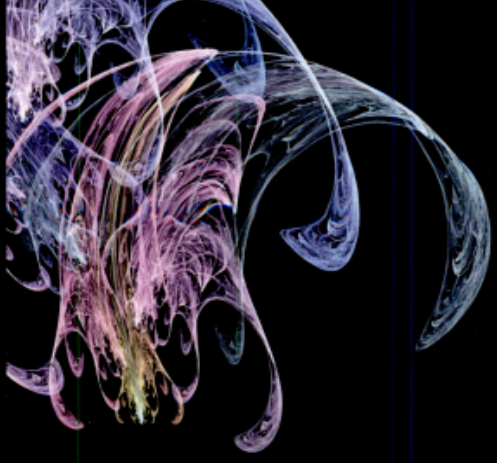

"Pickover contemplates realms beyond our known reality."
—The New York Times

The LOOM *of* GOD

Tapestries *of* Mathematics *and* Mysticism

Clifford A. Pickover

THE LOOM OF GOD

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Contents

Introduction

I have always thought it curious that, while most scientists claim to eschew religion, it actually dominates their thoughts more than it does the clergy.
—Astrophysicist Fred Hoyle

IS GOD A MATHEMATICIAN?

Mathematical inquiry lifts the human mind into closer proximity with the divine than is attainable through any other medium.
—Hermann Weyl (1885–1955)

Mathematics and mysticism have fascinated humanity since the dawn of civilization. Throughout history, numbers held certain powers that made it possible for mortals to seek help from spirits, perform witchcraft, and make prayers more potent. Numbers have been used to predict the end of the world, to raise the dead, to find love, and to prepare for war. Even today, serious mathematicians sometimes resort to mystical or religious reasoning when trying to convey the power of mathematics.

Has humanity's long-term fascination with mathematics arisen because the universe is constructed from a mathematical fabric? In 1623, Galileo Galilei echoed this belief by stating his credo: "Nature's great book is written in mathematical symbols." Plato's doctrine was that God is a geometer, and Sir James Jeans believed God experimented with arithmetic. Sir Isaac Newton supposed that the planets were originally thrown into orbit by God, but even after God decreed the law of gravitation, the planets required continual adjustments to their orbits.

16

THE LOOM OF GOD

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Astronomy by Charles-Nicolas Cochin The Younger (1715–1790)

Is God a mathematician? Certainly, the world, the universe, and nature can be reliably understood using mathematics. Nature *is* mathematics. For example, the arrangement of seeds in a sunflower can be understood using Fibonacci numbers (1, 1, 2, 3, 5, 8, 13 ...), named after the Italian merchant Leonardo Fibonacci of Pisa. Except for the first two numbers, every number in the sequence equals the sum of the two previous. Sunflower heads, like other flowers, contain two families of interlaced spirals—one winding clockwise, the other counterclockwise. The number of seeds and petals are almost always Fibonacci numbers.

The shape assumed by a delicate spider web suspended from fixed points, or the cross-section of sails bellying in the wind, is a catenary—a simple curve defined by a simple formula. Seashells, animal's horns, and the cochlea of the ear are logarithmic spirals which can be generated using a mathematical constant known as the golden ratio. Mountains and the branching patterns of blood vessels and plants are fractals, a class of shapes which exhibit similar structures at different magnifications. Einstein's $E = mc^2$ defines the fundamental relationship between energy and matter. And a few simple constants—the gravitational constant, Planck's constant, and the speed of light—control the destiny of the universe. I do not know if God is a mathematician, but mathematics is the loom upon which God weaves the fabric of the universe.

Fractal fern exhibiting self-similar branching, that is, similar structures repeated at different size scales. A single branch of the fern looks like a miniature copy of the entire fern.

THE LOOM OF GOD

Physicists are excited about discovering how reality behaves in terms of mathematical descriptions. This process is akin to discovering some hidden presence in the behavior of the universe—a gnosis. In this sense, physics is the inheritor of the tradition of Pythagoras.

—Anonymous IBM physicist

Marilyn vos Savant is listed in the *Guinness Book of World Records* as having the highest IQ in the world—an awe-inspiring 228. She is author of several delightful books and wife of Robert Jarvik, M.D., inventor of the Jarvik 7 artificial heart. Her column in *Parade* magazine is read by 70 million people every week. One of her readers once asked her, "Why does matter behave in a way that is describable by mathematics?" She replied:

> The classical Greeks were convinced that nature is mathematically designed, but judging from the burgeoning of mathematical applications, I'm beginning to think simply that mathematics can be invented to describe anything, and matter is no exception.

Marilyn vos Savant's response is certainly one with which many people would agree. However, the fact that reality can be described or approximated by *simple* mathematical expressions suggests to me that nature has mathematics at its core. Formulas like $E = mc^2$, $\vec{F} = m\vec{a}$, $1 + e^{i\pi} = 0$, and $\lambda = h/mv$ all boggle the mind with their compactness and profundity. $E = mc^2$ is Einstein's equation relating energy and mass. $\vec{F} = m\vec{a}$ is Newton's second law: force acting on a body is proportional to its mass and its acceleration. $1 + e^{i\pi} = 0$ is Euler's formula relating three fundamental mathematical terms: e, π, and i. The last equation, $\lambda = h/mv$, is de Broglie's wave equation indicating matter has both wave and particle characteristics. Here the Greek letter lambda (λ) is the wavelength of the wave-particle, and m is its mass. These examples are not meant to suggest that *all* phenomena, including subatomic phenomena, are described by simple-looking formulas; however, as scientists gain more fundamental understanding, they hope to simplify many of the more unwieldy formulas.

I side with both Martin Gardner and Rudolf Carnap who I interpret as saying: nature is almost always describable by simple formulas not because we have invented mathematics to do so but because of some hidden mathematical aspect of nature itself. For example, Martin Gardner in his classic 1985 essay "Order and Surprise" writes:

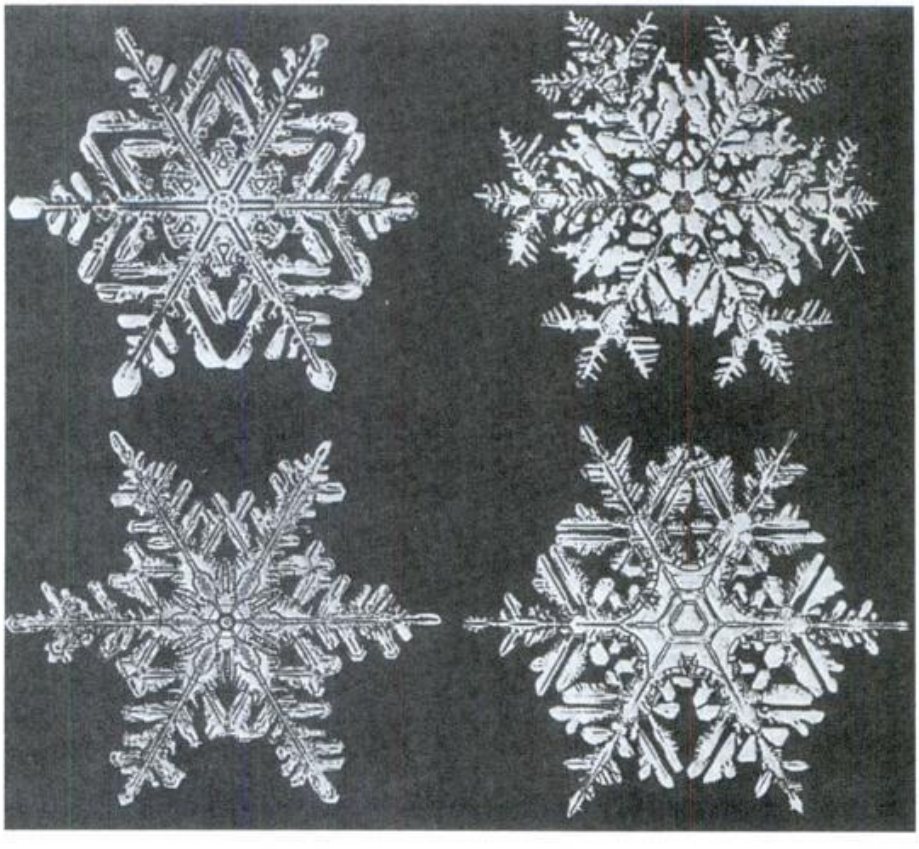
> If the cosmos were suddenly frozen, and all movement ceased, a survey of its structure would not reveal a random distribution of parts. Simple geometrical patterns, for example, would be found in profusion—from the spirals of galaxies to the hexagonal shapes of snow crystals. Set the clockwork going, and its parts move rhythmically to laws that often can be expressed by equations of surprising simplicity. And there is no logical or *a priori* reason why these things should be so.

Here Gardner suggests that simple mathematics govern nature from molecular to galactic scales.

Rudolf Carnap, an important 20th century philosopher of science, profoundly asserts:

> It is indeed a surprising and fortunate fact that nature can be expressed by relatively low-order mathematical functions.

