TIME TO LEARN

ABOUT TIME

Dom Massaro and Don Rothman

Illustrated by Bill Rowe

A Fuzzy Book Production

Time to Learn About Time

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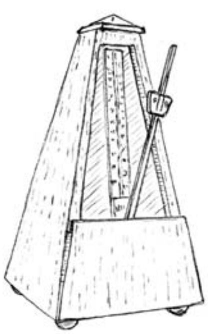
Chapter 1

Time and Its Measurement

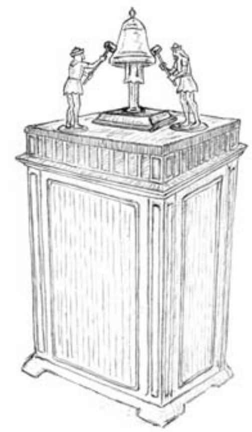


Chapter 2

The Importance of Time Keeping

Chapter 3

Early Timepieces



Chapter 4

More Recent Timepieces

Chapter 5

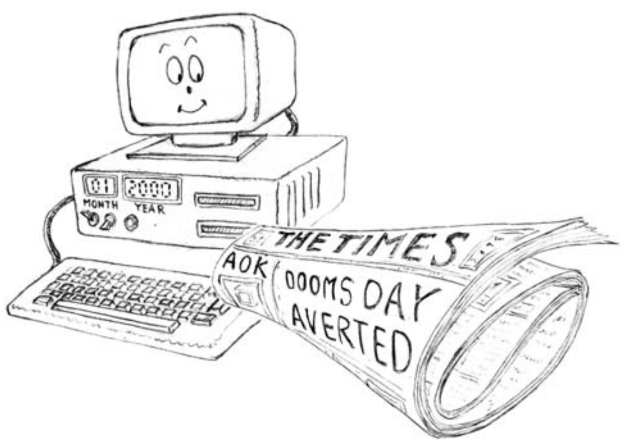
The Many Faces of Clocks

Chapter 6

The Value of Analog Clocks

Chapter 7

The Kid Klok



Chapter 8

The Future of Time

One: Time and Its Measurement

An Old Proverb

I look and I see.
I listen and I hear.
I do and I understand.

In this book you will have fun looking, listening, and doing to help you see, hear, and understand time.

An Old (Wordy) Relationship with Time

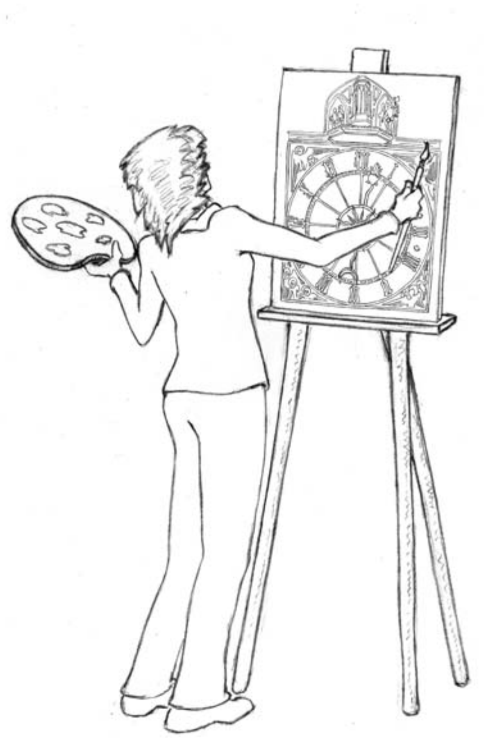
We begin our exploration of time with the Greek word *chronikos* (pronounced kro-ne-kos). Cronus was the Greek god of agriculture, often depicted with his scythe for harvesting grain. Eventually he became known as Chronos, the god of time, sometimes called Father Time. His scythe has come to symbolize the cutting, or reaping, of the passing years.

Throughout this book you will encounter English words whose origins in Greek and Latin reveal interesting aspects of our subject, time. For example, chronometer means clock, a device for measuring time.

Our Interest in Time

Our interest in time centers around the scientist's impulse and need to understand it, the artist's desire to represent its mysteries, and the engineer's ingenuity to build mechanisms to measure it.


The scientist


The artist

The engineer

Measuring Time and Time Periods

Scientists, artists, and engineers often grapple with hard problems by measurement and imagination. Chronology (chro-no-lo-gy) is the scientific study of time, although the word has come to mean the order of events in time. Time is measured by steps or equal periods. Can you think of any games that require the measurement of time? What about *Hide and Go Seek* or *soccer*?

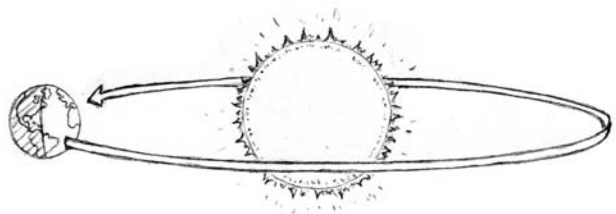
We can divide time into different parts, called periods. A period of time can correspond to some physical event. For example, a day is equal to the time it takes for the earth to rotate around its axis once. Here is a list of time periods, along with the physical event that each period measures.

Table of Time Periods

Period	**Measure**
Year	One complete revolution of the earth around the sun
Month	One complete revolution of the moon around the earth
Day	One complete rotation of the earth around its axis

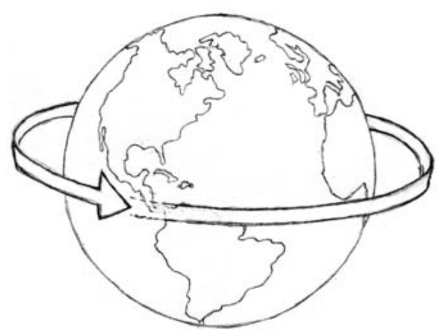
Visualizing Time Periods

One year
One complete revolution of
the Earth around the sun



One month
One complete revolution of
the moon around the Earth.

One day
One complete rotation
of the Earth around its axis



Making new units of time

We can add these units of time together to define new units. Seven days make a week. We can also divide a unit to define smaller units. For example, an hour is a part of a day.

Period	Measure
Week	Seven days
Hour	1/24th of a day; a day has 24 hours.
Minute	1/60th of an hour; an hour has 60 minutes.
Second	1/60th of a minute; a minute has 60 seconds.

The Hours and Minutes of a Day

Days are very familiar to us. We wake up, eat, play, study, and go to sleep. The next day is more or less like the previous one. As you know, however, your activities change with the time of day, and weekdays differ from weekends.

A long time ago, days were broken up into smaller periods to help remind people when various activities took place.

We call parts of the day hours. The word hour (in Latin, *hora*) used to mean the time for daily prayer (*orison*). We call parts of the hour minutes. The word minute means a small part.

The Earth's Time Zones

You may know that your friend across the country lives in a different time zone from you. When you call you have to remember that it may be earlier or later where she is. Can you guess why there are 24 time zones? What about the 24-hour day?

Picturing the earth

Our Earth
is round

but we can
flatten it.

Two: The Importance of Time Keeping

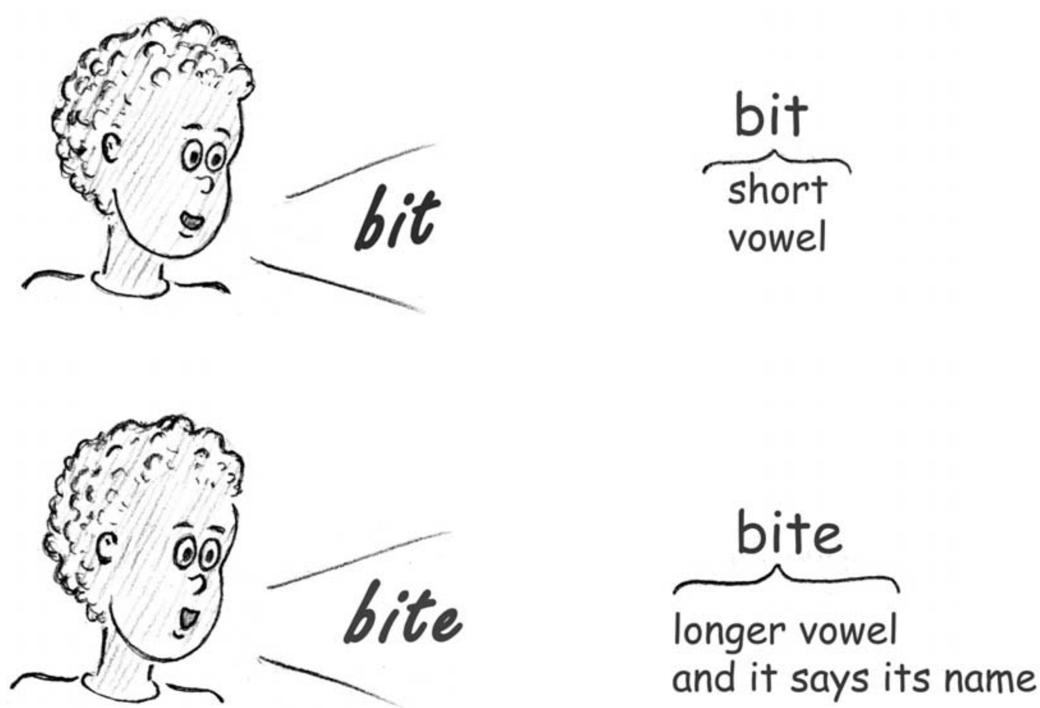
Long and Short Vowels

Our individual and social lives depend on our ability to perceive and monitor time. Time keeping is particularly important in language and music. As every young child learning to read discovers, our vowels are pronounced as long or short. We have similar words like *hop* and *hope*.

Say these two words to yourself or out loud. Can you tell the difference between them? The vowel takes less time to say in *hop* than in *hope*. Can you hear this time difference?

Learn the Rule

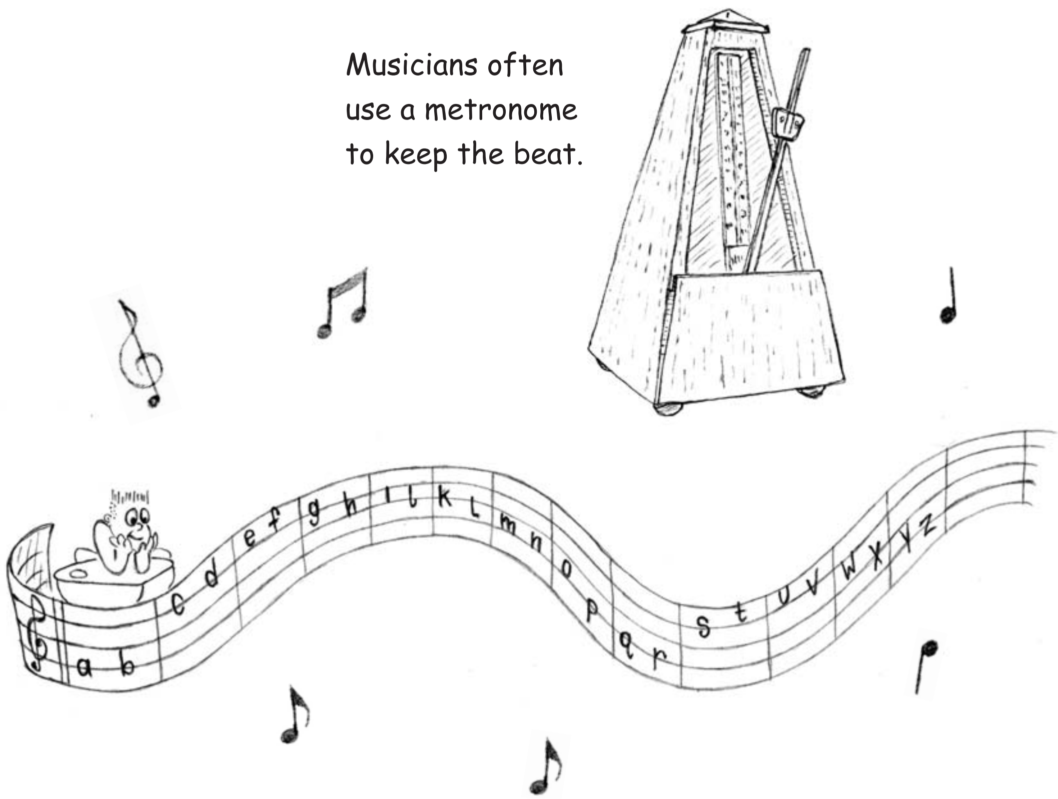
Reading is easier when we know this rule, and using it requires us to have a sense of time: "When the word ends in the letter e, the preceding vowel says its name. Otherwise the vowel is pronounced as short." What works for *hop* and *hope* also works for other words. Try the pairs *bit* and *bite*. Notice that it takes less time to say *bit* than to say *bite*.



