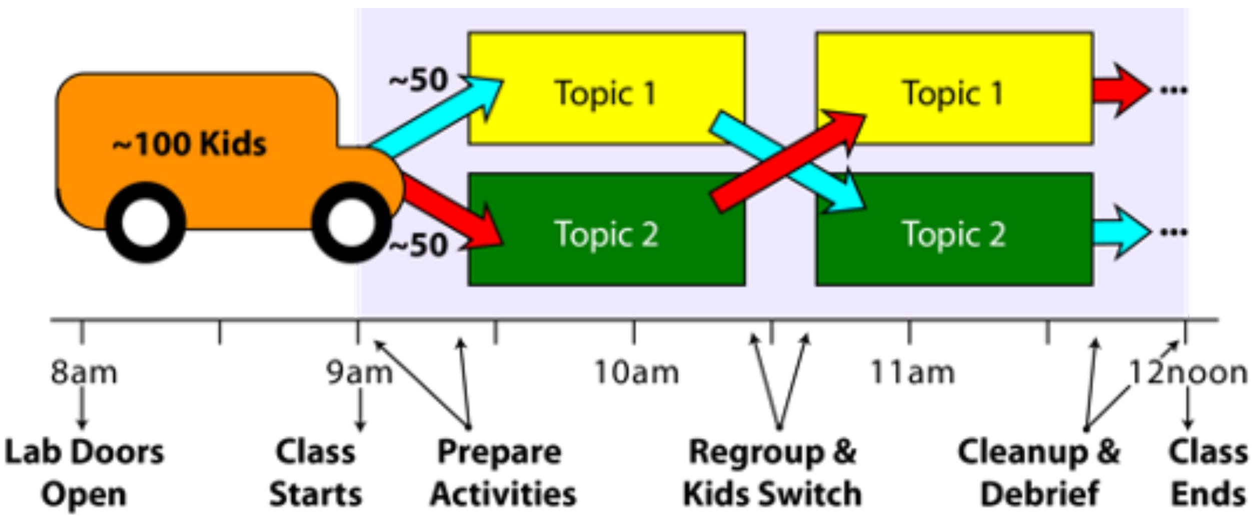
Supplemental Material

CBE—Life Sciences Education

Bush *et al*.



Supplemental Figure 1. A day in the LBDL. An LBDL teaching event takes place during a 3-hour lab period on Thursday or Friday mornings. Students are asked to arrive early if their schedules allow them to assist with set up. Around 9am, school busses arrive with that day's group of school children, their teachers, and chaperones and this group is split in half (schools are notified in advance that large groups must be divided). Meanwhile, in the labs, the SIs and FIs are engaged in final preparation, and short anticipatory discussions about the incoming group. From 9:20-10:20 am two teaching events take place in parallel. From 10:20-10:30 the school groups switch labs. During this short interval the SIs reset their teaching space, briefly reflect on the first hour, and make any 'quick fixes' necessary to help hour two go more smoothly. From 10:30-11:30 the SIs teach the same content to a new group of kids. At 11:30 am the school group leaves (to return to school or for other activities on campus). Between 11:30 am and noon, the SIs and FIs reflect on the day and discuss possible changes to be implemented the next week.

LBDL Pre-Survey
Modified STEBI-B survey administered to students enrolled in the LBDL prior to the first teaching event (i.e. during the first two weeks of the quarter.)

Note: Students are asked to provide their student ID for the purposes of matching pre and post survey data.

Welcome:
To improve the LBDL experience, we are interested in understanding how participating in the LBDL impacts Cal Poly Students. The following survey should take no more than 20 min. In part one it probes your thoughts on teaching science and in part two it will ask questions about you.

Part One: Science Teaching Beliefs
Please indicate the extent to which you agree or disagree with each of the following statements. There is no right or wrong answer! We just want to know what you think.
(For questions 1-23 the answer choices are: strongly agree, agree, neutral, disagree, strongly disagree)

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort.
2. I will continually find better ways to teach science.
3. Even if I try very hard, I will not teach science as well as I will most subjects.
4. When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.
5. I know the steps necessary to teach science concepts effectively.
6. I will not be very effective in monitoring science experiments.
7. If students are underachieving in science, it is most likely due to ineffective science teaching.
8. I will generally teach science ineffectively.
9. The inadequacy of a student's science background can be overcome by good teaching.
10. The low science achievement of students cannot generally be blamed on their teachers.
11. When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.
12. I understand science concepts well enough to be effective in teaching elementary science.
13. Increased effort in science teaching produces little change in students' science achievement.
14. The teacher is generally responsible for the achievement of students in science.
15. Students' achievement in science is directly related to their teacher's effectiveness in science teaching.
16. If parents comment that their child is showing more interest in science, it is probably due to the child's teacher.
17. I will find it difficult to explain to students why science experiments work.
18. I will typically be able to answer students' science questions.
19. I wonder if I will have the necessary skills to teacher science.
20. Given a choice, I will not invite the principal to evaluate my science teaching.

21. When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand.
22. When teaching science, I will usually welcome student questions.
23. I do not know what to do to turn students on to science.

Part Two: Who Are You?

This section will ask you to share some demographic information and career goals.

