Genetic Engineering

Using Biology to Solve Real-World Problems

INTRODUCTION :: Real-World Problem Example

PROBLEM: Plastic Waste Build-Up

- Plastic takes hundreds of years to break-down naturally in the environment
- Plastic pollution builds up rapidly in global ecosystems
- No easy, quick way to get rid of plastic waste

INTRODUCTION :: Biodegradation

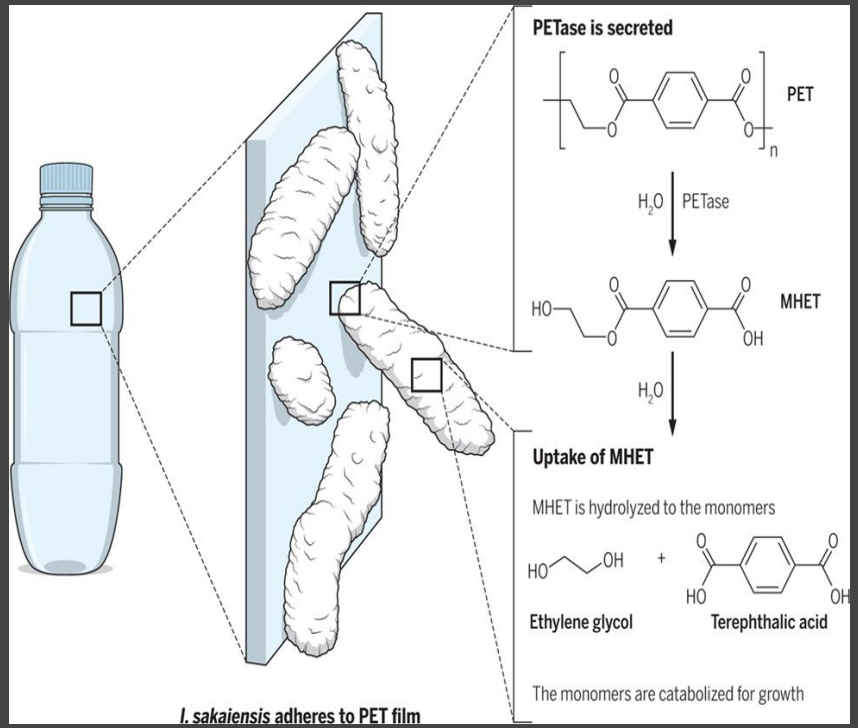
How does organic waste breakdown in nature?

- Microbes like bacteria and fungi do most of the work
- Over time, microbes slowly disintegrates organic material via a biochemical process called **BIODEGRADATION**

INTRODUCTION :: Plastic Degradation

<u>Can plastic be biodegraded?</u>

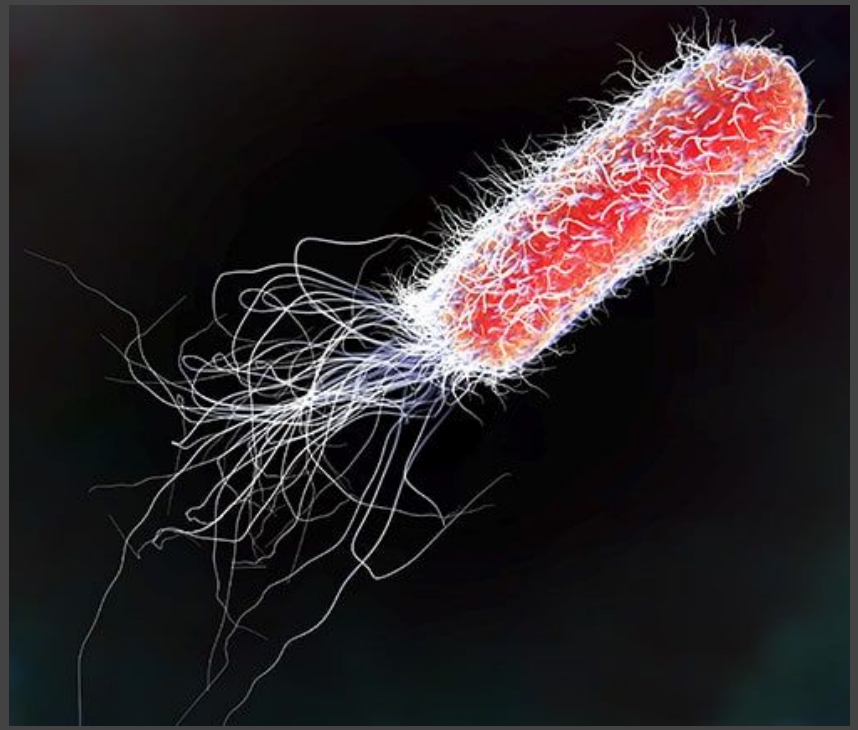
- Most microbes have not evolved ability to biodegrade plastic
- In 2016, a new species of bacteria was discovered to produce enzymes needed to degrade **PET plastics** (type of plastic used in water bottles)
- **PROBLEM:**
  - Species is not well-studied and degrades PET slowly



