NUMBERS IN NATURE

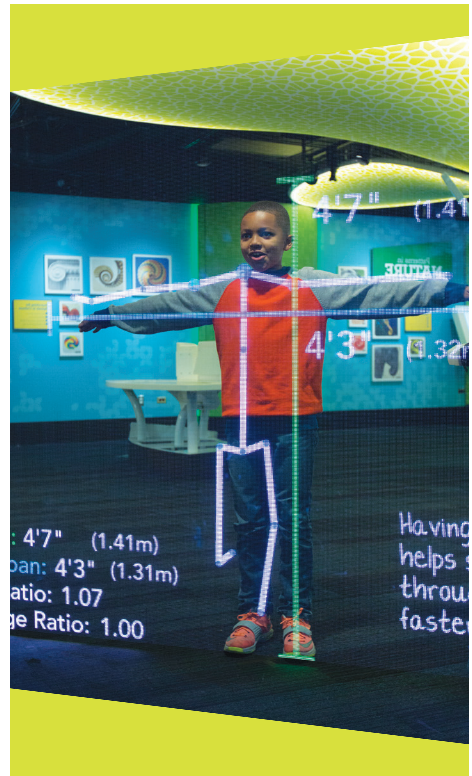
# A MIRROR MAZE

museum of science+industry chicago

## TEACHER RESOURCE PACKET

***Numbers in Nature: A Mirror Maze***, an interactive and immersive exhibit created by the Museum of Science and Industry, Chicago, reveals and explains the mathematical patterns that abound in the natural world–from the delicate nested spirals of a sunflower's seeds, to the ridges of a majestic mountain range, to the layout of the universe. Through hands-on activities, an immersive film, a mirror maze and mathematical artifacts, *Numbers in Nature* provides a unique perspective of our daily surroundings.

# EXHIBIT EXPERIENCES




**Introduction to Patterns:**
An immersive theater presentation of a large-format media piece features stunning footage of nature, the human body, and even art and architecture, with overlaid animation that uncovers mathematical patterns—spirals, the Golden Ratio ($\Phi$), Voronoi patterns and fractal branching—beneath these familiar objects. Building upon the examples in the theater, an interactive area allows guests to identify patterns that surround them every day and to create numerical patterns of their own.

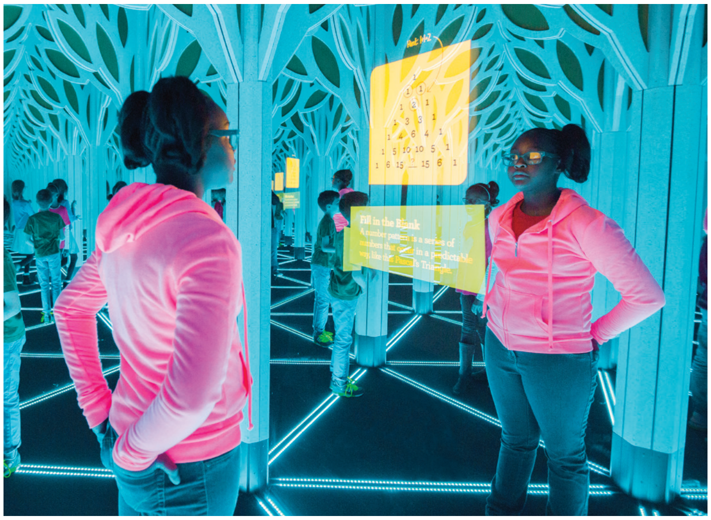
**The Mirror Maze:**
The centerpiece of the exhibit exposes guests to a pattern of triangles that repeat in a dizzying array of mirrors. This fascinating, yet challenging, space envelops guests within what appears to be an endless pattern—1,800 square feet of it! Guests encounter intriguing questions and activities to further immerse themselves in the repetition, symmetry and tessellation presented in the maze. Dead ends are scattered throughout, and hidden within this self-guided experience is a small secret room with bonus puzzles, imagery and artifacts.

**Hands-on Discovery:**
Upon leaving the maze, guests have more opportunities for hands-on activities in a final gallery. Highlights include:

- Step in front of a large two-way mirror and strike various poses while a projection superimposes patterns and proportions on your body in real time.
- Observe just how much symmetry—or lack thereof—is present in the human face.
- Draw patterns on a digital screen—like connecting dots to draw spirals and creating Fibonacci rectangles—and see real-world objects that show that same pattern.
- Compose a piece of music using symmetry: vary a single musical motive and hear your creation.

# CENTRAL IDEAS OF *NUMBERS IN NATURE*

Nature has an inherent structure that can be expressed through numeric and geometric patterns. These mathematical tools help us understand, manipulate, and appreciate the world around us.




## Patterns exist everywhere in nature and the designed world.

- A pattern is a set of shapes or numbers that repeats in a characteristic way and can be described mathematically.
- Patterns are an expression of math.
- There are many types of patterns.


## Patterns help us understand, manipulate and appreciate the world around us.

- Patterns describe relationships between objects or systems.
- The pattern and shape of natural and designed objects are related to their function.
- Patterns can be used for a variety of practical applications in the designed world.

## Guests visiting *Numbers in Nature* can:

- Identify patterns in nature.
- Recognize that nature has an inherent, underlying structure that can be described mathematically.
- Experience a sense of wonder and excitement around math by participating in fun and experimental activities that allow them to create, experience and manipulate patterns.
- Recognize that patterns can be described using math.
- Feel engaged and excited enough to seek opportunities to learn more about math.

# NEXT GENERATION SCIENCE STANDARDS

*Numbers in Nature* is aligned with the following Next Generation Science Standards.

### Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

### Crosscutting Concepts:

- Patterns
- Scale, proportion and quantity
- Structure and Function

### Disciplinary Core Ideas:

- LS1: From Molecules to Organisms: Structures and Processes
- LS3: Heredity: Inheritance and Variation of Traits
- ETS1: Engineering Design
- PS4: Waves and their Applications in Technologies for Information Transfer

# CLASSROOM LESSONS

To enhance a *Numbers in Nature* visit, teachers can use these free classroom lessons before and after their visit.

1

### Patterns Everywhere

Explore what patterns are and the many places they can be found.

2

### Patterns in DNA

Use everyday materials to extract DNA from your cheek cells and learn about the patterns found in DNA.

3

### It's a Secret

Utilize patterns to help decode messages.

In addition, the *Numbers in Nature* Patterns Museum Exploration Guide lesson focuses your field trip visit. Students use a worksheet to record their observations and experiences in the exhibit then complete a follow-up activity back in the classroom.

# Numbers in Nature Additional Resources

## WEBSITES

**Codes and Code Breaking**
nrich.maths.org/2197

**Computer Science Unplugged**
csunplugged.org/activities

**Cryptology Club**
cryptoclub.org

**Fibonacci Math for Kids**
mathsisfun.com/numbers/fibonacci-sequence

**Fractal Foundation**
fractalfoundation.org

**Numbers in Nature**
msichicago.org/numbers

**Make Your Own Geometric Drawing**
nathanfriend.io/inspirograph/

**Vi Hart (a self-described "recreational mathemusician")**
vihart.com/

## BOOKS

**By Nature's Design: An Exploratorium Book**
Diane Ackerman

**The Golden Section: Nature's Greatest Secret**
Scott Olson

**Growing Patterns: Fibonacci Numbers in Nature**
Sarah C. Campbell

**Mathematics: The Science of Patterns**

**The Search for Order in Life, Mind and the Universe**
Keith Devlin

**Symmetry: The Ordering Principle**
David Wade

# PATTERNS EVERYWHERE (60 MINUTES)

## AT A GLANCE

Students will explore what patterns are and the many places they can be found.