Can you pronounce *rod* and *rode*? What about *cut* and *cute*? Can you think of other pairs? Can you figure out a way to measure the time difference between words with short and long vowels?

Time and Music

Music would be a bore without time. It uses time to organize notes into separate groups. Even singing your ABCs would be impossible without a sense of timing or rhythm.

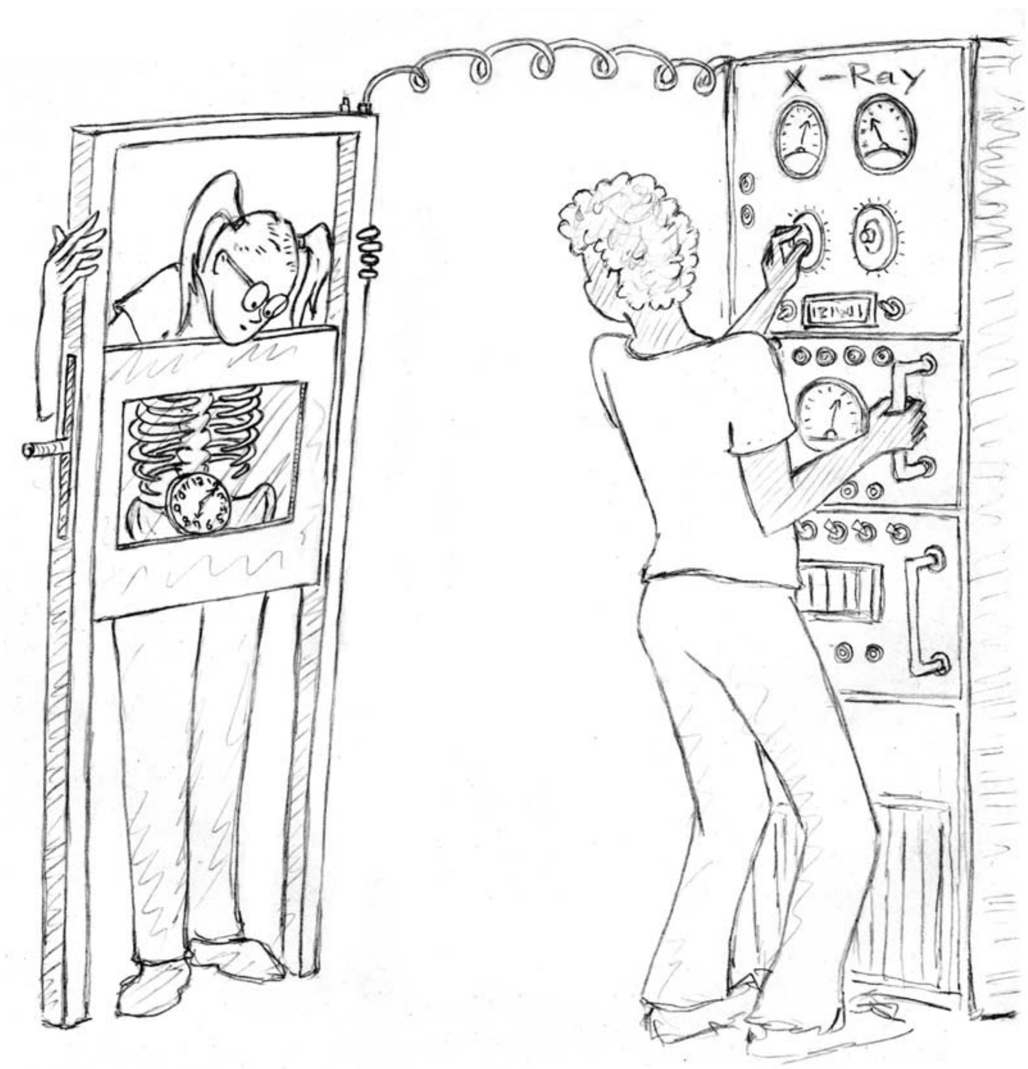


e f t u
c d g...... s.. v...
h i w
j k x
l m n o y
a b p...... q r z

Why didn’t our parents and teachers simply have us learn the letters of the alphabet, rather than embedding them in this crazy melody? Surely, they didn’t do it to instill a love of music. Rather, they knew that putting the letters in a song would make them easier to learn. As a result, our memory for the alphabet will always be linked to our memory for the song.

People Clocks

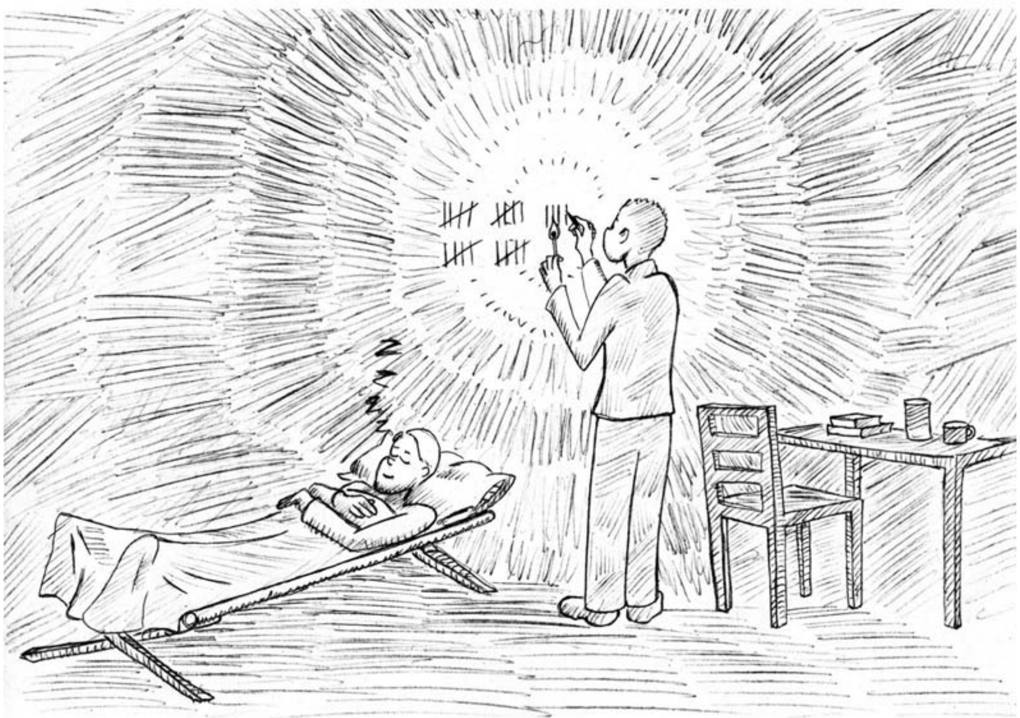
A dictionary defines clock as a device for indicating or measuring time. We usually think of clocks as artifacts, built with mechanical or electronic parts. As suggested by the title of this section, however, clocks can be made *of* rather than *by* people.



It might surprise you to learn that each of us comes wired with our own internal clock. We learned this from an interesting experiment.

Cave Dwellers

In a famous experiment, Nathaniel Kleitman and Bruce Richardson lived in a large room in Mammoth Cave, Kentucky. All of us live a 24-hour day, but they made their artificial world run on a 28-hour day. This means that the next day would not start until 28 hours after the start of the previous day. The lights and their daily activities in the cave were completely controlled to correspond to a 28-hour day. To try to accommodate, they slept for nine hours and stayed awake for the other 19 hours. Scientists wondered if they would easily adjust to this new stretched-out day. Would living a 28-hour day be like living a 24-hour day? Would they be hungry and eat heartily at meal time, sleep soundly, and generally feel OK?

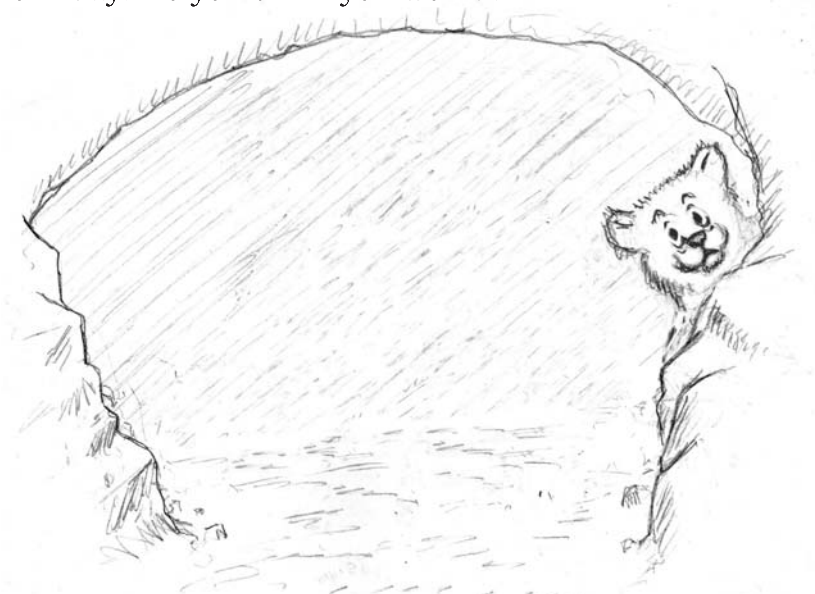


After 32 days in the cave, it was clear that Richardson had easily adapted to the new schedule. Kleitman had not. He had trouble sleeping at night, was tired during the day, and simply felt weird. Have you ever traveled a long way and felt jet-lagged? If so, you know what is was like for Kleitman.

Cave Living

One experiment barely starts the ball rolling in scientific inquiry. Our story necessarily builds on follow-up investigations. In new experiments designed to further our understanding of internal clocks, people were left to determine their own schedules. Try to imagine living in a world with no day-night cycle or other regular changes in your life. Would you behave any differently?

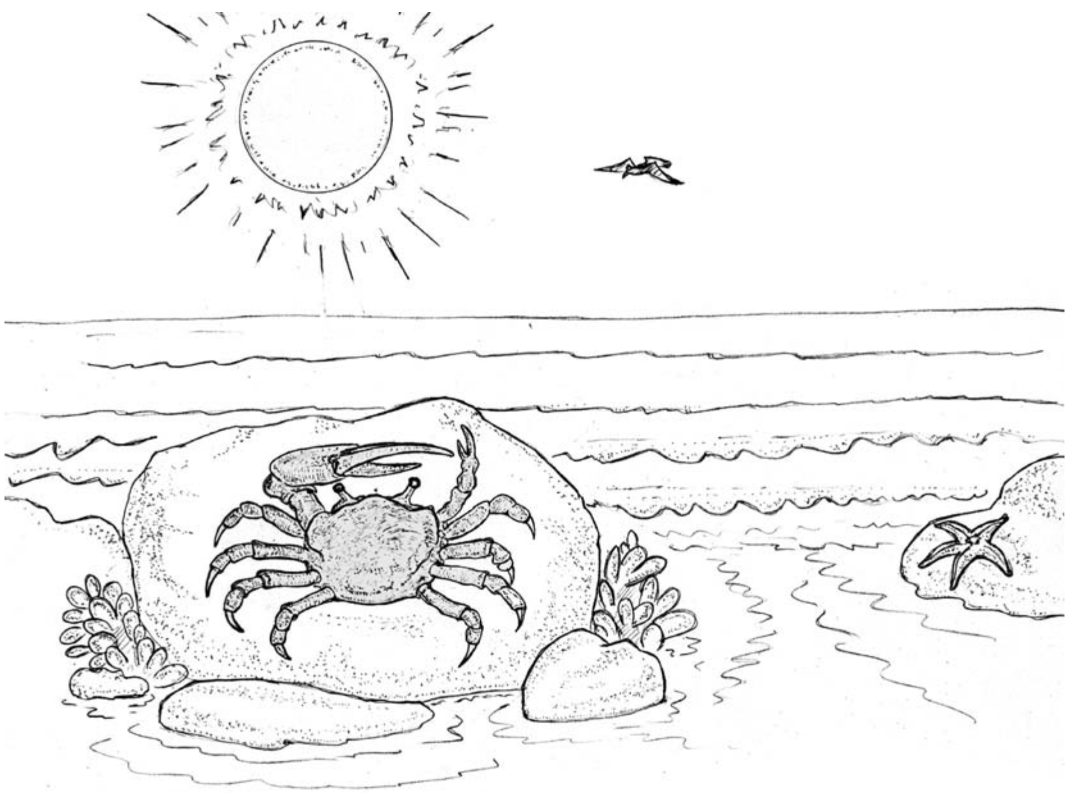
To make this imaginary situation real, some men were paid to live in a cave with a constant artificial light. They were told to behave as they wished. The scientists who did this experiment wanted to know whether these people would continue to live a typical 24-hour day. Do you think you would?



