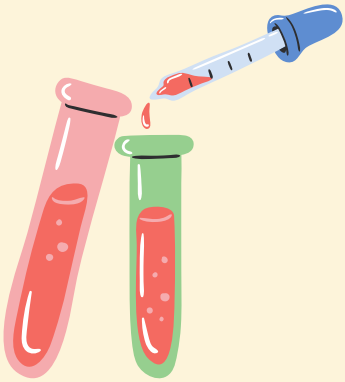
SYN-SYNC

A synbio companion!



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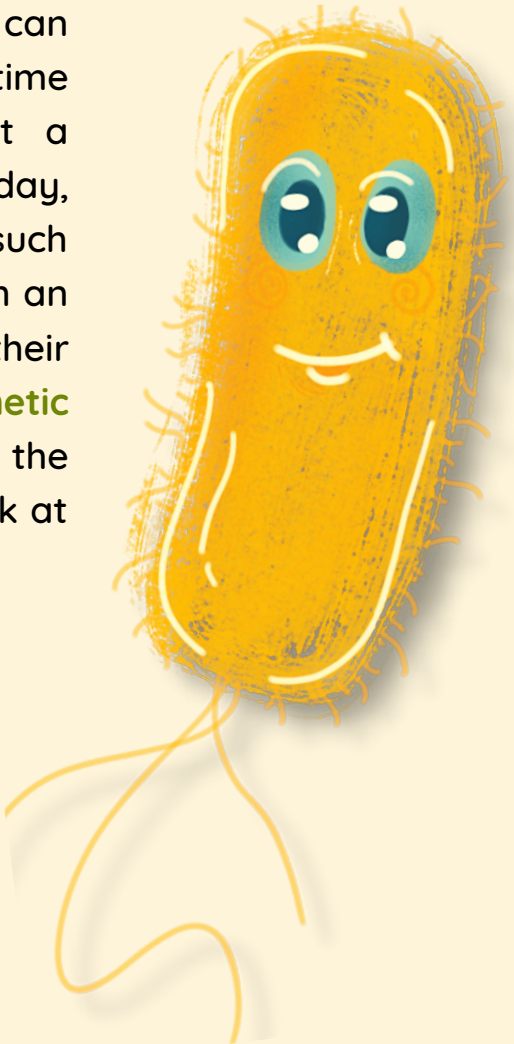
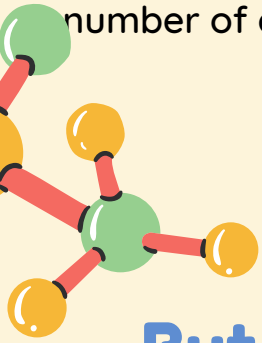
HI FRIENDS!

I am Escherichia coli, a bacterium from the depths of the human intestine, but you can call me E.coli. There was a time where I was seen as just a bearer of disease, but today, scientists have made such advancements that now I am an indispensable resource in their new area of research, Synthetic Biology. Before we get into the subject itself, let's take a look at my machinery.



Cell: an overview

To begin with, let's talk about cells. Every living being is made up of cells. The human body is estimated to have 37.2 trillion cells in it. , i.e., **37200000000000** cells in a single human body! Imagine what the number would look like if we counted all humans, animals, plants, fungi, and smaller bacterias. It's safe to say that the total number of cells on our planet is huge.



But what exactly is a cell?

The cell is the smallest unit with the basic properties of life. Some organisms exist as a single cell, while others are a group of many cells with various functions. Cells are classified into two kinds, the simpler **prokaryotic cells**, and the more complex **eukaryotic cells**.

Prokaryotic cells

are simple, small cells with no nucleus. The inside of the cells is not compartmentalized and hence they are not organized into membranous structures or organelles. Since there is no clear nucleus they just have a circular piece of genetic material i.e. DNA.

Eukaryotic cells

on the other hand, are slightly more complex. They have distinct organelles that perform various functions. Their defining feature is their membrane-bound nucleus that contains the genetic material. Fungi, plants, and animals are examples of eukaryotic organisms.

PLANT CELL STRUCTURE

The cell membrane, nucleus, cytoplasm, and everything in between.

NUCLEUS

It gives instructions for different activities in the cell.

NUCLEOLUS

It is the "brain" of the nucleus. It helps in the synthesis and production of ribosomes.

RIBOSOMES

It is where protein synthesis takes place.