INTRODUCTION :: Genetically Engineering a Solution

How could we genetically engineer a solution?

- Isolate the plastic-degradation genes from new bacteria species
- Insert genes into a well-studied and faster growing species of bacteria (i.e. *E. coli*)
- Newly-inserted genes should give *E. coli* the ability to also degrade PET plastics

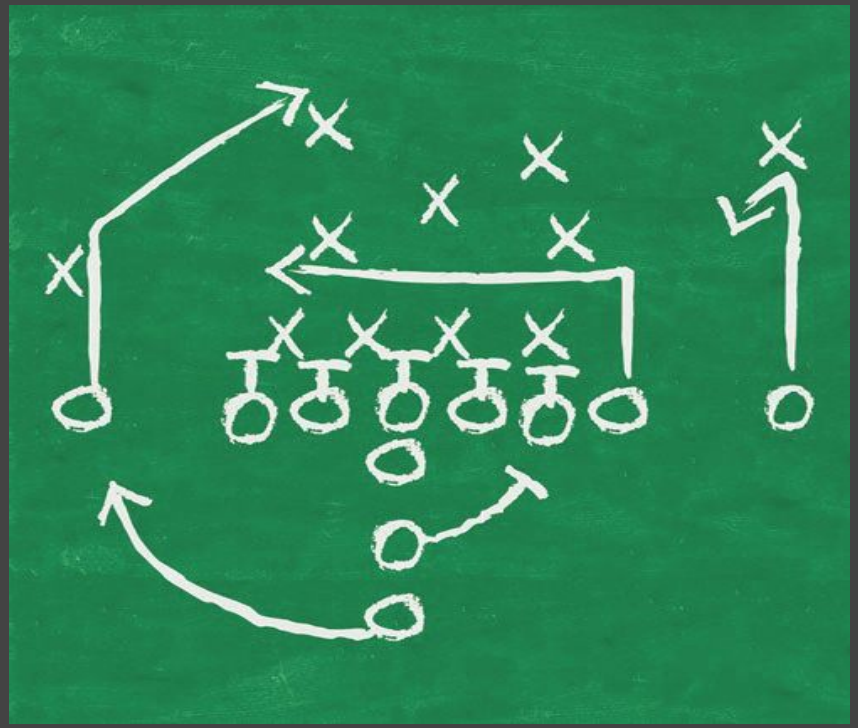


INTRODUCTION :: Today's Game Plan

GOALS:

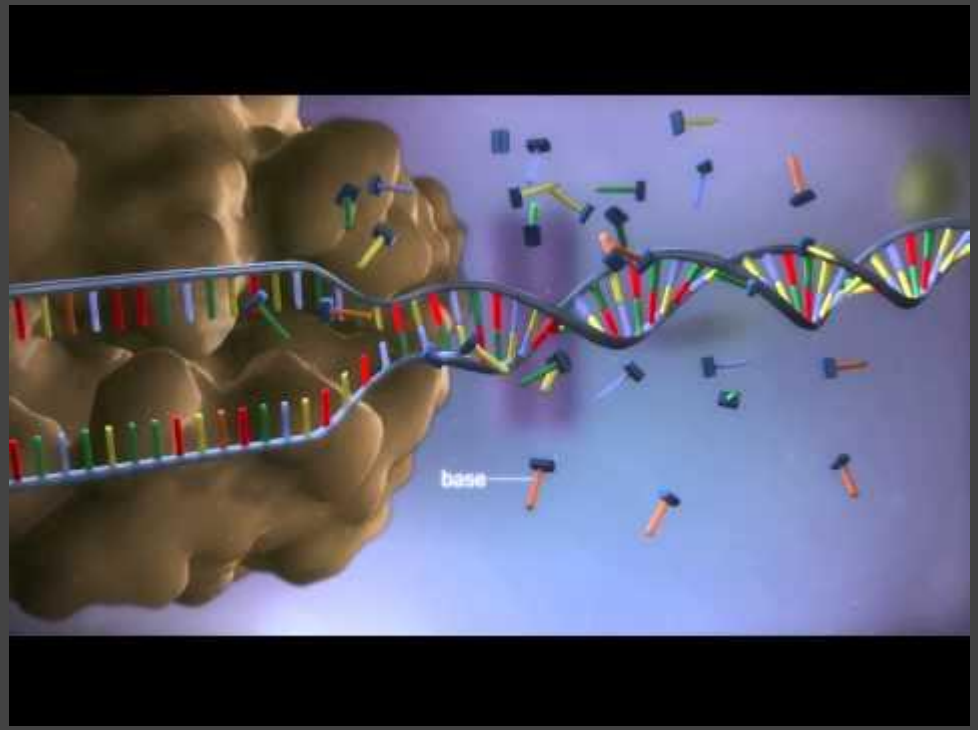
1) Understand the **THEORY** behind genetic engineering

2) Understand the **APPLICATION** of theory to real-world situations



THEORY :: The Central Dogma of Biology

- The big theme of biology
- Explains how cells work, and how we can manipulate them
- Describes the flow of information in a cell
- DNA --> RNA --> proteins

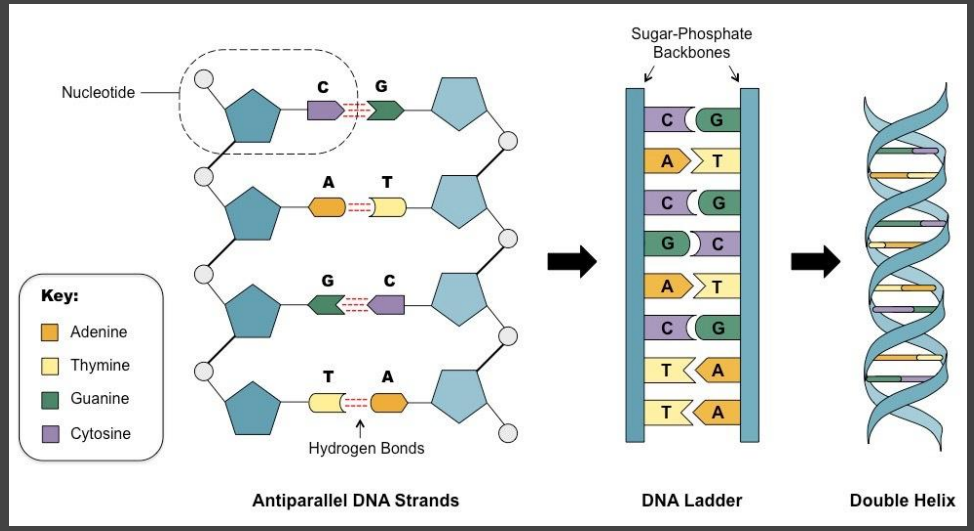


THEORY :: What is DNA?

- DNA stands for **D**eoxyribo**N**ucleic **A**cid
- All living things have DNA
- DNA is a double stranded helical structure
- The building blocks of DNA encode instructions for the cell