There was no reason to wake up and go to sleep once every 24 hours. They could stay up as late as they wished. It turned out, however, that these men, and many people tested in similar situations since then, lived, more or less, a normal 24-hour day. We appear to have a built-in circadian (sir-kay-dee-in) clock. Circadian means a day-night cycle. We continue to live according to a normal day-night cycle even though our outside world gives no clues about day and night (even with constant light and even if our parents don't tell us to go to bed). Although we appear to have an internal day-night clock, it is not necessarily a clock that runs exactly on a 24-hour cycle. Richardson, in the first experiment, easily lived a 28-hour day. Some people's cycles are actually less than 24 hours. The average person has about a 25-hour cycle.

Fiddler Crabs

Other animals have even more dramatic internal clocks. The astonishing fiddler crab is found in the salt marshes along the Massachusetts shore.



If you stumble onto this crab during the day, you will see its dark greenish-brown skin. When the sun sets, its skin color changes to a pale brown. The darker color during the daylight provides the fiddler crab's sunscreen. Can you spot these differences in the two pictures?

Scientists realized that the crab's color changes might be governed by the sun itself rather than an internal clock. To distinguish between these two possible explanations, they housed a school of crabs in a laboratory darkroom.

You guessed it! These lab crabs continued to change color at the appropriate time even though they didn't have the benefit of the day/night cycle of their natural environment. Like us, fiddler crabs have an internal timekeeper.

Bears

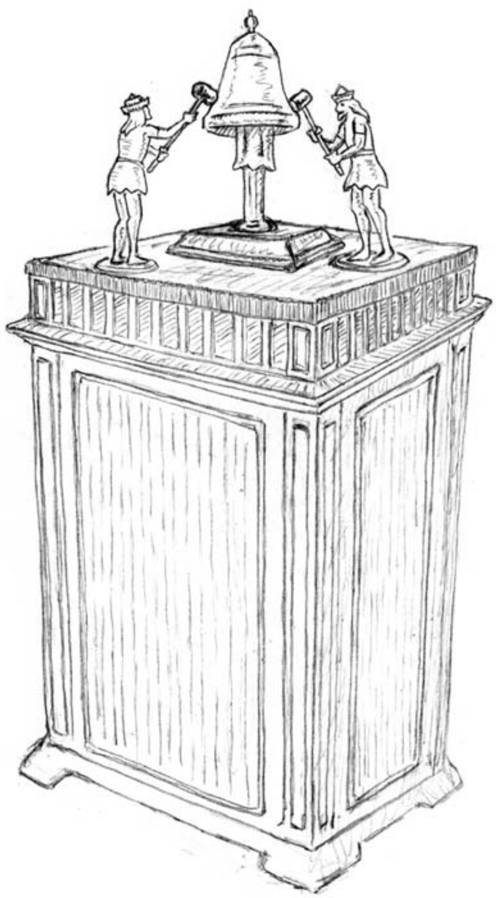
The fiddler crab's timekeeper signals a change twice each day. It turns darker during the day and lighter at night. Other animals have much longer timekeepers. Black bears, as you know, take long naps in the winter, as long as three or four months. Their clocks seem to signal large time periods corresponding to the changing of the seasons. They enter sleep well-prepared, having eaten 20 hours a day for many months, and having built a layer of fat about as thick as the middle of a football. Their heartbeat decreases from about 40 beats per minute to just eight. They don't eat, drink, urinate or defecate. If people slept for three months, we would call them lazy. When bears do it, we call it hibernation. Tolerance goes only so far: people are not meant to hibernate.

What's surprising about this picture?
Hint: Who is up and who is sleeping?

Three: Early Timepieces

The Importance of External Clocks

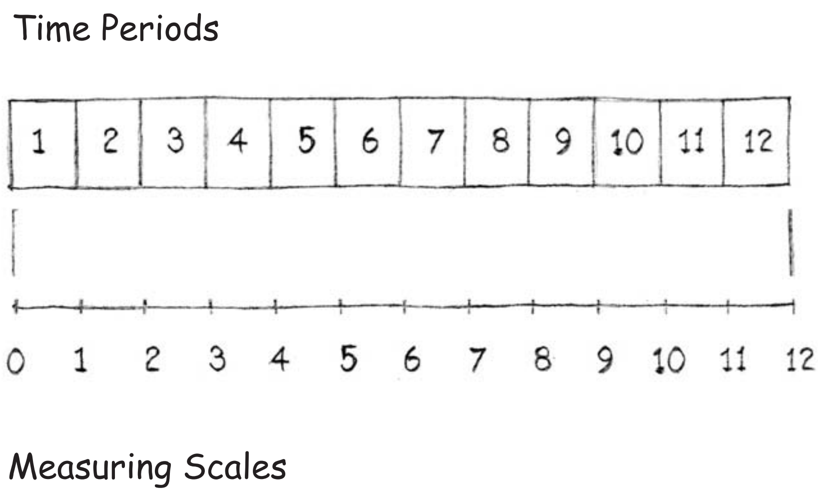
It is natural to think of the clock as simply a means of keeping track of hours and minutes. But, in fact, it is much more for it guides our lives. It keeps us in step or synchronizes our behaviors. We learned that there are some natural differences in people's sense of time. The clock provides a standard. Observe how people use clocks to get to movies when they start and to arrive at school, plays, baseball games and picnics on time.



The word "clock" derives from the French word *cloche* and the Latin word *clocca*, which originally meant a bell. The first weight-driven clocks were really nothing more than bells striking at specified intervals, at least some of the time calling people to prayer. But before people built clocks, they had to develop ways of thinking about time that made measurement possible.

Timepieces: A Human Idea

We have learned that our bodies, as well as the bodies of other animals, function as timekeepers. As far as we know, however, only humans can construct timekeeper machines. This is possible in part because we can imagine the division of time into equal periods on a line or scale.

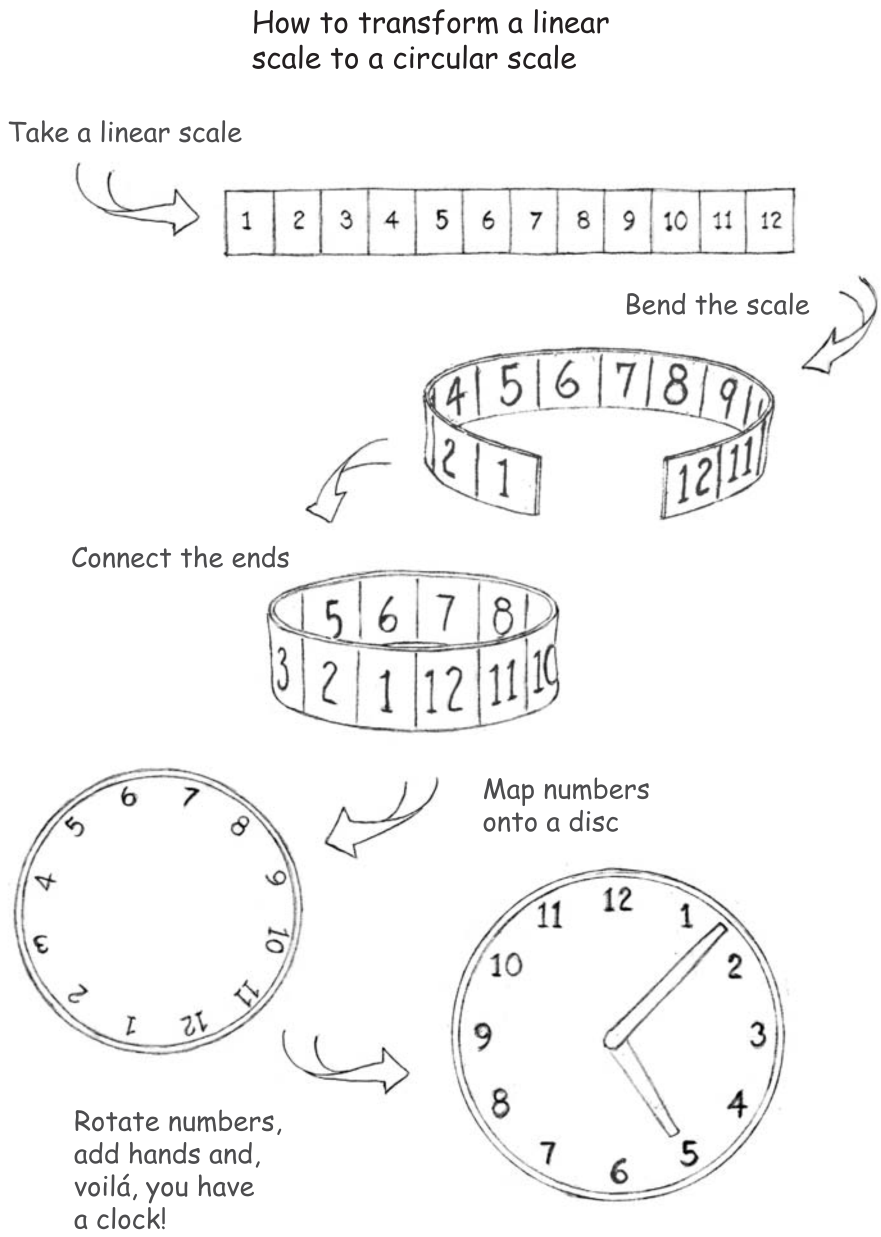


Time Scales

When most of us think of the past, we often see it, or represent it, to the left of the present, which is to the left of the future. In much of the world, cartoons depict the passage of time chronologically in frames from left to right. In some cultures events in time may be represented in other ways, but some orderly depiction is virtually universal. One familiar form of representation is a measuring scale showing equal time periods from left to right. Moving from 0 to 1 marks one time period. Moving from 2 to 4 marks two time periods.