## OBJECTIVES

- Students will explore patterns that occur in a variety of different familiar materials.
- Students will discover that patterns can happen in the natural world.

## KEY VOCABULARY

**SYMMETRY:** When one shape becomes exactly like another if you flip, slide or turn it (i.e. the human body is symmetrical because you can divide it in equally in half).

**FRACTAL:** An irregular shape that looks the same at any scale on which it is looked at (i.e. the branches of a tree look random but are actually similar shapes repeated over and over again with varying sizes).

**TESSELLATION:** A pattern arranged in a mosaic fashion (i.e. salt crystals).

**FIBONACCI SERIES:** A mathematical sequence of numbers that happen to represent a vast number of measured relationships in nature. The sequence (1, 1, 2, 3, 5, 8, 13…) is comprised of the first two terms being 1 and 1 and each following term is the sum of the two just before it.

**VORONOI PATTERNS:** A pattern where every point within a given region is closer to the "seed" inside that region than it is to any other point outside that region. Each point along a region's edge is equidistant from the two nearest seeds. It's seen in places ranging from cracked mud to giraffe skin to foamy bubbles. Voronoi patterns can help solve geometric problems like packing, strategic placements and patterns of growth.

## NEXT GENERATION SCIENCE STANDARDS

**SCIENCE AND ENGINEERING PRACTICES:**

- Asking questions and defining problems
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

**CROSSCUTTING CONCEPTS:**

- Patterns
- Scale, proportion and quantity
- Structure and function

**DISCIPLINARY CORE IDEAS:**

- LS1: From Molecules to Organisms: Structures and Processes

## ADVANCE PREPARATION

**CRYSTAL ANALYSIS:** In each square of the crystal analysis worksheet place a small amount of the material that is indicated: salt, sugar, sugar substitute and baking powder. Place a magnifying glass at the station.

**SPIROGRAPH:** Put out the Spirograph and enough scrap paper with one blank side so each student can use at least one page at the station. It may be useful to show students how to use the Spirograph prior to having them try themselves.

**FINGERPRINTS:** Put out an ink pad, extra paper, wet wipes and the finger print worksheet.

**MIRROR SYMMETRY:** Put out five mirrors and the symmetry activity worksheet.

**FRACTAL FEATHERS:** Put out feathers, magnifying glasses and the worksheet.

## MATERIALS PER GROUP

Pictures of patterns
Salt packet
Sugar packet
Sugar substitute packet
Baking power
Magnifying glass
Spirograph
Stick-um or double-sided tape
Pencils
Gel pens
Scrap paper
Fingerprinting ink pad
Wet wipes
Mirror
Feathers

## WHAT YOU NEED TO KNOW

A pattern is a set of shapes or numbers that repeats in a characteristic way and can be described mathematically. Patterns are useful for sorting and classifying natural and designed objects. They can be used for identification and to make predictions.

There are many different kinds of patterns. An example of a mathematical pattern can be as simple as starting with 1 and adding 2 repetitively. That pattern would look like 1, 3, 5, 7. The same rule is applied repeatedly and you can predict what the next number in the sequence would be.

Patterns can also be geometric. Examples of objects arranged in a geometric pattern include bricks forming a wall or even desks arranged in a classroom. Many natural objects are arranged in patterns like the petals of the flower or spots and stripes used by animals for camouflage.

Patterns and shapes that make up nature and the man-made world can also be found in the human body. Out the window, through a microscope, or in the mirror—patterns surround us. They form the veins of a leaf, the spiral of a nautilus and the spots on a giraffe. Patterns also inspire us as we create or build things. Some of the patterns found in nature include fractal branching and Voronoi patterns.

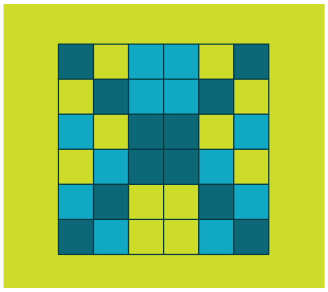
Fractal branching is a detailed pattern that looks similar at any scale and repeats itself. It takes a simple rule and applies it over and over again, resulting in complex shapes. From snowflakes to river systems to urban development, fractals can help us understand seemingly complex behavior.

In a Voronoi pattern, every point within a given region is closer to the "seed" inside that region than it is to any other seed outside that region. Each point along a region's edge is equidistant from the two nearest seeds. It's seen in places ranging from cracked mud to giraffe skin to foamy bubbles. Voronoi patterns can help solve geometric problems like packing, strategic placements and patterns of growth.

Throughout history, humans have replicated the natural world's patterns, intentionally or subconsciously, in their architectural concepts. This has occured across thousands of years and continents.

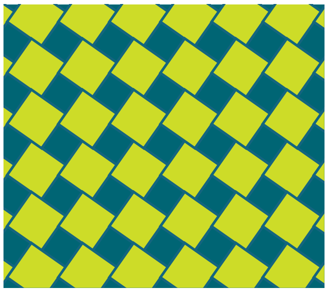
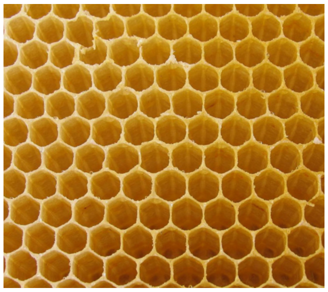
# EXAMPLES OF PATTERNS

### SYMMETRY LIKE TWO SIDES OF A FACE OR MIRROR IMAGE

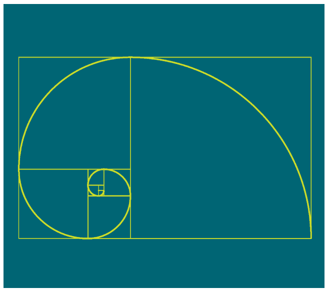
### SPIRALS LIKE THOSE FOUND IN GALAXIES AND GROWING FERNS


### TESSELLATIONS LIKE TILE PATTERNS AND CRYSTAL STRUCTURES

### FRACTALS LIKE BRANCHING PATTERNS OF TREES OR SNOWFLAKES


### THE FIBONACCI SERIES AND GOLDEN RATIO

### VORONOI PATTERNS THAT DESCRIBE HOW SOAP BUBBLES AND GIRAFFE SPOTS ARE ARRANGED


# WARM UP

1. Show pictures of various patterns and discuss patterns with the group. Patterns can be found everywhere in the world and are in places you'd never think to look. Ask questions such as:
   - Have you ever looked closely at your classroom wall or the ceiling in your living room and seen a pattern?
   - Have you ever seen patterns in a carpet or the tiles on a wall?
2. Using the activity guide have the students go on a patterns field trip around the room. If available, have students use cell phone, iPad or Android tablet cameras to take pictures of patterns in the room.
3. With the class, walk around the room and find as many patterns as possible. Ask them:
   - What patterns do you see? How many different patterns can you find?
   - What shapes/colors are the patterns?
   - Where are they found?
   - Why do you think patterns emerge in things we build?
   - Why do you think patterns emerge in nature?
   - Do feathers have more than one pattern?
4. Discuss other places outside of the classroom where patterns exist, including in the natural world.
5. Have students make a sketch of their favorite patterns.

