GRADES K-5

Synthetic Biology

This activity booklet has been developed by the iGEM team at The College of William & Mary. If you have any questions regarding this activity booklet, please contact the iGEM team at igem@wm.edu

What is

Synthetic Biology?

From SyntheticBiology.org, "Synthetic biology refers to both: the design and fabrication of biological components and systems that do not already exist in the natural world [and] the re-design and fabrication of existing biological systems." Here at W&M iGEM, we don't think anyone should need to Google that definition. Synthetic biology is an incredibly interdisciplinary and powerful emerging field of science, and access to all that SynBio has to offer should not be left to students who happen to stumble across it in college. As synthetic biology becomes increasingly prevalent in our everyday lives, people should have the knowledge to recognize how SynBio will affect them. Unfortunately, surveys, including our own, show most people don't understand what synthetic biology is, but they are afraid of the potential consequences.

Our Solution

Workshops & Activities

In past summers, our iGEM team has held workshops across the state of Virginia, both in our lab and at other schools, for students and parents alike. The feedback has been overwhelming. Following each event parents email us about how their children are still talking about the activities, and adults stay after to share their excitement about being able to openly learn and communicate with the people who are actually doing the science!

Sustainability

Activity booklet & Support

Being on a summer iGEM team is an exciting part of any synthetic biology researcher's life, but the sad truth is that we will not be able to hold large workshops for students and parents throughout the school year. However, the learning should not stop with us. We have developed this activity booklet so that anyone, with any degree of science backgrounds, can teach synthetic biology in an engaging way!

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Twizzler DNA

Grades 1-3
Time: 30 min

What does DNA look like?

Learning Objectives

In this module, students will learn the basic structure of DNA. They will learn that DNA looks like a twisted ladder, and that it holds instructions "written" in base pairs. They will understand that specific bases bind with other specific bases to form base pairs.

Materials

Each participant will need:
2 Twizzlers
5 toothpicks
10 colored marshmallows*

*You will need 4 different colors. Each color represents a nucleotide base. You can use gummy bears instead of marshmallows.

Approximate Cost: $6 for 25 Students

Procedure

Introduce the concept of DNA (tips on how to do this are in the Background). Explain that the Twizzlers represent the backbones of DNA, and ask them what they think DNA looks like (it is helpful to let them draw their guesses). Discuss how information may be carried by DNA through base pairs. Pass out marshmallows, assigning each color a base pair (adenine, thymine, guanine, and cytosine, or A, T, G, and C). Explain that A always matches T and G always matches C. Give each student one colored marshmallow and ask what color marshmallow they need to make a base pair, checking that they understand the concept of matching bases forming base pairs. Students should put two matching marshmallows onto each of the five toothpicks and attach them between the Twizzlers. Twist the whole structure to see the double helix.

Background

How does your body know to be human and not a dog or a jellyfish or a cactus? DNA! DNA, also known as deoxyribonucleic acid, is a tiny molecule that every part of your body "reads" in order to make you who you are. DNA tells your nose to be a nose and your foot to be a foot; it tells your hair what color to be and tells your skin if you have freckles. So… what is DNA? We know what it does, but what does it look like? If you had super vision that let you see the tiniest molecules and atoms, what would you see?

In this activity, we use Twizzlers to represent the backbone of DNA, because in the body the backbone is made of sugar—similar to the sugar in this candy—and phosphate, a yellow-brown mineral.

If DNA is a set of instructions, bases are like letters. The DNA alphabet only has four letters, A, T, C, and G. Two bases make a base pair. Explain that one marshmallow (representing one base) is attached to one backbone and the other marshmallow is attached to the other backbone. If the colors of the marshmallows match, then they "click" together and bind to one another, kind of like puzzle pieces.

Critical Thinking Questions

What happens if a DNA strand has A matched to C or G matched to T?

How many different DNA sequences did you see in your classroom?

If there were a billion base pairs instead of five like you had on your model, how many different DNA sequences do you think you would see?

Do different people have different DNA sequences?

What kinds of information might a DNA sequence tell the body?

Activity adapted from:
http://www.andersononline.org/ourpages/auto/2015/1/21/52509287/Twizzler%20Lab.pdf

DNA Bracelet

Grades 1-3
Time: 30 min

What does my DNA say about me?

Learning Objectives

This activity should engage students in examining the types of traits for which their DNA codes. The bracelet concept also implies the sequential structure of genes: each bead represents a locus for the gene (order/location matters!). Students should notice that their bracelets look different from each other, because their DNA is different. If there are siblings in the class, their bracelets may look very similar, because genes are inherited.

Materials

Colored pony beads: one bead per student per trait
String/Pipe cleaners: one per student
Key rings to make key chains instead of bracelets
Traits table (see template)

Procedure

Approximate Cost: $8 for 25 Students

Each student will need a copy of the included Traits Table. The table lists questions about traits the student may have. All the questions have "yes" or "no" answers. Students should highlight or circle the "yes" or "no" column for each row. Within the Yes/No columns are colors. If the student answers "yes" for a trait, that student should add a bead of the corresponding color to his or her bracelet/keychain, and likewise if the student answers "no." The beads should all be added in the same order as the traits table, to represent how each gene has its own specific location on a DNA strand.

Background

DNA is deoxyribonucleic acid. DNA molecules are very stable, very long, and composed of nucleotides. Nucleotides include cytosine, adenine, guanine, and thymine, abbreviated respectively as C, A, G, and T. These nucleotides are "strung together," one after another in a DNA molecule, forming a sequence (i.e. TACTAG... and so on). The sequence of nucleotides composing a DNA molecule forms a genetic code, which the cell can "read."

DNA is structured as a double helix, two connected helices running in opposite directions. The two helices connect as the nucleotides align against each other. Cytosine nucleotides on one helix connect to guanine nucleotides on the opposite, and adenine connects to thymine (C to G, A to T).

DNA codes for all biological aspects of the organism. Genetically determined traits include hair color, eye color, height, blood type, and whether you're a boy or a girl.

Critical Thinking Questions

Knowing what you do about the two DNA backbones running in opposite directions and the way the nucleotides pair, can you predict the corresponding sequence on the opposite DNA backbone to "TACTAG?"

What other traits do you think your DNA determines?

Do you think your DNA determines all of your traits?

Activity adapted from:
http://www.sepa.duq.edu/darwin/pdf/DNA%20Bracelet%20Activity%20Classroom.pdf

Tree of Traits

Grades 2-4
Time: 45 min

Are all traits equally common?

Learning Objectives

In this activity, students should explore the concept of genes. The traits on the included list all have yes/no answers (the student will either have the trait or will not) and are meant to demonstrate examples of easily visible traits that our genes code for, and the diversity therein. Once class data is compiled, students should practice graphing the information. Finally, students should take some time to discuss in groups the implications of genes, and how they make everyone different (see Critical Thinking Questions).

Materials

Graph paper
Markers
Ruler

Approximate Cost: Free

Procedure

Students should highlight a box in the "Yes" or "No" column for each trait listed in the included traits table. In case you are doing this activity in conjunction with the DNA bracelet, each trait lists a color in the Yes/No column. These tables should be collected and the data should be graphed in histograms, showing the frequency of each trait.
By the end, students should be able to compare their tables, bracelets, and/or key chains. Who are they most similar to? Who are they most different from? Which traits are the most common? Which traits are the most rare? Can you match a bracelet back to a person using the table? This is like using DNA to tell people apart!

