WASHINGTON iGEM

Synthetic Biology Activity Booklet

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ENGINEER AN ORGANISM

The goal of this activity is...

- To have a basic understanding of what genes and DNA are.
- To be introduced to the concept of genetic engineering.

LOGISTICS

- Handout the following introduction sheet to students and have them follow along as you read over the introduction and directions to them.
- Handout the "Your Own Bacteria" and "Genes" sheets and have students cut out and paste what genes they want to insert into their plasmids.
- After having done so, have students draw out what their bacteria would look like based off of what genes they pasted onto their plasmids.

SUPPLIES/COST

- Coloring supplies
- Scissors
- Glue sticks
- Copies of sheets provided from this activity

ENGINEER AN ORGANISM

WHAT ARE GENES?

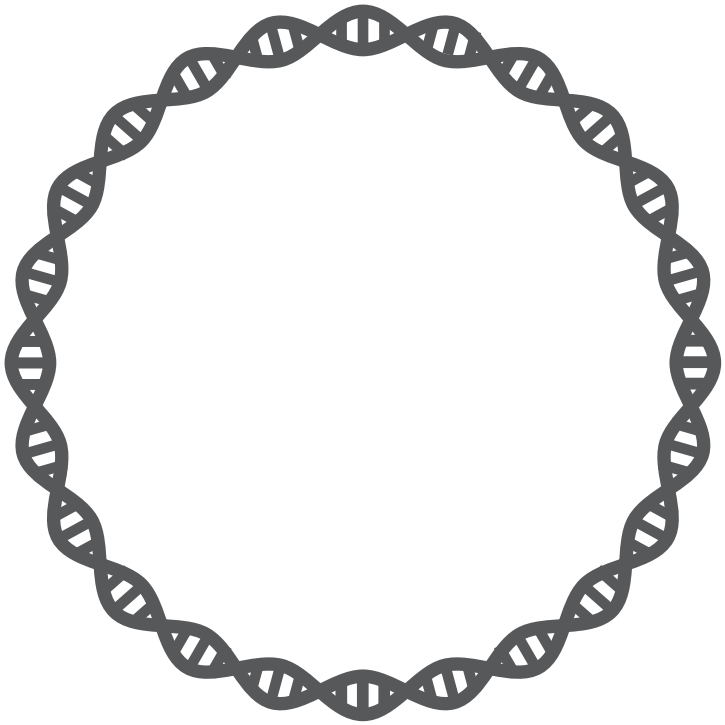
- Genes are the "recipe" for building up an organism.
- YOU have genes! Lots of them!
- Genes can determine the color of your skin, eyes, and hair.
- Genes are stored **DNA**

WHAT IS DNA?

- DNA is a double stranded molecule with a double-helix shape

A strand of DNA looks like this!

- In humans, our DNA is like a really long string.
- Bacteria are special because they have string DNA and circular DNA called **plasmids**



WHAT CAN WE DO WITH DNA?

- Scientist have found a way to take out and or put in specific genes that they want into DNA! This is what we call "genetic engineering."
- For example, scientist have engineered cats that can glow in the dark!

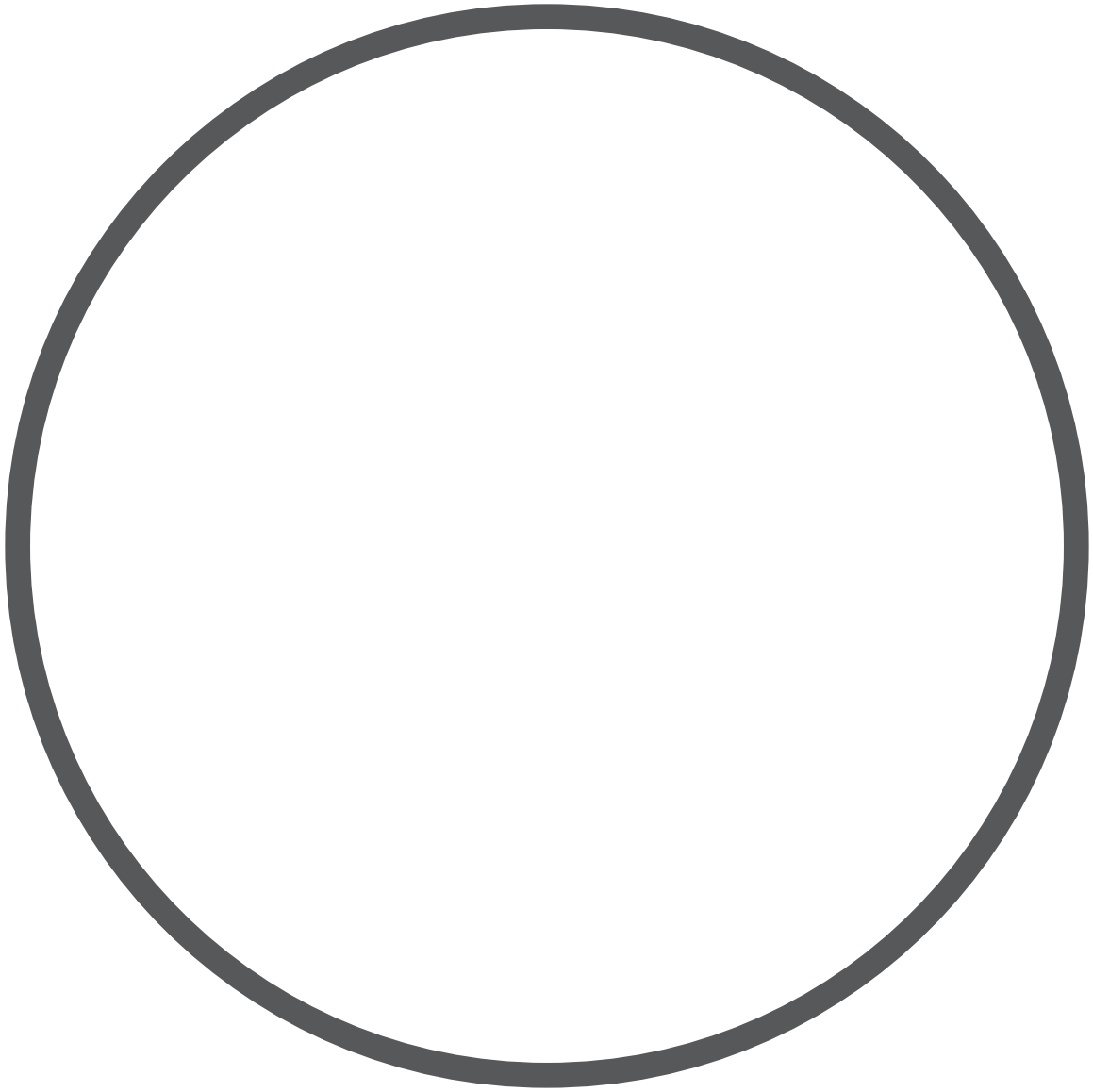
Scientific American. Doctors at the Mayo Clinic accomplished this by inserting certain jellyfish genes into feline DNA.

Today, YOU will be a genetic engineer and design your own bacteria! Your job is to pick and cut out which genes you want your bacteria to have from the “Genes Sheet” and paste them onto your bacteria’s DNA.

Once you are done with that, your bacteria will come to life as you draw out what it’s meant to look like based off what genes you gave it.

Bacterial DNA = plasmid (aka the circle)

1. Cut out the genes (rectangles on the back page) that you want & paste them onto the plasmid below!



2. Based on the genes you pasted onto your plasmid, draw & color your bacteria.

Your bacteria's name: _____

blue	mustache	polka dots
red	glasses	stripes
green	earrings	checkered
pink	braces	hat
yellow	short hair	bow tie
purple	long hair	crown
orange	fangs	mohawk

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GEL ELECTROPHORESIS BUNNY ACTIVITY

Through this activity, we seek to help students...

- Understand the basic components of gel electrophoresis and the reasons behind doing it
- Apply knowledge about gel electrophoresis onto the bunny comic crime scenario
- Introduce an awareness about the uses of biology, especially about the importance of DNA

LOGISTICS

- Hand out and explain the "Introduction to Gel Electrophoresis" sheet or explain the premise of gel electrophoresis via a slideshow presentation.
- Give a gel electrophoresis demonstration or show a demonstration video (linked below).
- Deliver the comic introduction via slideshow presentation or print out individual comics and handout to students.
- Hand out the "Bunny Crime Scenario" gels and allow the students to figure out who the culprit is and answer the discussion questions.
    - See instructor answers to discussion questions on the next page.
- Deliver the "Paternity Test Scenario" comic via slideshow presentation or print out individual comics and handout to students.
- Hand out the "Paternity Test Scenario" gels and allow the students to figure out the kid bunny that is not the parents' and answer the discussion questions.
    - Wrap up the activity with the discussion questions.

ADDITIONAL INFORMATION

- When teaching the students about why DNA migrates towards the positive electrode, a common analogy we like to use is magnets!
- If you have access to a gel electrophoresis machine, we encourage you to show students a demonstration to supplement this activity.
    - However, we realize that this is not always feasible, so we have linked some great demonstration videos.
        - https://www.youtube.com/watch?v=Wwgs-FjvWlw
            - This video has no sound; the instructor should talk while the video is playing.
        - https://www.youtube.com/watch?v=ZDZUAleWX78
            - This video has cute animations!

SUPPLIES/COST

This activity has no associated costs other than printing instruction sheets! We wanted to make this activity inexpensive for use in a variety of settings. Additionally, teams/schools can save money by using slides with pictures of our comic instead of printing it.

SAMPLE ANSWERS TO DISCUSSION ANSWERS (FOR INSTRUCTOR USE)

Gel 1 (Bunny Crime Scenario):

- **Who was the culprit?**
  - Bob
- **Why is gel electrophoresis a good technique in crime investigations instead of just using evidence found at the crime scene?**
  - Evidence found at the crime scene can be circumstantial. This means innocent people sometimes end up in prison. DNA evidence is indisputable.
- **Can any assumption(s) be made about the size of the DNA at the top of the gel compared to the bottom?**
  - Longer strands up top and smaller ones at the bottom
- **What happens if you have several fragments of DNA that are the same length?**
  - Darker/brighter/thicker bands!
- **How do we know the size of each of the fragments?**
  - DNA ladder with known fragment sizes as a reference
  - They probably won't get this but it's a good question to think about even if they don't get it right

Gel 2 (Paternity Test Scenario):

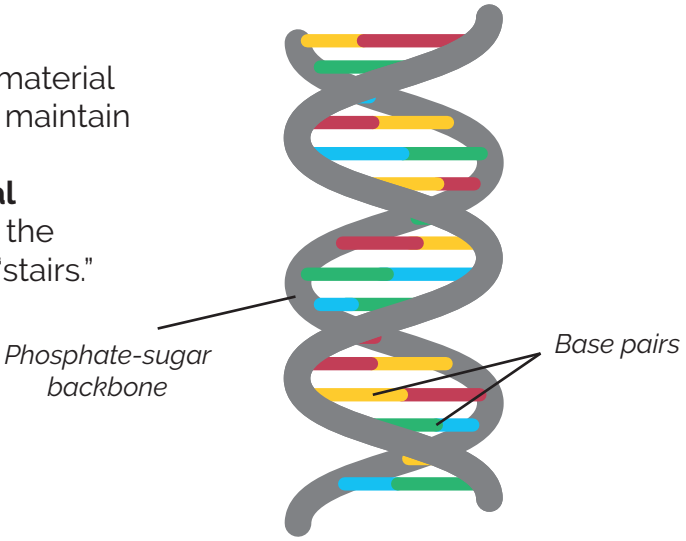
- **Which bunny was not related to the mommy and daddy bunnies?**
  - Bunny 2
- **Why is it important to consider both the mommy & daddy bunnies' DNA when determining which bunny was not related?**
  - The bunny children get their DNA from both the mommy and daddy bunnies

INTRODUCTION TO GEL ELECTROPHORESIS

WHAT IS DNA?

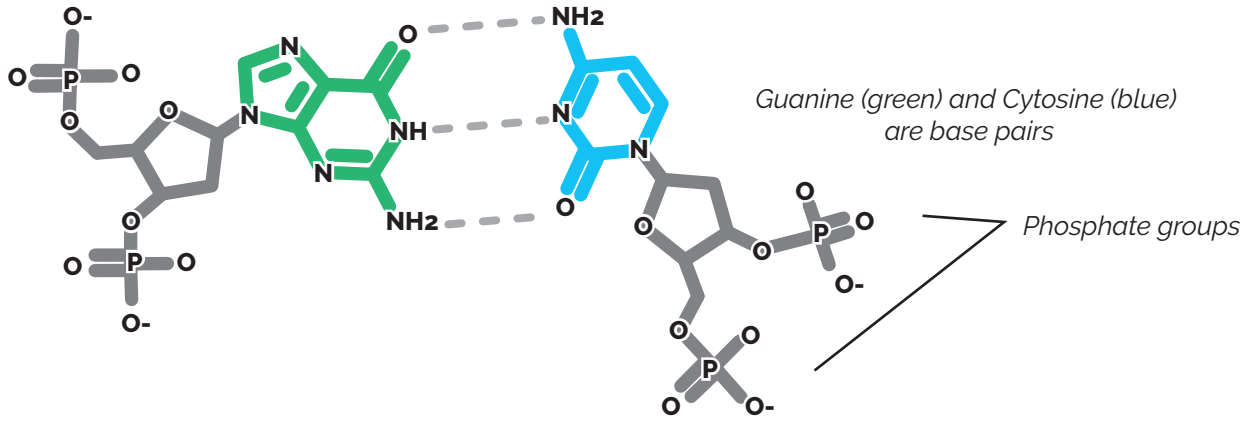
DNA (Deoxyribonucleic acid) is the genetic material that has all the information necessary to build and maintain an organism.

Its double helix structure is similar to a **spiral staircase. Phosphate and sugar molecules** make the "railings," while **base pairs** act as the steps on the "stairs."



WHAT CHARGE DOES DNA HAVE?

DNA has a negative charge!
This charge comes from its phosphate groups.



WHAT IS GEL ELECTROPHORESIS?

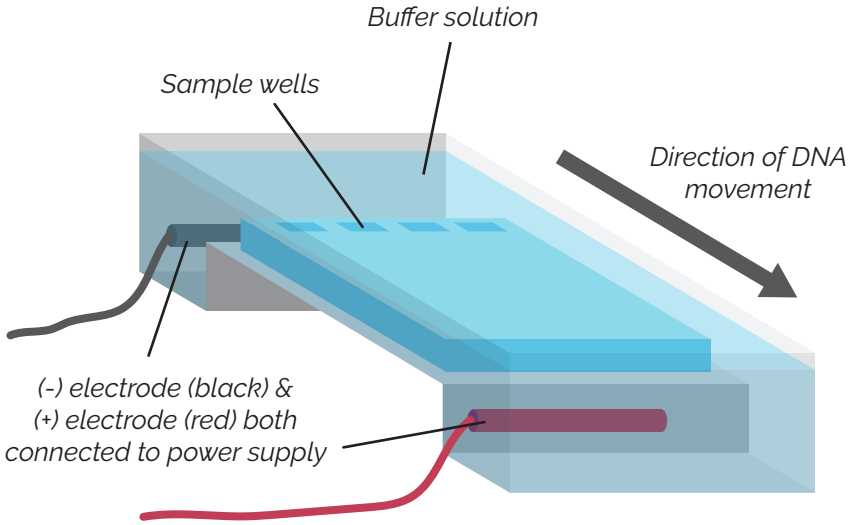
Gel electrophoresis is a laboratory technique used to separate macromolecules like DNA, RNA, and proteins by their size and charge.

WHAT IS GEL ELECTROPHORESIS USED FOR?

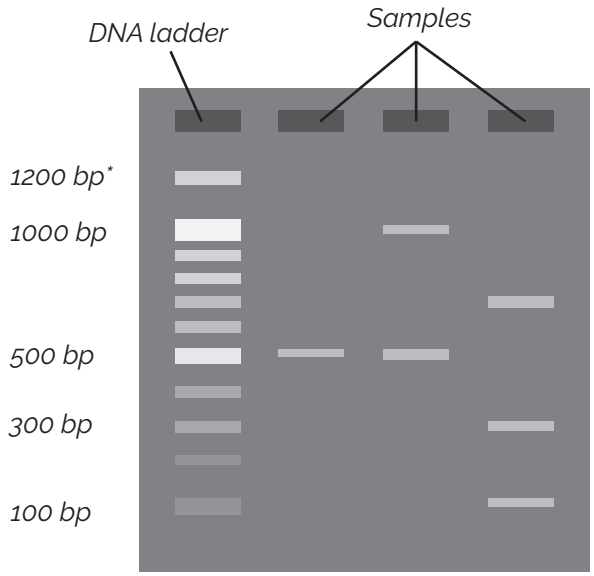
- Finding criminals
- Paternity testing
- Determining evolutionary relationships
- Determining the size of DNA fragments

HOW DOES GEL ELECTROPHORESIS WORK?

- A gel is prepared that has **wells**. The DNA will be placed into the gels & travel through the gel
- After turning on the power supply, the DNA "swims" through the gel towards the **positive** charge of the box



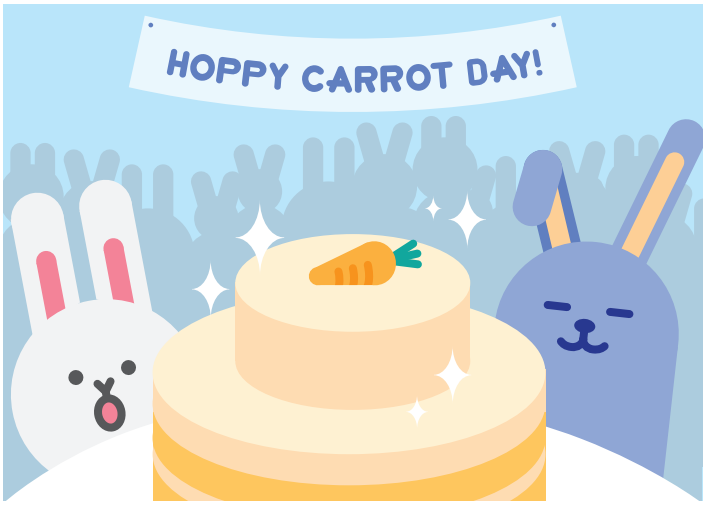
- Usually, the first well is loaded with **DNA ladder**
    - A ladder is used as a marker for known lengths of DNA fragments
- DNA fragments show up as bands on the gel, which can be seen with UV light
    - The more negative and **shorter strands** travel through the gel **faster**



*bp is shorthand for "base pairs"

Now that you have learned all about gel electrophoresis, it is your turn to solve a crime!

BUNNY CRIME SCENARIO



Once a year, all the bunnies in Bunniesville gather to celebrate the mighty carrot for being an excellent source of vitamins and minerals and being so delicious.

As part of the celebration, a large carrot cake is baked for everyone in the town to share a piece of.

The bunnies of Bunniesville take their carrot cake very seriously, so if anything were to be wrong with the cake, the townsbunnies would be very angry.

On the day of the party, everyone is having a good time until suddenly...

...The power goes out for a few moments. No one thinks much of it until the lights come back on and a deafening scream fills the room.

Oh the horror!

Someone has taken a bite out of the sacred carrot cake and left very little for everyone else!

Rightfully outraged, the bunnies look to you, Chief of Police of Bunniesville, to figure out who would committed the terrible crime.

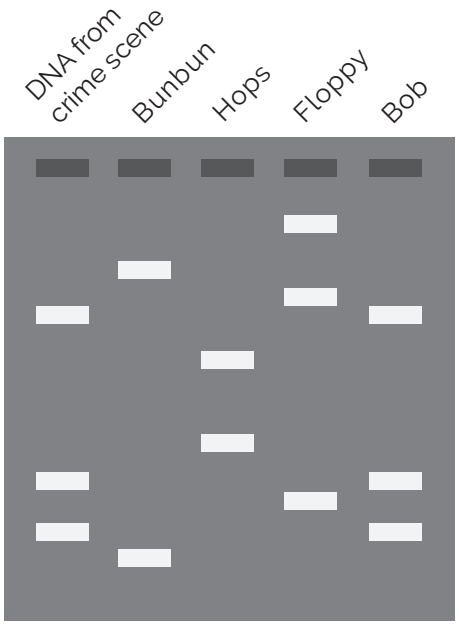
Lucky for you, you have the DNA of the bunny who committed the crime from the saliva that he or she left behind on the cake. This should be a piece of cake!

You collect a sample of saliva that was left on the cake as well as a samples from all of the townsbunnies, which they have voluntarily given up for the investigation. You collect saliva because you know that their DNA can be found in their saliva. After extracting the DNA from the saliva, you perform **gel electrophoresis** on all your samples to find out whose bunny DNA matches the bad bunny's DNA.

After a preliminary investigation, the police of Bunniesville have four key suspects: **Bunbun, Hops, Floppy,** and **Bob.**

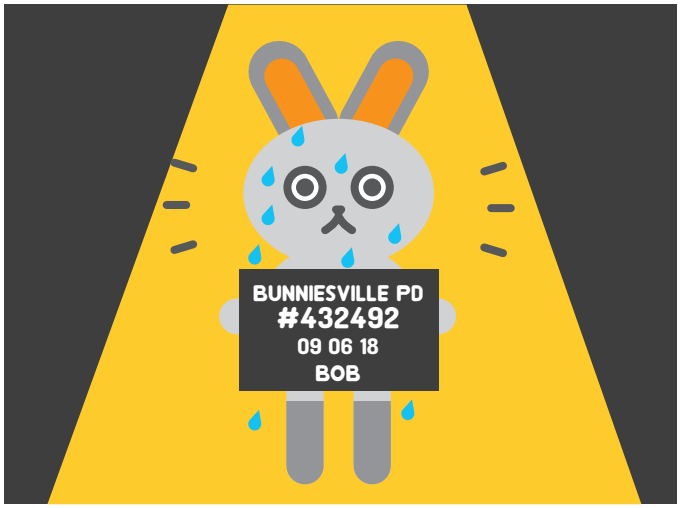
You are given the results of the gel electrophoresis of the bunny who committed the crime and of the suspects.

As Bunniesville's Chief of Police, your job is to compare the bunny criminal's results to the prime suspects to figure who did it.



Based on the gel electrophoresis results on the left, who do you think is the guilty bunny?

After a thorough and intensive investigation, you and all members of your police unit have come to the logical conclusion that the culprit is none other than **Bob!** As for his punishment, he will be tasked to rebake the carrot cake for everyone to share this time.



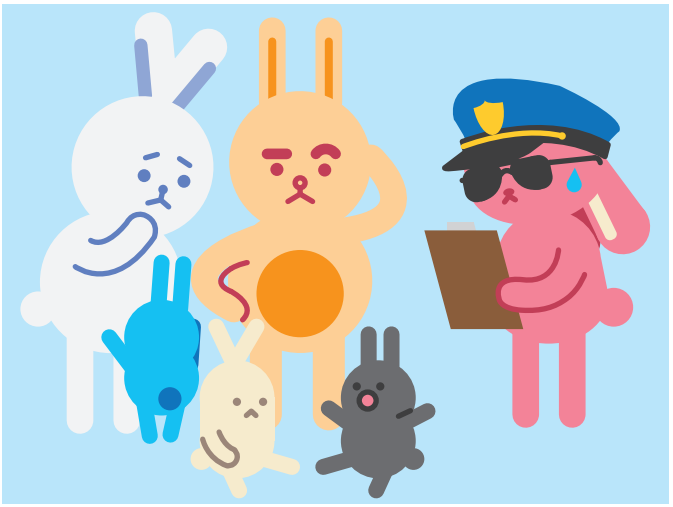
DISCUSSION QUESTIONS

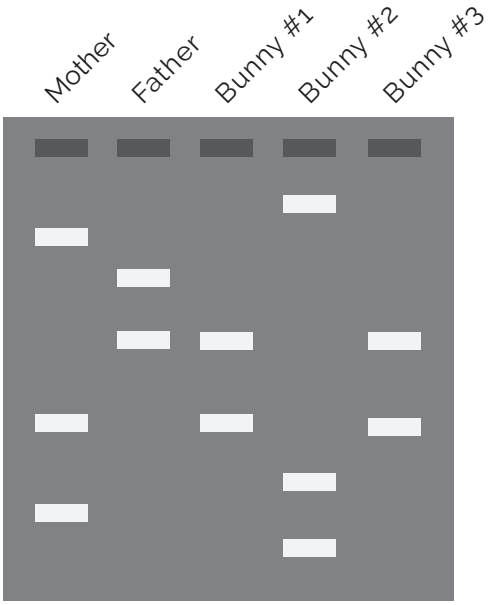
- Why is gel electrophoresis a good technique in crime investigations?
- Can any assumption(s) be made about the size of the DNA at the top of the gel compared to the bottom?
- What happens if you have several fragments of DNA that are the same length?
- How do we know the size of each of the fragments?

PATERNITY TEST SCENARIO

Shortly after the party, three lost baby bunnies turn up who have seem to have been lost for hours! A mommy bunny and daddy bunny later come to collect their children.

They claim they only have two children, but there are three present. Due to bunny short term memory, the babies forgot who their parents are!