How to Make a Circle from a Line

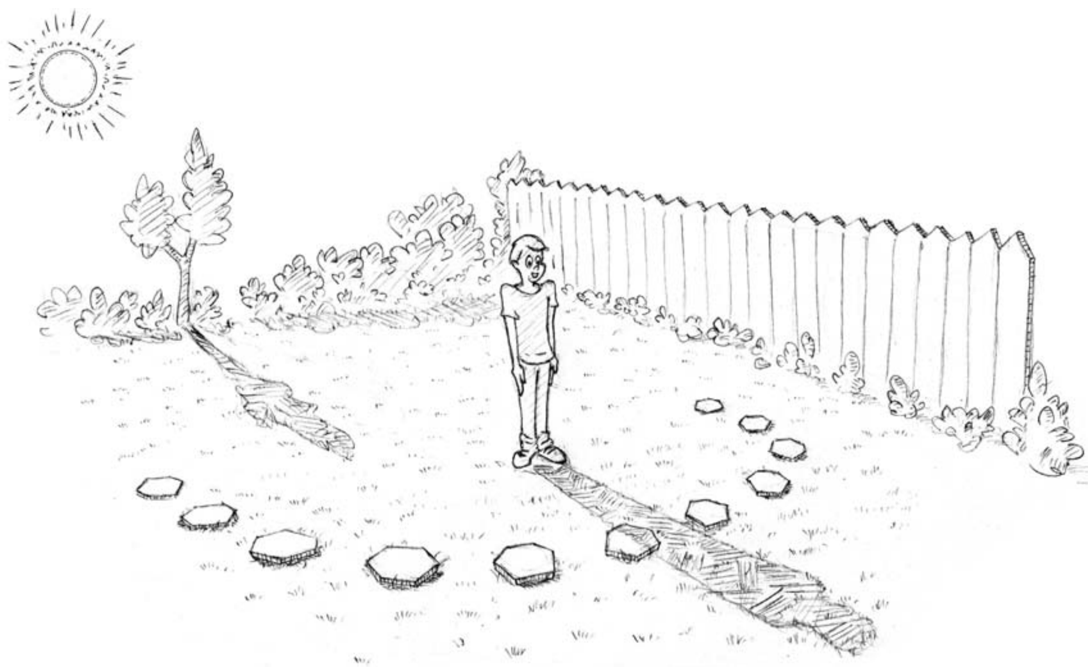
People have used sundials and clocks to measure hours and minutes. They arrange time periods in a circular display. A linear scale can be displayed in a circular arrangement by bending the line scale and connecting the open edge of the 1 with the open edge of the 12.



We can think of sundials as transitions between our individual internal clocks and the mechanical clocks we will discuss soon.

Sun, Shadows, and Sundials

The time of day can be roughly determined from the location of the sun in the sky. However, looking at the sun is no fun and, in fact, it can hurt your eyes (so don't do it!). Have you ever noticed that you can determine the location of the sun from changes in the shadows that it makes?

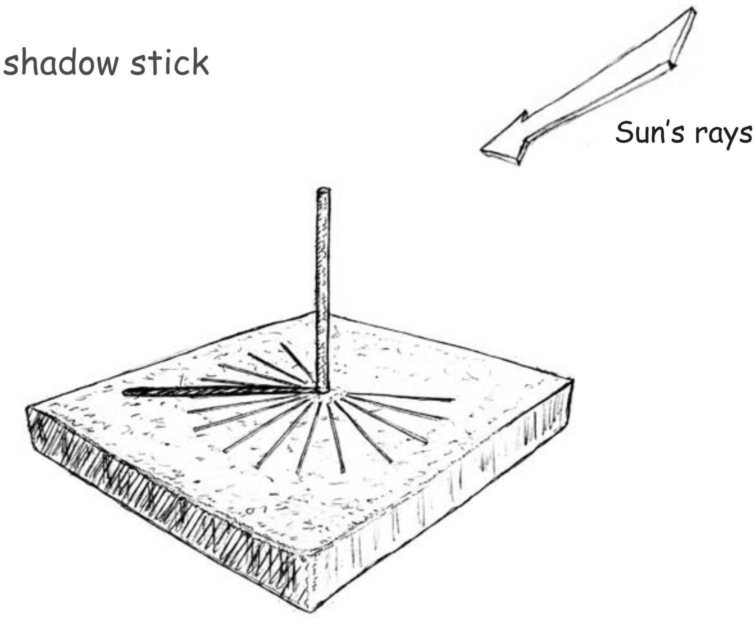


This observant person probably noticed how the shadow of a tall tree moves slowly but continuously from morning to night. One problem with trees, however, is that they grow in weird directions and shapes. So, people used sticks or other stable markers to observe shadows.

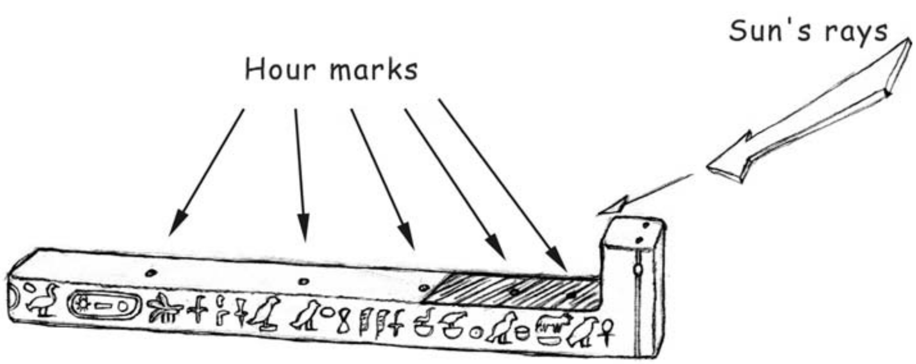
Ancient Early Clocks

The Egyptians measured the time of day by the movement of a shadow cast on or projected across markers. The first clock was probably the Egyptian shadow stick. It was used about 3500 years ago

Egyptian shadow stick

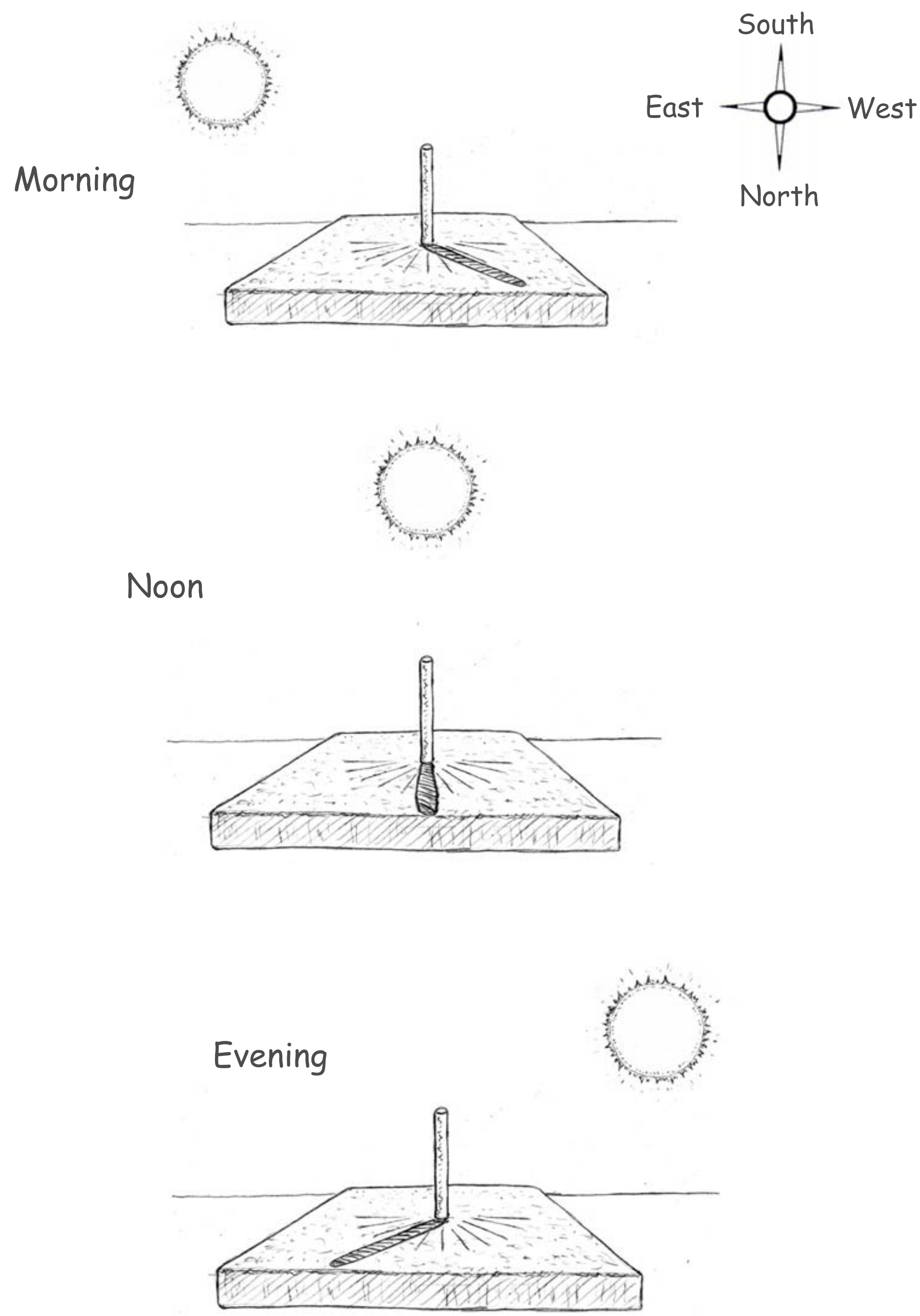


Egyptian shadow clock



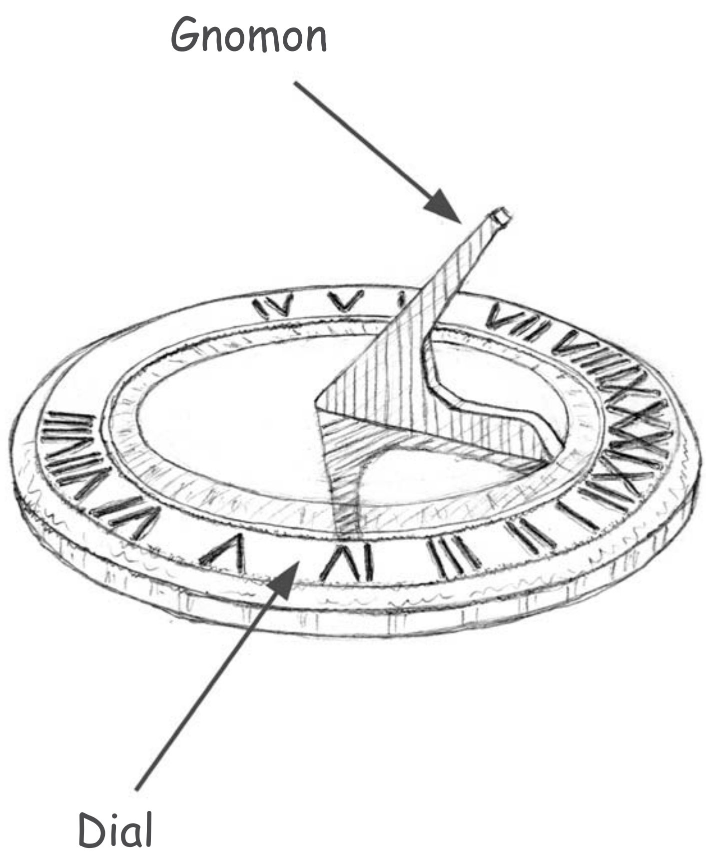
How Sundials Work

The earth rotates in a circle, and we see our sun moving from east to west. A tree or other vertical object casts a shadow, which moves from west to east.



The Traditional Sundial and Its Parts

The sundial has a dial and a hand. The word dial comes from the Latin word *dies* meaning day. The dial is the face of the sundial. The hand is the object that casts the shadow.



The word hand comes from the Greek word *gnomon* (pronounced no man), which means interpreter or one who knows. This name reveals the importance of knowing the time. Notice that the *gnomon* is slanted. Its angle depends on the latitude, which is the angle of the location from the equator. In addition, the gnomon must be set to point to the North Star.

You might want to make your own sundial. Detailed instructions are at:

http://www.sundials.co.uk/projects.htm.