# ACTIVITY

Tell students there will be five stations for them to explore different materials that exhibit different types of patterns. Review what the class will do at each station before splitting them into five groups and starting a rotation.

### CRYSTAL ANALYSIS

Using a magnifying glass, students will observe salt, sugar, sugar substitute and baking powder under a magnifying glass. Salt and sugar are examples of crystal structures while sugar substitute and baking powder are not. The activity guide will prompt students to identify which of the substances have predictable shapes.

### SPIROGRAPH

Each student will make their own Spirograph design and count the number of loops in the design after the end meets back up with the beginning. This should be exactly 13 rotations (or loops). It is important to keep the ring part stationary. Use the stick-um or tape to hold it in place. Put a piece on the ring and press it to the paper. Alternatively you can use a clipboard to keep a stack of paper and the ring can be secured using the clip.

### FINGERPRINTS

Instruct students to gently press one of their fingers in the ink pad and roll that finger on page of their journal. Wipe their finger off with a Wet Wipe when done. Students then identify the type of fingerprint they have. The three basic types of fingerprints are:

- Whorl: Ridges form a circular pattern.
- Arch: Ridges form a hill or tent-shaped pattern.
- Loop: Ridges form an elongated loop pattern.

### MIRROR SYMMETRY

Use the mirrors to observe images that are symmetrical. Have students predict which pictures and shapes are dividd symmetrically. Then have them place a mirror on the lines to check their predictions.

### FRACTAL FEATHERS

Use the magnifying glass to observe the feather and determine what parts of the feather are similar at different scales.

## CHECK FOR UNDERSTANDING

Have students answer the following questions in their teams or as a whole group discussion.

- What did you notice at the pattern stations?
- What have you discovered?
- Can you think of some patterns in nature that you may have seen?
- How can patterns help us find solutions to problems?

## WHAT'S HAPPENING?

Spirals are curves that start from a center point and get farther away as they circle around that point. They can be found in pinecones, pineapples and hurricanes. A logarithmic spiral is a special type of spiral where the distance between each turn of the spiral is progressively larger than the one before it, as in a nautilus shell. Spirographs all fall into a family of patterns called hypotrochoids and the patterns can all be described mathematically.

Criminologists use fingerprints to solve crimes because all fingerprints are unique. The FBI has been utilizing this knowledge to track criminals for years. The bureau uses the Integrated Automated Fingerprint Identification System, or IAFIS, as a tool for identifying and matching fingerprints. The large database operates as a pattern-matching machine. Within 27 minutes of submission, the system can identify a fingerprint of someone if they are in the database. It contains the prints and criminal histories of over 70,000 people, demonstrating that use of patterns is not only for making observations and predictions in science labs.

## DIFFERENTIATED INSTRUCTION

- Assign each group member a specific job at each station to facilitate teamwork. For example, one person can be in charge recording information and another person can report their results.
- Assign mixed-ability peer partners as groups and encourage students to help one another.

## EXTENSIONS

1. In teams, have students create their own patterns stations and share where they found patterns with the rest of the class.
2. Have students explore and share careers that involve the use of patterns, such as:

   **SOFTWARE ENGINEER:** These scientists use patterns as a general reusable solution to a commonly occurring problem within a given context in software design. A design pattern is not a finished design that can be transformed directly into source or machine code. It is a description or template for how to solve a problem that can be used in different situations. Patterns are formalized best practices that the programmer can use to solve common problems when designing an application or system.

   **ARCHITECT:** Symmetry finds its ways into architecture at every scale, from the overall external views of buildings such as Gothic cathedrals and the White House, through the layout of floor plans to the design of building elements such as tile mosaics.

# PATTERNS EVERYWHERE

NAME:

Have you ever looked closely at your classroom wall or the ceiling in your living room and seen a pattern? Have you ever seen patterns in a carpet or the tiles on a wall? Patterns can be found everywhere in the world. If you train your eyes to see them, you can find them in places you'd never think to look.

**1.** **WHAT PATTERNS DO YOU SEE? HOW MANY DIFFERENT PATTERNS CAN YOU FIND?**

**2.** **WHAT SHAPES/COLORS ARE THE PATTERNS?**

**3.** **WHERE ARE THEY FOUND?**

**4.** **MAKE A SKETCH OF YOUR FAVORITE PATTERNS.**

# CRYSTAL ANALYSIS

NAME:

Examine each material under the magnifying glass.

**1.** **WHICH MATERIALS ALL SEEM TO BE THE SAME SHAPE?**

**2.** **WHICH MATERIALS SEEM TO BE ALL DIFFERENT SHAPES?**

**3.** **SKETCH WHAT YOU SEE UNDER THE MICROSCOPE**

| Salt | Sugar Substitute | Baking Power | Sugar |
|---|---|---|---|

# FINGERPRINTS

NAME:

Use the ink pad and paper to make your own fingerprint. Compare your print to the pictures below and answer the following questions.

Arch

Loop

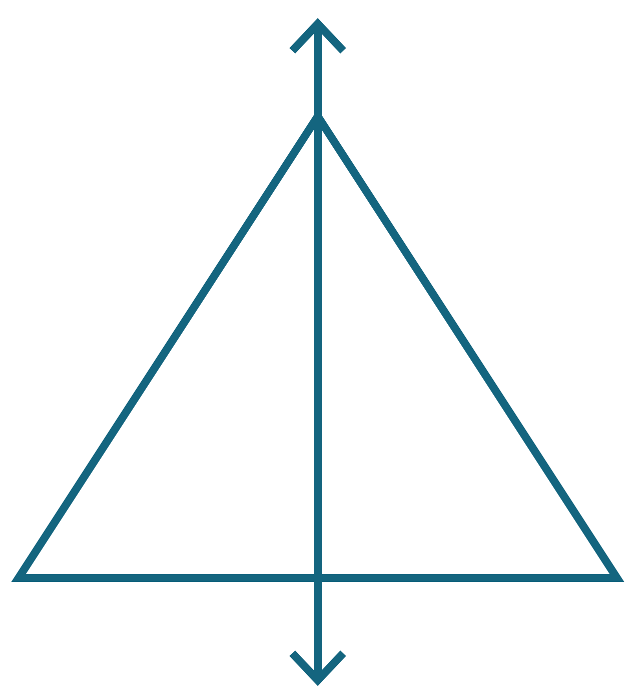
Whorl

**1. ARE YOUR FINGERPRINTS ALL THE SAME PATTERN?**

**2. COMPARE YOUR FINGERPRINTS TO OTHERS IN YOUR GROUP. HOW MANY HAVE ARCHES? LOOPS? WHORLS?**

# SYMMETRY STATION

Predict which lines divide the shapes into symmetrical sides. Place the mirror on the lines on the pictures and shapes to test your prediction