CELL WALL

It is the cell's outer cover. It protects and gives shape to the cell.

ENDOPLASTIC RETICULUM (ER)

It creates and transports materials into different parts of the cell.

CELL MEMBRANE

Found inside the cell wall, it controls what materials go in and out of the cell.

ROUGH ENDOPLASTIC RETICULUM

This ER helps in the production and quality control of proteins. It also has millions of ribosomes.

CENTRAL VACUOLE

It stores waste, water, and nutrients. Most plants only have one vacuole.

SMOOTH ENDOPLASTIC RETICULUM

This ER helps in the production and synthesis of lipids. Unlike rough ER, it does NOT have ribosomes.

CYTOPLASM

It is a thick liquid that fills spaces in the cell to help retain its form.

AMYLOPLAST

It serves as starch storage for plants.

MITOCHONDRION

It breaks down sugar (from the chloroplast) into energy that the cell can use. It is also called the "powerhouse" of the cell.

DRUSE CRYSTAL

It stores excess calcium, called calcium oxalate, in plants. High amounts of this calcium makes a plant poisonus to humans.

GOLGI APPARATUS

It is a series of flattened sacs that help sort proteins synthesized in the rough endoplastic reticulum.

CHLOROPLAST

Through photosynthesis, this organelle makes sugar for the cell.

Parts of a Eukaryotic Cell: Cell organelles

Much like you have organs in your body, I have organelles that help me function as a cell. They all float around in me. Let me introduce them to you.

Cytoplasm: Before going into organelles, you must know that these organelles are not loosely present in a cell. They are in fact suspended in a fluid like matrix that is called the cytoplasm.

Nucleus (contains DNA): The nucleus is arguably the most important organelle in a eukaryotic cell. The nucleus contains DNA which is the source of all information required for the functioning of a cell. In a way, it is sort of like a brain for a cell, the command centre. This nucleus however is not well defined in prokaryotic cells and the DNA is more scattered in the cell.

Mitochondria: We call them the powerhouses of the cell. The mitochondria are the primary centre for the production of ATP. Cells that require more energy have more mitochondria, like the muscle cells, whereas red blood cells don't have any.

Chloroplast: These guys are found only in plants. The chloroplast converts the Sun's energy into sugars for the plant cells to use by a well-known process, photosynthesis. The chloroplast helps plants produce the oxygen which you and I breathe.

Ribosomes: These are essential organelles found in every living cell. Their job is to prepare proteins according to the instructions from DNA. Proteins are required by every cell, however small or big.

Golgi Complex: The Golgi complex is a series of layered membranes. Their function is mainly packaging and secretion of proteins that it receives from the endoplasmic reticulum.

Endoplasmic Reticulum(ER): These are a network of membranes found in the cell connected to the nucleus. The ER works with the Golgi apparatus and ribosomes to form a manufacturing and packaging system, kind of like a combined factory and post office for proteins. Cells with high protein requirements thus have more ER. There are two kinds of endoplasmic reticulum, smooth and rough, depending on their membranes.

Lysosomes: A lysosome is a vesicle that holds digestive juices. They break down the worn-out cell parts and sometimes self-destruct if the cell is beyond repair. Thus, lysosomes ensure that damages and worn-out cellular components are promptly removed, keeping your cells healthy!

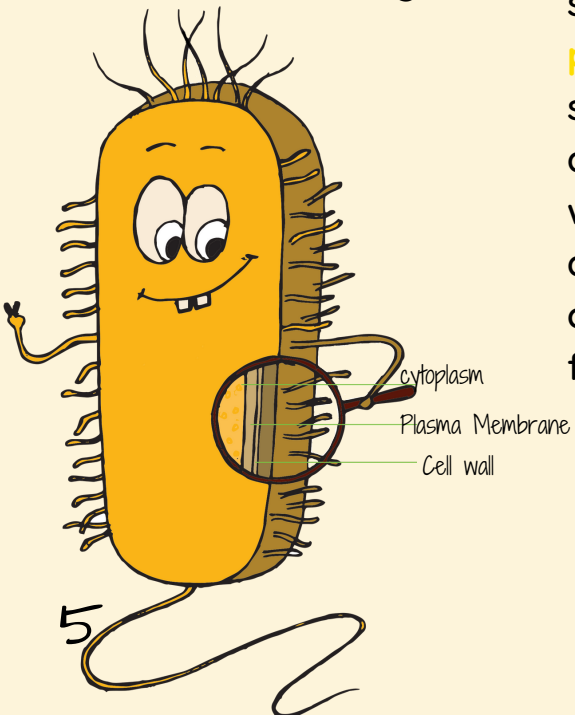
Vacuole: These are small membrane-bound spaces devoid of cytoplasm. They are smaller in animal cells and larger in plant cells. They help get rid of waste and maintain the water balance.