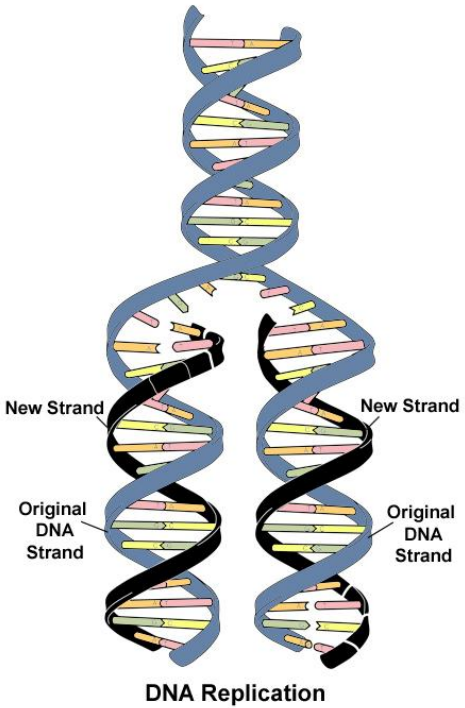
THEORY :: The building blocks of DNA

- Consists of 4 bases that we call nucleotides
  - Adenine (A)
  - Guanine (G)
  - Cytosine (C)
  - Thymine (T)
- Nucleotides bind to each other in a specific manner
- Instructions for a cell come from the specific order of nucleotides in DNA
  - Similar to how the alphabet can “code” for english words and sentences



THEORY :: Complementary Strands - how DNA works

- DNA strands bind to each other in a **complementary** manner
- This means that the nucleotides on one strand bind to their partner on the other strand
- From one strand of DNA, a cell can construct the complementary strand of DNA
- This process is used for more than just DNA!

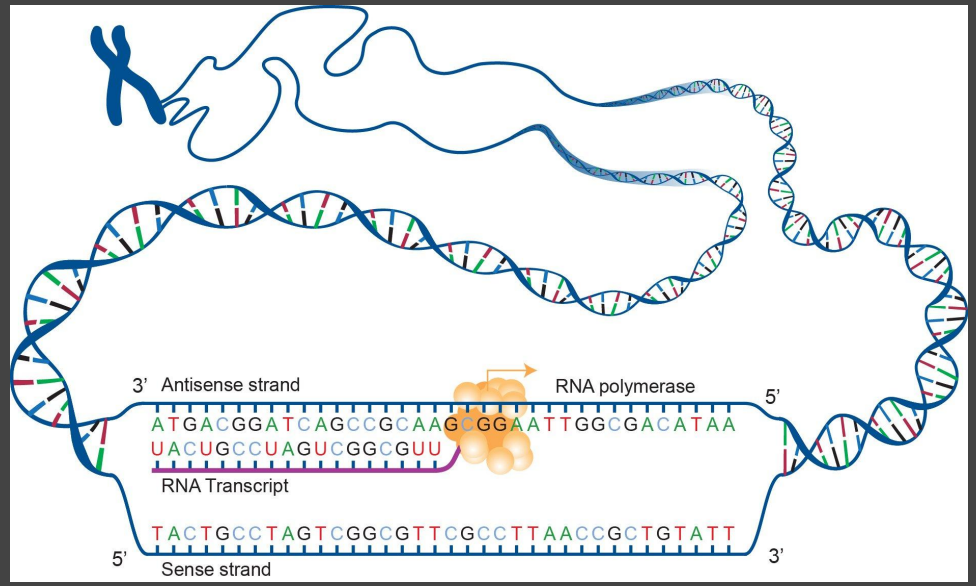


DNA Replication

Image adapted from: National Human Genome Research Institute.