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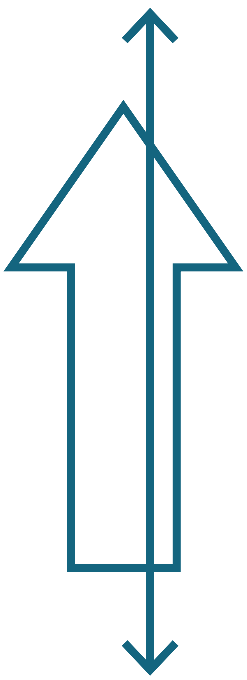

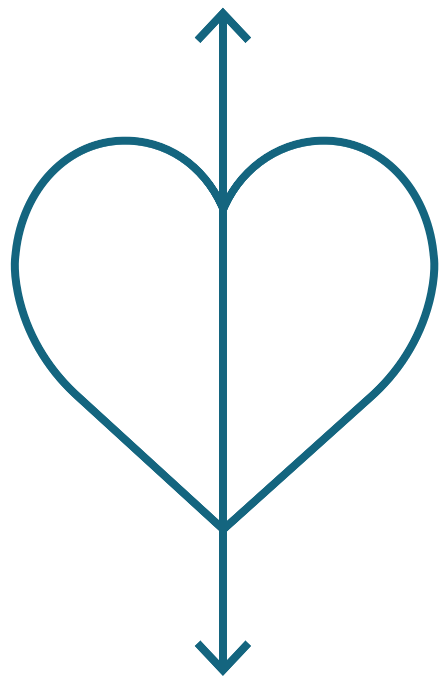

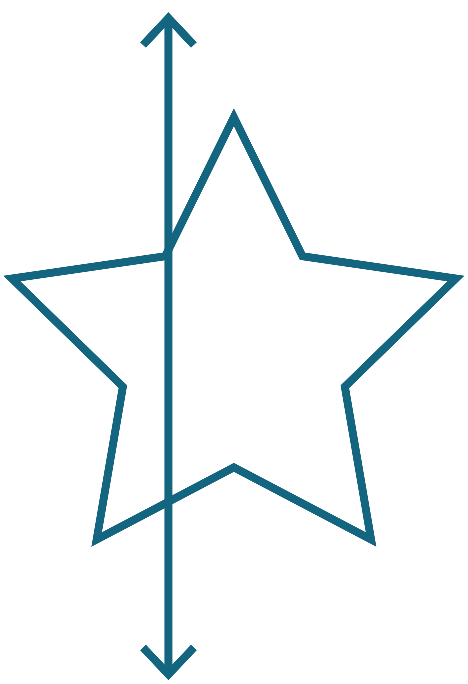

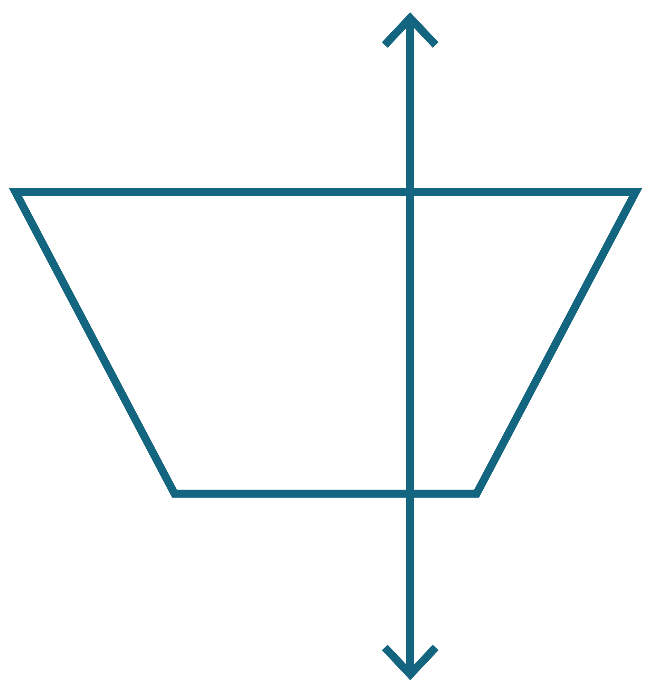

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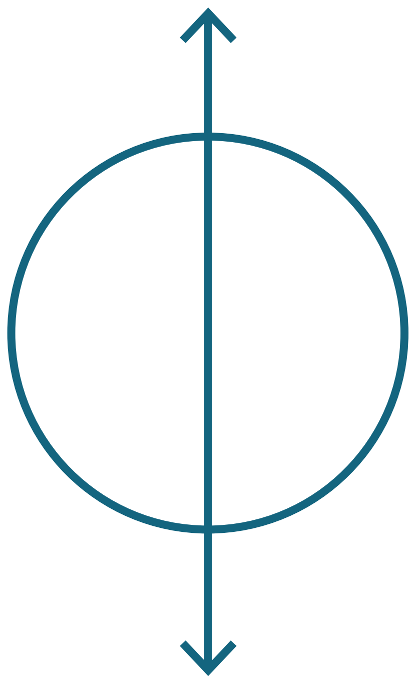
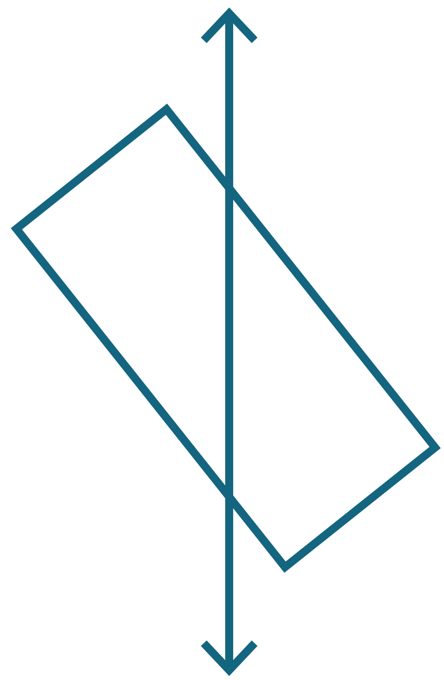
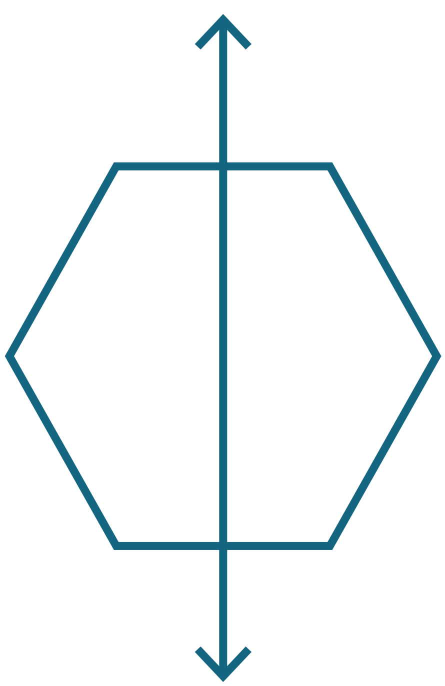
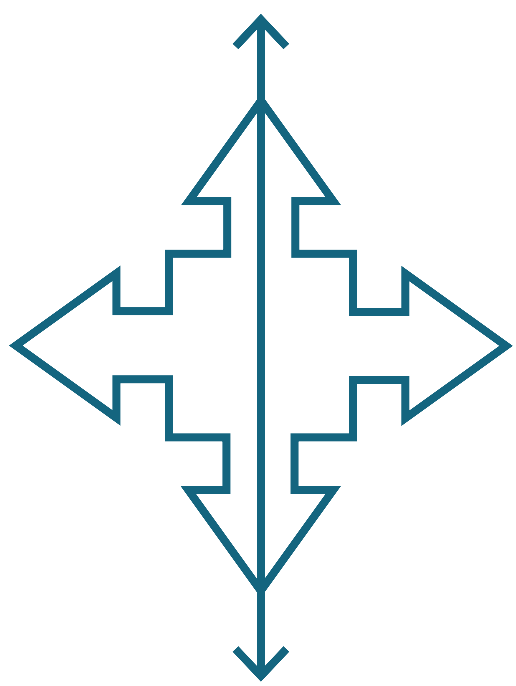








