When Life Gives You Lemons…

Target Grade: Elementary/Middle School
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Brief Overview

In this biology based lesson, mentees will explore the science behind taste! They will learn about the taste pathway, PTC, and how miraculin alters taste receptor ability to perceive flavor. The lesson will conclude with the classic homemade ice cream experiment, with a 'sweet' twist. By the end of the lesson, mentees should also be familiar with the Scientific Method and its steps.

Teaching Goals

- **The Scientific Method**: a process for experimentation that is used to explore observations and answer questions. It is comprised of the following steps- ask a question, form a hypothesis, experiment, analyze results, and conclude
  - Hypothesis: a proposed explanation made on the basis of limited evidence as a starting point for further investigation
  - Control group/variable: a part of the experiment that is not being tested and is used for comparison; a part of an experiment that is not changed for the purpose of comparing
- **The taste pathway**: chemicals from the food we eat attach to taste receptors on our tongue, sending a signal to our brain which differentiates between flavors
  - Papillae are the larger bumps on our tongue that we can see with the naked eye. Within the papillae are taste buds which is where taste receptor cells are located.
- **PTC**: some taste this chemical as extremely bitter (the "supertasters"), tolerably bitter (the "tasters"), and some don't taste any bitterness at all (the "nontasters")
  - The reason for this has to do with genetics
- **Miraculin**: a chemical that alters taste perception
  - At acidic pH- makes sour food taste sweet by activating sweet taste receptors

Careers and Applications

Taste is important, in general, to be able to discern between healthy and poisonous substances, as well as between fresh and spoiled food. Can you imagine how boring eating would be if we weren't able to distinguish flavors? Without taste, eating would be a chore and we wouldn't have as much of a desire to keep our bodies nourished. The science of taste is more complicated than you'd think, and researchers are continually reporting new findings and revising old theories regarding the taste pathway, bitter food perception, and other taste-related research questions. How do scientific researchers do this? They use the Scientific Method to form hypotheses, experiment, analyze, revise, and conclude.

Agenda

- Module 0: Visualizing Taste (5 min)
- Module 1: Like Vegetables? (5-10 min)
- Module 2: The "Miracle" of Miraculin (5-10 min)
- Module 3: Ice Cream! (20-30 min)
- Conclusion

Module 0: Visualizing Taste

Introduction

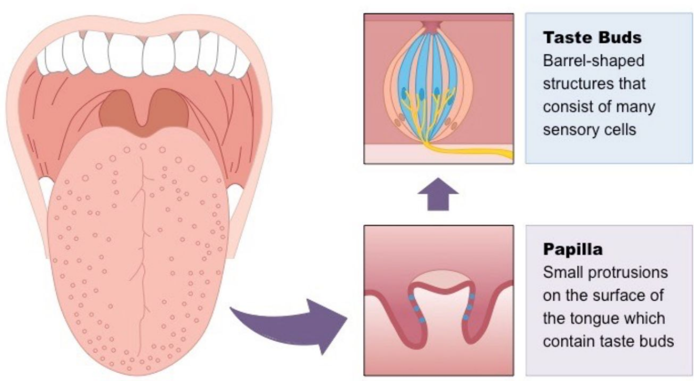
Open the lesson with a fun activity where the mentees will get to see their own papillae! The goal of this module is to teach mentees what papillae are and how they relate to taste.

Teaching Goals

1. **The taste pathway:** From papillae → taste buds → taste receptors → brain

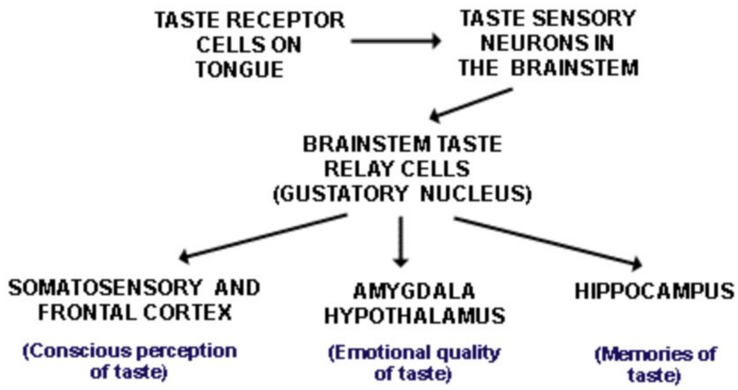
Background for Mentors

Papillae are bumps on our tongue which are involved in the sensations of taste. They contain ***taste buds***.



Papillae and taste buds: what's the difference?