Background

The DNA inside every human contains instructions which help determine who they are—how their body starts out and how it will grow. DNA can be compared to an instruction manual. A gene is a specific DNA instruction for one small part of the body—for example, one gene determines whether someone has dimples or not, but it takes many genes to determine the color of someone's eyes. A gene can be compared to a sentence of the DNA instruction manual. It is important to know that genes do not always have the final say on how someone turns out—even if someone's genes have instructions for being of average height, environmental factors, like the quality of their diet and the frequency of exercise, can make them end up taller or shorter than expected. It is important to remember that genes are a very fundamental, baseline-level concept. In order for any life to function it needs some sort of information storage system to dictate how it functions and reproduces itself—genes are this information storage system. Please take caution not to instill the notion that genes are only responsible for minute, easily observable physical traits like those presented in this activity.

Critical Thinking Questions

What do you think would happen if there were no genes?
If you could change the instructions in your genes, would you?
What would you change them to say?
How do you think this would change the person you are today?
You can't control what the instructions in your genes say, and you can't change them. How does this make you feel about treating people differently based on the traits from their genes?

Activity adapted from:
https://www.genome.gov/pages/education/modules/treeofgenetictraits.pdf
Image from: https://www.flickr.com/photos/bluecockatoo/3208181695

HELLO
MY NAME IS

And these are my traits...

Bead Number:	Trait	Yes	No
1	Are you female?	Pink	Blue
2	Do you have brown eyes?	Red	White
3	Do you have blonde hair?	Yellow	Black
4	Do you have attached earlobes?	Green	Blue
5	Do you have a Widow's Peak hair pattern?	White	Yellow
6	Can you roll your tongue?	Blue	Black
7	Are you left handed?	Orange	Red
8	Do you have a round jaw?	Yellow	Green
9	Do you have a cleft in your chin?	Red	Black
10	Is your hair curly?	Yellow	Blue
11	Do you have big eyebrows?	Green	Yellow
12	Are your eyebrows straight?	White	Black
13	Do you have short eyelashes?	Blue	Red
14	Do you have dimples?	Orange	Green
15	Do you have long fingers?	Yellow	Orange
16	Do you have freckles	Black	Pink
17	Can you make a clover shape with your tongue?	Red	Yellow
18	Can you fold your tongue sideways?	Green	White
19	Do you have a ridge on your nose?	Red	Pink
20	Do you have Hitch-Hiker's thumb?	Black	Orange
21	Do you sunburn easily?	White	Yellow
22	When you clasp your hands together, is your left thumb over your right?	Blue	White
23	Do you have big feet?	Yellow	Black
24	Do you have wide nostrils?	Orange	Pink
25	Are you colorblind?	Red	Green
26	Are you tall?	Blue	Orange

Monster Alleles

Grades 2-5
Time: 30 min

What are dominant and recessive genes?

Learning Objectives

Students should discover how some traits are more common than others due to dominant and recessive genes. They will learn about the concept of "alleles". Students will have the opportunity to practice converting genotype to phenotype through their monster drawings. They will see some generalized examples of the kinds of traits genes can code for.

Materials

Colored crayons
Paper
Allele cards (see template)
Allele key (see template)

Approximate Cost: Free

Procedure

Before beginning:
Prepare allele cards (included in the template), and the allele key (also included in the template), or have students make their own allele card sets on index cards.
After cards are prepared:
Discuss the concept of alleles with students. Explain the meanings of dominant, recessive, homozygous, and heterozygous. Discuss the allele key with students: explain which traits the cards will decide for the monster they draw (i.e. a long tail is dominant over a short tail). Finally, shuffle the cards and lay them out on a table. Have students match all the letters and determine if the monster will be homozygous dominant, homozygous recessive, or heterozygous for each trait. Have the students draw their monsters based on the given traits. Point out that everyone's monsters still look very different—that's because we only specified a few traits! A real monster's DNA would specify almost every trait.

Background

Alleles are different forms of the same gene. We are born with two sets of chromosomes. One set comes from our mothers, and the other set comes from our fathers. However, our mothers and fathers do not have exactly the same genes. For example, if a mother has blue eyes and a father has brown eyes, a baby will have two copies of the eye color gene that say different things. How does the baby's body decide what color to make the eyes?

The answer is in dominant and recessive genes. A dominant gene is represented by a capital letter, and recessive by a lowercase letter. We know that blue eyes are a recessive trait (b) and brown eyes are a dominant trait (B). If a baby has one copy that says blue and one copy that says brown (Bb, heterozygous), the baby will have brown eyes, because brown is dominant. If the baby had two copies of genes that said "blue eyes," the baby's eyes would be blue (bb, homozygous recessive), and if the baby had two copies that said "brown eyes," the baby's eyes would be brown (BB, homozygous dominant).

Critical Thinking Questions

How do individuals get their traits?
Do plants and animals have dominant and recessive traits too?
Bacteria reproduce by splitting off from themselves. Does this affect how they get their traits? (There are not two sets of chromosomes.)
How does this influence diversity in traits?
How could you change someone's traits?
Do two individuals with the same parents get all the same traits?

Activity adapted from:
http://www.glencoe.com/sites/common_assets/science/virtual_labs/E09/E09.html

Monster Alleles Key

This activity uses cards (following pages) that should be printed such that the two blue pages are back to back, and the two green pages are back to back. The T should line up with the t on the other side of the page so that when the cards are cut out, each card has a lowercase letter corresponding to the capital letter on the other side.

Alternatively, you can make your own Allele Cards using index cards.