# FANCY FEATHER STATION

NAME:

Use the magnifying lens to look at the feather and observe the individual barbs or pieces of the feather.

1. **WHAT DO YOU NOTICE?**

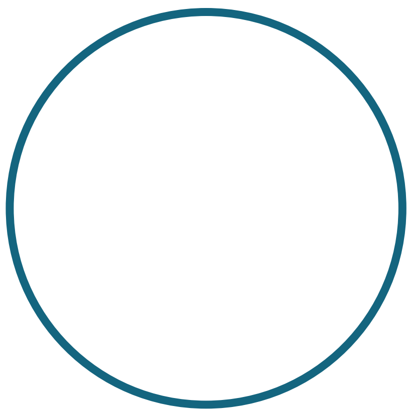
2. **DO YOU SEE A PATTERN?**

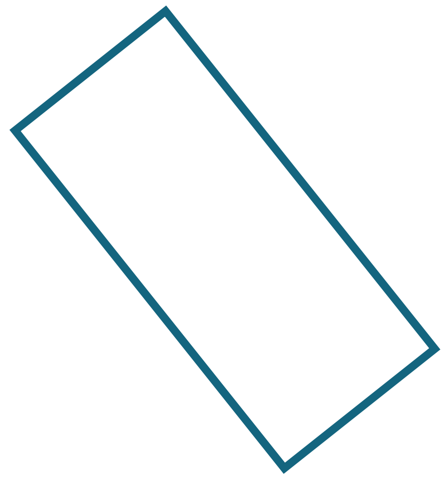
3. **DO FEATHERS HAVE MORE THAN ONE PATTERN?**

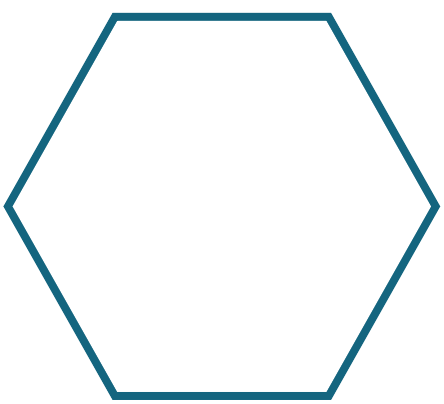
4. **SKETCH WHAT YOU SEE.**

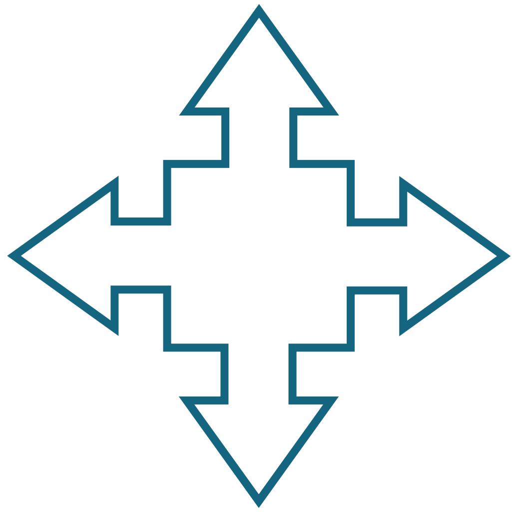
# SYMMETRY STATION (ADVANCED)

Draw lines of symmetry for the following shapes. Where could you place the mirror so that the reflection completes the original shape?









# PATTERNS IN DNA

# (45 MINUTES)

## AT A GLANCE

Students will use everyday materials to extract their DNA from cheek cells and learn about the patterns found in DNA.

## OBJECTIVES

- Students will extract DNA from their cells.
- Students will describe two patterns associated with DNA.

## KEY VOCABULARY

**DNA:** Deoxyribonucleic acid is the unique hereditary material in humans and other living things.

## NEXT GENERATION SCIENCE STANDARDS

### SCIENCE AND ENGINEERING PRACTICES:

- Asking questions and defining problems
- Planning and carrying out investigations

### CROSSCUTTING CONCEPTS:

- Patterns
- Scale, proportion and quantity

### DISCIPLINARY CORE IDEAS:

- LS3: Heredity: Inheritance and Variation of Traits

## ADVANCE PREPARATION

Place isopropyl alcohol in the refrigerator.

## MATERIALS PER GROUP

Salt packet
Dixie cup
Test tube
Pipette
Cold isopropyl alcohol
Liquid soap
Wikistix (Optional)

## WHAT YOU NEED TO KNOW

DNA, or deoxyribonucleic acid, is the hereditary material in humans and almost all other organisms. With the exception of red blood cells, every cell in the body has DNA and every cell in a person's body has the same DNA. Most DNA is located in the cell nucleus, but a small amount of DNA can also be found in the mitochondria. The only people with the exact same DNA are identical siblings.

DNA provides the instructions for building and operating all living things. The instructions are divided into segments called genes. Each gene provides the information for making a protein, which carries out a specific function in the cell.

A molecule of DNA is composed of two backbones and four types of chemical bases. The backbone is formed by a chain of alternating phosphates and sugars. Each sugar molecule in the backbone provides an attachment site for one of the chemical bases. The four types of chemical bases are: adenine, thymine, cytosine and guanine. They are represented with A,T,C and G. The bases form pairs in a very specific way, A-T and C-G.

DNA is very long. It can only fit into a cell by being packaged up into small units called chromosomes. Chromosomes are the storage space for DNA, and they are what can sometimes be seen in a microscope when looking at a cell. Humans have 46 chromosomes in each cell. Each parent gives a person 23 chromosomes, or half of their genes. Genes are what give people their specific traits, ranging from eye color and hair color to whether or not they are prone to certain diseases. Scientists have discovered that genes are inherited in certain patterns. For example: if a woman has red hair, a man has black hair and their child has black hair, where did the child's black hair gene come from? The father.

In this activity, students will see their own DNA. Keep in mind that the DNA you see in this activity is actually clumps of thousands of strands of DNA. To see the individual strands of DNA, you would need an electron microscope.

## WARM UP

Have a discussion with students. Ask them: Is it true that every living thing is made of cells?

Yes, this is true. In fact, humans and other animals share the exact same cell structure. Our cells are identical.