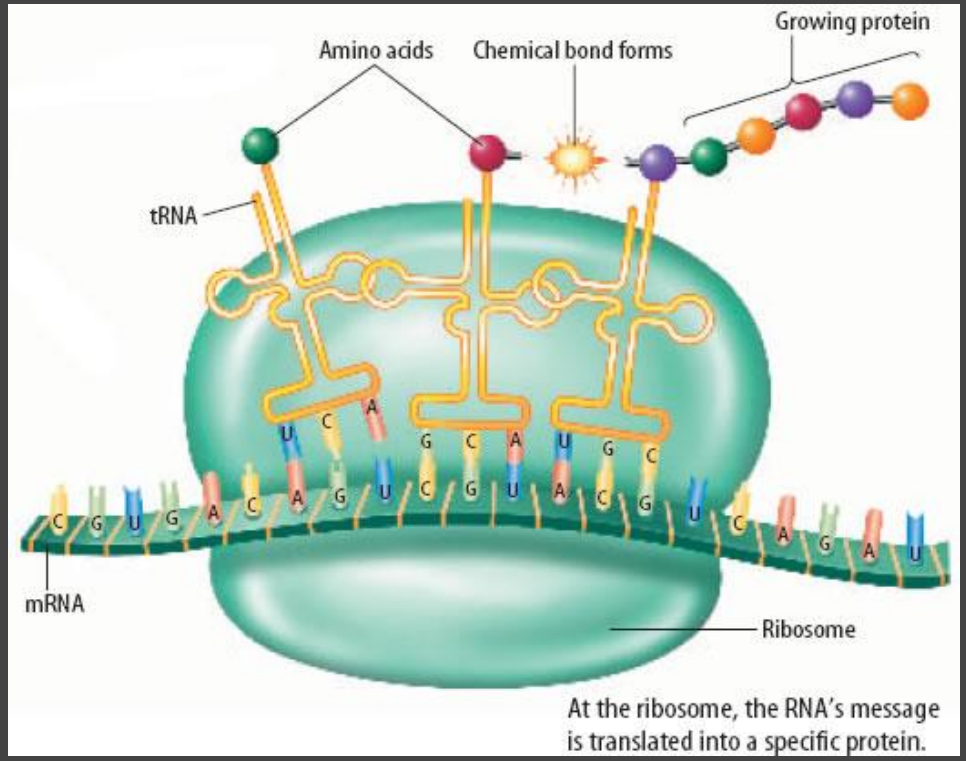
THEORY :: What is RNA?

- A cell can't understand the code in DNA
- In order to use instructions, a cell converts a **template** DNA sequence into a complementary RNA sequence
  - This process is called **transcription**
- RNA stands for **R**ibo**N**ucleic **A**cid
- RNA uses the same nucleotides as DNA with one change; Thymine is replaced with Uracil
- Where DNA acts as the code for the cell, RNA acts as the message or signal for a cell to make something



THEORY :: What are proteins?

- Proteins are the tools that carry out the functions of a cell
- Proteins are made from 20 amino acids
- Once a cell has RNA, the cell can start to make proteins using the message in the RNA
    - This process is called **translation**
- Translation is done by the ribosome
- Using the RNA message, the ribosome translates the **genetic code** into amino acids, which make up proteins



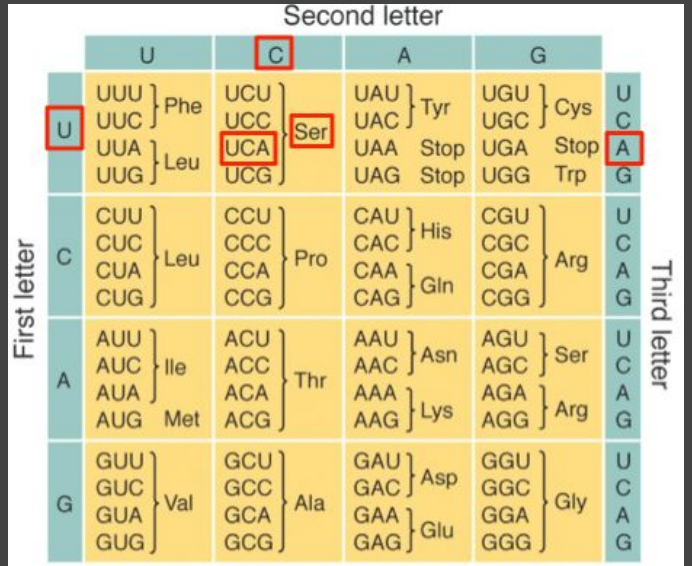
At the ribosome, the RNA's message is translated into a specific protein.

ACTIVITY :: Decode the Secret Message

Decode the Secret Message from the Template DNA Sequence using what you have learned about the Central Dogma of Biology!

<u>Template DNA Sequence:</u>

TCG ACG TAA CTT TTG ACG CTT TAA TCG CCG GCG CTT CGC TGG



ACTIVITY :: Decode the Secret Message

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Template DNA Sequence:

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mRNA Sequence:

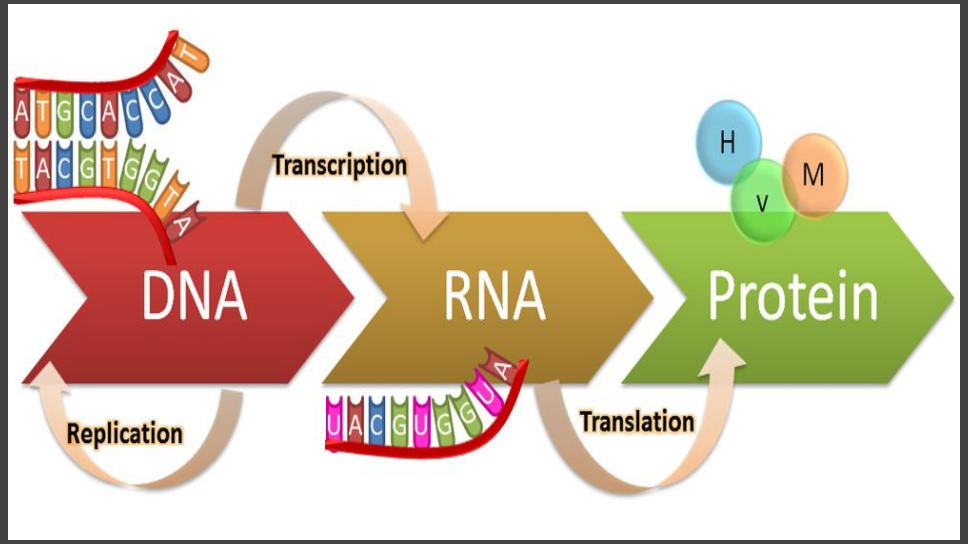
AGC UGC AUU GAA AAC UGC GAA AUU AGC GGC CGC GAA GCG ACC

Amino Acid Sequence:

S C I E N C E I S G R E A T

THEORY :: From proteins back to DNA

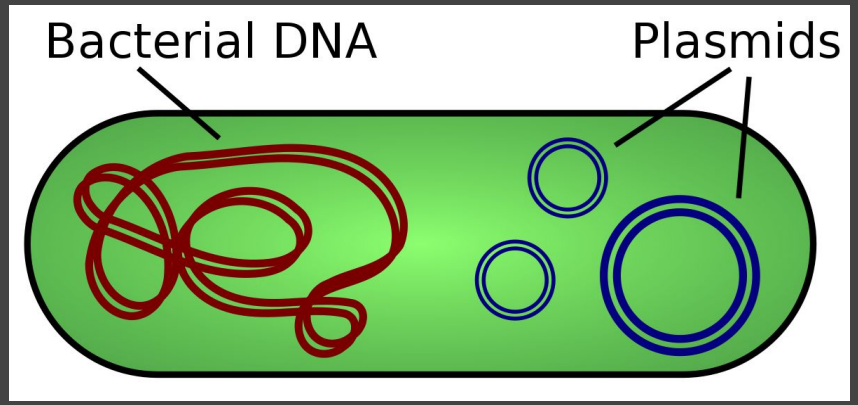
- Now that we understand the central dogma of biology, we can use it
- See a problem that requires a specific protein to fix
  - A cell digesting a new food source
- In order to make the new protein, we need the right message of RNA
- In order to have the right message of RNA, the cell needs the right code in DNA
- We can insert DNA into a cell in order to give it new proteins and new functions

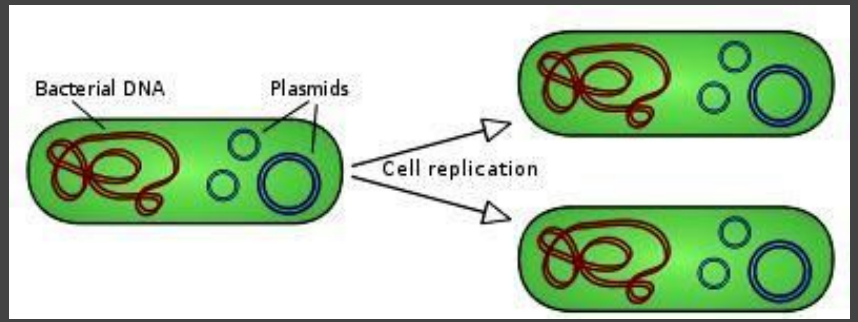


APPLICATION :: Plasmids

What are plasmids?

- Small, circular pieces of DNA
- Separated from the rest of a cell's DNA
- Replicates independently
- Super important for genetic engineering
- Can act as a "flash drive" for genetic information

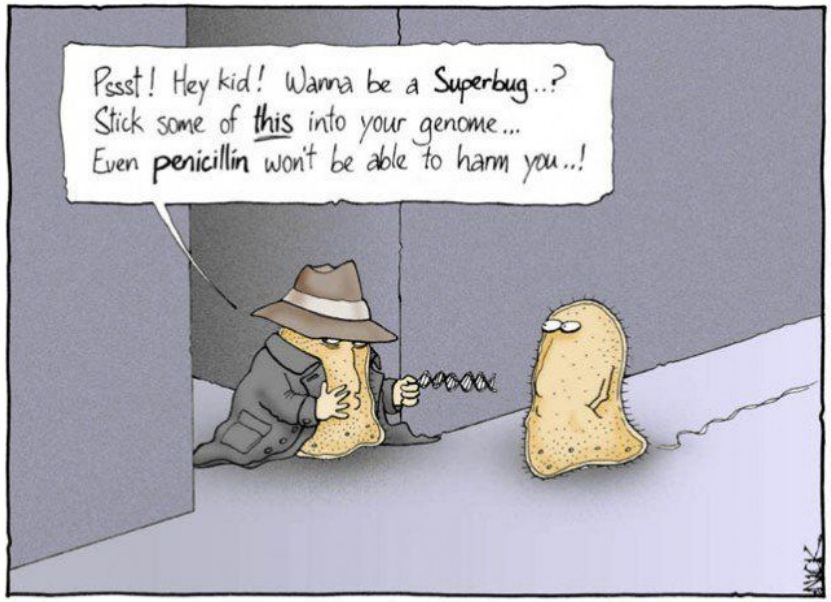




APPLICATION :: Using Plasmids

Why are plasmids useful?

- Plasmids carrying new foreign genes can be transferred into bacteria cells
- Newly transferred plasmid can give cells new abilities and functions (depending on what genes are on the plasmid)
- Allows biologists to introduce new genes into various cells

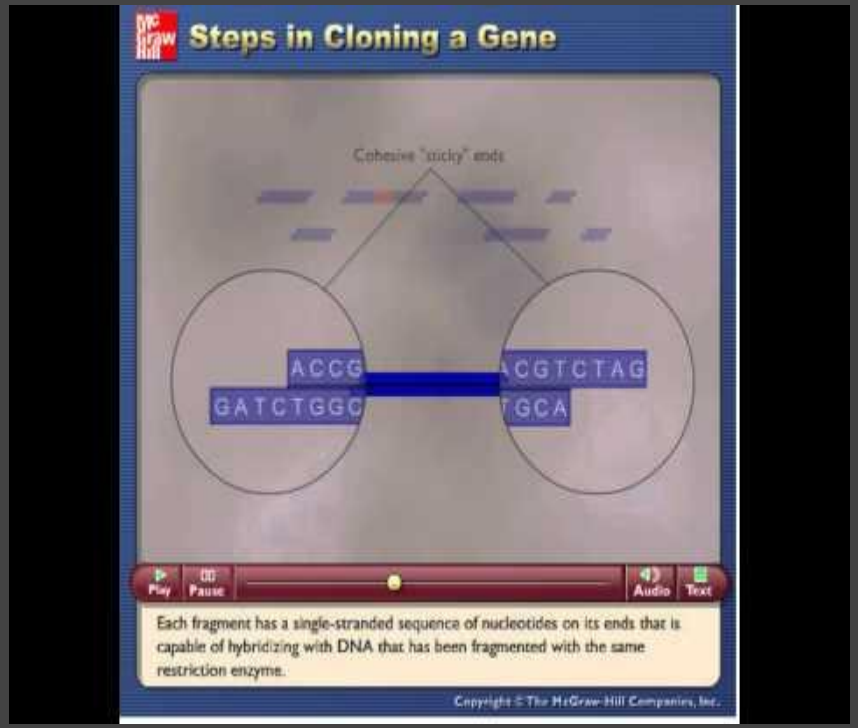


It was on a short-cut through the hospital kitchens that Albert was first approached by a member of the Antibiotic Resistance.

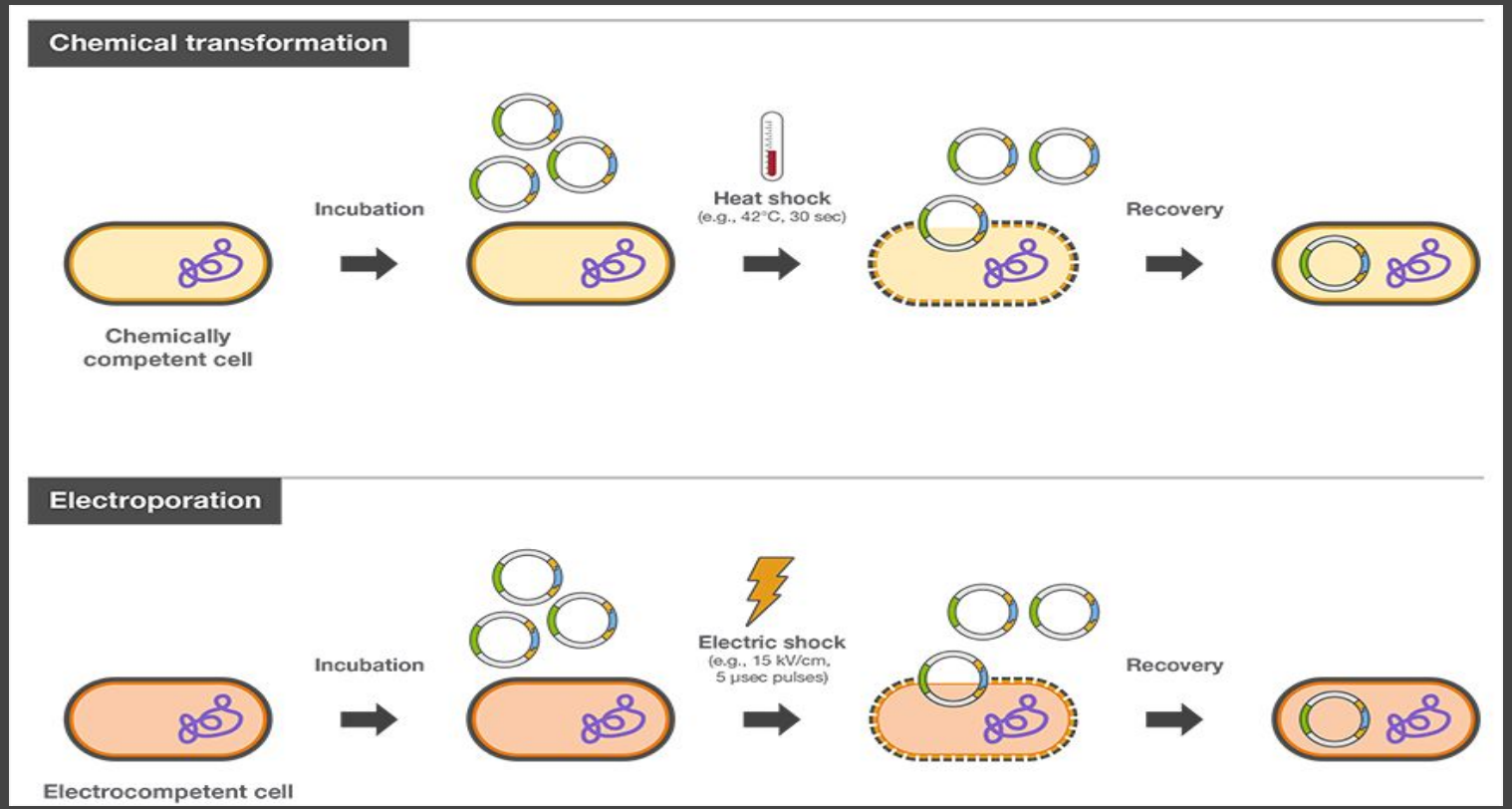
APPLICATION :: Constructing Plasmids

<u>How to insert genes into plasmids?</u>

1) Isolate the DNA sequence for the **gene** of interest
2) Start with an empty plasmid template called a **vector**
3) Use **restriction enzymes** to cut complementary **sticky ends** on the gene and vector
4) Use an enzyme called **ligase** to fully bond the gene to the vector



APPLICATION :: Getting Plasmids into Cells



ACTIVITY :: Making Glowstick Plasmids