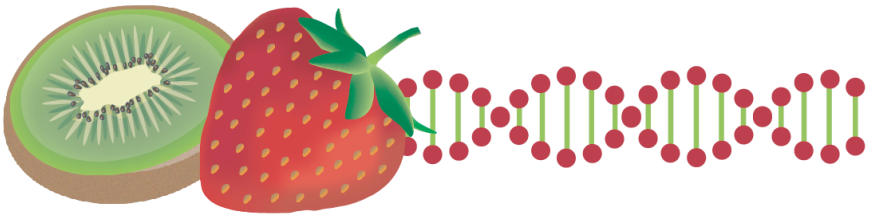




Your job is to figure out which two of the three baby bunnies belong to the parents. What comes next?

DISCUSSION QUESTIONS

- Which bunny was not related to the mommy and daddy bunnies?
- Why is it important to consider both the mommy & daddy bunnies' DNA when determining which bunny was not related?



FRUIT DNA EXTRACTION

The goal of this activity is to...

- Extract and visibly see DNA from kiwis and strawberries
- Comprehend the mechanics behind and perform DNA extraction
- Understand the basics of experimental design

LOGISTICS

- Hand out and explain the "Introduction to Gene Therapy & CRISPR" sheet or explain the premise of gel electrophoresis via a slideshow presentation.
- Allow the students to answer the discussion questions & create a conversation
- Allow the students to answer the discussion questions & create a conversation to wrap up the activity

ADDITIONAL INFORMATION

- This activity is great for combining with the "Structure of DNA" activity
- To minimize preparation time in a classroom, instructors can add salt into the plastic bags before handing them out.

SUPPLIES/COST

- Small Plastic Bags
- Clear Plastic Cups
- Salt
- Dish Soap
- Peeled Kiwis
- Strawberries

SAMPLE ANSWERS TO DISCUSSION QUESTIONS (FOR INSTRUCTOR USE)

EXPERIMENTAL DESIGN

1. What is the controlled variable?

Sample answers include amount of dish soap, type of cups used, brand of dish soap, etc.

2. What is the manipulated variable?

Type of fruit (strawberries or kiwis)

3. What is the responding variable?

Amount of DNA (can approximate or weigh using a scale)

FINAL DISCUSSION QUESTIONS

1. From which fruit did you get more DNA from?

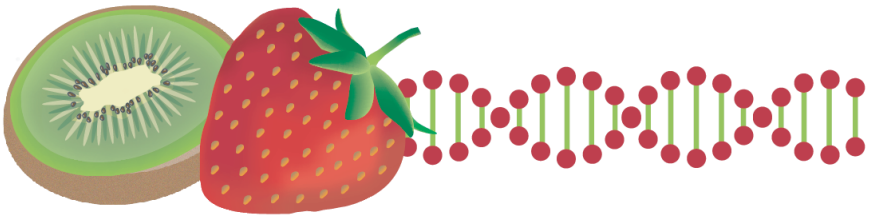
Strawberry!

2. *Challenge:* why do you think this fruit had more DNA?

Unlike kiwis, strawberries' DNA is on the outside of the fruit, making it easier to extract. The DNA extraction occurs due to the phospholipids in the dish soap breaking down the cell membrane of the fruits' cells.

Additionally, strawberries have more chromosomes than kiwis (groups of coiled DNA), so they have more DNA overall.

(Instructors will have to explain this. This is the part where students learn about the mechanics of the fruit DNA extraction.)



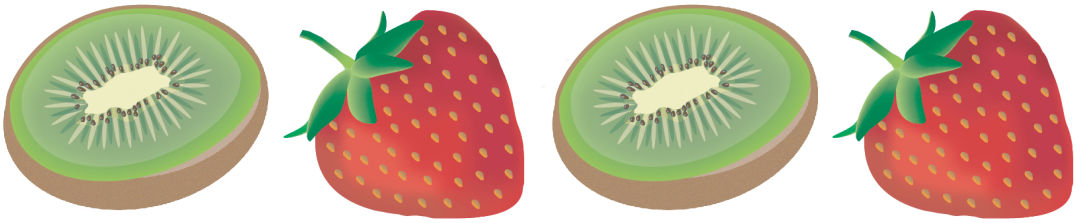
EXPERIMENTAL DESIGN

- Before scientists conduct experiments, they must design them!
- Scientific experiments have a few variables:
    - ***Controlled Variables:*** Things that are consistent, kept the same throughout the experiment.
    - ***Manipulated Variable:*** The aspect that is changed.
        - Usually, you only have one manipulated variable at a time.
    - ***Responding Variable:*** What is being measured
- You will be extracting DNA from kiwis and strawberries, and seeing which fruit you can get more DNA from.
- With this in mind, answer the questions below:

1. What are some controlled variables?

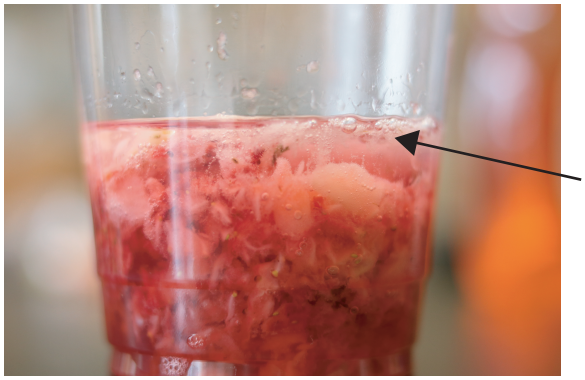
2. What is the manipulated variable?

3. What is the responding variable?

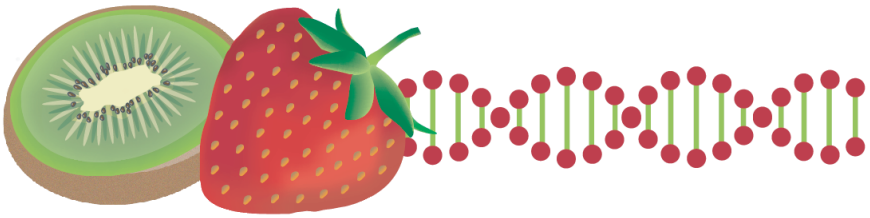


FRUIT DNA EXTRACTION PROCEDURE

1. Place one or two strawberries in a plastic bag and one peeled kiwi in a separate plastic bag.
2. Add 0.5-0.75 tablespoons of salt and a tablespoon of dishwashing soap to the plastic bag with fruit.
3. Smash the fruit up in each ziploc bag with the dishwashing soap and salt.
4. Pour the mashed fruit into a cup.
    - Try to avoid whole chunks - you can use a coffee filter if you like.
5. Pour a little bit of rubbing alcohol into the cup. There should be enough that you can see a layer of rubbing alcohol over the fruit.
6. Wait until a white clump (the DNA) separates from the rest of the mixture.
7. Compare the amount of DNA extracted from the strawberries to the amount of DNA extracted from the kiwi.



The white, bubbly substance is DNA!



DISCUSSION QUESTIONS

1. From which fruit did you get more DNA from?

2. ***Challenge:*** Why do you think this fruit had more DNA?

LEGO DNA/ JELLYBEAN PEPTIDE ACTIVITY

The goal of this activity is to...

- Comprehend the structure and makeup of DNA
- Understand the relationship between nucleotides, DNA, amino acids, and peptides
- Comprehend that only certain base pairs match up
- Apply knowledge about DNA and amino acids to build a unique peptide from jellybeans
- Learn the application of peptides in the real world (For example: Aspartame is a sugar substitute)

LOGISTICS

- Have students divide into small groups
- At the beginning of the activity, briefly describe the premise of the Central Dogma to students.
    - This activity skips the mRNA aspect since it is meant for younger students.
    - For this part, Washington iGEM uses a PowerPoint as a supplement.
- Then, have the students go through the lego part of the activity (handouts provided).
    - First, the instructor should ask the students if they know anything about DNA and give a basic description of what DNA is
        - Ex: DNA is like the blueprint for what makes you; it's what makes you unique from everybody else!
    - Have select their two backbones for the DNA segment. The backbones should be a neutral color.
        - Washington iGEM has tan Lego pieces for the backbone, but other colors like grey (as depicted in the instruction sheet) also work!
    - Have them select three different colored Legos (nucleotides) and have them place the nucleotides in the order they want on one of the backbones
        - Explain what each Lego represents
    - Have them find their matching lego set for their nucleotide/Lego sequence and have them put the two sides together.
        - In the instruction sheets, the red and yellow pieces match up (adenine and thymine) and the blue and green pieces (guanine and cytosine)
        - Explain why only certain legos/nucleotides match up if the students are more advanced
            - Explain that they base pair through Hydrogen Bonding
            - We compare the partial charges that lead to Hydrogen Bonding to magnets' +/- interaction to help the students understand.

LOGISTICS (CONT.)

- Then, have the student find their amino acid from their DNA on the amino acid and lego codon sheet
    - Explain what amino acids are
    - One analogy that Washington iGEM likes to use is that the amino acids are individual "beads," and the entire protein is a "necklace"
- Now that the students know what their amino acid sequence is, have them move on to the jellybean portion of the activity
    - Have the students pick out their jellybean/amino acid using the jellybean codon chart
    - Explain that multiple amino acids make up a peptide
    - Have the student pick out 2-4 more jelly beans out of the bag, or use the peptide sheets at the end of the handout to create a specific protein.
    - Have the student then connect the jelly beans with marshmallow fluff to show that they are bonded to each other
        - The students might need tissues after fluffing due to the sticky gooey nature of fluff
        - In some countries, it is difficult to find marshmallow fluff. In this case, we recommend using icing.
    - Then, share real world examples of peptides and explain what a peptide is using the peptide example sheets
    - Allow the students to eat their peptide if they want
- Clean up

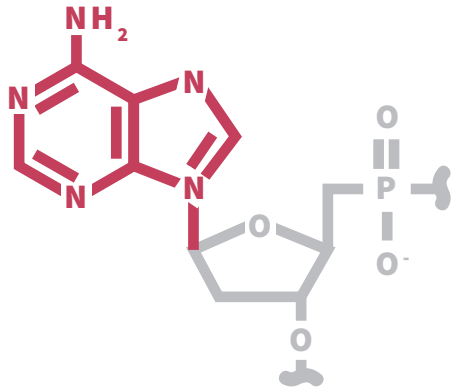
ADDITIONAL INFORMATION

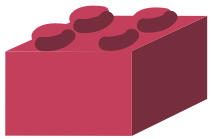
- This activity requires lots of instructor help; the instructor should be running the entire activity & can also provide a supplementary Powerpoint if needed.
- Target audience is elementary and middle school students
- This activity is meant to expose children to the concepts of what DNA does, why it is important, and how it makes individuals unique.
- This can get quite messy, but kids love it!
- This activity is done best in small groups

SUPPLIES/COST

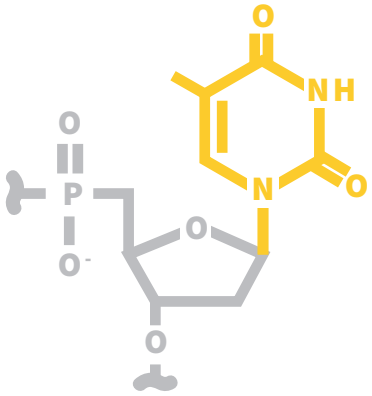
- Activity sheets
- Marshmallow fluff
- Popsicle sticks (to get marshmallow fluffy on the jelly beans without getting totally messy)
- Plastic spoons for scooping out the marshmallow fluff
- Lots of Jelly Belly jellybeans or jellybeans with similar colors (to match the jellybean codon chart)
- Tissues or paper towels (for sticky hands)
- Plates or clean surface for jelly bean fusing
- Legos (blue and green blocks (one length), and yellow and red blocks (a different length), and long Legos (to act as a back bone for the DNA structure).
    - If you can't find long Lego pieces, you can connect several smaller Lego pieces to use as the backbone.
        - We highly recommend using a neutral color for the backbone, like tan or grey

LET'S BUILD SOME DNA!

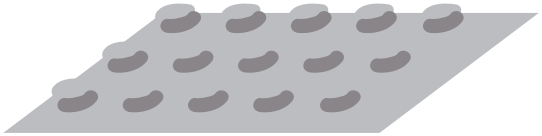




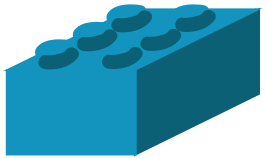
Adenine



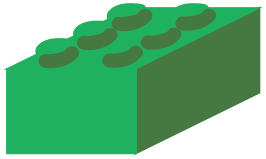
Thymine



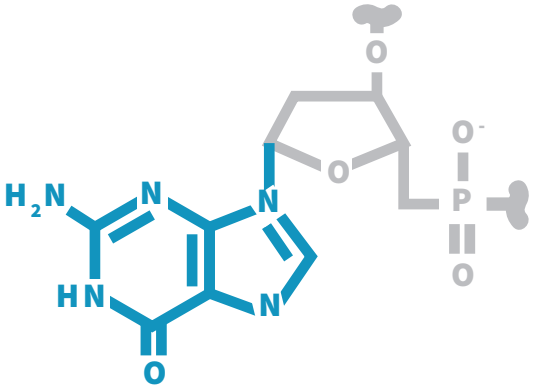
Sugar Phosphate Backbone

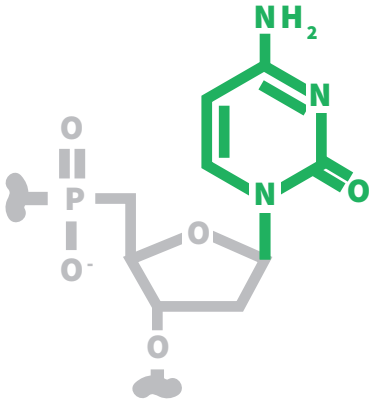


Guanine



Cytosine



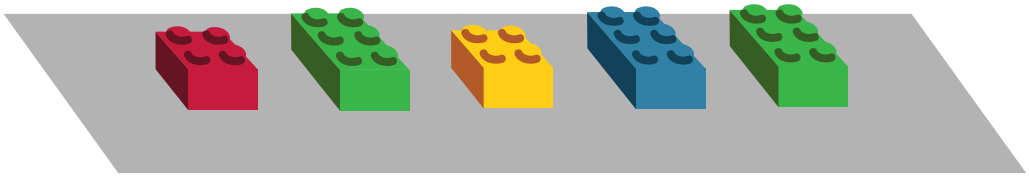


BUILDING YOUR DNA

1. Start building your DNA by adding a nucleotide base to your backbone.

Combine two base plates for a super long sugar phosphate backbone!

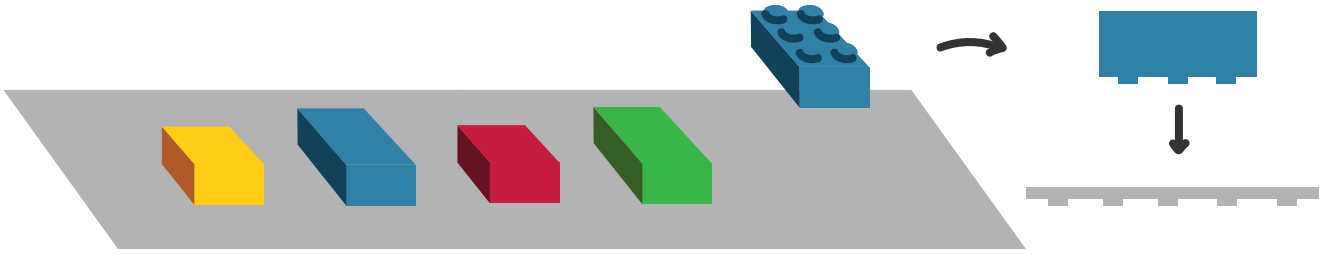
2. Keep adding bases onto your backbone until it is completely filled.



And... presto! You've built your first strand of DNA!

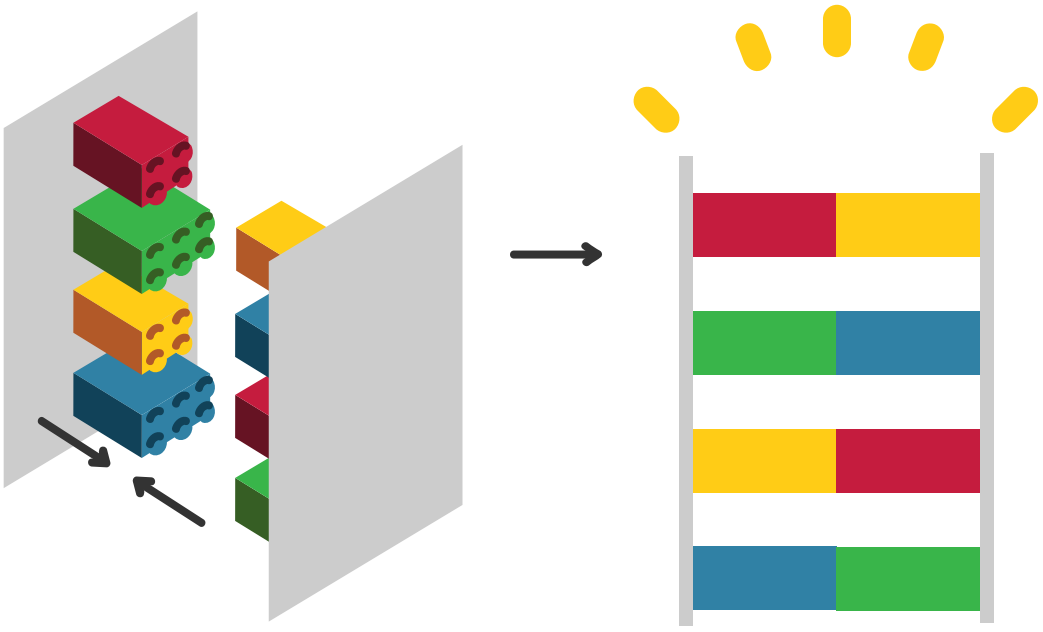
3. We still need another strand to complete our DNA. Using another set of grey plates and bases, build a "sister" strand.

Make sure to build your 2nd DNA strand face down so that you can connect both strands in step 4!



4. When building your sister strand, make sure your nucleotides "base pair" correctly.

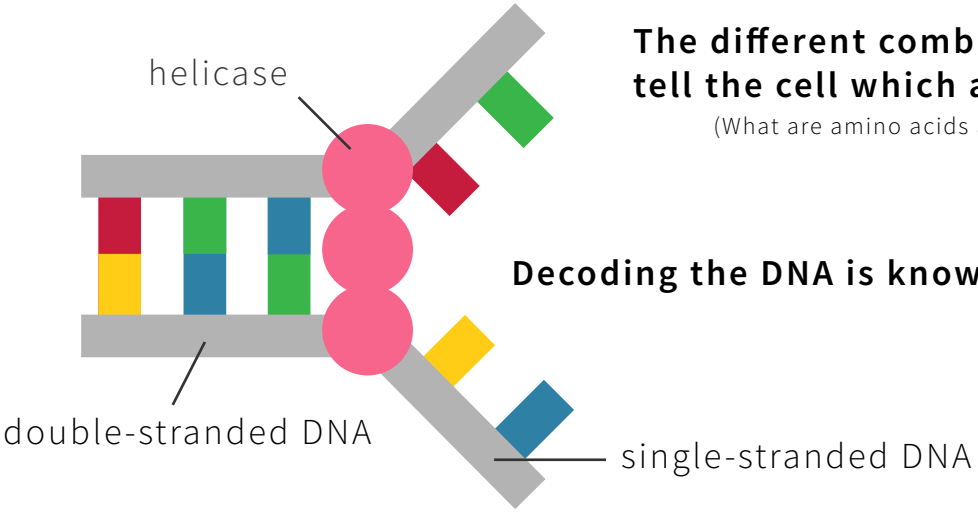
5. Now that you have both strands built, bring them together to complete your DNA. If you base paired everything correctly, it should be a seamless fit!



Whoo! You just built some DNA!

Now, what can we do with it?

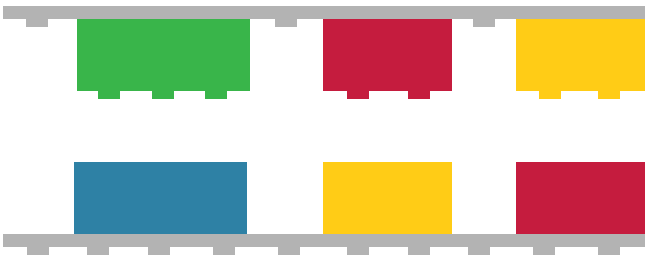
DECODING YOUR DNA



The different combinations of bases tell the cell which amino acid to make.
(What are amino acids and what do they do?)

Decoding the DNA is known as "transcription."

1. **In the first step of transcription, DNA is unwinded by helicase. So, you'll need to separate your strands and pick one side to read.**

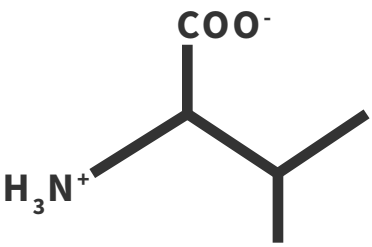


Pull apart the DNA you worked so hard to make!

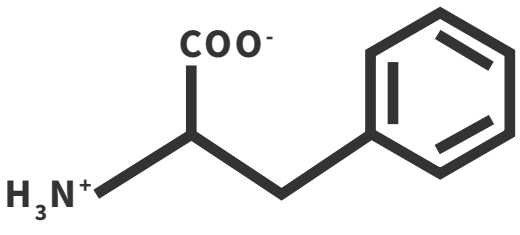
In order to read DNA, we only focus on one strand.

(What does this combination of bases spell out?)

2. **Read your strand from left to right. What bases do you have? Write them down, and compare your sequence to the Amino Acid Table to see which amino acid you made!**



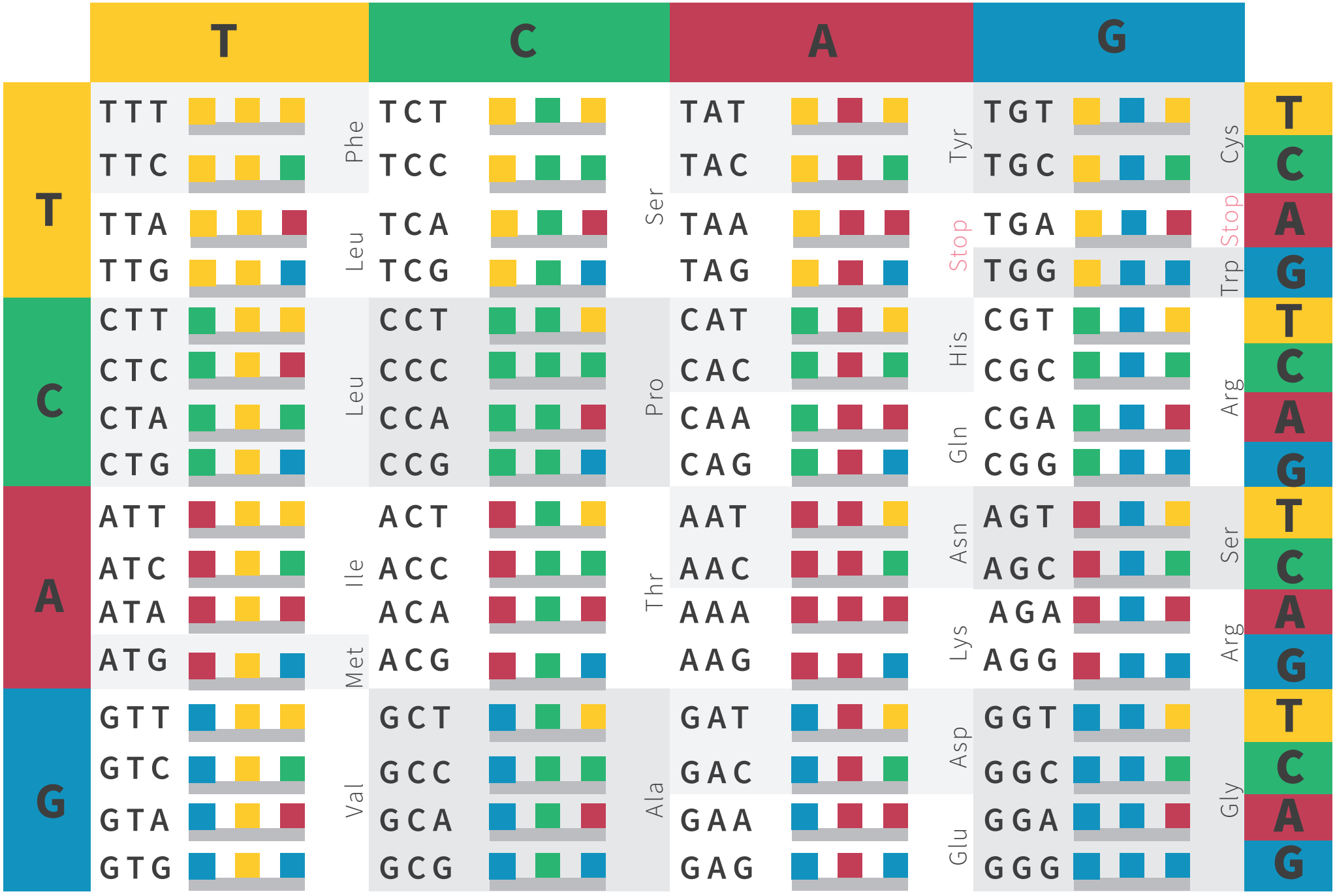
GTA



TTC

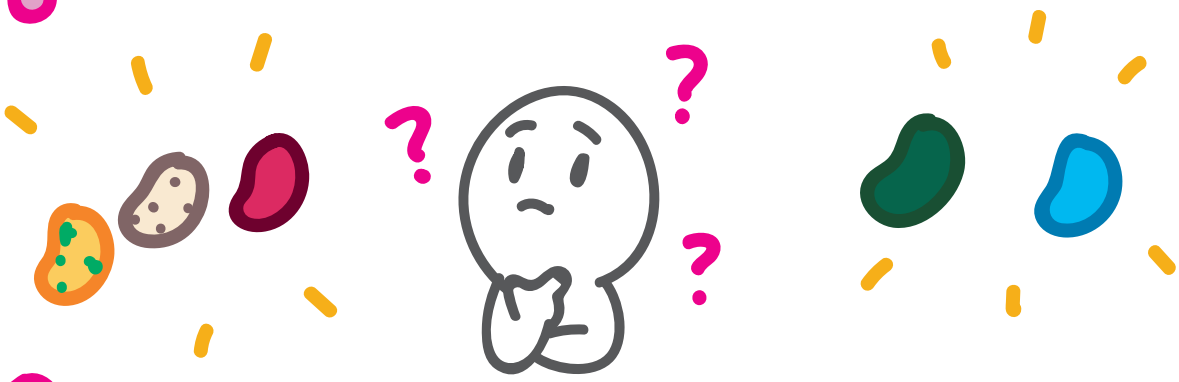
Lego DNA/Jellybean Peptide Activity
Washington iGEM

WHAT IS YOUR AMINO ACID?