To best understand Carnap's idea, consider the first great question of physics: "How do things move?" Imagine a universe called JUMBLE where Kepler looks up into the heavens and finds that most planetary orbits cannot be approximated by ellipses but by bizarre geometrical shapes that defy mathematical description. Imagine Newton dropping



an apple whose path requires a 100-term equation to describe. Luckily for us, we do not live in JUMBLE. Newton's apple is a symbol of both nature and simple arithmetic from which reality naturally evolves.

ARE MATHEMATICS AND RELIGION SEPARATE?

> *Had Newton not been steeped in alchemical and other magical learning, he would never have proposed forces of attraction and repulsion between bodies as the major feature of his physical system.*
>
> —John Henry, *Let Newton Be!*

In our modern era, God and mathematics are usually placed in totally separate arenas of human thought. But as this book will show, this has not always been the case, and even today many mathematicians find the exploration of mathematics akin to a spiritual journey. The line between religion and mathematics becomes indistinct. In the past, the intertwining of religion and mathematics has produced useful results and spurred new areas of scientific

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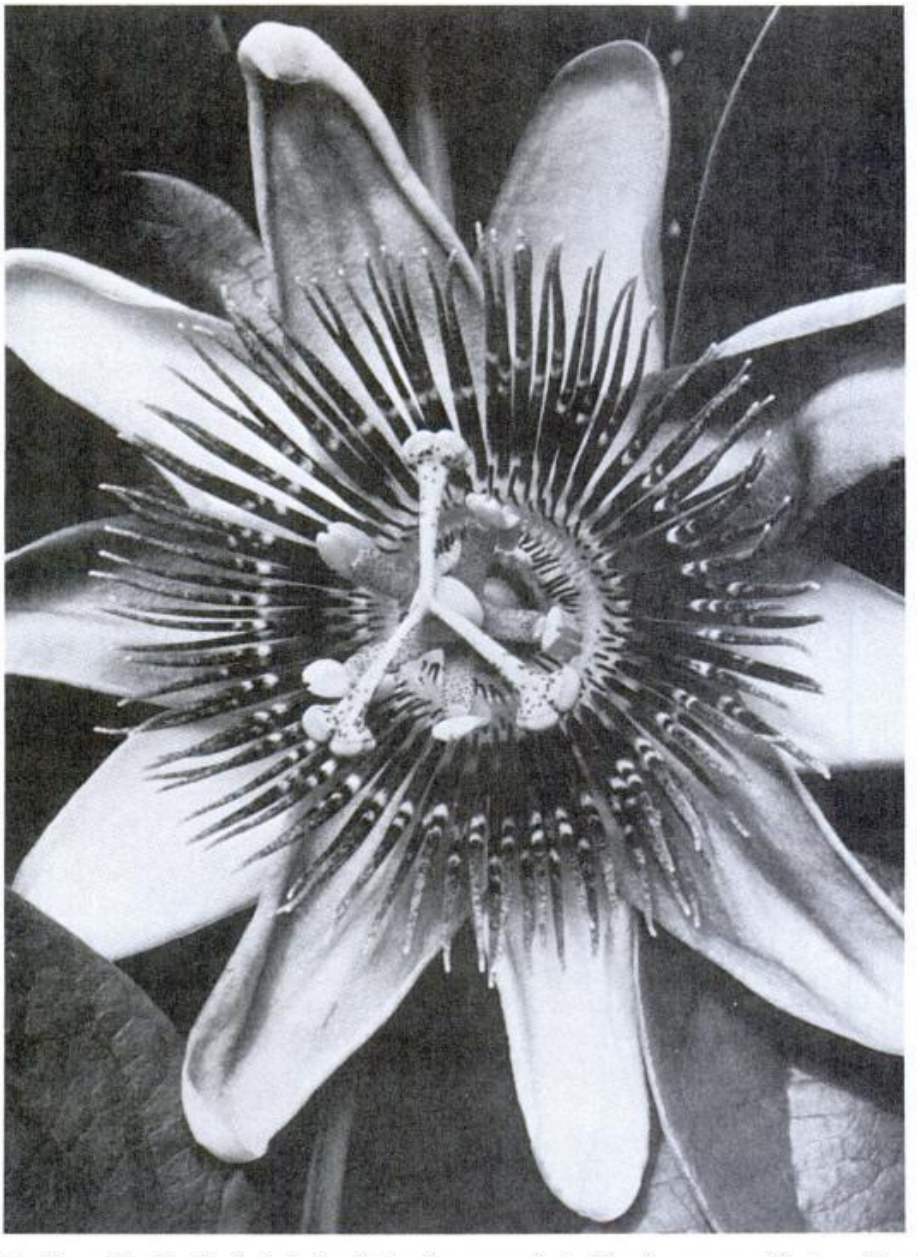
thought. Consider as just one small example numerical calendar systems first developed to keep track of religious rituals. Mathematics in turn has fed back and affected religion because mathematical reasoning and "proofs" have contributed to the development of theology.

In many ways, the mathematical quest to understand infinity parallels mystical attempts to understand God. Both religion and mathematics attempt to express relationships between humans, the universe, and infinity. Both have arcane symbols and rituals, and impenetrable language. Both exercise the deep recesses of our minds and stimulate our



Passion flower. The first Spaniards in South America connected this flower's structure with signs of Jesus' Crucifixion: The three upper parts of the pistil were the three nails. The five stamens were the five wounds surrounded by a crown of thorns. The ten "petals" represented the ten apostles of the Crucifixion.

imagination. Mathematicians, like priests, seek "ideal," immutable, nonmaterial truths and then often try to apply these truths in the real world. Some atheists claim another similarity: mathematics and religion are the most powerful evidence of the inventive genius of the human race.

Of course, there are also many *differences* between mathematics and religion. For example, many of religion's main propositions are impossible to prove, and religion often relies on faith unaffected by reason. In addition, while various religions *differ* in their beliefs, there is remarkable *agreement* among mathematicians. Philip Davis and Reuben Hersh in *The Mathematical Experience* suggest "all religions are equal because all are incapable of verification or justification." Similarly, certain valid branches of mathematics seem to yield contradictory or different results, and it seems that there is not always a "right" answer....

HOW MUCH MATHEMATICS CAN WE KNOW?

> *Einstein's fundamental insights of space/matter relations came out of philosophical musings about the nature of the universe, not from rational analysis of observational data—the logical analysis, prediction, and testing coming only after the formation of the creative hypotheses.*
>
> —R. H. Davis, *The Skeptical Inquirer*, 1995

We can hardly imagine a chimpanzee understanding the significance of prime numbers, yet the chimpanzee's genetic makeup differs from ours by only a few percentage points. These minuscule genetic differences in turn produce differences in our brains. Additional alterations of our brains would admit a variety of profound concepts to which we are now totally closed. What mathematics is lurking out there which we can never understand? How do our brains affect our ability to contemplate God? What new aspects of reality could we absorb with extra cerebrum tissue? And what exotic formulas could swim within the additional folds? Philosophers of the past have admitted that the human mind is unable to find answers to some of the most important questions, but these same philosophers rarely thought that our lack of knowledge was due to an organic deficiency shielding our psyches from higher knowledge.

If the yucca moth, with only a few ganglia for its brain, can recognize the geometry of the yucca flower from birth, how much of our mathematical capacity is hardwired into our convolutions of cortex? Obviously specific higher mathematics is not inborn, because acquired knowledge is not inherited, but our mathematical capacity *is* a function of our brain. There is an organic limit to our mathematical depth.

How much mathematics can we know? The body of mathematics has generally increased from ancient times, although this has not always been true. Mathematicians in Europe during the 1500s knew less than Grecian mathematicians at the time of Archimedes. However, since the 1500s humans have made tremendous excursions along the vast tapestry of mathematics. Today there are probably around 300,000 mathematical theorems proved each year.[1]

In the early 1900s, a great mathematician was expected to comprehend the whole of known mathematics. Mathematics was a shallow pool. Today the mathematical waters have grown so deep that a great mathematician can know only about 5% of the entire corpus. What will the future of mathematics be like as specialized mathematicians know more and more about less and less until they know everything about nothing?

