic-enzymes inside the BMC. The DNA code is a specific sequence of nucleotides (a gene) that can be read by the cell to tell it which amino acids to put together. The amino acid order tells the protein how to fold to carry out its function and where to go.

- Objective 1 – Describe the structure and function of DNA
- Objective 2 – Describe the structure and function of proteins
- Objective 3 – Explain how the DNA code can be translated into protein (DNA → protein)

## Activity 1 – DNA: the instruction manual

The sequence of the DNA nucleotides is essential to produce a fully functional protein. Genes that code for proteins that work together are often found next to each other, in an operon. What are the important features of DNA?

Write a description of DNA, include these keywords:

double helix, nucleotide base, backbone, gene, chromosome, genetic code, operon

## Activity 2 – Protein: the machinery

Proteins have specific folds that are essential to their function. What are the specific functions of the BMC proteins?
Describe the structure and function of a protein, using BMC examples

## Activity 3 – The process of building machinery

The DNA code (the letters) that indicate the correct amino acid (the words). The order of these amino acids make a sequence that join and fold into a function protein (the sentence).
Explain how the DNA code is translated into a functional protein, use a diagram.

## Homework – Modelling a molecule

Using your knowledge and any further research on DNA and protein structure and function, build a DNA and/or protein molecule.
Include as much detail as possible and be ready use your model to explain the structure and function.

# Tutorial 4 – The Technology in Biology

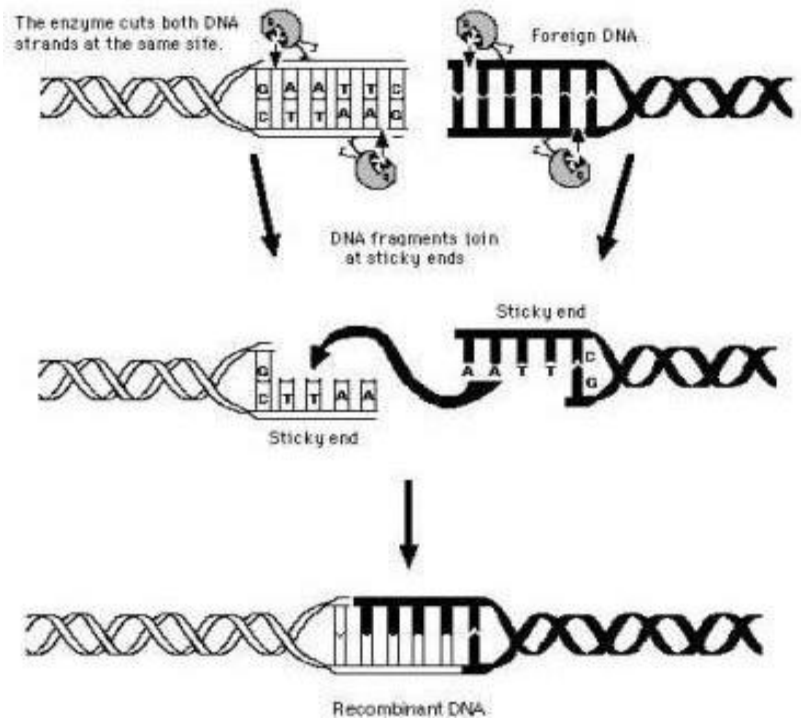



**Figure 5: Diagram of DNA being cut and pasted.** Showing a restriction enzyme cutting different DNA strands, producing ends that are compatible and pasting the two DNA strands together.

## What is the Purpose of Tutorial 4?

Genetic engineering is a key process in biotechnology. Genetic engineering uses new or improved genes and adds them into a cell of choice. This can create cells that produce different proteins, and ultimately functions.

- Objective 1 – Explain the process of genetically engineering bacteria
- Objective 2 – Outline the ethical opinions on genetic engineering
- Objective 3 – Identify the different uses of genetic engineering in BMCs

## Activity 1 – Process of genetic engineering

Genetically engineering bacteria is a multistep process, from selecting the DNA to the production of a protein.
Write step by step method explaining how to genetically engineer bacteria.

## Activity 2 – Ethics of genetic engineering

Genetic engineering brings with it a big ethical debate. Do you think it is right to alter a living organism, to make it do something unnatural?
Make note of possible outcomes, positive and negative.

| Positive | Negative |
| --- | --- |
| | |

## Activity 3 – Uses for genetic engineering

Biotechnology is the use of living organisms to make new or improved chemicals. With genetic engineering techniques we can make bacteria into mini factories, producing individual proteins and even whole metabolic pathways of choice.
Why would you want to genetically engineer a cell or individual protein?