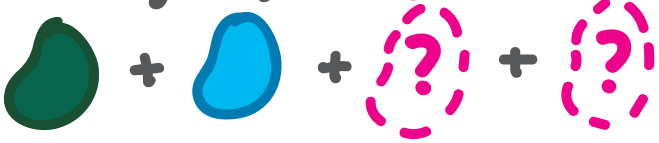
JELLYBEAN PEPTIDE

1 Choose from the list what peptide you want to make



2 Build your peptide according to the amino acid sequence listed on the table

Arg-Tyr-Lys-Phe

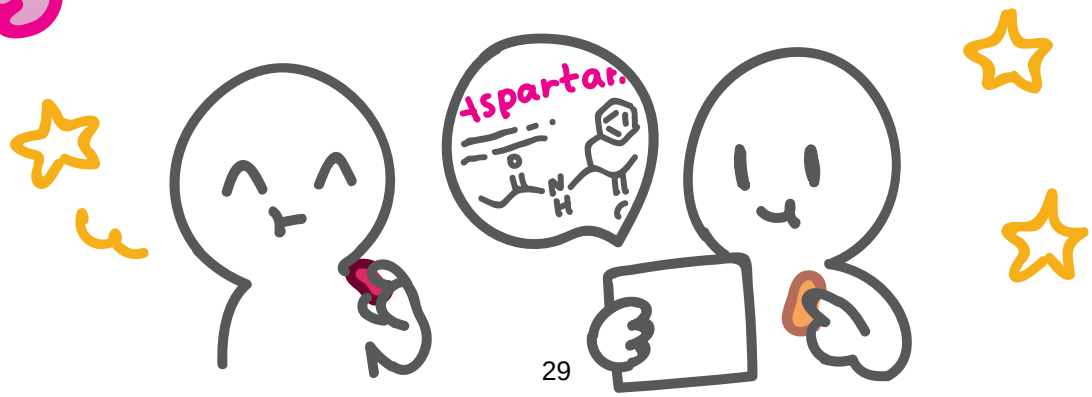


Use marshmallows to “glue” your amino acids together

Check the guide to see what color each amino acid is

Now, that’s a good-looking peptide!

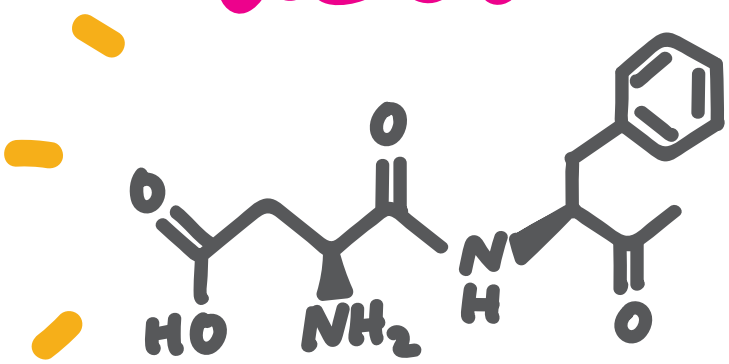
3 Feast on your creation (with your instructor’s permission)!



JELLYBEAN PEPTIDES

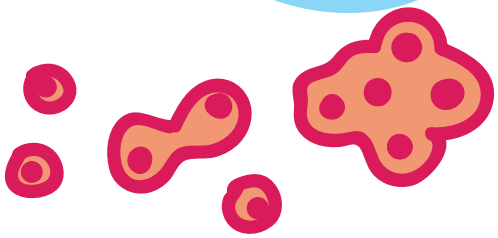
Ala	Island Punch		Ile	Toasted Marshmallow		Arg	Berry Blue	
Cys	Mango		Lys	Cantaloupe		Ser	Red Apple	
Asp	Lemon Lime		Leu	Cotton Candy		Thr	Wild Blackberry	
Glu	Sunkist Orange		Met	Green Apple		Val	Piña Colada	
Phe	Coconut		Asn	Tutti-Fruitti		Trp	Chocolate Pudding	
Gly	French Vanilla		Pro	Bubble Gum		Tyr	Watermelon	
His	Kiwi		Gln	Cinnamon		Stop	Very Cherry	

ASPARTAME



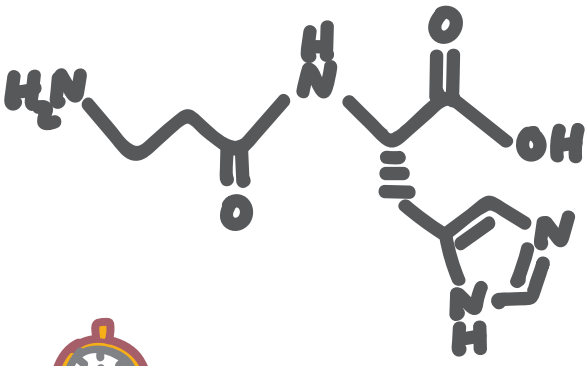
L-Asp
+
L-Phe

Aspartame is a popular sugar subsitute

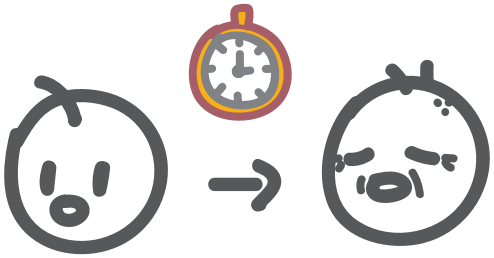


At one point, it was controversial for allegedly causing cancer - this has since been disproven

CARNOSINE

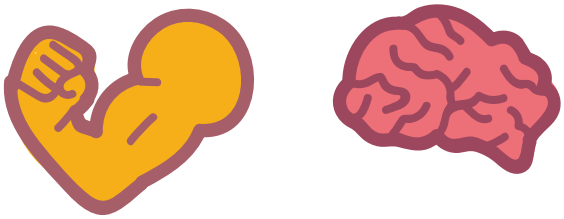


β-Ala
+
His



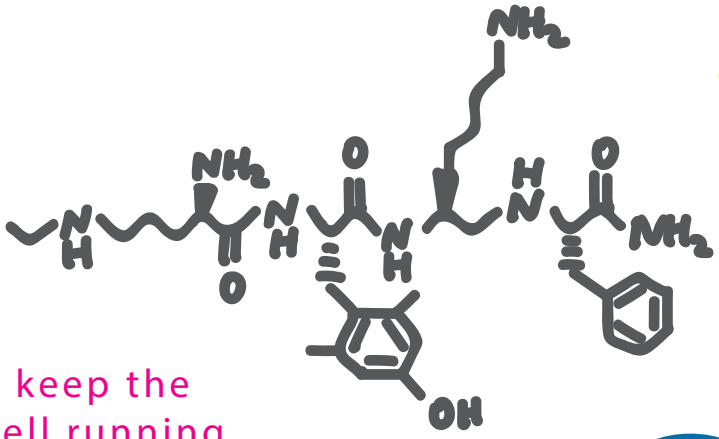
Carnosine is shown to contribute to aging

It is primarily found in muscle and brain tissues of animals

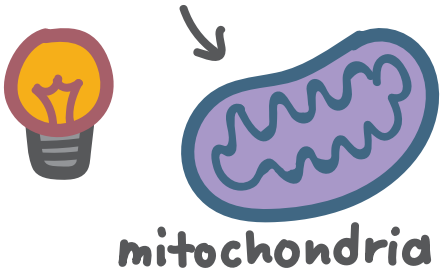


ELAMIPRETIDE

Arg + Tyr
Lys + Phe



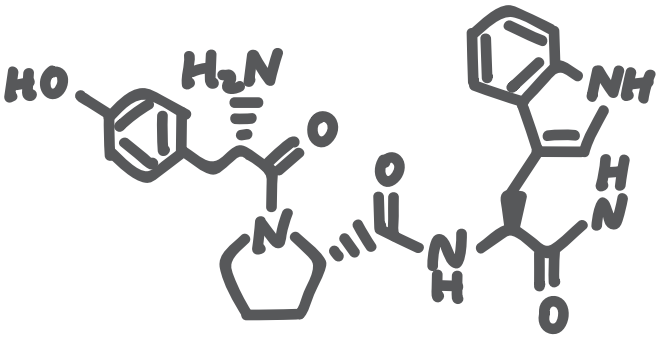
Elamipretide helps keep the powerhouse of the cell running

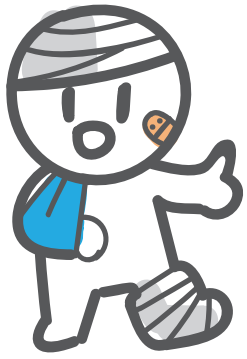


It is an antioxidant, which protects against free radicals

ENDOMORPHIN

Tyr+ Pro
Trp + Phe

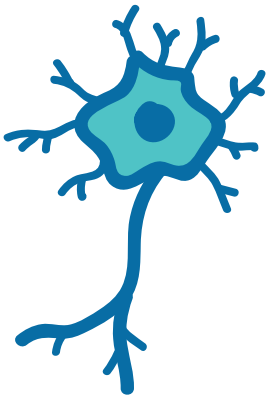




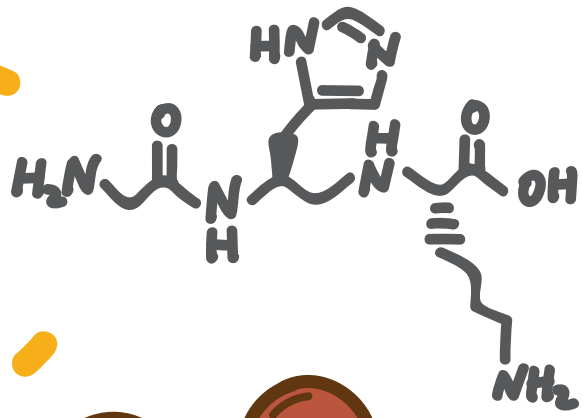
Endomorphin is very important since it helps alleviate pain

It is found in brain neurons

It is also involved in some functions in the immune system



GHK-Cu

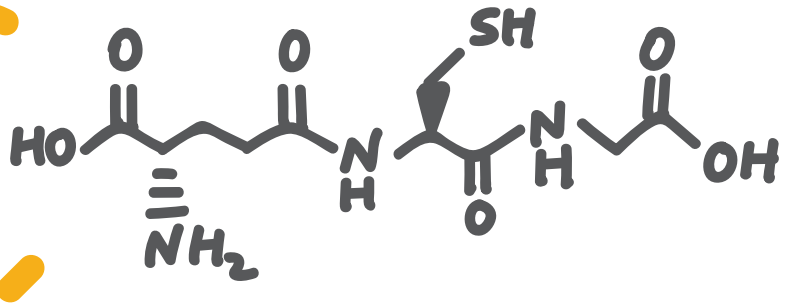


Gly + L-His + L-Lys

It helps heal wounds and repair skin

GHK-Cu is a copper peptide, and has a very high affinity for copper

GLUTATHIONE

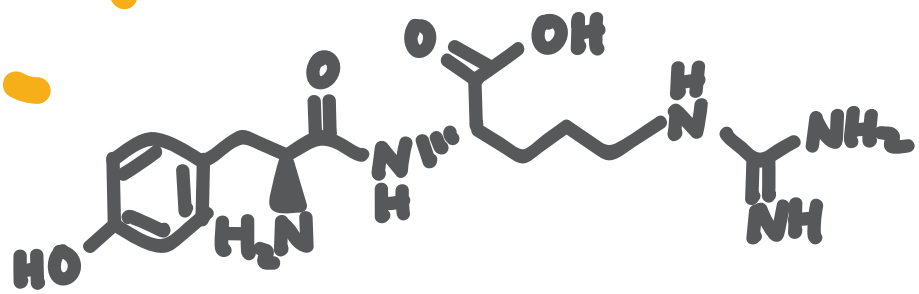


Cys + Gly + Glu

Like elamipretide, glutathione is also an antioxidant

It prevents damage to cells caused by free radicals and heavy metals

KYOTORPHIN



L-Tyr + L-Arg

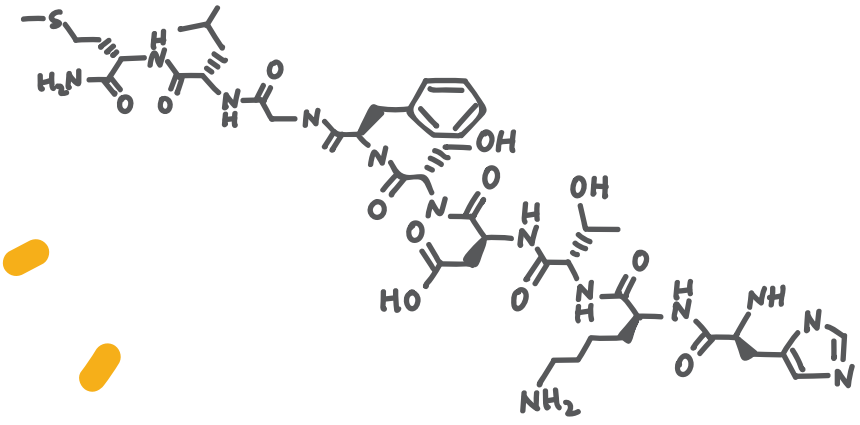
Kyotorphin was discovered in Kyoto, Japan

loading . . . . . ouch!

It is involved in pain processing and regulation

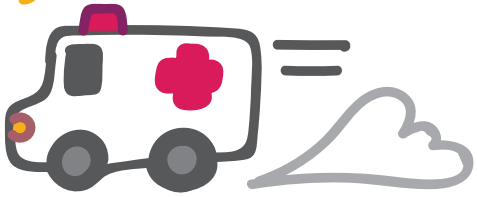
Patients with chronic pain have lower Kyotorphin levels than normal

NEUROKININ



His + Lys
Asp + Ser
Phe + Val
Gly + Leu
Met

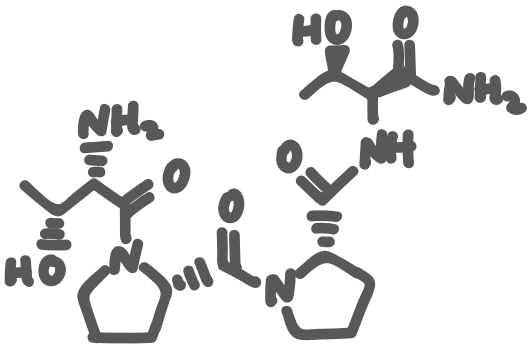
Neurokinin plays a major role in immediate pain and infection repsponses



It helps inflame areas of pain and attracts white blood cells

RAPASTINEL

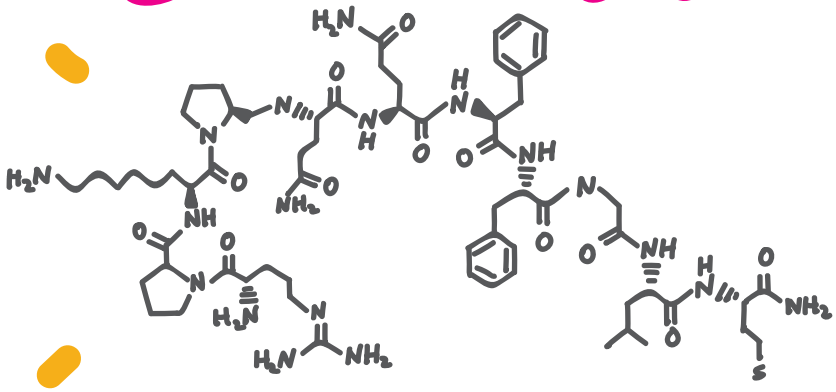
Thr + Pro
Pro + Thr



It improves brain function by regulating sent messages

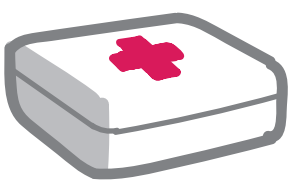
Rapastinel is a relatively new peptide involved in antidepressants

SUBSTANCE P



Arg + Pro + Lys
Pro + Glu + Glu
Phe + Phe + Gly
Leu + Met

Substance P serves as the body's immediate defense reponse



The "P" stands for "Preparation"

- [x] stay alert
- [x] be everywhere
- [ ] kick butt

It is found in many cells throughout the body

PROGRAMMING & SIMULATION ACTIVITY

The goal of this activity is to...

- Learn the basics of programming through a straightforward drag and drop interface.
- Give an interesting and exciting overview of how computer science and biology intersect!

LOGISTICS

- This activity can be run using a single computer in a classroom, in groups, or individually if more computers are available.
- An instructor should run the activity using the "Instructor Guide" provided.
    - We highly recommend that the instructor gets familiar with Scratch before running the activity to explain concepts and show examples.
- The instructor should give the students the provided handout worksheet at the start of the activity.
- Then, throughout the activity, students combine what they have done, and try to mimic an assigned biological model. (Predator/Prey)

SUPPLIES/COST

- Need access to a computer, at least one.
    - If there is only one computer available, this activity can be used as a demo.
    - However, if there are more computers available, each student can work on it.
- Internet access to **beta.scratch.mit.edu**

INSTRUCTOR HANDOUT

****Before the instructor uses this handout, we highly recommend that the instructor look over the student handout.****

PART 1: LEARN

Goal: In this section, the instructor should show students how to access Scratch, navigate the interface, and walk through some basic blocks and simple programs. There is a hand-out to give to the students, and the instructor should follow along when explaining the students.

1. The instructor should direct the students to the website (beta.scratch.mit.edu), and show the students the main buttons and sections to demonstrate how to navigate the website.
    a. This includes describing what is in the four colored boxes on the handout.
2. It is then up to the instructor to let the students work on the handout by themselves, or to go through the handout and give further insight to each part.

PART 2: PRACTICE

Goal: In this section, the instructor should give the students three example problems and have them work through them. Then, the instructor should walk through the solution to give the students a better understanding.

First Problem: Make the Cat sprite move around randomly but not move instantly. Then, add in a second sprite, the Chick, scale both down to 50%, and make the Chick also move around randomly.
Solution: Simply use the [glide (x) secs to random position] block!

Second Problem: Have both the Cat and the Chick create another of itself at some rate.
Solution: Put a clone itself block in the last part of the handout!

Third Problem: Make it so that when the Cat and the Chick touch each other, the Chick "turns into" the Cat.
(Hint: This is related to the last problem!)
Solution: Make it so that when the Cat and Chick touch, the Cat clones itself and the Chick gets deleted!

PART 3: APPLY

Goal: Now that the students have basic skills in Scratch, read the predator/prey model to the students and tell them to make adjustments to their program to depict this model.

Predator/Prey: This is a useful model used by biologists to show how the populations of different animals change.

PART 4: REFLECT

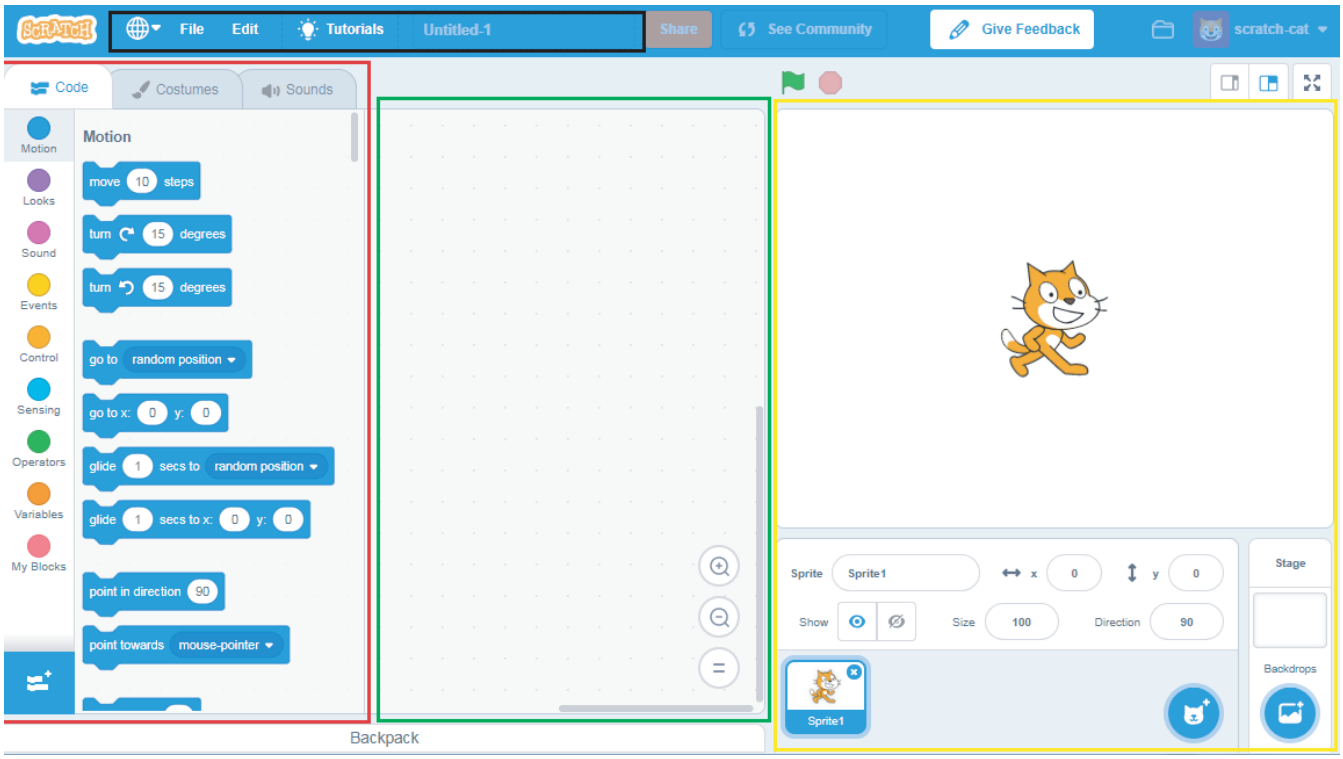
Discussion: Have them think about other things they could model or make, and what they want to learn next. Additionally, discuss the application to simulating a protein in biology.

STUDENT HANDOUT

Link to Scratch: **beta.scratch.mit.edu**

Scratch is a simple to use language for learning programming in a visual way. You take blocks from the left side, put them together in the middle, add an event block on top, and watch what happens on the right side!

Interface - Look at the colored boxes in the images below.



Black - You can save your work up here from the File menu.

Red - These are the different blocks that you can use as the pieces of your program.

Green - This is where your program lives. Drag the blocks and connect them here. The block on the top is completed first and then completed in order until the last block.

Yellow - This is where you can edit your sprites and see your program in action. You can also add more sprites (each with their own programs!) by clicking the blue and white cat button, or change the background with the blue and white picture button.

GUIDE TO THE BLOCKS

Event Blocks

- These blocks are used to run the different sections of your code.
    - These blocks are required, but you can also click the different parts of your code to make them run.

Motion Blocks

- These blocks are self-explanatory; they make the sprite move!

Control Blocks

- These blocks are the main part of your program that will be used to control the sprites.

“Loop” blocks

- Repeat - This block will repeat the blocks that you put inside of it before moving on to the next block.

Forever - Like the repeat block, but will never move to the next block.

Wait - Essentially a repeat loop block that repeats until x seconds have passed.

“If/then” blocks

- These form the basis of your logic, and require the addition of operator blocks.
- If <>, Then - This block says that if the statement in the space evaluates to true, then the blocks inside of it will run next.
    - If the statement is false, then the contents are skipped.
- If <>, Then, Else - Like the previous block, but if the statement inside is false, then the “else” contents are ran instead.

“Until” blocks

- These blocks are a combination of the “If/then” and “Loop” blocks, they will repeat or wait until the statement is true.

