october 2012

curiosity

A MUSEUM IN YOUR HANDS

18 | CUBAN MISSILE CRISIS
50 YEARS AGO THIS MONTH

10 | **CUBISM EXPLAINED**
WITH CUBES

16 | **QUITE A CHARACTER**
THE AMPERSAND'S STORIED PAST

26 | **THE SECRET OF FLIGHT**
WHAT REALLY KEEPS PLANES ALOFT?

PERSPECTIVE

This month, *Curiosity* examines the power of perspective, in all its possible permutations. A true renaissance figure, it has many varied and versatile connotations. In its literal sense, perspective was discovered by Italian painters 700 years ago, only to take a 180 degree turn at the hands of modernists in the 20th century. But it has been around much longer than that; as long as there has been consciousness, there has been perspective, or rather, perspectives, providing unique points of view from which to view the world. *Curiosity* set out to sample some of these frames of reference, and returned with what we hope you'll agree are some intriguing specimens. We examine the standardization of punctuation in written language that has resulted in a shared context between reader and writer, preventing miscommunication and allowing for ideas to be accurately expressed, and we question its future within the ever-changing nature of language itself. Likewise, the laws of physics governing lift have been under assault by physicists and aeronautical engineers for decades, but what it really boils down to is a shift in the way these laws are perceived. Similar motifs are at work concerning the basis for our 24-hour day (turns out 24 is isn't such a random number after all), the reason the moon waxes and wanes, and even our delight at seeing the world rendered from the eyes of a dog. From the existential mindset imbued upon a nation in a time of crisis to the fundamental moral nature of bacteria (they really aren't all bad; it just depends on—you guessed it—your perspective), join us in our inaugural issue as we investigate the world around us, one perspective at a time, led always by our curiosity.

curiosity

Curiosity explores how the world works and why, as seen from the realms of art, language, history, science, and math.

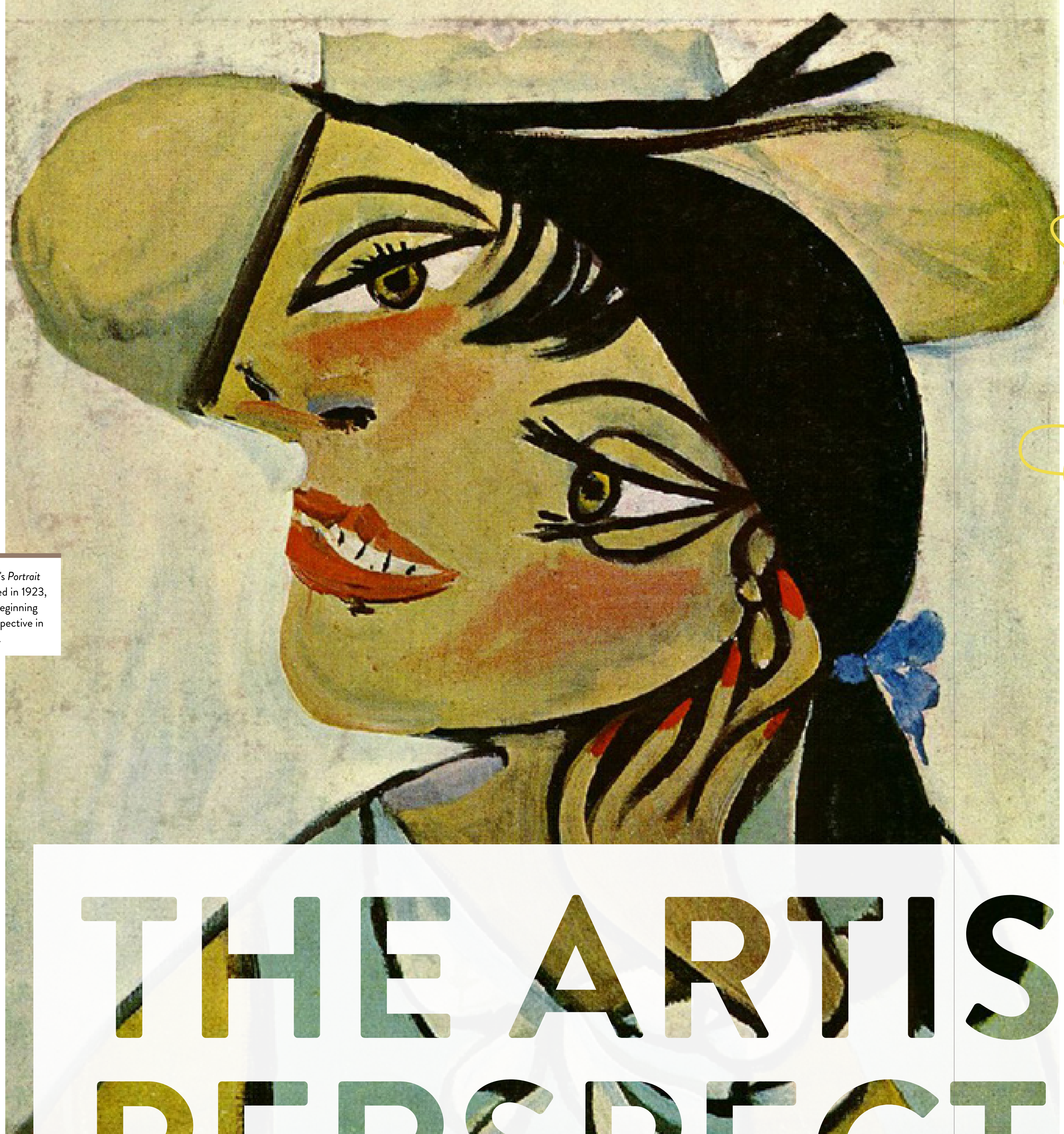
CURIOUS? CONTACT US:

curiositymagazine.com

curious@curiosity.com

Curiosity Magazine
4237 8th Ave. NE #103
Seattle, WA 98105

ART



Pablo Picasso's *Portrait Rouge*, painted in 1923, marked the beginning of a new perspective in the art world.

THE ARTIST'S PERSPECTIVE

curious about cubism? learn more on page 10

JAMES ELKINS

The system of linear perspective we take for granted today links the science of three-dimensional geometry with the art of illusionistic representation. It is a relatively recent discovery in artistic history, and artists have not always followed the forms it dictates. Before the 14th Century little to no attempts were made by artists to realistically depict the three dimensional world in the way we are now accustomed to seeing it. The Italian masters Giotto (1267–1337) and Duccio (1255–1319) began to explore the idea of depth and volume in their paintings, and can be credited with introducing an early form of perspective, using shadowing to great effect to create an illusion of depth, but it was still far from the kind of perspective we are used to seeing in art today. In the 13th and 14th centuries, occasionally artists employed something called reverse perspective, in which parallel lines splay rather than converge as they approach the horizon line. One of the rules set forth in an early artists' manual is that elements above the eye of the viewer tend downward, like roofs, while elements below the viewer's eye tend upward, like tables. While arbitrary tilting of lines upward and downward can create unusual effects, this is generally considered to be a significant step in the progression toward the rational application of linear perspective. It was not until the Renaissance that artists began to refine this science. Linear perspective soon emerged as the tool for artists to capture the world around them in a remarkably illusionistic manner. This was the same time that cartographers were mapping the surface of the earth using a similar system of mathematical projection. The first known picture to make use of linear perspective was created by the Florentine architect Fillipo Brunelleschi (1377–1446). Painted in 1415, it depicted the Baptistery in Florence from the front gate of the unfinished cathedral. The linear perspective system projected the illusion of depth onto a two dimensional plane by use of 'vanishing points' to which all lines converged, at eye level, on the horizon. Soon after Brunelleschi's painting, the concept caught on and many Italian artists started to use linear perspective in their paintings. Some artists of the Renaissance were not as concerned with putting their subjects in perfect perspective as they were with making religious statements. For example, in pictures that include the Virgin Mary the vanishing point is often intentionally placed on Mary's womb to indicate her place as the mother of Christ. This placement of the vanishing point had religious significance and may not have been related to the intention to create a rational perspectival space. Still others exploited the new discovery, using forced perspective or *erspectival anamorphosis*, requiring a specific vantage point to view. The earliest known example can be traced back to Leonardo da Vinci's *Leonardo's Eye* in 1485. The German painter Hans Holbein the Younger's 1533 painting The Ambassadors famously featured a hidden skull that could only be seen from specific perspectives. Since the Renaissance, painters have reworked and refined linear perspective. The American 19th-century realist Thomas Eakins (1844–1916) created remarkably accurate outdoor scenes, with shadows painted so precisely that art historians have been able to determine, based on their knowledge of where the works were painted, the exact date and time of day he painted them. Towards the end of the 19th Century French painter Paul Cézanne (1839–1906) began to question the underlying structure of his subjects. He began to ignore the laws of classical perspective, allowing each object to be independent within the space of a picture while letting the


1


3


2


4a

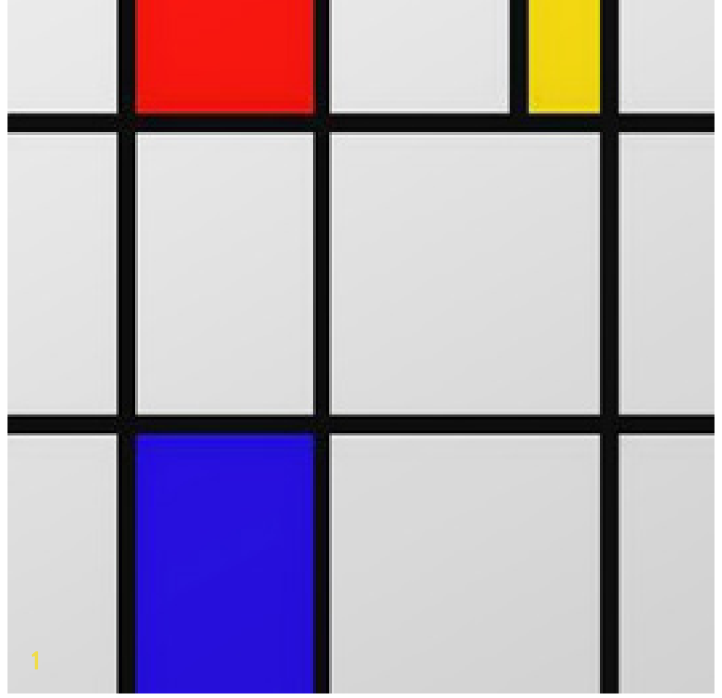

4b

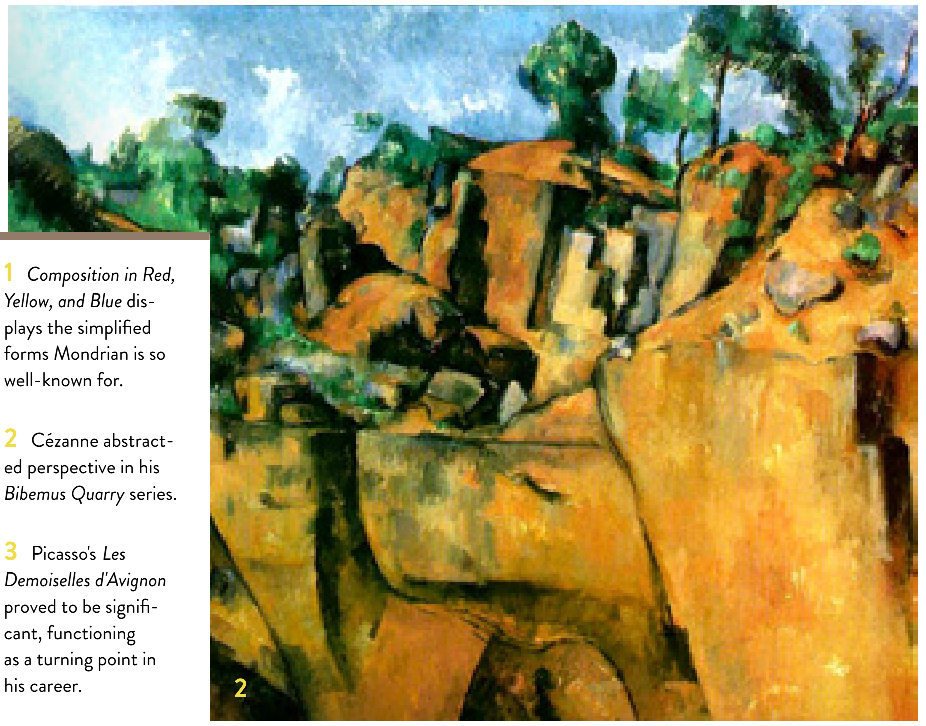
1 The boat in Duccio's *The Calling of the Apostles Peter and Andrew* shows signs of early attempts to show depth and shading.

2 Similarly, Duccio's *The Maesta* portrays the table as though it is tilting forward, in a technique now called isometric perspective.

3 *The Nave of the Church*, painted by Brunelleschi, was one of the first works to demonstrate an optical perspective.

4a, b Hans Holbein the Younger concealed a scull in his painting *The Ambassadors*, which can be perceived when viewing the image from a severe side angle.





1 *Composition in Red, Yellow, and Blue* displays the simplified forms Mondrian is so well-known for.

2 Cézanne abstracted perspective in his *Bibemus Quarry* series.

3 Picasso's *Les Demoiselles d'Avignon* proved to be significant, functioning as a turning point in his career.

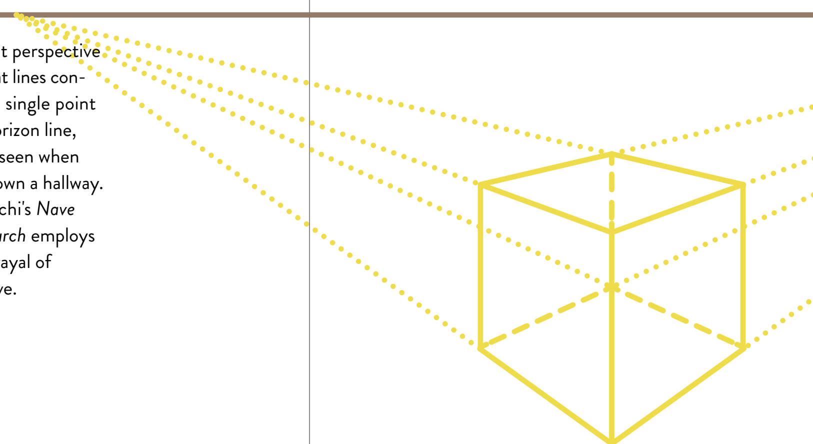
4 Forced perspective within photography has been applied for several decades, but has recently experienced a resurgence in popularity.

relationship of one object to another to take precedence over traditional single-point perspective. Pablo Picasso was one of the great innovators and changed the course of art history. His early work was beautiful, but essentially traditional. The painting which marked his breakaway from the traditions of perspective, Les Demoiselles d'Avignon was painted in 1907, but its significance was not recognized for many years. In the following years Picasso continued to develop the angular, structural style, dubbed Cubism by critics, some of whom argued that he had destroyed modern perspective by breaking up the picture plane and dividing the forms into individual geometric pieces. Early modern artists were simply borrowing from, elaborating on, and redefining perspective. Wassily Kandinsky was the first painter to completely abandon contact with reality and to give form and color alone priority in his paintings. Kandinsky's work often appeared confused, but it had a great freshness, fluidity and vitality. Piet Mondrian moved to Paris in 1912 where he immediately fell under the spell of cubist art. Although his works from this period still showed elements of representation, as time went on, he began to simplify his shapes and lines until, by the 1920s, his work was entirely removed from reality. The forms he used were colored squares–often just the three primary colors–rectangles and black lines. Mondrian was very influential among the artists that followed him. His philosophy was that painting should stand on its own, totally free of reality and representation. Another artist who felt that art needed a radical and complete revision was Kazimir Malevich, who said that he wanted to eliminate from art what he called 'nonsense realism'. Malevich used simple geometric shapes—mainly focused on the square and the circle—and limited color schemes through which he felt that he 'expressed eternity'. Whereas early artistic movements had sought to create a visually realistic representations of the world, Malevich claimed that experimentation and innovation had overtaken traditional perspective as the driving force in art. On the more guerrilla side of the art world, chalk artists began to use forced perspective in street art, similar in form to the illusionistic techniques practiced on occasion by da Vinci and Holbein the Younger, creating alternate landscapes and impossible scenes. Kurt Wenner began the movement in the mid-1980s after selling all of his belongings and moving to Rome to study art. Julian Beever, another well-known perspective artist, began making works with chalk in the mid-1990s. In a similar vein, forced perspective photographs became a widespread practice among amateur photographers in the early 2000s with the emergence of inexpensive digital cameras. It is a photography technique in which an optical illusion is created by strategically placing a subject or object to appear farther away, closer, larger or smaller than it actually is. While the technique has been employed by various professional photographers and artists for many decades,it has been embraced again because of the ease and ubiquity of digital photography.