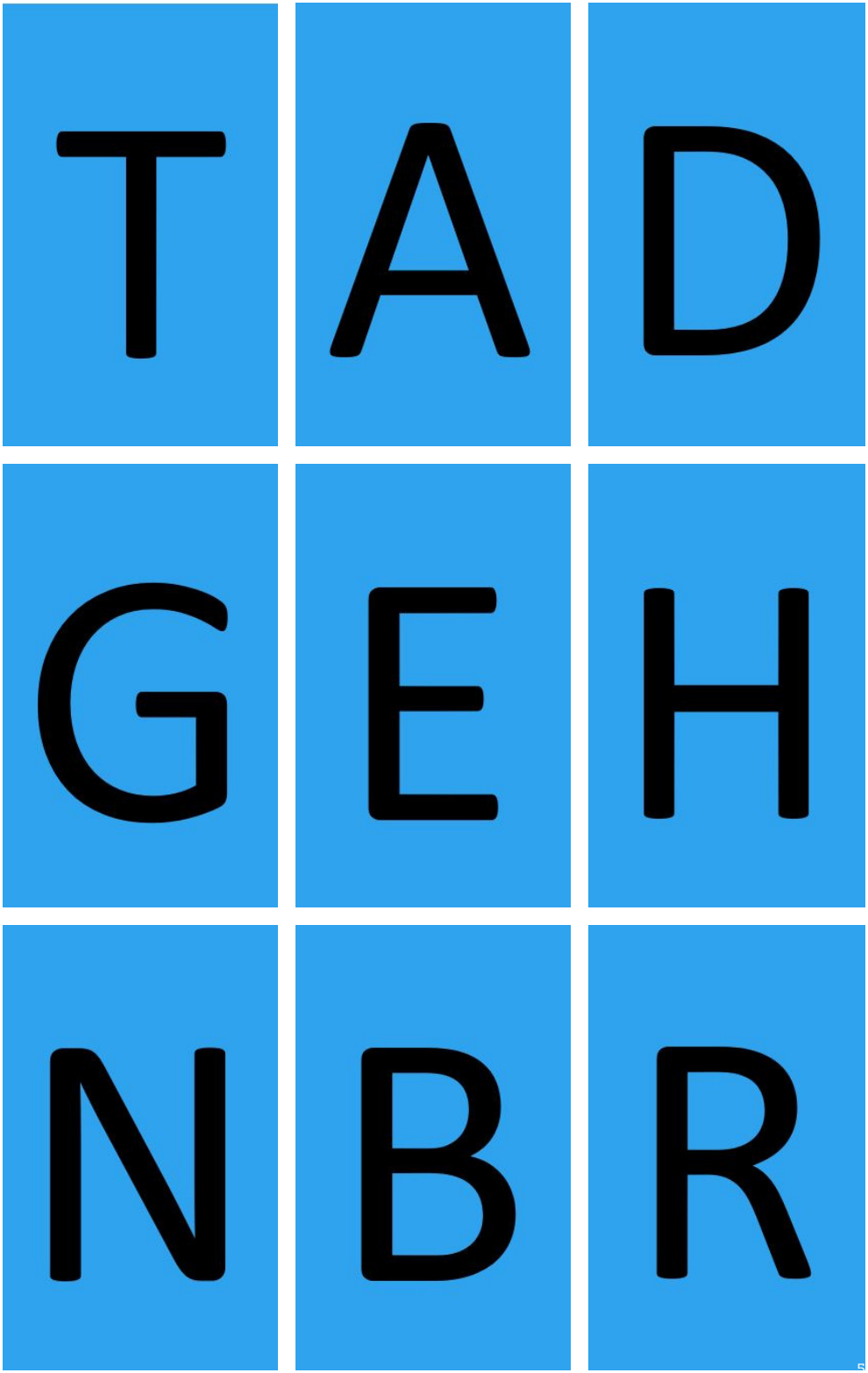
Below is a sample key of what the cards can be used to represent. Feel free to adjust the traits we have given, or make your own key, with whatever traits you would like the game to specify.

Dominant	Trait	Recessive	Trait
T	Long tail	t	Short tail
A	Antennae	a	No antennae
D	Droopy ears	d	Pointy ears
G	Beak	g	No beak
E	Two eyes	e	One eye
H	Horns	h	No horns
N	Long neck	n	Short neck
B	Breathes fire	b	Doesn't breathe fire
R	Furry	r	Scaly

The cards will be mixed up, each color set represents one parent. Then, one card of each letter will be chosen from each parent to represent the alleles. If the combination is TT, for example, the monster will have a long tail. If the combination is Tt, the monster will still have a long tail, because the long tail is dominant. tt will call for a short tail, which is recessive.

Dominant	Trait	Recessive	Trait
T		t	
A		a	
D		d	
G		g	
E		e	
H		h	
N		n	
B		b	
R		r	

A blank table is also provided if teachers would like to make their own key.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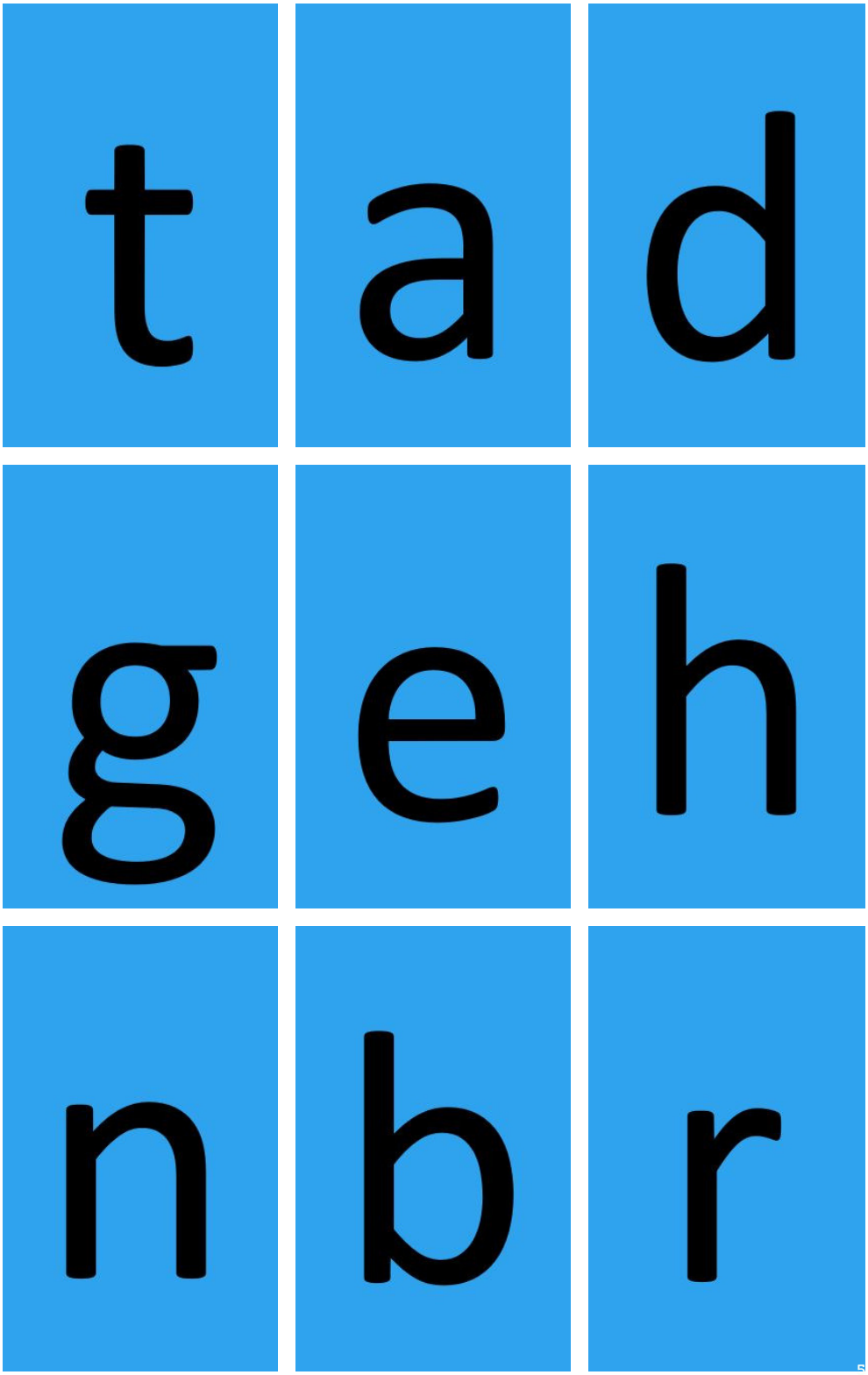
G E H
N B R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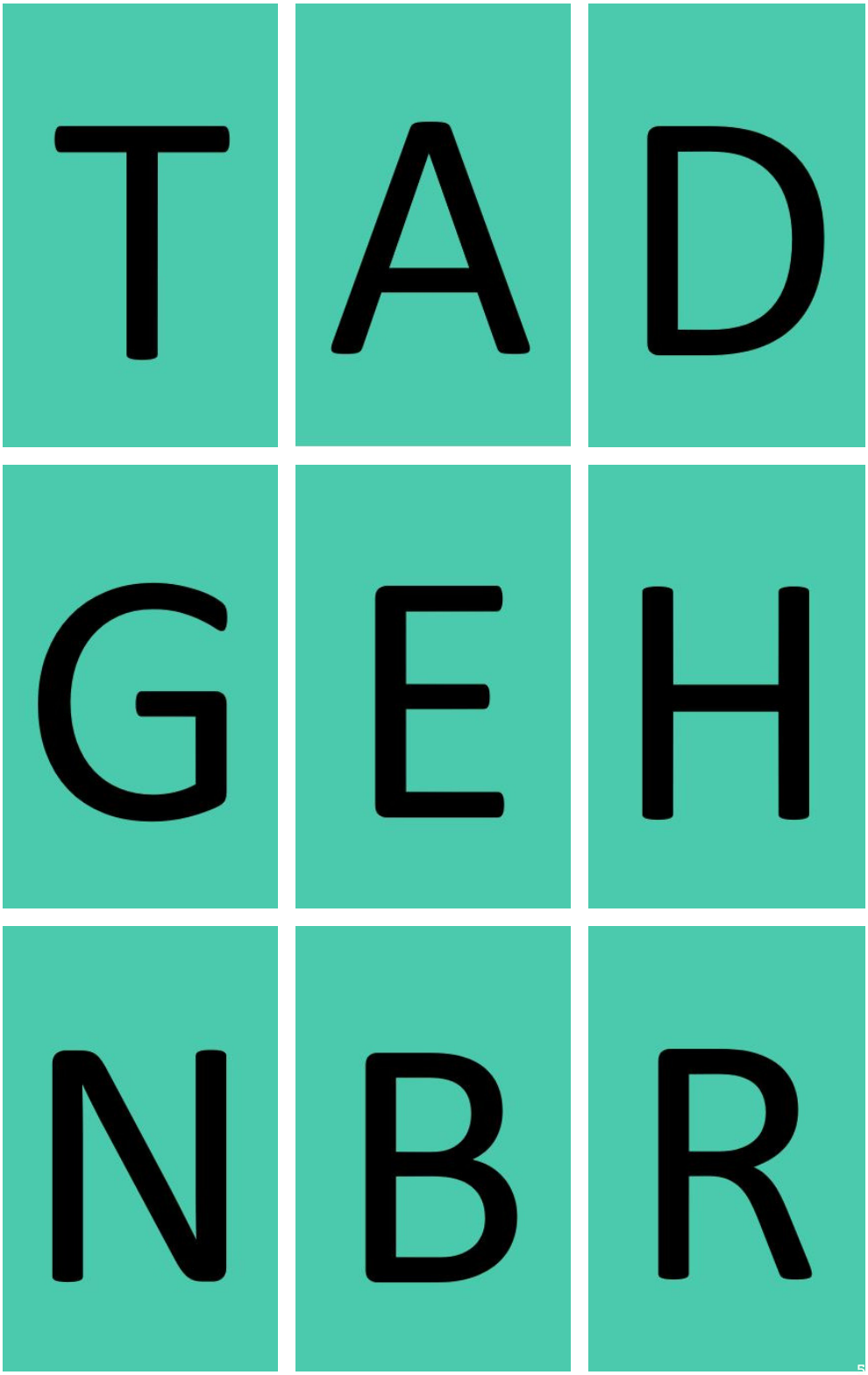