Parts of E Coli

HI GUYS IT'S E COLI! LET ME TAKE YOU

Let me start with my protective layer. Just like you'd wear a thick coat on a cold winter's day, I have a **cell wall** to protect me from environmental stresses. Not just that it also provides me with structural strength and support.

The primary material used to construct my cell wall include **peptidoglycan**, which makes it strong.

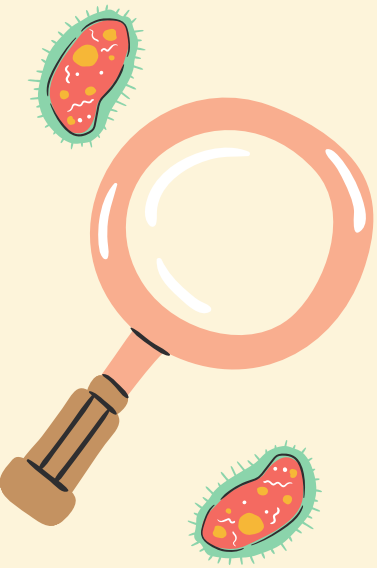


Now my next layer is the **plasma membrane**. It is a selectively-permeable membrane that allows only certain molecules to pass through.

Now different organisms have different methods of movement. A caterpillar may crawl, a human, like you, may have limbs to move. I have specialized structures like **flagella** and **pili** to achieve this. These structures are filamentous and originate from the cell wall. While flagella are long and whip-like, pili are comparatively shorter filaments.

For the proper functioning, we need instructions, in my case, it's the nucleus that provides it. Just like your brain controls most of the activities of your body, the nucleus does the same. It controls and directs all of my cellular activities and stores hereditary information. But unlike other eukaryotic cells, my nucleus lacks a nuclear membrane, nucleoplasm, and nucleolus.

Coming to the blueprint of my life, it is none other than DNA. Deoxyribonucleic Acid i.e. DNA is an extremely long chain of molecules that contains all the information necessary for the life functions of a cell. The individual molecules that makeup DNA are called nucleotides.