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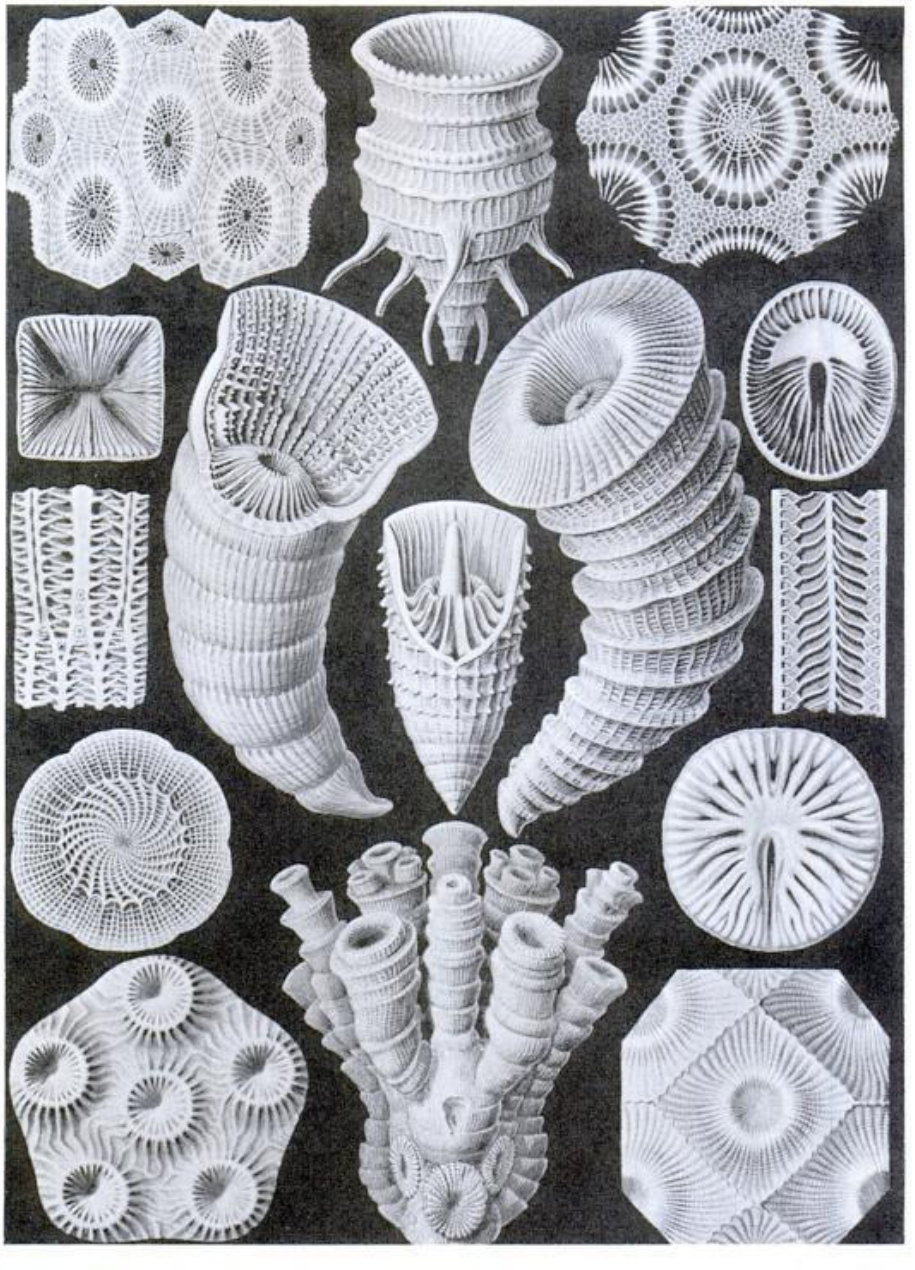


Various species of star corals exhibiting simple geometrical patterns.

More significant mathematical work has been done in the latter-half of this century than in all previous centuries combined.

—John Casti, *Five Golden Rules*

During their early days, both science and math have been connected with fictitious beliefs. Astronomy was connected with astrology, chemistry with alchemy, and mathematics with numerology. *The Loom of God* does not neglect this wild side of mathematics and its effect on human belief systems. The initial emphasis will be on Pythagoras, the ancient Greek mathematician whose ideas continue to thrive after three millennia of mathematical science. Philosopher Bertrand Russell once wrote that Pythagoras was one of the most intellectually important men who ever lived, both when he was wise and when he was unwise. Pythagoras was the most puzzling mathematician of history because he founded a numerical religion whose main tenets were transmigration of souls and the sinfulness of eating beans, along with a host of other odd rules and regulations. To the Pythagoreans, mathematics was an ecstatic revelation. They, like modern day fractalists, were akin to musicians. They created pattern and beauty as they discovered mathematical truths. Mathematical and theological blending began with Pythagoras, and eventually affected all religious philosophy in Greece, played a role in religion of the Middle Ages, and extended to Kant in modern times. Bertrand Russell felt that if it were not for Pythagoras, theologians would not have sought logical proofs of God and immortality.

Engraving by French illustrator Gustave Dore (1832–1883) suggesting the mathematical fabric of reality.

HARMONY OF MATHEMATICS AND RELIGION

An intelligent observer seeing mathematicians at work might conclude that they are devotees of exotic sects, pursuers of esoteric keys to the universe.

—P. Davis and R. Hersh, *The Mathematical Experience*

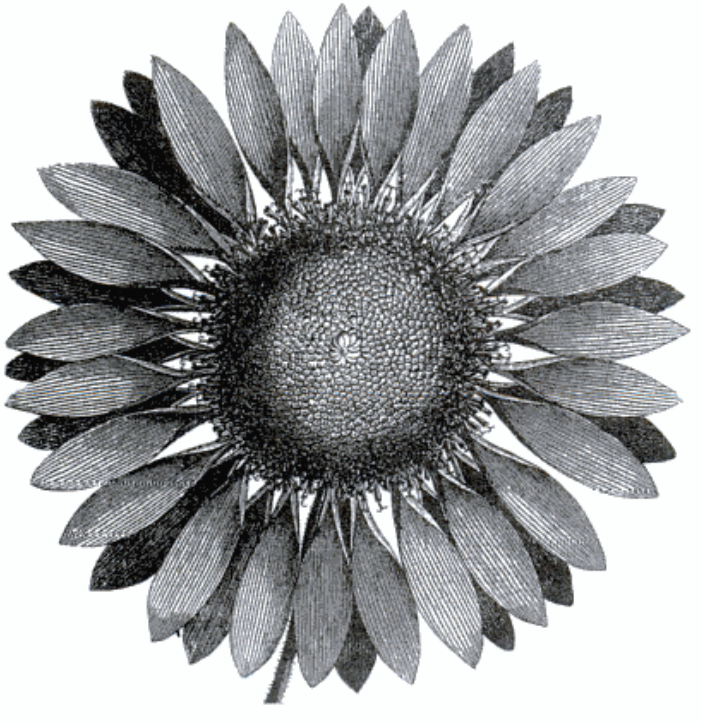
Pure mathematics is religion.

—Friedrich von Hardenberg, circa 1801

The emphasis of this book is on *theomatics*—a word I coined in 1995 to denote the blending of mathematics and religion. I also discuss many end-of-the-world scenarios—

from ancient theological prophesies to modern astrophysical predictions. Numbers have played a central role in both religious and scientific apocalypses. To start you on your journey, we will first trace the logic of mathematics far back in time and examine humanity's search for ultimate answers to the mystery of existence, God, and the universe. The initial focus is around 550 B.C. because numbers had an auspicious reign in ancient Greece, especially for the Pythagoreans, the secret society devoted to exploring the mysteries of numbers. You will soon realize that both ancient and modern mathematicians trespass on territory that is often considered the exclusive province of religion.

There is a harmony in the universe that can be expressed by whole numbers. Numerical patterns describe the arrangement of florets in a daisy, the reproduction of rabbits, the orbit of the planets, the harmonies of music, the relationships between elements in a periodic table. On the controversial side, mathematics and religion have often come together to predict the end of the world, and numbers have been worshipped like gods. In this book, I'll give some unusual examples of this juxtaposition of God and mathematics, and also describe some of the current astronomical theories for the end of the earth.



Philosophers and writers make statements about mathematics that have religious undertones. For example, author Alan Watts has described mathematicians in the following way:

> The pure mathematician is much more of an artist than a scientist. He does not simply measure the world. He invents complex and playful patterns without the least regard for their practical applicability.

Through history, many philosophers and skeptics have probably made similar statements about religion.

Similarly, Aristotle describes mathematics in his *Metaphysics*: "Those who claim that the mathematics is not concerned with goodness and beauty miss the truth." Notice that if you were to examine the writings of many philosophers, and replace "mathematics" with the word "religion," their statements would be equally powerful and comprehensible. Why is this so? (For example, try this with Aristotle's quotation by replacing "mathematics" with "religion.") Is it because both mathematics and religion start with a belief (or axiom) system?

One of my favorite quotations describing the mystical side of science comes from Richard Power's *The Gold Bug Variations*:

> Science is not about control. It is about cultivating a perpetual condition of wonder in the face of something that forever grows one step richer and subtler than our latest theory about it. It is about reverence, not mastery.

Again notice how the word "science" is easily replaced with "religion" or even "art."

The End of the World

> *We, while the stars from heaven shall fall,*
> *And mountains are on mountains hurled,*
> *Shall stand unmoved amidst them all,*
> *And smile to see a burning world.*
> —Millerite Hymn, 1843

Throughout our history, various prophets of doom have predicted the end of the world using arcane mathematical manipulations. The end takes many forms: a huge comet crashing into the Earth, California sliding into the sea, the Apocalypse predicted in the Book of Revelation. No matter what form Doomsday takes, one thing is clear: the end of the world did not only intrigue ancient religious prophets; interest is still strong in our modern society. Just turn on your T.V. any Sunday morning to find some preacher telling you the world is about to end. Popular books predicting imminent disaster always find large and enthusiastic audiences. Today, in the United States there are probably more "doomists" than there ever were in some medieval or Roman town. Some fundamentalist Christians not only believe that there will be a Judgment Day when the world will end, but they also believe that the world *should* end.