T A D
G E H
N B R

t	a	d
g	e	h
n	b	r

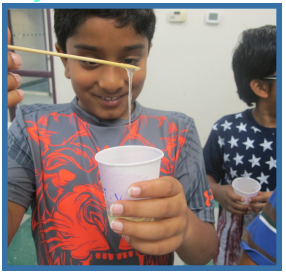
DNA Extraction

Grades 3-5
Time: 90 min

How can we take DNA out of a fruit?

Learning Objectives

Students extract DNA from fruit to get a tangible sense of what DNA looks like on a macroscopic scale. They should understand that there is DNA in every cell and that DNA contains the instructions for life. They are also introduced to protocols that synthetic biologists use in order to research genetics and modify DNA.



Materials

Per student:
1/4 of a banana, substitutable with any other fruit
Ziploc bag with 1 inch of water
Detergent
Disposable cup with two coffee filters
Ethanol (refrigerate before use)
One wooden skewer

Approximate Cost: $10 for 25 Students

Procedure

First, introduce the idea of DNA. DNA is a tiny molecule that acts like an instruction manual for each of your cells. Your DNA tells you to be you, and a banana's DNA tells it to be a banana. Let students guess what DNA looks like on a human scale (without a microscope).

Give each student (or pair of students) 1/4 of a banana in an open ziploc bag with water, and close the bag. Tell students to gently mash up the banana by squeezing the bag. Once the banana is a lumpless mush, put some detergent into each bag and close the bag. Students should gently mix in the detergent, trying to avoid creating bubbles. Give each student or pair a disposable cup with two coffee filters taped to the top. Carefully pour the contents of the bag into the coffee filters and let the liquid drip through the filter into the cup. Let the banana-detergent mix sit in the cup for 20-30 minutes. This is a good time to talk about DNA, or do a different activity from this collection, like Codon Cards or Monster alleles.

Throw away the coffee filters and any material that didn't drip through the filter, keeping the cup and the liquid that collected in it.

Pour cold ethanol into the cup. The more you pour in, the more DNA will precipitate out of the liquid. Use the toothpick or skewer to stir the white-clear substance that precipitates out, or collects at the top of the liquid: this is the DNA!

Background

DNA is located in the nucleus of the cell. DNA contains the code for all biological aspects of an organism. Individual genes are parts of the DNA that code to control particular traits. Scientists extract DNA to study particular genes and how they affect organisms. Scientists can study DNA in individual humans to determine traits relevant to their health and development and diseases to which they may be susceptible. Scientists can change the expression of genes in organisms. This is most easily done in simple organisms like bacteria. The process of changing genes involves a process called molecular cloning. Molecular cloning is changing the composition of a DNA molecule and expressing that DNA in an organism.

What each step of the extraction does: Mashing up the banana allows more banana cells to be exposed to the water and whatever liquid is added to the bag. The detergent breaks open the cells so that the DNA can enter the liquid solution. The filter removes the broken cells. The ethanol separates the DNA from everything else in the solution.

Critical Thinking Questions

Now that you know what banana DNA looks like, what do you think human DNA looks like? Why?

If you put banana DNA in a human cell, what would the cell look like?

If you could cut and paste pieces of banana DNA into apple DNA, what traits would you give the apple?

Would you eat fruit that had modified DNA? Why or why not?

How do you feel about the idea of putting DNA from one organism into another organism? What are the potential benefits of "recombining" DNA? Potential negative effects?

Activity adapted from:
https://askabiologist.asu.edu/activities/banana-dna

Codon Cards

Grades 4-5
Time: 30 min

How can we take DNA out of a fruit?