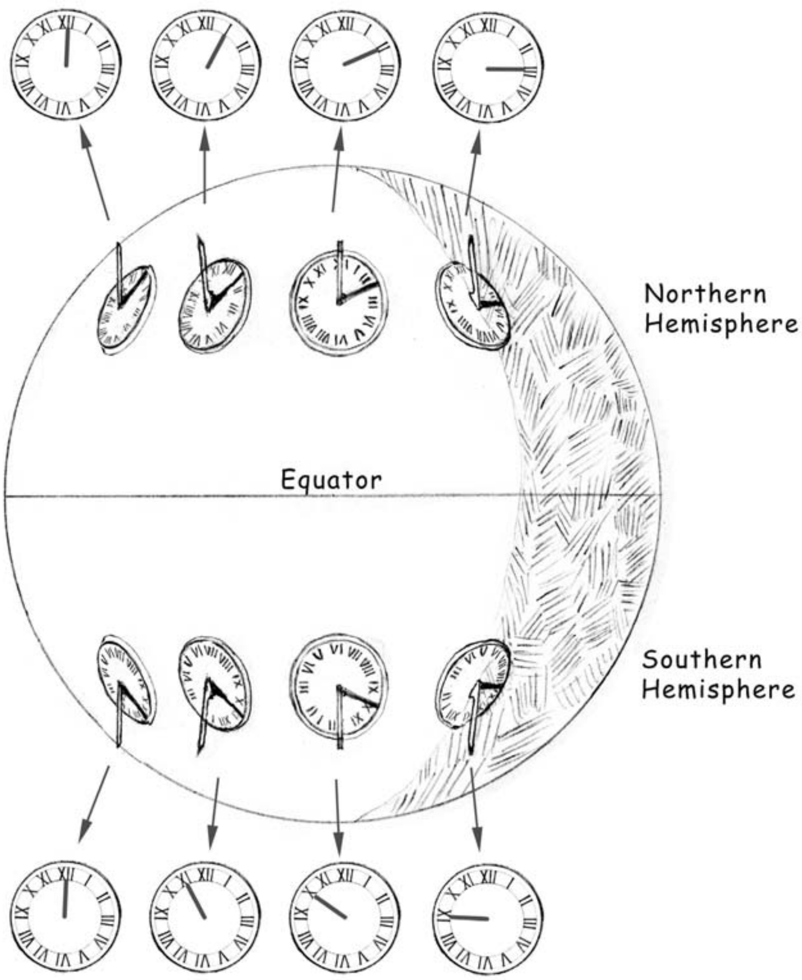
The Downside of Stealing Sundials

The hand of the sundial is slanted to point at the North Star, which gives a correct measure of time all year. When the *gnomon* is set parallel to the earth's axis, the direction of the shadow at a given hour will be independent of the season. Each new location of a sundial requires a unique angle and a unique setting of the *gnomon* to point at the North Star. This fact was not known to early thieves who stole a sundial in Egypt and took it to Greece. The thieves were annoyed to discover that the sundial was not accurate in its new location. The moral of the story is that thievery doesn't pay,

Clocks and Clockwise Rotation

You might have wondered why the hands move around the clock in what is called a clockwise direction. Why was this direction chosen rather than the opposite counterclockwise one? The reason is that the clockwise direction mimics how a shadow moves in the Northern Hemisphere.

The hands of clocks go in a clockwise direction because the sundial was invented in the Northern Hemisphere, and the clock was invented in the Northern Hemisphere. Just think, if the sundial had been invented in the Southern Hemisphere the hands of our clock would move counterclockwise.

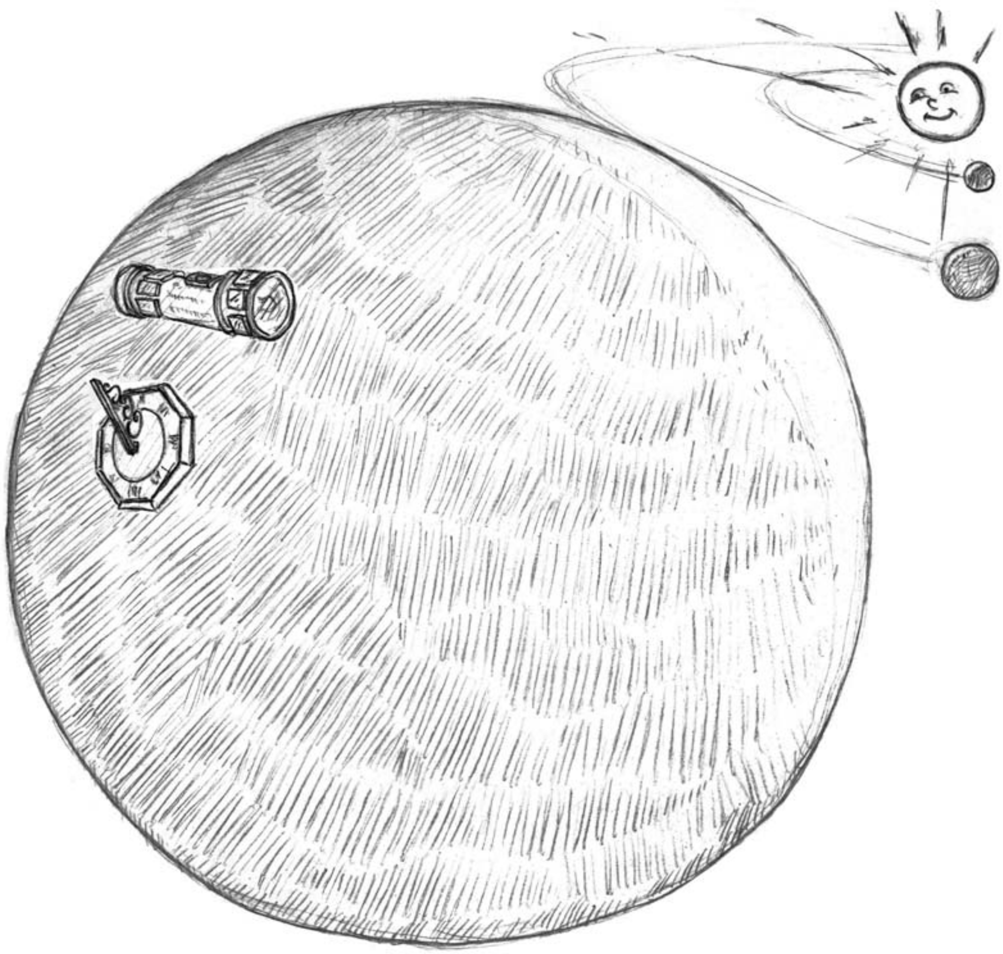


The different times of the day are represented by different positions of the sundials on the earth. As can be seen in the drawing, the shadows on the sundials in the Northern Hemisphere are changing in a clockwise direction whereas those in the Southern Hemisphere are changing in a counterclockwise direction.

A Good Idea Goes Only So Far

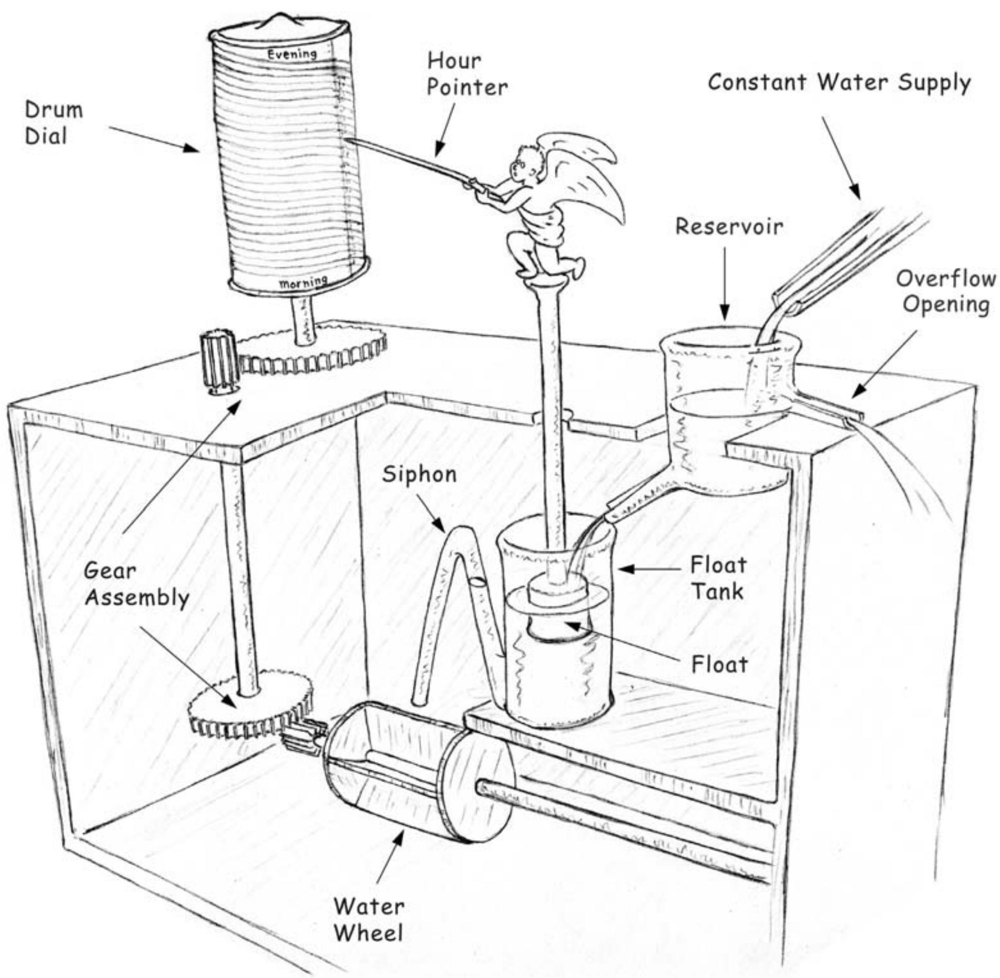
One limitation of sundials is that they work well only on sunny days. They are harder to read on cloudy days, and they are useless at night.

The commercially unsuccessful solar-powered flashlight and the sundial have similar problems at night



Water Clocks

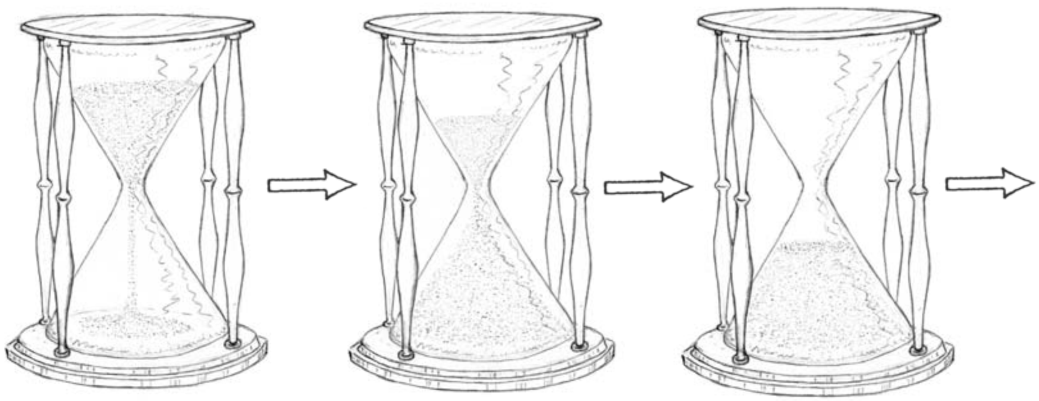
Water permeates all aspects of our existence, and it is only natural that it should be linked with time. A water clock is much more complicated than a sundial, but one advantage is that it records time day and night. The emptying and filling of a vessel takes time, and can be used to measure how much time has elapsed. A constant supply of water can feed into a reservoir. An overflow opening is used to keep its water level and pressure constant, which maintains a steady outflow from its bottom.



This outflow fills a float tank, which raises a float that carries an angel. The wire from the angel marks the hour on a drum dial, which moves with the turning of the waterwheel. The angel is always functional, which is an improvement on the sundial's light-dependent *gnomon*.

