**AEROSPACE PALACE ACADEMY, NIGERIA**
**(A subsidiary of Aerospace Palace International, Nigeria)**

# LESSON 68: SCIENCE, MATHEMATICS, AND ART

To many people, the world of science and mathematics is completely removed from the world of art. Science is a quest to discover ideas which explain how the world around us works; mathematics, often called the Queen of the Sciences, is the language we use to express these ideas. Art is a harder concept to define, but we might describe it as an attempt to find beauty and/or meaning in the world. While these two disciplines differ in many ways, there is something they have in common: a desire to understand the world around us. Indeed, mathematics and science have often inspired art and the search for beauty has often inspired scientists and mathematicians. This lesson explores some of the connections between science, mathematics, and art.

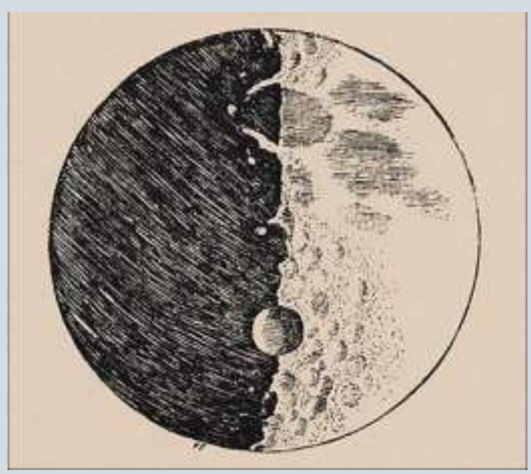
Let us note that this micro lesson only touches on what is truly an incredibly diverse and profound subject. It does not even mention other arts such as music and dance and the role that science and mathematics play in them—the mathematics of musical intervals and timing, the science behind creating musical instruments, and the physics of the motions of dance. One can spend literally semesters exploring the field in depth.

Next Generation Science Standards (NGSS):

- Discipline: Earth and Space Sciences.
- Crosscutting Concept: Patterns.
- Science & Engineering Practice: Developing and Using Models.

## ***GRADES K-2***

NGSS: Crosscutting Concept: Patterns. Observed ~~patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.~~



One obvious example of science affecting art is astronomical painting. The night sky has captivated human beings for as long as we can tell, and throughout the centuries, many artists have depicted the sky either directly or indirectly in their works. As scientists have learned more about the heavens, artistic depictions of the cosmos have become more accurate. For example, the famous scientist Galileo is widely credited as being the first person to observe the moon through a telescope. He published sketches of what he saw through his telescope, and his observations allowed other people to realize that the moon

## ***GRADES K-2 (CONTINUED)***

was not just a glowing sphere, but a planetary body with similarities to our own earth such as mountains, valleys, and canyons. One of these sketches is shown here. Galileo's drawings, published in 1609, changed the way that humans saw the moon, and artists who followed him would create increasingly intricate depictions of the lunar surface.

However, the relationship between science and art goes both ways; art can also help to inform and inspire science. One example of this is the use of old paintings to learn about the motion of stars and other celestial bodies. Amazingly, astronomers have used paintings from hundreds of years ago to identify astronomical phenomena. In particular, comets are a fascinating link between historical art and present-day science. Comets—large balls of dust and ice that hurtle through space—leave long trails in the night sky as they pass near to Earth, and artists throughout history have recorded these cosmic sightings in paintings and drawings. Perhaps the most famous example is Halley's Comet, which passes by Earth roughly every 76 years. Scientists have been able to identify this specific comet in artwork from around the world, ranging from 11th-century France (the Bayeux Tapestry—comet shown here) to 14th-century Italy (Adoration of the Magi) to ancient China and Greece. In this way, artists' attempts to depict the world around them have helped astronomers to establish a long scientific record of Halley's Comet.