The doomists have never been right—but one day they will be. Certainly the world will come to an end some time in the future, but more on this subject later...

Travel through Time and Space

> *There is no question about there being design in the Universe. The question is whether this design is imposed from the Outside or whether it is inherent in the physical laws governing the Universe. The next question is, of course, who or what made these physical laws?*
> —Ralph Estling, *The Skeptical Inquirer*, 1993

This book will allow you to travel through time and space, and you needn't be an expert in theology or mathematics. To facilitate your journey, I start most chapters with a dialogue between two quirky explorers who are interested in God and mathematics. You are Chief Historian of an intergalactic museum floating in outer space, a teacher and historian. Your able student is a scolex, a member of a race of creatures with bodies made of diamond.[2] Their hard bodies shield them from injury. Your personal scolex, Mr. Plex, helps you perform calculations and protects you from the dangers of time travel.

Prepare yourself for a strange journey as *The Loom of God* unlocks the doors of your imagination with thought-provoking mysteries, puzzles, and problems on topics ranging

from Stonehenge to Armageddon. A resource for science fiction writers, a playground for computer hobbyists, an adventure and education for beginning students in theology, history, astronomy, and mathematics, each chapter is a world of paradox and mystery. Often various experiments in each chapter are accompanied by short listings of computer code in the Appendix. Computer hobbyists may use the code to explore a range of topics: from fractals, to asteroid cratering, to perfect numbers. However, the brief computer programs are just icing on the cake. Those of you *without* computers can still enjoy the journey and conduct a range of thought experiments. Readers of all ages can study theomatics using just a calculator.

As in all my previous books, you are encouraged to pick and choose from the smorgasbord of topics. Many of the chapters are brief and give you just a flavor of an application or method. Often, additional information can be found in the referenced publications. In order to encourage your involvement, I provide computational hints and recipes for producing the computer-drawn figures. For some of you, program code will clarify concepts.

Some information is repeated so that each chapter contains sufficient background information, but I suggest you read the chapters in order as you and Mr. Plex gradually build your knowledge. The basic philosophy of this book is that creative thinking is learned by experimenting.

An equation for me has no meaning unless it expresses a thought of God.
—Ramanujan (1887–1920)

Let me wrap up by mentioning some other topics you will encounter in this book as you journey from the ancient past to the far future. You'll meet enigmatic Greek warriors, Kabalists, St. Augustine, and Ramon Lull. You'll construct numerical gargoyles and visit prehistoric number caves. You'll hold an Incan fractal quipu in your hand, and discuss Doomsday. Strange numbers will surround you: pentagonal, perfect, oblong, and golden....

The oldest mathematical tablets found by archeologists date back to 2400 B.C., and I assume that humanity's urge to create and wonder about mathematics goes back to the earliest protohumans. Numbers were used by the ancient Amerindians, Sumerians, Babylonians, Chinese, Egyptians, and Indians. The Assyrians and Babylonians even assigned sacred deity-numbers to astronomical objects: our Moon was 30 and Venus was 15. Unfortunately, if we attempt to go back beyond the invention of writing, sometime around 6000 years ago in Sumeria, we find ourselves with little information. Mathematical and religious use of numbers before this time will forever remain a mystery.

In closing, let me remind readers that humans are a moment in astronomic time, a transient guest of the Earth. Our minds have not sufficiently evolved to comprehend all the mysteries of God and mathematics. Our brains, which evolved to make us run from lions on the African savannah, are not constructed to penetrate the infinite mathematical veil. And only a fool would try to compress several millennia's blending of mathematics and religion. We proceed.

Notes to the Paperback Edition

I am delighted that Sterling Publishing has invited me to prepare the new paperback edition of *The Loom of God*. Indeed, both public and scientific fascination in subjects relating to God, religion, mathematics, mysticism, and Doomsday seem to be growing, as indicated by the explosion of works ranging from the popular *Left Behind* series of apocalyptic novels and *The Da Vinci Code* to the recent movie version of *I Am Legend*.

Apocalyptic thinking about the End of Days for humanity is increasingly on our minds as we ponder the ramifications of catastrophic climate change, nuclear proliferation, and the likelihood of asteroid or comet impacts with Earth. Another form of the End of Days is the so-called technological singularity for which some futurists predict technological progress so astonishingly rapid that artificial intelligences will surpass us as the smartest and most capable life forms on Earth. Even the most serious cosmologists now ponder the ultimate fate of the universe. For example, if the acceleration of the universe continues as a result of a dark energy that seems to pervade our cosmos, this dark energy may eventually exterminate the universe in a "Big Rip" as all matter is torn apart.

With the year 2012 fast approaching, authors and publishers appear to be starting a countdown to another form of potential Doomsday apocalypse with a slew of books that predict calamity, spiritual transformation, or other momentous change in 2012—the year that a Mayan calendar cycle is completed. The Mayan Long Count calendar spans more than 5000 years, then resets to year zero in 2012. Depending on the author, we find any of the following are predicted to happen: an asteroid will collide with Earth, supervolcanoes erupt, the Earth's magnetic field reverses, or a mysterious global connection occurs with the emergence of a transhuman consciousness formed from the interactions of multiple human minds.

Our brains may be wired for belief in God or unseen entities. Religion is at the edge of the known and the unknown, poised on the fractal boundaries of psychology, history, philosophy, biology, and many other scientific disciplines. Because of this, the topics in *The Loom of God* are important subjects for contemplation. Even with the great scientific strides we will make in this century, we will nevertheless continue to swim in a sea of mystery. Humans need to make sense of the world and will surely continue to use both logic and religious thinking for that task. What patterns and connections will we see as the twenty-first century progresses? Who or what will be our God?

In closing, I would like to update readers on certain terms and concepts discussed in this book. Due to incredible advances in computing power, at least one numerical world record in this book has recently been broken. For example, as of 2008, the largest known perfect number (a concept discussed in Chapter 7) $2^{32,582,656} \times 2^{32,582,657} - 1$, with an amazing 19,616,714 digits.

As I mention in Chapter 14, the ancient Incas used *quipus* (pronounced "key-poos"), memory banks made of strings and knots, for storing numbers. Until recently, the oldest-known quipus dated from about 650 A.D. However, in 2005, a quipu from the Peruvian coastal city of Caral was dated to about 5000 years ago.

In Chapter 16, I mention that one of the world's fastest computers performs scientific calculations at a rate of around one teraflops—that is, one trillion floating point operations per second. In 2008, the fastest supercomputers achieve performances of over 1000 teraflops.

Chapter 21 discusses the infamous 1908 Tunguska explosion, which mysteriously leveled a very large area of Siberian forest. Supercomputer simulations performed in 2007 suggest that such devastation may have been caused by an impacting asteroid far smaller than previously thought, due to the asteroid's likely creation of a supersonic jet of expanding superheated gas. This finding suggests that any defensive strategy that we may develop to ward off asteroid impacts may need to consider the dangers of even smaller-sized menaces.

Although I did indeed "coin" the word *theomatics* with its particular meaning for use in this book, this word has been employed before my use. Prior use of this term often involved the numerological study of the Greek and Hebrew texts of the Christian Bible.

A great deal of this book focuses on Pythagoras, the ancient Greek mathematician and philosopher who is often credited with the invention of the Pythagorean theorem. However, evidence suggests that the theorem was developed by the Hindu mathematician Baudhayana centuries earlier, around 800 B.C., in his book *Baudhayana Sulba Sutra*. Pythagorean triangles were probably known even earlier to the Babylonians. Although the famous theorem that bears Pythagoras' name, $a^2 + b^2 = c^2$ for a right triangle with legs a and b and hypotenuse c, was probably known much earlier than the days of Pythagoras, some scholars have suggested that Pythagoras or his students were among the first Greeks to *prove* it.

For the latest reader comments, corrections, updates, and suggestions—including those with respect to the program code at the back of this book—please visit my new website: www.pickover.com/loom.html. As you peruse this book, I hope you will feel the sense of adventure I had when exploring all of the diverse subjects.

CHAPTER 1

Are Numbers Gods?

The hidden harmony is better than the obvious one.
—Heraclitus, 6th–5th century B.C.

The year is 2080 and you are Chief Historian of an intergalactic museum floating in outer space. Nicknamed *Theano*, your large ship carries objects of archeological interest from several star systems. Currently on your view-screen is a marble temple surrounded by massive fluted columns.

You turn to your assistant while pointing at the view-screen. "Mr. Plex, that beauty is the Temple of Apollo at Corinth, circa 540 B.C."

Your assistant is a scolex, a member of a race of creatures with diamond-reinforced exoskeletons that allow them to safely explore outer space.

"It's beautiful," Mr. Plex says. His slight hesitation is betrayed by the quivering of his forelimbs. Perhaps he feels you are about to send him on a dangerous expedition.