Hourglasses

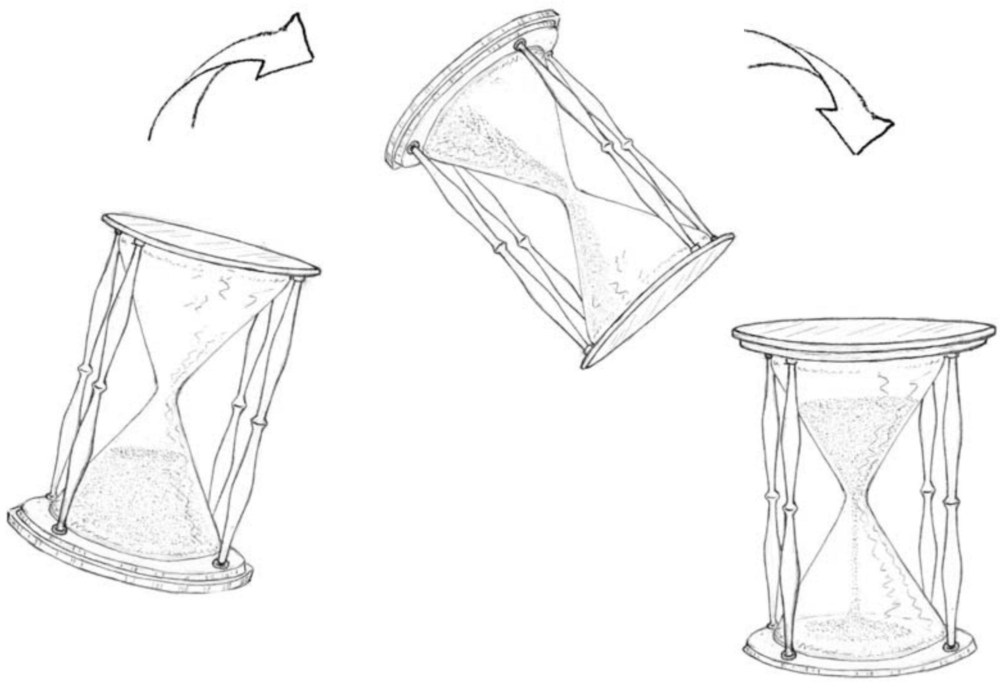
The hourglass is based on the same principle as the water clock, but with sand rather than water as the medium. The hourglass is actually two glasses connected by a small opening. A certain amount of sand is placed in one of the two glasses. The sand trickles from the top to the bottom glass through the small opening. Why does the amount of sand set the amount of time for one period?



When all of the sand drains from the top glass into the bottom one, one time period has elapsed. Once the sand empties into the bottom glass, the hourglass can be flipped again to begin measuring another time period. This constant flipping, however, can become tedious.

An hourglass would be valuable for measuring the duration of short time periods that correspond to some fixed number of turns of the hourglass. By flipping the glass, you can begin timing an event, such as the amount of time required to boil an egg. One downside is that the hourglass has to be monitored fairly continuously to spot exactly when the top of the glass empties.

The expression “the sands of time” comes from the hourglass.

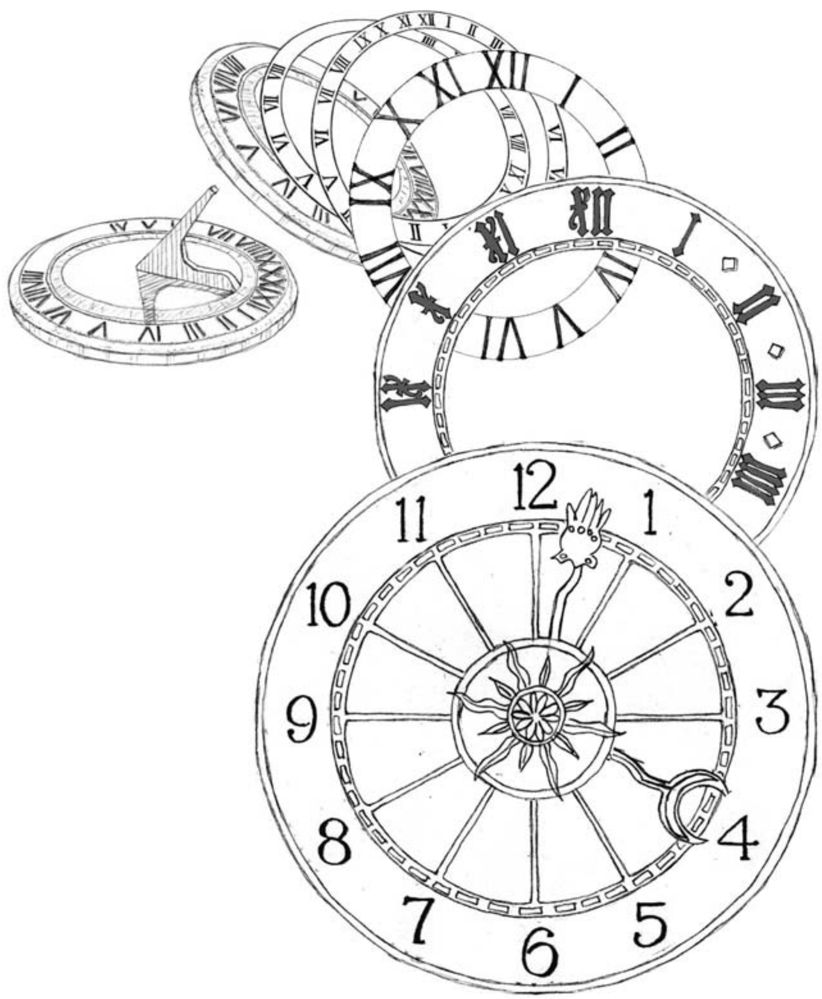


An hourglass created by Nobuho Nagasawa as part of her artistic work, *Where Are You Going? Where Are You From?*

Four: More Recent Timepieces

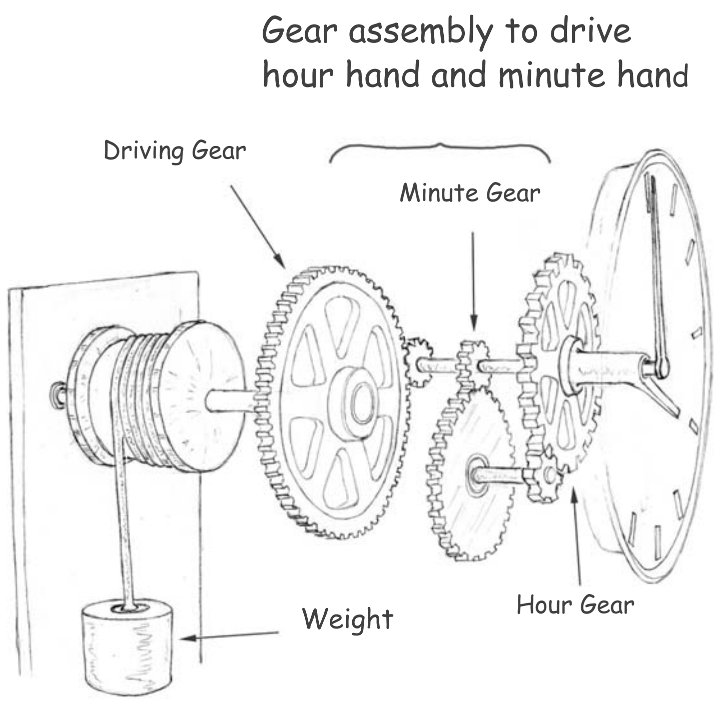
A Transformation

The sundial served as the basis for the mechanical clock. The face of the sundial became the dial, and the *gnomon* became the hour hand of the mechanical clock.



Mechanical Clocks

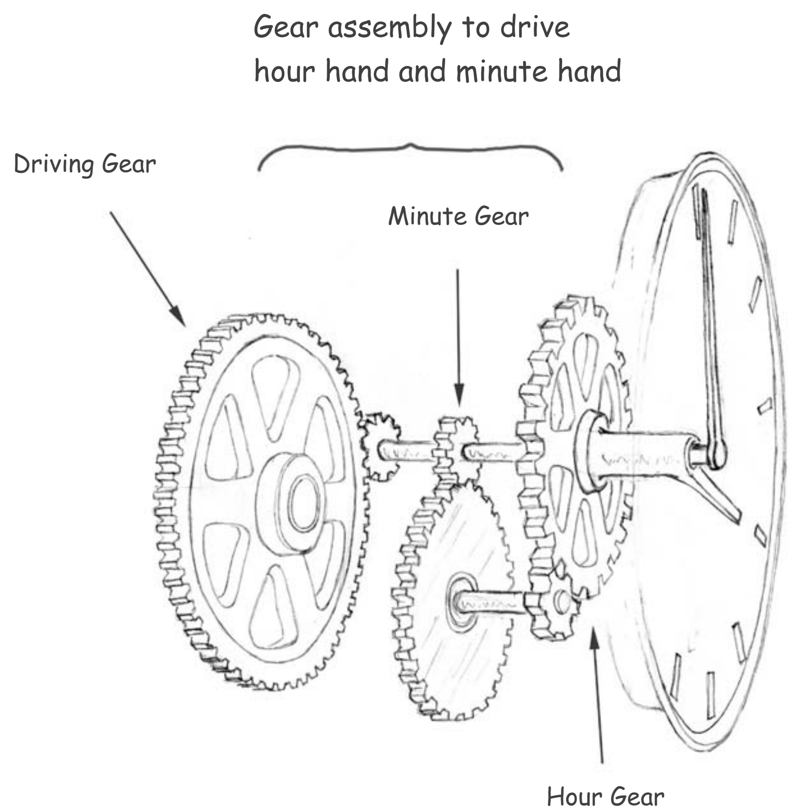
Mechanical means a physical machine that runs, more or less, on its own. The clocks familiar to us are mechanical. The invention of gears made it possible to move the hands of mechanical clocks in small accurate steps.



Here is a picture of a weight-driven clock mechanism. A falling weight turns a shaft that turns the driving gear which, in turn, drives a set of gears that turn the hands of the clock.

The Gear Assembly

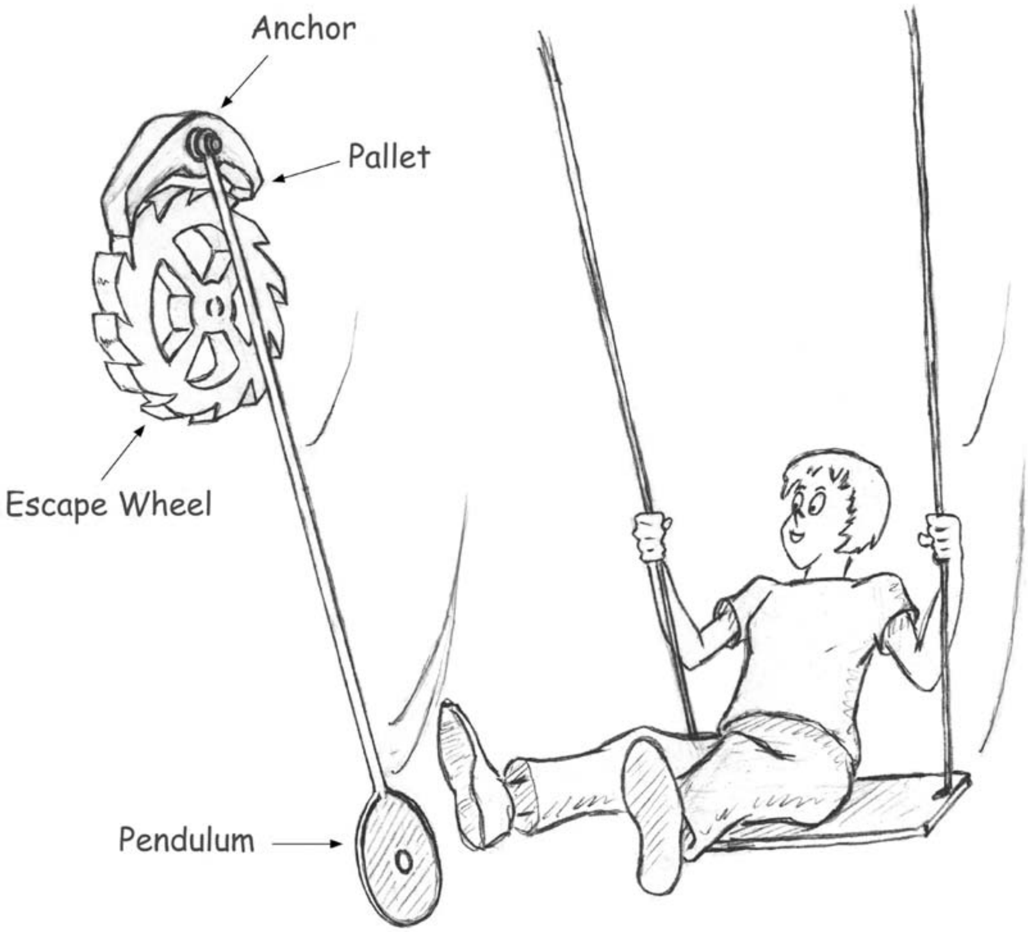
The hands of the clock are rotated by a driving gear that is driven by either a spring or a weight. The rate at which the gears turn is determined by the number of teeth along their outer edge. The number of teeth on the gear wheels in the picture is fixed so that the hour gear makes one revolution for every twelve revolutions of the minute gear.