Learning Objectives

Students should learn that there are four bases: adenine, thymine, guanine, and cytosine. A and T bind, and G and C bind. They should understand that a single stranded DNA can bind to another strand that has the reverse sequence (T in the place of A, C in the place of G, etc.) to create double-stranded DNA. Students will interpret their three base sequence, called a "codon", and learn which amino acid their codon encodes.

Materials

Class set of artino acid-codon chart (see template)
Codon Card Key (see template)
Codon cards - one match per two students (see template)

Approximate Cost: $2 for 25 Students

Procedure

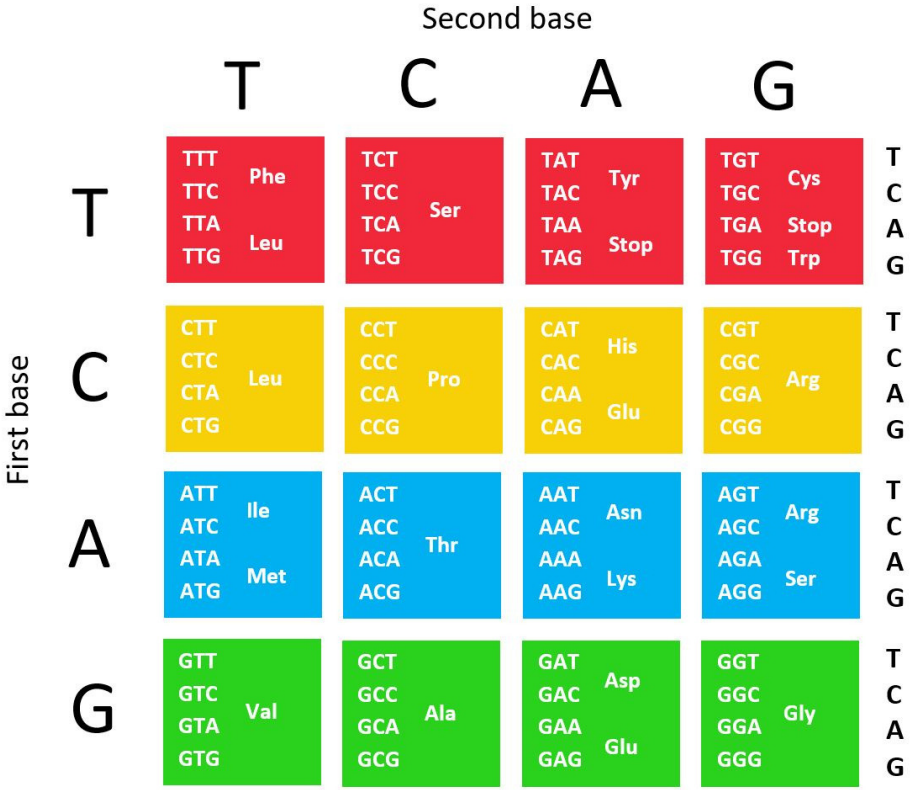
First introduce the idea of DNA and explain bases and base pairs. Then, tell students which color circle represents which base:
blue=acterine (A), red=thymine (T), green=guanine (G), yellow=cytosine (C)
Pass out codon cards, face down so that students can't see the colored circles. Have students hold the cards up on their foreheads so that they can't see the card, but everyone else can. Make sure that the orange triangle is pointing up. Test students to ask other students yes or no questions about their sequence. ex.: is my first base adenine? is my first circle blue? Once students think they know what is on their card, they should find a partner with the corresponding sequence. If a pair thinks they match, they should ask the teacher to confirm if they match or not. You can check the match by referring to key. After all the pairs are matched, explain that each three base pair sequence, called a codon, codes for one amino acid. Show students the amino acid-codon chart and ask students to get in groups of three (and line up) to to create a sequence that will code for an amino acid. Make sure the students understand that they now represent only the template strand (as only one of the double strands is actually read) that will be read to create the amino acids. Then check the groups identified their correct amino acid by using the key. Finally, summarize what students learned: base pairs match, every three base pairs code for one amino acid.

Background

DNA is composed of nucleotides, including adenine, guanine, thymine, and cytosine, abbreviated A, G, T, and C. These nucleotides are strung together forming a sequence in the DNA molecule. The sequence of nucleotides in the DNA compose a genetic code which the cell can "read." The cell first transcribes the DNA code by making another molecule, RNA, based on the code. The cell then reads, or “translates” the RNA, which came from the DNA, to determine how to build proteins. Proteins compose an organism, and are made of amino acids, which are "strung together" forming a sequence in a somewhat similar way (Conceptually, not chemically) to the way nucleotides are stringed together in DNA. RNA is read in groups of three nucleotides. These groups are called codons. Each codon signals to add a particular amino acid to the protein for which a sequence codes.
What each step of the extraction does: Mashing up the banana allows more banana cells to be exposed to the water and whatever liquid is added to the bag. The detergent breaks open the cells so that the DNA can enter the liquid solution. The filter removes the broken cells. The ethanol separates the DNA from everything else in the solution.

Critical Thinking Questions

If you know a sequence of DNA, can you predict the corresponding sequence?
Why is there a coding strand and a non-coding strand? What would happen if both strands were read by the cell? Would they create the same amino acids?
Proteins are made of many amino acids. How could you change DNA to create a protein?
If one base in a sequence is deleted, what happens to the sequence following it? Would those sequences code for the same amino acids or would the codons be affected?


Second base
T
C
A
G
First base
T
C
A
G
TTT TTC Phe TTA TTG Leu
TCT TCC TCA TCG Ser
TAT TAC Tyr TAA TAG Stop
TGT TGC Cys TGA Stop TGG Trp
CTT CTC CTA CTG Leu
CCT CCC CCA CCG Pro
CAT CAC His CAA CAG Glu
CGT CGC CGA CGG Arg
ATT ATC ATA Ile ATG Met
ACT ACC ACA ACG Thr
AAT AAC Asn AAA AAG Lys
AGT AGC Arg AGA AGG Ser
GTT GTC GTA GTG Val
GCT GCC GCA GCG Ala
GAT GAC Asp GAA GAG Glu
GGT GGC GGA GGG Gly
T C A G
T C A G
T C A G
T C A G
Third base

Codon Cards Key

Adenine (A)

Guanine (G)

Thymine (T)

Cytosine (C)

Coding Strand

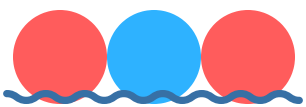
Non-Coding Strand

Pair 1 - Threonine

ACG

TGC

Pair 2 - Tryptophan



TAT

ATA

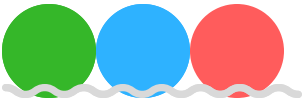
Pair 3 - Arginine

CGA

GCT

Pair 4 - Leucine

CTA



GAT

Pair 5 - Stop Codon

TGA

ACT

Pair 6 - Serine

TCG

AGC

Pair 7 - Tyrosine

TAC

ATG

Pair 8 - Arginine

CGC

GCG

Pair 9 - Glutamine

CAG

GTC

Pair 10 - Isoleucine

ATC

TAG

Pair 11 - Arginine

AGG

GCC

Pair 12 - Glycine

GGT

CCA

Pair 13 - Glutamic Acid

GAG

CTC

Pair 14 - Alanine

GCC

CGG

Pair 15 - Alanine

GCA

CGT

Dessert Cells

Grade 5
Time: 60 min

How do plant,animal, and bacteria cells differ?