24. How would you characterize your gender identity? (woman, man, decline to state, other)
25. With which group(s) do you most closely identify? (American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, White, Decline to state, other)
26. With which ethnicity do you most closely identify? (Hispanic or Latino, Not Hispanic or Latino, Decline to state)
27. What other teaching experiences have you had?
28. Overall, my science teaching experiences have been… (positive, negative)
29. I could imagine becoming a teacher. (strongly agree, agree, neutral, disagree, strongly disagree)
30. I plan to become a teacher. (strongly agree, agree, neutral, disagree, strongly disagree)
31. Describe your dream career…

LBDL Post-Survey
Modified STEBI-B survey administered to students enrolled in the LBDL after the final teaching event (i.e. during the last week of the quarter.)

Note: Students are asked to provide their student ID for the purposes of matching pre and post survey data.

Welcome:
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22. When teaching science, I will usually welcome student questions.
23. I do not know what to do to turn students on to science.

Part Two: Who Are You?

This section will ask you to share some about your experience in the Learn By Doing Lab and your career goals.

24. I would recommend taking the Learn By Doing Lab to a friend. (strongly agree, agree, neutral, disagree, strongly disagree)
25. Explain your reasoning regarding your recommendation answer above.
26. I could imagine becoming a teacher. (strongly agree, agree, neutral, disagree, strongly disagree)
27. I plan to become a teacher. (strongly agree, agree, neutral, disagree, strongly disagree)
28. How did your experience in the Learn By Doing Lab impact your thoughts about a career in teaching?
29. What skills do you feel you developed or used in the Learn By Doing Lab that might help you in ANY career?
30. What is the most important thing you will take away from your time working in the Learn By Doing Lab?
31. Describe your dream career...

Learn By Doing Lab: Modules and Materials

Numerous hour-long curriculum modules have been developed for the LBDL. On this page are the titles and short description of some of the life science and physical science modules. On the following 6 pages are 'foldables' handed out to the visiting students. **Drafts of these foldables were developed by the faculty instructors. As part of the run-up to teaching, the students instructors requested edits and supplemental content based on their teaching goals**. Instructions for folding these pages into an 8-page mini-book can be found at: https://www.instructables.com/An-8-Page-Book-From-a-Piece-of-Paper/

Genetics Exploration
Students isolate DNA while learning about cell structure. Students will explore the relationship between an organism's DNA (genotype) and its physical traits (phenotype). Comparing live normal and mutant organisms will demonstrate how changing the DNA can alter the organism. Students determine their taster status using PTC test strips then associate taster status with DNA sequence of the *TAS2R38* gene.

Physiology Exploration
Students will build a working circulatory system using tubing, bulbs, and Luer-Lok connections to learn about the role of one-way valves in the heart. Students build a small model of the lungs using balloons, tubing and pill vials to learn how diaphragm contraction changes pressure in lungs during breathing.

Phase Exploration
Students learn about the different states of matter and how transitions between these stages occur. Students develop scientific definitions of solids, liquids, and gases through guided experimentation with a variety of materials.

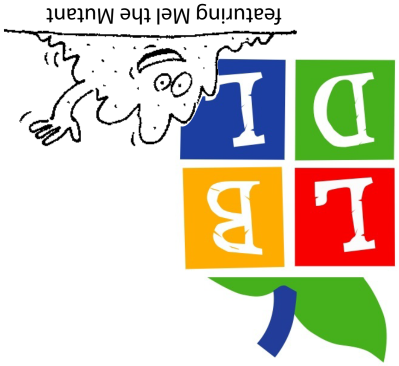
Magnet Exploration
Students uncover and discover properties of magnets through a series of hands-on explorations. Students build, test, and refine a model for how magnets and magnetism work. We may just turn the whole class into a giant magnet for fun.

Atoms and Molecules
Students use an interactive domino-like learning platform, Atomic Tiles, to learn basic principles of atoms and bonding, build and explore the periodic table, investigate how atoms come together to form molecules, and see how molecules are relevant to our daily lives.

Acids and Bases
Students learn about the acids and bases that are all around us. Students are introduced to the relationship between hydrogen ions and the pH LOG scale. Students experience their own citric acid base test. Finally, students create their own artwork using a mixture of several color changing molecules using the universal indicator.

Name: ____________

Cal Poly
Learn By Doing Lab

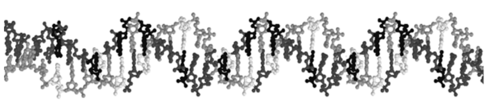


featuring Mel the Mutant

Genetics Exploration

DNA FACTS: DNA is made up of four chemical units called nucleotides. Each nucleotide is represented by a letter: A, C, G and T. Human DNA is made up of six billion (6,000,000,000) of these nucleotides arranged in pairs...one on each strand of the double helix. A pairs with T and C pairs with G. A strand of human DNA is about 2 meters long (about the size of an average adult). But if you wanted to read the DNA one letter at a time at a speed of one letter per second it would take you 94 years to read the whole thing. Here are 1000 nucleotides from the human insulin gene:

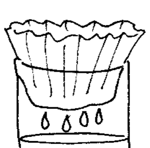
DNA = deoxyribonucleic acid



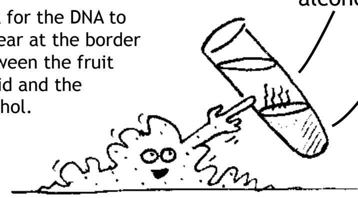
DNA from fruit? It's pretty easy but you need a few things to get started:

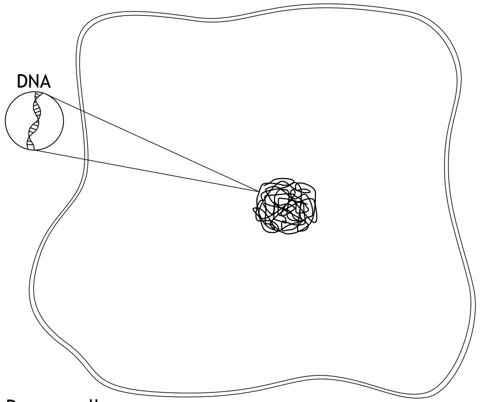
-squishable fruit like a strawberry, kiwi or bananna
-1/2 cup wter mixed with 1 tablespoon shampoo or dish soap and 1/4 teaspoon salt.
-rubbing alcohol -small ziplock bag -coffee filter
-cup or mug the coffee filter will fit into
-small, clear plastic tube or cup (A florist shop might give you a little tube used on the end of cut flowers.)

