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A TOUR THROUGH *NUMBERS IN NATURE: A MIRROR MAZE*

Numbers in Nature: A Mirror Maze is an interactive and immersive new permanent exhibit at the Museum of Science and Industry, Chicago that exposes 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, an 1,800-square-foot mirror maze and mathematical artifacts, *Numbers in Nature* will change the way guests look at the world.

A glimpse at the nearly 20 activities and more than 30 artifacts featured in the 7,250-square-foot exhibit is described below.

Introduction to Patterns in Our World
Upon entering the exhibit, lenticular graphics animate stunning imagery from nature and the designed world. When guests walk past wall, these images reveal the hidden math and repeating patterns in the world that are easily identifiable—if you know where to look!

Immersive Theater
The visual journey continues within an immersive theater that displays a large-format, four-minute media piece that reveals the elegance and pervasiveness of patterns in nature and introduces guests to a new way of seeing the world around them.

Four primary patterns—**the Golden Ratio (ϕ), spirals, fractal branching and Voronoi patterns**—are introduced. Guests learn about the Golden Ratio, a common proportion that are particularly pleasing to the eye; spirals, curves that start from a center point and get further and further away as they circle around that point; fractal branching, a detailed pattern that looks similar at any scale and repeats itself; and Voronoi patterns, 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.

Captivating images of nature, the human body, even art and architecture are shown with overlaid animated computer graphics to describe the mathematical patterns beneath these familiar objects. Patterns can be found in Nautilus shells, hurricanes, galaxies, brain cells, city lights at night from space, lightning, tree branches, human lungs, and more.

Exploring Patterns
After exiting the theater, guests are able to explore what they learned in the film at interactive stations. Spin round discs to explore objects that were featured in the film and reveal the mathematical patterns within.

With interactive touchscreens, create additive number sequences to understand that the ratio of adjacent numbers always approximate phi (ϕ), the Golden Ratio. An animation of the Fibonacci sequence describes what a sequence is and how ratios, proportions and patterns can be derived from them.

The Mirror Maze — Journey Into Patterns
In the centerpiece of the exhibit, the mirror maze, become immersed in a pattern of triangles that repeat in a dizzying array of mirrors. The mirror maze itself is a pattern, combining several characteristics of geometric patterns: **repetition, symmetry and tessellation** using repeated equilateral triangles. These triangles fit together without any gaps or overlaps, creating a tessellation. Mirrored surfaces all around reflect the pattern so that it repeats and appears infinite. The combination of many symmetrical reflections keeps you guessing which way you're headed—posing an inviting, yet challenging, space for you to navigate.

Several dead ends are scattered throughout the **1,800-square-foot maze**. At some of these points, you'll discover additional intriguing facts and have to solve some mathematical puzzles.

Try finding the small **hidden room** nestled within the maze, to unlock bonus experiences and artifacts. Not all guests will find this mystery room, so navigate carefully!

Discovering Patterns
After exiting the mirror maze, head to multiple digital drawing stations to create patterns on a series of touchscreens. Choose to draw particular sequences, shapes or objects, including:

- **Golden Ratio:** Connect the dots to draw squares and see how the ratios of the side lengths are approximately the same, and equal to the Golden Ratio.
- **Fractals:** Explore fractals by dividing a triangle and continuing to divide it into smaller triangles seemingly infinitely.
- **Spirals:** Connect dots to draw counter-spiral patterns.
- **Voronoi patterns:** Starting with a basic Voronoi pattern, you'll be prompted to add points and drag them around the screen to see how the pattern changes in response.

Patterns in Nature
Learn how nature has an inherent structure through a series of hands-on activities, which include:

- **Experiment with fractal branching** by twisting the knobs on a screen's console, creating a tree. Tweak different aspects of its branching by controlling how many times the branching element repeats, how many new branches occur as it divides, the rotation and angle of the model, and how natural forces affect the "perfect" mathematical shape.
- **Take on the role of a digital animator** to create mountain ranges in computer graphics. Digital animators use the very same mathematical patterns that describe real mountains and other fractal patterns in nature to generate landscapes, just like those in Hollywood movies. Using a series of knobs, change variables to discover how this fractal geometric division makes a realistic mountain from a flat triangle.
- **Explore intriguing spirals, Voronoi pattern and Fibonacci numbers** by manipulating 3D models of objects—like a pinecone, artichoke, cabbage, tortoise shell and more.

