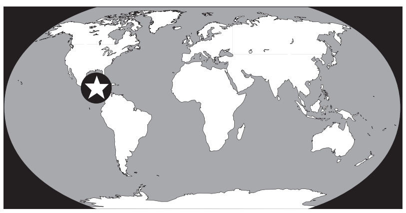
BREAKING THE MAYAN CODE Mayan Math

If you found a book full of lines, dots, and mysterious-looking pictures, how would you begin to figure out what it meant? That was the problem facing archaeologists who discovered written records left by the Maya of Central America.



A Little About the Maya

The Maya prospered in an area ranging from southern Mexico and the Yucatán Peninsula through Belize, Guatemala, Honduras, and El Salvador. They first came to the area around 2600 B.C., and at the peak of their civilization were spread across an area of about 311,000 square kilometers (120,000 square miles). They lived in city-states, which were like tiny countries made up of a city and the land around it.

Skilled in the arts and sciences, the Maya flourished in the jungles of their homeland. They built roads to connect their cities. They were master architects, and their buildings are still considered amazing achievements. They were also astronomers who studied the cycles of the moon, earth, and other planets.

At the height of their culture, from the third century A.D. to the ninth century A.D., called the Classical Period, the Maya built large stone temples covered with stucco and colorfully decorated. Some of these impressive buildings remain today. If you climb the steep stairway to the top of the Temple

What's It All About?

In this activity, you will decipher a page from the Dresden Codex, one of the few Mayan books still in existence. By thinking like an archaeologist, you'll combine your mathematical abilities with some basic logic and trial-and-error investigation to figure out what the codex means. In the course of your explorations, you'll discover:

- How archaeologists have figured out what Mayan documents mean
- How the Mayan system of counting is like ours, and how it is different
- How Mayan beliefs were tied to their understanding of mathematics

Is there anything special I should know?

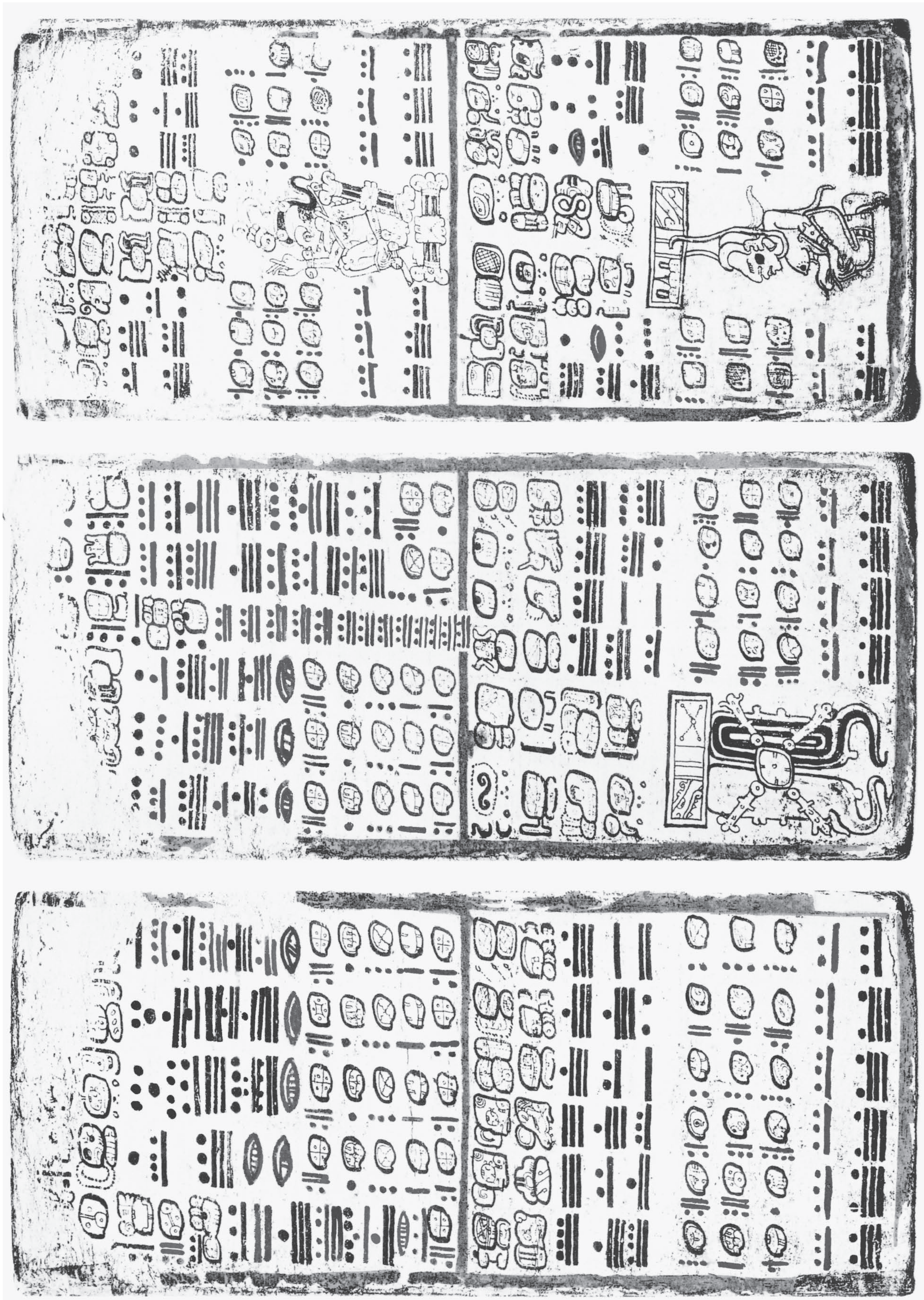
- This activity is recommended for ages 10 and up
- You can do this activity on your own, but it's much easier (and more fun) to work with others in a small group of 3 or 4
- In order to do this activity, you need to understand place value and number bases

How much time will I need?

- About 3 hours

What materials will I need?

- The portion of the Mayan codex shown on page 63
- Calculator (optional, but recommended)



of the Magician in Uxmal in the Yucatán, you'll get a bird's-eye view of the ancient city. From this point, you'll be struck by the way the Maya built in harmony with their surroundings.

In the third century, when Europe was in its infancy, the city of Palenque, on the Isthmus of Teuantepec, had a population of more than 100,000 people. This thoroughly modern city had its own drainage system and observatories, and buildings that towered 110 feet above the jungle floor.

In the 1500s, Spanish conquistadores invaded the Mayan cities. In their attempt to bring their version of civilization and religion to the Maya, the Spanish systematically destroyed Mayan books and documents that contained, according to the first bishop of Yucatán, "lies of the devil." As a result, little written information from the Maya survives.

The Mayan writings that still exist were carved on stone monuments or painted on pages of books that Western scholars call *codices* (singular, *codex*). Codices were made from pounded fig-tree bark treated with lime and covered with a thin layer of plaster. Their pages were painted in bright colors, folded accordion-style, and bound between pieces of wood. Of the few surviving Mayan codices, most are housed in European museums today.

From the rare documents we have, scholars have learned a lot about Mayan writing. The Maya had a number of different languages and a writing system of glyphs—symbolic pictures—that represented both words and syllables. Since Mayan glyphs can stand for both sounds and ideas, however, it's hard to know how to read each one. For example, a number could be written either with the number's symbol or with a picture of the god associated with that number—or both.

As scholars learned to read Mayan glyphs, they discovered that the Maya wrote about their lives and beliefs and kept extensive records of their possessions, important dates, and astronomical observations, many of which have proved to be valid today. When Europeans still believed that the world was only a few thousand years old, Mayan records alluded to life existing for millions of years.

The document you'll be looking at in this chapter is called the Dresden Codex because it found its way to the German city of Dresden. A portion of it is shown on page 63. The stains along one edge were caused by water damage during the firebombing of Dresden during World War II. Fortunately, the codex was saved.

Beginning with the Basics: Numerical Bases

Number bases have been invented by cultures throughout the world to meet their day-to-day needs. As you probably know, we count in base ten. Why do you think base ten is convenient?

The answer is simple: All humans—at some stage—count on their fingers. However, even though most people have the same number of fingers, not everyone counts in base ten. Every culture decides how to group things in order to count them. Some cultures count using only one hand, so their base is five. (In several African languages, the word for five means "hand full.") Other people count on both their hands and their feet, and use twenty as their base. Some Native Americans use base eight. Why eight? Count the number of spaces between your ten fingers.

Now imagine that you are visiting another planet where the intelligent beings are three-toed sloths. What bases do you think these beings would use for their sorting and counting?

The most likely bases for the sloths would be three (one foot), six (two feet), or twelve (all four feet).

If you understand the concept of using different bases, try practicing this important mathematical idea. The table below shows the number 459 broken down into three different bases. In each case, the 1s place is at the right, and the place values increase as you move to the left.

Base 20:

8,000s	400s	20s	1s
0	1	2	(Symbol for 19)

Base 10:

1,000s	100s	10s	1s
0	4	5	9

Base 5:

125s	25s	5s	1s
3	3	1	4

Why do you need a new symbol to represent the number 19 in base twenty? What other base-twenty numbers would you need to write with new symbols?

If you wrote "19" in base twenty, it would mean nine 1s and one 20 (which would be the number 29 in base ten).

In base twenty, every number less than 20 has to be written as a single digit in the 1s place. That's easy for the numbers 1 to 9. We already have symbols for those. But what about the numbers 10 to 19? They're two-digit numbers in base ten. So you'd have to create new symbols for all of them.

If you want more practice with different bases, choose two or three other numbers and write them in base twenty, base ten, and base five.

Which Way Is Up?

Take a look at the Mayan text on page 63. This text shows three pages of the Dresden Codex, one of the few existing examples of Mayan writing. Can you find some clues to help you figure out which way to read this writing?

Did you notice the position of the figure of the Mayan woman? This helps you tell which way is right side up. When archaeologists study a manuscript, they begin by using clues like that.

Now you can look for patterns in the Mayan writing. If you look at the pages from a distance, you'll see that the symbols on each page are in groups. If you still don't see a pattern, try squinting.

One thing to notice is that there are groups of symbols inside rectangles. In some rectangles, these symbols—called glyphs—are made up of elaborate designs with roundish borders. Other groups of symbols are made up of simple bars and dots. There are both numbers and words in this text. Which do you think is which? (Think about our own writing system: Do we have more symbols that make up words or more symbols that make up numbers?)

If you figured that the glyphs are the words and the groups of bars and dots are the numbers, you were right.

Reading the Numbers

Now take some time to focus on the numbers. How can you figure out what the bars and dots mean? Suppose that one of these symbols counts the 1s. Which do you think it is—the bars or the dots?

The dots are simple and are similar to the small, round pebbles that people all over the world have used to keep count of things. Let's start by counting them as single marks—1s.

Now look for the largest number of dots that appear together in one row.

Notice that there are never more than four dots side by side. If the dots are 1s, and there are never more than four dots together, how would you represent five items?

What about the bars? There are never more than three bars in a group. Could each one be a 5? A 10? Here's a way to explore that question: Assume the bars are 10s. Now try writing the numbers from 1 to 20. (The dots are 1s, and you can use only four dots together.)

You probably discovered that if a dot is 1 and a bar is 10, there's no way to write the numbers from 5 to 9 or 15 to 19. But if the bars are 5, you can write all the numbers from 1 to 20.

What Base Are We In?

Now that you can read individual numbers on the codex pages, look for the largest single grouping of bars and dots you can find. (A group is a single row of dots and the bars under it. Some of the numbers may be only dots or only bars.)

In some places, the number symbols run together, making them hard to read. If you look at the clearest number groups, you'll find that the largest one contains three bars and four dots. If the bars are 5s and the dots are 1s, what is the value of this largest number represented by this group of bars and dots? Does this give you a hint about the base being used here?

The number 19—three bars plus four dots—is the largest single number in the Mayan counting system. So how could the Maya write bigger numbers?

Think about how our number system works. We use ten different symbols, 0 through 9, and combine them to write larger numbers. We can tell what each symbol means from where it appears. For example, "4" means four 1s, but "400" means four 100s, zero 10s, and zero 1s.

The same idea applies to the Mayan counting system. Each group of bars and dots is an individual *digit* that is part of a larger number. The position of the digit tells us what its value is.

If 19 is the largest number the Maya could write in any one position, it makes sense that their system might be base twenty. To represent 20, the Maya would write one dot in the second position, just as we would write a 1 in the second position to represent 10 in our base-ten system. The next position in the Mayan system would be the 400 (20 x 20) place-value position.

Which Way Do We Go?

Now you can begin to figure out what a whole section of numbers in the Mayan codex might mean. Look at how the numbers appear on the pages of the codex.

You probably notice that most of the groups of dots and bars appear in clear rows and columns.

Archaeologists always choose the clearest areas of information to

A modern-day Mayan woman and her child in a marketplace in Guatemala.

begin their work, so let's begin with the large group of digits (dots and bars) just below the center of the first page of the codex.

Right away, you face another problem. You can read the individual digits. You even know that they have place values. But how do you know which digits go together to make a number? There are six columns and three rows. Which way do you read? Left to right? Right to left? Top to bottom? Bottom to top? The best way to answer these questions is to choose your best hypotheses and test them. It often helps to hear other people's thoughts when you reach this point, so if you're working with friends, discuss your ideas with them.

If your group is large enough, different people can try different experiments. For instance, one group can look at the symbols as three six-digit numbers read from left to right. Another group can read the same digits from right to left. A third group can read the symbols as six three-digit numbers read from top to bottom. A fourth group can try reading the six three-digit numbers from bottom to top.

Remember, you are working in base twenty, so the first digit is in the 1s place, the second digit is in the 20s place, the third digit is in the 400s place, and so on. Record all the different results, then see if one set of numbers makes more sense than the others.

If you read the symbols horizontally (either right to left or left to right), you came up with some huge numbers. After all, the sixth digit in base 20 is the 3,200,000s place! So that's probably not the correct interpretation.

If you read the digits up and down, you came up with more workable numbers. Check to see if you got the following results.

Reading from top 1s to bottom 400s (and left to right):

5,934 4,555 3,535 2,156 1,136 4,117

Reading from bottom 1s to top 400s (and left to right):

5,934 6,151 6,328 6,545 6,722 6,910

Take some time to study these numbers. Can you discover any order or pattern in either of these sets of numbers?

You might have noticed that the numbers read from bottom to top change in a more regular pattern. They get larger from left to right, and they change at a fairly steady rate. Do you think a set of numbers in a pattern is more likely to carry useful information than a more random set of numbers?

What Does It All Mean?

Now you've figured out that the Maya counted in base twenty. You've also discovered that they wrote and read their numbers from the bottom up, and from left to right. But what were they writing about in this codex? How would you begin to answer that question?

Look at the list of numbers you just deciphered, reading from bottom to top. One way to explore a series of numbers is to find the difference between each pair of numbers:

6,151 – 5,934 = 217
6,328 – 6,151 = 177
6,545 – 6,328 = 217

and so on.

Check to be sure you got these differences:

217 177 217 177 188

What could they mean? The archaeologists who studied the Dresden Codex found an important clue when they added any two of the numbers together. See what happens when you do that.

All of your answers should be between 354 and 434. One of the sums is 365. Does that remind you of anything?

Each of the numbers you added is close to half of 365—the number of days in a year.

An astronomer would also recognize the number 177 as exactly six lunar months of $29\frac{1}{2}$ days each.

It turns out that this part of the Dresden Codex is a record of astronomical observations made by the ancient Maya. This text gives the timing of eclipses of the moon, which occur about every half year.

One More Problem

You may be wondering why all five numbers do not divide exactly into lunar months. To begin to solve the problem, look at the bottom of the same page on the codex. Another easily identifiable group of numbers is there. Use what you have learned to discover what those numbers are.

Check to see if you got these numbers:

177 177 177 177 177 148

Two of these numbers match the differences above, but three do not. This is because Mayan mathematicians used two different numbering systems. For their everyday accounting needs, they used the standard base twenty with its succession of powers: 1, 20, 400, 8,000, and so on, as we have done so far. When working with astronomical calculations, however, they used slightly different bases: 1 and 20 were the same, but instead of 400, they used 360 in the third place value, and 360 x 20—which is 7,200—in the fourth place.

Why? Probably to take advantage of the fact that 360 corresponded more closely to the number of days in the Mayan astronomical year, which was 360 days long, with an additional five days they considered "unlucky." (For more on the Mayan calendar system, see Chapter 7.)

If you want, go back to the groups of symbols near the middle of the left-hand page of the codex. Calculate the symbols again, but this time read the places as 1s, 20s, and 360s.

Check to see if you got these results:

5,374 5,551 5,728 5,905 6,082 6,230

Now find the differences between each successive pair of numbers as you did before.

Check to see that you got these results:

177 177 177 177 177 148

These numbers match the numbers at the bottom of the codex exactly! Five of the numbers are the same: 177. They represent six lunar months of 29 1/2 days each. The last number, 148, represents five lunar months (147 1/2 days).

This activity was developed by Maurice Bazin and Modesto Tamez.

Making Connections

- Do you know anyone who speaks a language different from the one you speak? If so, ask that person to write something down for you in that language. How different is it from your written language? Is the alphabet the same? Does it have special marks that change the way the words or letters are read? Do you read it from right to left? Left to right? What similarities and differences can you find?
- Some Mayan writing uses glyphs—pictures—that stand for words or parts of words. Can you invent a writing system that does the same thing? What picture would you use for the word "hand"? How about "apple"? Is it harder to create glyphs for words like "sour," "comfortable," or "color"? What could you do to solve this problem?

Recommended Resources

Aveni, Anthony F. *Skywatchers of Ancient Mexico*. Austin: University of Texas Press, 1983.

Coe, Michael D., and Justin Kerr. *The Art of the Maya Scribe*. New York: Harry N. Abrams, 1998.

Coe, Michael D. *Breaking the Maya Code*. New York: Thames & Hudson, 1993.

McLeish, John. *The Story of Numbers: How Mathematics Has Shaped Civilization*. New York: Fawcett Columbine, 1991.