1) Squish the fruit in the plastic bag...the better you squish the better it works.
2) Add 10 mililiters (about 2 tablespoons) of the soap/salt mixture to the fruit bag and mix thoroughly by squeezing the bag.
3) Place the coffee filter into a cup and pour the squished fruit in. Allow the liquid to drip through for about 10 minutes (not all of it will go through...that's OK.)



4) Pour the fruit liquid from the cup to the small plastic cup or tube.
5) SLOWLY, add rubbing alcohol by pouring down the side of the cup or tube.
6) Look for the DNA to appear at the border between the fruit liquid and the alcohol.





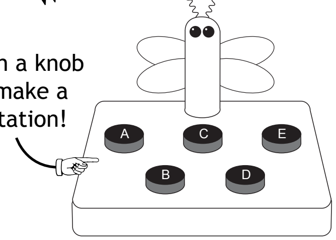
Draw a cell...

You can learn a lot from a...

Mutations are changes in the letters of DNA. When the letters change it can alter the way an organism looks or behaves. Scientists look at mutants to figure out how DNA works.

What do the knobs do?

turn a knob to make a mutation!



Red

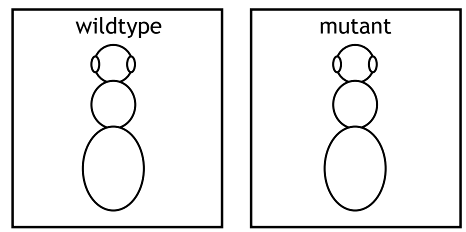
Green

Volume

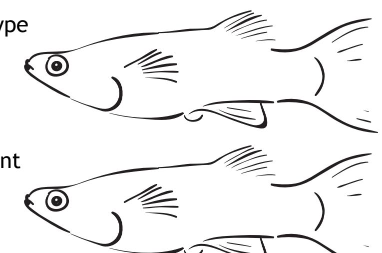
Blue

Pitch

"Wildtype" is a word geneticists use to mean "normal". A wildtype organism has the appearance that is most common for that species. In the space below sketch the wildtype and mutant flies from lab. How are they different?



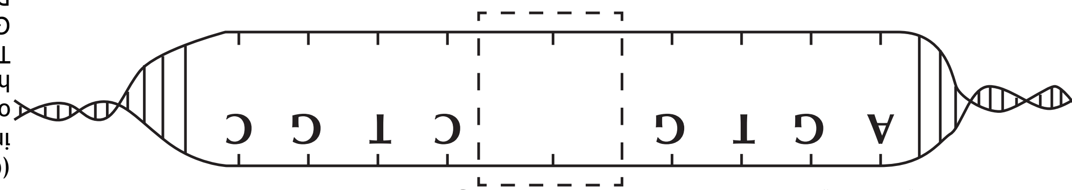
The altered DNA in the mutant controls the growth of ____________ .



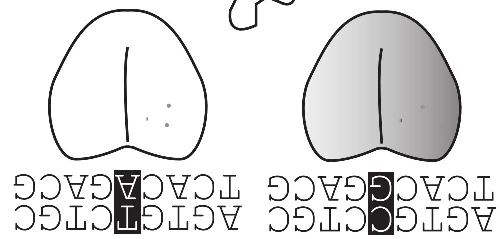
Which would survive in nature?

I am a PTC.....Taster. ☐ NON-Taster. ☐

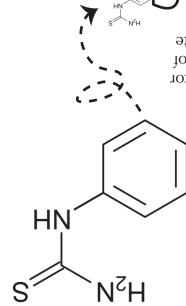
My sequence for the taste gene (*TAS2R38*) is...



The two tongues below have different DNA sequences. CIRCLE the tongue that can taste PTC.



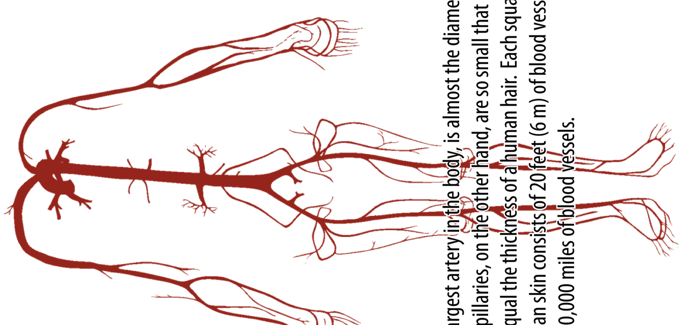
The molecule shown to the right is **Phenylthiocarbamide** or **PTC**. To many people PTC tastes bitter but some people can't taste PTC at all! The difference between tasters and non-tasters is found in the DNA of those people. The TAS2R38 gene encodes a receptor that sticks off your tongue and allows you to detect bitter molecules like PTC. A change of just a single letter pair in the DNA sequence of the TAS2R38 prevents the receptor from working. Some people who are tasters of PTC report disliking bitter foods like chocolate and coffee.