1-point perspective

One-point perspective means that lines converge at a single point along a horizon line, as can be seen when looking down a hallway. Brunelleschi's *Nave of the Church* employs this portrayal of perspective.

2-point perspective



Two-point perspective, as its name suggests, relies on lines receding to two points along the horizon line. It is used to realistically portray buildings and other objects from a three-quarters view.

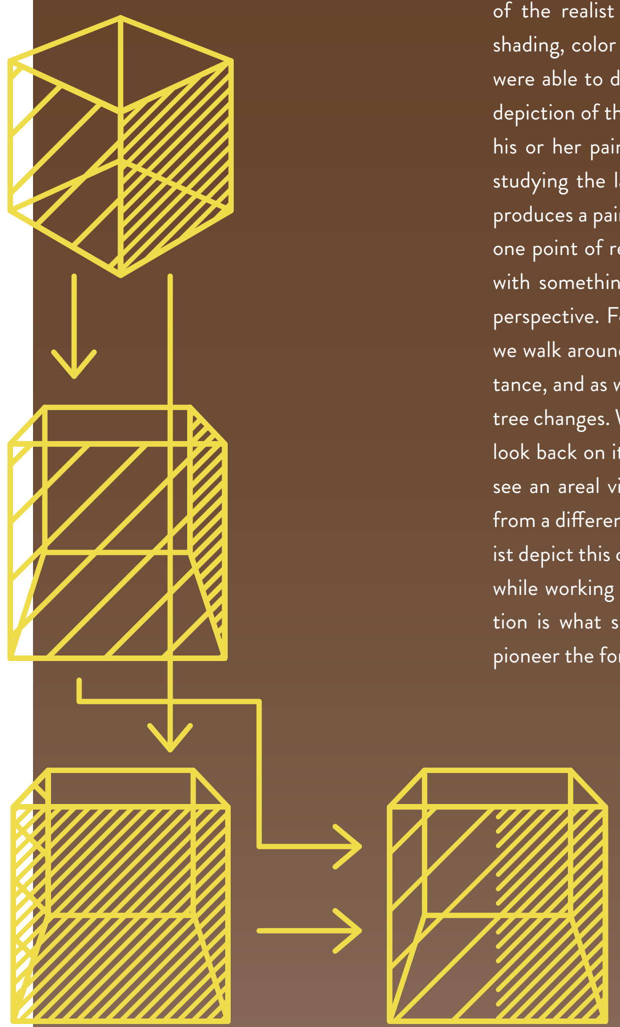
3-point perspective

Three-point perspective features three points that lines recede to, one along each of the three axis of the object depicted. Large buildings, when viewed from above or below, appear to adhere to this type of perspective.

CUBISM: A SPATIAL REVOLUTION

SCOTT CROSIER

THE CUBISTS LEFT NO DIMENSION UNTURNED IN THEIR PURSUITS TO PORTRAY THE WORLD



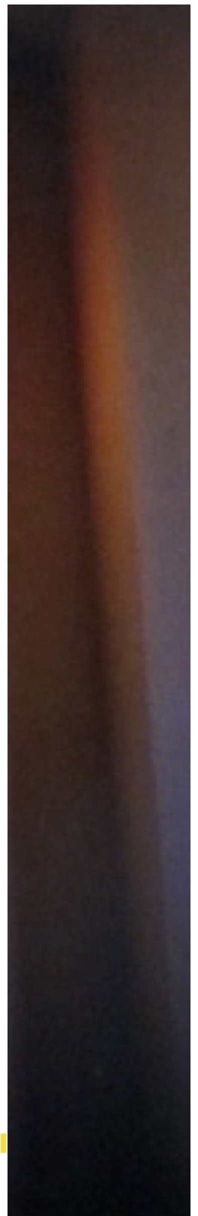
Cubism, the artistic expression that fore-fathered all abstract art, was simply a method of portraying multiple dimensions onto a two dimensional canvas. This is not unlike the task of the map maker in representing the earth in two dimensions. | Many people, when considering what makes "a good painting," consider the ability of a painting to depict an actual or realistic image of the person, object or location that the artist is presenting. We often think of the realist artists, who, through their skills in shading, color use, perspective, and understanding, were able to draw or paint a nearly picture perfect depiction of the subject. We idealize the artist, with his or her paints and palette, working at an easel, studying the landscape or their subject. The artist produces a painting depicting that object from their one point of reference. | However, as we interact with something, we rarely interact using only one perspective. For example, as we appreciate nature, we walk around. We might see a tree off in the distance, and as we approach it, our perspective of the tree changes. We might even walk past the tree, and look back on it from a completely different view or see an areal view of the location and appreciate it from a different perspective. How, then, can an artist depict this changing interaction with the subject, while working on a flat piece of canvas? This question is what spurred several artistic innovators to pioneer the form of all abstract art called Cubism. |

Although inspired by the later work of Cézanne, the era of Cubism was first begun by Pablo Picasso and Georges Braque. The major benchmark of this work was in Picasso's painting *Les Demoiselles d'Avignon*. The Cubists, including Picasso, Braque, Metzinger, Gris, Duchamp, and Léger, were attempting to depict their subject matter not as the eye, but as the mind saw the subject. | This style was in revolt to the traditional artistic expressions. These traditions followed many rules or elements that artists were strictly tied to. This included the use of paint to accurately depict texture and color, play of light on a form and shape, atmosphere, and the illusions derived by following the rigid, scientific laws of perspective. To break away from these traditions, the cubists fragmented the subject (usually into planes) and reconstructed it into an interlocking pattern. This is evident and perhaps most popular in many of Picasso's portrait paintings in which the front of the face and the profile of the face are interlocked, usually along the ridge of the nose. The cubist revolution in visual artistic expression spurred much controversy and an alternative way of thought throughout all artistic expression, including poetry, dance, theater, and sculpture. | Many perhaps jest at how the presentation of the subject matter is so distorted by Picasso and his comrades, however, if we consider the methods attempted for centuries by cartographers, of distorting the spatial properties of the earth in fitting a sphere, the globe, to a two-dimensional representation, a map, then these ideas are perhaps not so extreme or difficult to accept. Work is also being done to allow a user to navigate a subject by "moving" in, out, and around in a "virtual reality" to better understand the subject. Is this much different than what the Cubists did? They too attempted to help the viewer better understand by presenting many perspectives of the subject, rather than just one singular perspective.

LANGUAGE

FROM INTER-PUNCTS TO INTERRO-BANGS

TOM KELLY



Unbelievably, our literate Greco-Roman ancestors would find modern text unfamiliar. Their manuscripts, tablets, and monumental inscriptions were rendered as a series of characters representing words with no space or punctuation. These ancient readers most likely read aloud to themselves, sounding out letters and inserting pause and intonation after they grasped the meaning of phrases.

Just as our Western alphabet has evolved to meet the needs of readers and writers, so has the way we intersperse space and analphabetic symbols (those that do not represent a sound) in our written and printed text. Additionally, a sort of shorthand was slowly added to our character set. Special symbols, sometimes what we might consider a ligature, were developed to convey a specific meaning.

Early spacing and insertion of dots and dashes was not what we would consider punctuation, but rather stage directions for a reader. In a world where literacy was a privilege of royalty and the wealthy, many texts were written for oral delivery to those who could not read.

As the Western world became united by the Roman Empire, and subsequently under the proselytizing influence of the Roman Catholic Church, accuracy in stage direction became more important.

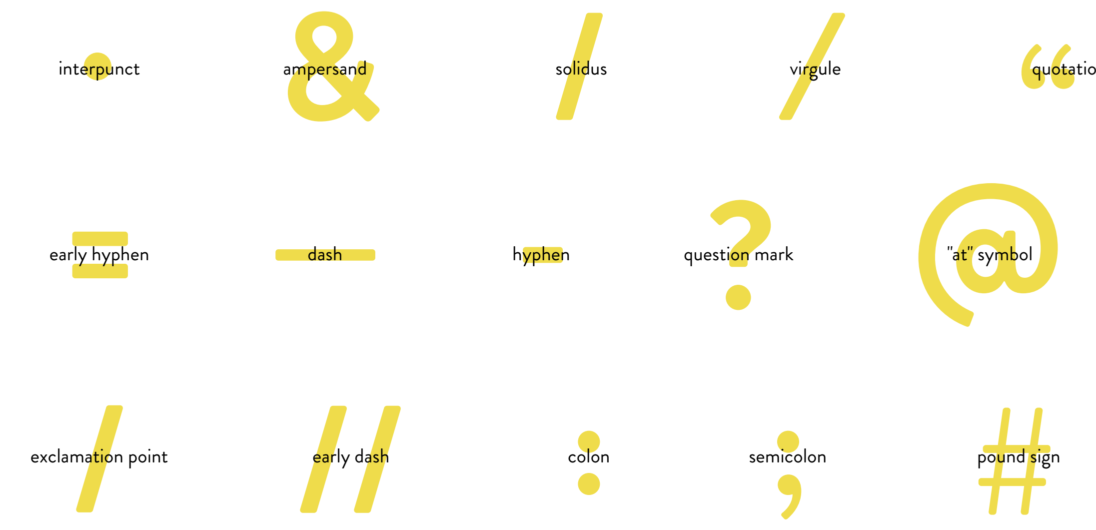
Around 200 BC the Greek scholar and librarian, Aristophanes, introduced a system using dots placed at varying heights in strategic places to represent a short pause, a long pause, and a full stop. Aristophanes' system was not widely adopted. By the first century BC, it had fallen out of fashion. Around this time the Romans began to use a small dot, or midpoint, called an interpunct to mark a division between words. Soon after, however, a renewed interest in Greek language and scholarship swept through the Roman Empire, and the lowly interpunct disappeared as well.

Interestingly, the privileged children of the Roman Empire were taught to read and write Latin with grammar manuscripts employing word spaces so these young students could learn the language. Consequently, spaces between words were considered childish and illiterate. Some language scholars will also argue that the Latin language has such uniform grammatical constructions that spacing and punctuation was not as critical as it is to the languages it spawned.

With the Roman Empire in decline during second and third centuries CE, the Roman Catholic Church is credited with keeping literacy alive in a chaotic Europe. Through its network of bishops based throughout the former empire, bibles, religious commentary, and other manuscripts were traded between monasteries for duplication for the purpose of converting the barbarians of Europe. In the 6th century CE, the aforementioned children's grammar manuscripts made their way to monastic scribes in Britannia and Ireland who were just learning the Latin language. It is these monastic scribes who first began to use word spacing in any consistent way.

Around this time, our modern-day romance languages were developing. The local vernacular was merging with Latin, the *lingua franca* of the day. Latin grammatical constructions were not as easily adapted. Consequently, a need for transcription with clear stage direction was arising.

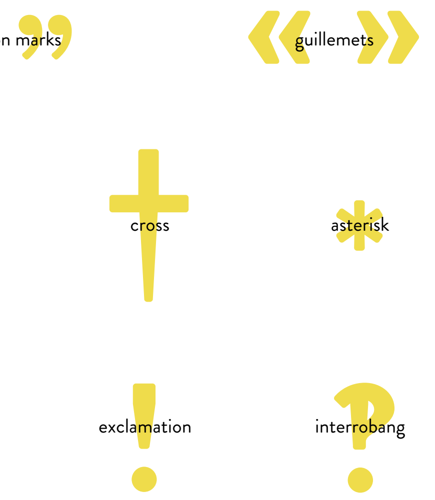
The Carolingian Empire, begun by Frankish kings originating in modern-day Germany and Northern France, became a dominant power in Europe from about 750 to 900 BC. They subsequently converted to Christianity and held some power over the Roman Catholic Church. One of these later kings, Charlemagne, established a centralized scriptorium for his empire. It was from here that space between words, along with capitalization of the first word of a phrase, use of paragraphs to indicate a new train of thought, and the beginnings of uppercase and lowercase letterforms were standardized and popularized throughout Europe.



THE BEGINNINGS OF PUNCTUATION Although the word-separation issue had been resolved to some degree, the representation of natural pauses, emphasis, and halt of the spoken word in written form was left to the discretion and style of the scriptorium producing the manuscript. Aristophanes' system was rediscovered and was introduced into medieval manuscripts. Aristophanes' dot, called a *komma*, was placed at the top of line, mid-level, or at the bottom to represent what we now think of as a colon, comma, and period. However the *komma* was not universally used. Some scribes employed the slash to indicate pause: one slash mark indicating a comma, two indicating a dash.

Eventually the *komma* on the baseline became our modern-day period. The slash however took two different routes; the single and double slash were used interchangeably. Eventually the double slashes were stacked horizontally, like an equal sign, and finally evolved into a single slash on the horizontal: the dash, as we know it today. In the 16th and 17th centuries our modern-day colon and semicolon were developed to further convey an author's intention in written text.

Medieval scribes, whether for speed, economy, or artistic license, also began to employ a small dash, or hyphen, for a continuation of a word and invented abbreviations for frequently used words. The ampersand is one of their creations as well. It is the amalgamation of the lowercase letters "e" and "t", the Latin word *et*, meaning "and". The "e" and "t" letterforms can easily be discerned in the ampersand of some fonts, while it is stylized in other faces looking like a kind of uppercase backward



cursive "S". Meanwhile, the simple cross form is theft of the addition or plus sign from mathematical notation. These innovations in transcribing an-alphabetic characters and use of space were by no means universal. Writing, like any communication system, needs wide adoption.