Learning Objectives

Students should learn the organelles in a cell as well as the approximate relative size of each organelle. They should understand that there is no "empty space" in a cell. They should learn the main function of some organelles and understand that each organelle has a unique job within the cell and that the organelles work together to perform larger functions.

Materials

Cookie
Poptart
Hotdog bun
Spread (jam, butter, apple sauce)
Assorted toppings to represent organelles

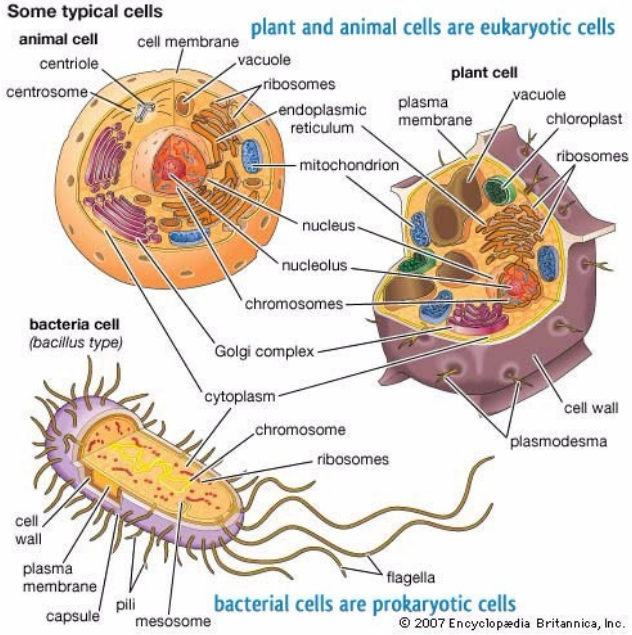
Approximate Cost: $15 for 25 Students

Procedure

With students, make a 3-way Venn Diagram of the similarities and differences in animal, plant, and bacterial cell structures. Discuss the role of each organelle.
Then, pass one sugar cookie to each child to represent an animal cell, a piece of bread to represent a plant cell, and half a hotdog bun to represent a bacterial cell. Apply toppings to represent organelles and important cell structures that make each cell type unique. The same organelles should be represented by the same topping across different "cells". Try to make the 'organelles' roughly accurate size: the nucleus should be much larger than other organelles, the mitochondria and ribosomes should be small and there should be many of them, etc. After students complete their 'cells' discuss which toppings represent which organelles and why.

Background

Plant and animal cells are eukaryotes because they have nuclei. Bacterial cells are prokaryotes because they do not have nuclei. Plant cells and bacterial cells both have cell walls, but animal cells do not. Bacterial cells have pili and flagella to help them move and sense, animal and plant cells do not.



Critical Thinking Questions

Why do bacteria need flagella, but animal and plant cells do not?
Why would it be like if animal cells had cell walls?
Which cell would it be easiest to add/change DNA in?
Which cell type seems most primitive? Which seems most advanced?

Images from: https://www.pinterest.com/explore/edible-animal-cell, https://www.britannica.com/science/bacteria

Dessert Cells

For each organelle write the function and what you used to represent the organelle.

Nucleus
Represented by: _____
Function: _____

Mitochondria
Represented by: _____
Function: _____

Cytoplasm
Represented by: _____
Function: _____

Ribosomes
Represented by: _____
Function: _____

Rough ER
Represented by: _____
Function: _____

Smooth ER
Represented by: _____
Function: _____

For each organelle write the function and what you used to represent the organelle.

Golgi Body
Represented by: _____
Function: _____

Cytoskeleton
Represented by: _____
Function: _____

Vacuoles
Represented by: _____
Function: _____

Peroxisome
Represented by: _____
Function: _____

Lysosomes
Represented by: _____
Function: _____

Bean Genes

Grade 5
Time: 45 min

What are incomplete dominance and codominance?

Learning Objectives

Students will learn about heredity and how genes can combine. It is an excellent introduction to Punnett Squares because students will explore the ratios among phenotypic expression. Students will develop a deeper understanding of homozygous, heterozygous, dominant, recessive, and learn about codominance and incomplete dominance.

Materials

Per group of students:
(recommended pairs)
10 red beans
10 white beans
2 paper bags
Garden Tally sheet (included)

Approximate Cost: $5 for 25 Students

Procedure

Give each pair/group of students 2 paper bags. In one bag put 10 red beans, and in the other, put 10 white beans. The beans represent the genes for flower color (red or white). Red flowers are dominant (R), and white flowers are recessive (r). Choose one bag to be the female flower and the other to be the male flower: then, pick one bean from each bag with your eyes closed. If both are red (RR) color a flower on the Garden Tally red. If both are white, leave a flower white (rr). If one is red and the other is white, color the flower pink (Rr) for incomplete dominance or spotted red/white for codominance (one partner should do codominance, the other should do incomplete dominance). Return each bean to its original bag. Keep going until all your flowers have been accounted for. Be very careful that each bag always has 10 of the correct color bean!
When students are done, they should tally their results in the red boxes. Which color flower was most common? What percentage of the total flower were that color? What about least common?

Background

This module assumes basic understanding of recessive, dominant, homozygous, and heterozygous traits. If you would like further background information on these topics, please see the Monster Alleles background information.
The new information in this module is about incomplete dominance, and how it differs from codominance. Incomplete dominance is when one allele for a trait is not entirely dominant over the other allele. The trait is still controlled by a single gene (with two alleles, one from each parent), and each of those alleles contributes equally to phenotypic expression.
In the context of flowers: pink flowers (the offspring of a red flower and a white flower) with the genotype Rr are an example of incomplete dominance. The phenotype is in between red and white.

What if the red and white genes were instead codominant? We will again see a third phenotype, but in this case, both parental traits appear together. The Rr flowers would be spotted red and white!
Another example of codominance is blood type: a mother with Type A and a father with Type B will produce offspring with Type AB: both A and B markers are on the surface of the offspring's red blood cells.

Critical Thinking Questions

If you cross two pink flowers, what are the possible phenotypes of the offspring?