In the picture above, the wheel labeled minute gear turns at a rate of one revolution per hour. This gear is on a shaft connected to the minute hand which, therefore, makes one revolution every hour. The minute gear also turns a larger gear which is connected to a shaft that turns a smaller gear which, in turn, drives the hour gear. The hour gear is on a shaft which drives the hour hand.

Escapement Mechanism

The escapement mechanism plays an important role in the development of clocks. Both the Dutch Christian Huygens and the British physicist Robert Hook are given credit for inventing the anchor escapement. In a pendulum clock, the anchor escapement swings about its center and is connected to the pendulum. The movement of the pendulum is made to lift the escapement, which advances the hand.



The escapement mechanism releases the energy of a spring or a weight in small regular bursts. These bursts are then sent to the time keeping part of the clock—the hands. The escapement mechanism also gives the pendulum a slight push with each swing. To imagine this, think of an adult keeping a child's swing in motion by pushing it very slightly on each return swing.

Pendulum Clocks

The great scientist Galileo Galilei, who knew that our bodies were like clocks, first used his pulse to time some of the events in his experiments. Then he designed a clock based on the timing of a pendulum. Time could now be measured more accurately by the number of back-and-forth movements of the pendulum.

What Galileo Discovered

Galileo learned that the time it took to move from one side to the other was determined by the length of the pendulum. The longer the pendulum rod the longer it takes to go from side to side. A rod of 40 inches gives one swing per second. Can you determine how long a swing takes for other lengths?

Galileo learned that the time it took to move from one side to the other was independent of how hard the pendulum was swung—or how high it moved during a swing. How would this help in making a clock?

Applying Galileo's Idea

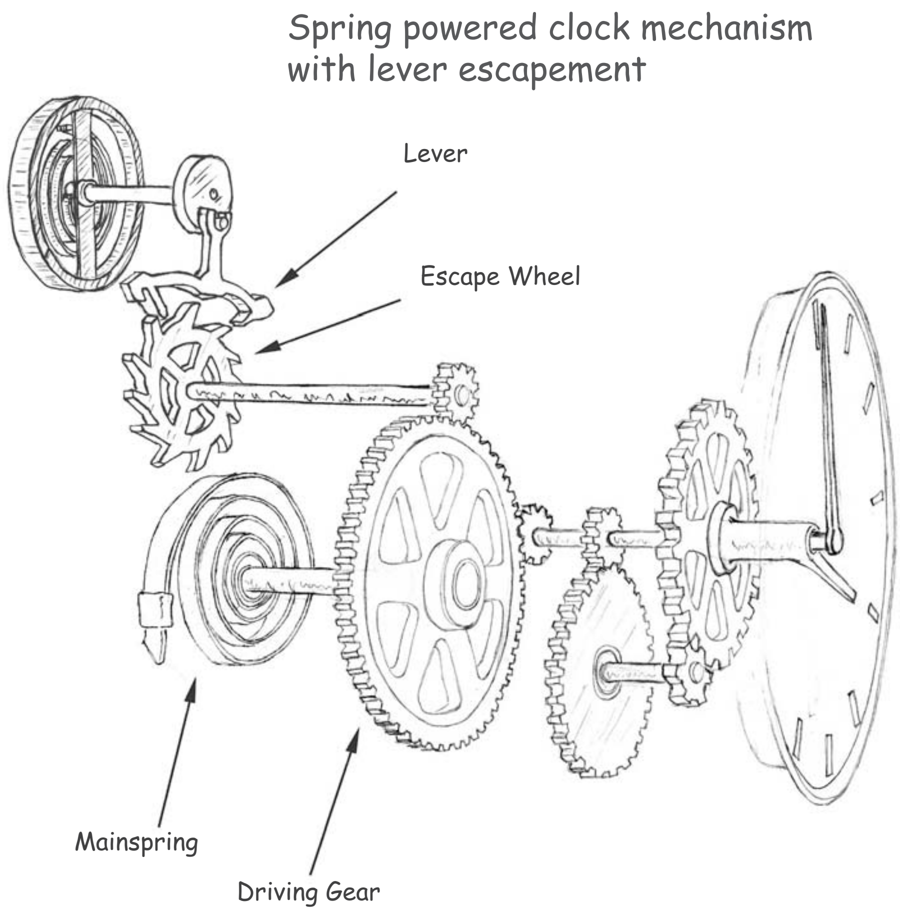
Christian Huygens teamed up with clockmaker Salomon Coster to improve the accuracy of clocks. Their innovation was to replace the balance wheel regulator with a pendulum hanging freely from a cord or wire. The accuracy of the clock was greatly improved, from an error of about 15 minutes a day to one of only 10 seconds. More important, their modification of the clock was so easily implemented that not only were all new clocks designed in this way, existing clocks were modified accordingly.

Huygens's invention created some controversy because the Italians accused him of plagiarizing Galileo,who designed a clock but never had it built. It seems, however, that Galileo didn't anticipate the method Huygens conceived to hang the pendulum freely. Although Hugyens qualified for a patent in his home country, Holland, other countries refused to recognize his invention, primarily because clockmakers were unwilling to pay royalties on every new clock they made.

Spring Clocks

Before batteries and electricity, people used springs to drive mechanical clocks. In spring clocks, the mainspring is wound into a tight spiral. The slow unwinding of this mainspring is made to move the gears, which move the hands of the clock.

The lever escapement shown below is what allows the clock to move in small, precise steps. As the mainspring unwinds it turns the driving gear. But the smooth rotation of the driving gear is interrupted by the escape wheel, which is alternately stopped and released by the claw-shaped lever of the escape mechanism.

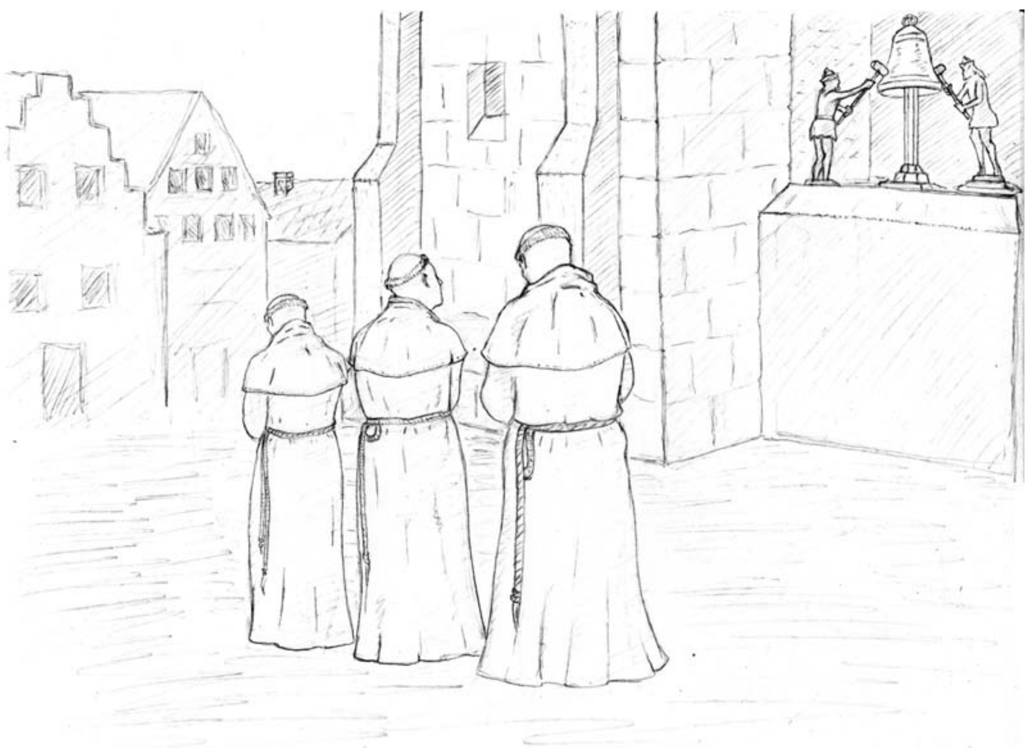


Peter Henlein of Nuremberg invented a wound spring of hardened iron for driving the train of gears. Jeweled bearings were introduced by the Swiss watchmaker Nicholas Facio to eliminate friction in the clock mechanism. Springs make it possible for the clock to be small and therefore carried in a pocket or tied around the wrist.

Five: The Many Faces of Clocks

Your Clock is Calling You

People in practical work, such as farming, could see daylight, or listen for a rooster's crowing, and know that it was time to go to work. Of course, an alarm clock would have been useful, especially if their rooster slept in.



The first clocks were used to call the monks to prayer.

Do you ever get called by a clock?

The Hands of Clocks

The first mechanical clocks had no hands at all. They simply gonged at certain times. This may not surprise you, since many modern clocks have no hands.

Eventually, someone added an hour hand to the clock. Finally, minute and second hands were added.

The Good Old Days

It was easier to read time in the old days when clocks had just one hand. Time was always stated in terms of hours.

"It is three o'clock."

"It is a little past three."

"It is a lot past three."

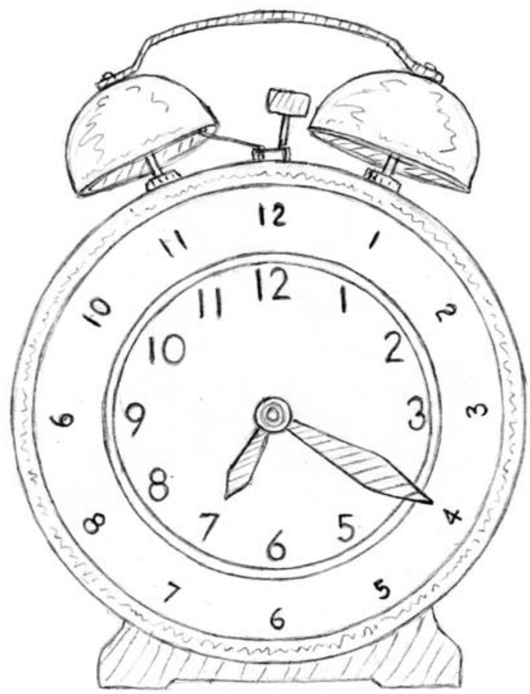
We often give the time in this way when there is no reason to be exact.

Adding the Minute Hand

Reading time became more precise (and more difficult) when a minute hand was added. Therefore, an hour was divided into smaller parts, called minutes. Minute is related to the word *minute* (my-nute), which means very small. The minute hand moves completely around the clock every time the hour hand moves from one hour to the next.

Twelve Minutes to the Hour

If the same 12-hour parts and numbers that we use for hours were used for minutes, there would have been 12 minutes to the hour. When the hour hand is on the 7 and the minute hand on the 4, we would have called this time **seven-oh-four (7:04)** or 4 minutes past seven.



This imaginary clock has twelve minutes to the hour

A New Problem: Boiling Eggs

Although easy to read, this clock had only 12 minutes to the hour. Let's call these parts 12-minutes. Twelve minutes to the hour are not small enough parts to give a precise measure of time.