Taste buds contain multiple ***taste receptors*** which are cells that detect chemicals in our food. When we "taste," these chemicals attach to taste receptors on our tongue which send signals to our ***brain*** to interpret different tastes. The five main flavors are sour, sweet, umami (savory), salty, and bitter.



The brain's role in the taste pathway

For the purpose of this lesson, there is no need to go into the different parts of the brain (ie. hippocampus, somatosensory cortex, etc) that perceive taste. Mentees should just understand that signals are sent to the brain, which is how we perceive taste.

Materials

- 3-4 bottles of blue/red/green dye (or food coloring) per site
- 1 cotton swab per mentee

Procedure

1. Have each mentee coat their own tongue with the food coloring using a cotton swab (or they can coat a partner's tongue with dye, site depending)
2. Now the bumps (papillae) will stand out!
3. Instruct mentees to view their partner's tongue while mentors explain what papillae are and discuss the taste pathway

Additional Notes for Mentors

- Younger mentees tend to love to waste dye (why though??), so try to keep them from overusing it!

Module 1: Like Vegetables?

Introduction

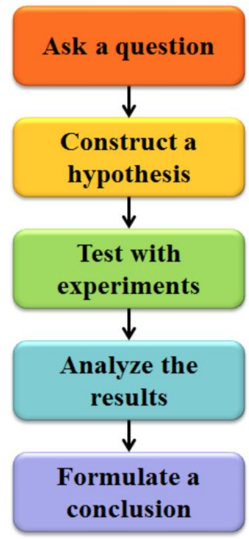
In this module mentees will explore the Scientific Method using PTC strips to answer the question, who is more likely to taste the bitterness of PTC, those who like vegetables or those who don't?

Teaching Goals

1. **The Scientific Method:** Ask a question, form a hypothesis, experiment, analyze results, conclude.

2. **Hypothesis:** a proposed explanation made on the basis of limited evidence as a starting point for further investigation
3. **Control group/variable:** a part of the experiment that is not being tested and is used for comparison; a part of an experiment that is not changed for the purpose of comparing
4. **PTC and genetics:** "supertasters" v. "tasters" v. "non-tasters"

Background for Mentors



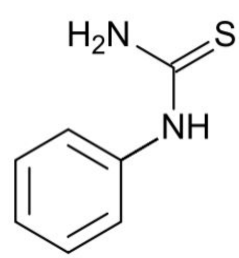
The Scientific Method is a process for experimentation that is used to explore observations and answer questions. It is comprised of the steps in the figure to the *right*.

A ***hypothesis*** is a proposed explanation made on the basis of limited evidence as a starting point for further investigation. Hypotheses are generally written in "if...then" statements, but they don't have to be.

In this module, The Scientific Method should look something like this…

1) Question- Who is more likely to taste the bitterness of PTC, individuals who like broccoli/cauliflower or those who don't?
2) Hypothesis- *If* a mentee **can't** taste PTC, *then* they **will** like vegetables.
3) Experiment- Mentors will record the amount of mentees who claim to like vegetables, tolerate vegetables, and dislike vegetables. Mentees will then test their hypothesis by tasting the control and PTC strips.
4) Analyze- What happened when mentees performed this experiment? Did your site's results match up with the theoretical results? (provided below) If not, why? (possible human error?)
5) Conclude- Theoretically, our hypothesis should be correct! If a mentee can't taste PTC, then they will like vegetables.

This module will also introduce mentees to the concept of a ***control group/variable*** which is a part of the experiment that is not being tested and is used for comparison, or a part of an experiment that is not changed for the purpose of comparing. Our control for this experiment is the control strips, which have no chemical on them.



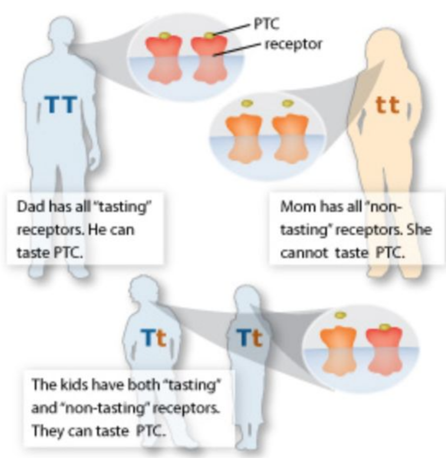
PTC is a chemical, phenylthiocarbamide. The chemical structure of PTC resembles toxic chemicals found in poisonous plants (see figure to the *right*.) Although PTC is *not* found in nature, the ability to taste it correlates strongly with the ability to taste other bitter substances (mainly toxins) which do occur in nature. The ability to taste toxic compounds conveys a *selective advantage*, since eating anything with toxins can be deadly. Perhaps this is why humans evolved the ability to taste bitter substances.

Why can some people taste the bitterness of PTC, while other can't? It depends on genetics.

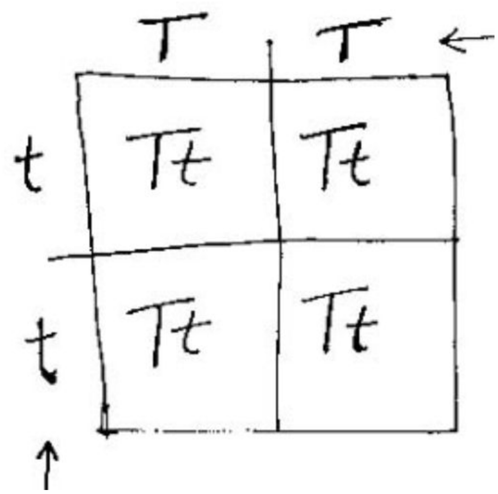
Individuals who have inherited the ability to taste PTC from their parents have ***taste receptors*** which bind to PTC. These individuals are the ***"tasters"*** and ***"supertasters."*** Individuals who can not taste PTC have taste receptors which do not bind to the chemical. These are the ***"nontasters."***

"Supertasters" are very sensitive to PTC. They taste an intense, intolerable bitterness. ***"Tasters"*** are sensitive to PTC, but not to the extent of the "supertasters" in that they find the bitterness tolerable. ***"Nontasters"*** can't taste any bitterness in PTC. To them, the PTC strip will taste like paper. (In fact, it's much more complicated in that some "tasters" can taste the bitterness of PTC stronger than other "tasters," but not as strong as "supertasters." Though there are varying degrees of ability to taste PTC, for the purpose of this lesson, let's stick to the three main categories.)

The ability to taste PTC is considered a dominant trait, in fact, about 70% of the population can taste PTC. This means that if one parent is a ***"supertaster,"*** they are homozygous for the "taster" allele, and the other parent is a ***"nontaster,"*** they are homozygous for the "non taster" allele, then their offspring will be ***"tasters."***

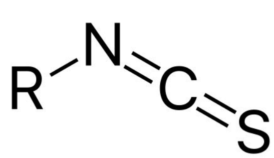


PTC genetics example
Dad- "supertaster"
Mom- "nontaster"
Kids- "tasters"



PTC Punnett square

Not a bio major and the genetics went over your head? That's ok! For the purpose of this lesson, mentees should understand that the ability to taste PTC is inherited, but there is no need to go into dominant and recessive traits, unless you want to.



How does this relate to vegetable preference? Theoretically, people who can taste PTC are less likely to eat cruciferous vegetables (vegetables such as cauliflower, broccoli, and brussels sprouts) due to the resemblance between isothiocyanates, a chemical group found in these vegetables (shown to the *left*,) and PTC (shown *above*.)

So, if the mentees are truthful throughout this module, the results

should look like this:
Mentees who *like* cruciferous vegetables = “nontasters”
Mentees who *tolerate* cruciferous vegetables = “tasters”
Mentees who *dislike* cruciferous vegetables = “supertasters”

Materials

- 1 control strip per mentee
- 1 PTC strip per mentee

Procedure

1. Begin by asking the mentees if they like vegetables such as broccoli/cauliflower. Record the number of those who *like* them, those who *tolerate* them, and those who *dislike* them.
2. Before beginning the PTC experiment, explain the Scientific Method to mentees and go over the steps together.
3. Now, explain PTC to mentees, and ask the question, who is more likely to taste the bitterness of PTC, individuals who like broccoli/cauliflower or those who don’t?
4. Have mentees come up with their own hypothesis. An example could be, ‘*If* I dislike vegetables, *then* I will be able to taste PTC,’ or something along those lines.
5. Onto the experiment! As a control, instruct mentees to taste the control paper (looks like the PTC strip, but does not contain the chemical, so it should just taste like paper.)
6. Have the mentees place the PTC strips in their mouths but **DO NOT LET THEM SWALLOW THE STRIPS** (PTC is toxic in large amounts; tasting is fine but swallowing the strip is not)
7. Record the “supertasters,” “tasters,” and “nontasters”
8. Do your site’s results match the theoretical results, above? Why or why not? Analyze results with your site, revise hypotheses if needed, and come to a conclusion.

Additional Notes for Mentors

- Why would your site’s results not match? Possibly, human error. Maybe most mentees in the class think broccoli is *disgusting*. In that case, a mentee could say they dislike broccoli to fit in, even if they absolutely love it. It’s also possible that mentees could over-exaggerate their ability to taste PTC. To mediate these problems, it might be good to remind mentees that *there is no right or wrong way to taste PTC and vegetables*. “Supertasters” are not better than “non-tasters” and vice versa.
- Consider connecting this lesson to Stephanie’s “Blue Gene Baby” lesson a few weeks back! Do mentees remember what genetics/DNA is? How does natural selection play a role in PTC tasting?

Module 2: The “Miracle” of Miraculin

Introduction

Much like Module 1, this module will continue to build on the mentee’s understanding of the

Scientific Method, but this time by asking the question, what does miraculin do and what will happen if we use it?

Teaching Goals

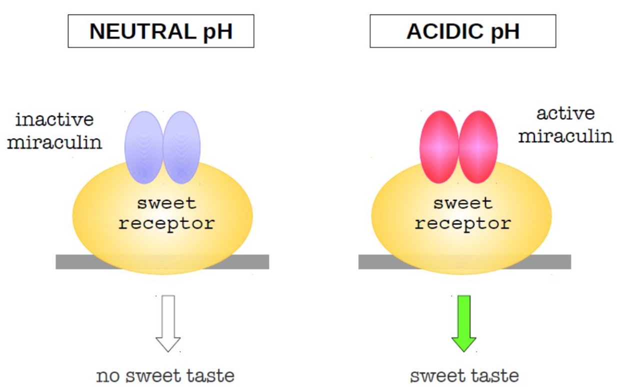
1. **The Scientific Method:** Ask a question, form a hypothesis, experiment, analyze results, conclude.
2. **Miraculin at acidic pH:** makes sour food taste sweet by activating sweet taste receptors

Background for Mentors

Miraculin is a naturally occurring taste modifier. It is found in the fruits of the *Synsepalum dulcificum* plant, known colloquially as the "Miracle Fruit." When coated on the tongue, miraculin causes sour foods to taste sweet! It is typically used by health/sugar conscious individuals, as it reduces the need/desire to add sugar to food and is a safe option used to aid in weight loss. People also use miracle fruit to treat diabetes and help with chemotherapy-related taste disturbances.

The Miracle Fruit

But, this isn't a miracle, it's science! Miraculin attaches to ***sweet taste receptors*** on our tongues. At an acidic pH, such as when we eat a lemon, miraculin activates the sweet receptor, which sends a signal to our brain. This makes us think we are eating something sweet. Interestingly enough, at neutral pH, miraculin blocks sweet receptors from sending signals to the brain. For the purpose of this module, we should only focus on the activation of the sweet receptors at acidic pH.



Miraculin at neutral and acidic pH

Materials

- ½ Miraculin tablet per mentee
- 1 lemon slice per mentee

Procedure

1. Begin by explaining what miraculin is and what it does at acidic pH.
2. Ask the mentees our question: what do they think will happen when they coat the miraculin on their tongues and taste a lemon? Have them come up with a hypothesis. (ie. *If* we coat miraculin on our tongue, *then* the lemon will taste sweet.)
3. Experiment! Have the mentees coat the ½ pill on their tongue by rolling it around in their mouths. (Make sure they effectively *coat* their tongue and they don't just swallow the pill! The miraculin needs to attach to taste receptors to be effective.)
4. Instruct the mentees to taste the lemon
5. Ask the mentees what they taste. (should taste sweet!) Is their hypothesis correct? Analyze the data and come to a conclusion!

Additional Notes for Mentors

- Miraculin's effects can last between 1-2 hours
- Miraculin is completely *safe* to use for diabetics and pre-diabetics, as it doesn't increase blood sugar levels but gives the individual the perception of sweetness.
- A mentee may be hesitant to try miraculin, and that's ok! Allow them to observe and encourage them to still come up with a hypothesis. (Note: Miraculin is *safe* to use for adults and kids alike; no negative side-effects have been reported in the history of its use)
- https://www.theatlantic.com/health/archive/2014/05/can-miraculin-solve-the-global-obesity-epidemic/371657/ - if anyone's interested, here's a cool read!

Module 3: Ice Cream!

Introduction

The scientific method will be reinforced in this final module, and mentees will get to make ice cream! But wait, what will ice cream taste like after they've consumed the miraculin?

Teaching Goals

1. **The Scientific Method:** Ask a question, form a hypothesis, experiment, analyze results, conclude.
2. **Miraculin at acidic pH:** makes sour food taste sweet by activating sweet taste receptors

Background for Mentors

As discussed in the last module, at acidic pH miraculin activates sweet taste receptors, which send signals to the brain. Therefore, when miraculin is coated on the tongue, sweetness will be perceived when sour foods are consumed.

Mentees will use this logic to hypothesize what ice cream will taste like when lemon juice is substituted for sugar as a sweetener! (Hint: it will taste sweet!)

Materials

- Each group will need…
    - ½ cup whole milk (or half and half)
    - ¼ teaspoon vanilla extract
    - 6 tablespoons salt
    - 2 cups of ice
    - 2 quart-sized ziploc bag (incase one breaks)
    - 2 gallon-sized ziploc bag (incase one breaks)
    - 3 tablespoons lemon juice
        - **Cragmont** only- substitute 1 tablespoon sugar per group
- 1 spoon per mentee
- 1 dry ice box per site

Procedure

1. Split mentees into groups of 2-4
2. Have each group mix the milk and vanilla extract in the pint-sized plastic bag (milk and vanilla pre-mixed for you, thank you logistics)
3. Place ice and salt in gallon bag and then place sealed pint bag into larger bag
4. Shake up ingredients for 5-10 minutes, until it reaches the consistency of ice cream.
5. Instruct mentees to taste the ice cream, as a control. What do they think it will taste like, at this point? (No sweetener, so shouldn't really taste like anything.)
6. Add the lemon juice to the small bag, and have the mentees shake for another minute or two.
7. While mentees shake the ingredients, ask the question, what do they think will happen when they taste the ice cream with added lemon juice? Have them come up with a hypothesis. (ie. *If* we taste the ice cream with lemon juice after we've taken miraculin, *then* the ice cream will taste sweet.)
8. Experiment by letting mentees taste the ice cream (it should taste sweet!)
9. Was their hypothesis correct? Analyze results and come to a conclusion.

Additional Notes for Mentors

- Though the ice cream contains no sugar, don't let the mentees eat too much! Too much lemon juice could still give them a stomach ache.
- Be mindful of any food restrictions and allergies of mentees at your site!
- If applicable, consider bringing **candy** for your site. Mentees will be in groups for this module and won't get to eat as much ice cream as they'd probably want to (we don't want them to get a stomach ache from so much lemon!)

Conclusion

Wrap up the lesson by summarizing the teaching goals. Do they understand the Scientific Method? Saliva? PTC? Maybe quiz them on their knowledge of each concept. Encourage students to think of more experiments they could do regarding taste at home! There are endless possibilities.

Also use this time to wrap up a great semester at BEAM! Spend time with your mentees. What was their favorite lesson of the semester? Did they learn anything new? Also, make sure to thank them for coming to BEAM each week!

References

- Biology 1al Lab Manual Fall 2018, UC Berkeley.
- Learn.Genetics, University of Utah. https://learn.genetics.utah.edu/content/basics/ptc/
- Ice Cream!, Marty Gelenter, BEAM Fall 2013

Summary Materials Table

Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
Blue/Green/Red food coloring/dye	3-4 per site	$14.89	Inventory
Cotton swabs	1 per student	$4.64	Amazon/Inventory
Lemon	1 slice of lemon per student/2 lemons per site	N/A	Grocery Store/Generous Donors
Control strips	1 per student	$27	https://www.amazon.com/Paper-Experiment-Control-Genetic-Testing/dp/B0085GRFSQ/ref=sr_1_3?keywords=control+ptc+strips&qid=1555027947&s=gateway&sr=8-3
PTC strips	1 per student	(See above)	(see above)
Miraculin tablets (cut in half)	½ tablet per student	$251.91	https://www.amazon.com/mberry-Miracle-Fruit-Tablets-10-Count/dp/B002JANPDI/ref=sr_1_3?keywords=miraculin&qid=1555899777&s=gateway&sr=8-3
Whole milk (or half and half)	½ cup per *group* (not per site)	~$3	Grocery Store
Sugar **(CRAGMONT ONLY)**	1 tablespoon per *group*	$2	Grocery Store
Vanilla Extract	¼ teaspoons per *group*	N/A	Grocery Store

Salt	6 tablespoons per *group*	$5	Grocery Store
Ice	2 cups per *group* (fill dry ice box as much as possible)	N/A	Latimer/Stanley/VLSB
Quart-sized ziploc bags	2 per *group*	$12.99	Amazon
Gallon-sized ziploc bags	2 per *group*	$16.40	Amazon
Lemon juice	~12 tablespoons/6oz per site (3 tablespoons per *group)*	$12.98	Amazon
Spoons	1 spoon per student	N/A	Inventory/amazon
Dry ice box	1 per site	N/A	Inventory