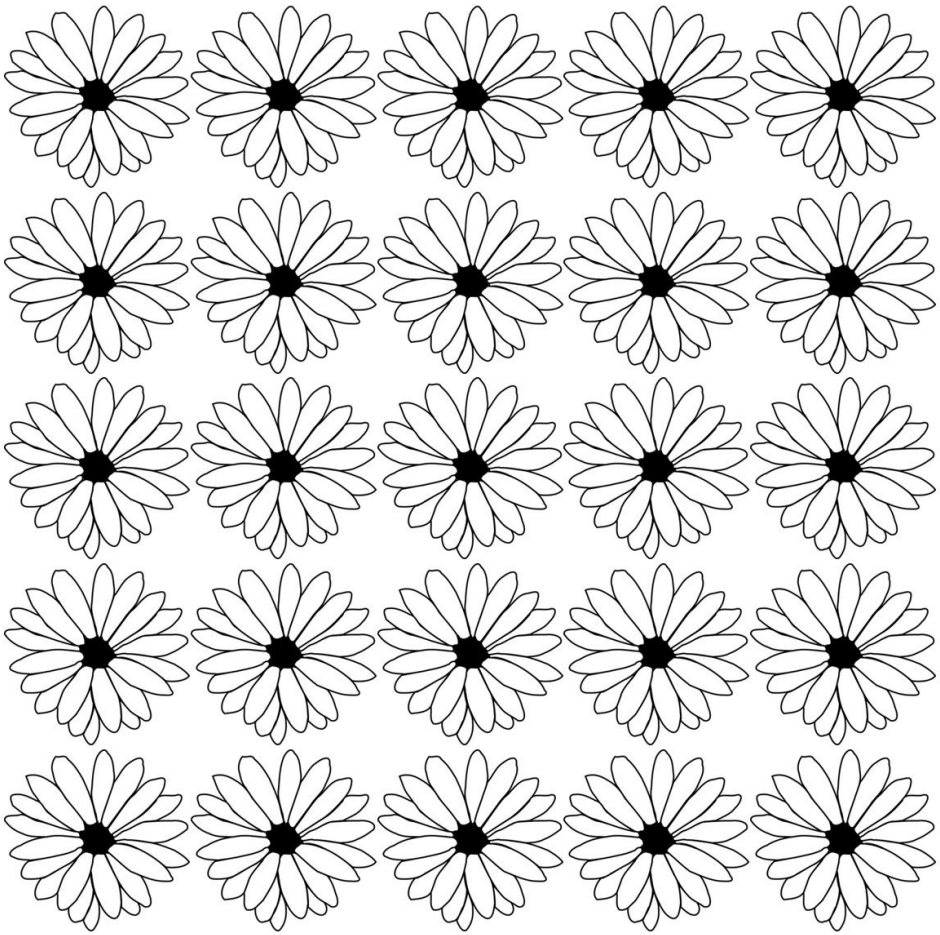
Codominance and incomplete dominance both produce a third phenotype. Can two alleles produce more than 3 phenotypes?

Activity adapted from:
http://science-class.net/Biology/genetics-heredity/bean_genes.pdf
Image from: https://sites.google.com/site/genpopfreevochaovetim/incomplete-and-codominance

HELLO
MY NAME IS

Circle One:
Codominance Incomplete Dominance

and this is my flower garden...



How many RR? %?	How many Rr? %?	How many rr? %?
These should be red	Codominance: spotted red/white Incomplete dominance: pink	These should be white

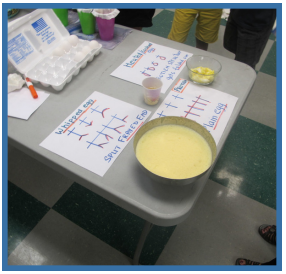
Egg Science

Grade 5
Time: 45 min

What does the shape of a protein do?

Learning Objectives

Students will explore how protein form follows function. This concept is vital in high school biology classes, and easy to visualize with the activity described here. Students will see how proteins can be heated, beat, and mixed with other solutions to change their structure and their outward appearance.



Materials

A dozen eggs
Hot plate
Pot
Bowls
Frying pan
Water
Oil
Whisk

Procedure

Approximate Cost: $4 for 25 Students

Unless you have a lot of hot plates, this is best done as a full class activity. Crack several eggs into three different bowls. Try heating the eggs in one of the bowls: put it on a frying pan and over a hot plate. How does the look of the egg change? Are there differences in consistency? Does the egg feel different? What about if you beat the egg?
In the second bowl, mix the egg with a whisk. What changes do you see? Finally, prepare an oil/water mixture. Discuss how the differences in oil/water polarity do not allow the two to mix. Then add egg to the oil/water solution, and watch as it creates an emulsion. Discuss how the egg proteins may be interacting with the oil and water to bring this about (you can alternatively use this activity to make pavlova, hollandaise sauce, and deviled eggs).

Background

Proteins are made up of long changes of amino acids decided by your DNA. In the white part of an egg, we see "globular" proteins: if you magnified them they would look like a long string folded up into a spherical shape. The proteins stay curled up tightly using many different types of chemical bonds.

When we heat the egg, the proteins become more energetic: they bounce into each other and into the water molecules (also in the egg). This breaks up some of the bonds that keep the proteins in their globular shape, and it also makes new bonds connecting the proteins together! If you keep heating, the egg proteins will form a web of interconnections, and your egg will feel rubbery.

When we beat the egg, like chefs do to make soufflé, air bubbles get caught in the egg mixture. Egg proteins have both hydrophobic (water-repelling) and a hydrophilic (water-attracting) ends. When the air gets caught in the egg, the hydrophobic part of the egg protein touches the air bubble, and the hydrophilic part stays in the water. However, the protein was all coiled up before. To make it so all the water-attracting parts can touch the water, the proteins uncurl, just like they did when we heated the egg. If you cook a whisked egg, the proteins will form connections with each other but leave the air bubbles in place: the egg will come out fluffier.

Finally, when you mix the egg into oil and water, the same hydrophobic/hydrophilic principle applies. The hydrophilic end of the protein attracts the water and the hydrophobic end attracts the oil, so water and oil molecules can be held close together with an egg protein in between.

Critical Thinking Questions

What foods can you think of that use the properties of egg proteins to affect texture?

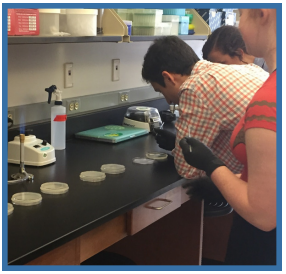
Yeast Streak

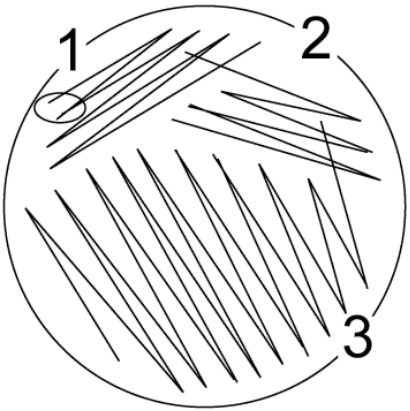
Grade 5
Time: 45 min

How can we grow fungal colonies?

Learning Objectives

Learn to make medium to grow colonies, pour plates, streak plates, and observe growth.





Materials

Petri dishes or foil cupcake liners
Gelatin medium (recipe in Background)
Baker's yeast packet dissolved in 2 cups warm water
Q-tips
Each student should bring a vegetable or cheese (blue cheese works well)

Approximate Cost: $15 for 25 Students

Procedure

Heat the gelatin/agar solution and help students each pour 3 mm of solution into two petri dishes. Allow these to solidify and label each plate with each student's name before proceeding.
Once the plates are solid, allow each student to dip the end of a toothpick into the yeast solution, and very gently glide the tip of the toothpick along one of the plates in the pattern shown above under Learning Objectives. Try not to poke into the gelatin surface. Next, allow students to do the same with a moist cotton swab over vegetable/cheese. Use the cotton swab the same way as the toothpick to streak the second plates. Allow plates to grow at room temperature for 4-7 days, and then observe.

Background

For the homemade medium, you will need to combine:
8 teaspoons sugar, 4 beef bouillon cubes, 4 envelopes of plain gelatin and 4 cups of water in a saucepan. Bring the solution to a boil as you stir. Allow it to cool slightly before allowing students to help pour plates. This recipe makes about 24 plates. Double the recipe so each student can have two plates. This mixture should provide the nutrients yeast and fungus need to grow.