A person could not use this clock to time the boiling of an egg, for example, because the time needed is much less than one of these 12 minute units. With this clock, your eggs would usually be raw or overcooked. And it would be clumsy to have to say: "cook for 1/4 of a 12-minute."

Solving the Problem

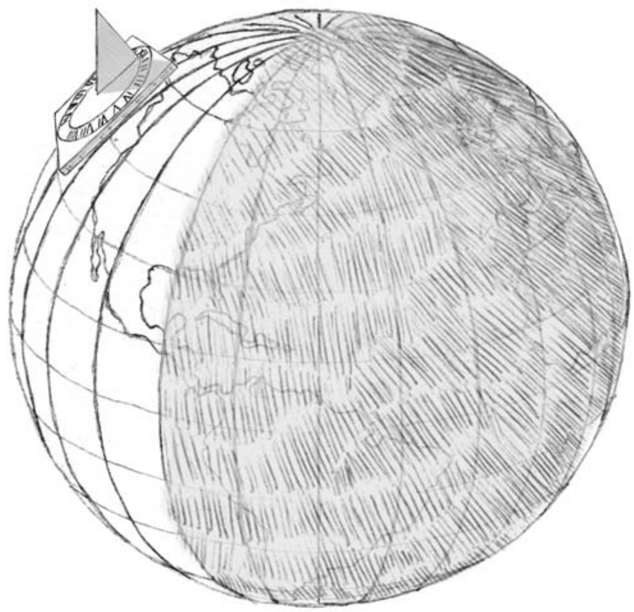
To solve this problem, each of the 12 parts was divided into 5 more parts. Given 12 parts, each divided into 5 more parts, we get a total of 12 times 5 (12 x 5) parts or 60 minutes. Now it takes about 3 of these minutes to boil an egg.

Seconds

Minutes have also been broken up to give 60 seconds per minute. A fairly accurate method of counting seconds involves counting “one thousand one,” “one thousand two,” “ one thousand three,” and so on. Every count gives roughly one second. Seconds can measure how long you can hold your breath. How many seconds can you hold yours? Find someone to count for you while you are holding your breath.

24 Hour Days and 12 Hour Clocks

A complete day has 24 hours. So, why do current clocks measure time in just 12 hours, or half of a complete day? The reason, once again, is that the clock is based on the sundial, and the sundial works only in the sun. The sun is hidden from us for about half the 24 hour day. We call this period night. The sundial can measure time only for about one-half of the day, when the sun is out.



Because of the sundial, we are stuck with a 12-hour clock to measure a 24-hour period. Each day has two 12-hour periods. We call the first a.m., based on the Latin phrase *ante meridian*. The word meridian means the point at which the sun is highest in the sky—the time that we call 12 noon, or mid-day. The word *ante* is the Latin word meaning before.

The second 12-hour period is called p.m., based on the Latin phrase *post meridian*. You guessed it. The word *post* is the Latin word meaning after.

Why Not 10-Hour Clocks?

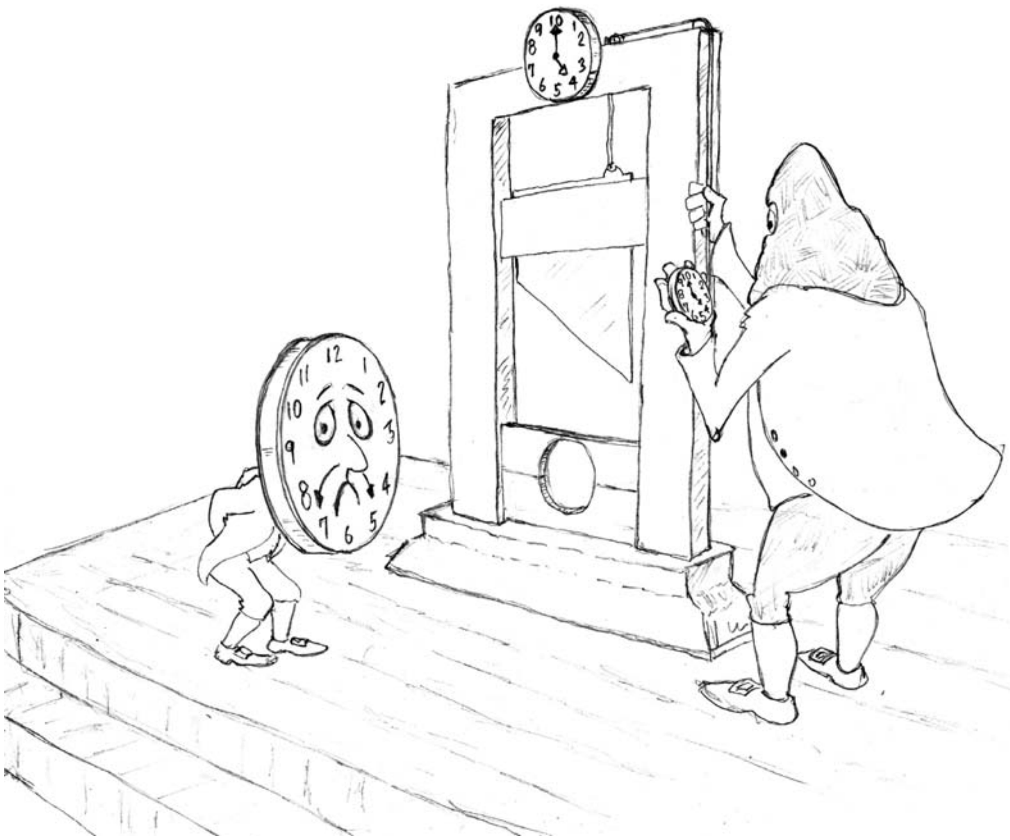
Why is the dial of the clock divided into 12 hours and not some other number such as 10? For us, 10 makes more sense because we count in units of 10. Some say because we have 10 fingers. We were not around, however, when clocks were invented.

A Babylonian counts by 12's

At that time, the Babylonians were around and they counted in units of 12. No, the Babylonians did not have 12 fingers. It was natural for them to divide the dial into 12 parts because they counted in units of 12.

The French Revolution

Although people's counting changed from units of 12 to units of 10, the numbers on our clocks did not. After the French Revolution (1789) the French tried to divide the clock into 10 parts, but failed to persuade others to change.



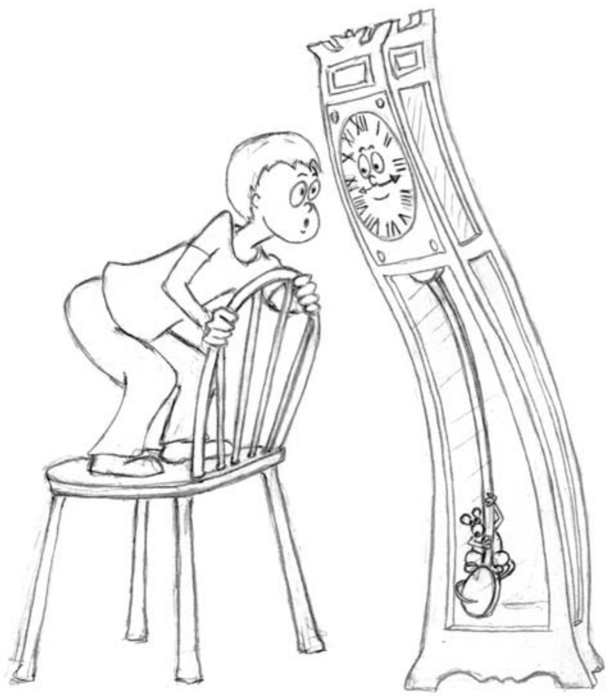
The French, enforcing the ten-hour clock

You might have heard of the metric system that measures in multiples of 10. A metric clock would have 10 hours and 100 minutes per hour. It failed because it is hard to get people to change. Can you think of another example of how hard it can be to get a sensible idea to be taken seriously?

Six: The Value of Analog Clocks

Analog Clocks: Their History

These mechanical clocks tended to go the way of the rotary phone. One dials this phone by moving a circular disc to the desired number. Most phones today are push button, and some children have never used a rotary phone.

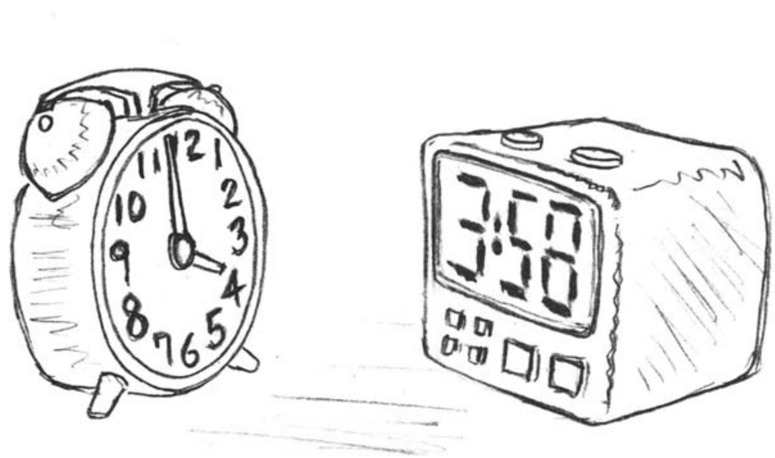


I'm a grandfather clock

Can you think of any other devices that have changed dramatically since the time of your parents' youth? What about the typewriter being replaced by a computer? Ask them about other household devices.

Analog and Digital Clocks

Traditional clocks, like the grandfather clock, are called analog clocks. Analog means continuous. Time changes occur continuously on an analog clock. Digital means discrete or step-like. Time changes occur in discrete steps on a digital clock.

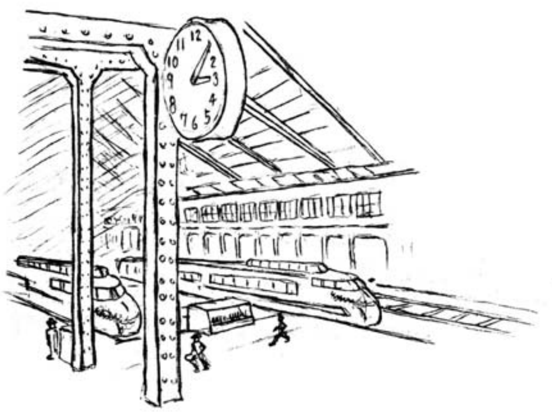


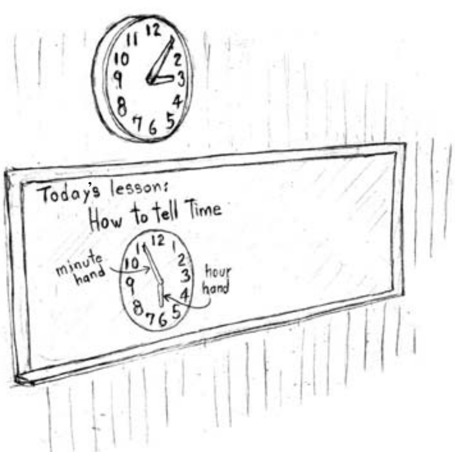
The digital clock is simply a presentation of the time as it is normally said or written. Here is a drawing of a traditional analog clock and a digital clock. Although it is easy to read a digital clock, it falls short of an analog clock in important ways.

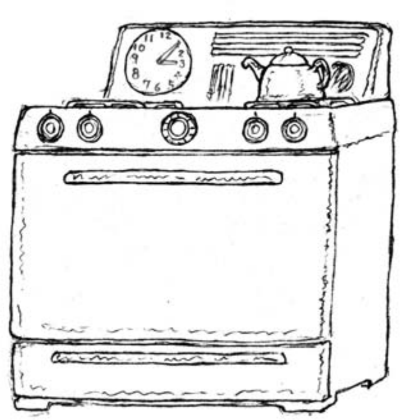
The traditional clock is an historical remnant, not an efficiently designed, easy to read device like a digital timepiece. No one should assume, however, that digital clocks will replace analog clocks. After all, analog clocks have withstood the test of time because they have significant, compelling virtues. