ART JOHNSON

Now & Then

Fiber Meets Fibonacci

Now . . .

AN OLD SAYING GOES SOMETHING LIKE THIS, "ARTISTS ARE born, not made." For Billie Ruth Sudduth, this statement is not quite true. Billie Ruth, who lives in the North Carolina mountains, makes baskets that are prized by collectors from all across North America and have been displayed in the Renwick Gallery of the Smithsonian Institution in Washington, D.C. She is internationally known for her basket artistry and was the first woman to be designated a Living Treasure by the state of North Carolina. But she was not always a basket maker.

Billie Ruth experienced a typical childhood while growing up in Birmingham, Alabama, and was interested in many hometown activities, but creative arts was not one of them. "My mother and my grandmother used to make hooked rugs, quilts, and do needlepoint. But I really wasn't interested in what they did." Instead of learning sewing crafts from her mother and grandmother, she spent time playing sports with her friends.

In school, Billie Ruth's liberal arts studies included only the basic mathematics needed to get into college: algebra 1, geometry, and algebra 2. "I really didn't care for math. It didn't seem important to me at the time. I didn't do well in my math classes, even though I always got top scores in any national tests in math." Her lack of enthusiasm for mathematics was to change sometime later, however.

Billie Ruth attended Huntington College in Alabama as an undergraduate, focusing on psychology and social issues. She continued her concentration in psychology and social work while pursuing a graduate degree at the University of Alabama, subsequently working as a school psychologist for nearly twenty years. So how did she work baskets into her schedule?

About fifteen years ago, after a particularly tiring school year, summer found Billie Ruth exhausted, both mentally and emotionally. A colleague suggested that she take a basket-weaving course. "I was already a collector of baskets, so I figured that maybe I could make one of my own. At the same time, I could get my mind off school for a bit and maybe learn something that could serve as a relaxation activity for other times when I became stressed."

That one basket-weaving class was a turning point in Billie Ruth's life. "I knew within the first fifteen minutes of the class that this was what I wanted to do for the rest of my life. I loved working with the basket materials and producing baskets. Something about the materials and the process resonated with me. Working with the natural materials captured my attention. I soon developed a real passion for crafting these baskets." In time, Billie Ruth began working a full day at school and then spending most of the evening making baskets. At first she adopted the time-honored techniques of basket making, but eventually she developed her

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own style. “I really wasn’t sure what the style was. I made baskets that just seemed to flow. The ones I liked best were also the ones people responded to.” Among Billie Ruth’s collectors were professionals, such as stock brokers, architects, and engineers, whose work involved mathematics.

Billie Ruth started to bring her basket-making talent into school by teaching her craft. A teacher in one school pointed out to Billie Ruth that her baskets and their designs incorporated the golden ratio, as shown by the ratios between height and width of her baskets and the spacing between patterns on the baskets. “Suddenly, everything I had been doing fell into place. The baskets that most clearly reflected the golden ratios were the ones I felt were my best, and those were the ones that seemed to sell fastest. What I had been doing intuitively I now could understand. I could now have a purpose behind my basket making.”

Billie Ruth had been weaving the golden ratio into her baskets on instinct. Her conscious use of this element has resulted in even more spectacular pieces. “Now that I know how to use the golden ratio in my baskets, I have made even more applications of it. I have developed more complex patterns using the golden ratio. It is really exciting for me to see how these designs look on a finished basket,” she explains.

Billie Ruth now designs baskets so that the ratio of the width to the height approximates the golden ratio. She also uses what she calls “nature’s sequence” for the weaving pattern. A typical basket weave alternates between over and under weaves. A nature’s-sequence weave is one over, one under, two over, and three under. These numbers are the first four terms of the Fibonacci sequence, in which each new term (after the first two terms) is the sum of the preceding two terms. The ratio of each term to its predecessor gets closer and closer to the golden ratio as you extend further into the sequence.

Billie Ruth also uses the golden ratio in line designs of her baskets. The zig-zag design is not random. “I call one pattern the ‘Fibonacci Five’ because it follows the Fibonacci sequence in the way the lines zig and zag on the basket.” (See the cover.) For example, beginning at the bottom, a line in ‘Fibonacci Five’ will zig at five rows from the bottom. The next zig comes eight rows later then continues to zig and zag at intervals of thirteen, twenty one, and thirty-four rows.” What had been an instinctive design for her baskets has now become a highly mathematical design that meets specific mathematical relationships in the size of the basket, its weave, and its line designs.

