Eureka!

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Creativity and Science

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When Archimedes lowered himself into the bath, a number of things happened almost simultaneously. The warm water washed over his body, stimulating millions of sensory receptors in the skin. His mind, weary from focusing on a perplexing puzzle, drifted into mental repose and out of nowhere he suddenly knew, in an instant, the answer he was looking for.

Archimedes uttered the legendary cry of "Eureka!" and euphorically ran from the baths and down the street. Famously, he was still naked.

The concept that struck Archimedes in the bath is remarkably simple. He realised that an object lowered under water will displace—push aside—a volume of water exactly equal to the volume of the object. This principle is still taught in introductory physics courses today and it can seem almost obvious. It is easy to gloss over the fact that Archimedes had thought of a brand-new idea. Nobody had ever formulated this physical relationship as a tangible idea in a human mind, capable of being transferred from one person's imagination to another. This was a moment of intense creativity, as Archimedes converted a string of thoughts, observations and motivations into this new concept of buoyancy. He didn't create buoyancy—but he did create the concept of buoyancy.

Science as creativity

It is not surprising that Archimedes made his tremendous breakthrough while bathing. Quite a lot is known about how creative thought processes work in the brain, and defocusing the mind with something like a warm bath can produce the perfect opportunity for an "Aha" moment. The connections to science and creativity are vast. In fact, we can use science to better understand creativity. But this is not a chapter about the science of creativity. Instead, I am going to focus particularly on the creativity of science.

Science is a creative way of living and thinking. It is innovative and inventive and many of the other words we usually associate with creativity. It is often understood that science is about answering questions that have never been answered before. This is true—but it is also about asking questions that have never previously been asked, and that is a remarkably creative process.

It is quite possible you've never thought of science being a creative activity, partly a result of the "creative medium" being rather technical. Imagine yourself back in kindergarten grappling with the strange shapes that could be crafted with a pencil. "This is the letter A," your teacher would say, "and this is B." There was not much creativity apparent at this stage of learning to write—in fact the rules could be stifling. The shapes had to be copied so precisely, and inventing a new letter was not encouraged. A little bit later, these letters were put in groups and called "words." Here again, there was little room for creativity. Mixing up the arrangement of letters was called "incorrect spelling," not "creativity."

Only after these basic skills of the "written medium" were mastered did it became possible to write creatively. Even then, an author is constrained predominantly to use words that already exist.

The creativity of science is more like inventing new words. But science is not like writing gibberish. In order to invent new words effectively, it is first necessary to have a knowledge of existing words. Since modern science has been expanding its vocabulary for four centuries, there is a lot of learning required before creativity can be expressed. Unfortunately but necessarily, what is studied as "science" at high school is rarely anything more than learning the alphabet. Not many people stick with it long enough to see the "creative writing" of science.

This does not make science superior to other creative endeavours. Even the traditional arts vary greatly in the amount of "prior knowledge" required before creativity can flourish. Painting is perhaps one of the easiest activities to "access creativity," whereas music tends to require skill development over many years because it involves a foundational learning of a language of sorts.

There are a number of ways in which science operates creatively. The experience of Archimedes is an example of *conceptual discovery*, which differs somewhat from the more traditional notions of discovery. The moment Christopher Columbus saw land on the horizon, he had discovered the American continent. This was not a moment of creativity but of observation. By contrast, Archimedes was not the first person to ever see something lowered into a tub of water. However, he was the first to take this observation and imagine the general concept of buoyancy. This was a moment of brilliant creativity.

Science also exhibits creativity in experimental techniques. New tools are continually invented, then adapted for all sorts of tasks beyond the original design brief. This "role re-allocation" is a highly creative activity. The moment Galileo decided to point his telescope at the night sky is an example of this. Using micro pores in rocks to filter and temporarily untwist DNA strands for genome sequencing is another. A tool from geology, when used creatively beyond its context, was able to revolutionise an experimental process in microbiology. Scientists are constantly innovating new ways of using what is in their hands, much like an artist.

Mathematics as poetry

Mathematics is an endeavour closely associated with science, as many scientific concepts are described mathematically. Typically, but incorrectly, maths is thought of as being roughly the opposite of creativity. Here's another way of thinking about it: if science is like a form of creative writing, then mathematics is like poetry. It is a special form of communicating ideas and feelings that transcend ordinary discourse. It has structural and symmetrical and rhythmic beauty accompanying the beauty of what it is talking about. It is particularly creative, because it is less constrained by experimental results and observation. Unfortunately, like some forms of poetry, mathematics can be extremely difficult to access. This makes it difficult to pick helpful examples from the vast plethora of mathematically creative ideas. Returning to Archimedes yields one such helpful illustration.

Almost all of us met numbers as children in the context of counting. There were two apples or five oranges or 10 fingers or 100 cents and so on. We need to count things and numbers are useful for that. But the *idea* of a number is something far more interesting, abstract, powerful and potentially creative than just being useful.

It was Archimedes who wrote to the king saying, "There are some, King Gelon, who think that the number of the sand is infinite in multitude; . . . Again there are some who, without regarding it as infinite, yet think that no number has been named which is great enough to exceed its multitude." Perhaps he was even thinking of the figures of speech we find in the Old Testament. When Abraham was promised descendants that outnumber the grains of sand on a beach (see Genesis 22:17), he almost certainly understood this to mean "too many to count." Archimedes goes on to name some numbers that he proves are larger than the number of sand grains that would fill the earth, and even the universe as he understood it to be. In order to construct such a number, he starts with a meaningful "known" number and then builds it up on itself. This is like describing one million as "one thousand thousands."[1]

The point here is that Archimedes constructed a number that was too big to be useful. Even if the universe was filled with grains of sand, this number would not be reached when counting all those grains. We can do the same thing even more exotically today and give a number larger than the count of atoms in the known universe. In fact, today some mathematicians even describe some infinities that are bigger than other infinities. Such numbers are absurd, in that they are literally impossible to visualise or comprehend in a "counting" way. Despite this, mathematicians can talk about such numbers quite sensibly. They still "work" but must be created—or imagined—in the mind.

Within the history of mathematics, there are perhaps as many examples of this kind of conceptual creativity as there are grains of sand on the earth. We can take a physically meaningful concept of a vector—something with size and direction, like wind speed on the weather report—and abstract it into *n* dimensions. The maths still works even if *n* goes to infinity! We can arbitrarily redefine what "size" and "distance" mean mathematically, and construct entirely new numbers. We can build algebraic systems that don't need numbers at all, but allow us to do real mathematics with squares and boxes or dogs and cats. Mathematics, in a sense, is a creative game of imagining and describing impossible things.

So why is it closely related to science? The short answer is "because it works." If you want to describe alternating-current electricity, the best way is to use "imaginary" numbers that include the square root of minus one. If you want to explain the shapes of intricate protein molecules, the best insights come from abstract symmetrical patterns in six and seven dimensions. Over and over again, the results of wild and unconstrained mathematical creativity have proved to be the perfect tool for examining nature in "real life."

Another way to the Creator

But why should the abstract mathematical creations of our human imagination turn out to describe nature and the universe so effectively? This question is poignant because mathematicians constantly strive for higher levels of abstraction. This might suggest that history show a gradual decline in the "usefulness" of mathematics—but precisely the opposite is observed. This is a question of such profundity that it has motivated philosophers across the ages. Einstein called it the "unreasonable effectiveness of mathematics." Perhaps it is a clue that our minds are an image in some way of The Mind behind the structures and patterns of nature.

The most prominent people in science have typically been those who have created a human concept that helpfully describes the behaviour of nature. These concepts are often referred to as "Natural Laws" because the universe is so remarkably consistent that it appears to be obeying laws. This reliability and repeatability has piqued the curiosity of many scientists, because there is no inherent reason why our universe should display such consistency.

Coming face-to-face with this kind of natural reality can easily provoke a form of spiritual experience. Einstein wrote, "Everyone who is seriously engaged in the pursuit of science becomes convinced that the laws of nature manifest the existence of a spirit vastly superior to that of men."[2] Even without an Einstein-like understanding of "Natural Laws," the simplest encounter with the complexities and profound ordering of nature can turn our hearts and eyes to God.

Kepler famously described science as "thinking God's thoughts after him". Artists have often used this same quote to describe their own acts of creativity. As King Solomon said, "Nothing under the sun is truly new." (Ecclesiastes 1:9)—but both the artist and the scientist are in the business of recording and describing the world around them in new ways. Science not only gives us the opportunity to explore the deepest and most mysterious things of this world—like the artist, the poet and the musician—but also to exercise our creativity in a way that draws us closer to the Creator and fulfils His plan for us.

—Lachlan Rogers is a research physicist currently working at Universität Ulm in Germany. At school, he once claimed to be a "scientist not an artist," but while studying science at Avondale College he realised the foolishness of that distinction. His PhD led into research that involves playing with individual atoms in glowing diamonds. His spare time is spent cycling, taking photos and creating LEGO® towers with his son.

1. You can read Archimedes' manuscript in Stephen Hawking's book *God Created the Integers*.
2. There is a somewhat intricate context behind this quote: <quoteinvestigator.com/2011/12/16/spirit-manifest>.