PRECURSORS TO PUNCTUATION

Transcribed language did not become widely standardized until the invention of movable type and the innovation of printing in the early Renaissance period. It stands to reason that transcribed works that are essentially duplicated and distributed to a wide audience would help popularize writing standards. For example, Renaissance printer Aldus Manutius is credited with popularizing the use of a dot, our modern-day period, on the baseline to indicate a full stop in prose, and one slash to indicate pause. Eventually, Manutius' single slash dropped down to the baseline, and took on a little hooked form differentiating itself to become our current comma. Moreover, the common slash, also known as a solidus, begat the virgule. The solidus is correctly used to note separation of words (such as in and/or). The virgule however, a slash with a more horizontal slope, is used between numbers when expressing a fraction. Prior to the introduction of the quotation mark, the reader had no visual cue and assumed direct quotation from the context of the text. Quotation marks began to appear in printed works in 17th century England. However, there was no standardization for the use of these marks. In early works readers would find quotation marks, distractingly, at the beginning of each line of a long quote. Eventually this typesetting style was abandoned and the quote marks were removed, but not the space they occupied. Today's experienced typesetter cum desktop publisher will see the relation to our modern-day style of setting block quotes, indented text following the paragraph above. Even today quotation mark use is not standard. Many of our European brethren use guillemets to denote a quotation, and depending on the language, the guillemets face into the phrase or out of the phrase. Even within the same language, use is not consistent. Opening and closing quote marks, particularly in long passages, are handled differently in North America as opposed to the way they are in the United Kingdom. The question mark, also known as the interrogation point, developed in England in the 16th century, and is believed to have derived from the Latin word *quaestio*, meaning question or simply, "what". With its Latin abbreviation of *qo*, it is easy to see how this punctuation mark was developed. Another explanation is that it derived from medieval manuscripts where a dot was followed by an upward, curving stroke, indicating the rising intonation of voice as in a spoken question. Like the question mark mentioned above and the ampersand noted earlier, many of our typographic symbols could be considered abbreviations or even ligatures. The pound sign, as it is called in the US, or the hash mark as it is known in most other countries, may have been an abbreviation for the French term *pound avoirdupois*, a term dealing with weight and volume, or a refining of the abbreviation for pound, "lb.", with a line on the lowercase "L". In either case we use this symbol to indicate a number, as in "#2 pencil", or for weight, as in "5# bag of potatoes". Some symbols were created from scratch. Printers of family trees in Feudal times needed a simple symbol to indicate that a date was a year of birth, as the cross usually indicated date of death. These printers are attributed with inventing the asterisk, a small, usually six-sided star shape. Of special interest is the "at" symbol. Its origin is easy to see for English readers and writers—a quick notation for the word "at". This abbreviation, or perhaps more accurately, ligature, is commonly used by grocers and accountants to note phrases such as "120 buttons @ $1.00/dozen". Others postulate that the "at" symbol has much older origins—from Greek or Latin word abbreviations concerning weights and measures. However, most 21st century readers recognize this symbol as an important component in an email address. A programmer, Raymond Tomlinson, working on the world's first email system is credited with using this sign to separate the name of the computer user from his network's location, but because its former modern-day use is limited primarily to English speakers, it has various names throughout the world: the Dutch call it an *apestaart* (monkey's tail); Czech people christened it *zavinac* (pickled herring); and Danish named it *alfa-tegn* (elephant's trunk). One of our most emotional an-alphabetic symbols is the exclamation point. Often over used and inappropriately placed, its origins have several possibilities. Some postulate that this symbol represents a Roman stylus over an interpunct, inserted by the scribe when stirred by the emotion of the text or when finished with a particularly difficult manuscript. Others suggest this mark represents a miniature scepter over an interpunct to stress the importance of the preceding line or phrase. It is even suggested that the exclamation mark is a phallic symbol connoting a feeling of braggadocio or to indicate a virile growl. Perhaps the most logical explanation of this character's origin is that this symbol is an abbreviation, or ligature, of the letters for the word *io*, a Latin exclamation of joy. By the 17th century, printing had a two-hundred-year history. Experiments with spacing, signs, and symbols had settled down to a system we recognize today. There is a space between each word, the first letter of a sentence is capitalized, a sentence ends in a period, and paragraphs are organized as trains of thought and indicated by indentation or line space. However, the finer points, much to the chagrin of modern-day elementary school students (and adult writers such as this one), are not as clear or easily understood. The correct use of serial commas, colons, and semicolons are the domain of editors and English teachers.

20TH CENTURY DEVELOPMENTS

In the early 1960s, the head of a New York advertising agency thought a new punctuation mark, the interrobang, was needed. He was an advertising executive, and needed a better way to express rhetorical questions in his copy. He designed the punctuation, and then solicited suggestions for what to name it. He chose "interrobang", which combines the Latin for question, *interro-*, with a proofreading term for exclamation: *bang*. So very Don Draper, circa Mad Men, season two, no? Much excitement surrounded this new character. Type foundries included the symbol in their fonts, and Remington added an interrobang key to some typewriters. Then it fell out of favor, and did not rise to the level of a comma, or other standard forms of punctuation. More than sixty years before the interrobang, the French proposed a *point d'ironie*. This irony mark looked like a sloped, backward question mark. Later on, French punctuation marks were suggested to aid in conveying authority, doubt, and love, among other emotions. None of these French punctuation marks made it past the conceptual stage of artists and authors. Today's quick-fingered e-mailers and compulsive senders of text messages have developed their own lexicon of abbreviations, ligatures, punctuation (or lack thereof), and spacing adapted for speed and economy for a small viewing area. Combining the letterforms and symbols from our standard alphabet, our cyber-scribes have created pictograms to convey a wide variety of emotions. These emoticons convey some very specific emotions (although you may have to turn your head to see/read them). Like the grammar students of classical Rome, this form of writing is shunned for formal written prose and documentation. Written language, like its spoken counterpart, adapts to the culture that employs it,although this written and printed part usually lags behind. We can pronounce things just fine. Recording it in writing is another matter. For instance, editors debate over new words such as the expression of the phrase most common for electronic mail. Most have finally settled on this spelling: "e-mail". Marketers, especially in the hi-tech arena, throw capitalization and spacing conventions to the wind in order to convey a modernity or innovation. Just like fads and styles come and go in design and use of typefaces, the way we present written language changes too, just at a slower pace. The adoption of punctuation and spacing depends on two things: many readers seeing and reading it, and then accepting that it makes the task of reading comfortable and comprehensible. Editors will chime in that there is a third, maybe most important, point: that any change or innovation in spacing, punctuation, or an-alphabetic character use should only be employed when it aids the reader in understanding the author's intentions. ◻

WE RELY ON PUNCTUATION TO GIVE LANGUAGE PERSPECTIVE AND CLARITY.

THE EVOLUTION OF THE AMPERSAND

CAMERON CHAPMAN

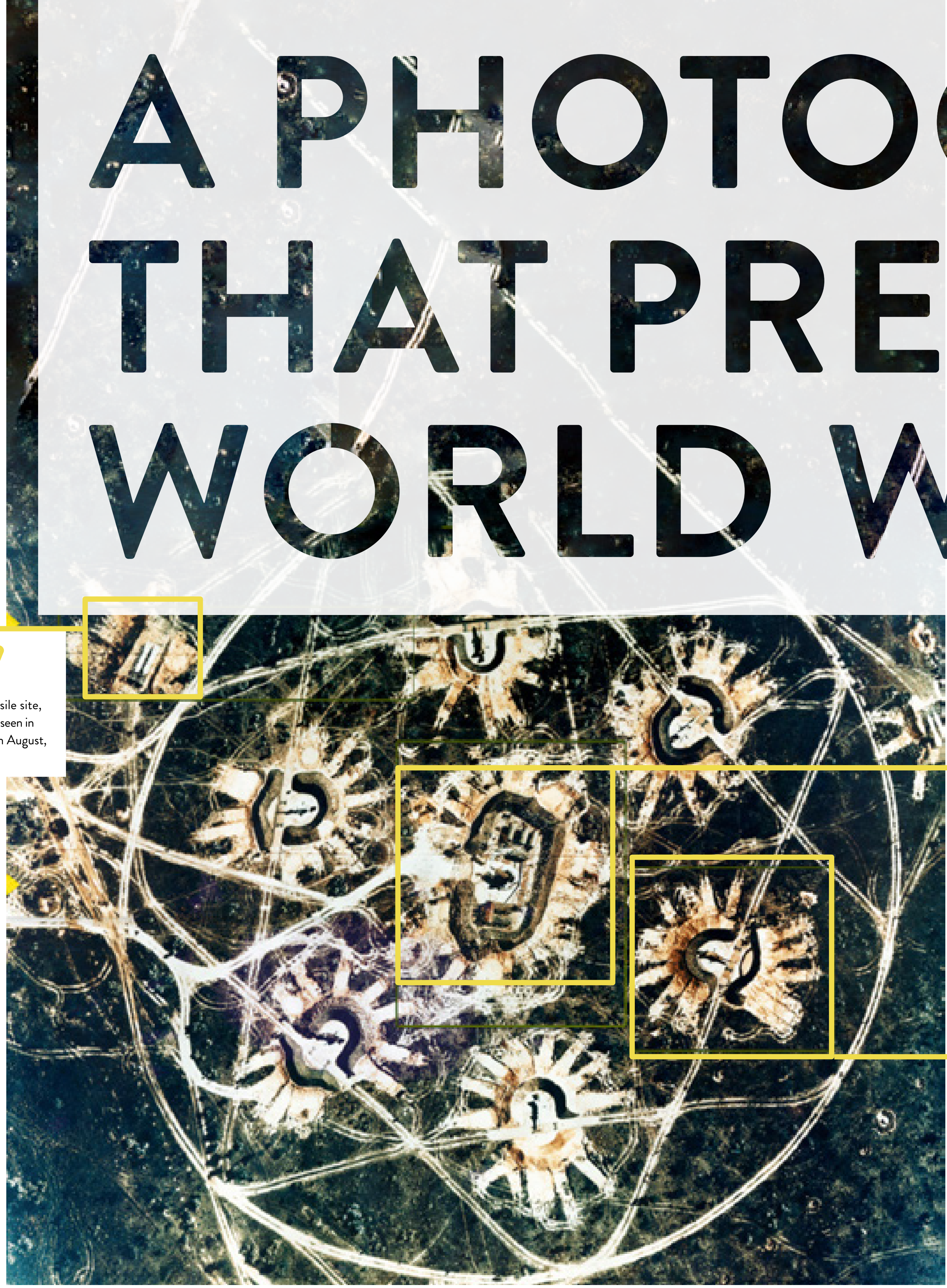
THE HISTORY OF THE AMPERSAND IS AS INTRICATE AS ITS FORM

The ampersand is one of the most unique typographical characters out there, simply by nature of the fact that typography designers can exercise a lot more artistic freedom in the design of the ampersand, ranging from very traditional representations to those that bear little resemblance to the original form. With all the variations available out there, there are a whole host of design possibilities presented by this particular character. | The ampersand can be traced back to the first century AD. It was originally a ligature of the letters "e" and "t" , or *et* for "and" in Latin. If you look at the modern ampersand, you'll likely still be able to see the "e" and "t" separately.

| The first ampersands looked very much like the separate "e" and "t" squished together, but as type developed over the next few centuries, it eventually became more stylized and less representative of its origins. The modern ampersand has remained largely unchanged from the Carolingian ampersands developed in the ninth century. | Italic ampersands were a later ligature of "e" and "t", and are also present in modern fonts. These were created as part of cursive scripts that were developed during the Renaissance. They're often more formal-looking and fancier than the standard Carolingian ampersand. | The word "ampersand" was first added to dictionaries in 1837. The word was created as a slurred form of "and, per se and", which was what the alphabet ended with when recited in English-speaking schools. Historically, "and per se" preceded any letter which was also a word in the alphabet, such as "I" or "a". The ampersand symbol was originally the last character in the alphabet, and is still a part of every roman font. It's used in modern text often, probably most frequently in the names of corporations and other businesses, or in other formal titles. | It's experiencing a bit of a resurgence in general usage, as it commonly replaces "and" in text messages and Twitter updates, where minimizing the number of characters used is of the essence.

HISTORY

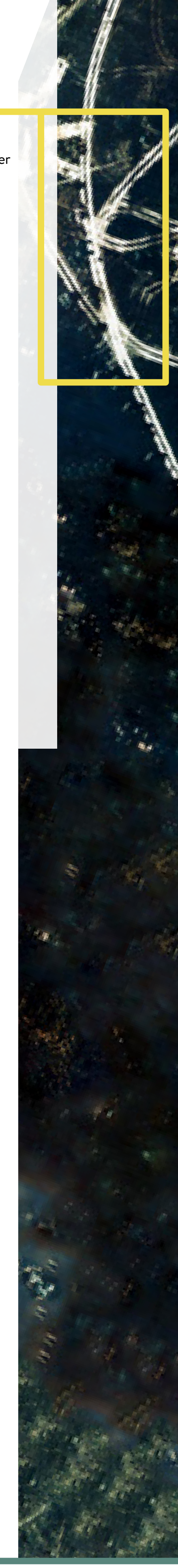
A PHOTOGRAPH THAT PREVENTED WORLD WAR III



An SA-2 missile site, similar to one seen in La Coloma, in August, is visible.

This photograph offers a clear view of the Guidance-and-Control Radar Station at the center of the SA-2 missile site.

Here, you can see the launch pad with the bulldozer tracks radiating from it. You can also see how the road intersects with the launcher, allowing the Soviets to drive a missile into position.



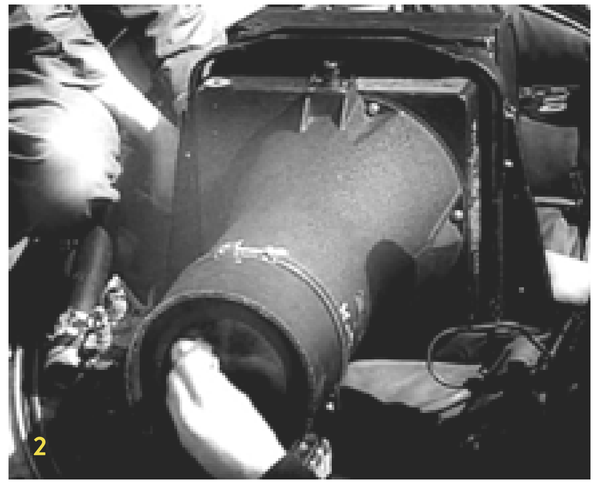
Wide radius turns indicated trucks longer than 65 feet used the site, as predicted for large missiles.

MICHAEL DOBBS

On October 23, 1962, a U.S. Navy commander named took off from Key West at midday in a jet equipped with five reconnaissance cameras. Accompanied by a wingman he headed toward a mountainous region of western Cuba where Soviet troops were building a facility for medium-range missiles aimed directly at the United States. A U-2 spy plane, flying as high as 70,000 feet, had already taken grainy photographs that enabled experts to find the telltale presence of Soviet missiles on the island. But if President John F. Kennedy was going to make the case that the weapons were a menace to the entire world, he would need better pictures. Swooping over the target at a mere 1,000 feet, Ecker turned on his cameras, which shot roughly four frames a second, or one frame for every 70 yards he traveled. Banking away from the site, the pilots returned to Florida, landing at the naval air station in Jacksonville. The film was flown to Andrews Air Force Base outside Washington, D.C. and driven by armed CIA couriers to the National Photographic Interpretation Center, a secret facility occupying an upper floor of a Ford dealership in a derelict block at Fifth and K streets in Northwest Washington. Half a dozen analysts pored over some 3,000 feet of newly developed film overnight. | At 10 o'clock the following morning, CIA analyst Art Lundahl showed Kennedy stunningly detailed photographs that would make it crystal clear that Soviet leader Nikita Khrushchev had broken his promise not to deploy offensive weapons in Cuba. As the Cuban missile crisis reached its peak over the next few days, low-flying Navy and Air Force pilots conducted more than 100 missions over the island in Operation Blue Moon. While Kennedy and Khrushchev engaged in a war of nerves that brought the world the closest it has ever come to a nuclear exchange, the president knew

"THERE WAS EVERY EXPECTATION CIVILIZATION WOULD COME TO AN END."

1



2

3

little about his counterpart's intentions—messages between Moscow and Washington could take half a day to deliver. The Blue Moon pictures provided the most timely and authoritative intelligence on Soviet military capabilities in Cuba, during and immediately after the crisis. They showed that the missiles were not yet ready to fire, making Kennedy confident that he still had time to negotiate with Khrushchev.

In the 50 years since the standoff, the U.S. government has published only a handful of low-altitude photographs of Soviet missile sites—a small fraction of the period's total intelligence haul. However, thousands of cans of negatives were transferred to the National Archives, making them available for public inspection.

Those photos bring home the dangers and difficulties the pilots faced. Working long before the invention of automated GPS systems, they navigated primarily with maps and compasses and used landmarks like bridges and railroads to find their targets. Flying over the treetops at 550 miles per hour, they had to operate a battery of cumbersome cameras while keeping an eye out for construction sites, military vehicles or other suspicious activity. To take useful pictures, they had to keep their platforms steady and level for the all-important few seconds they were over the target. The risk of mechanical failure or getting shot down was more or less continuous from the moment they entered enemy territory.

Each reel seats the viewer in the cockpit: Early frames typically show the ground crews at the naval air station on Key West checking out the cameras and planes. Surf splashes up against the Crusaders' fuselages as they fly low across the Straits of Florida and cross the beaches of northern Cuba before heading over the island's mountains. Plazas and baseball diamonds suddenly give way to missile sites and military airfields. In one series of

4

1 The United States' U-2 plane flies over Cuba to capture photos from above.

2 The camera used had to be cleaned and handled with the utmost care. Even a small speck of dust obscuring the lens could be to render photos useless.

3 The photographer had to take anticipate where the plane would be by the time the image was actually captured by the camera, no small feat considering the U-2 plane flew at speeds upward of 550 miles per hour.

4 Russia used Cuba as an ally during their experimentations with nuclear warfare.

1 Nuclear fallout shelters, and those that owned them, became very popular stateside.

2 Military officers had to examine the aerial photos of Cuba very closely before determining their next order of attack.

3 The machine used to examine photos was every bit as complex to use as the camera that took the photos. Brugioni and other photoanalysts had to spend hours looking through the machines.

images, the landscape goes suddenly haywire: The pilot has yanked his joystick to avoid anti-aircraft fire. As I reeled through the 6-by-6-inch negatives on a light table similar to the one the CIA's photo interpreters used, I found myself holding my breath until the pilot escaped back over the mountains to the open sea. In addition to bringing the viewer back into the moment, the photographs offer insights into American intelligence-gathering. According to Dino Brugioni, a sharp 91 year old responsible for preparing annotated briefing boards for the president during the crisis, "When you look at the photography, you are looking for anything that is alien to that environment". At the peak of the crisis, Brugioni and other photo interpreters were reviewing 30 to 40 rolls of film per day. They were familiar with Cuba's sugarcane fields, ranch land, railroads and baseball diamonds, so Soviet tents and missile trailers stood out. Analysts were also trained to spot certain "signatures," or man-made patterns in the earth indicative of missile sites. An ominous gap concerned the location of the warheads for the 36 medium-range missiles capable of hitting Washington and New York. The whereabouts of the warheads was critical, because the missiles could not be fired without them. Kennedy asked for the information repeatedly, but the CIA was never able to answer him definitively. By the second week of the crisis, the photo interpreters had concluded that the warheads were probably stored in a closely guarded facility near the port of Mariel. But by analyzing the raw intelligence film and interviewing former Soviet military officers, photo analysts discovered that they were wrong. The one-megaton warheads (each 70 times more powerful than the bomb that destroyed Hiroshima) were actually stored some 20 miles away near a town called Bejucal, a few miles south of the Havana airport. The CIA—and, by extension, Kennedy—was completely unaware of this at the time. The giveaway was the presence of specially configured vans that were used to transport the warheads from Bejucal to the Sagua La Grande missile site starting on the night of October 26, as the crisis was approaching its height. The Bejucal facility had been photographed on several Blue Moon missions. At the beginning of the crisis, a CIA briefer had even told Kennedy that it was the "best candidate" for a nuclear storage bunker and was marked for "further surveillance." But the photo interpreters lost interest in Bejucal because of the seemingly lax security arrangements there. They noted that the site was protected by a single fence, rather than the multiple fences used to protect similar installations in the United States and the Soviet Union. As it turned out, the lack of security proved to be the best security of all, from the Soviet point of view. What might have happened had the CIA interpreted the intelligence correctly? Had Kennedy known where the warheads were stored, he might have been tempted to order a pre-emptive strike to seize or disable them. The mission could have been a success, strengthening his hand against Khrushchev, or it could have gone badly wrong, resulting in firefights between Americans and the Soviets guarding the nuclear weapons. We will never know. As it was, Kennedy, armed with only partial intelligence about what the Soviets were doing, refrained from taking pre-emptive action. At the same time, the photo interpreters did provide Kennedy with information that shaped his response to Khrushchev at several points. On October 26, they correctly identified a nuclear-capable missile launcher. Their most important contribution was their day-to-day assessment of the combat-readiness of the different missile sites. As long as the president knew the missiles were not yet ready to fire, he had time to negotiate. That changed on October 27—Black Saturday—when the CIA informed Kennedy for the first time that five out of six medium-range missile sites on Cuba were "fully operational." The analysts reached this conclusion by monitoring progress made on the missile sites. The president now understood that time was running out, and the confrontation had to be brought to a close. That evening, he delegated his brother Robert, his confidant and the attorney general, to meet with Soviet Ambassador Anatoly Dobrynin at the Justice Department and warn that U.S. military action was imminent. He also offered Khrushchev a couple of carrots: If he pulled his missiles out of Cuba, the United States would promise not to invade the island and would also withdraw similar medium-range missiles from Turkey. Fortunately for humanity, Khrushchev accepted the deal. Today, the photographs that helped to avert this crisis are available through the National Air and Space Museum; their collection contains hundreds of reconnaissance photographs from the Cuban Missile Crisis, many donated by Brugioni. ▪

Russia's missiles would have been able to reach almost every part of the contiguous states. The SS-7 Saddler missiles, of which they harbored 36, could be launched 1,100 miles, while the four SS-7 Sapwood missiles were capable of reaching 2,200 miles.

JFK & KHRUSHCHEV: UNLIKELY PEN-PALS

JACOBINA CZEN

THE FATE OF MILLIONS HINGED UPON THE ABILITY OF TWO MEN TO REACH A COMPROMISE IN OCTOBER OF 1962

The closest the world has come to nuclear war was the Cuban Missile Crisis of October 1962. The Soviets had installed nuclear missiles in Cuba, just 90 miles off the coast of the United States. U.S. armed forces were at their highest state of readiness. Soviet field commanders in Cuba were authorized to use tactical nuclear weapons if invaded by the U.S. The fate of millions literally hinged upon the ability of two men, President John F. Kennedy and Premier Nikita Khrushchev, to reach a compromise. | Perhaps what amazes people the most about this crisis was the modes of communication that the heads of states of USSR and the United States used to get their messages across to each other. They had no faxes, no e-mail, no top secret phone lines to each other, and no computers like we have today. Instead they relied heavily on hand carried letters, both formal and "back channel" to threaten and negotiate. In a situation this explosive, having to rely on a slow speed of a letter seemed to be toying with nuclear disaster. Dino Brugioni, a photo analyst for the CIA during the crisis described the mood that blanketed the nation as "a certain grim inevitability over those two weeks. There was every expectation civilization would come to an end; that it didn't almost came as a surprise." President Kennedy knew he had a problem if he needed an immediate response from Khrushchev. Early on in the crisis, on October 18, President Kennedy had a meeting in the Oval Office. The President asked a few of his advisors how long it would take for him to get a message back and forth to Moscow:

JFK: *How quick is our communication with Moscow? Say we sent somebody to see him and he was there at the beginning of the 24-hour period to see Mr. Khrushchev, how long would it be before Khrushchev's answer could get back to us as far as communications?*

LLEWELLYN THOMPSON: *It would have to go in code probably, what, probably five or six hours... [unintelligible]...You could telephone of—*

JFK: *Wouldn't really have to go in code, would it?*

THOMPSON: *You could save time by not putting it in a highly confidential...[unintelligible]...machine?*

JFK: *Then it would be a couple of hours?*

Why did Kennedy prefer to write letters to Khrushchev as the primary way of communicating during the crisis in spite of this time lag? Evidently, letter writing with Chairman Khrushchev had been established earlier in President Kennedy's presidency. This correspondence was intended to exchange ideas in a purely informal way, and was known later as "the pen pal" correspondence. | Although slower than the phone lines, the letters, given their importance, moved remarkably fast. Moving them in the space of "a couple of hours," in spite of the distance that the letters had to go and the translations that had to take place, must have been quite a feat. Many of these letters were more in depth and thoughtful than you could expect from a phone conversation. The leaders could prepare statements and edit their thoughts using the tried and true format of letters, Kennedy and Khrushchev could talk to each other as friends, not as enemies. | It is possible that this personal and informal form of correspondence helped prevent the crisis from getting any worse than it already was. Both sides were able to express that they had to prevent the crisis from spinning violently out of control.

SCIENCE

LIFT, REVISITED

ROBERT KUNZIG

The question of how an airplane flies may seem like third-grade science, but aeronautical engineers can and do disagree on it. Scott Eberhardt is a professor of aeronautics at the University of Washington in Seattle, where he teaches a popular introductory class. In the typical aeronautics curriculum, he says, students are showered with complex equations but are never given an intuitive understanding of what lifts an airplane. "Most of the students who graduate today don't have a fundamental understanding because we haven't taught them that," says Eberhardt. "They can explain it in mathematics. But that's not understanding."

David Anderson, a physicist at Fermilab, had precisely that experience when he studied physics at the University of Washington decades ago, before Eberhardt's time there. "When I was through, I had a good intuitive understanding of all of physics," he says. "But I didn't understand how a wing flew. I'd worked all the problems, aced all the tests—and I just had this feeling they were peeing on my boots and telling me it was rain."

It's not fair to blame that kind of weather on Bernoulli, who died even before the first manned ascent in a hot-air balloon. But somewhere along the way in the 20th century, his famous—and perfectly true—principle got misapplied in every man's explanation of aerodynamic lift. The explanation goes like this: Air flows faster over the top surface of the wing than underneath the bottom. Bernoulli's principle says that when any fluid moves faster—for instance as it passes a bottleneck in a pipe—the static pressure in it decreases. Therefore, borrowing Bernoulli's logic, the air above the wing must be at lower pressure than the air below. That lifts the wing.

But why, in the first place, does the air on top flow faster? That, say Anderson and Eberhardt, is where the popular explanation crashes and burns. Even popularizers like me have wondered about the usual answer: The air flowing over the curved upper surface of the wing travels farther than the air traveling under the bottom, and so it has to travel faster to get to the trailing edge at the same time. The problem is, there is no earthly reason why the air should get there at the same time. In fact, it doesn't. Someone, somewhere (and let's hope it wasn't a science journalist) made up the "principle of equal transit times." The air on top actually gets to the trailing edge sooner than the air on the bottom, because it really does travel faster. But the popular explanation doesn't tell you why, and thus it is no explanation at all.

So why does an airplane stay up? The question nagged at Anderson as he pursued his career at various physics labs. It bugged

curious about the forces involved with lift?
learn more on page 29

him especially when he was at Los Alamos in northern New Mexico and began piloting a Cessna 182. Much later, at Fermilab, Anderson found himself on a committee in charge of bringing in outside speakers from time to time to take the inmates' minds off the Higgs boson. One day he decided to find an expert who could explain airplane flight. He called his alma mater and got put through to Eberhardt.

The forces acting on an airplane's wings are as subtle as they are elemental. According to a principle known as the Coanda effect, air flowing over the top of the wing sticks slightly to the surface and is pulled downward. This produces a low-pressure zone above and a high-pressure zone below, which pushes the wing up. The greater a wing's "angle of attack," the more powerful its lift.

"We were chatting, and I was kind of feeling him out," Anderson recalls. "Because if he was going to give me Bernoulli, I wasn't going to waste my money. So I said, 'What makes a wing fly?' And he said, 'Lift is a reaction force. The wing pushes the air down, so the air pushes the wing up.' And I said, 'Yes!'"

Thus began a long collaboration that culminated in Understanding Flight. Eberhardt stresses that there is no new physics in the book. To understand lift you need only Newton's three laws and something called the Coanda effect. The Coanda effect is just the tendency of air or any even slightly viscous fluid to stick to a surface it is flowing over, and thus to follow the surface as it bends. As air follows the upper surface of a wing, it gets bent downward—because the surface is curved but also because the leading edge is tilted up (especially when ascending) at what is called the angle of attack. The air that is bent downward pulls on the air above it, distending it and creating a low-pressure zone.

BUT WHY DOES THE AIR ON TOP FLOW FASTER? THAT, SAY ANDERSON AND EBERHARDT, IS WHERE THE POPULAR EXPLANATION CRASHES AND BURNS.

To bend the air downward, the wing has to exert a force on it (that's Newton's first law). That action inevitably elicits an equal and opposite reaction (Newton's third law). By means of the low-pressure zone above the wing and the higher pressure below it, the air exerts an upward force on the wing: That's lift. The size of the force is equal to the mass of air the wing has diverted downward multiplied by the acceleration of that air (Newton's second law). A pilot can increase the lift by flying faster (adding power) or by increasing the angle of attack (pulling back on the stick); either way the wing diverts more air down and behind the plane.

The wings of a 250-ton airliner, Anderson calculates, pump down about 250 tons of air every second. "That's the problem with Bernoulli," he says. "There's no work done—it's all magic. It doesn't make sense that a wing could cut through the air like a knife, leave a small transient ripple in the air, and hold up a 250-ton airplane. A 250-ton airplane is working. It's holding itself up by brute force."

Bernoulli, R.I.P.? Well, not quite. After all, aircraft designers do use the Bernoulli principle, with obvious success, in their complex calculations of airflow. And you too can use it, if you want, to understand lift. But then think of things this way: The leading edge of a wing is an obstruction, like a bottleneck in a pipe. It squeezes the air flowing around it, and it squeezes more where the path is more curved—over the top of the wing. Obeying Bernoulli, the flow there speeds up, the pressure drops, and *voila*: lift.

Both explanations are correct, really; there's no reason to get hot about the subject. But as far as I'm concerned, Anderson and Eberhardt ace a crucial test: They're a lot easier to explain to my third-grader than Bernoulli ever was.

Air pressure and attractive forces between molecules pull air along the surface of the wing, sometimes called the Coanda effect, and because of the angle of attack, that direction is downward. The curved shape of the wing helps the air flow hug the surface. When this flow detaches from the wing surface, which occurs at steep angles, the lift disappears, and the airplane stalls and falls.

NEWTON & BERNOULLI: THE BASICS

TOM BENSON

A NASA SCIENTIST EXPLAINS THE TWO THEORIES AND HOW THEY DIFFER

Theories on the generation of lift have become a source of great controversy and a topic for heated arguments for many years.

The proponents of the arguments usually fall into two camps: those who support the "Bernoulli" position that lift is generated by a pressure difference across the wing, and those who support the "Newton" position that lift is the reaction force on an object caused by deflecting a flow of gas.

When a gas flows over an object, or when an object moves through a gas, the molecules of the gas are free to move about the object; they are not closely bound to one another as in a solid. When the molecules move, they have an associated velocity. Depending on the shape of the object, the velocity within the gas can have very different values at different places near the object. Bernoulli's equation relates the local velocity of a gas to its pressure, because the more the surface of an object bulges, the greater the velocity of airflow over that portion of the object, and the thinner spread the molecules there are, which results in a low pressure zone.

Thus a wing generates lift because the air goes faster over the top creating a region of low pressure. But why does the air have to go faster over the top of the wing in the first place? This incorrect theory, known as "equal transit time" is where the popular explanation of lift falls apart. It states that wings are designed with the upper surface longer than the lower surface, to generate higher velocities on the upper surface because the molecules of gas on the upper surface have to reach the trailing edge at the same time as the molecules on the lower surface.

In reality, the pressure (and therefore the velocity) on the upper surface of a lifting wing is much higher than can be explained with the equal transit time theory. If we do a simple calculation we would find that, under the equal transit time theory, in order to generate the required lift for a typical small airplane, the distance over the top of the wing must be about 50% longer than under the bottom. The wing for a 747 would have to be taller than it is long.

So, if that is incorrect, how does a wing generate lift? Newton's first law states that a body at rest will remain at rest, or a body in motion will continue in straight-line motion unless subjected to an external applied force. That means, if the flow of air changes, there is a force acting on it.

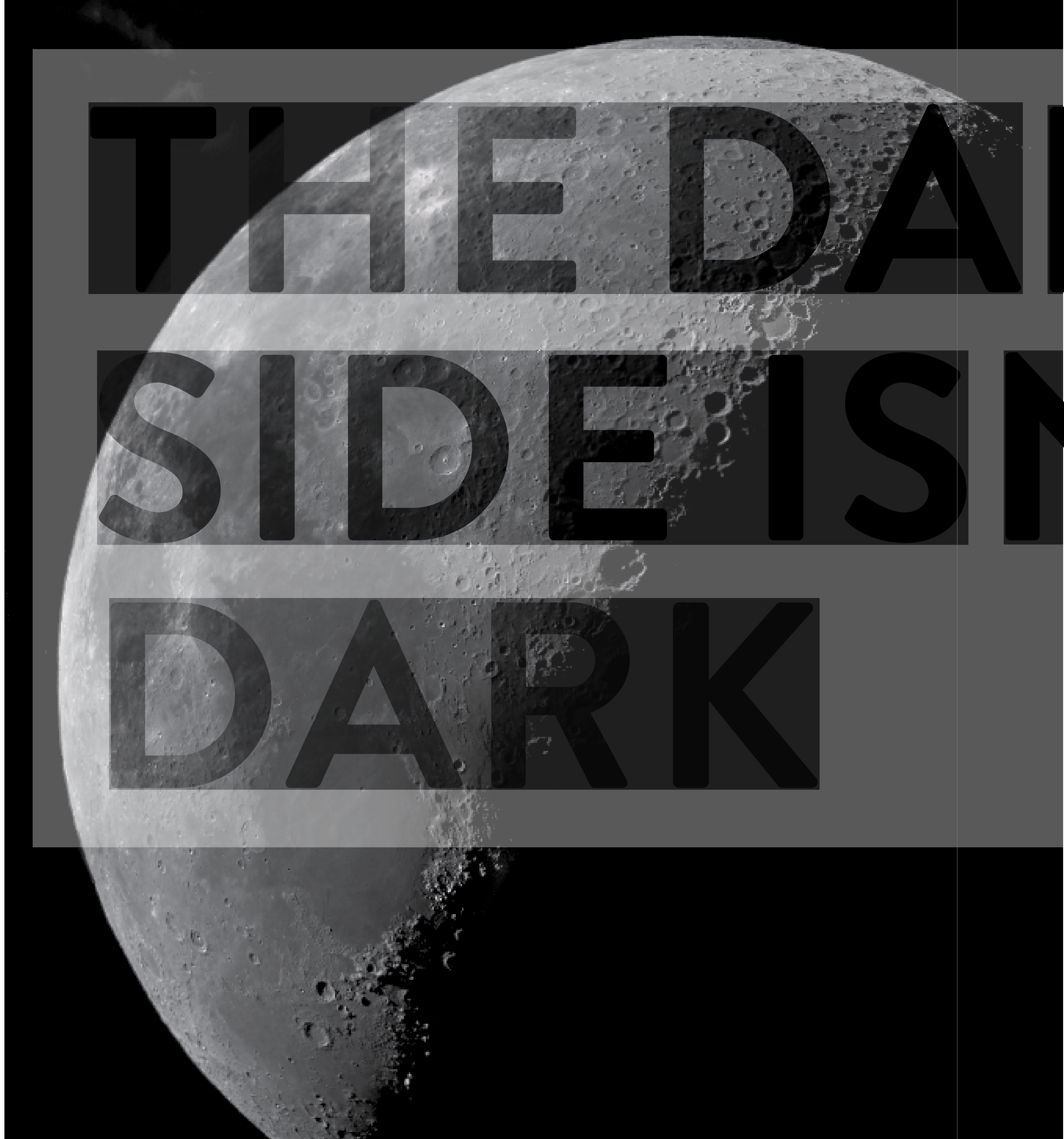
Newton's third law states that for every action there is an equal and opposite reaction. What the wing does to the air is the action, while lift is the reaction. In order to generate lift a wing must divert air down, lots of air. So how does a thin wing divert so much air? The top surface of the wing does much more to move the air than the bottom, but not in the way described by the equal transit time theory. Wings function as a scoop diverting a certain amount of air from the horizontal to roughly the "angle of attack" or the angle of the wing's top surface relative to the ground.

So, according to Newtonian mechanics, a wing's angle of attack works to divert, or act on, the surrounding air. This action produces the equal and opposite reaction of lift.

Arguments arise because people misapply Bernoulli's and Newton's equations and because they over-simplify what is going on during lift. Both theories are correct, and they don't change what is happening among the forces present. The only thing they change is the perspective from which lift is seen, and one or the other may be more helpful to a complete understanding.

actual wing cross-section dimensions

wing cross-section dimensions as predicted by equal transit time



THE DARK SIDE ISN'T DARK

LORETTA HIDALGO WHITESIDES

How embarrassing is it for someone with advanced degrees in science and a life-long love of space exploration to be caught referencing the famed "dark side of the moon" (at least I was up on my Pink Floyd) only to be met by a surprised look from my astronomical colleague with the comment, "Loretta, you know there isn't really a dark side of the moon." But how can it not exist? There is a whole album dedicated to it. Well it's true: although there is a part of the moon that we never see from Earth, since it always keeps the same side towards us, the backside isn't dark. It's just the far side of the moon, first seen by human eyes in 1968 thanks to Apollo 8. Half the time the far side is in sunlight and half the time it's not, just like the Earth. Because the moon always keeps one face towards us, if you were at an outpost on that face you would consistently see the earth at the same place in the sky every day all of the time, although the Earth would rotate in front of you and even go through phases like the moon does. But why does it keep the same side toward Earth all the time? In order to do so, it has to revolve exactly one time on its axis for every one time it orbits around the earth, which seems like a remarkable coincidence. It turns out that the moon's rotation is perfectly synchronized with its orbit, but, no, it's not coincidence. It has to do with the moon's mass distribution, and the same force that gives us sea tides on earth. An orbit can be considered as a balance between gravity and centrifugal force. Yes, I said centrifugal force: It's a perfectly valid way to describe the physics, and in this case, it happens to be the simplest. Centrifugal force is pulling the moon out, and gravity is pulling it in. But these forces aren't uniform: Centrifugal force gets stronger as you get further from the center, while gravity gets weaker as you get further from the center. What this means is that the balance is only perfect at the center of the moon: For a piece of moon closer to the earth, the earth's gravity is stronger than the centrifugal force, and for a piece of moon on the far side, the centrifugal force is stronger than the earth's gravity. This effect is referred to as tidal force, and it has the effect of slightly elongating the moon—that is, pulling it into a football shape pointing toward the earth. (I exaggerate, of course.) Tides on the earth work in the same way, which is why there are two tidal bulges on the oceans, one on the side of earth directly beneath the moon, the other on the earth's

The moon's rotation and its orbit around Earth are perfectly synchronized, meaning we only ever see one hemisphere. As this face rotates around the moon's axis, the whole moon is orbiting, too.

far side. Of course, the tides on earth are mostly noticeable on the oceans, since water stretches a lot more easily than rock, but even rock on the moon can be pulled out of place to some extent. Now let's picture a moon that's not perfectly synchronized. It's always trying to stretch out on a line pointing towards and away from the earth, but that line isn't always in the same place. So the distortion is constantly changing as it tries to keep up. This constantly-changing distortion heats up the rock and causes energy to be lost from the rotation. So the moon slows down until it's synchronized. It still feels the effects of tidal distortion, but now the distortion is constant and permanent: The moon is slightly elongated, with its long axis pointing towards and away from the earth. In fact, this is the situation of moons in general: All of the moons in the solar system are synchronized, or tidally locked, with their primary planet, and in the case of Pluto and its moon Charon, the planet is locked to its moon as well. For an even more interesting case, the planet Mercury has what's called a harmonic lock with the sun: Mercury's rotational period is exactly two thirds of its orbital period. This is because Mercury's orbit is very elliptical, as planets go, and a 2/3 ratio lets its permanent elongation line up every orbit when it's closest and the tides are strongest. Lunar motion has a few additional subtleties to it. The period of rotation does exactly match the period of revolution, but that doesn't mean the two are perfectly synchronized. To put it another way, over the course of a month, the speed of the moon's rotation can be considered constant, but its orbital speed can't be. That's because the orbit is slightly elliptical rather than circular, and an orbiting object moves faster the closer it is to the center. So sometimes the rotation leads the revolution by a bit, and sometimes it lags a bit, and the moon appears to wobble by a few degrees in the sky. This may seem like no great shakes, but in fact it results in shakes of fairly substantial proportions: Due to the wobble, called libration, the tidal distortion is still changing and energy is still going into heat in the moon, occasionally causing moonquakes. Currently, this energy is coming from the orbital energy of the moon in such a manner that the orbit is becoming more circular. On our moon, this just causes occasional minor quakes, but it can be much more significant: Because of tidal heating, Jupiter's moon Io is the most volcanically active world in the solar system.

BUT WHY DOES THE MOON KEEP THE SAME SIDE TOWARD EARTH ALL THE TIME? IN ORDER TO DO SO, IT HAS TO REVOLVE EXACTLY ONE TIME ON ITS AXIS FOR EVERY ONE TIME IT ORBITS AROUND THE EARTH, WHICH SEEMS LIKE A REMARKABLE COINCIDENCE.

The moon's regularized rotation is also linked to its phases, or the shapes it takes in the sky. This is also why the tides are associated with lunar phases.

THE EIGHT PHASES OF THE MOON

JERRY COFFEY

There are eight phases of the Moon: new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter, and waning crescent. A lunar phase refers to the appearance of the illuminated portion of the Moon as seen by an observer on Earth. The lunar phases vary cyclically as the Moon orbits the Earth. One half of the lunar surface is always illuminated by the Sun except during a lunar eclipse. The portion of the illuminated hemisphere that is visible to an observer is what varies. The boundary between the illuminated and un-illuminated hemispheres is called the terminator. Each of the eight phases of the Moon is called a syzygy. In basic terms a syzygy happens when three celestial bodies are aligned. In this case it is the Sun, Moon, and Earth. A phase of the moon is caused by observing the illuminated portion from a different perspective, not by a shadow being cast on the Moon by the Earth. The time between the same phase of the Moon is about 29.53 days. 29 days, 12 hours, 44 minutes to be exact. This is called a synodic month. Since the calendar month is 30 days and the synodic month is only 29.53 days, the eight phases of the moon shift slightly from month to month. If you think about the eight moon phases, you might conclude that there should be a solar eclipse and a lunar eclipse every month, since the three bodies line up. As you know this does not happen. The plane of the moon's orbit around the Earth is tilted by about 5 degrees with respect to the plane of Earth's orbit around the Sun. This slight tilting is what prevents the eclipses from happening every month.

1 FULL MOON This is the phase when the moon is brightest in the sky. From our perspective here on Earth, the moon is fully illuminated by the light of the Sun. This is also the time of the lunar month when you can see lunar eclipses—these occur when the moon passes through the shadow of the Earth.

2 WANING GIBBOUS In this phase, the moon is less than fully illuminated, but more than half.

3 LAST QUARTER At this point, the moon has reached half illumination. This time it's the left-hand side of the moon that's illuminated, and the right-hand side in darkness (from a northern hemisphere perspective).

4 CRESCENT This is the final sliver of illuminated moon we can see.

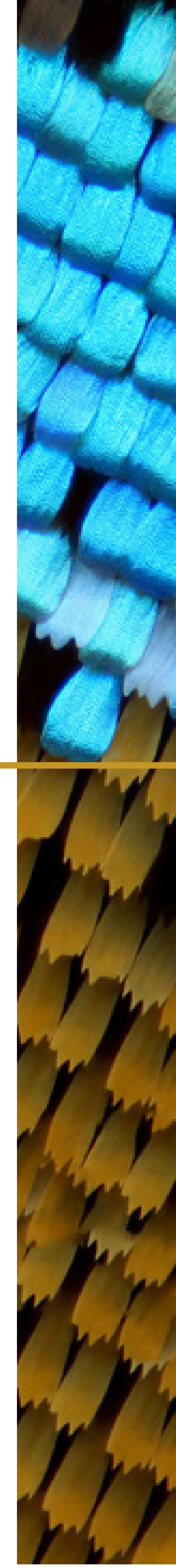
5 NEW MOON When the illuminated side of the moon is away from the Earth. The moon and the Sun are lined up on the same side of the Earth, so we can only see the shadowed side. This is also the time that you can experience solar eclipses, when the moon passes directly in front of the Sun and casts a shadow onto the surface of the Earth. During a new moon, we can also see the reflected light from the Earth, since no sunlight is falling on the moon—this is known as earthshine.

6 CRESCENT The crescent moon is the first sliver of the moon that we can see. From the northern hemisphere, the crescent moon has the illuminated edge of the moon on the right. This situation is reversed for the southern hemisphere.

7 FIRST QUARTER Although this is called a quarter moon, we actually see this phase when the moon is half illuminated. This means that the Sun and moon make a 90-degree angle compared to the Earth.

8 WAXING GIBBOUS This occurs when the moon is more illuminated than half, but it's not yet a full moon.

THE APPEARANCE OF THE MOON IS CAUSED BY EARTH'S RELATIVE PERSPECTIVE, ONE THAT IS ALWAYS IN FLUX



UNDERNEATH THE LENS

ROBB DUNN

photos by PRÜFTECHNIK URI

We fool ourselves most days. We imagine the Earth to be ours, but it belongs to them. We have barely begun to count their kinds. New forms turn up in Manhattan, in backyards, nearly anytime we flip a log. No two seem the same. They would be like extraterrestrials among us, except that from any distance we are the ones who are unusual, alien to their more common ways of life.

As the vertebrate monsters have waxed and waned, the insects have gone on mating and hatching and, as they do, populating every swamp, tree, and patch of soil. We talk about the age of dinosaurs or the age of mammals, but since the first animal climbed onto land, every age has been, by any reasonable measure, the age of insects too. The Earth is salted with their kind.

We know, in part, what makes the insects different. Those other first animals tended to their young, as do most of their descendants, such as birds, reptiles, and mammals, which still bring their young food and fight to protect them. Insects, by and large, abandoned these ancient traditions for a more modern life.

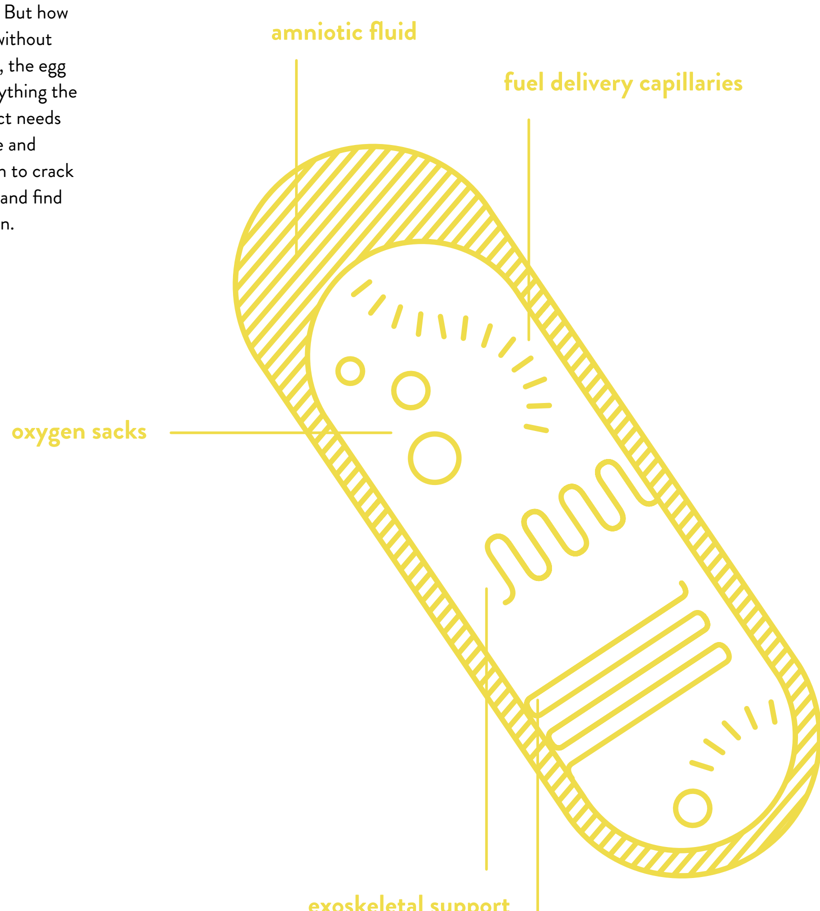
Insects evolved hardened eggs and with them a special appendage, an ovipositor, which some use to sink their eggs into the tissue of Earth. Lift a stone and you will find them. Split a piece of wood, and they are there, but not only there. Birds struggle to find good places to nest, yet insects evolved the ability to make anything—wood, leaves, dirt, water, even bodies (especially bodies)—a nursery. If there is a single feature that has ensured insects' diversity and success, it is the fact that they can abandon their young nearly everywhere and yet have them survive—because of those eggs.

They began simply, smooth and round, but over 300 million years, insect eggs have become as varied as the places where insects reign. Some eggs resemble dirt. Others resemble plants. When you find them, you might not know what you are seeing at first. The forms are unusual and embellished with ornaments and apparatuses. Some eggs breathe through long tubes that they extend up through water. Others dangle from silky stalks. Still others drift in the wind or ride on the backs of flies. They are as colorful as stones, shaded in turquoises, slates, and ambers. Spines are common, as are spots, helices, and stripes.

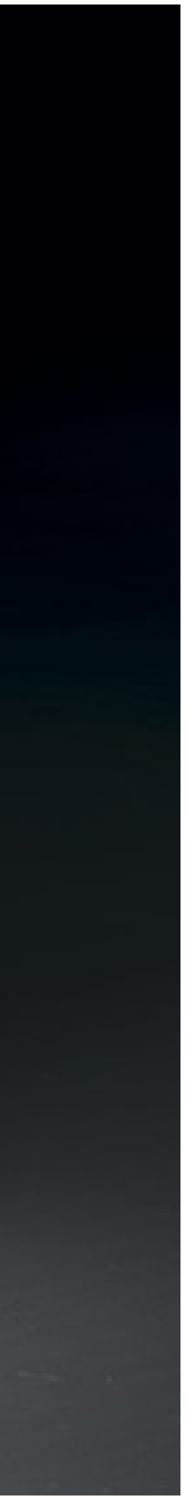
These images were made with a scanning electron microscope, which uses beams of electrons to trace the surfaces of objects. The resulting black-and-white images were then colored to reflect their natural appearance.

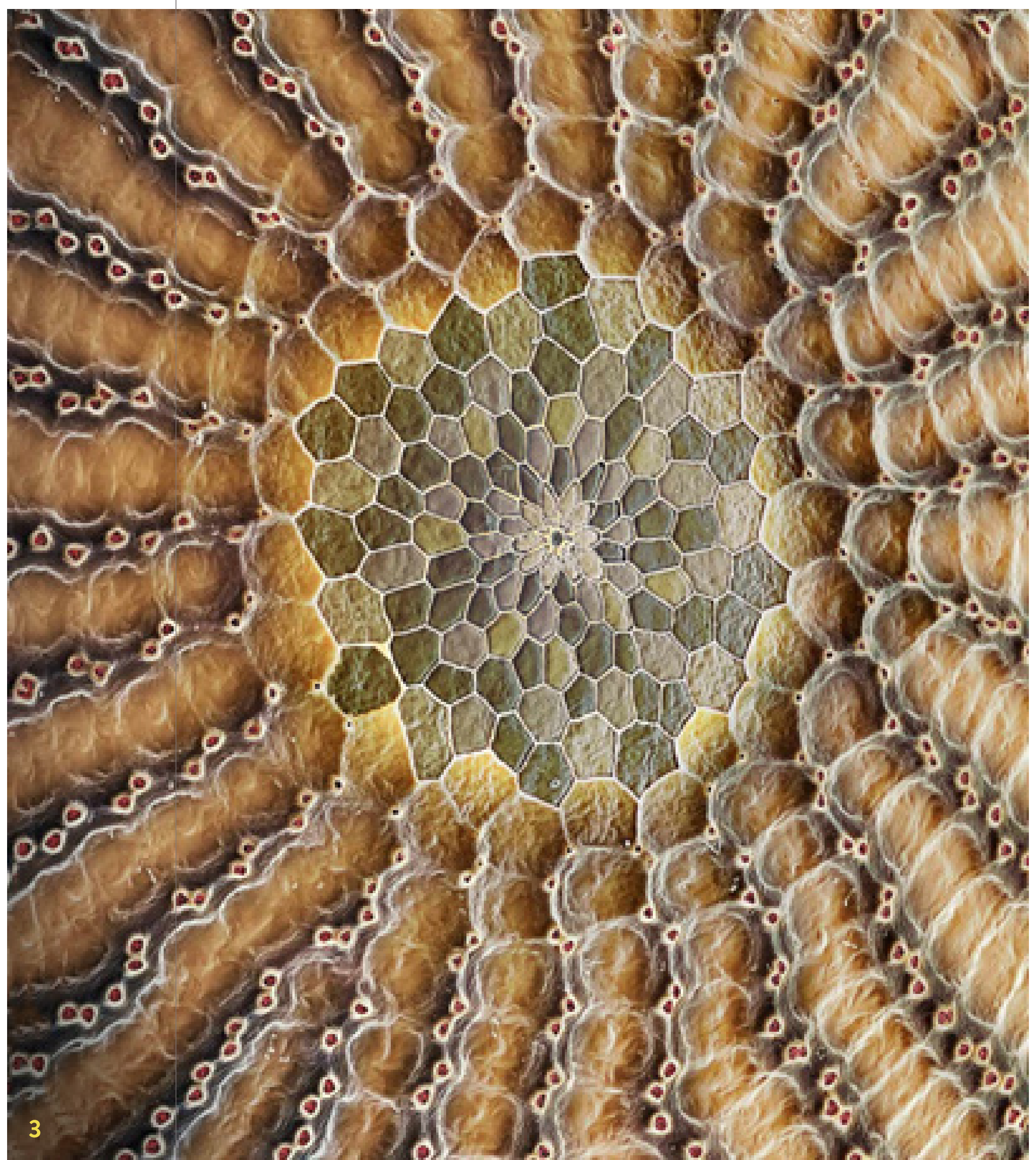
More than biology, their designs suggest the work of an artist left to obsess among tiny forms. They are natural selection's trillion masterpieces; inside each is an animal waiting for some cue to break free. The basic workings of insect eggs, however, like the basics of any egg, are recognizable. The egg develops its shell while still inside the mother. There the sperm must find and swim through an opening at one end of the egg, the micropyle. Sperm wait inside the mother for this chance, sometimes for years. One successful sperm, wearied but victorious, fertilizes each egg, and this union produces the undifferentiated beginnings of an animal nestled inside a womb-like membrane. Here eyes, antennae, mouth parts, and all the rest form. As they do, the creature respires using the egg's aeropyles, through which oxygen diffuses in and carbon dioxide out. That all of this occurs in a structure typically no larger than a grain of raw sugar is simultaneously beyond belief and ordinary. This is, after all, the way in which most animals ever to have lived on Earth had their start. What you see in the accompanying photo gallery are the eggs of a few small branches of the insect tree of life. Among them are those of some butterflies that face extraordinary travails to defend themselves against predators and, sometimes, against plants on which they are laid. Some passionflowers transform parts of their leaves into shapes that resemble butterfly eggs; mother butterflies, seeing the "eggs," move on to other plants to deposit their babies. Such mimics are imperfect, but fortunately so is butterfly vision. Eggs must also somehow escape having the eggs of another type of insect, parasitoids, laid inside of them. Parasitoid wasps and flies use their long ovipositors to thrust their eggs into the eggs and bodies of other insects. Roughly 10 percent of all insect species are parasitoids. It is a well-rewarded lifestyle, punished only by the existence of hyper-parasitoids, which lay their eggs inside the bodies of parasitoids while they are inside the bodies or eggs of their own hosts. Many butterfly eggs and caterpillars eventually turn into wasps as a consequence of this theater of life. Even the dead and preserved eggs shown here are likely to hold mysteries. Inside some are young butterflies, but inside others may be wasps or flies that have already eaten their first supper and, of course, their last. Every so often, and against all odds, a group of insects has regressed a little and decided to care more actively for its young. Here and there we see the evidence. Dung beetles roll dung balls for their babies. Carrion beetles roll bodies. And then there are the roaches, some of which carry their newborn nymphs on their backs. The eggs of these insects have become featureless and round again, like lizard eggs, and in so doing also become more vulnerable and in need of care, like our own young. Yet they survive. Perhaps they are the vanguard of what will come next, the next kingdom beginning to rise. Though perhaps not. Recently I watched a dung beetle rolling a ball, and the ball looked like a rising sun. Above that beetle was a fly trying to lay an egg inside the beetle's head. Insects have been cracking out of eggs for hundreds of millions of years. It is happening now, all around you. If you listen, you can almost hear the crumbling of the shells as tiny feet, six at a time, push into the world.

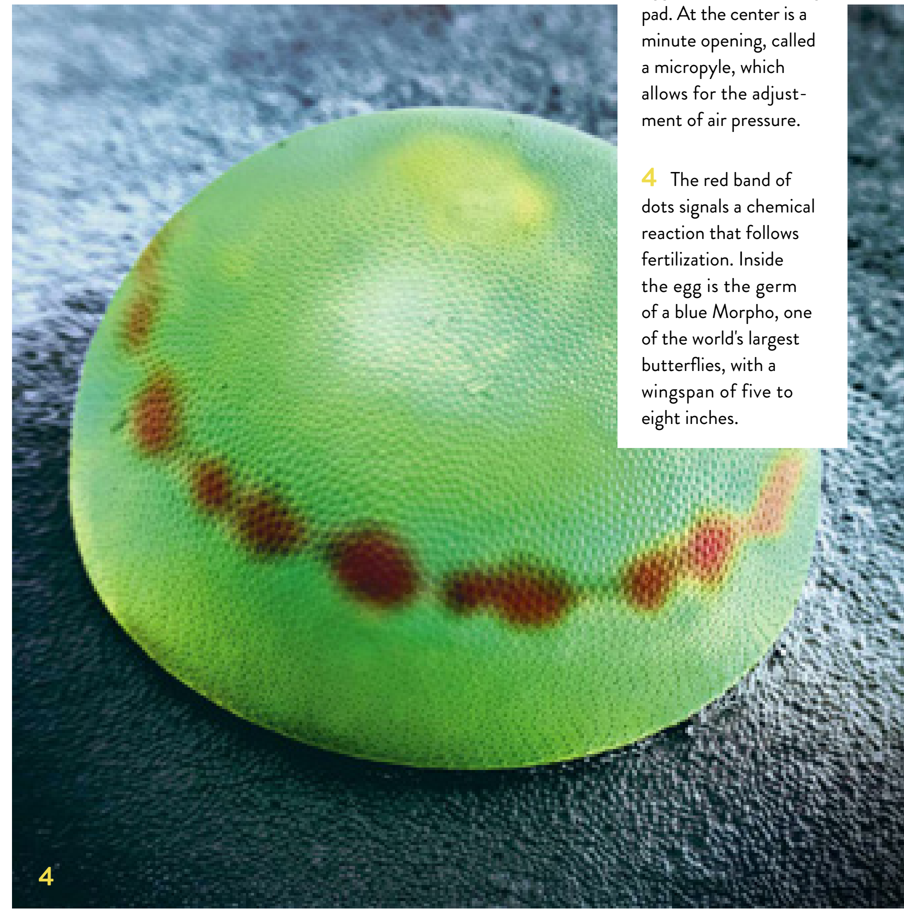
Inside the egg, the insect is growing little by little. But how does it grow without food? Luckily, the egg provides everything the youthful insect needs until it is large and strong enough to crack open its shell and find food of its own.



Perched on the tendril of a Passiflora plant, the egg of the Yellow Heliconian butterfly may be safe from hungry ants. This species lays its eggs exclusively on this plant's twisted vines.





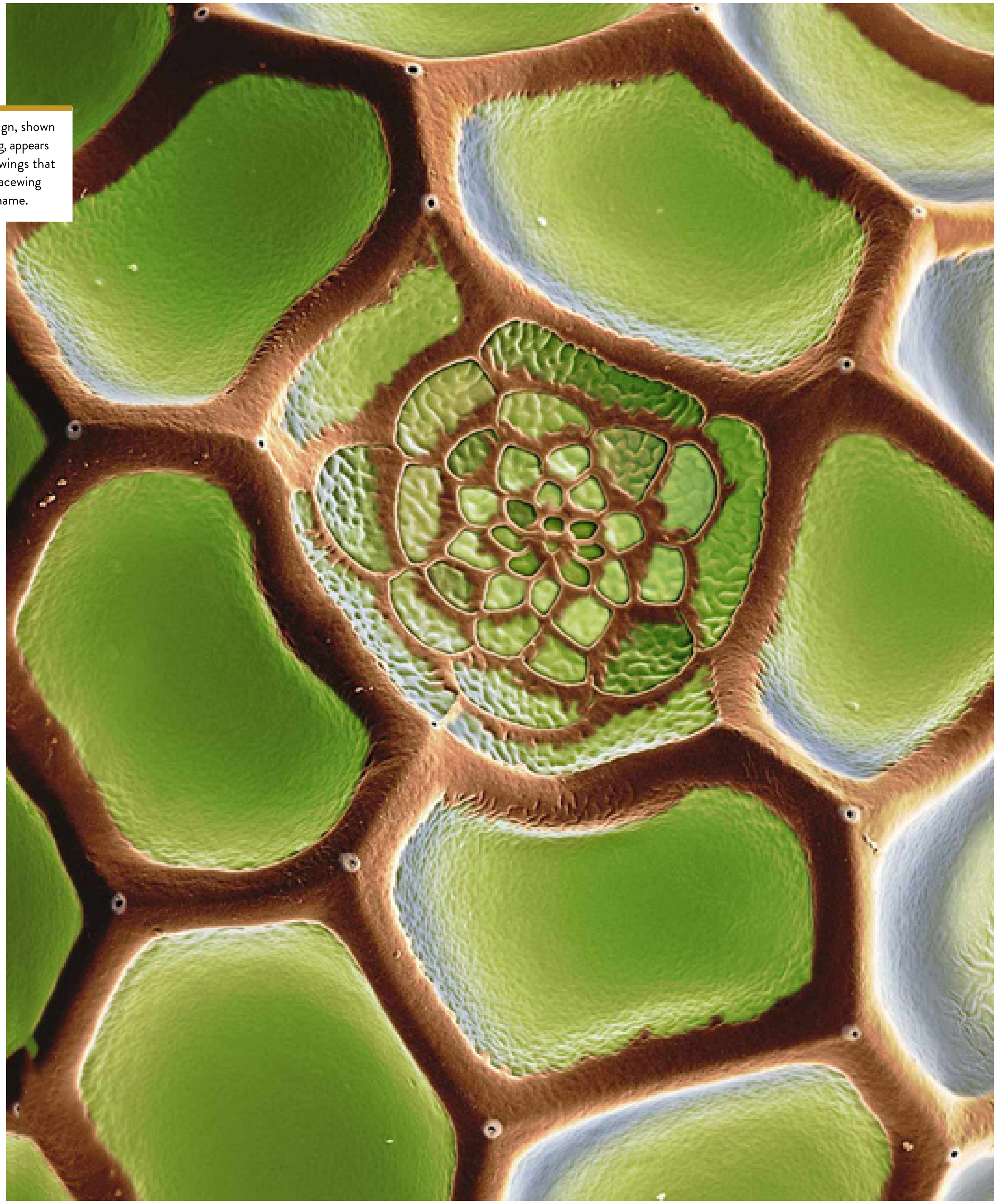


1 The orange hue of this zebra longwing butterfly egg may warn predators: "Eat me if you dare." The threat would not be idle. The egg contains cyanide and other toxins ingested by adults from the plants they eat.

2 Stinkbugs often lay their eggs in clumps. The delicate projections may aid, like snorkels, in respiration.

3 The mosaic pattern on an owl butterfly egg looks like a landing pad. At the center is a minute opening, called a micropyle, which allows for the adjustment of air pressure.

4 The red band of dots signals a chemical reaction that follows fertilization. Inside the egg is the germ of a blue Morpho, one of the world's largest butterflies, with a wingspan of five to eight inches.



A similar design, shown here on an egg, appears on the scaly wings that give the red lacewing butterfly its name.

MATH

HOME BASE

curious about Babylonian counting?
learn more on page 44

KALID MIKEL

Base systems like binary and hexadecimal seem a bit strange at first. The key is understanding how different systems "tick over" like an odometer when they are full. Base 10, our decimal system, "ticks over" when it gets 10 items, creating a new digit. We wait 60 seconds before "ticking over" to a new minute. Hex and binary are similar, but tick over every 16 and 2 items, respectively.

WAY BACK WHEN: UNARY NUMBERS Way back in the day, we didn't have base systems. When someone wanted to count one, he'd write: "I". When he wanted 5, he'd write: "IIIII". And clearly, 1 + 5 = 6: "I + IIIII = IIIIII". This is the simplest way of counting.

ENTER THE ROMANS In Roman numerals, two was one, twice. Three was one, thrice: one = I, two = II, three = III. However, they decided they could do better than the old tradition of lines in the sand. For five, we could use V to represent IIIII and get something like: I + V = VI. And of course, there are many more symbols (L, C, M) that can be employed. The key point is that V and IIIII are two ways of encoding the number 5.

A NAME, NOT A NUMBER Another breakthrough was realizing that each number can be its own distinct concept. Rather than represent three as a series of ones, we give it its own symbol: "3". Do this from one to nine, and you get the symbols: 1, 2, 3, 4, 5, 6, 7, 8, 9. The Romans were close, so close, but only gave unique symbols to 5, 10, 50, 100, and 1000.

USE YOUR POSITION Now clearly, not every number can have its own symbol; there's simply too many. But notice one insight about Roman numerals: they use the position of the symbols to indicate meaning: IV means "subtract 1 from 5", and VI means "add 1 to 5". In our number system, we use position in a similar way. We always add and never subtract. And each position is 10 more than the one before it. So, 35 essentially means "add 3 x 10 to 5 x 1" and 456 means "4 x 100 + 5 x 10 + 6 x 1".

OUR CHOICE OF BASE 10 If we want to roll the odometer over every 10, so to speak, we need symbols for numbers one through nine; we haven't reached ten yet. Imagine numbers as ticking slowly upward—at what point do you flip over the next unit and start from nothing? For our current number system, this threshold is 10, hence its name of base 10. Why did we choose to multiply by 10 each time? Most likely because we have 10 fingers. Not all civilizations have used base 10, though. The Mayans used a base of 20, the Egyptians 12, the Babylonians 60, and a number of Native American tribes used bases of four or eight. Each system has its advantages and disadvantages. Most numerical systems are surmised to have been established by using ones fingers, or digits, to count, in varying ways.

the base 60 Babylonian numeral system

The Babylonians used ones like tallies to count. However, they tended to arrange the symbols into neat piles. Once they got to ten, they turned the stylus on its side to make a different symbol.

finger binary counting

ENTER ZERO What happens when we reach ten? How do we show we want exactly one "ten" and nothing, in the "ones" column? We use zero, the number that doesn't exist. Zero is quite a concept, it's a placeholder, a blank, a space, and a whole lot more. Suffice it to say, zero is one of the great inventions of all time. Zero allows us to have an empty placeholder, something the Romans didn't have. Look how unwieldy their numbers are without it: George Orwell's famous novel "1984" would be "MCMLXXXIV". In the same way that several ancient civilizations used different bases than we do today, many of them also had different constructs for the concept of zero, or they simply got around having to use it, using an empty space as a placeholder.

CONSIDERING OTHER BASES We roll over our odometer every ten, so our counting looks like this: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10—now it's "ticked over " and time to start a new digit. What if we ticked over at 60 when we counted, like we do for seconds and minutes? 1 second, 2, 3, 4, 5...58, 59, 1:00—60 seconds, or 1 minute. We've started a new digit. Note that we use the colon indicate that we are at a new "digit". In base 10, each digit can stand on its own. If we want base 16, we could do something similar: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 1:00 (16)—we've started a new digit. However, we don't want to write hexadecimal numbers with the colon notation (even though we could). We'd rather cook up separate symbols for 10-15 so we can just write numbers like we're used to. We've run out of numbers (1-9 already used, with 0 as a placeholder) so we need some other symbols. We could use some squiggly lines or other shapes, but the convention is to use letters, Roman style. Just like 5 became V, programmers use letters A-F to get enough digits up to 16. That is: 1, 2, 3, 4, 5, 6, 7, 8, 9, A (10), B (11), C (12), D (13), E (14), F (15), 10 (16—we start a new digit). Now we can use one digit per "place", and we know that 10 actually means we've "ticked over to 16" once. 20 means we've ticked over to 16 twice (32). 25 means we've ticked over to 16 twice (giving us 32) and gone an extra 5. The total is 32 + 5 = 37. Also notice that base 16 is more "space efficient" in the sense we can write a number like 11 in a single digit: B. Base 16 really isn't that different from base 10, it just takes longer to "tick over".

THE WONDERFUL WORLD OF BINARY There are plenty of base systems, from over-simple unary, to the unwieldy Roman numerals, the steady-going base 10 and the compact base 16. What's great about binary? In the spirit of keeping things simple, it's the simplest number system that has the concept of "ticking over". Unary, where we just write I, II, III...just goes on forever. Binary, with two options, 1 and 0, looks like this: 1 (1), 10 (2), 11 (3), 100 (4), 101 (5), 110 (6), 111 (7), 1000 (8). Every time a new placeholder digit is added, it is because the previous one "filled up", or had a 1, in place of a zero, since there are only 1s and 0s in binary base. Because binary is so simple, it's very easy to build in hardware. It just need things that can turn on or off (representing 1 and 0), rather than things that have 10 possible states, like our base 10.

EVERYDAY BASES We use other bases all the time, even dynamically changing bases, like hours, minutes, and seconds: 1:32:04. We know this is 1 hour, 32 minutes, 4 seconds. In just seconds, this is 1 x 60 x 60 + 32 x 60 + 4 seconds. Then there are feet and inches: 3' 5". This is 3 feet, 5 inches or 3 x 12 + 5 inches. Pounds and ounces, too: 8 pounds, 5 ounces. Since a pound is 16 ounces, this is 8 x 16 + 5 ounces. Turns out we've been using a base 16 number system all along, just not every digit was getting its own character.

10 IS THE BASE OF ALL BASES "10" in any number system indicates the base, and means its "ticked over" once. 10 in binary means two, 10 in decimal means ten, and 10 in hexadecimal is sixteen.

HOW TO KEEP ALL THESE NUMBERS APART? Programmers will often write "0b" in front of binary numbers. So 2 in binary is 0b10. Similarly, they'll write 0x in front of hex numbers. So 16 in hex is: 0x10. If there aren't any symbols (0b or 0x) in front, its safe to assume it's base 10, a regular number, at least according to our current numeration system. If you're an ancient Babylonian, you might have another idea. ◼

In the binary number system, each numerical digit has two possible states (0 or 1) and each successive digit represents an increasing power of two. Finger binary is a system for counting and displaying binary numbers up to 31, using the fingers of a single hand. A raised finger represents a binary digit in the "1" state and a lowered finger to represent it in the "0" state. Each successive finger represents a higher power of two.

TELLING TIME THE EGYPTIAN WAY

JACOBINA CZEN

THE 24-HOUR DAY ISN'T QUITE AS ARBITRARY AS IT MIGHT AT FIRST SEEM

In today's world, the most widely used numeral system is commonly referred to as decimal, also known as base 10, a system that probably originated because it made it easy for humans to count using their fingers. The civilizations that first divided the day into smaller parts, however, used different numeral systems, specifically duodecimal (base 12) and sexagesimal (base 60).

Thanks to documented evidence of the Egyptians' use of sundials, most historians credit them with being the first civilization to divide the day into smaller parts. The first sundials were simply stakes placed in the ground that indicated time by the length and direction of the resulting shadow. As early as 1500 BC, the Egyptians had developed a more advanced sundial. A T-shaped bar placed in the ground, this instrument was calibrated to divide the interval between sunrise and sunset into 12 parts. This division reflected Egypt's use of the duodecimal system—the importance of the number 12 is typically attributed either to the fact that it equals the number of lunar cycles in a year or the number of finger joints on each hand (three in each of the four fingers, excluding the thumb), making it possible to count to 12 using the thumb as a kind of pointer to these joints on the palm side. The next-generation sundial likely formed the first representation of what we now call the hour. Although the hours within a given day were approximately equal, their lengths varied during the year, with summer hours being much longer than winter hours.

Without artificial light, humans of this time period regarded sunlit and dark periods as two opposing realms rather than as part of the same day. Without the aid of sundials, dividing the dark interval between sunset and sunrise was more complex than dividing the sunlit period. During the era when sundials were first used, however, Egyptian astronomers also first observed a set of 36 stars that divided the circle of the heavens into equal parts. The passage of night could be marked by the appearance of 18 of these stars, three of which were assigned to each of the two twilight periods when the stars were difficult to view. The period of total darkness was marked by the remaining 12 stars, again resulting in 12 divisions of night, another nod to the duodecimal system. During the New Kingdom (1550 to 1070 BC), this measuring system was simplified to use a set of 24 stars, 12 of which marked the passage of the night. The *clepsydra*, or water clock, was also used to record time during the night, and was perhaps the most accurate timekeeping device of the ancient world. The timepiece—a specimen of which, found at the Temple of Ammon in Karnak, dated back to 1400 BC—was a vessel with slanted interior surfaces to allow for decreasing water pressure, inscribed with scales that marked the division of the night into 12 parts during various months.

Once both the light and dark hours were divided into 12 parts, the concept of a 24-hour day was in place. The concept of fixed-length hours, however, did not originate until the Hellenistic period, when Greek astronomers began using such a system for their theoretical calculations. Hipparchus, whose work primarily took place between 147 and 127 BC, proposed dividing the day into 24 equinoctial hours, based on the 12 hours of daylight and 12 hours of darkness observed on equinox days. Despite this suggestion, laypeople continued to use seasonally varying hours for many centuries. Hours of fixed length became commonplace only after mechanical clocks first appeared in Europe during the 14th century.

Hipparchus and other Greek astronomers employed astronomical techniques that were previously developed by the Babylonians, who resided in Mesopotamia. The Babylonians made astronomical calculations in the sexagesimal (base 60) system they inherited from the Sumerians, who developed it around 2000 BC. Although it is unknown why 60 was chosen, it is notably convenient for expressing fractions, since 60 is the smallest number divisible by the first six counting numbers as well as by 10, 12, 15, 20 and 30.

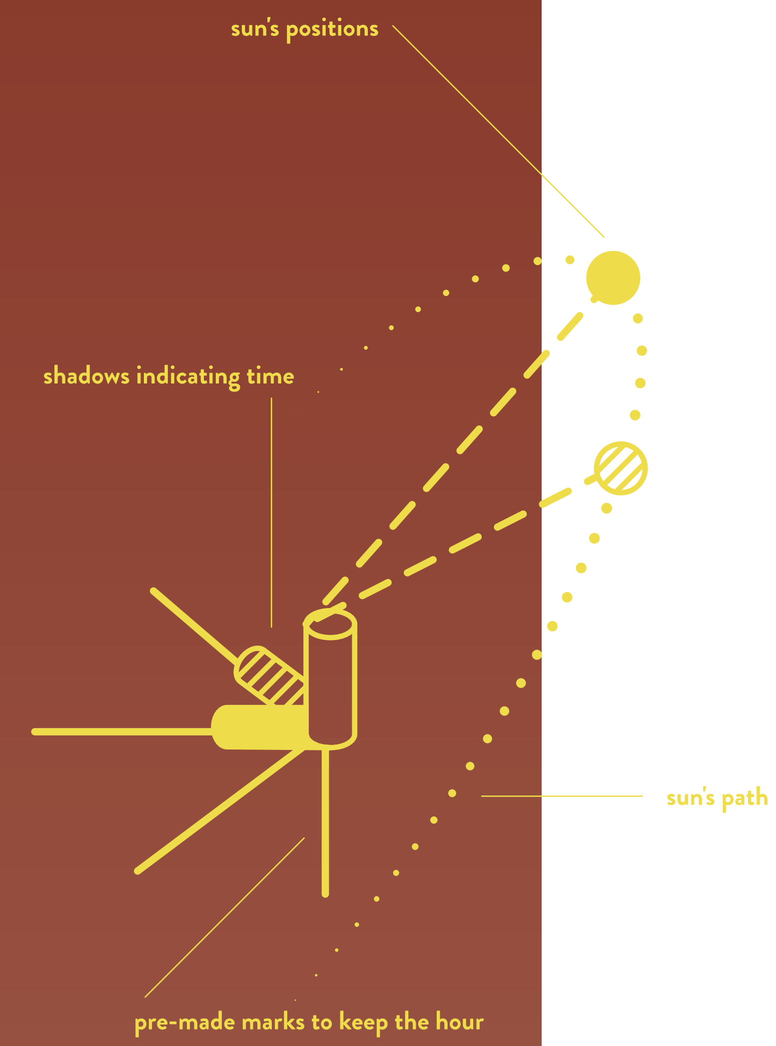
Although it is no longer used for general computation, the sexagesimal system is still used to measure angles, geographic coordinates, and time. In fact, both the circular face of a clock and the sphere of a globe owe their divisions to a 4,000-year-old numeric system of the Babylonians.

The Greek astronomer Eratosthenes who lived 276 to 194 BC, used a sexagesimal system to divide a circle into 60 parts in order to devise an early geographic system of latitude, with the horizontal lines running through well-known places on the earth at the time. A century later, Hipparchus normalized the lines of latitude, making them parallel and obedient to the earth's geometry. He also devised a system of longitude lines that encompassed 360 degrees and that ran north to south, from pole to pole. Claudius Ptolemy later explained and expanded on Hipparchus' work by subdividing each of the 360 degrees of latitude and longitude into smaller segments. Each degree was divided into 60 parts, each of which was again subdivided into 60 smaller parts. The first division, *partes minutae primae*, or "first minute", became shortened to just the "minute." The second segmentation, *partes minutae secundae*, or "second minute," became known as the "second".

Minutes and seconds, however, were not used for everyday timekeeping until many centuries after the Almagest. Clock displays divided the hour into halves, thirds, quarters and sometimes even 12 parts, but never by 60. In fact, the hour was not commonly understood to be the duration of 60 minutes. It was not practical for the general public to consider minutes until the first mechanical clocks that displayed minutes appeared near the end of the 16th century. Even today, many clocks and wristwatches have a resolution of only one minute and do not display seconds.

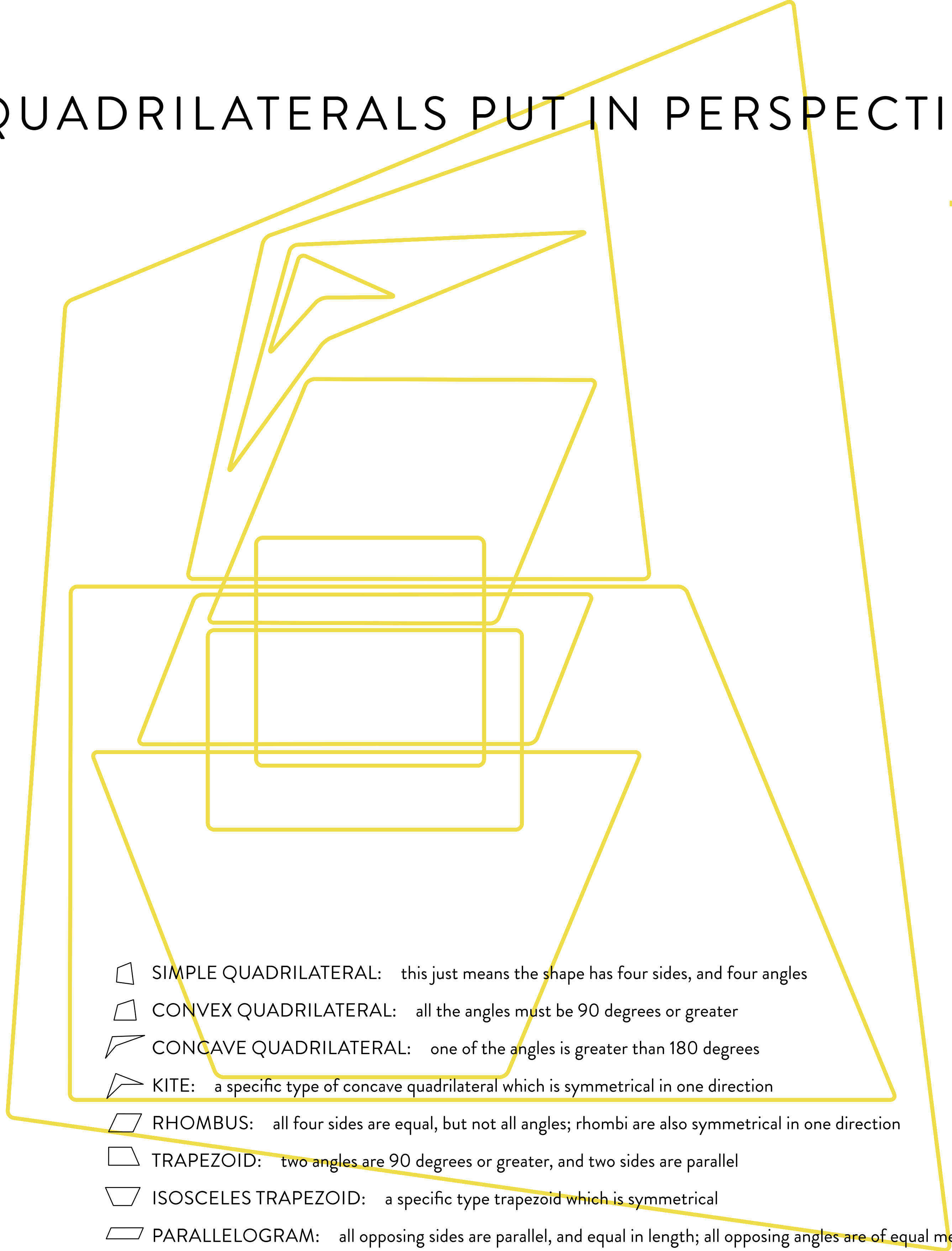
Thanks to the ancient civilizations that defined and preserved the divisions of time, modern society still conceives of a day of 24 hours, an hour of 60 minutes and a minute of 60 seconds. Advances in the science of timekeeping, however, have changed how these units are defined. Seconds were once derived by dividing astronomical events into smaller parts, with the International System of Units (SI) at one time defining the second as a fraction of the mean solar day and later relating it to the tropical year. This changed in 1967, when the second was redefined as the duration of 9,192,631,770 energy transitions of the cesium atom. This re-characterization ushered in the era of atomic timekeeping and Coordinated Universal Time (UTC).

Interestingly, in order to keep atomic time in agreement with astronomical time, leap seconds occasionally must be added to UTC. Thus, not all minutes contain 60 seconds. A few rare minutes, occurring at a rate of about eight per decade, actually contain 61.

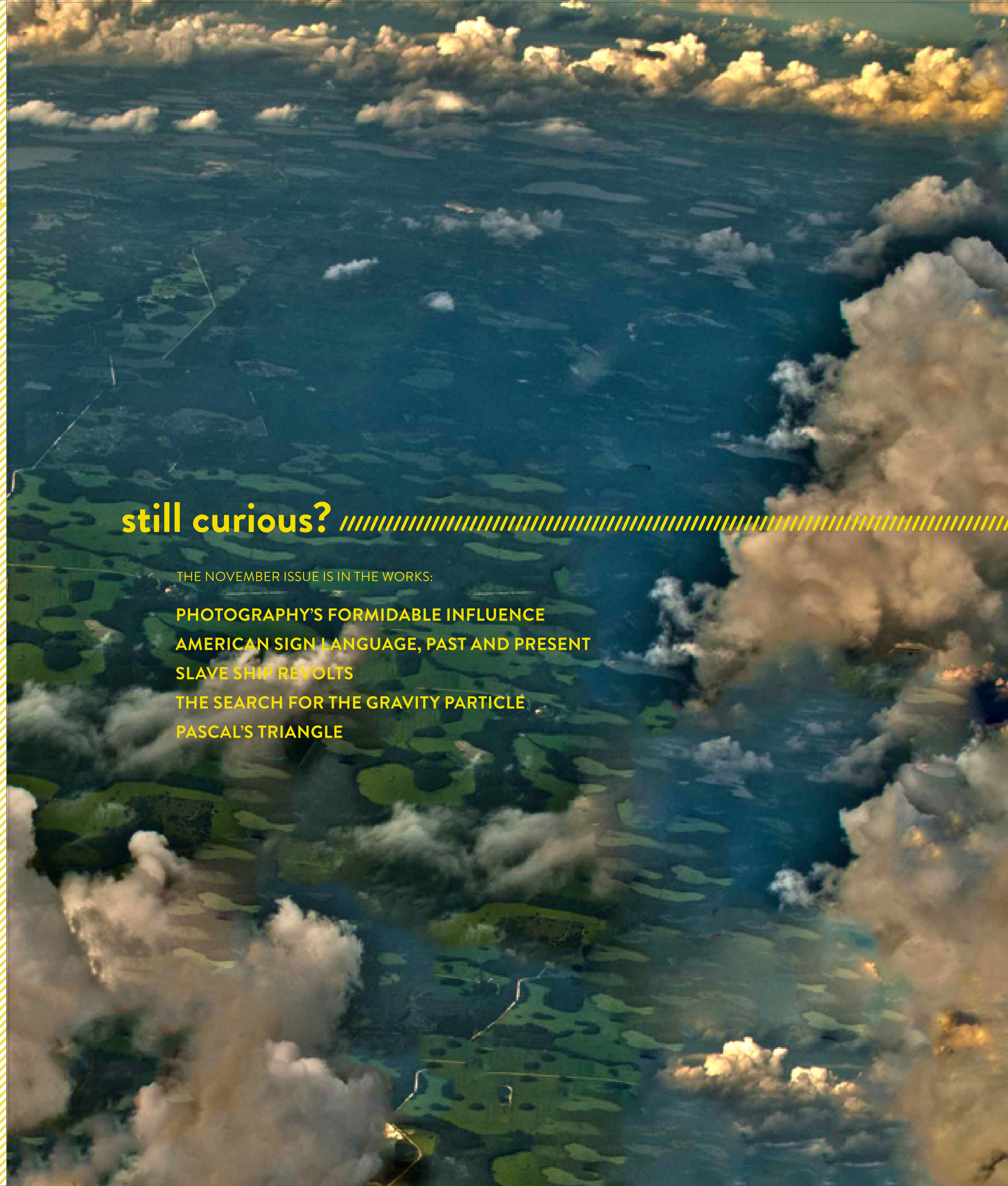


QUADRILATERALS PUT IN PERSPECTIVE

You are probably aware that a square is a rectangle, but not all rectangles are squares. But what do you know about quadrilateral categories beyond that? This visual Venn diagram will provide you with everything you need to know about these four-sided figures, so central to the field of geometry, and to modern life in general. The more you look, the more you'll find these structurally significant shapes.



- SIMPLE QUADRILATERAL: this just means the shape has four sides, and four angles
- CONVEX QUADRILATERAL: all the angles must be 90 degrees or greater
- CONCAVE QUADRILATERAL: one of the angles is greater than 180 degrees
- KITE: a specific type of concave quadrilateral which is symmetrical in one direction
- RHOMBUS: all four sides are equal, but not all angles; rhombi are also symmetrical in one direction
- TRAPEZOID: two angles are 90 degrees or greater, and two sides are parallel
- ISOSCELES TRAPEZOID: a specific type trapezoid which is symmetrical
- PARALLELOGRAM: all opposing sides are parallel, and equal in length; all opposing angles are of equal measure
- RECTANGLE: a specific type of parallelogram in which all angles are exactly 90 degrees
- SQUARE: a specific type of rectangle in which all sides are of equal length



still curious?

THE NOVEMBER ISSUE IS IN THE WORKS:

PHOTOGRAPHY'S FORMIDABLE INFLUENCE
AMERICAN SIGN LANGUAGE, PAST AND PRESENT
SLAVE SHIP REVOLTS
THE SEARCH FOR THE GRAVITY PARTICLE
PASCAL'S TRIANGLE

perspective

noun \ pêr · ˋspek · tiv \

from Latin *perspectus*, past participle of *perspicere*: to inspect, see clearly

1 *a* : the technique or process of representing on a plane or curved surface the spatial relation of objects as they might appear to the eye
b : the relation of two figures in the same plane, such that pairs of corresponding points lie on concurrent lines, and corresponding lines meet in collinear points

2 *a* : a view over some span in space or time; especially one giving a distinctive impression of distance : VISTA

3 *a* : the interrelation in which a subject or its parts are mentally viewed [places the issues in proper ~] : POINT OF VIEW
b : true understanding of the relative importance of things : A SENSE OF PROPORTION
c : a particular attitude toward or way of regarding something : FRAME OF REFERENCE