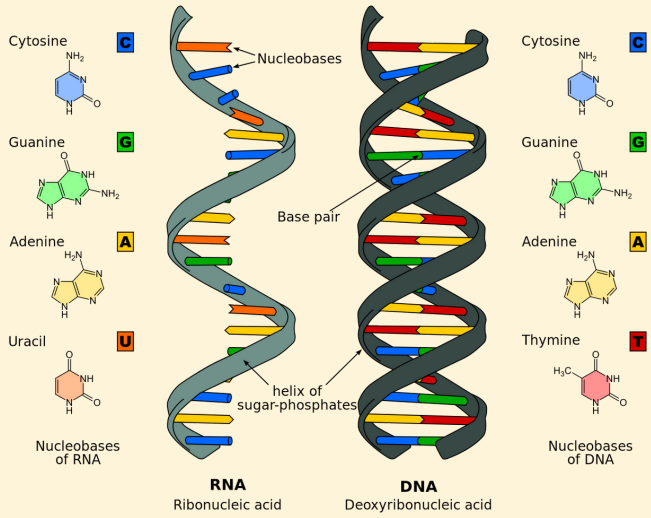
DID YOU KNOW

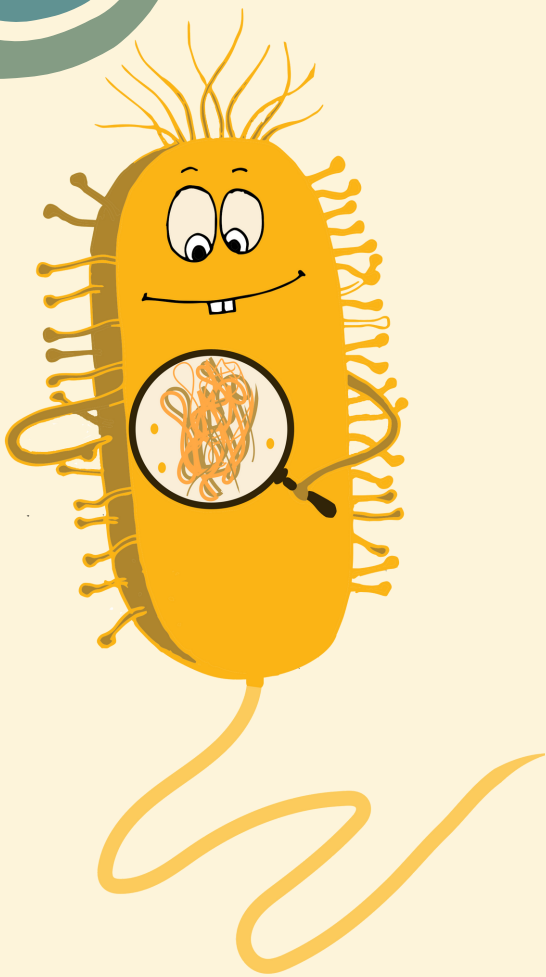
Proteins: Proteins build, maintain, and replace the tissues in your body. You might have seen them as an important part of a balanced diet. This is because they are the building blocks of our body and are necessary for keeping the body healthy. You find proteins in foods like eggs, nuts, beans, fish, meat, and milk.

There are 4 kinds of nucleotides, adenine (A), guanine(G), thymidine(T), and cytosine(C). These pair with each other, A pairs with T, and G pairs with C thus forming two parallel strands that give us the DNA double helix. This pairing is called base pairing and one pair of nucleotides is called a base pair.

DNA has the ability for its strands to act as a template for producing another strand, that is, it has the property of replication. This is what makes it a good genetic material, as it can replicate and be passed down the generations.

Chromosomes are threadlike strands made up of DNA. These are how DNA is arranged in a cell and can be passed on to the next generation. An E Coli like myself would have a single circular chromosome while humans like you have 23 pairs of chromosomes.



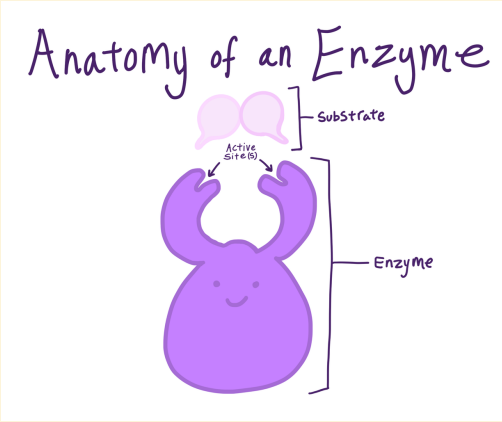


I also have small, extra, circular self-replicating genetic structures called plasmids which provides me with additional survival benefits.. You see, you need to make the right nicks and cuts to make extremely useful tools out of me. This manipulation, known as genetic engineering is only possible due to plasmids.

These plasmids act as delivery boys. Whenever we want to deliver products to some other place, we call our delivery agent. Similarly, these plasmids deliver genes to the bacteria. We somehow insert genes into these plasmids and they then deliver it to a particular cell.

DID YOU KNOW

Enzymes are proteins that make reactions happen faster in living organisms. These enzymes are often essential for the functioning of a cell and making reactions happen, which would take very long to complete if there was no enzyme.



Now that you understand how I function, it's time to learn about Synthetic Biology and see how you can use E Coli in SynBio.

So here comes the big question,

What is synbio?

Synbio, or synthetic biology, is a technique of redesigning an organism to extract useful resources or properties from them. These new modifications may not have existed in nature before and are made by humans for their benefit. The gene of an organism is the blueprint to its whole being. Now imagine, if a skilled scientist made the right cuts and additions, maybe even creating a whole new sequence, they could make the organism behave differently according to their will. This is in essence how synbio works.

The biosynthesis of human insulin in the 1980s was a landmark moment in synthetic biology. Now synthetic biology methods are used to produce bio-products, renewable chemicals, biofuels, and therapeutic treatments for human diseases.

Insulin is an important hormone that is required by our body. Our body makes it with the help of DNA strands which give information to the required cell parts that later manufacture insulin. This insulin is essential to regulate the level of sugar in our blood.

However, some individuals do not have enough insulin in their bodies. This may lead to a disease known as diabetes. To overcome this disease they are sometimes required to take insulin by injection. This insulin can be made with the help of synthetic biology. Let's learn how...

Step 1: **Gene that gives the information for the making of insulin is taken.**
Step 2: **The gene we obtain is inserted into a plasmid.**
Step 3:**These plasmids are then introduced into the bacteria.**
Step 4: **The bacteria now have the required DNA that gives them the ability to make insulin.**
Step 5: **This insulin that the bacteria now produces is extracted and purified to be made fit for human use.**

By using this simple process, the American company **Eli Lily** prepared the DNA sequences for human insulin and introduced them to E.coli thus enabling the manufacture of it on a large scale.

Tools in Synthetic Biology

Let us now look at some tools used in our synbio labs and what we do with them:

RESTRICTION-ENZYMES:

Also known as molecular scissors, these enzymes cut the DNA into fragments. Every restriction enzyme can recognize a particular sequence of bases in the DNA. What is interesting about these sequences is that they are palindromic. This means that the sequences read the same backward and forwards. An example of a palindromic word is racecar.

The palindromic sequence of EcoR1, a commonly used restriction enzyme is:

5' GAATTC 3'

3' CTTAAG 5'

These sequences are called the restriction sites of the given enzyme.

PCR:

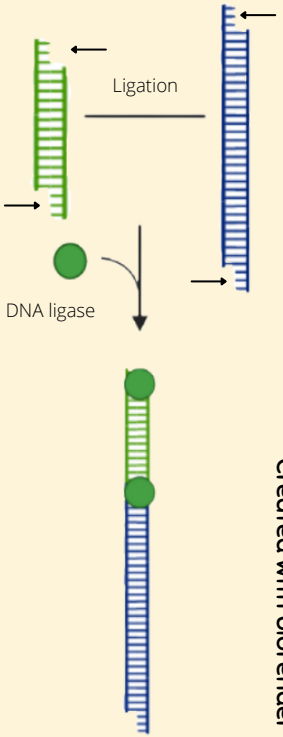
Polymerase Chain Reaction is an essential process used to amplify the DNA. This means that by performing PCR, we can make multiple copies of the DNA piece that we isolate. Therefore, instead of cutting individual strands every time, we just need to perform PCR on the fragment(gene) we are interested in.

DID YOU KNOW

Hormones are important chemicals in the body that help control mood, growth and development, the way our organs work, metabolism and reproduction

LIGASES:

After cutting a gene from the DNA of one organism, you need to insert it into the vector for which you'd need something that can act like glue. This is done by ligases. Imagine you want to insert a brick from one wall to another. For that, you need cement (to glue these bricks together). That's the exact way these ligases work. Ligases are also called molecular glues as they are helpful in joining two molecules together.



CLONING VECTORS:

These are small pieces of DNA that replicate into which foreign DNA fragments can be inserted, making recombinant DNA. A recombinant DNA is therefore a DNA with an added foreign fragment.

These cloning vectors could be viruses but the most common ones are bacterial plasmids.

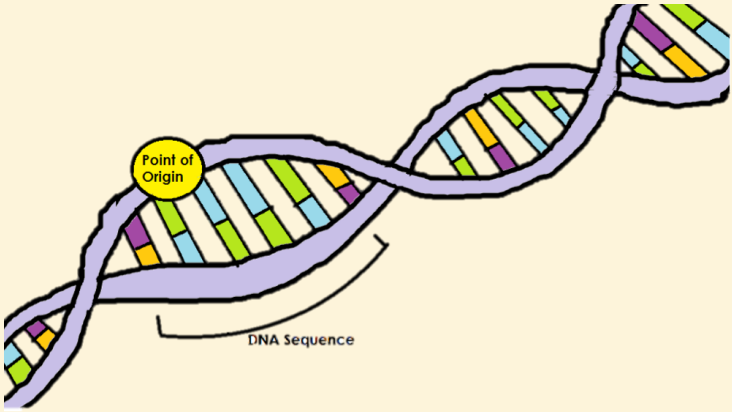
Now for a plasmid to qualify as a cloning vector, it needs to have certain properties:

Origin of Replication (Ori):

This is the site at which replication of the DNA strands starts in order to make copies.

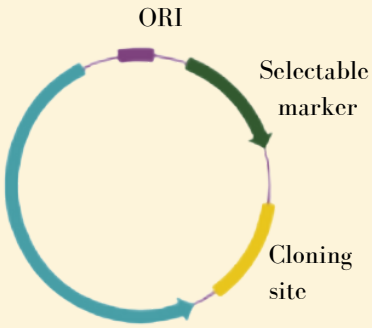
CLONING SITE:

This is a site where restriction enzymes can make a cut on the plasmid so that the foreign DNA can be inserted and made to stick using an enzyme called ligase. A plasmid may have different sites that can be cut by different kinds of restriction enzymes.



SELECTABLE MARKER:

These are fragments of DNA that give the plasmid certain properties when inserted into it. These properties help us differentiate between the original plasmid and the new mixed plasmid.



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DID YOU KNOW

Bacterial transformation is a process whereby foreign DNA is introduced into a bacterial cell. It refers to the process of making a bacteria take up a plasmid in a laboratory setup

Now that you have learned about the tools required for a synthetic biology experiment, put on your lab coats, and let's put your SynBio knowledge to the test.

Remember how we had learnt about the synthesis of insulin? Now let us help your friend Escherichia Coli gain the ability to make insulin too!

1. First steps first, You are given a strand of DNA that has the insulin coding gene in it. But it is in the middle and you need to get it out! What are you going to add to your DNA sample to isolate the genes you want?

Option 1: Ligases
Option 2: Restriction enzymes
Option 3: lysozyme (cell wall digesting enzyme)

2 . So now that you have managed to cut your DNA, we need to make many copies of it so that we have enough to introduce into the bacteria that require it. How do we do this?

Option 1: continuously cut different DNA strands
Option 2: introduce it to a bacteria and have it reproduce
Option 3: PCR

3. Now we have with us multiple copies of the desirable DNA strand. How do I introduce them to E Coli?

Option 1: using plasmid as a vector
Option 2: directly mixing with E Coli
Option 3: injecting DNA into the bacterial cells.

4. If you marked the first option, you are on a great track! But to introduce our DNA to the plasmid,
we need enzymes to help us cut the plasmid and paste the DNA strand in it. So what do you think we need to do?

Option 1: Restriction enzymes
Option 2: Ligases
Option 3: Both (1) and (2)

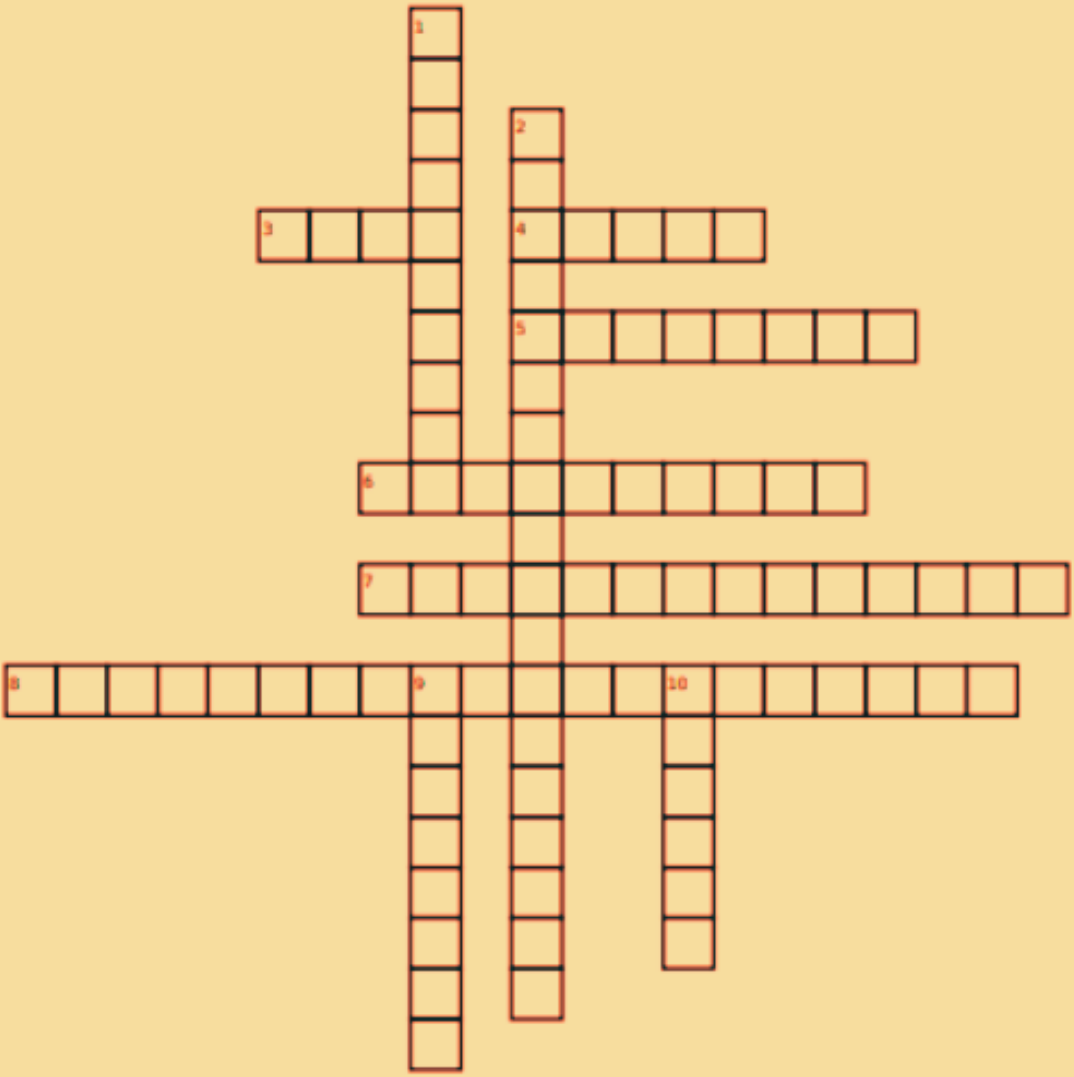
5.Now that you have put your DNA in the plasmid and it is introduced to your bacteria, you must select the bacteria that have successfully taken in the necessary plasmid. Let us suppose the plasmid you gave them also had the property of antibiotic resistance. So how do we separate the desirable bacteria from the non-desirable ones?

Option 1: picking out the required bacteria but observation
Option 2: using antibiotics to remove the undesirable bacteria
Option 3: randomly selecting bacteria

Answer:
1(2) 2(3) 3(1) 4(3) 5(2)

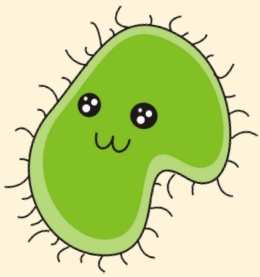
GAMES

CROSSWORD PUZZLE



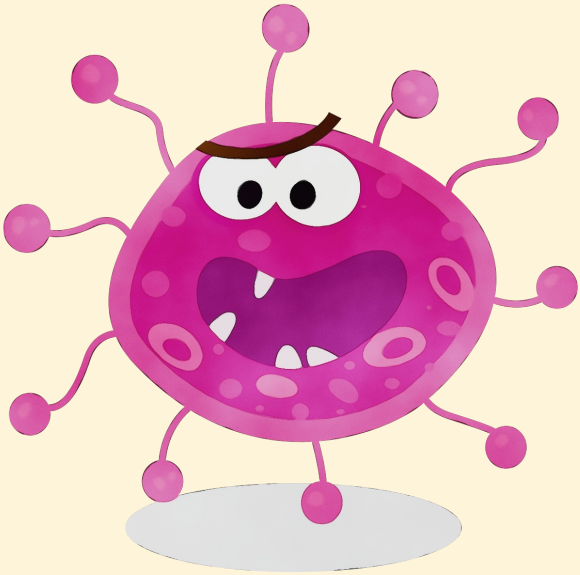
DOWN:

1. A vessel capable of supporting cell culture
2. A protein produced from a foreign DNA sequence introduced into a cell
9. Recognize and bind the antigen
10. A technique edit DNA sequences



ACROSS:

3. Basic unit of genetics
4. A sequences of 3 nucleotide within DNA
5. Change in sequences of nucleotides
6. An organism that has been implanted with genes from another species.
7. The transfer of genetic material into bacterial cells.
8. The process of extracting and purifying a product from cell culture.



WORDSEARCH

LIGASE, BASEPAIR, PLASMID, NUCLEOTIDE
RECOMBINANT, CLONE, GENOME, VECTOR, ORISITE,
ARTEMISININ, ANTIGEN, URACIL, BIOREACTOR
MUTATION