## Homework – The story of genetic engineering

You have your step by step method of genetic modification and have discussed some modifications that could be useful.
Design a short scientific poster explaining the steps you would take to genetically modify bacteria. Use a modification of your choosing and explain the reasons for your modification. This can be done on the computer, so you can adapt it for your final assignment.

# Tutorial 5 – The Design Process

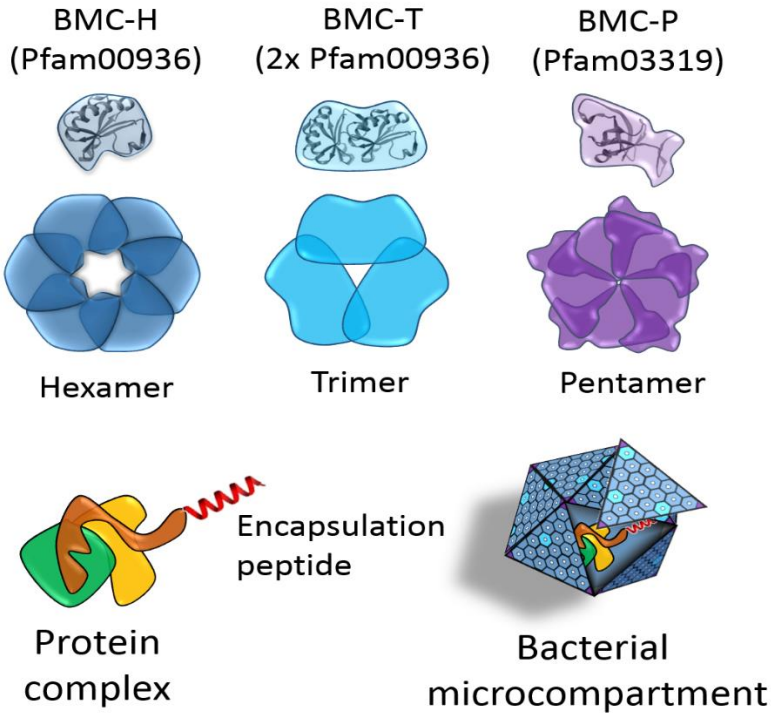



**Figure 6: The building blocks of the BMC.** The shell proteins and the encapsulated proteins, indicating the functional domains (parts). Representation of the interaction between the proteins that make up the BMC.

## What is the Purpose of Tutorial 5?

You have now looked at bacterial cells and their metabolism, the composition and function of BMCs and the use of genetic engineering to adapt bacteria into mini factories. Now we are going to apply this biotechnological approach to the BMCs in bacteria.

- Objective 1 – Outline the considerations of genetically engineering a BMC
- Objective 2 – Explain the stages in the design and engineering in bacteria

## Activity 1 – Targets for genetic engineering

The BMC has many building blocks that could be changed or improved. Which components would you need to take into consideration if you were going to genetically modify a BMC?
List the components of BMCs that could be genetically modified.

## Activity 2 – Biotech for BMCs

There are many potential biotechnological applications including a structural function, channelling metabolic pathways and producing new chemicals. Why would you want to genetically engineer whole BMCs or its individual proteins?
List the components you would like to modify in your design and explain what changes you would make.

## Activity 3 – The design brief

The BMC has multiple components, and you many require multiple proteins for the function of your design. To produce your new or improved function which components are essential and how will these be incorporated?
Outline the steps you would take to design your new or improved use for a BMC or its individual proteins. Include selection of genes, modifications you will make and incorporation of these into the bacteria.

## Final Assignment – Bacterial Factories: The application of BMCs in biotechnology

At scientific meetings posters are used to show research accurately and quickly. Along with the poster the presenter is required to write an abstract of their project to inform the reader about the key points of the research. The presenter must also be able to talk through their poster with their peers and other scientists that come to read it.

Your assignment is to design a scientific poster, write an abstract for the poster and present the poster. The poster should outline the stages in the modification of a BMC to a new biotechnological application, with focus on a specific adaption.

Your scientific poster must have:

- Title and Authors name
- Images / diagrams – properly labelled. Try to refer to them in the text
- References – referred to in text
- ~750 words

Your abstract should contain ~250 words and summarise the key aspects of your project.
You will have to be able to talk through all aspects of your project quickly and concisely, in ~5mins. You should use your poster and any other resources to support and illustrate your explanation.

Content of your assignment must include:

- Introduction – describing BMCs and their building blocks
- Scientific Knowledge – Show off what you know; genetic engineering, BMC proteins, enzymes, targeting to BMCs, etc.....
- Specific modification or design – focus of a specific use (natural or engineered) of BMCs, I can give you a focus or you can pick your own (metabolism, biofuel, cellular scaffolds, etc.). Use the literature. Describe the process used to produce the new function. Give details of the BMC components used for this biotech application.
- Conclusion / Evaluation – Discuss the potential impact and application of this design. Include a brief outline of the possible weaknesses in the design

# Tutorial 6 – Feedback tutorial

## What is the Purpose of Tutorial 6?

- To receive feedback on final assignment drafts – abstract and poster.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.

## Micro-presentation

Give a brief explanation of your project as if you were presenting it to staff, peers or family. It should take no longer that 5mins and use your poster and models you made to support your explanation.

## Final assignment feedback

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

| My target for future work is… |
|---|
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# Tutorial 7 – Feedback tutorial

## What is the Purpose of Tutorial 7?

- To receive feedback on final assignments.
- 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… |
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## Reflecting on Uni Pathways

| What did you most enjoy about Uni Pathways? |
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| • <br><br>• <br><br>• |

| What did you find challenging about the programme? | How did you overcome these challenges? |
| --- | --- |
| • <br><br>• <br><br>• | • <br><br>• <br><br>• |

# 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 – Research of Interest

This is a list of articles, web links and videos that I will be using and can also be used as sources for your own reading.

## Articles

- Axen, S. D.; *et al.* (2014)"A Taxonomy of Bacterial Microcompartment Loci Constructed by a Novel Scoring Method". PLoS Computational Biology.
- Parsons, J. B.; *et al.* (2008). "Biochemical and Structural Insights into Bacterial Organelle Form and Biogenesis". Journal of Biological Chemistry.
- Lawrence, A. D.; *et al.* (2014). "Solution Structure of a Bacterial Microcompartment Targeting Peptide and Its Application in the Construction of an Ethanol Bioreactor"
- Parsons, J., *et al.* (2010). "Synthesis of Empty Bacterial Microcompartments, Directed Organelle Protein Incorporation, and Evidence of Filament-Associated Organelle Movement". Molecular Cell.
- Gonzalez-Esquer, C.R., *et al.* (2016) "Bacterial microcompartments as metabolic modules for plant synthetic biology. The Plant Journal.
- Sutter, M., *et al.* (2017) Assembly Principles and Structure of a 6.5-MDa Bacterial Microcompartment Shell. Science.
  Young, E. J., *et al.* (2017) Engineering the Bacterial Microcompartment Doman for Molecular Scaffolding Applications. Frontiers in Microbiology
- Lee, M. *et al.* (2017). Engineered synthetic scaffolds for organizing proteins within the bacterial cytoplasm. Nature Chemical Biology
- Liang, M. *et al.* (2017). Bacterial microcompartment-directed polyphosphate kinase promotes stable polyphosphate accumulation in E. coli. Biotechnology Journal
- Lee, M. *et al.* (2018). De novo targeting to the cytoplasmic and luminal side of bacterial microcompartments. Nature Communications

## Links

- Martin Warren, University of Kent (publication list) - https://www.kent.ac.uk/bio/profiles/staff/warren.html
- MSU lab website (non-scientists page + publication list) - https://www.kerfeldlab.org/
- Structure of a Bacterial Microcompartment - https://www.newswise.com/doescience/?article_id=690312&returnurl=aHR0cHM6Ly93d3cubmV3c3dpc2UuY29tL2FydGljbGVzL2xpc3Q
- Sun to solve the earths biggest problems - https://www.nytimes.com/paidpost/msu/a-new-superpower-on-the-horizon.html?fbclid=IwAR2AvGY8SIWQZ1RGK_613masnYMo-onxmayJSBrQGEQAobC-6sGm2j0qSas
- iGEM – international genetically engineered machine

## Videos

- Building blocks of bacteria - https://www.youtube.com/watch?v=R9AKhyb5LCU
- Intersection of the unknown - https://www.youtube.com/watch?v=mvLeGWFDpEY
- Prof Cheryl A. Kerfeld (presentation) - https://www.youtube.com/watch?v=7_SBDPbE47w
- Tomorrow more sustainable - https://www.youtube.com/watch?v=2oMz6g7tpwQ
- Multistep assembly of a microcompartment encapsulating hundreds of molecules (I) - https://www.youtube.com/watch?v=ePIlRmKvZt4
- Visualization of Bacterial Microcompartment Facet Assembly Using High-Speed Atomic Force Microscopy - https://www.youtube.com/watch?v=iUFianuXnH4
- BioBricks - https://www.youtube.com/watch?v=F1mXoy1-Vr0

# Notes

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# Bacterial Factories

## Key Stage 3 Programme

researchersinschools.org