You tap on the view-screen. "That's our destination, Mr. Plex. Now you know why we've been studying the ancient Greek language. I want to understand humanity's use of numbers in the search for ultimate answers. I want to find relationships between God and mathematics. We'll see where it all started and how the world will end."

The scolex has a confused expression on his face. "Sir, how will the Temple of Apollo help?" There is a vague metallic twang to his voice.

"First we're going to visit an ancient Greek religious cult that believed numbers were sacred, godlike. Religion and math were one." You take a step closer to Mr. Plex. "Interested in coming?"

The scolex takes a deep breath. "Sounds safer than your last idea of sending me into space to study a black hole."

You raise your left eyebrow. "Certainly. What could go wrong?"

Mr. Plex points to the view-screen. "Why the Temple?"

"We're going to hide out in an unused backroom of the Temple. We'll set up our

computers and observing equipment there." You gaze at the Temple and then turn back to Mr. Plex. "Ready?"

The scolex nods his large head and grins, revealing row upon row of diamond teeth that glitter in the incandescent light. "Ready!" he says.

"Calm yourself, Mr. Plex."

You press a button beneath the ship's view-screen and are transported to ancient Greece.

Mr. Plex quietly motions toward a row of olive trees. The ancient trunks are illuminated by a flood of moonlight, and their branches are cruelly twisted by the oceanic winds.

The weather is cool, but no more so than any bracing summer night on the spaceship *Theano*. In the distance you hear the gentle splashing of the Mediterranean.

What if you miscalculated and you are not in Pythagoras' time? What if you are miles from the designated location? You clear your mind of turbulent thoughts and envision the nearby sea crashing endlessly on the beach, one wave after another, like the beating of ancient drums.

You take a deep breath expecting the air of ancient Greece to be pure, invigorating. But instead you have to move your hand to cover your nose. You are not used to the pungent odor of rancid goat's milk.

Distant olive branches move. This must be the place. This must be the time. You tap Mr. Plex's forearm. "Follow me."

You move through olive trees that have branches so low and leafy you have to duck under them. There are places where someone could stand completely hidden by the trees.

Mr. Plex is so close you can hear him breathing. "Is that him?" he whispers as he points to your right.

You gaze between the olive branches and see the silhouette of a teenaged boy. He is smiling as he gazes upward at the Temple of Apollo. Or perhaps he is looking at the incredible lamp of stars.

"This can't be Pythagoras," you whisper to Mr. Plex.

There is a sound of a young woman laughing. Then in the darkness you see the dark form of a female adjusting her garments, whispering. The woman seems surrounded, cozily enclosed by the trees as their leaves flutter in the cool breeze. You smell her minty perfume.

You return your attention to the man and see a shiny discoloration on his thigh. Then without a word, he runs away along a stone path leading from the Temple of Apollo.

"Mr. Plex, there's got to be some mistake."

"What did you expect?"

"Not some smelly teenager. Not this."

"You expected someone more mythical, less human?"

"Yes. I expected a sage. A bearded wizard."

Mr. Plex tosses up his front limbs. "Ah, humans. You want to deify your heroes."

A storm seems to be coming from the west. The olive leaves are flapping like little birds, and some of the skeletal branches are scratching you. Even the wind seems ominous.

Strange odors waft up from the valley, and the wind periodically makes a sighing sound, like a dying god gasping for air.

Mr. Plex begins to shiver. "I hope we don't have to scrap the project, sir."

From a belt on your waist, you pull out a small hip flask of Kylonian brandy[1] and take a sip. "Care for a some?"

"Never touch the stuff, sir."

You perform a few mental calculations. "We've arrived too early. Let's jump ahead a dozen years. Give Pythagoras a chance to mature." You put away the flask. "Shall we give it another try?"

Mr. Plex nods.

You press a travel button on your belt. "Here we go-o-o...." You feel the usual jarring effect that accompanies this mode of time travel. You also feel faint nausea and smell the strange combined odor of vomit and rose blossoms. You and Mr. Plex are whisked away....

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"I–I can't believe it," Mr. Plex screams. "That's him!"

You gaze at the view-screen hanging on a stone wall of the Temple of Apollo. You are in a cramped backroom which hasn't been used in the last few years, or so your staff has told you. You hope this is true, because you wouldn't want to be discovered with computer equipment. How would history be altered if the ancient Greeks gazed upon Mr. Plex and your computers?

A few dusty statues share the room with you. Perhaps they are gods which have fallen out of favor to make room for the latest Greek deities.

On the screen is a handsome, middle-aged man with long brown hair and beard. In the distance are some low hills.

"Pythagoras?" Mr. Plex asks you again.

Your heartbeat grows in intensity and frequency. "Yes," you whisper. "We got it right this time." You pause. "Pythagoras and his followers have some fascinating ideas and taboos. They're vegetarians, but never eat beans. They wear white clothes. They believe that numbers are divine ideas that create and maintain the universe."

Mr. Plex takes a step closer to the view-screen. "How are we observing them?"

"I released an electronic fly near Pythagoras' home. The fly has audio and video receptors."

"Can we turn up the volume?"

You nod and rotate a dial on the view-screen. Pythagoras' deep voice emanates from a cheap speaker dangling beneath the view-screen. For a moment you think you hear the chanting of monks.

"The study of arithmetic is the way to perfection," Pythagoras says to his disciples, a group of men and women clad in white. "By devotion to numbers, we discover both the divine plan and the mathematical rules of the universe."

Mr. Plex's eyes appear to be dilating with pleasure. "Mon Dieu," he whispers. "We're actually listening to the great Pythagoras."

"Quiet, Mr. Plex. I want to hear." You pause. "Look at what he's drawing."

Pythagoras sketches a figure with 10 dots forming a triangle:

Below the figure, Pythagoras writes: 1 + 2 + 3 + 4 = 10. Then he writes the Greek letters τετρακτυζ. The Pythagoreans gaze silently at the figure.

Mr. Plex looks at you. "Sir, what in the world is that?"

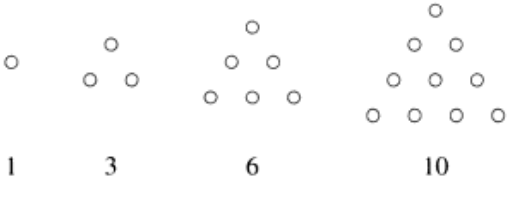
"It's the *tetraktys*." You pronounce it "te-tra-ktees" with an accent on the last syllable, your voice just a whisper. "They revere it. It's as important to them as the cross to the Christian. Initiates are required to swear a secret oath by the tetraktys when they begin their several years of silence as novices. They even pray to it."

"What's so special about a triangular array of dots?"

"They like the fact that it shows important musical intervals, 4:3 (the fourth), 3:2 (the fifth) and 2:1 (the octave). For example, choose any note. Another note an octave higher than this first note has a frequency twice that of the first note. I denote this by '2:1'. The musical interval called the fifth contains a note 3/2 times the frequency of the first note. And so on. Also notice that the first point in the tetraktys corresponds to the number of vertices of a point (1), the next pair to the vertices of a line (2), next a triangle (3) and at the bottom, a pyramid (4)." You pause to let the suspense heighten. "The most important thing is that 10 is a triangular number."

"A triangular number?"

"Yes." You drop your voice half an octave and assume a professorial demeanor. "Triangular numbers form a series, 1, 3, 6, 10,... corresponding to the number of points in ever-growing triangles." You take a piece of old charcoal from the Temple floor and draw on the wall:



"Incredible, sir. The possibilities are endless. The fourth triangular number is 10. I wonder what the 100th triangular number is?" He begins to count using his multiple limbs.

"Mr. Plex, there's an easier way. The nth triangular number is given by a simple formula:

$$\tfrac{1}{2}n(n + 1)$$

n is called the "index" of the formula. If you want the 100th triangular number, just use $n = 100$ for the index. You'll find that the answer is 5050."

Perhaps you detect admiration in Mr. Plex's eyes elicited by your mathematical prowess. "Sir, can we use a computer to determine the 36th triangular number?"

Next to you is a marble statue of Aphrodite. You reach into the statue's stomach where you have secretly stashed your notebook computer. A hinged door swings out, and you remove the computer and toss it to Mr. Plex.

Unfortunately, your aim is inaccurate, forcing Mr. Plex to make a leaping dive for the computer. He catches it but in doing so, crashes into a marble frieze running along the entablature decorated with marble representations of wild animals, centaurs, Hercules seizing Acheolus, and of men feasting. Hercules crashes down upon Mr. Plex.

Mr. Plex struggles to free himself of the horizontal Hercules and brushes himself off. "Never mind, sir. My diamond body can't be hurt by marble." He begins to furiously type on the computer's keyboard with his multiple legs. He hands you a computer printout:

```
Triangular Numbers:
1, 3, 6, 10, 15, 21, 28, 36, 45, 55, 66,
78, 91, 105, 120, 136, 153, 171, 190, 210, ...
```

"Sir, I can't believe it! The 36th triangular number is 666—the number of the beast in the Book of Revelation." Mr. Plex begins to quote from the Bible: '*Here is wisdom. Let him that hath understanding count the number of the beast; for it is the number of a man, and his number is six hundred, three score, and six.*' "

"Just coincidence, Mr. Plex."