Billie Ruth thinks that somewhere back in high school she had heard of the golden ratio and Fibonacci, but she is not sure. “If had known about the golden ratio and the Fibonacci sequence when I started making baskets, it would have helped me a lot. I could have found the techniques I use now a lot earlier, and wouldn’t have had to struggle to find the basket designs I like to make.” Billie Ruth took very few mathematics courses after high school. “I wish I had taken more mathematics in high school and college. At the time, I thought, ‘What do I need this for?’ I couldn’t see why it would do me any good. It was only when I needed a graduate math course that I took one. By then I could see the relevance of it to what I wanted to do, and I did fine.

“I am sure students today feel like I did about math and think they will never use it. Well, look at me. I make baskets for a living, and I use math all the time. I wish I had taken more math. Now I am experimenting with making spiral designs on my baskets and I need to know more about logarithms and fractals. So I have to teach myself these things now because I didn't take the right courses in high school and college."

Billie Ruth's baskets are made with two main colors. She uses black or red on her walnut-colored materials. "I think black stands out the best to show a pattern, and I use red because no one else knows how to make the permanent red dye that I do." All of Billie Ruth's dyes are natural, something she adopted when she first started making baskets. "The American Indians, like the Cherokee and Choctaw, used only natural dyes. They had a respect for the earth, and I think that by using natural materials and the golden ratio, I show the same respect for the earth that they have shown for so many centuries."

One of Billie Ruth's baskets is in the American Embassy in Niger because her work blends well with the African baskets created by native basket makers. "I think it has to do with the Fibonacci ratios," says Billie Ruth. "The golden ratio is found in so many places in nature that it only makes sense that different cultures would incorporate it into their designs and that different peoples would respond to artwork that reflects the golden ratio."

Billie Ruth is not just a basket maker. She spreads the word about art and mathematics by visiting schools and working with students and teachers. "When I left my school position and started to make baskets full time, I missed the kids. Being an artist is an individual, almost private pursuit, and I needed to connect with kids. By visiting schools, I can do that and still be a basket maker."

Anyone interested in knowing more about baskets and basket making can visit Billie Ruth Sudduth's Web site at **www.brsbasket.com.** For more information, send a self-addressed envelope with two stamps to her at 109 Wing Road, Bakersville, NC 28705.

Note to Teachers

THE FIRST THREE QUESTIONS ON THE WORKsheet involve the *golden ratio,* which determines one of the most famous shapes in mathematics. The golden rectangle has been used by artists and architects since the time of ancient Egypt. Rectangle *ABCD* is a golden rectangle. See **figure 1**'s rectangle; explain that in rectangle *ABCD,* the ratio of the longer side *DC* to the shorter side *BC* is *DC:BC,* or about 1.6:1. Any rectangle whose sides are *approximately* in the ratio of 1.6/1, or simply 1.6, is called a *golden rectangle.* (See the "Then" portion for a precise mathematical definition of the golden ratio.)

Question 2 asks students to investigate which physical proportions reflect the golden ratio. Students should realize that the golden ratio is a classical model and that most people only approximate it in some of the physical proportions listed. Teachers may want to make this question optional. Question 3 reproduces the rabbit problem that Fibonacci explored. Have students become mathematics investigators and discover the Fibonacci sequence.