Circulatory System

CAL POLY
Learn By Doing Lab

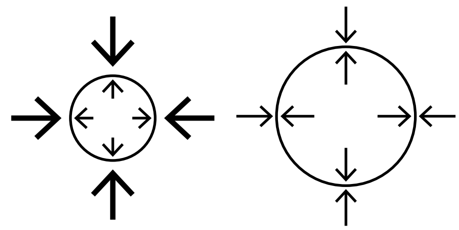
Name: ______________



Can you find the aorta?

The aorta, the largest artery in the body, is almost the diameter of a garden hose. Capillaries, on the other hand, are so small that it takes ten of them to equal the thickness of a human hair. Each square inch (2.5 cm) of human skin consists of 20 feet (6 m) of blood vessels. An adult has over 60,000 miles of blood vessels.

Pressure and volume have an **INVERSE** relationship (when one goes up, the other goes down.) Look at the air bubble to the right. When the pressure (arrows) is high outside it stays small. When the outside pressure decreases the volume increases and the bubble expands.



Volume

pinch here

Pressure

Number of heart beats in 10 seconds = [ ]

[ ] × 6 = number of beats in a minute

[ ] × 1440 = number of beats in a day

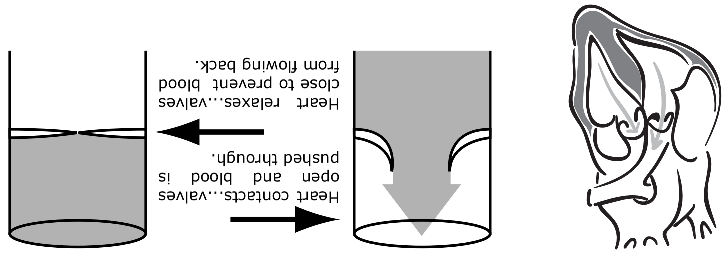
[ ] × 365 = number of beats in a year

[ ] × your age = number of beats in your life

The average human heart will beat 3 billion times in its lifetime and pump 48 million gallons of blood

5

1



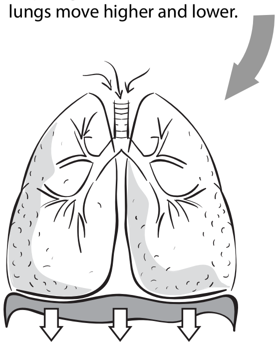
Blood takes about 20 seconds to circulate throughout the entire vascular system.

One-Way valves in the heart insure that blood is only pumped in one direction. The human heart has four of these valves...one at the exit of each chamber.

ONE WAY

2

LUNG FLIPBOOK: Lift this page up and down to see the lungs work. Watch the diaphragm at the bottom of the lungs move higher and lower.

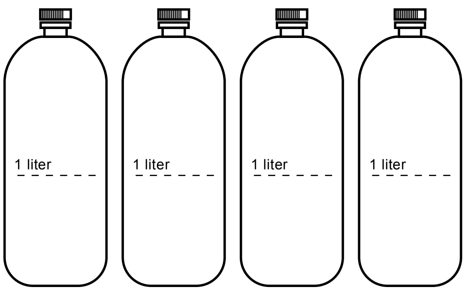


Use a SPIROMETER to measure the volume of air in your lungs.

My lung volume is ________ liters.

1 liter = 1000 cm^3

How many soda bottles could you fill with one breath?



3

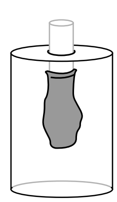
The human heart creates enough pressure to squirt blood 30 feet (9m).

HEART FLIPBOOK: Lift this page up and down to see the heart beat. Look for the valves that open and close to ensure the one-way flow of blood.

The Blue Whale has the largest heart of any animal. The Blue Whale heart weighs 1300 pounds (590 kg) and is about the size of a small car. The largest blood vessel in a blue whale is 10 inches (24 cm) across...a child could crawl through it. Whale hearts are thought to beat about 20-30 times a minute while moving 7000 liters of blood through the body (your body has about 3 liters of blood.) In contrast, a mouse heart beats about 500 times per minute!

4

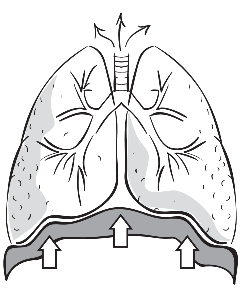
The balloon inside the capsule represents the lung. The balloon at the bottom represents the diaphragm. Pulling down on the balloon creates negative pressure in the capsule.



Diaphragm down, air goes... [ ]

Diaphragm up, air goes... [ ]

(write "in" or "out" in the boxes)



Name ____________________

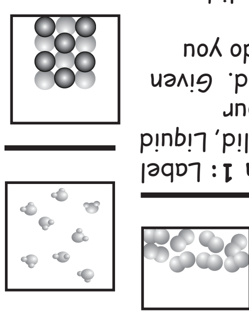
Phase Exploration

LBDT

learn by doing lab

Say Hi, to Nano-Guy!

Nano Guy's Brain Candy



Thought Question 1: Label each sketch as Solid, Liquid or Gas. Explain your answers to a friend. Given this picture, why do you think ... Gases are compressible by Solids are not?

Thought Question 2: In outer space the temperature is -270 °C (3K, -454 °F) and pressure is 0.000000000000001 atmospheres, both far less than they are on earth. What would happen to a ball on taken from conditions on the surface of earth to the conditions of outer space? Assume the balloon will not pop, crack or leak. Explain your answer to a friend.