"And the 666th triangular number is 222111. What a strange arrangement of digits!"

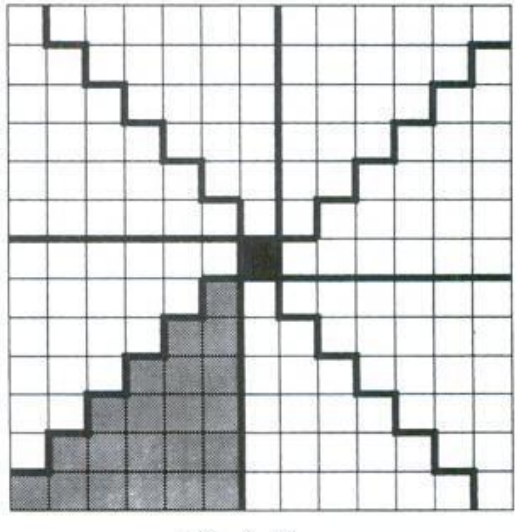
"Calm down, Mr. Plex. It's just coincidence."

"Sir, did you know that each square number is the sum of two successive triangular numbers?"

"What are you getting at?" Your voice is low.

"Square numbers are numbers like $5 \times 5 = 25$ or $4 \times 4 = 16$. Every time you add two successive triangular numbers, you get a square one. For example, $6 + 10 = 16$."

You are intimidated by Mr. Plex's mental agility, but then quickly snap back with a mathematical gem of your own: "Each odd square is 8 times a triangular number plus 1." You begin to draw a grid of squares on the wall. "Look at this." You point to the diagram.



$8T + 1 = K$

You look back at Mr. Plex. "The Greek mathematician Diophantus, who lived 200 years after Pythagoras, found a simple connection between triangular numbers T and square numbers K. My diagram shows this. It has 169 square cells in an array. This represents the square number $K = 169$ (13×13). One dark square occupies the array's center, and the other 168 dots are grouped in 8 triangular numbers T in the shape of 8 right triangles. I've darkened one of the 8 right triangles."

Mr. Plex gasps, and you stare at each other. You feel as if the air has suddenly been evacuated from your dusty marble tomb.

"Sir," Mr. Plex whispers with a trace of hesitation, "no wonder the Pythagoreans worshipped triangular numbers. You can find an infinite number of triangular numbers such that when multiplied together form a square number. For example, for every triangular number, T_n, there are an infinite number of other triangular numbers, T_m, such that $T_n T_m$ is a square. For example, $T_3 \times T_{24} = 30^2$.

You slam your fist down feeling a slight pain as it makes contact with the cold marble.

You need to outdo Mr. Plex. After all, he is your pupil and assistant. You shout back, "666 and 3003 are palindromic triangular numbers. They read the same forwards and backwards."

Mr. Plex roars and begins to type on the notebook computer like a drunken spider. "It cannot be," he screams. "The 2662th triangular number is 3544453, so both the number and its index, 2662, are palindromic."

You feel a strange shiver go up your spine as you look into the scolex's glistening eyes. You feel a chill, an ambiguity, a creeping despair. Mr. Plex is still. No one moves. His eyes are bright, his smile relentless and practiced. Time seems to stop. For a moment, your secluded chamber in the Temple of Apollo at Corinth seems to fill with a cascade of mathematical symbols. But when you shake your head, the formulas are gone. Just a fragment from a dream. But the infuriating Mr. Plex remains.

"Mr. Plex, I grow weary of your little competition."

You gaze at the view-screen. The electronic fly is following Pythagoras as he walks to his domicile and prepares for bed.

"Come back," you say into a microphone to retrieve the fly.

"Sir, triangular numbers are fascinating. Are there other numbers like this? Pentagonal numbers? Hexagonal numbers? Did anyone worship these? What properties might these have?"

"Mr. Plex, that's the subject for another day. Throughout our journey I'll be emphasizing that humans have always intertwined numbers and religion, and simple formulas describe nature. It's as if God weaved the fabric of reality on a mathematical loom. But it's late now. Why don't we try to get some sleep?"

THE HISTORY AND SCIENCE BEHIND THE SCIENCE FICTION

> *It would not be right to say that the luxuriant development of religion in all its forms, a development that reached a kind of climax during the sixth century, helped science, nor yet that it harmed it. Then as now the two developments, scientific and religious, were parallel, contiguous, interrelated in many ways. They were not necessarily antagonistic.*
> —George Sarton, *A History of Science*

Pythagoras and Transmigration of Souls

The imagined monologue of Pythagoras is based on historical fact. Why is it that scientific and religious beliefs often took hold in the same minds through history? (For example, see *Postscript 2* at the end of this book which gives a listing of famous mathematicians who were religious.) Pythagoras is one of many mathematicians and scientists with *theomatic* tendencies. For example, German astronomer Johannes Kepler (1571–1630) was a mystic and theomatic. He published on the "music of the spheres" to explain why there were only a certain number of planets with particular orbits. He also felt that reality—from planetary motions to human illnesses—was an expression of God. If Kepler had a boil, he would not clean or lance it because he did not want to interfere with God's expression.

Another example of a theomatic was Isaac Newton. He published as much material on theology and alchemy as he did on physics. How did our modern science emerge from a tradition so rooted in mysticism and theology? How has theology changed as a result of the emergence of modern science?

Let's return our attention to ancient Greece where several communities arose sharing occult doctrines and various new revelations. Both men and women shared eschatological secrets in secret brotherhoods or communities of families. I believe that the most captivating of the ancient Greek societies were the Pythagoreans. Pythagoras was born on the island of Samos in 580 B.C. He lived roughly 80 years. In 525 B.C, Pythagoras traveled to Croton in southern Italy where he established secret societies devoted to exploring the mysteries of numbers.

Here are few Pythagorean beliefs, some of which had a lasting influence on humanity:

1 *Souls*—God created souls as spiritual entities which have the possibility of merging with the divine. The soul is an eternal, self-moving number which passes from body to body. Pythagoras believed in transmigration of the souls and claimed a semidivine status in close association with the god Apollo. He told his followers he remembered his earlier incarnations, thus increasing his prestige and the perception that he had superior knowledge of mathematical and spiritual lore. In fact, Pythagoras believed that the soul can leave the body either temporarily or permanently, and that it can inhabit the body of another human or even an animal. Like Jesus, the Pythagoreans lived simply and poorly, often going barefoot.
2 *Reality*—The universe was created and is currently guided by divine plan. The ultimate reality, however, is spiritual, not material, consisting of numbers and numerical relations. Ideas are divine concepts, superior to matter and independent of it.
3 *Life*—Marriage, faithfulness, and child-rearing are important. Children should be taught the faith in the power of numbers. Women are the equal of men. (Pythagoras had women followers.) The study of arithmetic is the way to perfection. By devotion to the sect and to numbers, individuals discover aspects of God's plan and the mathematical rules that guide the universe.

Pythagoras gives many rules to his followers. I have not come across rational explanations for many of the rules. For example, they must not eat meat, fish, or beans, or drink wine. The leaders must be celibate. They must avoid woolen clothes, and wear white clothes. (Wool is probably forbidden because it is an animal product. Linen, for example, is permitted.)

You've just read about some of Pythagoras' taboos, and you probably think that the Pythagoreans are a pretty unusual bunch. But wait a minute. They are even much stranger than you think, because the list of taboos multiplies. Pythagoreans are forbidden to:

1 Stir a fire with an iron poker.
2 Eat from a whole loaf of bread.
3 Pick up what has fallen.
4 Touch a white cock.
5 Urinate against the sun.

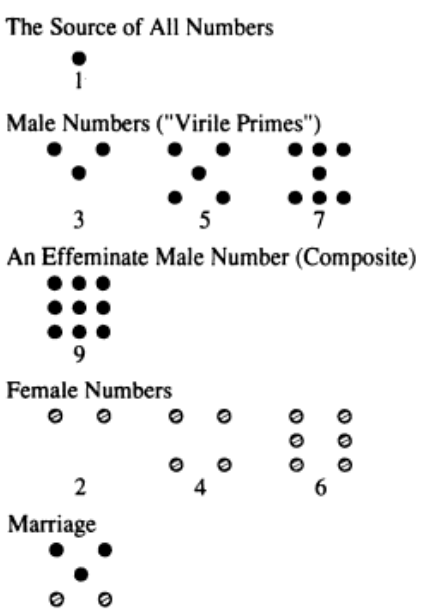
Some researchers have suggested that these and other Pythagorean taboos should not be interpreted literally. For example, "Do not urinate against the sun," might mean, "Be modest." If this is true, the inanity of certain phrases is certainly decreased.