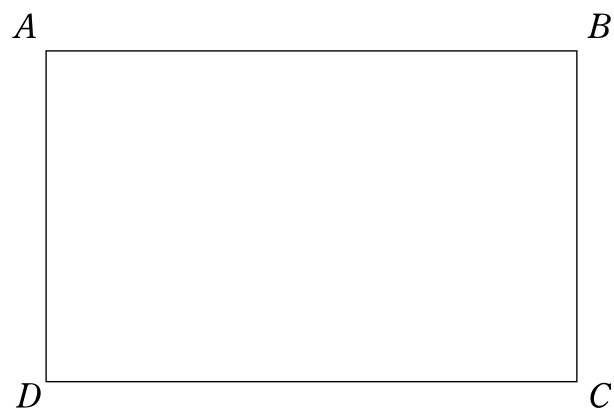


Fig. 1 The golden rectangle

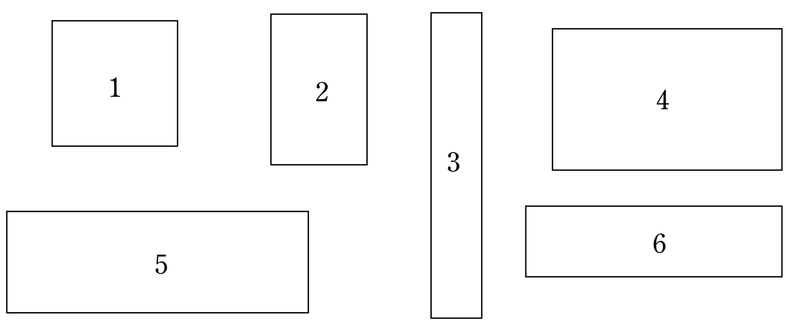
. . . & Then *(Continued on page 261)*

Golden Explorations

NAME ______________________________

1. One reason that artists have used the golden rectangle, such as the one above, extensively in their work is that its shape is one of the most pleasing to the human eye. Which of the rectangles below are golden rectangles? Try to select the golden rectangles by observation only. Use a ruler to check your results. (*Hint:* You can use the golden rectangle above as a model.)

1. ____________________ 4. ____________________
2. ____________________ 5. ____________________
3. ____________________ 6. ____________________



2. The ratio between the sides of a golden rectangle (1.6:1) is called the *golden ratio*. This ratio is found in many natural settings, such as the curves of a canary's claws, pineapples, pinecones, and flower petals. Many physical proportions show the golden ratio. Work with a partner to fill in the following data chart to compare some of your physical proportions with the golden ratio.

Measurement 1 (m_1)	Measurement 2 (m_2)	Ratio $\frac{m_1}{m_2}$
1. Mid neck to navel:	Top of head to mid neck:	
2. Navel to floor:	Top of head to navel:	
3. Knee to navel:	Knee to floor:	
4. Bottom of nose to mid eyes:	Bottom of nose to midmouth:	
5. Bottom of nose to chin:	Mid eyes to bottom of nose:	
6. The length of the middle joint of any finger:	The length of the end joint of that same finger:	

From the January 1999 issue of Mathematics Teaching in the Middle School

NAME ____________________________

3. The golden ratio is closely related to a famous problem written by Fibonacci in the thirteenth century. His problem was the following:

> A man put a pair of rabbits in a certain place entirely surrounded by a wall. How many pairs of rabbits will be produced from that pair in a year if the nature of these rabbits is such that each month each pair bears a new pair, which from the second month onward become productive?

The number of rabbit pairs produced each month constitutes a pattern. You can use a number pattern to answer the question once you have enough data. Copy and extend the table below to help you figure out the number of rabbit pairs for the next few months. Rabbit pair A produces a new pair, B, at the end of 2 months. In month 3, pair A produces pair C. In month 4, pair A produces another rabbit pair, D; and pair B produces a new pair, E. The pattern continues for a whole year. Use a number pattern to answer Fibonacci's question. To find out how this problem is related to the golden ratio, find the ratio between rabbit pairs in month 12 and month 11 and then express the ratio as a decimal.

Month		Rabbit Pairs
Month 0	A	1
Month 1	A	1
Month 2	A B	2
Month 3	A C B	3
Month 4	A D C B E	5
	⋮	⋮

4. Because the golden rectangle is so pleasing to the human eye, it is used as the shape for many different manufactured goods. Use your estimation ability to spot golden rectangles in your home. Then use a ruler and measure the items to be sure you found a golden rectangle. Remember, the ratio of sides in a golden rectangle is *approximately* 1.6:1, so in this case, close counts! Fill in this list with five items that you found.

	Item	Length	Width	Ratio
1.				
2.				
3.				
4.				

5. Draw a basket, vase, or other object using the principle of the golden ratio in its design and dimension. Look up golden ratio (or golden section) in a dictionary. Explain why your design agrees with this definition.

From the January 1999 issue of **Mathematics Teaching in the Middle School**

The Shape of Things to Come

(Continued from page 258)

. . . & Then

THE HISTORY OF THE GOLDEN RATIO STRETCHES back thousands of years to ancient Egypt. The pyramids, statues of Egyptian gods and pharaohs, and even Egyptian hieroglyphics show the golden ratio in their proportions. A royal decree to artisans and architects alike was that they include *suq,* the golden ratio, in some facet of their work.

The golden ratio next appeared in the Brotherhood of Pythagoreans. This mystical, religious group was headed by Pythagoras (c. 570 B.C.–500 B.C.), who is best remembered for the Pythagorean theorem, relating the lengths of three sides of a right triangle ($a^2 + b^2 = c^2$). As a group, the Brotherhood of Pythagoreans viewed numbers as being sacred in their cosmology and adopted the five-pointed star, or pentagram, as its emblem (see **fig. 2**). The pentagram is replete with the golden ratio in many comparisons of its segment lengths. Every pentagram has a regular pentagon at its center. Drawing in the diagonals of this pentagon results in another pentagram with a new set of segments whose lengths can be compared to obtain the golden ratio. Inside this pentagram is another pentagon inside of which can be constructed still another pentagram. This process can be continued indefinitely, resulting in an infinite number of examples of the golden ratio.

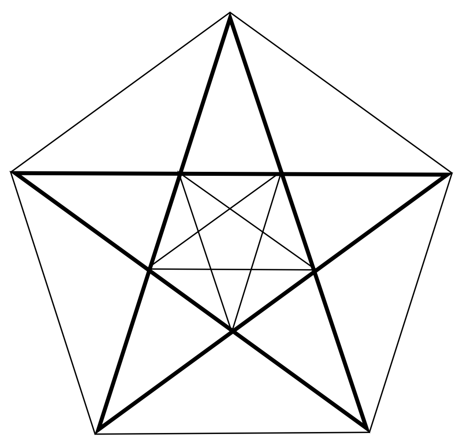
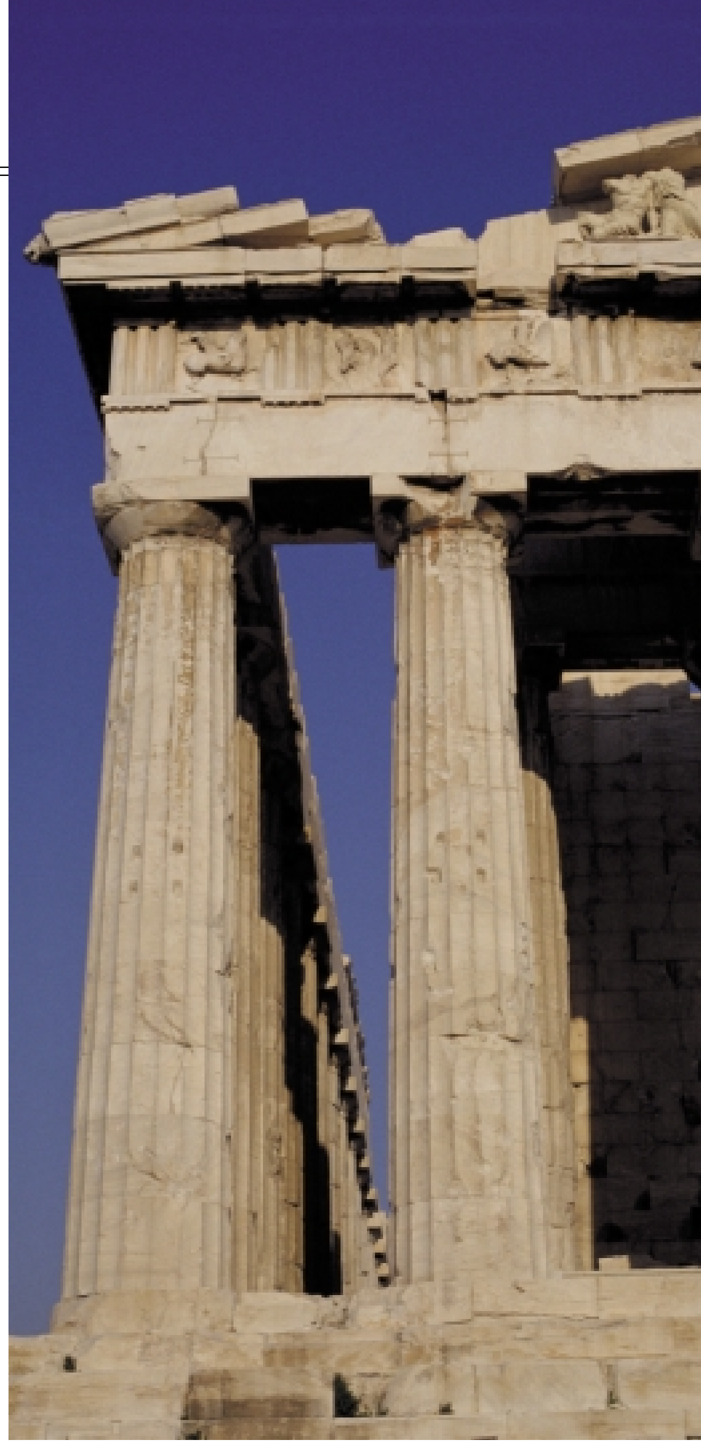


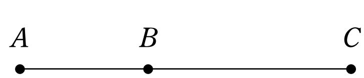
Fig. 2 A five-pointed star, or pentagram, was the emblem of the Brotherhood of Pythagoreans.

Several decades after Pythagoras died, the Brotherhood of Pythagoreans faded into obscurity, but the golden ratio did not. It continued to be an important element in life, especially in classical Greek architecture and notably in the Parthenon in Athens. Inside the Parthenon was a forty-foot-tall statue of the goddess Athena that also showed the golden ratio in its proportions. Both the temple and the statue were designed by Phidias (c. 485 B.C.–430 B.C.), the first artist known to use the golden ratio extensively in his work. It is fitting that the symbol for the golden ratio is the Greek letter phi, ϕ, the first letter in Phidias's name.



The pentagram is replete with the golden ratio

Over a century later, Euclid (c. 300 B.C.) discussed what is currently known as the golden ratio in his classic work *The Elements.* Segment AC shown here



is divided by point B in such a way that the following relationship is true:

$$\frac{AB}{BC} = \frac{BC}{AC}.$$

Euclid did not use algebraic representations of the golden ratio, but succeeding mathematicians did. In the preceding diagram, if $AB = 1$ and $BC = x$, then the proportion becomes

$$\frac{1}{x} = \frac{x}{x+1}.$$

When this proportion is solved for x,

$$x = \frac{1+\sqrt{5}}{2}.$$

Thus,

$$BC = \frac{1+\sqrt{5}}{2},$$

or about 1.6.

Following Phidias, many artists and artisans used the golden ratio in some form or another in their work, whether in proportions of the human face and body or in architecture. In 1509, Leonardo da Vinci (1452–1519) illustrated for Italian mathematician Luca Pacioli (1445–1514) a mathematics text titled *De divina proportionale* (The Divine Proportion). In his book, Pacioli showed the golden ratio in many different settings, from the human form to buildings and paintings; however, da Vinci first used the term "golden section," or golden ratio.

Leonardo da Vinci first used the term "golden section"

One name that is inextricably linked to the golden ratio is Leonard of Pisa (1180–1250), better known as Fibonacci. He was one of the most accomplished mathematicians in Europe since the time of the ancient Greeks. He learned the mathematics of the time while accompanying his merchant father on visits to the Islamic seaports of the Mediterranean and North Africa. During these business travels, Fibonacci probably encountered what was then a new way of writing numbers—the Hindu-Arabic positional system of ten digits that we use today. Fibonacci was one of the first European mathematicians to use the new system, and in his work *Liber Abaci* (1202), he strongly advocated its use. *Liber Abaci* was a seminal work for several reasons. First, it was one of the first western-European books to use and advocate Hindu-Arabic numbering. Second, it was the outstanding mathematics book of the century. Third, it contained the rabbit problem, already discussed in the student activity. As terms are added to the sequence of numbers representing each of the rabbit pairs in each month, the ratio of each new term to its preceding term approaches the golden ratio.

It was left to a Scottish mathematician some centuries later to make the connection between the golden ratio and Fibonacci's rabbit problem. Robert Simson (1687–1768), a geometer known for his translation of Euclid's *Elements,* noticed that consecutive terms of the solution to the rabbit problem (1, 1, 2, 3, 5, 8, 13, 21, 34, 55, . . .) showed the golden ratio; for example,

$$\frac{55}{34} \approx 1.618.$$

Some years earlier, Johannes Kepler (1571–1630), famous for his model of the solar system, had coined the term "divine section." He said, "Geometry has two great treasures: one is the theorem of Pythagoras; the other, the division of a line into extreme and mean ratio [golden ratio]. The first we may compare to a measure of gold; the second we may name a precious jewel." Kepler first noticed that leaf arrangements on some plants and petals on some flowers follow the pattern of what is now called the Fibonacci sequence.

Since Kepler's time, the golden ratio has been found in many natural settings, including snail shells, ram horns, pinecones, elephant tusks, and even the DNA spiral. Today, the Fibonacci Society, a group interested in the golden ratio, continues to discover and apply the Fibonacci sequence in a wide range of human and natural representations.

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