Thought Question 3: Does Gas have mass?

Shape, Fluidity and Compressibility

Quick Facts: **Solid, Liquid** and **Gas** are three common **states of matter.** These states of matter are often referred to as "phases". Scientists use **macroscopic** observations of properties like **compressibility** and **fluidity** to contrast the behavior of different phases and to try to understand the **sub-microscopic** behaviors of solids, liquids and gases.

Word Wall...

Macroscopic: Large enough to see with your eyes. e.g. bulk stuff all around us. Macro- = big -scopic = to see

Submicroscopic: Too small to see with a normal microscope. e.g. atoms an molecules. Sub- = below -micro- = small -scopic = to see

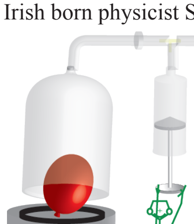
Data Table

		Fixed Shape	Able to Flow	Compressible
Solid	Prediction:			
	Observation:			
Liquid	Prediction:			
	Observation:			
Gas	Prediction:			
	Observation:			

Properties of Gases

Quick Facts:

The behavior of gases can be described in terms of a few **macroscopic** quantities. In 1662 the Irish born physicist Sir Charles Boyle presented a careful study of the relationship between **Pressure (P)**, the force exerted by a gas on the walls of its container, and **Volume (V)**, the physical size of the gas container. We will explore this relationship today using a vacuum pump and marshmallows...



The 18th century French chemist (and early balloon enthusiast) Jacques Charles studied the relationship between Volume and Temperature (T). We will explore this relationship using liquid nitrogen and balloons...

Change Temperature

P

Lower Temperature

Prediction: T_↓_ V____

Observation: T_↑_ V____

As the temperature decreased, the volume of the balloon ____________. As the temperature increased, the volume of the balloon ____________. Taken together these two observations suggest there is a ____________ relationship between volume and temperature.

Lower Pressure

Prediction: P_↓_ V____

Observation: P_↑_ V____

As the air was removed from the bell jar, the pressure decreased and the volume of the balloon ____________. As the air returned to the bell jar, the pressure increased and the volume of the balloon ____________. Taken together these two observations suggest there is an ____________ relationship between volume and pressure.

T V

Phase Transition Scavenger Hunt

Check each Phase Transition you see.

Circle the Phase Transitions that REQUIRE energy.

☐ Liquid ➡ Gas **Boiling or Vaporization**
Substance:________________

☐ Solid ➡ Gas **Sublimation**
Substance:________________

☐ Gas ➡ Solid **Deposition**
Substance:________________

☐ Gas ➡ Liquid **Condensation**
Substance:________________

☐ Liquid ➡ Solid **Freezing or Fusion**
Substance:________________

☐ Solid ➡ Liquid **Melting**
Substance:________________

Phun Phase Phacts...

By changing external conditions like temperature or pressure one can induce phase changes. Phase changes for pure compounds occur at characteristic temperatures.

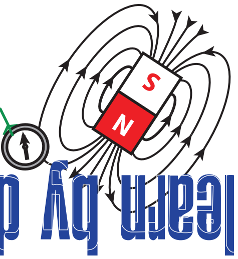
- Liquid nitrogen (N_2) boils at: -196 °C (77 K, -321 °F)
- Solid carbon dioxide (CO_2) sublimes at: -79 °C (194 K, -110 °F)
- Solid iron (Fe) melts at: 1538 °C (1811 K, 2800 °F)

Magnet Exploration

Name ____________________

learn by doing lab

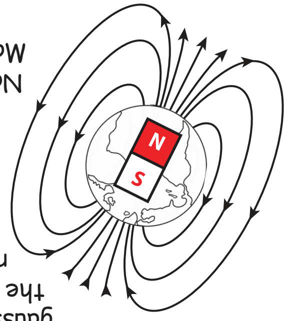
LBDL



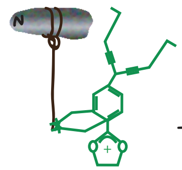
Say Hi, to Nano-Guy!

Nano Guy Brain Candy

The Planet Earth has a magnetic field of ~0.5 gauss, about 1/10 the strength of a refrigerator magnet.



Flipped out! Earth's Geographic North Pole is its Magnetic South Pole.

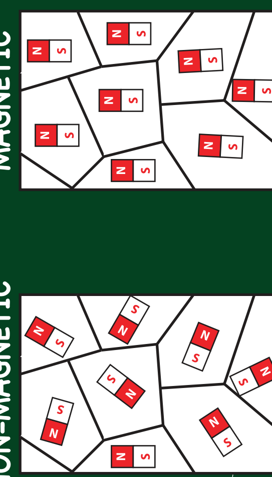


The First Compasses were built using iron-rich rocks called **Loadstones**, which are naturally occurring permanent magnets. Mariners could attach a loadstone to a string and the stone's magnetic field would align with the Earth's magnetic field.

Magnetic Model...

The "Domain" model of magnetism postulates that inside a potential permanent magnet there are microscopic regions that act like mini-magnets.

- In a non-magnetic material these mini-magnets point in random directions and cancel each other out.
- In magnetic materials these mini-magnets point in the same direction, and add collectively.



Make a domain model sketch of your magnet

Magnetic Personalities

How do magnets interact with ...

... Each Other?