All through the 4th and 5th centuries B.C., the Pythagoreans pursued their research, much of which was quite valid and important. How is it that such a weird bunch produced such fascinating mathematical ideas? One answer is that the fully initiated Pythagoreans weren't very concerned about taboos, and found themselves more interested in eschatology, science, and religion. Purification of the soul was accomplished by means of music and mental activity in order to reach higher incarnations. It is impossible to know about many of Pythagoras' doctrines because members were pledged to silence and secrecy. Sadly, after Pythagoras' death, many of his followers were massacred by the locals and, as with all religions, the martyrdom of his disciples increased Pythagoras' prestige.

Mathematics and Mysticism

Number is the measure of all things.
—Pythagoras

Speculations about numbers, numerical proportions, and harmonies are the most characteristic features of Pythagoreanism. Numbers resemble things and in some cases *are* things. The Pythagoreans even believed that abstract ideas have a number. For example, justice is associated with the number four and with a square. (Is this why today we have the expressions "a square deal" and "being all square?") Marriage is associated with the number five. Modern historians wonder what psychological associations the Pythagoreans used to make such numerical assignments.



Numbers had sex according to Pythagoreans.

Some numbers are compatible and friendly. Some are very evil, do not belong with other numbers, and bring calamity to humankind. Even numbers are female, odd numbers male. (Again we should ask what psychological associations Pythagoras made when coming to this conclusion. Are males more ornery and females more even-tempered?) The number 1 is the source of all numbers, and 2 the first female number. The first male number is 3, and the sum or union $2 + 3 = 5$ stands for marriage. (Around 1000 B.C. in China, odd or male numbers were designated as white circles and even or female numbers as black.) The number 8 holds the secret of love since it adds male potency 3 to marriage 5!

Pythagoreans do not consider an odd composite number as properly masculine. (Composite numbers, as opposed to prime numbers, can be expressed as the product of other numbers, e.g., $10 = 5 \times 2$.) Mathematician Albert Beiler says, "True masculine qualities required a stern individuality such as only primes possessed." Therefore odd composites such as 9 or 15 are effeminate. But the number 3, an odd prime, is considered a fitting mate to feminine 2 to consummate marriage, 5. While males can unite with females, there is no barrier preventing males from coupling with

males or females with females. Pythagoreans believed it is the task of arithmetic to discover the relationships between numbers and their place in the divine plan. Composite numbers (e.g., 630) can be broken down into their various factors (e.g., $2 \times 3 \times 3 \times 5 \times 7$) for which we can find all sorts of relations. For Pythagoreanism, these relations are evidence that the Creator has a definite plan which can be discovered by a proper understanding of number sequences.

Later Pythagoreans assumed that the distances of the heavenly bodies from the Earth correspond to musical intervals. The Pythagoreans reasoned that just as musical harmonies can be described by certain ratios of string lengths, observation of the regular movements of planets and stars can be understood in numerical ratios.

It is often said that when Hippasus discovered that the ratio between the side and the diagonal of a rectangle cannot be expressed in integers, this shattered the Pythagorean world view. $\sqrt{2}$ is not an integer but rather 1.4142..., and this bothered Pythagoras a great deal. He loved the integers. The problem caused an existential crisis in ancient Greek mathematics, because $\sqrt{2}$ is the diagonal of a square with sides of length one, and it does not exist as a fraction. The digits of 1.4142... go on forever without any pattern. Pythagoreans dubbed these irrational numbers as *alogon* or unutterable.

Triangular Numbers

> *There was a theology of number, and the mathematician was a theologian who discovered and proclaimed the divine order.*
>
> —John McLeish, *The Story of Numbers*

We've seen that the sacred 10-dot triangle or tetraktys has a cosmic significance in Pythagoreanism. There is a relevant story of the merchant who asked Pythagoras what he could teach him:

"I will teach you to count," said Pythagoras.

"I know that already," replied the merchant.

"How do you count?" asked Pythagoras.

The merchant began, "One, two, three, four..."

"Stop," cried Pythagoras, "what you take to be four is ten, or a perfect triangle, and our symbol."

Pythagoras was most interested in numbers and relations that can be represented as dots drawn in sand, or as pebbles grouped in various ways. (Most historians believe that written numerals were not yet in use in Pythagoras' time.) As you and Mr. Plex observed, of particular interest to Pythagoras were the triangular numbers formed by triangular arrangements of dots. If you have visited a bowling alley, triangular numbers should be familiar: the 10 pins are set up in a triangular array. Pool players use a triangular frame to store 15 balls. 15 and 10 are triangular numbers. Pythagoras, as we've seen, knew that the fourth triangular number was ten and he called it the *tetraktys*. Pythagoreans took an oath to the tetraktys. It went something like this:

> Bless us, divine number, thou who generates gods and men! O holy, holy tetraktys, thou containest the root and source of the eternally flowing creation!

This example is one of many in history where religion intermingles with mathematics. Why does this occur so often? Is it because both religion and mathematics strive to understand the ultimate answers? Their goals are often similar, but their methods very different.

Triangular numbers determined by $\frac{1}{2}n(n + 1)$ continue to fascinate mathematicians (but not the clergy) to this day.[2] Various beautiful, almost mystical, relations have been discovered. Here are just some of them:

- A number N is a triangular number if and only if it is the sum of the first M integers, for some integer M. For example, $6 = 1 + 2 + 3$.
- $T_{n+1}^2 - T_n^2 = (n + 1)^3$, from which it follows that the sum of the first n cubes is the square of the nth triangular number. For example, the sum of the first four cubes is equal to the 4th triangular number: $1 + 8 + 27 + 64 = 100 = 10^2$
- The addition of triangular numbers yields many startling patterns:

$$T_1 + T_2 + T_3 = T_4$$
$$T_5 + T_6 + T_7 + T_8 = T_9 + T_{10}$$
$$T_{11} + T_{12} + T_{13} + T_{14} + T_{15} = T_{16} + T_{17} + T_{18}$$

- 15 and 21 is the smallest pair of triangular numbers whose sum and difference (6 and 36) are also triangular. The next such pair is 780 and 990, followed by 1,747,515 and 2,185,095.
- Every number is expressible as the sum of, at most, three triangular numbers. German mathematician and natural philosopher Karl Friedrich Gauss (1777–1855) kept a diary for most of his adult life. Perhaps his most famous diary entry, dated 7/10/1796, was the single line:

  EYPHKA! $num = \Delta + \Delta + \Delta$

  which signifies his discovery that every number is expressible as the sum of three triangular numbers. The figures on p. 39 illustrate additional features of triangular numbers.

Triangular Number Contests

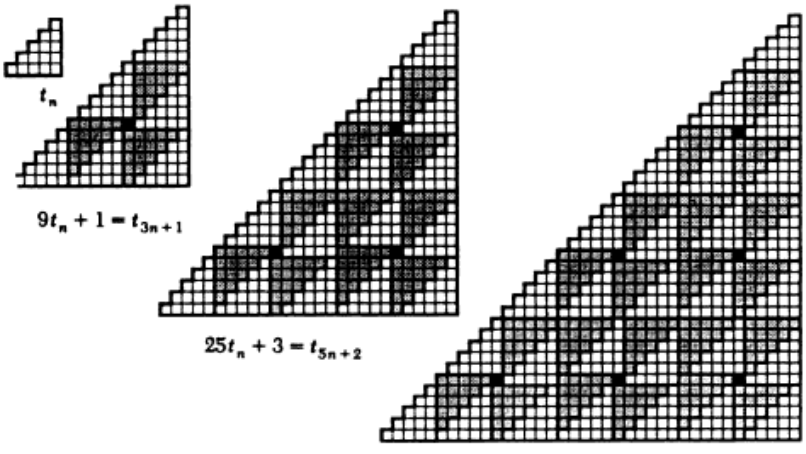
If you square 6, you get 36, a triangular number. Are there any other numbers (not including 1) such that when squared yield a triangular number? It is rumored that the next such number contains 660 digits, and humans have never found a greater example. Can you? Why are these types of numbers so secretive in our number system?

Some numbers such as 36 are both triangular and square. The next such *triangular-square numbers* are 1225, 41,616, and 1,413,721. What is the largest such number you can find?

We can use a little trick for determining huge triangular-square numbers. $8T_n + 1$ is always a square number. If the triangular number is itself a square, then we have the equation $8x^2 + 1 = y^2$. The general formula for finding triangular-square numbers is $1/32((17 + 12\sqrt{2})^n + (17 - 12\sqrt{2})^n - 2)$.

Can any triangular number (not including 1) be a third, fourth, or fifth power?

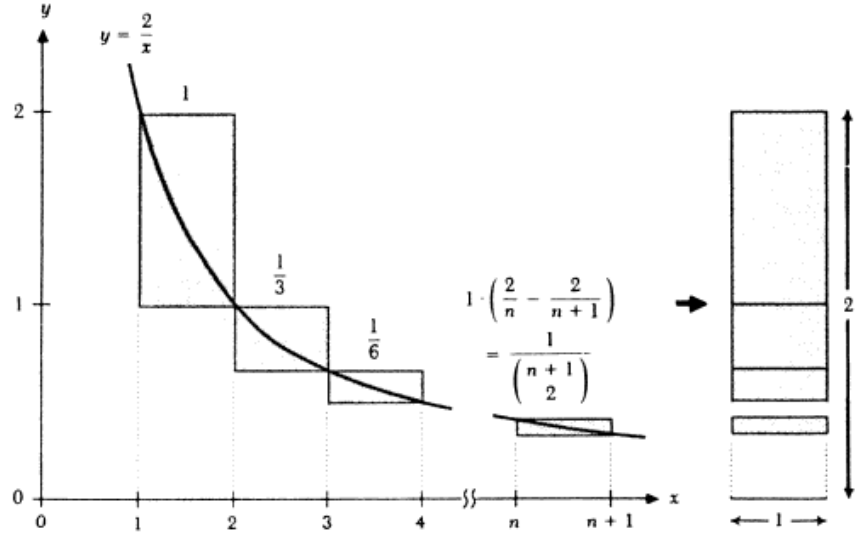
Proof without Words: A Triangular Identity



$$t_n = 1 + 2 + \cdots + n \Rightarrow (2k+1)^2 t_n + t_k = t_{(2k+1)n+k}$$

Proof without words: a triangular identity. These "visual proofs" illustrate various relationships between triangular numbers t_n. Small triangular numbers are represented by small triangles consisting of 15 squares. Larger triangular numbers are made by grouping these smaller triangular numbers, with the addition of individual squares as needed. (From Roger Nelsen; see References.)

$$\frac{1}{1} + \frac{1}{3} + \frac{1}{6} + \cdots + \frac{1}{\binom{n+1}{2}} + \cdots = 2$$



Proof without words: sum of reciprocals of triangular numbers. This "visual proof" illustrates the fact that the sum of reciprocals of triangular numbers equals 2. (From Roger Nelsen; see References.)

Mathematician Charles Trigg has found that $T_{1,111}$ and $T_{111,111}$ are 617,716 and 6,172,882,716, respectively. Notice that both the triangular numbers and their indices are palindromic, i.e., can be read backwards to yield the same number. Can you find a larger palindromic triangular number than these? Why the frequent occurrence of the digits 617 in these examples?

Obviously today we can compute huge triangular numbers using modern computers. What's the largest triangular number that Pythagoras could have computed? Would he have been interested in computing large triangular numbers?

If humanity devoted its energy to computing the largest possible triangular number within a year, how large a number would result? It turns out that this question has little meaning because we can construct arbitrarily large triangular numbers by adding zeros to 55 such as in 55, 5050, 500500, and 50005000. These are all triangular! Therefore, one large triangular number is:

500000000000000000000000000000005000000000000000000000000000000000.

You can continue this pattern as long as you like. I wonder if Pythagoras or one of his contemporaries noticed a similar pattern.

Consider triangular numbers represented as an array of dots, as in the tetraktys. The dots are spaced 1/4-inch apart. What triangular number diagram has an edge length equal to the distance from our sun to the center of the galaxy (1.1×10^{21} feet)?

The longest lived stars will have used up all their fuel in 10^{12} years. If a computer computed successive triangular numbers at a rate of one a second, how large would be the triangular number when all the starts have died? What would be the triangle's size if drawn as an array of dots using a standard-sized font? Would it fit in the volume of the universe?

If you showed Pythagoras a huge triangular number produced using an average personal computer, and you convinced him of its validity, how would this have changed his philosophy and religion? How would Pythagoras' life have changed if he came into possession of a personal computer?

Religion and Odd Numbers

Pythagoras generally considered odd numbers good and associated with light, and even numbers evil and associated with darkness. Why is it that so many religions have unknowingly agreed with Pythagoras? For example:

> *Verily God is an odd number and loves the odd numbers.*
> —Islamic saying

> *The deity is pleased with the odd number [Numera deus impare gaudet]*
> —Virgil

> *There is no doubt that in the beginning the origin was one: the origin of all numbers is one and not two.*
> —Abdu'l-Baha, 19th Century

> *There is divinity in odd numbers.*
> —Shakespeare, *The Merry Wives of Windsor*

Here are some additional examples. The Talmud contains numerous examples of odd

numbers and the avoidance of even ones. The Prophet Mohammad broke his fast by consuming an odd number of dates. When performing witchcraft, an odd number of persons should be present.

In this chapter, we've focused on number theory—the study of the properties of integers. Number theory is an ancient discipline. Much mysticism accompanied early treatises; for example, as we've seen, Pythagoreans based all events in the universe on whole numbers. Only a few hundred years ago courses in numerology were required by all college students, and even today such numbers as 13, 7, and 666 conjure up emotional reactions in many people. (Numerology is the study of mystical and religious properties of numbers.) Today integer arithmetic is important in a wide spectrum of human activities. It has repeatedly played a crucial role in the evolution of the natural sciences (for a description of the use of number theory in communications, computer science, cryptography, physics, biology, and art, see Schroeder (1984)).

CHAPTER 2

The End of the World

Truly the gods have not from the beginning revealed all things to mortals, but by long seeking, mortals make progress in discovery.

—Xenophanes of Colophon

The pure mathematician, like the musician, is a free creator of his world of ordered beauty.

—Bertrand Russell, *A History of Western Philosophy*

"Where the hell is Pythagoras?"

"Sir, our electronic fly indicates he's taking a nap beneath an old chariot in his back yard."

You remove a piece of yellowed paper from the marble floor of the temple. On the paper is some text beneath a woodcut showing apocalyptic horsemen flying through the sky on Judgement Day. (See p. 43)

"Ah, never mind Mr. Plex, we can use the time to examine a strange article one of my agents found in the year 1947." You pause. "There's always been predictions of the end of the world based on numbers. But predictions usually don't appear in serious mathematical journals." You raise your eyebrows. "This one appeared in a January 1947 issue of the *American Mathematical Monthly*."

"Sir, let me see that," Mr. Plex says in a voice an octave too high.

Mr. Plex grabs the tattered paper from your hand and begins to read from the article:

> The famous astrologer and numerologist Professor Umbugio predicts the end of the world in the year 2141. His prediction is based on profound mathematical and historical investigations. Professor Umbugio computed the value from the formula
>
> $$W = 1492^n - 1770^n - 1863^n + 2141^n$$
>
> for $n = 0, 1, 2, 3$, and so on up to 1945, and found that all numbers which he so obtained in many months of laborious computation are divisible by 1946. Now, the numbers 1492, 1770, and 1863 represent memorable dates: the discovery of the New World, the Boston

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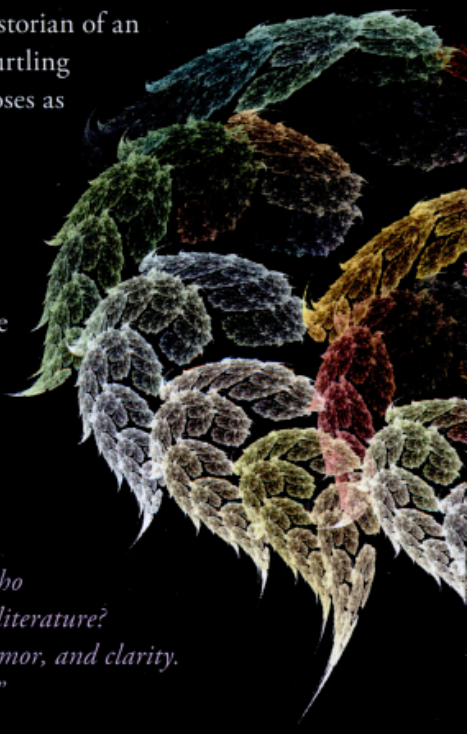
From the mysterious cult of Pythagoras to the awesome mechanics of Stonehenge to the "gargoyles" and fractals on today's computers, mathematics has always been a powerful, even divine force in the world. In a lively, intelligent synthesis of math, mysticism, and science fiction, Clifford Pickover explains the eternal magic of numbers. He appoints you chief historian of an intergalactic museum who must travel with a quirky cast of characters, hurtling through the ages to explore how individuals used numbers for such purposes as predicting the end of the world, finding love, and winning wars. Pickover writes, "I do not know if God is a mathematician, but mathematics is the loom upon which God weaves the fabric of the universe."



Clifford A. Pickover is a prolific author, having published more than 40 books, translated into dozens of languages, on topics ranging from science and mathematics to religion, art, and history. He received his PhD from Yale University's Department of Molecular Biophysics and Biochemistry, holds over 40 U.S. patents, and is an associate editor for several scientific journals. His research has received considerable attention from media outlets ranging from CNN and *WIRED* to *The New York Times*.

"Are there mathematical proofs of God? Who are the great mathematicians who believed in a deity? Does numerology lead anywhere when applied to sacred literature? Pickover covers these and many other off-trail topics with his usual verve, humor, and clarity. And along the way the reader will learn a great deal of serious mathematics."
—Martin Gardner, author of *The Book of Visual Illusions*

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"Clifford A. Pickover leads readers on a dazzling, lushly illustrated tour of the intersection of number and the numinous." —*Publishers Weekly*

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