Why is it then, that we look completely different from a cat? And how come we don't look exactly like the person sitting next to us?

The answer is DNA, deoxyribonucleic acid, known as the blueprint of life. DNA carries a coded set of instructions that tell our cells how to arrange proteins. The way these proteins are put together determines everything from our eye color to which cells become our liver cells.

Ask students to think about where DNA is stored in our cells—in the nucleus. Each cell has a nucleus that contains an exact copy of our DNA. But is there a way to get a closer look at DNA? What would we have to do?

## ACTIVITY

1. Divide students into groups. Tell students they will do an experiment in which they extract DNA from the cell nucleus, and that they will be able to see DNA by scraping their check cells.
2. Give each student one cup and one salt packet.
3. Empty the salt packet into the cup and fill the cup about one-quarter full with water.
4. Pour the salt water solution into your mouth and swish vigorously for 45 seconds. Spit the solution back into the cup.
5. Pour the solution from the cup into the test tube, filling the test tube halfway. Discard the rest of the salt water solution.
6. Add four drops of liquid soap to the test tube. Close the tube, gently hold it and swirl it in a circular motion for about one minute.
7. Use a pipette to slowly fill the rest of the test tube with the isopropyl alcohol. The alcohol should float above the liquid soap solution.
8. Let the solution stand for 30 seconds to one minute. Then use the pipette to slowly move the alcohol into the liquid soap layer. You should see long white strands—this is DNA.
9. Explain that each cell contains a long strand of DNA in this ladder-type formation. The shape of the DNA strand is twisted inside our cells. This twisted ladder formation is called a double helix.

## CHECK FOR UNDERSTANDING

Have students answer the following questions in their teams or as a whole group discussion.

- What is DNA?
- Where was the DNA stored in the cell?
- What separated the DNA from the cell?
- Why did you add alcohol and liquid soap?

## WHAT'S HAPPENING?

Salt helps loosen cells from the surface of the inside of the mouth. The salt also helps shed the water molecules from the DNA and makes it easier for the DNA to clump together.

Think about when you wash dishes–what does the soap do to the oil on the dishes? It breaks the oil up. Cell membranes are also made of lipids. By adding soap to your cheek cells, it breaks up the membranes of the cell and nucleus and frees the contents of the cell, including DNA. So the DNA begins to float near the top of the soapy water.

DNA is soluble in water but not in alcohol. The alcohol helps the DNA precipitate or separate as a solid from a liquid solution. The result is a white clump of thousands of DNA strands that you can see with your naked eye.

By swirling the salt water in your mouth, you collected a great deal of cells from the inside of your cheeks. Salt also bonds with DNA and helps the DNA strands stick together. By spitting those cells (along with the salt water and saliva) into the test tube and mixing them with soap, you were able to break up the outer membrane and nucleus of each cell.

The cell membranes and the nuclear membranes are made up of lipids (very similar to fats). The dish soap that you added dissolved these lipids, thus exposing the DNA. This DNA then floats up through the soap until it hits the alcohol solution. DNA can't dissolve in cold alcohol, so it separates from the solution and forms the long white strands at the bottom of the layer of alcohol.

## DIFFERENTIATED INSTRUCTION

- It's also possible to extract DNA from food, such as peas and strawberries. After students are done extracting their own DNA, have them research and complete this process.
- Simplify vocabulary and instructions. Students of all ability levels will be able to participate in some way. Students with taste or texture sensitivities can use another student's DNA sample.

## EXTENSIONS

Build a DNA model to better understand the patterns in DNA. Start with two orange Wikki Stix, and press them tightly together, along their entire length. Do the same with two bright blue Wikki Stix. These become the sides, which are actually a linked chain of sugar and phosphate molecules. Lay the two sets down, 2 inches apart.

To make the bases, start with dark blue and purple, cutting them to equal sizes and press them together in the middle, making the span long enough to reach the two sides of the "ladder." Attach them to the sides.

Then use yellow and green and follow the same directions, attaching the base to the sugar phosphate "ladder" slightly below the dark blue and purple. For the fourth bases reverse the yellow and green colors, and attach to the ladder. You now have the pattern for the four bases and can alternate them.

When completed, pick up the "ladder" and gently twist it. The resulting shape is called a double helix.

# INSTRUCTIONS

1. PROVIDE ONE CUP AND ONE SALT PACKET PER PERSON.
2. EMPTY THE SALT PACKET INTO THE CUP.
3. FILL THE CUP ONE QUARTER FULL WITH WATER AND SWIRL TO MIX.
4. SWISH THE SALT WATER IN YOUR MOUTH FOR 45 SECONDS AND SPIT IT BACK IN THE CUP.
5. POUR THE SOLUTION FROM THE CUP INTO THE TEST TUBE, FILLING THE TEST TUBE HALFWAY.
6. DISCARD THE REST OF THE SOLUTION INTO A SINK OR TRASHCAN.
7. ADD FOUR DROPS OF THE LIQUID SOAP INTO THE TEST TUBE. CLOSE THE TUBE AND GENTLY ROCK IT BACK AND FORTH OR SWIRL IT FOR ABOUT ONE MINUTE.
8. USE A PIPETTE TO SLOWLY FILL THE REST OF THE TEST TUBE WITH THE ISOPROPYL ALCOHOL. THE ALCOHOL SHOULD FLOAT ABOVE THE LIQUID SOAP SOLUTION.
9. LET THE SOLUTION STAND FOR 30 SECONDS TO ONE MINUTE. YOU SHOULD SEE LONG WHITE STRANDS—THIS IS DNA.

# IT'S A SECRET

# (60 MINUTES)

## AT A GLANCE

Students will use patterns to help decode messages.

## OBJECTIVES

- Students will use patterns to successfully decode a message.
- Students will communicate strategies and outcomes from an activity.

## KEY VOCABULARY

**ALGORITHM:** A set of steps that are followed in order to solve a mathematical problem or to complete a computer process.

**CHRONOLOGICAL:** Arranged in the order that things happened or came to be.

**CRYPTANALYST:** Someone that decodes information from encrypted sources.

**CYPHER:** A way of changing a message to keep it secret.

**DECRYPTION:** Changing coded information back into a plain text message.

**ENCRYPTION:** Taking plain text information and coding it into a secret language.

## NEXT GENERATION SCIENCE STANDARDS

### SCIENCE AND ENGINEERING PRACTICES:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

### CROSSCUTTING CONCEPTS:

- Patterns

### DISCIPLINARY CORE IDEAS:

- ETS1: Engineering Design

## ADVANCE PREPARATION

Use a set of index cards to create coded messages. Number each card and put a code letter on it. Examples on the next page.