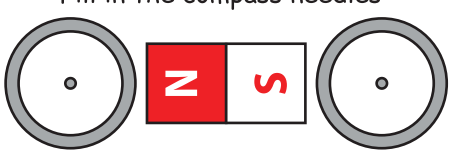
Fill in the observation table

		Magnet 1 North	Magnet 1 South
Magnet 2	North		
Magnet 2	South		

A for Attract
R for Repel

... A Compass?

Fill in the compass needles



... Other Stuff?

1. Take a stand. Write a general rule for what is, or is not, attracted to a magnet.

____

____

2. Make predictions and collect data.

Material	Prediction	Observation

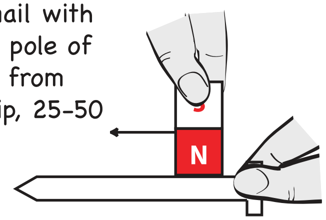
3. Refine your rule using your observations.

____

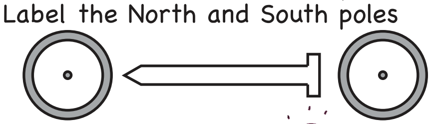
____

Lets Make a Magnet

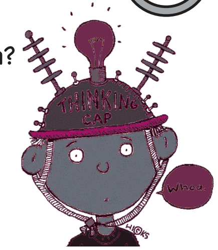
1. Rub a nail with the north pole of a magnet, from head to tip, 25-50 times.



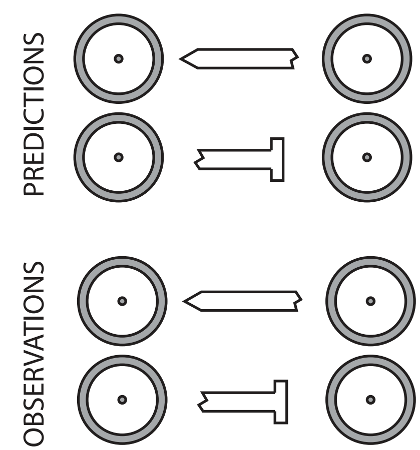
2. Test your nail with a compass. Label the North and South poles



3. What's going on? Make an Intial Magnet Model!



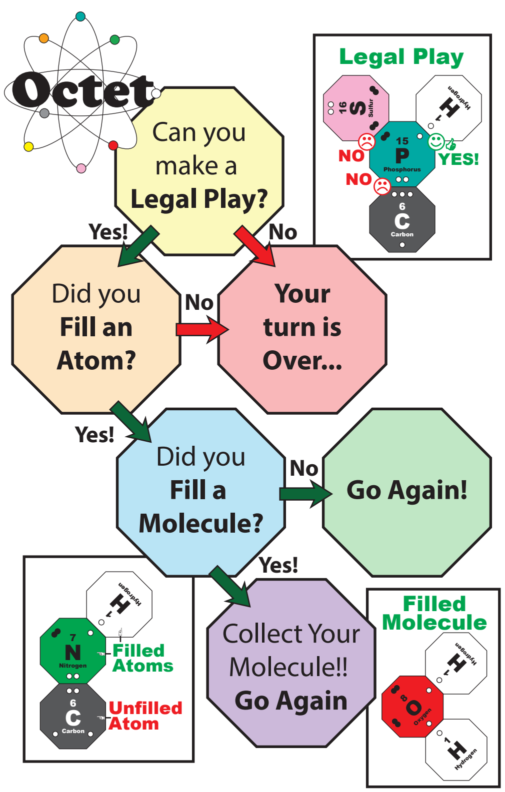
4. Test the magnet model.



My OBSERVATIONS...

Support   Do Not Support

... my Intial Magnet Model



How Atomic Tiles Work

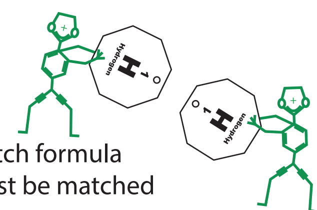
Atoms are nature's building blocks. Everything around you, from the shoes on your feet to the air in this room, is made of atoms. Atomic Tiles are models of atoms. They help us understand how atoms form bonds to create molecules.

Open Circles: Bonding valence electrons	Closed Circles: Non-bonding valence electrons

Atoms form bonds by sharing bonding valence electrons. When you make a match with Atomic Tiles, you are making a bond!

1. Given your observations so far...
Which element likely forms ...
...the most bonds? ...the fewest bonds?
...bonds in the most different ways?

Lets Build Molecules



Making Molecules:

Rule One: Elements must match formula
Rule Two: All open circles must be matched

1. Getting Started

A. H_2O (Water) (2 H atoms, 1 O atom)
B. O_2 (Molecular Oxygen) (2 O atoms)

2. Ramp it up

A. NH_3 (Ammonia)
B. N_2 (Molecular Nitrogen)
C. HCN (Hydrogen Cyanide)
D. HNO (Nitroxyl)

3. Kick it up a notch

A. CO_2 (Carbon Dioxide)
B. C_2H_4 (Ethene)
C. C_2H_6 (Ethane)
D. C_2H_2 (Ethyne)

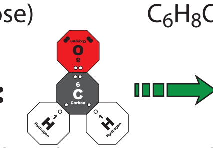
Summation Station:

	Valence Electrons	Bonds
Carbon		
Nitrogen		
Oxygen		
Hydrogen		

4. Test your Skills!

H_2O_2 (Hydrogen Peroxide)
N_2O_2 (Dinitrogen Dioxide)
CH_3COOH (Acetic Acid)
CH_2O (Formaldehyde)
CCl_2F_2 (Freon-12)
$C_6H_{12}O_6$ (Glucose)
N_2H_4 (Hydrazine)
CH_3OH (Methanol)
CH_3CH_2OH (Ethanol)
CCl_3F (Freon-11)
$H_4C_2Cl_2$ (Freon-150)
$C_6H_8O_6$ (Ascorbic Acid)

Lewis Dot Structures:



Bonds:
Single Dot Match = Single bond = Single line between atoms
Double Dot Match = Double bond = Double line between atoms
Triple Dot Match = Triple bond = Triple line between atoms
Lone Pairs:
Non-bonding electrons => lone pairs… two dots

Lets Build a Periodic Table

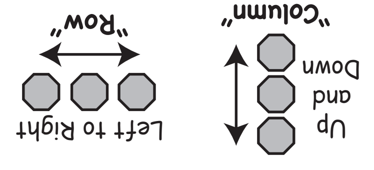
1. What is one thing you notice about your periodic table?

____

____

2. Elements in a family tend to have very similar chemical properties.

Take a stand!
I think familys likely go: (cirlce)



Explain your answer.

____

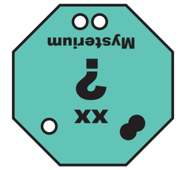
____

Brain Candy...

The development of the periodic table is a triumph of critical thinking and careful observation. In the late 1800's chemists struggled to find coherence among the chemical and physical properties of elements. While many scientists worked on this problem, Dmitri Mendeleev, a Russian high school chemistry teacher in the late 1800's, is credited with envisioning the modern periodic table in his 1868 textbook, "Principles of Chemistry". His approach to organizing the known elements stood the test of time as much for what it **did not** include as for what it did include. Confident in his organizational structure, Mendeleev left several gaps in his periodic table that accurately predicted future elemental discoveries.

3. Which family do you think this Mysterium is in?

Hydrogen Helium
Carbon Nitrogen
Oxygen Fluorine

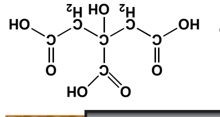


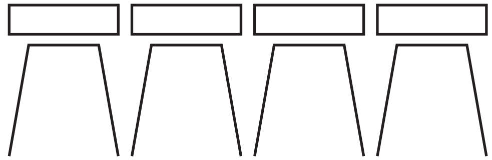
Quick Facts...

Citric acid is one of the molecules that give citrus fruits like oranges and lemons their tart taste. Citric acid is acidic, it will react with baking soda ($NaHCO_3$) to form carbon dioxide (CO_2) gas.

Acid Taste Test

Taste, React and Observe





1. I think__________ juice has the most citric acid based on this evidence:

____

____

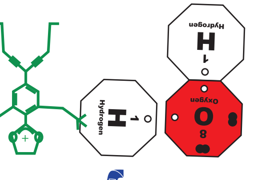
2. What is the Formula for Citric Acid?

C	H	O

Name______________________

Atoms and Molecules Exploration

learn by doing lab



Thoughts on Implementation

Prior to creating the LBDL, we hosted school groups on an irregular schedule. Bush and Himelblau are Science Faculty with Education Specialties (SFES) with a focus on K-12 education in the Chemistry/Biochemistry and Biological Sciences Departments respectively. Each school visit required a rotating pool of student volunteers to be identified, rooms to be reserved, etc. We realized that by institutionalizing the LBDL as an official course we could i) serve many more local schools; ii) compensate students and faculty involvement with units; and iii) reduce some less desirable management tasks that fell to SFES (or at least replace those tasks with a more sustainable and scalable system). The LBDL course was created under the general prefix for the College of Science and Mathematics rather than under a particular department course prefix to acknowledge that faculty from across the college are involved in teaching. There has been strong and consistent support for the course on our campus with the departments covering the teaching units for the faculty involved, and the College of Science and Mathematics covering the salary of an administrative assistant for several hours per week.

<u>Course Mechanics:</u> The LBDL was designed to provide a low-barrier teaching experience for STEM undergraduates. The course description in the catalog is: "Early teaching experience in an informal science, technology, engineering, and mathematics (STEM) teaching and learning environment. Principles of inquiry-driven STEM education, lesson design, implementation and assessment. Intended for undergraduates exploring STEM teaching as a career." To enroll, students must have fulfilled their life science and physical science General Education course requirements (one lower-division course in biology, and one in chemistry, earth science, or physics). This requirement biases enrollment toward students in their second year and above. That said, we have had many first-year students enroll in the class with instructor permission and they have been successful. The course is two units, reflecting the one-hour-per-week seminar and the three-hour-per-week teaching event. We elected a credit/no credit grading scheme for the class because grading is based on participation only; there are no quizzes or exams, and work outside of class is intentionally kept minimal. Because the scientific focus shifts from term to term, the course is repeatable. Some departments within the College of Science and Mathematics have added the LBDL to their list of electives allowing students to apply the course to their degree. In all cases, the departments have limited the number of units students may apply to their degree. For example, students in Biological Sciences can only apply two units of LBDL toward their degree as an elective.

<u>Recruiting</u>: Students are actively recruited to participate in the LBDL. Today, the LBDL has been offered consistently for over 10 years and word-of-mouth among students drives much of the enrollment. Initially, active recruiting by faculty was essential. Short classroom visits targeting 2nd-year STEM majors, advertising in student newspapers, and posting informational fliers in public spaces in STEM departments have all been effective. We provide evidence that LBDL experience increases perceptions of the teaching profession and specifically increases affirmation to prompts like "I plan to become a teacher." However, the majority of LBDL participants do not intend to become teachers. Hence, in our recruiting materials and presentations we are careful to avoid saying that the experience is intended exclusively for pre-service teachers. Evidence presented here indicating that LBDL experience develops 21st century competencies should be incorporated into recruiting for any LBDL-like program to appeal to students focused on health professions, engineering, or any other STEM field.

Timeline: The quarter-long (10 week) timeline for the LBDL (Figure 2) was driven by the needs of the SIs, many of whom were doing their first-ever teaching experience. We *could* have increased the number of visiting school children if we reduced the class time devoted to preparation and collaboration. Three of the ten weeks are dedicated to preparation and practice and we strongly encourage any SFES considering an LBDL-like program to resist the urge to maximize the number of visiting schools at the expense of some of these 'quiet' weeks. We believe that the first two weeks, during which no schools are visiting, are essential to helping these novice teachers prepare and build a supportive community. In the sixth week of the quarter the cohorts of SIs switch the content they are teaching (i.e. the students who were teaching life science switch to teaching physical science and vice versa.) This mid-point switch has several advantages. The midpoint switch provides a break from the high-energy weeks (3-5 and 7-10) when students visit. The switch also helps to keep the content fresh for the SIs who might tire of teaching the same hour-long module for the entire duration of the course. However, the biggest benefit of switching content is to give the SIs the opportunity to apply what they learned from their first weeks of teaching. We are always impressed by how effectively the SIs, now with three weeks of teaching experience under their belts, collaborate to plan the teaching of the new content making evidence-based decisions about pedagogy and scaffolding.

Administration and Funding: Throughout its development the LBDL has benefited from strong institutional support. Most logistics are managed by an administrative assistant at CESAME who is committed to LBDL-related activities for about 10 hours per week during quarters when the LBDL is offered. The administrative assistant covers most non-teaching-related details of the LBDL. For example, the administrative assistant sends email notifications about the program to local schools, manages the registration list (see below), arranges day-of logistics with schools especially related to bus drop off, pick up, and parking, and is the day-of contact with the lead teacher from any visiting school. LBDL does not manage other aspects of a school's visit to campus but we have developed an information packet with suggestions for places to eat lunch (including when it's raining), and lists of other on-campus groups with outreach programs that schools can take advantage of if they wish to extend their on-campus field trip beyond the LBDL hours.

Practically, the LBDL offers a no-cost option for a STEM focused field trip. School sites and individual teachers are invited to apply to bring groups of 3-8th grade students of any size, with up to 100 students on any given day. Larger school groups are split across multiple days. If several small school groups apply, they are grouped together to yield approximately 100 visiting students. Because demand for accommodations is far greater than our 3500 student/year capacity, a lottery system using an algorithm developed to maximize the number of students who are able to attend the laboratory is employed to ensure equitable access. Priority is given to school sites that have not visited the LBDL in the prior year.

Materials costs for the LBDL are covered in two ways. Most new lab activities require an initial investment in permanent materials (i.e. equipment). These are purchased using funds from the CSU-wide Math Science Teaching Initiative (MSTI) program. The goals of the program are to support recruiting and training of STEM teachers and the LBDL fits well with this goal. Consumable materials are generally low cost and are paid for by the participating departments.

Adaptability to Virtual Teaching: During the COVID pandemic, implementing the standard in-person LBDL model was not an option. We could either develop a Virtual LBDL experience or not offer the course. As an advisor approved elective, a handful of students needed this course to graduate, so we decided to keep the course open and experiment with Virtual LBDL offerings. Over four terms, we have engaged more than 70 Cal Poly students and welcomed more than 3000 visitors, through live, synchronous Virtual LBDL sessions hosted via Zoom.

In experimenting with a Virtual LBDL offering, the experience of our SIs remained our top priority. To this end SIs were directly engaged in developing virtual, hands-on modules. While building modules, they focused on equity and safety, believing it was essential that visiting kids have easy access to the materials needed for any given activity and that activities could be carried out safely with minimal in-person supervision. To date SIs have developed three modules one focused on Kitchen Chemistry, one focused on Environmental Literacy and Engineering, and one focused on Visualizing Unseen Forces (tied to a NASA uplink). The process SIs went through to develop and refine virtual modules mirrored our traditional face-to-face approach and seemed to give SIs similar opportunities for growth.

We have experimented with two models for recruiting and engaging visiting kids. Our first model engaged families directly through social media, local parent teacher associations, and word of mouth. Families could sign-up kids from 3-8th grade to join a 90-minute session and would receive short one-page descriptions of each activity and the materials kids would need. During the activities, visiting kids were encouraged to do the activities as modeled by the SIs. This recruitment approach resulted in large, diverse groups of visitors, mostly from California but with representation from 10 other states, Canada, Europe, South America, and Asia. This model was effective for visitors when public school offerings were virtual and heavily asynchronous. Our second model for recruiting and engaging visiting kids reverted to our traditional "classroom" based approach. Using our existing lottery system, regional teachers could apply to bring groups of up to 60, 5-8th or 3-4th grade students to the Virtual LBDL for a ~90-minute session. One-page activity descriptions were shared with teachers who distributed them to students in their classes. This recruitment approach resulted in visitor groups that most resembled our face-to-face meetings, with narrow grade bands from local schools. This model was most effective when school sites were 100% virtual and mostly asynchronous. This model was less effective in hybrid situations, where a portion of the visiting students were on-site at their schools and a portion were at home.