A wall of artifact cases and graphics display authentic examples from the natural world. These artifacts include moths, an aluminum anthill casting, a honeycomb and Bighorn sheep antlers.

Patterns in Nature and the Cultural World

Architecture, music and art also feature expressions of mathematical patterns that mimic those found in nature. This area allows for exploration of man-made patterns through more interactive activities.

Since the dawn of time, humans have looked at the patterns in the natural world and replicated them, intentionally or subconsciously, in architectural concepts.

- **Align logarithmic spirals** with a series of hand-held templates to compare and contrast objects from nature and the designed world.
- **Match patterns to architectural structures** across thousands of years and continents.

Mathematical patterns can't just be seen, they can also be heard.

- **Play a multistring harp and a single string "guitar"** to discover how ratios play a role in an octave scale. On the multistring harp, examine the ratio of one string's length to the others and how that changes the tone. On the single-string device, alter the length of the string to hear how the note changes.
- **Create and hear a piece of music you compose using symmetry.** Arrange cards printed with symmetric melodic patterns in any order you like. Once you have the cards arranged, press a button and hear your masterpiece played back to you. You can also hear an excerpt of **Bach's crab canon**, which employs many symmetrical musical patterns.

Learn about three artists and their process of inspiration and discovery using a combination of math and art.

- **Peter Randall-Page** uses nature's patterns, as seen in a maquette of his *Seed* sculpture. The sculpture is based on the Fibonacci sequence and on display at the Eden Project in Cornwall, England.
- **Erik and Martin Demaine** are mathematicians and artists who use folded paper sculpture, most commonly known as origami, as a means to explore fundamental mathematics. By folding and bending paper, they are exploring new shapes and how to express them mathematically. One of their curved crease sculptures is on display.

Patterns in You
Nature and the man-made world are made up of patterns and shapes, but those very same proportions and patterns can also be seen in the human body. Some of the experiences in this area feature:

- **Reveal the ratios and proportions in the body** by stepping in front of a large two-way mirror and striking various poses. A motion sensor reads the poses and, in real time, superimposes measurements over the live images of your body. These measurements include:
    - Feet together, arms straight out: measures to see if your height and wingspan are similar, as it is for most people.
    - Feet together, one arm out: measures the proportions of the bones in your arm.
    - Feet together, hands on hips: measures proportions along the height of your body.
    - The distance between the crown of the head, belly button and full height (Vitruvian Man pose): check to see if these proportions conform to the Golden Ratio.

- **Explore Voronoi patterns by examining your hand's skin** under a magnifier. Compare it with other objects featuring this same pattern.
- **Discover two different kinds proportions found in human faces**: symmetry and the Golden Ratio. Align your face with a small mirror that has the Fibonacci rectangles and a spiral drawn on it. Line your eye up to the pattern to see how closely your face conforms to the Golden Ratio. See a symmetric reflection of half of your face: Do you look the same?
- **Look into an eyepiece to examine the fractal branching** in the eye's blood vessels. A system of illuminated lenses will reflect back the magnified image of your retina to expose the fractal branching pattern of the capillaries.
- **Use a compass** to explore where the Golden Ratio appears in various images of natural objects.

Also in this area are descriptions of "perfectly imperfect" individuals who are able to do extraordinary things because of imperfect symmetry or non-conformity to the Golden Ratio. Olympic swimmer Michael Phelps has a very distinct set of proportions in his body: his wingspan is wider than he his tall; the ratio of his leg length to his torso length is much smaller than average. Sergei Rachmaninov has unusually large hands; this enabled him to play and compose piano music few others can play.

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