Why do we streak plates in this pattern? Often, scientists would like to get distinct colonies on a plate. This is because each colony represents a spot where a single yeast cell, fungal cell, or, as synthetic biologists are often concerned with, bacterium, began replicating. All the cells in that colony are clones of the original cell. Area 1 on the streaks will be the densest: colonies may not be distinct. We keep going with the toothpick/cotton swab so that eventually the colonies will be far enough apart because there are fewer and fewer cells left on the toothpick/cotton swab as we zigzag more across the plate.

Critical Thinking Questions

If a scientist is trying to add a new piece of DNA to a bacterium, say, to make it fluoresce red, how can the scientist make sure only bacteria that have that gene grow on a plate? (Think about antibiotics.)

When a scientist grows bacteria on a plate and then extracts DNA from a single colony (so that all the DNA is the same because they are all clones), is it better to do that extraction after the bacteria have grown for one day or after they have grown for one week? (Think about mutations)

Activity adapted from:
http://www.sciencebuddies.org/science-fair-projects/project_ideas/microbio_homemademedia.pdf,
Image from: https://www.gene.affrc.go.jp/manuals-micro_ampoule_en.php

Soap Membrane

Grade 5
Time: 60 min

What are the properties of a cell membrane?

Learning Objectives

Learn about the properties of cell membranes through soap bubbles! The following properties will be discovered:

1. Cell membranes are fluid and flexible. They can reform when broken.
2. Channel proteins float in the cell membrane. Channel proteins provide channels through the membrane.
3. Organelles are membrane-bound.
4. Binary fission.

Materials

Corn syrup
Water
Trays/Pans
Bendable Straws
Thread
String/Twine

Procedure

Approximate Cost: $5 for 25 Students

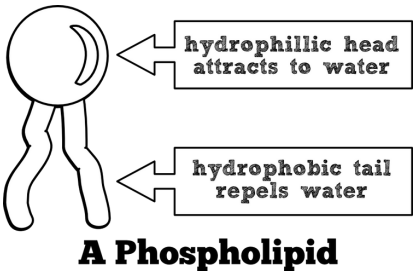
Bend the straws and crimp the short ends. Arrange them in a square to make the bubble frame. Tie thread in a small loop. Make bubble solution with 900 mL water, 100 mL dish soap, and 25 mL corn syrup. To demonstrate each objective:

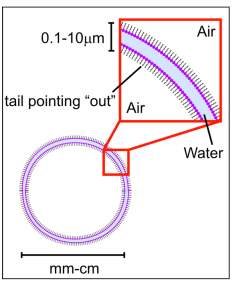
1. Dip bubble frame in solution. Move wet hand slowly through the soap film, watch as the film flexes and reforms when you take your hand out.
2. Put the thread loop in the bubble frame, and pop the part of the bubble inside the loop to represent a channel protein. Move the channel around.
3. Use a straw to blow bubbles inside other bubbles.
4. Use the twine to split bubbles on the tray into multiple bubbles.

Background

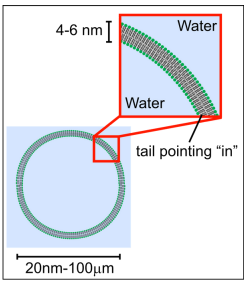
The membrane properties demonstrated by the soap bubbles are described in the Learning Objectives.

Additionally, it is useful to know the similarities between soap and membranes. Cell membranes are made of phospholipids, which have polar heads that interact with water and nonpolar tails that are hydrophobic. The phospholipids line up tail to tail so that the inside of the membrane is shielded from water while the outside touches water. Soap bubbles are similar but have a tail pointing outward and a layer of air in the middle.





Soap Bubble



Lipid Vesicle

Critical Thinking Questions

Why are membranes so important to life?
Can you think of anything else that acts like a membrane the way soap does?
Why do cell membranes have the hydrophobic tails facing in instead of out?
What other membrane properties can you think of that are not illustrated here?
How could you illustrate them with bubbles?

Images from: https://sites.google.com/site/genpopfreevochaovetim/incomplete-and-codominance, http://www.clearbiology.com/cell-membrane-bubble-lab/

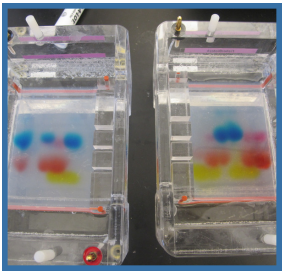
Electrophoresis

Grade 5
Time: 60 min

How can we separate molecules by size?

Learning Objectives

Gel electrophoresis is used almost daily by many molecular biologists. Students will firsthand make a gel with wells to load, choose colors of food coloring to load the wells with, and load them in with a disposable pipette. With a teacher's help, they will run the colors down the gel using 5 9-Volt batteries, and watch as the colors separate based on molecular size. The same color will always split into the same bands. This separation corresponds to the way scientists separate DNA molecules by size.



Materials

Electrophoresis Gel Box (May be borrowed from the local high school)
5 9-Volt battery
Saltwater solution
Gelatin/agarose
Food coloring
Disposable pipettes
Fork comb or plastic forks
Tape
TAE buffer solution

Approximate Cost: $25 initially, reusable

Procedure

Combine 50 mL TAE buffer solution with 0.5 grams agarose, heat in the microwave, and pour into the provided gel frame with the fork-comb (If using a plastic fork, wait until the gel is dry and poke holes along one edge of the gel). Once solid, remove the fork-comb. Pour just enough TAE buffer to cover the gel and fill all the wells. Finally, have students load the gel with 1 drop of food coloring in each well using disposable pipettes. For more colors, mix food coloring in advance. Have students guess what colors their lane will split into, and which molecules they think may be heaviest/go the shortest distance. Once the gel is loaded, attach the 5 9-Volt batteries to positive leads, and lay these leads in the gel chamber solution, such that the positive lead is at the bottom (opposite to the wells, and the negative lead is at the top (close to the wells).

Background

A gel is best thought of as a dense web through which we are running small molecules. These molecules have a slight negative charge, thus the current will pull them toward the positive end of the batteries (toward the positive lead). However, food coloring colors are made up of the primaries (red, blue, and yellow—some food coloring has a bit of pink that separates from the red as well). Each of these colors is a different size, so it moves at a different speed down the gel. Imagine a large molecule trying to move through dense web vs. a small molecule trying to move through the same web. Which will go further?

Scientists use electrophoresis to check the sizes of their DNA, because they cannot visually see how big the DNA molecules are. Usually, scientists know how long a piece they are looking for is, and running a gel can help them understand if the piece they have is approximately the right size.

When scientists run gels using DNA, they also run a ladder in one of the wells, which has a bunch of DNA fragments of different, known sizes. That way, they can compare the band their DNA makes to the bands on the known ladder and estimate the size.

Critical Thinking Questions

What are some applications of gel electrophoresis?

How does the current separate the DNA fragments by size?

If we were using DNA instead of food coloring, it could be clear. Scientists use a chemical called ethidium bromide in their gels, and then put the gel in a UV chamber to see where the DNA is. What does ethidium bromide do? What might it be dangerous to us?

Why does DNA migrate toward the positive end? (Think about the charge on DNA molecules.)