In more recent times (say, for the past 200 years or so), astronomical artists have used their imaginations to embellish scientific reality by painting alien landscapes and skies as they think would exist elsewhere in the universe. Some early examples are James Carpenter and James Nasmyth, who created sculpted models of what they imagined the Moon's surface to look like in 1874; a few years later, Paul Philippoteaux painted a view of what he thought the rings of Saturn might look like up close. These sorts of artwork can't be described as *scientific*, per se, but they often inspire people from all walks of life—including scientists—to seek out a deeper understanding of the universe.

Some astronomical artists also paint pictures of what they think life will be like in the future. The best-known of these artists in the last century, Chesley Bonestell, created a series of pictures of spacecraft, space stations, and astronauts. He worked with the best scientific minds in figuring out what these were likely to look like. Even with this help, though, he didn't always get things right; the linked page shows pictures by Bonestell of a canal on the surface of Mars and of a space station that looks nothing like the real thing. However, the realism (or lack thereof) of these pieces of art is beside the point if they are still able to inspire and encourage people's curiosity.

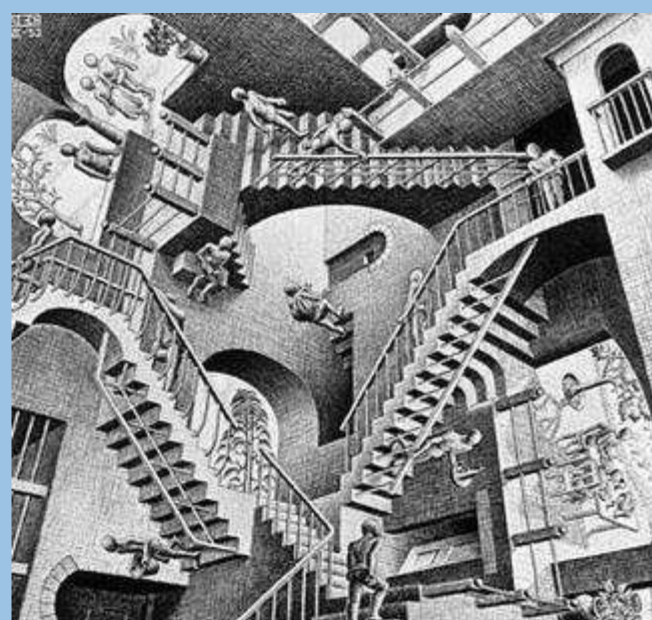
## ***GRADES K-2 (CONTINUED)***

Suggested Activity: Have the students draw a picture of something to do with astronomy or space exploration. It can range from the realistic to the very whimsical.

## ***GRADES 3-5***

NGSS: Crosscutting Concept: Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Of artists who have been inspired by science and mathematics, probably none is better known in modern times than Maurits Cornelis ("M.C.") Escher. His art is rife with tessellations, geometrical figures, paradoxes, and impossibilities. He was born in 1898 in the Netherlands and died there in 1972. Strikingly, he did not do well in mathematics classes in school; he was almost forty years old when he "came to the open gate, the open gate of mathematics."

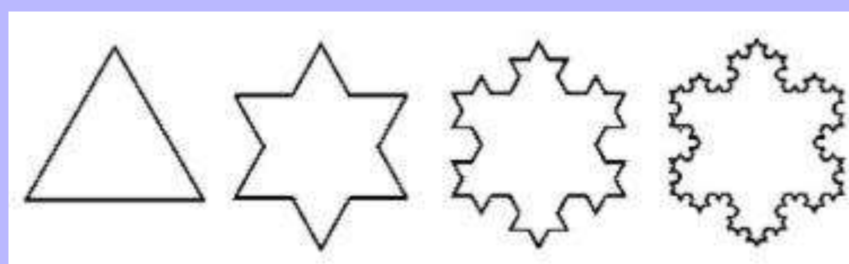


Escher's mathematical art falls largely into the categories of tessellations, geometrical figures, and logical paradoxes. A tessellation is a tiling of a plane by exact or approximate repetitions of one or more figures. Escher's tessellations range from the relatively simple (but only relatively) repetition of the same figures over the image through the gradual evolution of figures across the image to the intricate duplications of ever-smaller copies of the figures. His geometrical figures, usually three-dimensional, often include fantastical reptiles or other creatures within them. And Escher's images of logical paradoxes are the stuff of legend.

## ***GRADES 6-8***

NGSS: Crosscutting Concept: Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

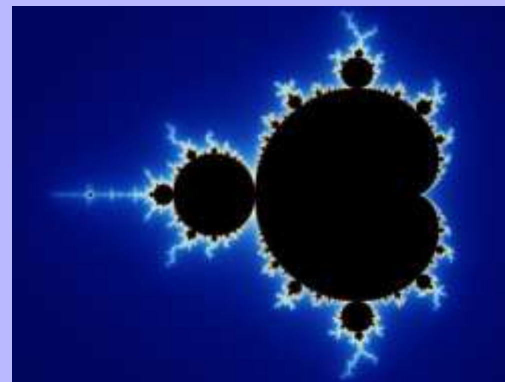
Perhaps one of the most striking confluences of analytical theory and aesthetic beauty is the topic of fractals. A fractal is an image made by continuously repeating one "element" in a pattern infinitely and on increasingly small scales (this is a slightly narrow definition; it is possible for fractals to take other, non-visual forms as well). What does this mean, exactly? Essentially, we can generate a simple fractal by taking some sort of shape, and modifying it in such a way that the resulting shape can be transformed again using the same rule. For example, if we start with an equilateral triangle, we could modify it by placing another equilateral triangle in the middle third of each side; this would give us a six-pointed star. We could then do the same procedure again—inserting a triangle into the middle third of each line—and get a more complicated shape. In fact, we can *keep* doing this, over and over again, until the shape becomes very intricate. This is a classic example of a fractal and is called a Koch snowflake.



What is the perimeter of a Koch snowflake? If the length of each side of the original triangle is one unit of distance, then the perimeter of the original triangle is three units. After you take out the middle third of each side (length one third) and replace it with the two line segments (length one third each, or two thirds per side of the triangle), the perimeter of the resulting star is four units. With each iteration, you change the length between the endpoints of each line segment from three to four, multiplying the complete perimeter by the ratio of four over three. If you do this infinitely many times to make a true Koch snowflake, you get an infinite sequence of multiplications. The perimeter of a Koch snowflake is thus infinite, even though it fits in a small area. This is the essence of it being a fractal shape.

The Koch snowflake is a simple example of a fractal, but there are many more complicated ones. Perhaps the most famous fractal is the Mandelbrot Set. The Mandelbrot Set is a collection of complex mathematical numbers (hence, "set"), but its fractal nature is strikingly beautiful when viewed visually. An image of the set is given on the right. You

## GRADES 6-8 (CONTINUED)



can see how intricate and complex the shapes are; one of the most mind-boggling things about fractals such as this is that they are just as complicated when you zoom in. That is, the patterns that make them up continue infinitely, so you could keep zooming in on an image like the Mandelbrot Set forever. In fact, there is a website which lets you do exactly that–by selecting an area with your computer mouse, you can zoom in millions or billions of times, but the image still looks just as complex as before (note: in this web demo, there *is* a limit on how far you can zoom in (around 100 quadrillion times), but this is a limitation of your web browser and not of the mathematics).

Fractals are more than just pretty patterns, however. Mathematicians have been able to use fractals to describe many processes and phenomena in the natural world. For example, snowflakes, leaves, and even some trees are have fractal-like geometries (although obviously none of these are infinite). Even lightning can have a fractal structure. In recent years, fractals have also been used in computers to simulate complex graphical phenomena like shadows.

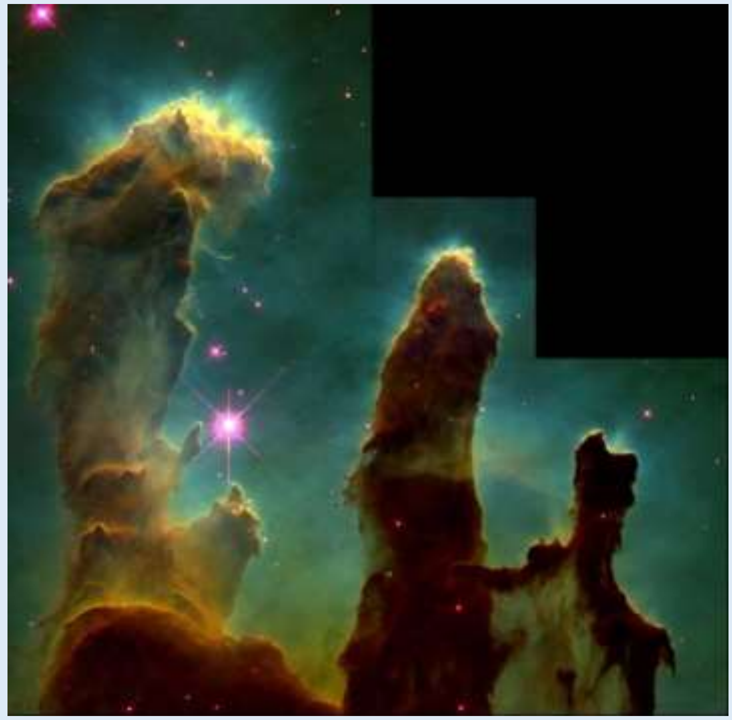
Fractals are a perfect example of math and art meeting in the middle. They are mathematical constructions, but they accurately describe the world around us in a beautiful way.

## GRADES 9-12

NGSS: Crosscutting Concept: Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

It is worth drawing a distinction between something that is beautiful and something that is sublime. "Beautiful," according to the dictionary, is "having qualities that delight the eye." "Sublime," on the other hand, is "of high spiritual, moral, or intellectual worth" or "inspiring awe." Thus a photograph by the Hubble Space Telescope, in addition to being beautiful, is also sublime. Besides pleasing the eye, it also inspires awe at the vastness of the universe and the intricacy of its contents. This is an important distinction—the

## GRADES 9-12 (CONTINUED)



difference between the worthiness of the object itself and one's personal reaction to it—which is often overlooked in modern times.

In addition to the inspiration that artists have often drawn from science and mathematics, scientists have often looked to the ideas of beauty and elegance to guide their theorizing. The "elegance" of a scientific theory has to do with its simplicity and its ability to explain—or describe—many widely different phenomena. Scientists find the quality of elegance to be notoriously difficult to put their fingers on and pin down; nevertheless, it is an important part of theorizing.

An example from the last century (updated, apparently, for the current century) that illustrates (although it does not explain) the idea of the elegance of a theory has to do with the color of emeralds. One theory about emeralds was that they are green in color, meaning that when one looks at them under ordinary lighting conditions they appear green. A second theory was that they are "grue" in color, meaning that until midnight on December 31, 1999 they appeared to be green but any time after that they appear to be blue. Which theory is correct? All observations of emeralds before December 31, 1999 supported both theories equally well; the only reason to prefer the first theory over the second was something other than the scientific observations. Yet nobody took the second theory seriously. (Your writer will remain silent on the question of having looked at an emerald on New Year's Day 2000 to test the second theory.) Obviously there is something besides matching observational data that is used in assessing whether or not a scientific theory is correct. That something is, at least in part, elegance.

Sixty Years Ago in the Space Race:

August 17, 1958: The American spacecraft "Pioneer 0" was launched toward lunar orbit but exploded 77 seconds after liftoff at an altitude of 15.2 kilometers.

August 24, 1958: The American Explorer 5 was launched but failed to reach orbit when its spent first stage collided with its second stage after separation.

August 27, 1958: The Soviets launched two dogs in a sounding rocket to an altitude of 281 miles and recovered them safely.