Contacts:
Amy Patti, amy.patti@msichicago.org, (773) 947-6005
Isabel Morales, isabel.morales@msichicago.org, (773) 947-6003

NUMBERS IN NATURE: A MIRROR MAZE FACTS

Numbers in Nature: A Mirror Maze is an interactive and immersive new permanent exhibit, where guests will never look at the world the same way again. Here are some astonishing and fascinating facts about patterns in the world around us:

Patterns in Nature

The **seeds in the center of a sunflower** are in a spiral arrangement. This allows the sunflower to pack the most seed heads in the least amount of space without smashing any one seed against its neighbors. The Fibonacci sequence, where each number is obtained from the sum of the two preceding, is present in some species of sunflowers. By counting the spirals going in each direction, the resulting numbers are always from the Fibonacci sequence. Thirty-four spirals go in one direction, while 55 spirals go in the opposite direction.

Some **beaches** form in a logarithmic spiral due to wave diffraction and refraction off the beach. Examples include Half Moon Bay, Calif.; Birch Bay, Wash.; La Restinga Beach, Venezuela; and Pearl Beach, Australia.

Spirals are demonstrated in a number of concepts in nature, such as modeling the growth rate of **seashells**, how **hawks** approach their prey, and the flight path of **insects** toward a light source.

Voronoi patterns, where a point within a given region is closer to the seed inside that region than it is to any other seed in any other region, are used frequently to study the world around us. They help to establish growth patterns in **forests** as predictive models for forest fires, to calculate **rainfall** for a given area, and to determine the capacity of **wireless networks**.

Patterns in Anatomy

The famous *Vitruvian Man* drawing by Leonardo da Vinci illustrates the **human body's ideal mathematical proportions**. The iconic pose centers the limbs on the navel by spreading the legs apart and raising the arms overhead. By knowing the proportions of the human body, Leonardo thought mankind could better understand the structure of the entire universe.

Objects that approximate the Golden Ratio (ϕ)—or a special proportion that describes the relationship between two objects—are thought to be more aesthetically pleasing to the human eye. Some research has been done to test this theory—both physically and psychologically, and for human faces and man-made objects—but there is no known scientific basis to support this claim. The degree to which an object or human face conforms to the Golden Ratio can be used only as a **subjective measure of aesthetic beauty**.

While **our faces** may appear symmetrical, they are not. Nature rarely conforms perfectly to the math that is used to describe it, and the human body is no different. The amount of asymmetry in our faces and bodies makes each of us unique.

When looking closely at **skin**, it's a seemingly random arrangement of polygons and triangles. This arrangement isn't random, however. Skins cells are actually organized into a Voronoi pattern.

Some individuals are able to do extraordinary things because they don't have perfect symmetry or conform 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, and the ratio of his leg length to his torso length is much smaller than average. Both of these things factor into his ability to swim faster.
- Russian composer **Sergei Rachmaninov** has unusually large hands. This enabled him to play and compose piano music few others can play.
- Other examples include peripheral vision in chess players, and manual dexterity with string musicians—based on the musician's hand's geometry, some instruments are better suited to their body.

Patterns in Music

Symmetry appears in music as well. Composers commonly take a **single string of notes** (a motive) and use symmetry to change it and repeat it throughout a piece of music. For example, a motive can be repeated (translated horizontally), transposed (translated vertically), inverted (reflected horizontally), in retrograde (reflected vertically) or in retrograde inversion (180-degree rotation).

The notes in a **pentatonic scale**, familiar to most Westerners' ears, are built on the same proportions as the Golden Ratio. Plucking a string, dividing it exactly in half and plucking it again results in the same tone one octave higher. This is the root, or tonic, note. Holding the string at a spot one-third of the way along the length results in the fifth, or dominant note, in the scale. Each note in the scale can be described according to its ratio to the tonic note.

Patterns in Architecture

Sometimes mathematical patterns are used implicitly in architecture, as is the case for the spiraling design of the **Engineering Plaza at California Polytechnic State University**. According to the landscape architect Jeffrey Gordon Smith, "As a guiding element, we selected the Fibonacci series spiral, or golden mean, as the representation of engineering knowledge."

Architects used a Voronoi pattern to create the iconic **"Bird's Nest" stadium** for the 2008 Olympic Games in Beijing. The lightweight structure was built without columns and is structurally sound in an earthquake-prone area. Although the structural form of the Stadium is popularly described as a "Bird's Nest," the pattern was initially inspired by Chinese-style pottery, typically found in Beijing markets, and the randomness of the natural world. The **"Water Cube" swimming stadium** at these Olympic Games also used a Voronoi pattern as inspiration.

French architect **Le Corbusier** designed housing complex Unité d'Habitation in Marseilles, France with the Golden Ratio in mind. He believed designing with the Golden Ratio created the most harmonious living design.

There is much debate as to whether or not the **Parthenon** in Athens, Greece, built from 447 to 438 BC, features the Golden Ratio in its design. Many believe it does.

The **Ba-ila Village** near Zambia, Africa reveals a fractal design of open-ended circles at several scales. This repeated shape unites family dwellings, cattle pens and a central chief's stockade into a single entity.

The **Taj Mahal**, commissioned by Emperor Shah Jahan in memory of his wife, is recognized around the world for its stunning symmetry.

Patterns in the Designed World

Mathematicians and artists Erik and Martin Demaine create **folded paper sculptures** that demonstrate how repeating a simple process—folding a sheet of paper—over and over again gives rise to a mathematical pattern and shape. They begin with a single sheet of paper then fold and twist it into a complex, three-dimensional mathematical form.

The Golden Ratio may be seen in **famous artwork** as well, but in each of these examples, no concrete evidence exists that the artists knowingly used this aesthetically pleasing pattern on purpose. *Mona Lisa* by Leonardo da Vinci, the pentagram composition used to outline the bodies in *Holy Family* by Michelangelo, and the overall composition of *Sacrament from the Last Supper* by Salvador Dali all display signs of the Golden Ratio.

Voronoi patterns are used in **robotics** to create navigation algorithms for robotic figures. By driving the robots down the lines of a Voronoi diagram, paths are determined that keep the robots the furthest away from all obstacles to minimize the possibility of collisions.

When trying to create computer graphic mountain ranges for films, **digital animators** use the very same mathematical patterns that describe real mountains in nature. This is also true when modeling the behavior of natural phenomena like molten lava, fire and water—as in the dramatic molten lava effects created in *Star Wars Episode III*.

# # #