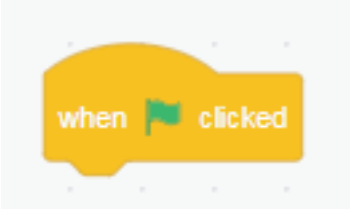
Operator Blocks

- These blocks are used together with control blocks for logic. They evaluate the statement inside of them to be either true or false.

ACTIVITY

Now that you have learned about the controls, it is time to test them out!

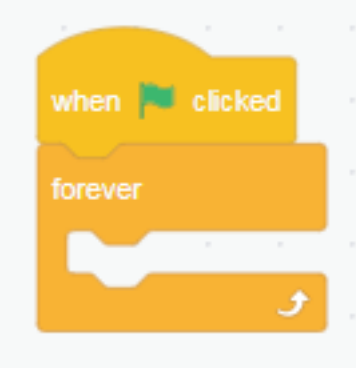
First Program:
The first thing we are going to do is grab an *event block*. The event block that we want to use has a green flag:



This makes it so that when the green flag next to the sprite area is clicked, the blocks that are connected to it will run from top to bottom.

After this, we want to make the sprite continually move and turn. To do that, we are going to use a couple different blocks.

The first block we are going to connect to our event block is the *repeat forever block*:

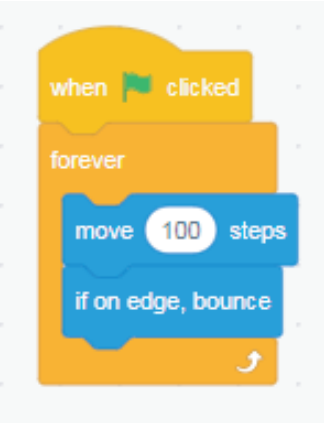


This means that whatever we put inside of the *forever block* will always happen until we click the stop sign.

The next block we want to use is a *move block*. For this, we are going to use the *move steps block.*

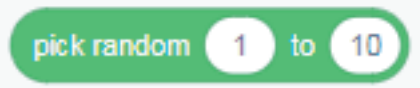
The “10” can be changed to whatever number you like. Now run the program by pressing the green flag. What do you see?

You should see the cat getting stuck inside the right wall. Now to fix that, we are going to make him bounce off the wall. For that, we are going to add this block:



You should now see the cat bouncing back and forth off the walls.

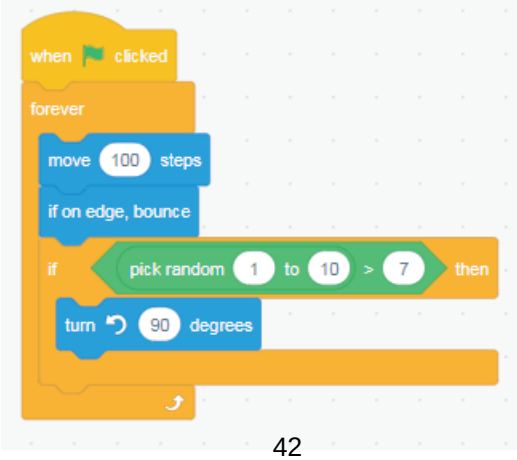
Now say we want our sprite to do something, but not every time. For this we can use an *if statement*. What we are going to do here is use the *random block*:



This will pick a random number between those two values. Then we will use an operator on the *random block*, and say if that random number is a above 7, this will be true:

Now if we put this combination into an *if/then block*, and put a *turn block* inside of that:

The sprite will now turn, but only once in awhile.



Now, take what you have learned and do these three problems!

1. Make the Cat sprite move around randomly, but not move instantly. Then add in a second sprite, the Chick, scale both down to 50%, and make the Chick also move around randomly.

2. Have both the Cat and the Chick create another of itself at some rate.

3. Make it so that when the Cat and the Chick touch each other, the Chick "turns into" the Cat. *(Hint: This is related to the last problem!)*

APPLICATION TO BIOLOGY

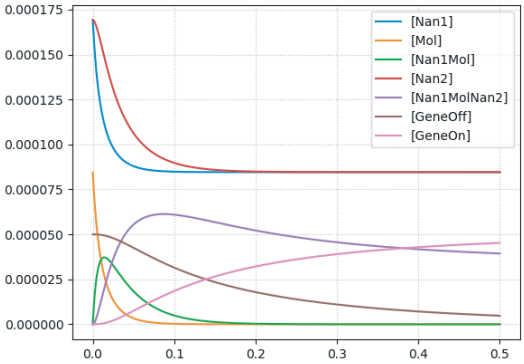
Now that you have learned the basics of programming, it's time to see how programming is used in the real-world, including in biology!

- With computers and math, we can model the complex behaviour of synthetic organisms and see how they might behave before physically creating them.
- Programming is also vital to generating images in biology!
- The image below was generated by Rosetta using programming to predict and visualize the structure of proteins, providing further information in designing organisms.

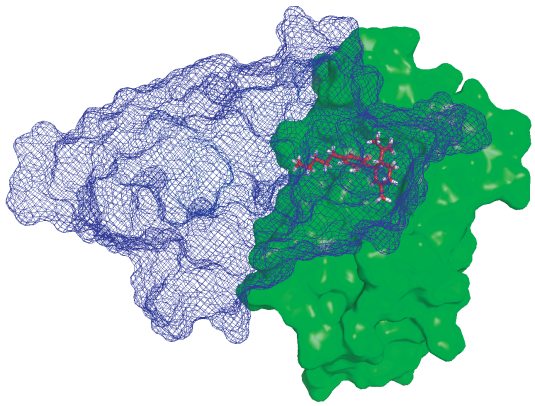
```
r = te.loada ('''
model feedback()
  // Reactions:
  J0: Nan1 + Mol -> Nan1Mol; (K1*Nan1*Mol);
  J1: Nan1Mol -> Nan1 + Mol; (K_1*Nan1Mol);
  J2: Nan1Mol + Nan2 -> Nan1MolNan2; (K2*Nan1Mol*Nan2)
  J3: Nan1MolNan2 + GeneOff -> GeneOn; (K3*Nan1MolNan2*GeneOff);
  //J4: GeneOn -> Nan1MolNan2 + GeneOff; (K_3*GeneOn);

  // Species initializations:
  Nan1 = 0.0001692; Mol = 0.0001692/2; Nan2 = 0.0001692; Nan1Mol = 0;
  Nan1MolNan2 = 0; GeneOff = 5*10^-5; GeneOn = 0;

  // Variable initialization:
  K1 = 6.1*10^5; K_1 = 8*10^-5; K2 = 3.3*10^5; K3 = 1*10^5; K_3 = 0;
end''')
```



An actual model used by our team!



Protein visualization from Rosetta

ENZYME ACTIVITY PART ONE: PINEAPPLE ENZYME & GELATIN

The goal of this activity is to...

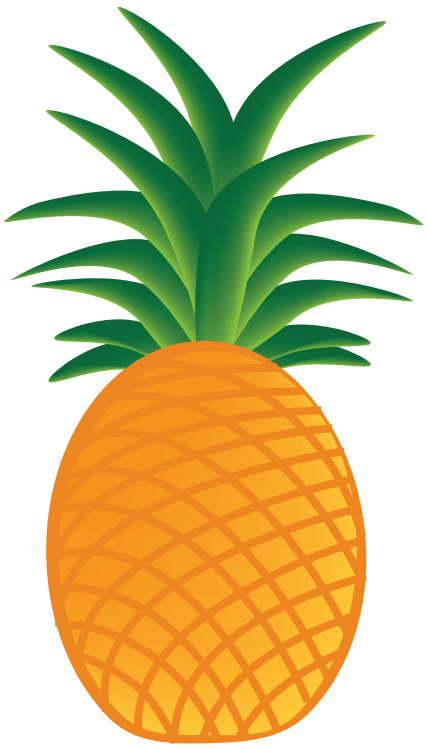
- Learn about what an enzyme is
- Understand the scientific process - what makes a good experiment?
- See how enzymes work through a pineapple enzyme and gelatin experiment

LOGISTICS

- This experiment should take 15 minutes to perform and results can be seen in ~4 hours .
- Prepare necessary supplies beforehand as it may be time consuming to do during experiment.
- Distribute handout and necessary supplies.
- Allow students time to read over the introduction and answer pre-lab questions. Have students share their questions and hypotheses.
- Divide students into groups and execute the experiment
- Have students complete post-lab questions and discuss the questions afterwards to ensure students have properly understood the key concepts and definitions introduced in this activity.

SUPPLIES/COST

- Handouts
- Two containers of gelatin
- 3 bowls
- 3 coins
- Fresh and canned pineapple chunks
- Spoon
- Water
- Kettle
- Measuring cup



POST-LAB QUESTION SAMPLE ANSWERS (FOR INSTRUCTOR USE)

- **What happened to the gelatin in each of the bowls?**
  The gelatin in the bowl with fresh pineapple should have liquefied while the jello in the other two conditions stayed the same.

- **What do you think caused the changes or no changes in the gelatin?**
  The gelatin with fresh pineapple had an active enzyme present to break down the collagen in the jello, which is why we see it liquefy. The bowl with canned pineapple must not have any active enzymes present. The process of canning pineapple must denature its enzymes to render them inactive. The bowl with no pineapple at all simple had no additionally changes to it which is why we don't see it change.

- **Do you think this experiment would work the same if we replaced jello with styrofoam (styrofoam is not made of collagen)?**
  No. As we learned earlier, enzymes are very specific and only work on specific molecules. In this case, bromelain only works on collagen, which styrofoam is not made of.

- **Did the results surprise you? Why or why not?**
  Open ended.

- **What was our enzyme and substrate in this experiment?**
  Enzyme: bromelain
  Substrate: collagen

- **Why did we have a bowl with just jello and nothing else?**
  This bowl was our control. We used it to compare what changed vs. unchanged jello looks like.

- **Create one new testable question regarding enzymes.**
  Open ended.

- ***Challenge:* How do you think the activation energy for breaking down the collagen in the bowl with no pineapple/canned pineapple compares to the activation energy in the bowl with fresh pineapple?**
  The activation energy required for breaking down the collagen in the bowl with fresh pineapple present must have been lower than in the bowl with canned/no pineapple.

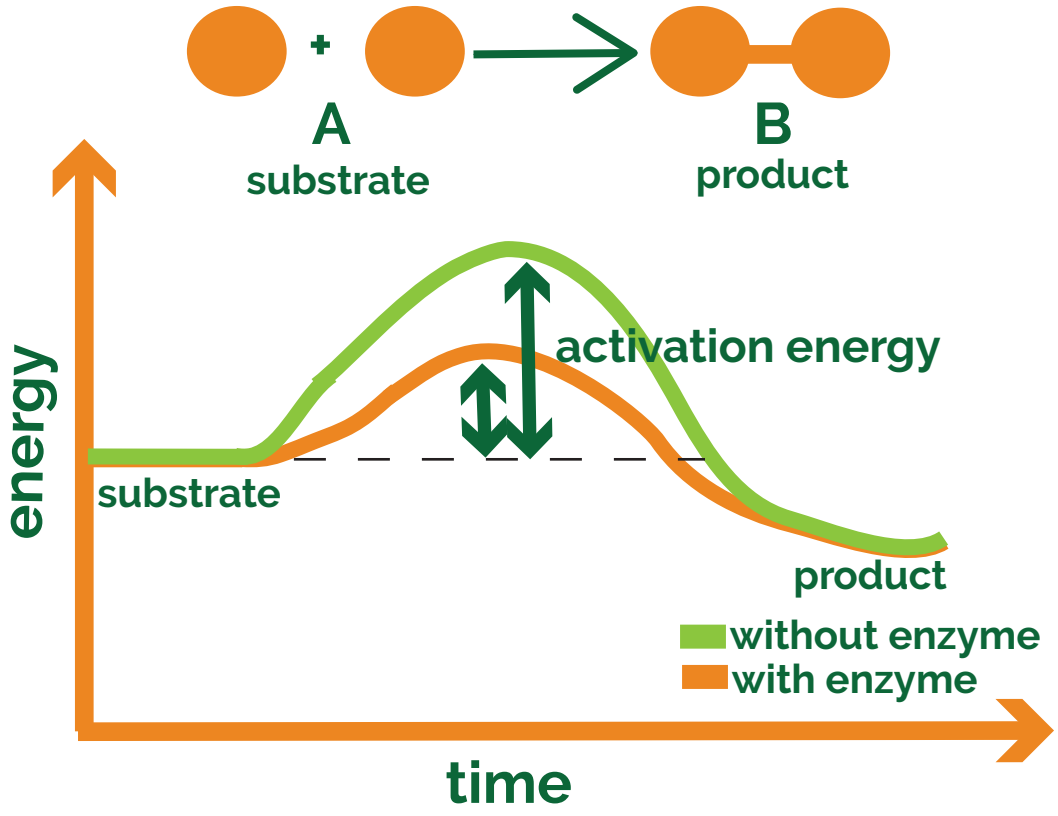
WHAT ARE ENZYMES?

Today, you will be exploring the world of enzymes by executing an experiment involving pineapples and gelatin. Before we move on, however, what is an enzyme?

Enzyme: Enzymes are proteins that act as biological catalysts. A biological catalyst speeds up chemical reactions. Chemical reactions involving enzymes occur throughout your body.

Imagine this - you have a bunch of molecules floating in space and they come into pairs about one per minute. What if you could have them pairing up at the rate of one per second? That is the job of enzymes - to act as these catalysts that speed up reactions like these. On their own, these reactions would maybe still occur (some of them), but enzymes help in making these processes go a lot faster.

Let's say that originally, amount of **activation energy** required to get from point A to point B is 100 joules (J). The activation energy is simply defined as the minimum amount of energy needed in a chemical reaction to get from point A to B. By adding an enzyme to the reaction, we've effectively lowered the activation energy from 100 J to 10 J. With enzymes, reactions have a much smaller "hill" to climb to get to their final products.



Most enzymes have very specific targets, or **substrates**, and produce **products.**

Equation:

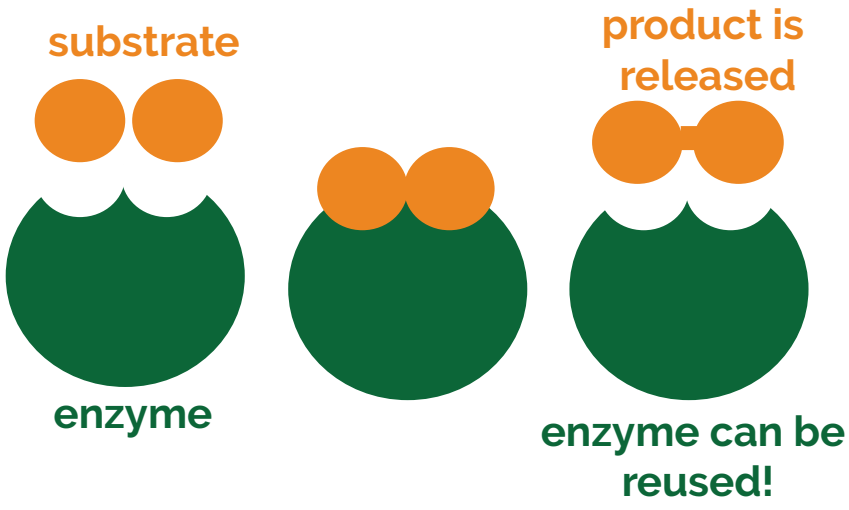
SUBSTRATE —(**enzyme**)→ **PRODUCT**

They play an important role in breaking down our food so our bodies can use it. There are special enzymes to break down different types of foods. They are found in our saliva, stomach, pancreas, and small intestine.

For example, there is an enzyme called lactase found in the small intestine that breaks down lactose from milk into two smaller sugar molecules known as glucose and galactose. If lactose is not broken down properly, it causes digestive issues. People who don't have this enzyme, lactase, have what's known as lactose intolerance because they are unable to break lactose down into its smaller component parts. In this example, lactose is the **substrate** of lactase and glucose and galactose are its **products.**

Enzymes also require very specific conditions to work at their most optimal rates. These conditions include pH, temperature, salinity, and whether or not certain molecules are present. If an enzyme is not in it's preferred working conditions, it will be unable to do its job and may about **denature**, which is to lose its structure and ultimately function.

Try to keep these things in mind as we move on to the actual experiment.



PINEAPPLE ENZYME & GELATIN LAB

Have you ever seen fresh pineapple and gelatin in one dish together? Probably not! We're going to explore the reason as to why that is so today.

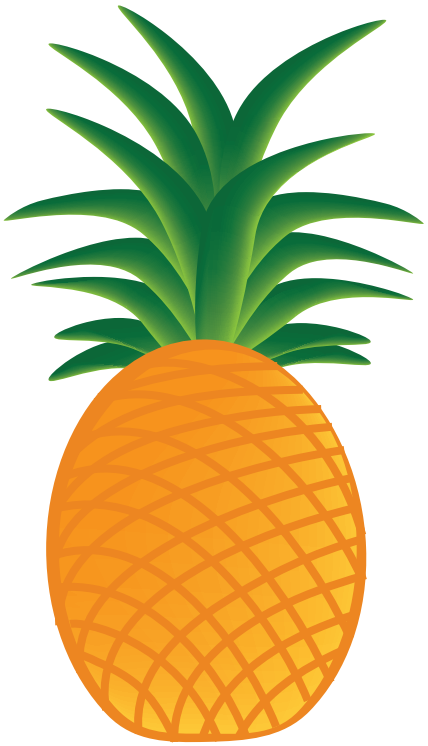
Here are some things you should know about gelatin and pineapples:

- Gelatin is made up of a protein called ***collagen.*** When gelatin is heated and then cooled, it forms into a semi-solid mass.
- Pineapples belong to a group of plants called Bromeliads. There is an enzyme in pineapples called ***bromelain*** that is responsible for the breakdown of collagen.

With this in mind, what scientific question are we exploring today? Please come up with one below.

1. What is the effect of _____ on _____?

2. What is your hypothesis or prediction for the outcome of this experiment?



EXPERIMENTAL DESIGN

- Before scientists conduct experiments, they must design them.
- Scientific experiments have a few variables:
    - ***Controlled Variables:*** Things that are consistent and kept the same throughout the experiment.
    - ***Independent Variable:*** The aspect that is changed. Usually, you only have one manipulated variable at a time.
    - ***Dependent Variable:*** What is being measured.
- You will be making three bowls of jello: one with fresh pineapple, one with cooked pineapple, one with nothing but the gelatin.
- With this in mind, answer the questions below:

1. What are some controlled variables?

2. What is the manipulated variable?

3. What is the responding variable?

EXPERIMENTAL PROCEDURE

1. In 3 separate bowls, mix gelatin powder with warm or hot water according to the package's instructions.
2. Label containers "fresh", "canned" and "just gelatin".
3. Add the appropriate pineapple chunk samples to the gelatin and water mixture.
4. Let the gelatin set for three to four hours.
5. Observe what happens over the course of this time and take notes at 1 hour intervals.
6. Record observations in a table on the next page.
7. You can see how well the gelatin has set in each sample by dropping a penny into it. If the gelatin has not set, the coin will sink to the bottom.
8. Clean up and share results.

Draw a table and record your results on this page.

POST-LAB QUESTIONS

- What happened to the gelatin in each of the bowls?

- What do you think caused the changes or no changes in the gelatin?

- Do you think this experiment would work the same if we replaced jello with styrofoam (styrofoam is not made of collagen)?

- Did the results surprise you? Why or why not?

- What was our enzyme and substrate in this experiment?

- Why did we have a bowl with jello and nothing else?

- Create one new testable question regarding enzymes.

- ***Challenge:*** How do you think the activation energy for breaking down the collagen in the bowl with no pineapple/canned pineapple compared to the activation energy in the bowl with fresh pineapple?

ENZYME ACTIVITY PART TWO: POTATO CATALASE LAB

The goal of this activity is to...

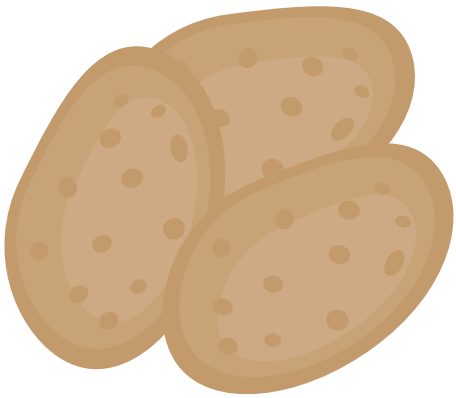
- Develop a further understanding about the mechanics of enzymes through an experiment using potatoes
- Comprehend and apply the components of a chemical reaction
- Comprehend that factors like temperature and pH can denature enzymes

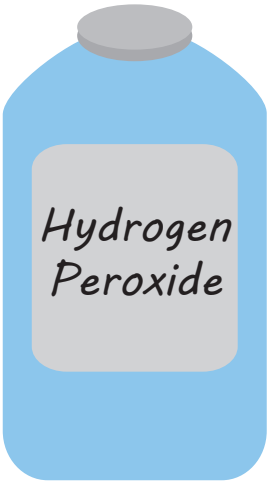
LOGISTICS

- Cut potatoes into small chunks, freeze, and boil before the lesson.
    - Also, prepare lemon puree and saline solution before the lesson.
- Teach students about how enzymes work and their purpose.
    - Use handouts from Enzyme Activity Part One
- Allow the students to conduct the experiment with potatoes and hydrogen peroxide
- Allow the students to answer the discussion questions

SUPPLIES

- Cut Potatoes
    - Some will need to be frozen
    - Some will need to be boiled
    - Some will be from reuglar room temperature
- Hydrogen peroxide
- Cups
- Lemon Puree
- Saline solution(pre-mix salt with water)





SAMPLE ANSWERS TO DISCUSSION QUESTIONS (FOR INSTRUCTOR USE)

PRE-LAB QUESTIONS

1. What is the substrate (reactant) in the reaction?

H2O2 (catalase)

2. What are the products of the reaction?

H2O and O2 (water and oxygen)

3. Taking into account the function of enzymes, do you think this reaction would would happen without a catalase?

The reaction would not have occurred quickly, because as an enzyme, catalase simply lowered the activation energy, speeding up the reaction. In theory, the reaction would have occurred eventually.

4. If there is no evidence of a reaction when it could have occurred, what might have happened to the enzyme?

The enzyme denatured.

5. How do you think temperature, pH, and salinity would affect the reaction (increase or decrease enzyme activity)?

Temperature: decrease
pH: decrease
Salinity: decrease

Note: Students might not get this question; this is just a space for them to hypothesize before conducting the experiment

FINAL DISCUSSION QUESTIONS

1. Why did bubbles form when the reaction occur? Taking into account the chemical equation, what is the gas?

Oxygen is a byproduct of the reaction.

2. Why were there fewer to no bubbles in some of the manipulations? What must have happened to the enzyme?

The reaction did not occur, because the enzyme denatured.

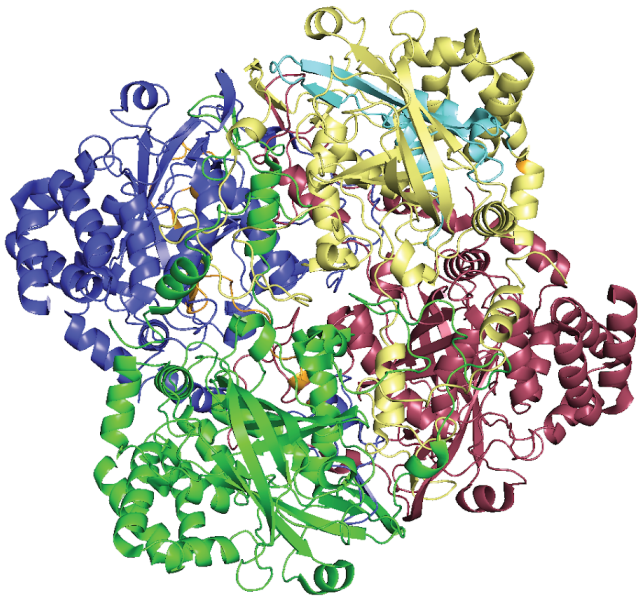
Note: No sample answers are given for the data table, as answers may vary. However, there should be little to no bubbles for the boiled potatoes, potatoes in acidic solution.

POTATO CATALASE LAB INTRODUCTION

- Enzymes are proteins that speed up the rate of a reaction by lowering the activation energy!
- Catalase is an enzyme found in the cells of many living organisms, including humans and fruits and vegetables.
- Catalase protects cells from peroxide, which is a byproduct of many regular cellular reactions.
- The reaction is:

  $2\ H_2O_2\ (l) \longrightarrow 2\ H_2O\ (l) + O_2\ (g)$

- If cells did not break down peroxide, they would become toxic and eventually die...



Molecular structure of Catalase

PRE-LAB QUESTIONS

1. What is the substrate (reactant) in the reaction?

2. What are the products of the reaction?

3. ***Challenge:*** Taking into account the function of enzymes, do you think this reaction would happen without catalase?

4. If there is no evidence of a reaction when it could have occurred, what might have happened to the enzyme?

5. How do you think temperature, pH, and salinity would affect the reaction (increase or decrease enzyme activity)?

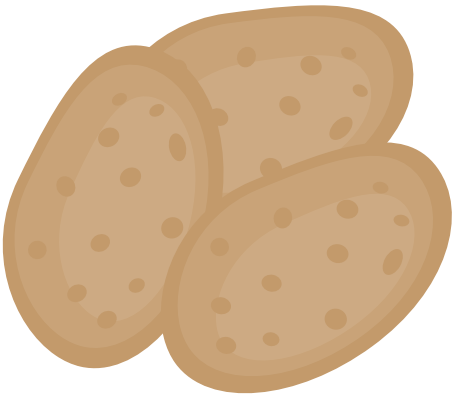
    Temperature:

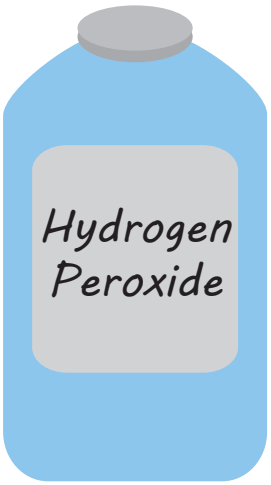
    pH:

    Salinity:

POTATO CATALASE LAB PROCEDURE

1. Label five plastic cups from 1 to 5. See data table for manpulations.
2. In cups 1, 4, and 5, place one tablespoon of the cut potatoes at room temperature.
3. In cup 2, place one tablespoon of the cut, frozen potatoes.
4. In cup 3, place one tablespoon of the cut, boiled potatoes.
5. In cup 4, add two tablespoons of lemon puree and mix with the cut potatoes.
6. In cup 5, add two tablespoons of saline solution and mix with the cut potatoes.
7. At approximately the same time, add hydrogen peroxide to each of the cups. There should be enough hydrogen peroxide that the cut potatoes are submerged.
8. Record observations in the data table and answer the discussion questions.





DATA TABLE

Cup	Manipulation	Relative Amount of Bubbles*	Other Observations
1	Control (Potatoes at room temp.)		
2	Frozen potatoes		
3	Boiled potatoes		
4	Potatoes in lemon puree (Low pH, acidic solution)		
5	Potatoes in saline solution		

**Rank on a scale of 1 to 5, with 1 being the lowest and 5 being the highest*

DISCUSSION QUESTIONS

1. Why did bubbles form when the reaction occurred? Taking into account the chemical equation, what is the gas?

2. Why were there fewer to no bubbles in some of the manipulations? What must have happened to the enzyme?

DRAGON GENETICS ACTIVITY

The goal of this activity is to...

- Develop a further understanding about how genetics are passed down
- Comprehend the difference between key phrases like heterozygous and homozygous, recessive and dominant alleles, and genotype and phenotypes
- Develop an understanding of how Punnett squares work

LOGISTICS

- Give each student a worksheet and coin.
- Have each student complete creating a parent dragon portion of the activity
    - Younger/less advanced students can stop here, as the next section is about Punnett Squares.
- Then, have students read and learn about Punnet Squares (worksheet provided) and have them pair up with another student.
    - One student's parent dragon from the first part of the activity will be the "mom," and another student's parent dragon will be the "dad."
- Using this information, the students can now complete the Punnett square portion of the activity and create a baby dragon.
- Finally, as a class, share all the baby dragon drawings, and discuss how the activity is applicable in the real world.

ADDITIONAL INFORMATION

- This is an adapted version of the Dragon Genetics activity from Science Kit & Boreal Laboratories (47794).
- Washington iGEM's version of the activity has a greater basis on genetics concepts, & all images provided are created by Washington iGEM.

SUPPLIES/COST

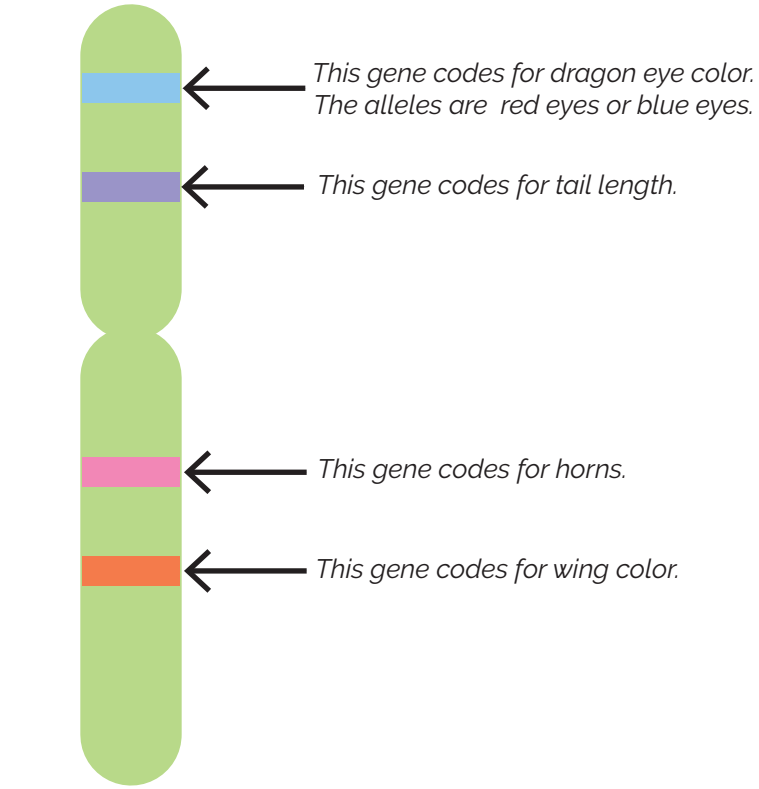
- Worksheet for each student
- Colored pencils or markers
- Coin for each person
- Paper clips for each pair of students

DRAGON GENETICS ACTIVITY

- Through this activity, your goal is to make a dragon based on genetic concepts!
- Traits are passed on through DNA, and segments of DNA are called **genes.**
- **Genes** code for traits, like what color hair you have!
- Alternative forms of genes are called **alleles.**
    - **Alleles** can be ***dominant*** or ***recessive.***
    - Dominant alleles are always expressed, but recessive alleles are only expressed with the absence of dominant alleles.
    - Letters are used to represent alleles.
        - Dominant alleles use capital letters.
        - Recessive alleles use lowercase letters.
- **Dominant alleles:** requires one dominant allele for trait to be expressed.
  (Example: ***XX*** and ***Xx*** would express the dominant trait)
- **Recessive alleles:** requires two recessive alleles for trait to be expressed
  (Example: ***xx*** would express the recessive trait)

The diagram below depicts a chromosome, which is DNA that has been tightly coiled.

Dragon Chromosome



Note: There are two pairs of every chromosome--one from mom and one from dad
This is why genotypes have two letters. Ex: EE codes for red eyes

ADDITIONAL TERMINOLOGY

Genotype: The set of genes an organism carries
(Example: XX, Xx, xx are all different Genotypes)
Phenotype: The organism's observable characterizes
{Example: Long tail vs short tail)
Homozygous: Having two identical alleles
(Example: XX and xx)
Heterozygous: Having two different alleles
(Example: Xx)

Time to make a dragon!

Refer to the key below to complete the activity:

DRAGON KEY

Upper case letter = dominant alleles
Lower case letter = recessive alleles

N = long neck **n** = short neck	**E** = red eyes **e** = blue eyes	**B** = colored belly **b** = black belly
H = horns **H** = no horns	**F** = fire breathing **f** = no fire	**TT** = five toes **Tt** = four toes **tt** = three toes
C = colored body **c** = gray body	**L** = long tail **l** = short tail	**X** = small size (XX = female)
S = spikes on tail **s** = no spike	**W** = colored wings **w** = black wings	**Y** = large size (XY= male)

MAKING THE PARENT DRAGON

- To determine what allele to give the dragon, flip a coin:
    - Heads=dominant allele, tails=recessive allele.
- Flip the coin twice for each trait and write down both alleles.
- Repeat the process until all the traits are flipped for and have two alleles. This will be your genetic code for you parent dragon.
- For example, if you are looking at neck length and get heads the first time and tails the second time, the genotype would be Nn.
    - This would be heterozygous, and the phenotype would be long neck.

Record your data in the tables on the next page.

CHROMOSOME PAIR NUMBER 1

Trait	Genotype	Homozygous/ Heterozygous	Phenotype
Neck length			
Eye color			
Horn?			
Spiky?			

CHROMOSOME PAIR NUMBER 2

Trait	Genotype	Homozygous/ Heterozygous	Phenotype
Tail length			
Body color			
Colored wings?			
Number of toes?			

CHROMOSOME PAIR NUMBER 3

Trait	Genotype	Homozygous/ Heterozygous	Phenotype
Belly color			
Color of spikes			

CHROMOSOME PAIR NUMBER 4

Trait	Genotype	Homozygous/ Heterozygous	Phenotype
Fire breathing?			
Dragon size? (sex)			

Now that you have figured out your phenotypes, draw your parent dragon in the space below:

Now that you've learned a bit about genetics, it's time to delve deeper by learning about Punnett Squares!

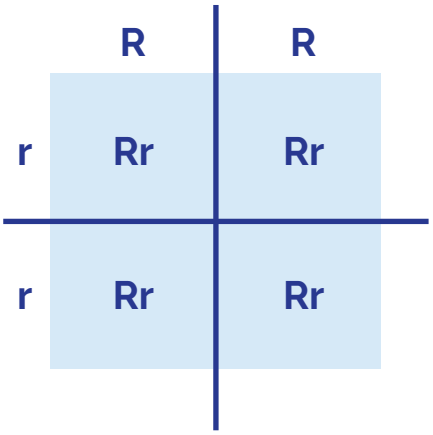
WHAT ARE PUNNETT SQUARES?

- Punnett squares are square diagrams that are used to predict the genotypes of a particular breeding experiment
- The parent genotypes go on the sides of the square, and the offspring genotypes are in the middle.

HOW TO USE A PUNNETT SQUARE

Example 1:

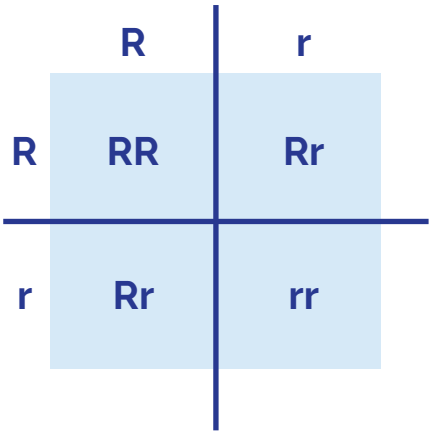
A red rose (RR) is being crossed with a white rose (***rr***).



Genotype: 4 Rr, 0 RR, 0 rr Phenotype = 4 red roses, 0 white roses

Example 2:

A red rose (***Rr***) is being crossed with a red rose (***Rr***).



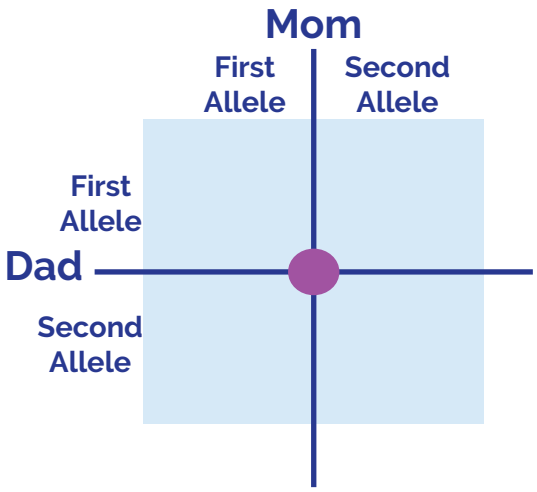
Genotype: 2 Rr, 1 RR, 1 rr Phenotype = 3 red roses, 1 white rose

Your turn to use Punnett squares!

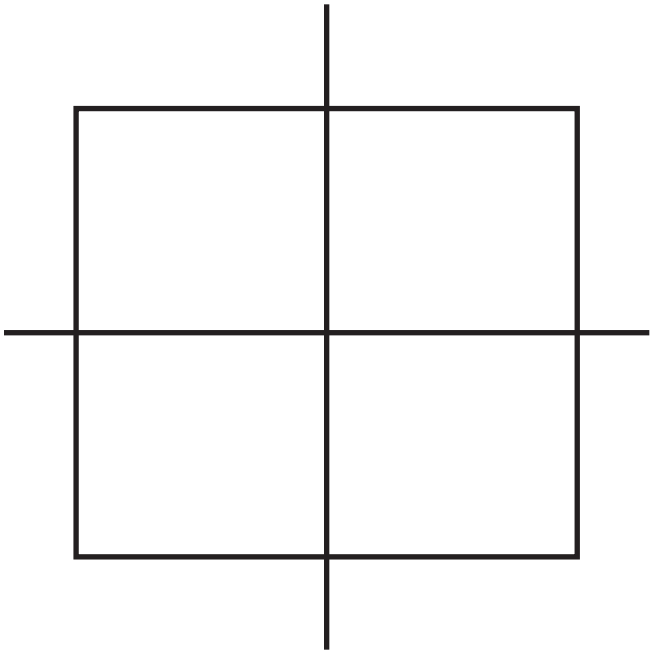
Find a partner in class, and decide who will be the "Mom Dragon" and who will be the "Dad Dragon." Use Punnett squares to determine the baby dragon's genetic code (genotype for each trait).

DIRECTIONS

1. Fill in the allele information for each box (follow the diagram on the right) & complete the Punnett squares.
2. Place a paper clip where the purple circle is, and use a pencil to keep the paper clip in place. Then, spin the paper clip (flick it) and whatever genotype the paper clip lands on is the genotype of your baby dragon for that trait.
3. Circle the portion of the box/genotype that the paper clip landed on (for record keeping purposes)



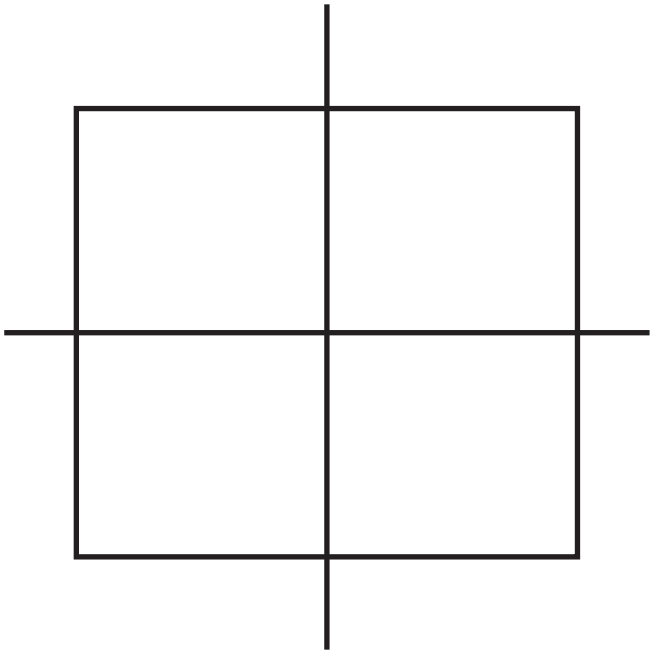
Neck length:



All possible genotypes:

All possible phenotypes:

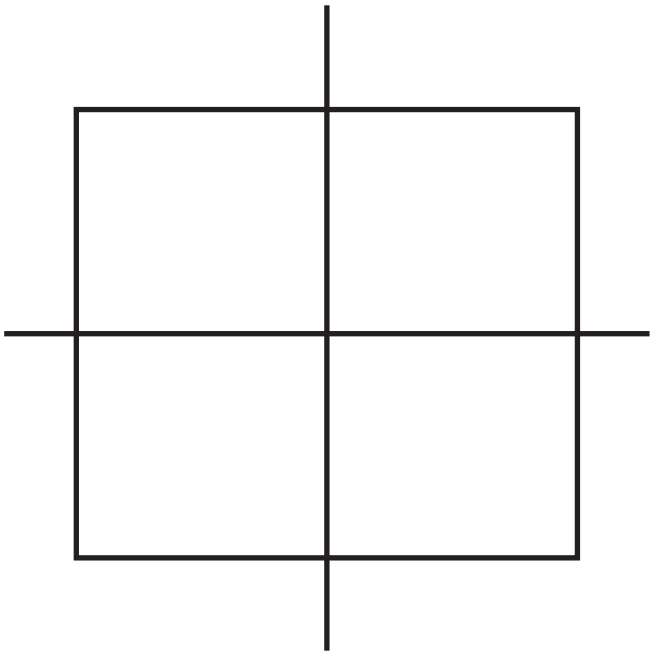
Eye color:



All possible genotypes:

All possible phenotypes:

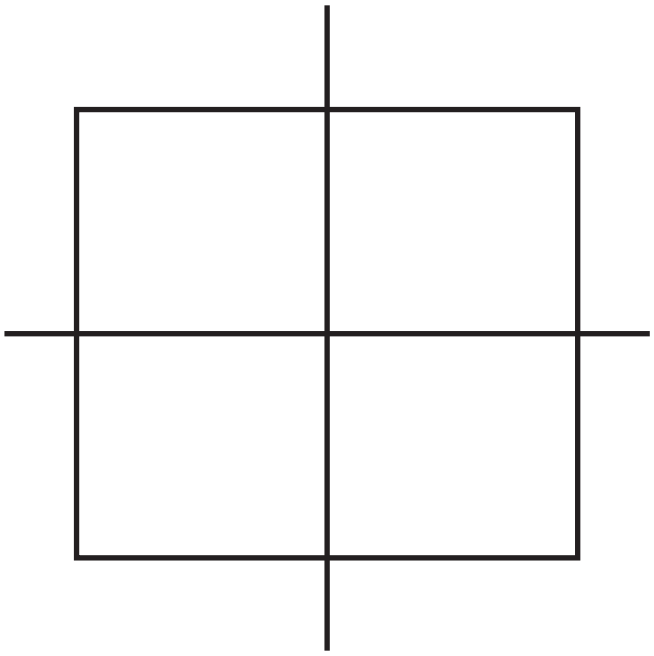
Horns:



All possible genotypes:

All possible phenotypes:

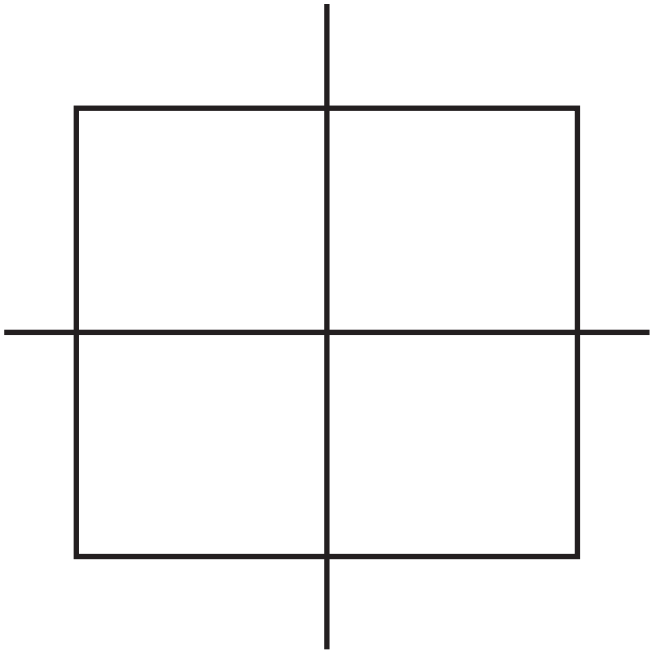
Spikes:



All possible genotypes:

All possible phenotypes:

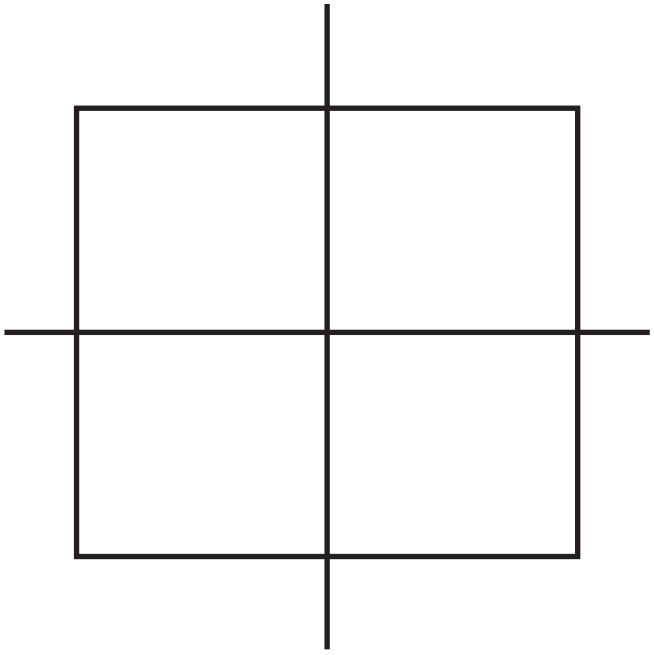
Tail length:



All possible genotypes:

All possible phenotypes:

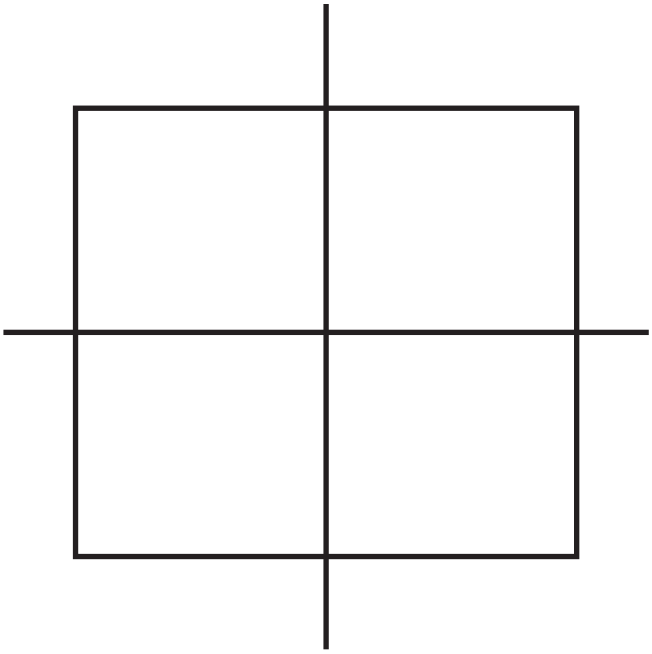
Body color:



All possible genotypes:

All possible phenotypes:

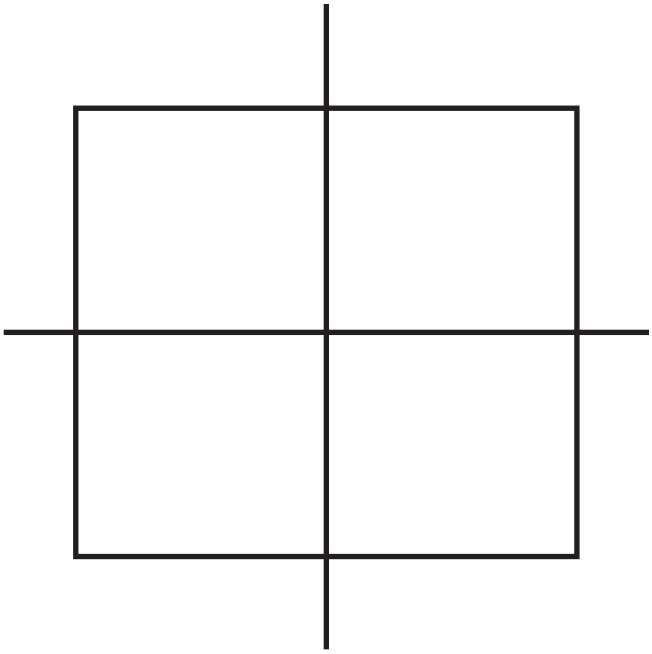
Wing color:



All possible genotypes:

All possible phenotypes:

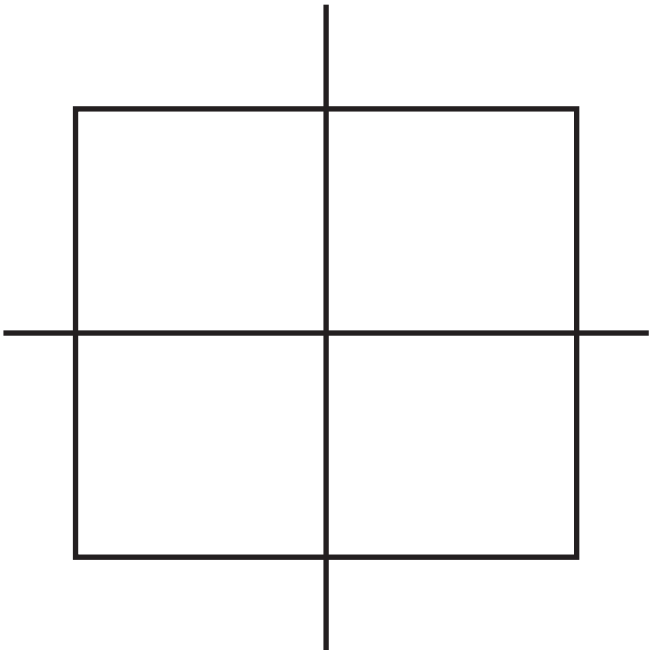
Number of toes:



All possible genotypes:

All possible phenotypes:

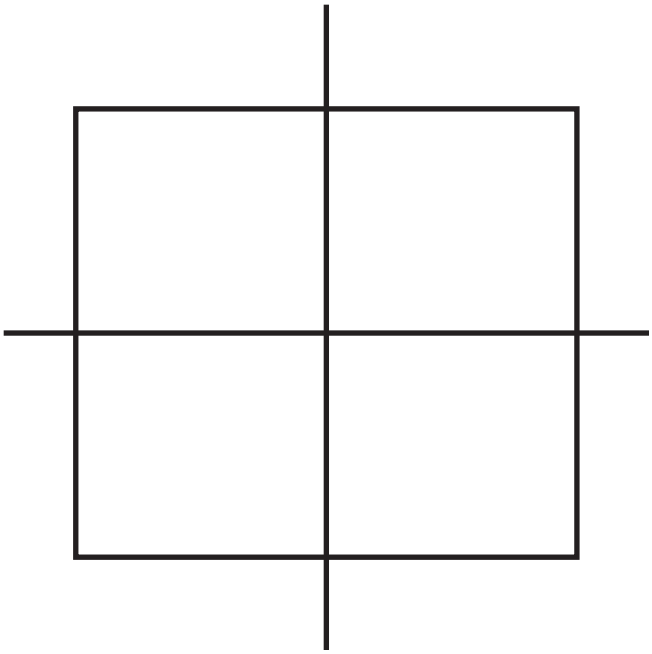
Belly color:



All possible genotypes:

All possible phenotypes:

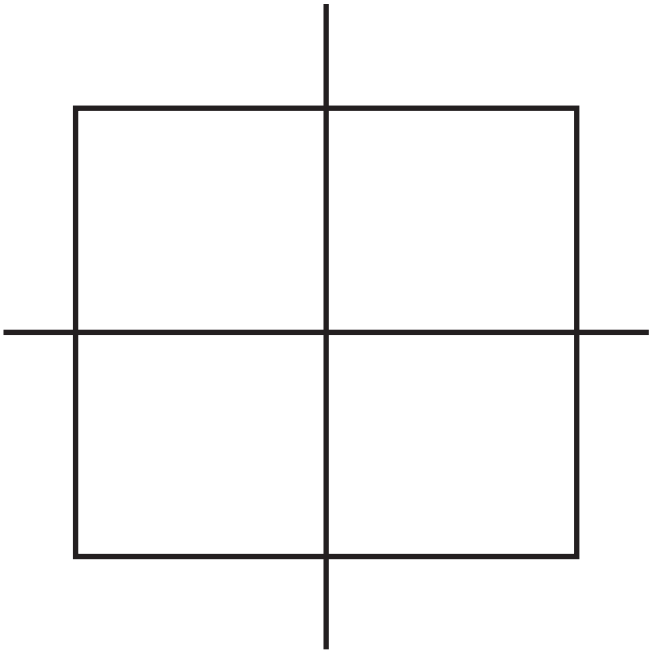
Color of spikes



All possible genotypes:

All possible phenotypes:

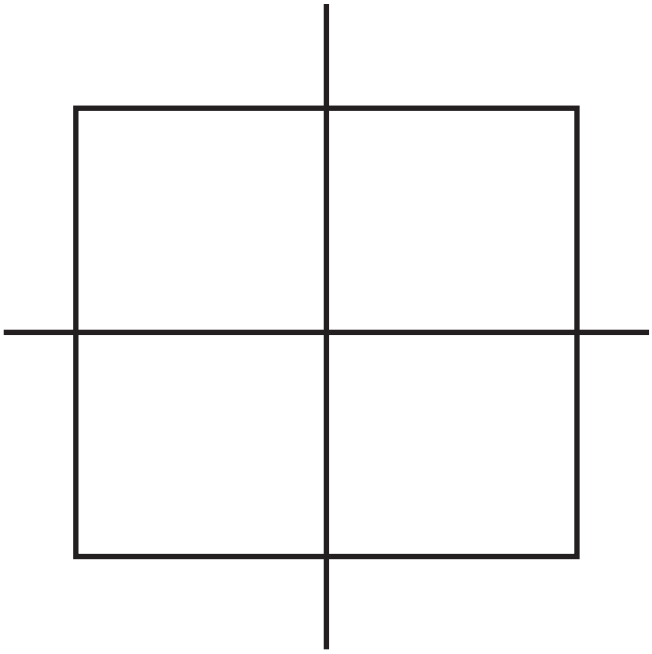
Fire breathing:



All possible genotypes:

All possible phenotypes:

Dragon size (sex):



All possible genotypes:

All possible phenotypes:

MAKING A BABY DRAGON

Fill in information from the punnett square portion of the activity.

CHROMOSOME PAIR NUMBER 1

Trait	Genotype	Homozygous/ Heterozygous	Phenotype
Neck length			
Eye color			
Horn?			
Spiky?			

CHROMOSOME PAIR NUMBER 2

Trait	Genotype	Homozygous/ Heterozygous	Phenotype
Tail length			
Body color			
Colored wings?			
Number of toes?			

CHROMOSOME PAIR NUMBER 3

Trait	Genotype	Homozygous/ Heterozygous	Phenotype
Belly color			
Color of spikes			

CHROMOSOME PAIR NUMBER 4

Trait	Genotype	Homozygous/ Heterozygous	Phenotype
Fire breathing?			
Dragon size? (sex)			

Draw the baby dragon below:

DNA STRUCTURE CRAFTING ACTIVITY

- General understanding of the basic subunits that make up DNA: Phosphate group, Deoxyribose, and Nitrogenous Base
    - Phosphate Focus: Allows every single nucleotide to bond to each other like a "ladder"
    - Deoxyribose Focus: Carbon numbering, holds the P-Group, and Nitrogenous base as one unit
    - Nitrogenous Base Focus: The varying Subunit that leads to the "code" for our genome, H-Bonds
- Comprehend how these subunits come together to form a nucleotide
- Phosphodiester Bonds between the 5' and 3' ends of Deoxyribose
- Base pairing to leads to double stranded DNA
    - Introduction to the antiparallel concept

LOGISTICS

- Have the students read the passage & answer the pre-lab questions.
- This should give the students a brief overview about DNA
- Next, the instructor should guide the students through the DNA Structure Summary Sheet while the students fill in the note blanks.
- The students should now be able to craft a DNA strand using the images given!

ADDITIONAL INFORMATION

- This activity would be great for high schoolers in AP/IB Biology
- The instructor can incorporate the explanation part into a Powerpoint using the work-sheets & images provided to save paper/guide the students through the activity

SUPPLIES/COST

- Worksheets (provided)
- Scissors
- Tape (recommended) or glue
- 2 different color writing utensils (accommodate for writing on paper or tape)
- Writing utensil

ANSWERS TO PRE-LAB QUESTIONS (FOR INSTRUCTOR USE)

PRE-LAB QUESTIONS

1. What analogy fits the description of DNA upon reading the introduction?

A. A machine meant to complete tasks
B. A proof reading program for your essays
C. A car for transportation
D. A blueprint for constructing an object

2. Which of the following is not a Subunit for DNA? Google Subunit if needed.

A. Phosphate Group
B. Deoxyribose
C. RNA
D. Nitrogenous base

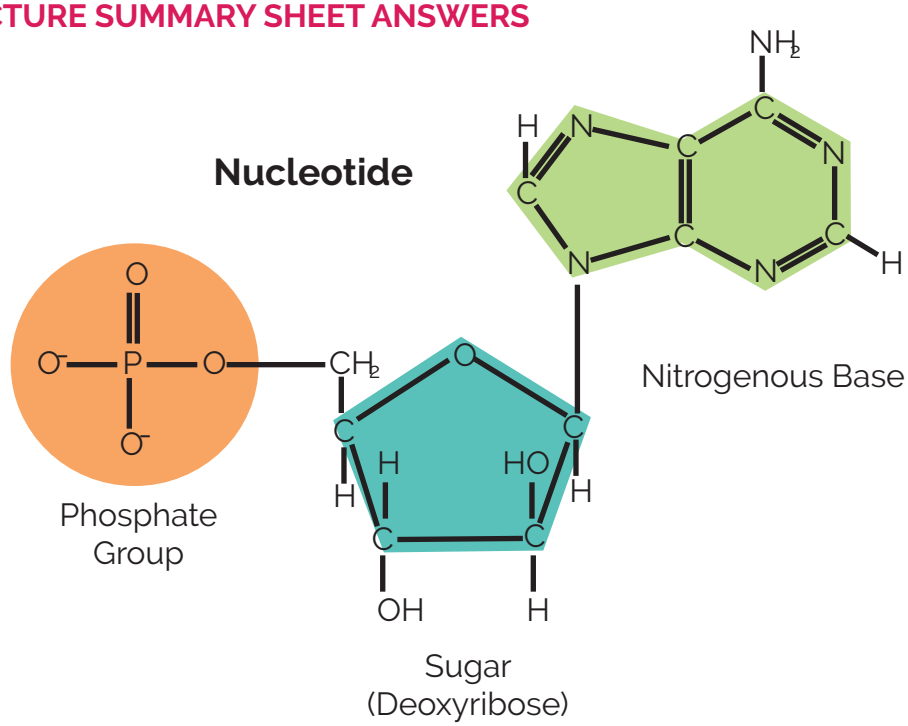
3. What overall structure does DNA have?

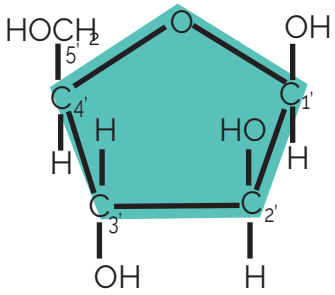
A. Ladder
B. Single-stranded
C. Double helix
D. Twisty ladder

4. How many different nitrogenous bases does DNA have?

A. 1
B. 2
C. 3
D. 4

DNA STRUCTURE SUMMARY SHEET ANSWERS

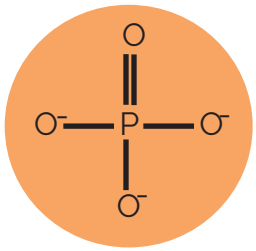




Sugar (Deoxyribose)

- **Nucleotides are the building blocks of DNA!**
  - They are composed of a **sugar**, **phosphate**, and **nitrogenous base**
- Nucleotides create **phosphodiester bonds** when they join together, creating a strand of DNA

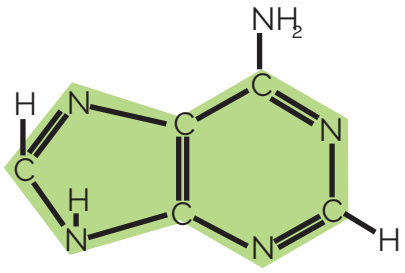
- **Sugar**
  - Deoxyribose is the sugar in DNA
    - It contains **five** carbons (labeled)
  - The 2nd carbon doesn't have an oxygen attached
    - Hence **"deoxy-"**ribose



Phosphate Group

- **Phosphate Group**
  - ***Trick:*** The phosphate group is attached to the **fifth** carbon of the deoxyribose in a nucleotide; **high 5!**
  - When connecting multiple nucleotides, the phosphate group attaches to the 3rd carbon of deoxyribose
  - The phosphate group's negative charge is responsible for the **negative** charge of DNA!

DNA STRUCTURE SUMMARY SHEET ANSWERS (CONTINUED)

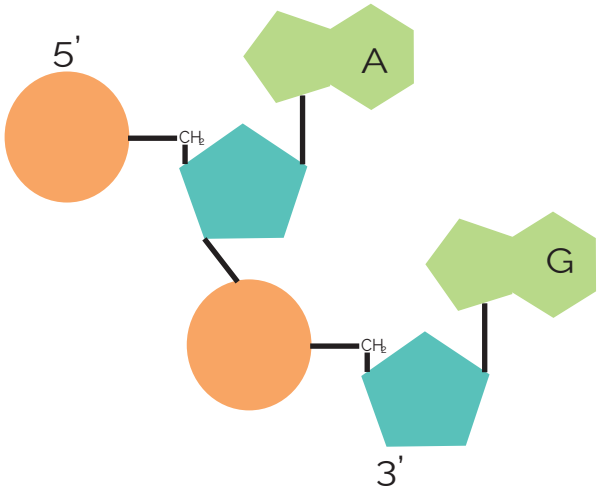


Nitrogenous Base

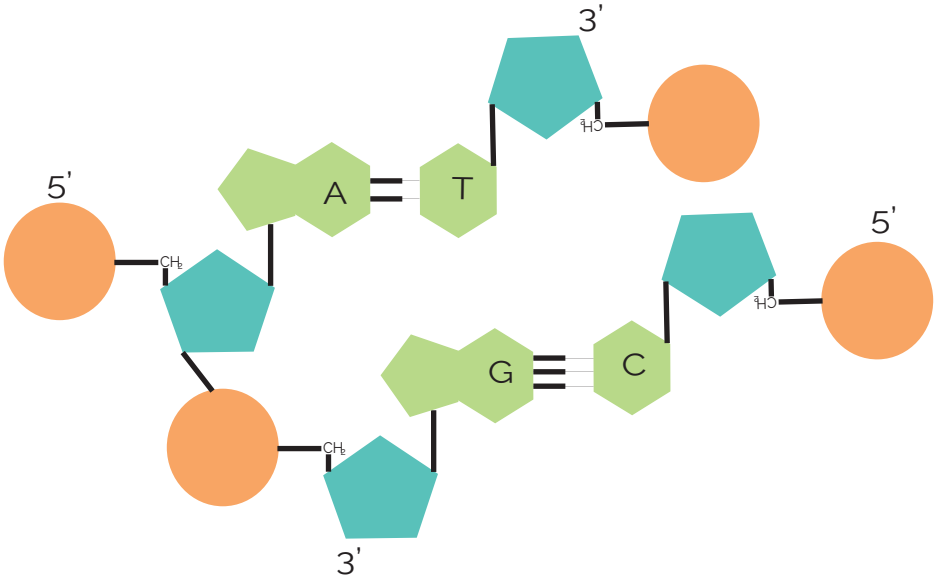
- **Nitrogenous Base**
  - The are **four** different bases: adenine, thymine, guanine, and cytosine
  - The bases are the alphabet/language of DNA
    - They make each person's DNA unique!
  - The bases are classified as purines & pyrimidines
    - Adenine & guanine are **purines**
      - Purines have two rings (like the nitrogenous base on the left)
    - Thymine & cytosine are pyrimidines
      - Pyrimidines have one ring
      - ***Trick:*** You can remember this b/c the one ring is similar to the shape of a **pyramid**
      - ***Trick:*** Like the word, p**y**ramid, the pyrimidines th**y**mine & c**y**tosine also have **y's** in their names!
  - DNA connects & becomes double stranded through the hydrogen bonding of the nitrogenous bases
    - **Adenine** bonds with **thymine**
    - **Guanine** bonds with **cytosine**

Now that you know the structure of an individual nucleotide, how do you connect multiple nucleotides together to form a strand of DNA?

- Once you have a nucleotide, the **phosphate** group binds to the 3' carbon of deoxyribose.
    - And presto! You have created one side of double-stranded DNA!

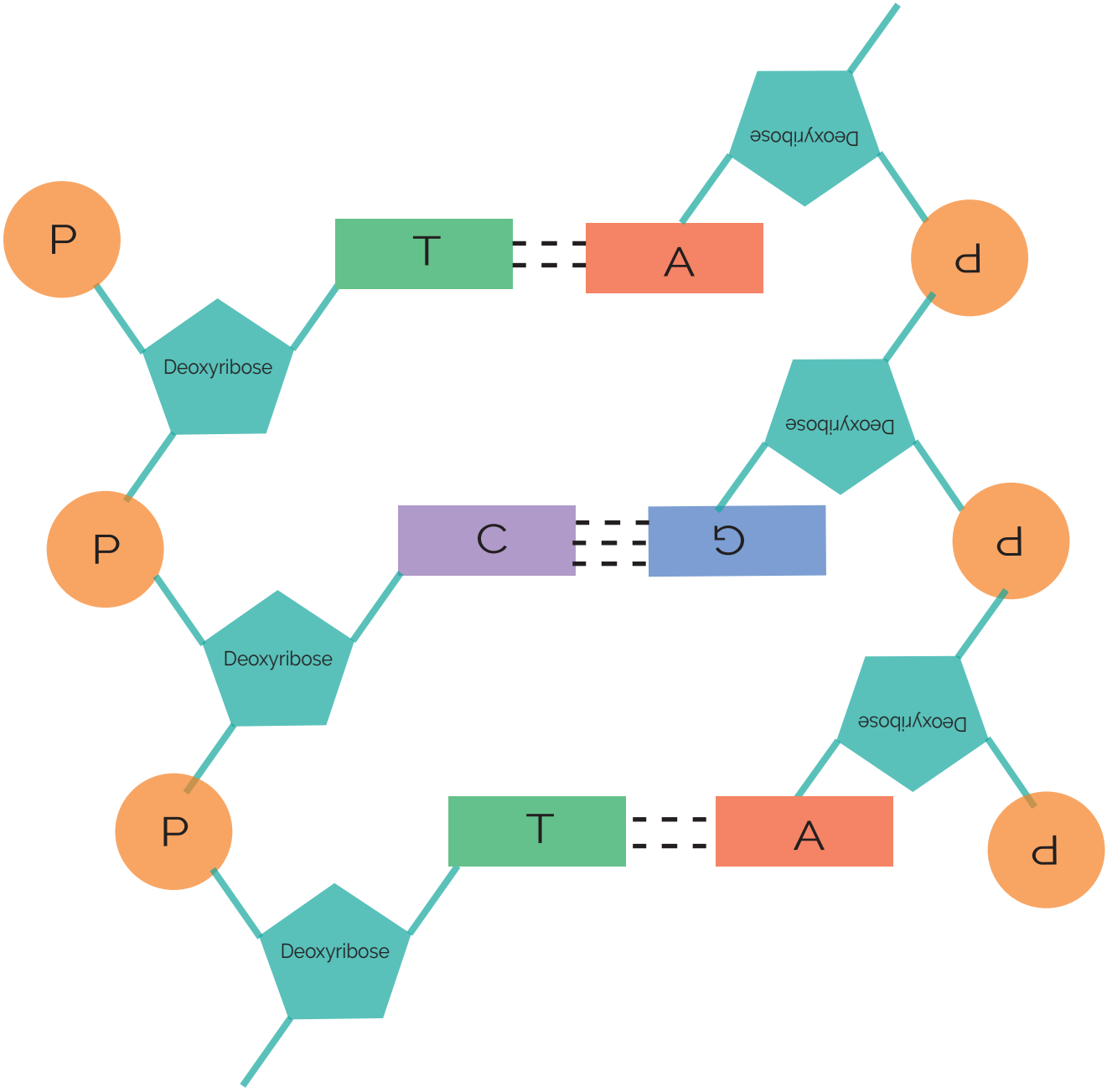


- But how do you join the strands of DNA together?
    - DNA is **antiparallel**
        - This means that one of the strands is 5' to 3', while the other strand is "upside down": 3' to 5'
    - Remember that the nitrogenous bases base pair together through hydrogen bonding!
        - Adenine & thymine form **two** hydrogen bonds
        - Guanine & cytosine form **three** hydrogen bonds



Now that you have learned about the structure of DNA, it is time to create your own strand!

CRAFTING ACTIVITY SAMPLE ANSWER



PRE-LAB

Brief introduction reading taken from:
https://ghr.nlm.nih.gov/primer/basics/dna

"**DNA**, or **deoxyribonucleic acid**, is the hereditary material in humans and almost all other organisms. Nearly every cell in a person's body has the same DNA. Most DNA is located in the cell nucleus.....

The information in DNA is stored as a code made up of four chemical bases: adenine (A), guanine (G), cytosine (C), and thymine (T). Human DNA consists of about 3 billion bases, and more than 99 percent of those bases are the same in all people. The order, or sequence, of these bases determines the information available for building and maintaining an organism, similar to the way in which letters of the alphabet appear in a certain order to form words and sentences.

DNA bases pair up with each other, A with T and C with G, to form units called base pairs. Each base is also attached to a sugar molecule and a phosphate molecule. Together, a base, sugar, and phosphate are called a nucleotide. Nucleotides are arranged in two long strands that form a spiral called a double helix. The structure of the double helix is somewhat like a ladder, with the base pairs forming the ladder's rungs and the sugar and phosphate molecules forming the vertical sidepieces of the ladder."

1. What analogy fits the description of DNA upon reading the introduction?

A. A machine meant to complete tasks
B. A proof reading program for your essays
C. A car for transportation
D. A blueprint for constructing an object

2. Which of the following is not a Subunit for DNA? Google Subunit if needed.

A. Phosphate Group
B. Deoxyribose
C. RNA
D. Nitrogenous base

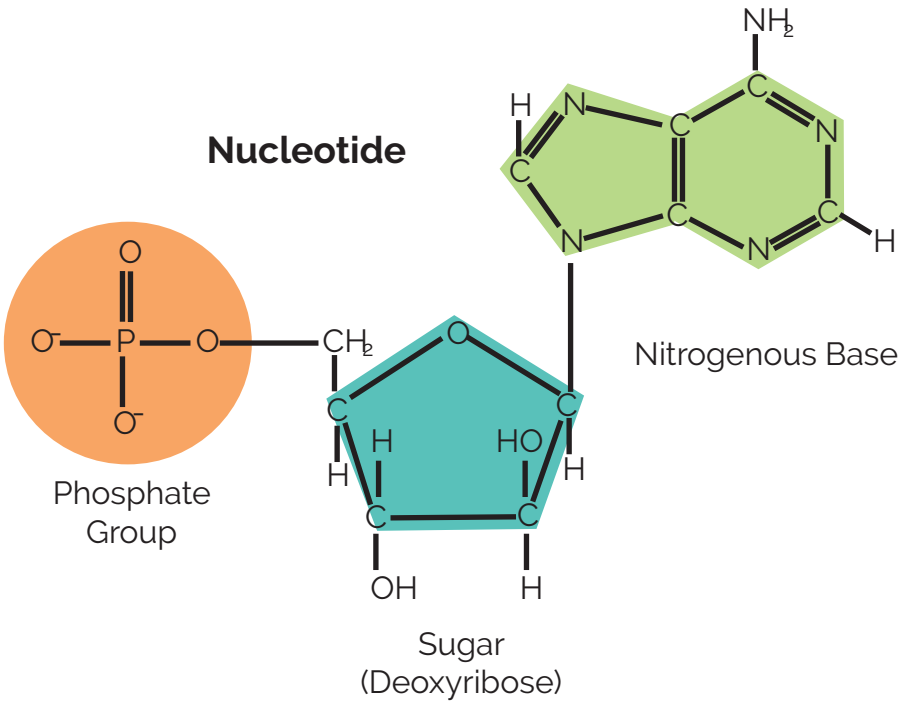
3. What overall structure does DNA have?

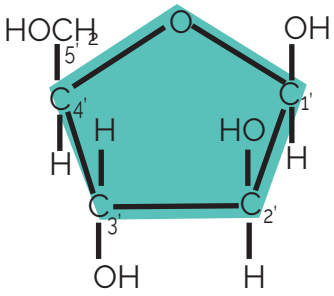
A. Ladder
B. Single-stranded
C. Double helix
D. Twisty ladder

4. How many different nitrogenous bases does DNA have?

A. 1
B. 2
C. 3
D. 4

DNA STRUCTURE SUMMARY SHEET

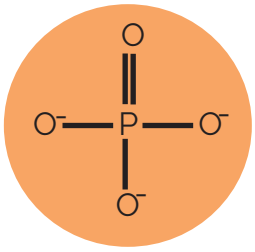




Sugar (Deoxyribose)

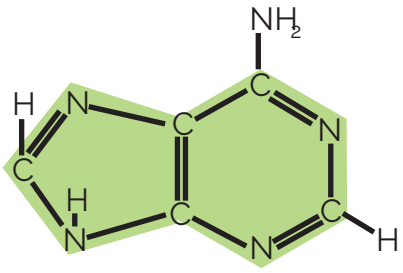
- _____ **are the building blocks of DNA!**
  - They are composed of a _____, _____ , and **nitrogenous base**
- Nucleotides create _____ when they join together, creating a strand of DNA

- **Sugar**
  - Deoxyribose is the sugar in DNA
    - It contains _____ carbons (labeled)
  - The 2nd carbon doesn't have an oxygen attached
    - Hence **"deoxy-"**ribose



Phosphate Group

- **Phosphate Group**
  - ***Trick:*** The phosphate group is attached to the _____ carbon of the deoxyribose in a nucleotide; **high 5!**
  - When connecting multiple nucleotides, the phosphate group attaches to the 3rd carbon of deoxyribose
  - The phosphate group's negative charge is responsible for the _____ charge of DNA!

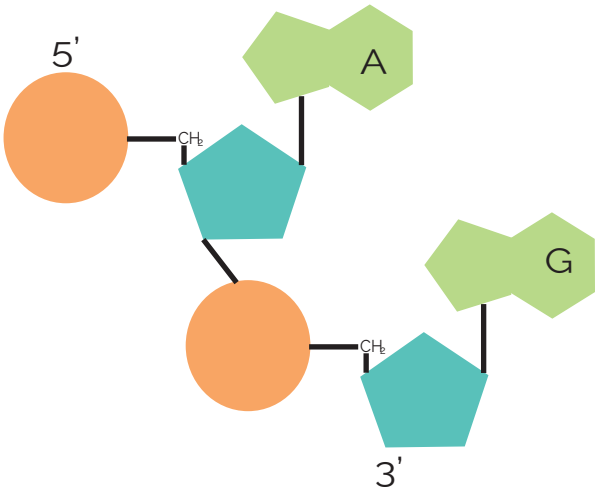


Nitrogenous Base

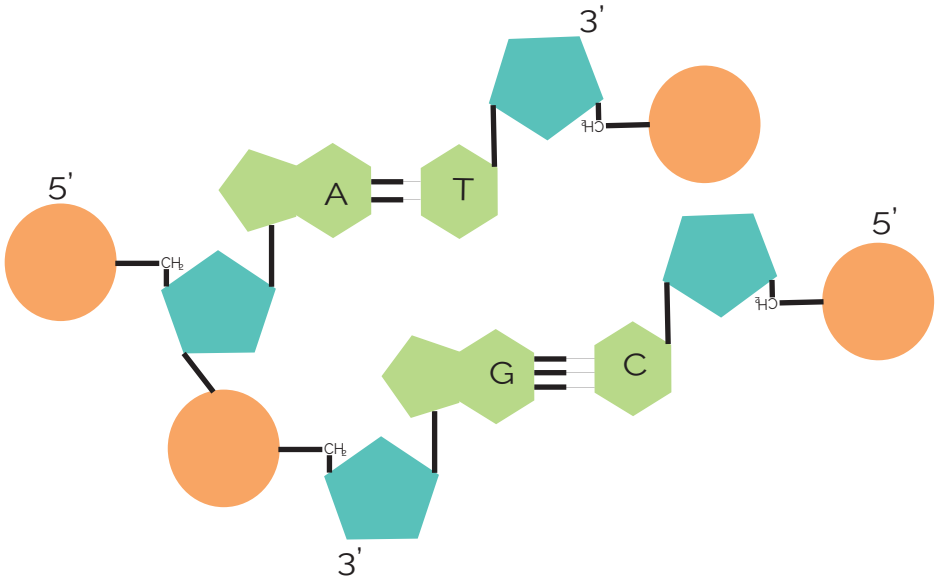
- **Nitrogenous Base**
  - The are _____ different bases: adenine, thymine, guanine, and cytosine
  - The bases are the alphabet/language of DNA
    - They make each person's DNA unique!
  - The bases are classified as purines & pyrimidines
    - Adenine & guanine are _____
      - Purines have two rings (like the nitrogenous base on the left)
    - Thymine & cytosine are pyrimidines
      - Pyrimidines have one ring
      - ***Trick:*** You can remember this b/c the one ring is similar to the shape of a _____
      - ***Trick:*** Like the word, p**y**ramid, the pyrimidines th**y**mine & c**y**tosine also have **y's** in their names!
  - DNA connects & becomes double stranded through the hydrogen bonding of the nitrogenous bases
    - **Adenine** bonds with _____
    - **Guanine** bonds with _____

Now that you know the structure of an individual nucleotide, how do you connect multiple nucleotides together to form a strand of DNA?

- Once you have a nucleotide, the _____ group binds to the 3' carbon of deoxyribose.
    - And presto! You have created one side of double-stranded DNA!



- But how do you join the strands of DNA together?
    - DNA is _____
        - This means that one of the strands is 5' to 3', while the other strand is "upside down": 3' to 5'
    - Remember that the nitrogenous bases base pair together through hydrogen bonding!
        - Adenine & thymine form _____ hydrogen bonds
        - Guanine & cytosine form _____ hydrogen bonds



Now that you have learned about the structure of DNA, it is time to create your own strand!

DNA STRUCTURE CRAFTING ACTIVITY

1. Cut out all of the images on the back pages. This includes the deoxyribose pentagons, the phosphate circles, and the rectangle nitrogenous bases.
2. Paste a deoxyribose pentagon on the next page. Then, paste the phosphate group onto the correct place & the nitrogenous base.
    a. Remember the carbon numbering. *Hint: High 5 for the phosphate group!*
3. Create another nucleotide. Then, connect the two nucleotides together by attaching one of the 5' phosphate groups to a 3' carbon on deoxyribose.
4. Repeat step 3 one more time & you should have a strand of DNA!
5. Now, it's time to make your second, antiparallel strand of DNA.
    a. Repeat steps 2-4, but this time, make sure that you have your nitrogenous bases in the correct order.
        i. Adenine binds with thymine
        ii. Guanine binds with cytosine
6. Now that you have both strands pasted, it's time to join them together!
    a. Draw hydrogen bonds using dashed lines between the nitrogenous bases.
        i. Adenine & thymine form two hydrogen bonds
        ii. Guanine & cytosine form three hydrogen bonds

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Create your DNA strand here:

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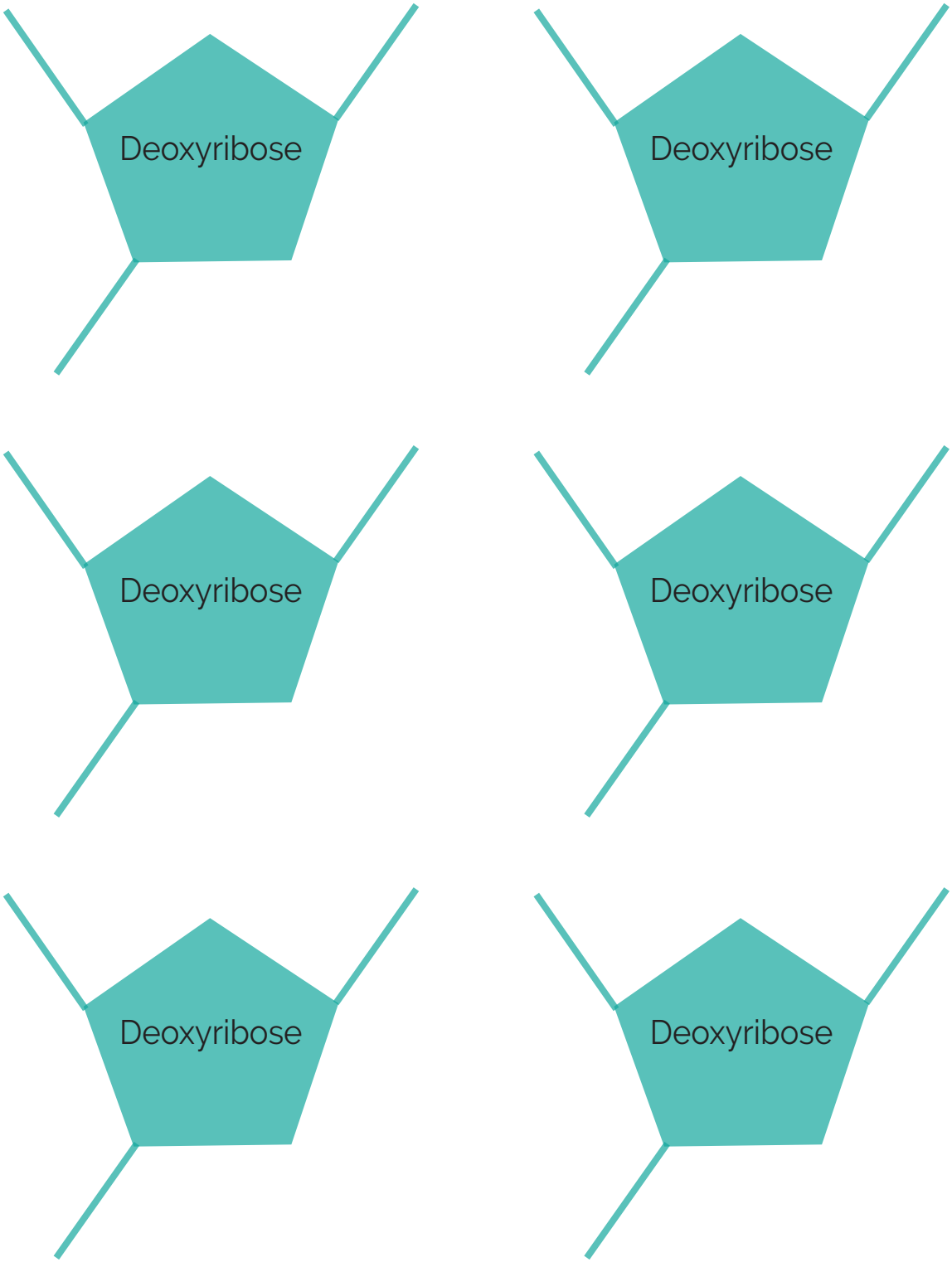
Deoxyribose
Deoxyribose
Deoxyribose
Deoxyribose
Deoxyribose
Deoxyribose

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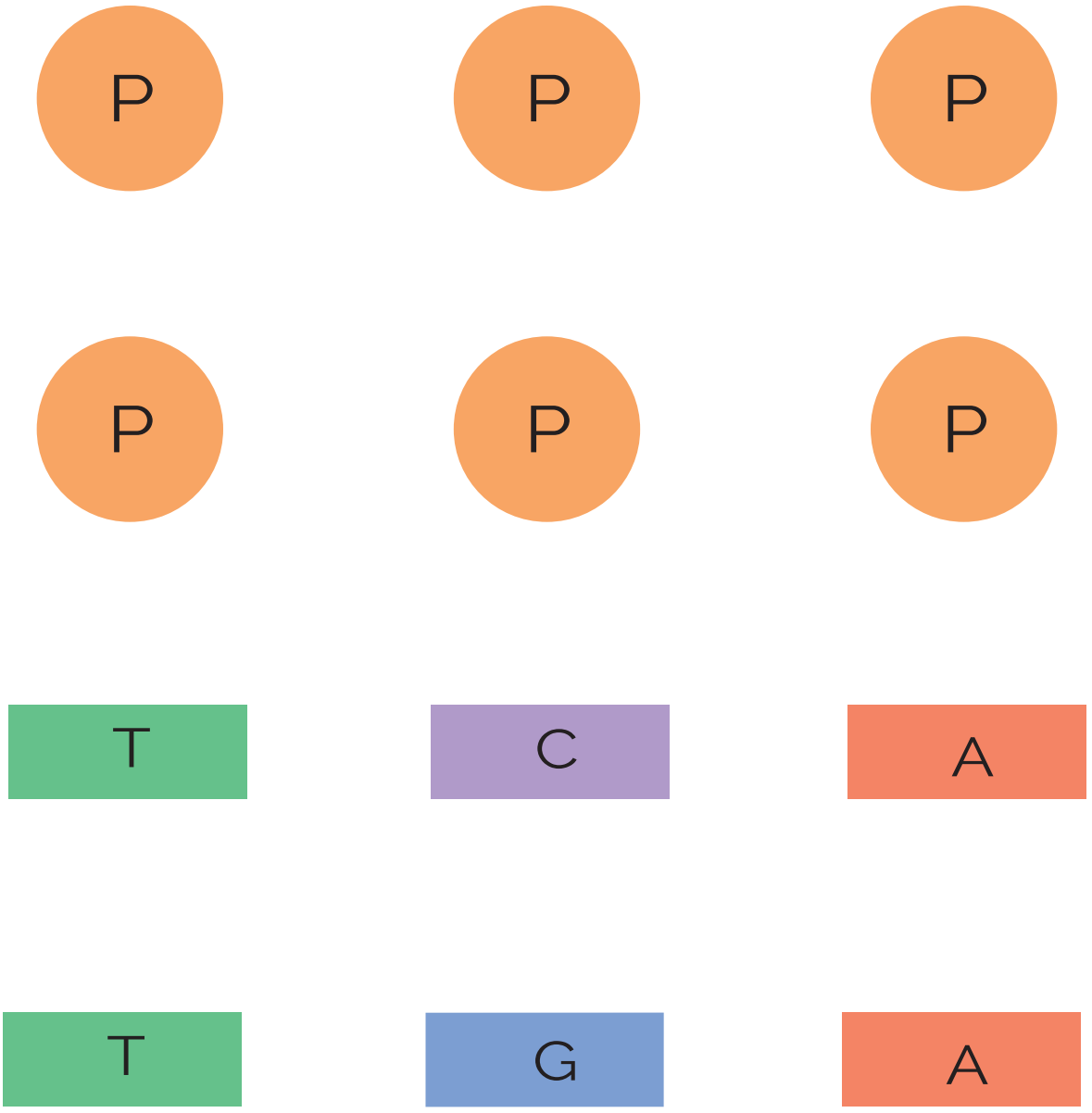
P
P
P
P
P
P
T
C
A
T
G
A

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HOW DOES CRISPR WORK?

The goal of this activity is to...

- Comprehend that many diseases have a hereditary basis from DNA
- Understand the basics of gene therapy & its importance
- Comprehend how previous methods of gene therapy worked and how CRISPR has advanced gene therapy
- Learn and apply the mechanics of CRISPR
- Begin to comprehend the potential implications for CRISPR both scientifically and ethically

LOGISTICS

- Hand out and explain the "Introduction to Gene Therapy & CRISPR" sheet or explain the premise of gel electrophoresis via a slideshow presentation.
- Allow the students to answer the discussion questions & create a conversation
- Allow the students to answer the discussion questions & create a conversation to wrap up the activity

ADDITIONAL INFORMATION

- The next activity "Ethical Implications of CRISPR" is great to combine with this activity!
- This activity was adapted from Dr. Alexa Clemmons' CRISPR teaching material.

SUPPLIES/COST

This activity has no associated costs other than printing instruction sheets! We wanted to make this activity inexpensive for use in a variety of settings. Additionally, teams/schools can save money by using slides with pictures of our activity instead of printing it.

SAMPLE ANSWERS TO DISCUSSION QUESTIONS (FOR INSTRUCTOR USE)

INITIAL DISCUSSION QUESTIONS

1. **Many of these kids had no effect, even though the correct gene was definitely inserted. How is this possible?**

   This question is discussing a repercussion of traditional gene therapy. Not all genes are expressed in cells, so if the gene isn't being expressed, its insertion will have no effect.

2. **These kids often developed leukemia. Why do you think this happened? Remember that cancer refers to when certain genes are overactivated, and there is no "brake" to cell growth, so there is an excess growth of cells.**

   The gene turned off the "brake" genes to cell growth. This resulted in the uncontrolled dividing of cells, which resulted in cancer (leukemia).

SCENARIO 1

You simply want to delete all of the CAG repeats.

1. **What tools do you need (ex: gRNA)?**
(Hint: You might need to use two of the same tool(s)! Ex: 2 gRNAs)

   2 gRNAS (one for each side), 2 Cas9 enzymes

SCENARIO 2

You want to insert a copy of the correct gene with the correct number of CAG repeats.

1. **What tools do you need?**

   2 gRNAS (one for each side), 2 Cas9 enzymes, engineered DNA template

FINAL DISCUSSION QUESTIONS

1. **What are the pros & cons of each scenario?**

   Sample answers could include that Scenario 1 involves fewer things to "fix" the DNA, but Huntington's disease might not necessarily be "cured" by removing all of the CAG repeats. The CAG repeats might be essential to neural function.

2. **Why are methods in both of the scenarios better than traditional gene therapy?**

   Both of the scenarios use CRISPR-Cas9. CRISPR-Cas9 ensures that DNA can be specifically targeted. This means that the DNA inserted won't be put into genes that aren't expressed or genes vital to cell cycle regulation, preventing cancer from occurring. Additionally, you can only ADD genes with traditional gene therapy; you can't delete bases.

3. **Challenge: After the DNA is "cut," how is it joined back together?**

   DNA spontaneously base pairs back together through hydrogen bonding!

INTRODUCTION TO GENE THERAPY & CRISPR

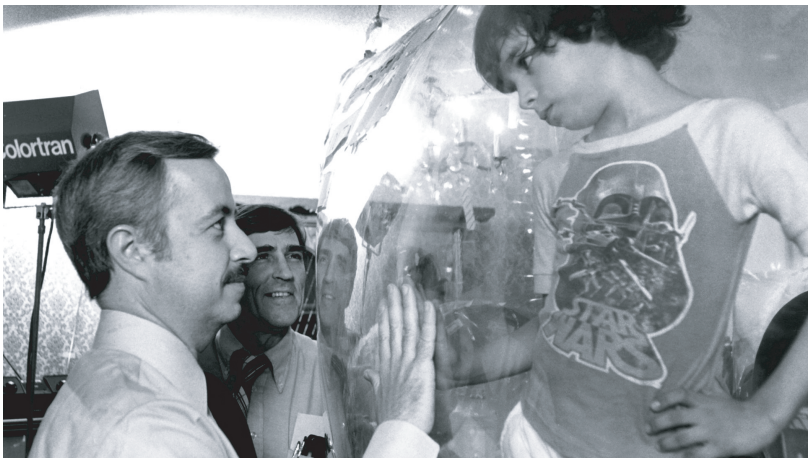
Across the world, billions of people suffer from hereditary diseases due to errors in DNA structure, many of which are often life threatening. Now, imagine that there was a way to "fix" a person's DNA. This is the premise of gene therapy.

Gene therapy is still in its experimental stages. However, there are several primary approaches to it:

1. Introducing a new gene to fight disease
2. Replacing a mutated (or "bad") copy of the gene with a healthy one
3. Inactivating (which includes "deleting") a mutated gene that is not functioning properly

When considering how gene therapy works, it is important to recognize that not **all** genes are expressed. This is why different cells have different functions. Additionally, there are also genes that regulate when other genes are expressed and how often cells divide; think of them as the "accelerator" & "brake" of cells. These "accelerator" genes are called proto-oncogenes and the "brake" genes are called tumor-suppressor genes.

In the 1900s, traditional gene therapy was used on children with Severe Combined Immunodeficiency (SCID). Traditional gene therapy refers to **adding** a functional copy of the gene to the cell (not replacing anything). SCID was often termed "Bubble Boy Syndrome," as kids with this syndrome were sequestered in a sterile environment due to resistance to typically innocuous substances.



New York Times. A child with SCID in a sterile "bubble."

With this information in mind, discuss the questions below:

1. Many of these kids had no effect, even though the correct gene was definitely inserted. How is this possible?

2. These kids often developed leukemia. Why do you think this happened? Remember that cancer refers to when certain genes are overactivated, and there is no "brake" to cell division, so there is an excess growth of cells.

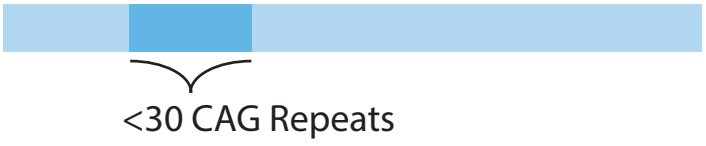
CRISPR-CAS9

In 2012, CRISPR-Cas9 was developed for gene editing. The CRISPR-Cas9 system consists of a molecule called gRNA, the cas9 enzyme, and engineered DNA can also be used. A virus can be used to insert the CRISPR-Cas9 system into an organism. Unlike previous methods of gene therapy, CRISPR-Cas9 enables the targeting specific DNA sequences.

HUNTINGTON'S DISEASE

Huntington's disease is an autosomal dominant neurological disease with late onset, which means that symptoms usually appear after the age of 40. It causes neurons to break down over time, leading to mental degradation and eventually death.:(Genetically, Huntington's disease is caused by excess CAG repeats in the IT15 gene.

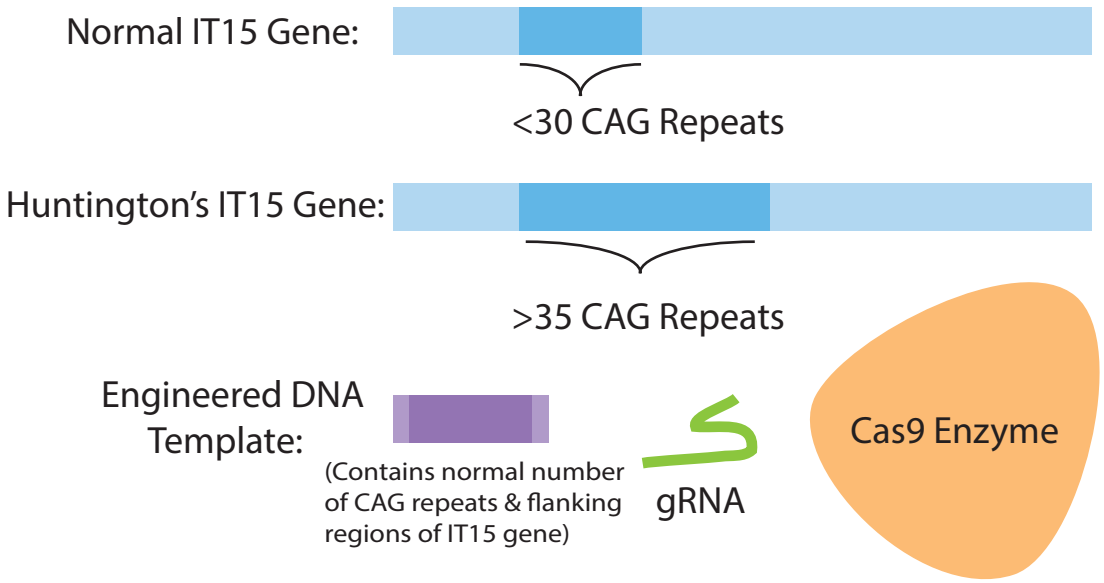
Normal IT15 Gene:



Huntington's IT15 Gene:

Today, your job is to determine how to fix a few segments of DNA using CRISPR-Cas9 to cure Huntington's disease.

YOUR TOOLBOX



GLOSSARY

- **gRNA:** gRNA is used as a guiding strand to find the DNA sequence to cut. It's sequence is complementary to the target DNA sequence.
- **Cas9 enzyme:** This enzyme makes "cuts" in the DNA. Think of it as a scissors.
    - While the gRNA simply allows one to find the part of the DNA that is cut, the Cas9 enzyme does the actually cutting.
- **Engineered DNA Template:** This DNA strand has the correct sequence. It is used to insert the correct gene. The engineered DNA template is not always used with CRISPR-Cas9.

CRISPR Cas9 can be used in several different ways to edit these "bad" genes with extra CAG repeats.

SCENARIO 1

You simply want to delete all of the CAG repeats.

1. What tools do you need (ex: gRNA) ?
   (Hint: You might need to use two of the same tool(s)! Ex: 2 gRNAs)

SCENARIO 2

You want to insert a copy of the correct gene with the correct number of CAG repeats.

1. What tools do you need?

DISCUSS

1. What are the pros & cons of each scenario?

2. Why are methods in both of the scenarios better than traditional gene therapy?

3. Challenge: After the DNA is "cut," how is it joined back together?

CRISPR ETHICS ACTIVITY

The goal of this activity is to...

- To understand the possible future applications of CRISPR
- To begin to consider the ethical decisions that need to be made due to advancements in technology

LOGISTICS

- Hand out the sheet after the students have fully completed the "How does CRISPR work?" Activity
- Allow the students to think and answer the discussion questions on their own
- Then allow the students to discuss the questions in small groups or as a class. This can be done in a "Socratic Seminar" style in which the students either choose or are assigned the "yes" or "no" perspectives.
- Debrief the activity by explaining that science, especially biology, has ethical implications that have to be considered. Science is not always "black and white."

SUPPLIES/COST

This activity has no associated costs other than printing instruction sheets! We wanted to make this activity inexpensive for use in a variety of settings. Additionally, teams/schools can save money by using slides with pictures of our activity instead of printing it.

NOTE ABOUT DISCUSSION QUESTIONS

We haven't included sample answers to discussion questions due to the open ended nature of the questions.

CRISPR ETHICS ACTIVITY

CRISPR has allowed us to alter the genetic code that forms the basis of all life, and it does so by working like the search and replace function in Microsoft Word. For the last decade, CRISPR has served as the primary tool used in genetic engineering, and has been used in a wide range of applications—from developing malaria resistant mosquitoes to cloning loved and lost pets. And while CRISPR may have opened the door to the improvement of various species, it also brings up a trove of ethical discussion on where, how, and even if should it be used.

One prominent topic is the possibility of utilizing CRISPR in humans to eradicate genetic diseases, but the questions raised are what should or should not be modified, and should it be used on human embryos?

YES	NO
• We already screen babies for disabilities Down Syndrome and give the parents the option of abortion. This isn't so different from creating "designer babies" with no health complications. • Could help decrease disabilities in the human population • Could develop faster, smarter, and stronger humans (super heros) • Designed to save lives	• We'd be playing God • Many disabled communities don't believe that their disability lowers their quality of life • "Designer babies" would put natural babies at a disadvantage, benefiting the rich who would be able to afford the technology • "Designer babies" are unnatural • You can design an individual but not their identity

DISCUSSION QUESTIONS

1. What diseases or impairments should be “fixed” using CRISPR?

2. How could gene editing cause more inequality?

3. Is informed consent possible since edits are to the embryo and future generations?

4. What safety concerns are there with gene editing?

5. How is gene editing morally different to the selective breeding of domestic animals (like dogs and cats) and plants?

STEM CELLS ACTIVITY

- To understand the three different types of stem cells.
- To consider the ethics of using embryonic and induced pluripotent stem cells in research and clinical settings.
- To see from different perspectives on topics concerning stem cells ethics.

LOGISTICS

- Hand out the "What are Stem Cells?" sheet to students and allow them time to read and answer the comprehension questions at the end.
- Allow students to ask questions for understanding and/or clarification before moving on to the main activity part.
- Hand out the "Consider the Ethics of iPSCs and ESCs" sheet and allow students time to read over the introduction and directions.
- Divide the classroom into two halves - "agree" and "disagree". Then present students with each "provocative statement" and allow them 1-2 minutes to pick their sides. Open a dialogue and have students justify their opinions.
- Optional: We suggest that to make students more engaged in the activity, have each side make it their goal to get at least one person from the other side to switch sides.
- Reconvene with all students at the end and emphasize that each has its advantages and disadvantages, but what's most important is that these types of discussions occur in order to ensure we are doing science that is right.

SUPPLIES/COST

This activity has no associated costs other than printing instruction sheets! We wanted to make this activity inexpensive for use in a variety of settings.

SAMPLE ANSWERS TO COMPREHENSION QUESTIONS (FOR INSTRUCTOR USE)

- **What are stem cells and the three different types of stem cells?**
  Stem cells are unspecialized cells that have the ability to become more specialized. The three different types of stem cells are embryonic stem cells, somatic stem cells, and induced pluripotent stem cells.

- **(Circle one) Embryonic stem cells are totipotent/pluripotent/multipotent/unipotent.**

- **Where are embryonic stem cells derived from?**
  Embryonic stem cells are derived from the inner cell mass of a blastocyst.

- **What type of stem cells can only give rise to placental cells?**
  Totipotent stem cells.

- **What is the main purpose of somatic stem cells?**
  For system repair and tissue replenishment.

- **Name at least three different places in the body where you can find somatic stem cells.**
  Bone marrow, fat (adipose), skin

- **What are induced pluripotent stem cells?**
  Multipotent stem cells that are reprogrammed back into being pluripotent.

- **Challenge question: In what way are induced pluripotent stem cells similar and different from embryonic stem cells?**
  They are similar in that they are both pluripotent. However, their origins differ as embryonic stem cells come from the inner cell mass of a blastocyst and induced pluripotent stem cells come from somatic stem cells that have a “history.

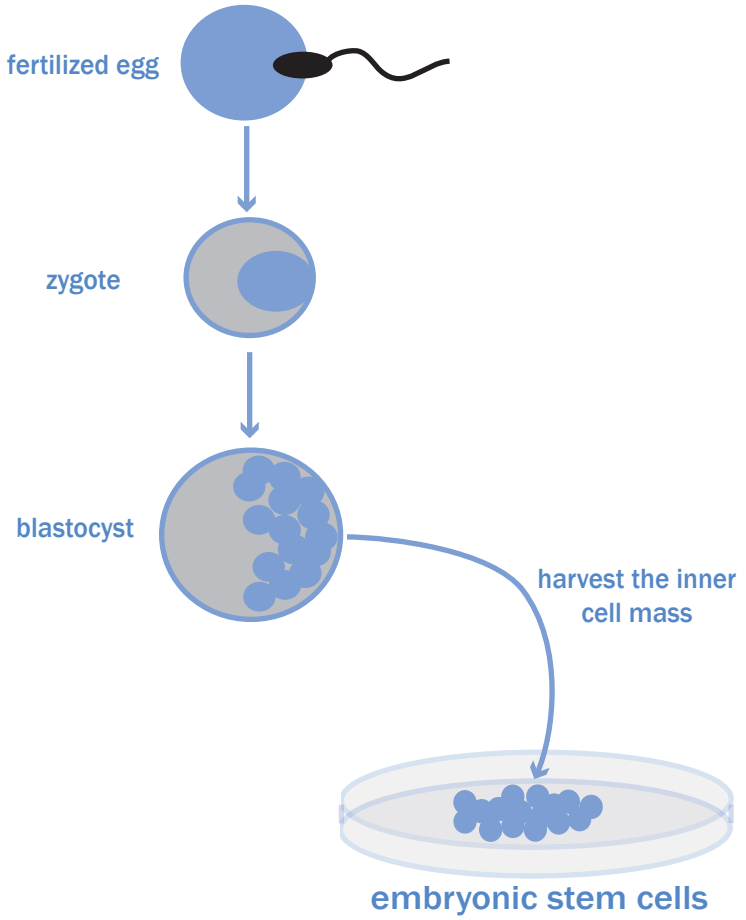
WHAT ARE STEM CELLS?

In general, stem cells are unspecialized cells that have the ability to self replicate become more specialized cells. By specialized, we mean having a specific function. For example, your blood cells are specialized for specific functions, one of them being delivering oxygen to your tissues. There are three main types of stem cells:

1. Embryonic stem cells (ESCs)
2. Somatic stem cells
3. Induced pluripotent stem cells (iPSCs)

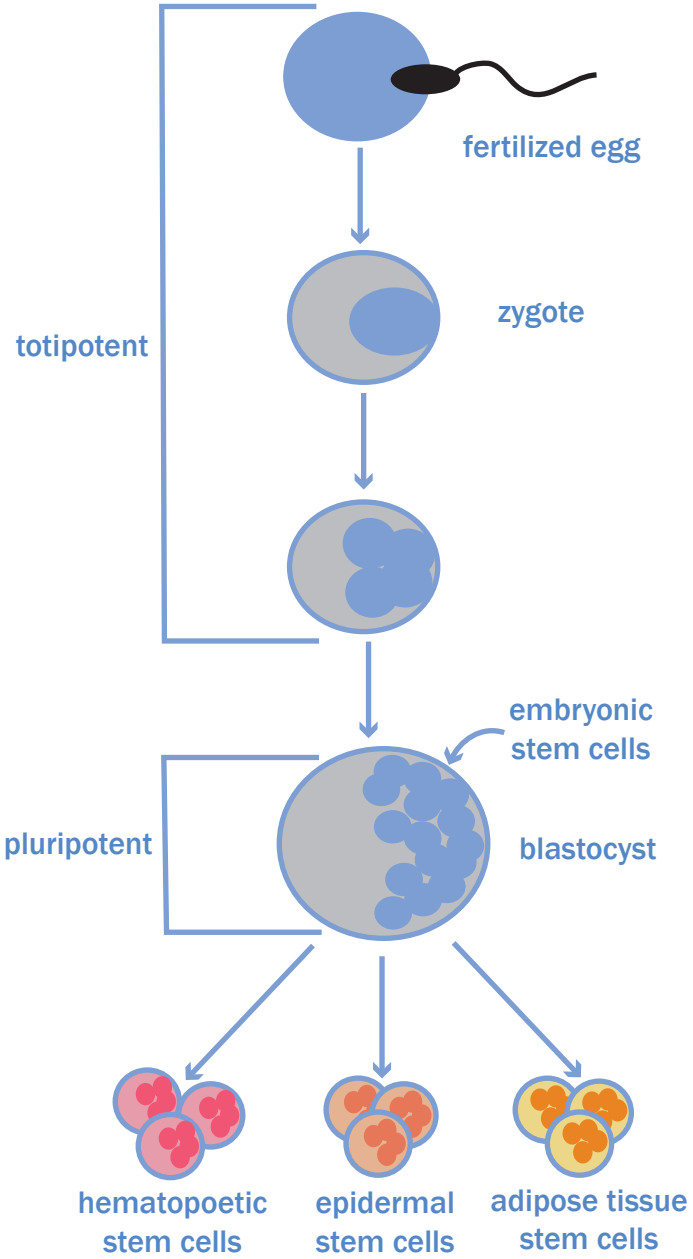
1. EMBRYONIC STEM CELLS (ESCs)

- When the sperm and egg meet and form a zygote. The zygote then continuously divides into a blastocyst which is a hollow ball of cells. In this hollow ball of cells, the inner mass of the cells are the embryonic stem cells.
- Embryonic stem cells are used to build our bodies in the development stages of life.
- Embryonic stem cells are pluripotent. Pluripotency is defined as cells that generate all cell types that make up the body except for placental cells (cells that make up the placenta). Only totipotent stem cells can give rise to placental cells. We only have totipotent cells at the zygotic stage of development.



2. SOMATIC STEM CELLS

- The purpose of somatic stem cells is mainly to function as a repair system and replenish tissue that needs to be replaced.
- Unlike embryonic stem cells, somatic stem cells are NOT pluripotent. You can find somatic stem cells in your skin where you have epidermal stem cells in your epidermis (the outer layer of the three layers that make up your skin). You lose a lot of skin per hour and your body needs a way to replenish your skin so you have epidermal stem cells which keep making new skin cells for you. Epidermal stem cells are unipotent because they can only specialize into one (uni-) cell type, skin cells.
- You can also find somatic stem cells in your bone marrow, gonads, and even fat tissue.
- Hematopoietic stem cells found in the bone marrow are multipotent as they can develop into red blood cells, white blood cells, or platelets.



3. INDUCED PLURIPOTENT STEM CELLS (iPSCs)

- Pluripotent stem cells offer a lot of value to the world of research and treatment. You can possibly treat diseases with it, test drugs without having to use actual subjects, and also study development of diseases.
- Is the only way we can get pluripotent stem cells from blastocysts? No! In 2007, researchers discovered that you can actually reprogram multipotent stem cells, like hematopoietic stem cells, into pluripotent stem cells. These cells became known as induced pluripotent stem cells or iPSCs for short.
- What potential does this give us? In theory, we can treat diseased people by harvesting their diseased/broken cells, reprogramming those cells back into "blank slates" (effectively repairing them) and then putting those repaired cells back in.

COMPREHENSION QUESTIONS

- What are stem cells and the three different types of stem cells?

- (Circle one) Embryonic stem cells are totipotent/pluripotent/multipotent/unipotent.

- Where are embryonic stem cells derived from?

- What type of stem cells can only give rise to placental cells?

- What is the main purpose of somatic stem cells?

- Name at least three different places in the body where you can find somatic stem cells.

- What are induced pluripotent stem cells?

- Challenge question: In what way are induced pluripotent stem cells similar and different from embryonic stem cells?

THE ETHICS OF ESCs AND iPSCs

Stem cell research offers a lot of potential for new scientific discoveries and treatments. Still, the use of human embryonic stem cells also raises lots of ethical dilemmas and considerations being that it involves harvesting cells from a human embryo. The discovery of induced pluripotent stem cells, however, should resolve those issues regarding the use of human embryonic stem cells. While it certainly does, it brings to light a whole other set of questions to consider.

Here are a few things to consider:

- iPSCs and ESCs are not entirely equivalent, so will we get the same exact results we do from ESCs if we replace them with iPSCs?
- iPSCs are an alternative to using human ESCs, so we are no longer destroyed human embryos.
- There is the possibility that iPSCs could be used to create human embryos.
- There are risks of developing cancer in the process of "reprogramming" multipotent somatic stem cells into induced pluripotent stem cells
- iPSCs can possibly be used to clone organisms, including humans.
- iPSCs have the potential to give couple who lack the reproductive abilities to have offspring that are genetically related to them.

DIRECTIONS

Your instructor will present you with a series of "provocative statements" to which you need to take a stance on - either agree or disagree by moving to the designated side of the room. Be ready to discuss and defend your opinions. Most importantly, try to be open to the thoughts and opinions of the other side.

STATEMENTS

1. Preventing stem cell research is unethical.

2. Couples who lack the reproductive abilities should have a chance at reproduction using iPSCs.

3. Embryonic stem cell research should be stopped completely now that we have iPSCs.

4. Stem cell treatments are safe and effective.

5. Stem cell research involving iPSCs should be regulated.

SOLVING GLOBAL PROBLEMS WITH SYNTHETIC BIOLOGY ACTIVITY

From decades, synthetic biology has been used to solve pressing issues across the globe. This activity was designed to promote an awareness about the uses of synthetic biology in students in upper grade levels and to encourage them to think of possible solutions while considering ethics, viability, and costs.

We have developed five scenarios to implement this activity on a classroom scale. Each scenario has an introduction to a pressing global problem followed by examples of solutions by past iGEM teams. As students designing the activity, we wanted to incorporate advances by past undergraduate iGEM teams specifically to inform and inspire students about the plethora of opportunities available with a post-secondary education, even as an undergraduate.

LOGISTICS

In a classroom, we encourage the instructor to divide the students into roughly groups of four or five. Each group should get one scenario, and in large classrooms, two groups will have the same scenario. The students should be given roughly 10-15 minutes to discuss the scenarios in their small groups to grasp the concepts and think of their potential solution.

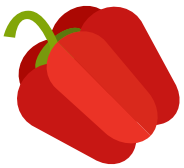
Next, in larger classrooms, the groups with the same scenario should combine to form larger groups for 10-15 more minutes. During this time, groups should discuss their solutions and apply their ideas to the "Current Global Problem Activity" section of the worksheet. The groups will develop a quick 3 minute pitch to present to the classroom.

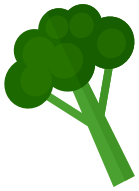
ADDITIONAL INFORMATION

We encourage the instructor to briefly inform the students about the costs associated with biotechnology. This could be something as simple as some machines costs $5,000!

SUPPLIES/COST

This activity has no associated costs other than printing instruction sheets! We wanted to make this activity inexpensive for use in a variety of settings.





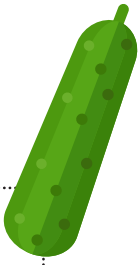
SCENARIO 4:
FOOD SHORTAGES & GMOs

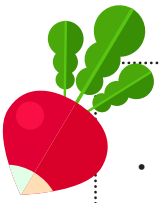
Synthetic biology is being used to solve the world's leading problems. Today, it is your job as a team to consider past solutions and think about how you can create novel solutions using synthetic biology.

Introduction: As Earth is approaching carrying capacity and the population is expected to double by 2050, there have been more and more food shortages. This has led to scientists developing alternative solutions to produce enough food, including the development of genetically modified organisms (GMOs) and enhanced pesticides.

Read through the following descriptions on what past iGEM teams have done and consider the questions below.

What past iGEM teams have done:





2017 iGEM SECA New Zealand

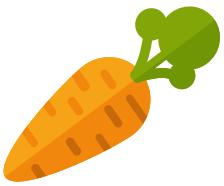
- 91% of kiwifruit growers in NZ think that winter temperatures are the greatest threat to crops
- Developed frost resistant gene
- Inserted the gene into the plant & let it grow and produce seeds
- Concept behind GMOs (editing the plant's genetics)

2017 iGEM IONS Paris

- Climate change has been negatively affecting France's vineyards due to extreme temperature events
- iGEM IONIS developed a biological "Softer Shock" spray for protecting grapevines
- Engineered a microorganism that will be inside the spray
- At low temperature, anti-freeze proteins interact with ice crystals to inhibit growth
- At high temperatures, light-reflecting compounds will limit evaporation with reflective layer

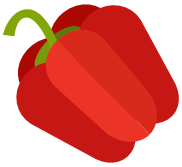
What are the pros and cons of each solution?

- Consider convenience, cost, ethics, etc.
  - For example, with IONIS-Paris, you might consider how to ensure biosafety and how to evaluate toxicity.



Think of at least one other potential solution that could be used.

- Keep this solution in mind as you consider the global problem.



SCENARIO 4:

FOOD SHORTAGES & GMOs

Current Global Problem: The extinction of commercial bananas is a looming threat. Commercial bananas lack genetic diversity, making them more susceptible to disease. For instance, Panama Disease cuts of nutrients and water from the banana plant, causing it to wilt. Moreover, a lack of genetic diversity means that there cannot be natural selection and thus evolution for disease resistance.

What solutions can you think of to this problem using synthetic biology?

- Consider what past iGEM teams have done and the solution you created in the previous discussion questions.

- Your job is to create a 3 minute pitch in which you briefly mention the problem you are solving and the solution you think is most viable and why.
    - Make sure to consider convenience, cost, ethics, etc. again

SCENARIO 2: POLLUTION

Synthetic biology is being used to solve the world's leading problems. Today, it is your job as a team to consider past solutions and think about how you can create novel solutions using synthetic biology.

Introduction: According to the World Health Organization, pollution has become the single most important environmental health risk. Pollution not only affects humans, but can also affect other plants and animals and thereby damage the balance of the eco-system.

Read through the following descriptions on what past iGEM teams have done and consider the questions below.

What past iGEM teams have done:

Team IONIS Paris

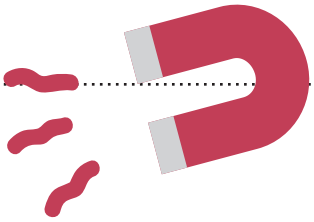
Created E. coli cells that could detect a particular pollutant and react by emitting bioluminescence

- Obtained gene for enzyme involved in bioluminescence process from the copepod Gaussia princeps.
- Optimized it for E. coli
- Introduced it into plasmid of E. coli to emit bioluminesce in presence of pollutants

Team Peking

Developed a method to remove Uranium from water

- Use a self-assembling crosslinking polymer in aqueous solutions.
- Add biotin-coated magnetic particles
- Then clear the Uranium-containing polymer network using a simple magnet
- Can be used for other heavy metals like cadmium and lead as well



What are the pros and cons of each solution?

- Consider convenience, cost, ethics, etc.

Think of at least one other potential solution that could be used.

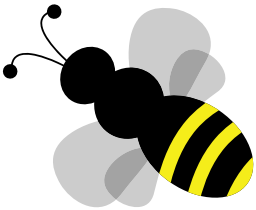
- Keep this solution in mind as you consider the global problem.

SCENARIO 2:
POLLUTION

Current Global Problem: Pollution is estimated to cause 3.7 million premature deaths and destroy crops that can feed millions of people every year.

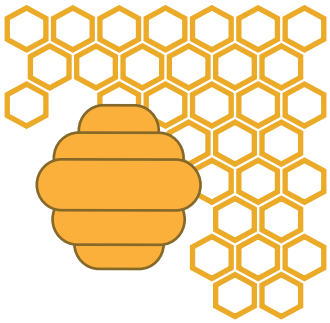
What solutions can you think of to this problem using synthetic biology?

- Consider what past iGEM teams have done and the solution you created in the previous discussion questions.
- Your job is to create a 3 minute pitch in which you briefly mention the problem you are solving and the solution you think is most viable and why.
    - Make sure to consider convenience, cost, ethics, etc. again



SCENARIO 3:

BEE POPULATION



Synthetic biology is being used to solve the world's leading problems. Today, it is your job as a team to consider past solutions and think about how you can create novel solutions using synthetic biology.

Introduction: Bees play a vital role in our ecosystem, responsible for pollinating a huge range of our plant life that we rely on for food production. Honeybees alone pollinate roughly $14 billion of crops per year in the United States. Since 2006, beekeepers from around the world have reported a sharp decline in their bee population, causing worry among experts on how we are going to continue to feed our ever growing population.

Read through the following descriptions on what past iGEM teams have done and consider the questions below.

What past iGEM teams have done:

Wageningen UR 2016
Engineered bacteria to release a toxin in honey bees which targets a parasitic mite that has been a leading cause of death for this species of bees

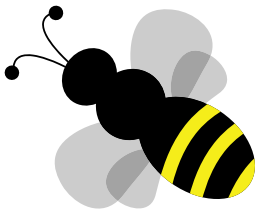
British Columbia 2015
Designed probiotic bacteria that can protect honey bees from the toxic effects of a common and powerful pesticide, neonicotinoid

What are the pros and cons of each solution?

- Consider convenience, cost, ethics, etc.

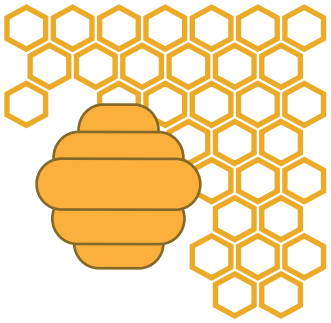
Think of at least one other potential solution that could be used.

- Keep this solution in mind as you consider the global problem.



SCENARIO 3:

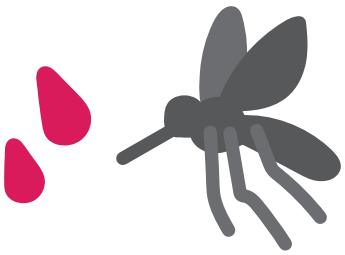
BEE POPULATION



Current Global Problem: While pesticides kill harmful insects and bugs, their increased use in food production is also causing the death of more bees. While one of the most harmful pesticides, neonicotinoid, has been banned in the EU to protect bees, farmers are seeing a drop in productivity due to being forced to use less effective pesticides. The Varroa mite is also a growing problem as it feeds off the blood of bees, making the bees significantly weaker and spreading diseases.

What solutions can you think of to this problem using synthetic biology?

- Consider what past iGEM teams have done and the solution you created in the previous discussion questions.
- Your job is to create a 3 minute pitch in which you briefly mention the problem you are solving and the solution you think is most viable and why.
    - Make sure to consider convenience, cost, ethics, etc. again



SCENARIO 4:
ZIKA VIRUS

Synthetic biology is being used to solve the world's leading problems. Today, it is your job as a team to consider past solutions and think about how you can create novel solutions using synthetic biology.

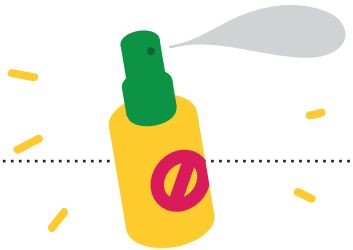
Introduction: Zika is a virus transmitted by certain species of mosquitoes; it can cause birth defects that tremendously impact the brain, but otherwise has similar symptoms to a flu. The spread of the virus lead to a widespread epidemic from early 2015 through late 2016.

Read through the following descriptions on what past iGEM teams have done and consider the questions below.

What past iGEM teams have done:

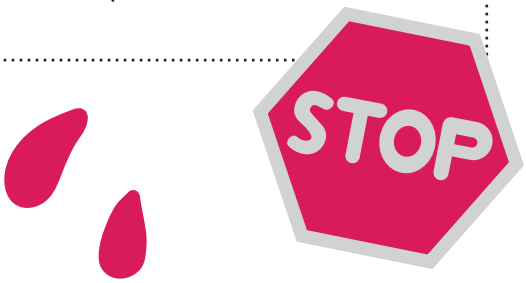
ColumbiaU NYC 2016

Genetically engineered bacteria to create strong, natural, long-lasting bug repellent chemicals. They also built a system to properly deploy it in a test container.



Minnesota 2016

Engineered a gene drive that could be used to overwrite all the copies of a single gene in a mosquito population to stop mosquitoes from biting humans. They also engineered a recovery drive, which would reverse the gene drive in the case of unforeseen consequences.



What are the pros and cons of each solution?

- Consider convenience, cost, ethics, etc.

Think of at least one other potential solution that could be used.

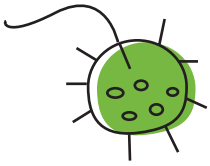
- Keep this solution in mind as you consider the global problem.

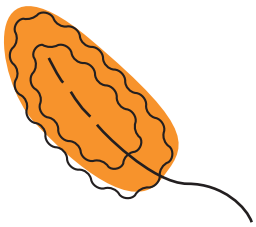
SCENARIO 4:
ZIKA VIRUS

Current Global Problem: Though no longer a worldwide epidemic, Zika continues to be prevalent in tropical regions such as Brazil.

What solutions can you think of to this problem using synthetic biology?

- Consider what past iGEM teams have done and the solution you created in the previous discussion questions.
- Your job is to create a 3 minute pitch in which you briefly mention the problem you are solving and the solution you think is most viable and why.
    - Make sure to consider convenience, cost, ethics, etc. again





SCENARIO 5:

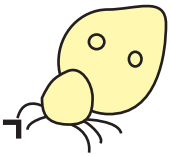
ANTIBIOTIC RESISTANCE

Synthetic biology is being used to solve the world's leading problems. Today, it is your job as a team to consider past solutions and think about how you can create novel solutions using synthetic biology.

Introduction: The discovery of antibiotics could be argued as one of man's greatest achievement, with antibiotics saving numerous lives after the discovery of penicillin during World War II. However, due to the misuse of antibiotics, the threat of antibiotic resistant bacteria (superbugs) is becoming an increasing pressing issue which needs to be addressed.

Read through the following descriptions on what past iGEM teams have done and consider the questions below.

What past iGEM teams have done:

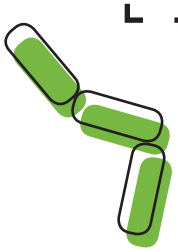


UiOslo Norway 2016

- Decided to analyze urine to analyze the bacteria in urinary tract infections by tracking beta-lactamase activity (an enzyme that occurs when bacteria is resistant to many types of antibiotics)
- During the dialogistic test, the color of the sample went from yellow to red if it was positive for resistant bacter
- Then developed a smartphone app to analyze the change of color of their sample

Edinburgh 2017

-"Phage therapy": Using phages (viruses) to kill pathogenic bacteria
-Used CRISPR (a gene editing technique) to target the molecule of interest and putting two well documented phages.
-The bacteria phages are limited in terms of the amount of DNA that can be packaged in their heads.
-However, current legislation is not set up to deal with the administration of phages to patients due to the fact that their behavior in the body is mostly undocumented.

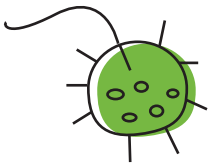


What are the pros and cons of each solution?

- Consider convenience, cost, ethics, etc.

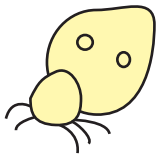
Think of at least one other potential solution that could be used.

- Keep this solution in mind as you consider the global problem.



SCENARIO 5:

ANTIBIOTIC RESISTANCE



Current Global Problem: Antibiotic resistant bacteria is a problem occurring around the world. However, developing countries are often suffering more from these superbugs due to the lack of availability of cheap medication and ways of shipping the medication to remote locations.

What solutions can you think of to this problem using synthetic biology?

- Consider what past iGEM teams have done and the solution you created in the previous discussion questions.

- Your job is to create a 3 minute pitch in which you briefly mention the problem you are solving and the solution you think is most viable and why.
    - Make sure to consider convenience, cost, ethics, etc. again