## CODED MESSAGE

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Z | L | | A | N | Z | R |
| V | F | | F | N | E | N |

## DECODED MESSAGE

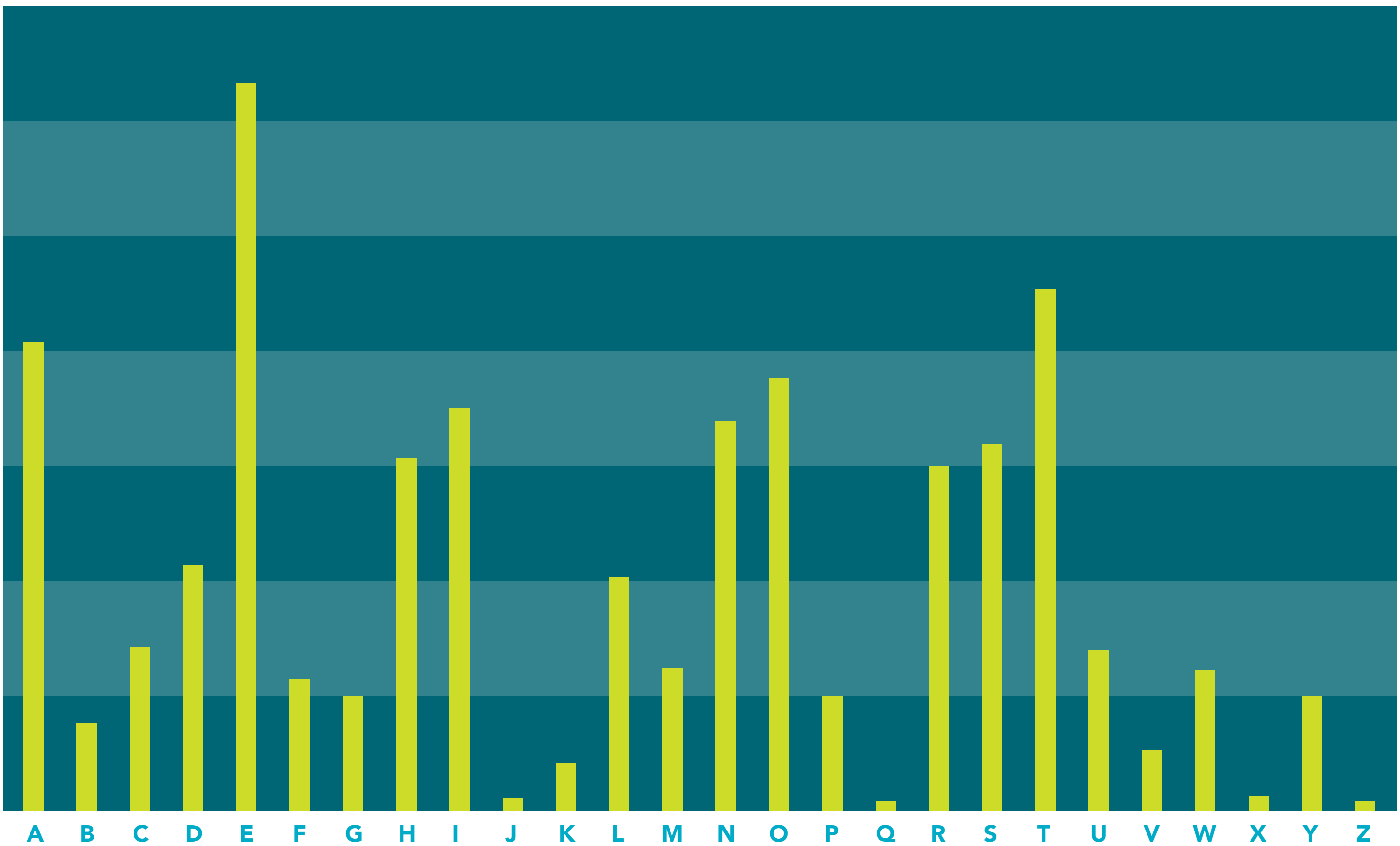
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| M | Y | | N | A | M | E |
| I | S | | S | A | R | A |

## MATERIALS PER GROUP

Pencils
Paper
Index cards
Completed ROT13 index card sets
Decoding chart
Bag

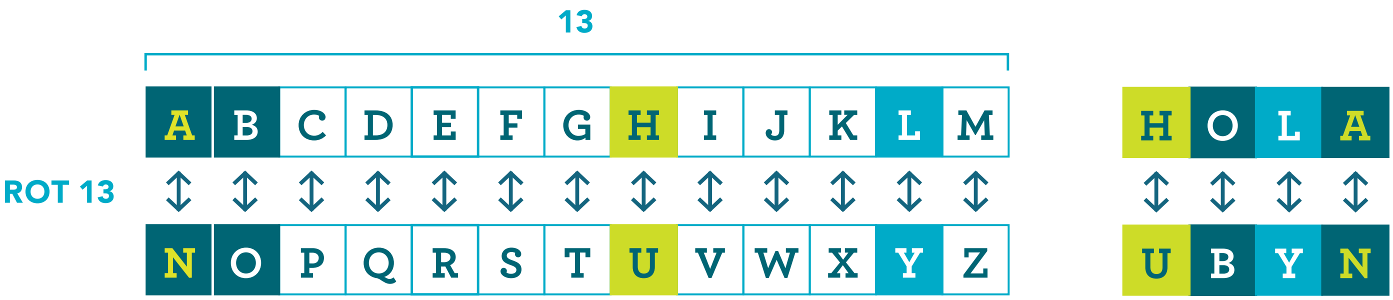
# WHAT YOU NEED TO KNOW

Cyphers (codes) have been used for centuries in order to protect information. And for centuries people have worked at breaking those codes using a variety of different methods. Most of those methods were rooted in seeing patterns within codes and analyzing them based on the frequency of letters found in any given language. Whether using machines to break the complicated algorithms (step-by-step solutions to completing a pattern series) behind some codes or relying on informants or stolen materials, the art of encryption (disguising information through codes) and decryption (cracking those codes) has been important throughout history. Most of these code breakers, or cryptanalysts, have to understand the language the code is written in incredibly well to crack it. You have to be able to see the patterns and frequency of the letters that are used in a message.




AVERAGE FREQUENCY OF LETTERS IN ENGLISH LANGUAGE
PHOTO CREDIT: HOW STUFF WORKS, 2007

Students will be using a form of coding called a ROT13 cypher for this activity. This cypher involves replacing the letters of the alphabet with the letter 13 characters away from it. See the grid on the next page for more information.




## WARM UP

1. Students will be creating their own codes to communicate with one another. Ask them to think about when codes might be used and different codes they've used in their lives. Why would people want to use codes?

2. Ask the students if they can think of different types of secret codes. Encourage examples like pig latin (moving the first letter of a word, placing it at the end of the word and adding"–ay" to it, i.e. hello becomes "ello-hay"), Morse code (a series of percussive taps that stand for letters) or a pigpen cypher (a group of graphics that replace different letters of the alphabet) by directing questions about where and how codes are used.

3. Discuss the fact that codes use patterns and the key is to determine what type of pattern is being used.

## ACTIVITY

1. Give each group a bag containing index cards that have numbers and letters on them. Each number is the order of the card in a sentence. The letter represents another letter in the alphabet according to the ROT13/Caesar Cypher used to encrypt the message.

2. Ask the students to explore the cards in their bag.

3. Ask the students what they see on the cards and what those items might mean. Guide them to think about the numbers/order of the cards.

4. Once the students recognize the order, have them order the cards chronologically.

5. Provide the decrypted text on poster paper and ask the students to think about what the code might be. Encourage them to consider the number placement in the alphabet as part of the pattern or to write out the alphabet and write the "decoded" letters down in order.

6. If they cannot immediately find the pattern, ask them to substitute the letters in the decrypted passage into their passages. Can they make guesses at what the statement might be saying?

7. Steer the conversation toward codes you could make up. Explain to students that they will need to create a code and encourage students to walk around during this time in order to foster a large amount of ideas. Have students share their codes with each other.

## CHECK FOR UNDERSTANDING

Have students answer the following questions in their teams or as a whole group discussion.

- What type of pattern did your code use?
- Who are some people that might use codes in their jobs?

## WHAT'S HAPPENING?

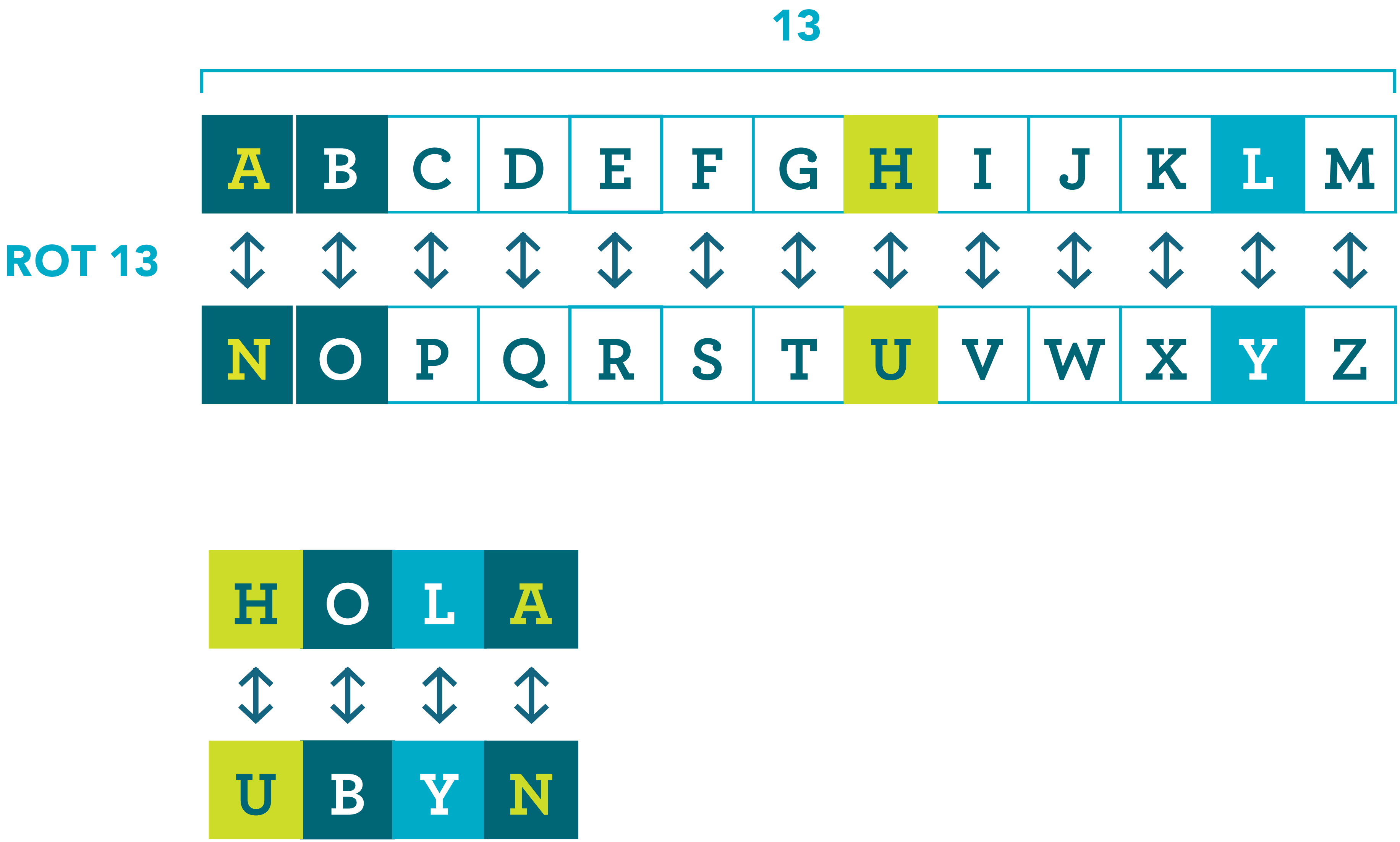
This is a type of shifted coded message. These messages rely on moving the letters of the alphabet a specific number of places and then using the alternate letters to write a message.

## DIFFERENTIATED INSTRUCTION

- Give students the same message using different types of code. Have them compare the patterns and how the same message can be written in different types of code.
- Provide students with a code key showing each letter and its substitution.

## EXTENSIONS

- Explore computer code. Ask students if they're ever noticed the message that pops up after shutting a computer down incorrectly. It looks like gibberish but is actually the encrypted message that allows the computer to run certain programs. For each program or app that you run, someone had to write that code for the electronic device to work when you push the button. That person is a computer programmer. Computer programmers create the "code" that allows this work to happen. If you are interested in learning this "language," explore www.code.org.
- Have students research and share different times that coded messages have been used throughout history.


13
ROT 13
A B C D E F G H I J K L M
N O P Q R S T U V W X Y Z
H O L A
U B Y N

museum of science+industry chicago

NAME

1

# PATTERNS

## Museum Exploration Guide

**INSTRUCTIONS**

Print to "actual size," cut pages, assemble in numerical order and staple to form a booklet. Use your guide to complete the Patterns worksheet after your field trip.

## What is a Pattern? 2

A pattern is something that repeats, meaning it happens over and over again. Find a pattern in the Museum and draw it.

**What interests you about this pattern?**

## Use Your Senses 3

We recognize patterns using our senses. We can hear, see, touch and smell patterns! Choose one of your senses other than sight and find a pattern in the Museum using that sense.

**WHAT SENSE DID YOU CHOOSE TO USE?**

**What did you discover?**

WE USE PATTERNS TO MAKE "SENSE" OF THE WORLD AROUND US!

## Types of Patterns 4

Patterns come in all shapes, sizes, sounds and textures.

Find and describe a pattern in the Museum that surprises you.
**HINT:** Patterns can be stripes, spirals, beeps, waves – and much more!

**FIND AND DESCRIBE A PATTERN IN THE MUSEUM THAT SURPRISES YOU**

**What surprises you about this pattern?**

# Objects

5

THE OBJECT I CHOSE IS:

A pattern can be in or on an object, such as inch marks on a ruler or veins in a leaf.

Find and draw an object in the Museum that has a pattern.

**Why do you think it was made with that pattern?**

# Actions

6

Patterns can be found in an action, like a bus route or the daily sunrise.

**Describe an action pattern you notice somewhere in the Museum.**

# Patterns in Nature

7

A pattern can happen naturally, like petals on a flower, bubbles and our DNA.

Find and draw a pattern in the Museum that is found in nature.

**What do you wonder about this?**

# Inspired Patterns

8

Things we make are inspired by nature. A spiral staircase or computer chip might use a pattern from nature.

Design a pattern from your imagination. Get creative!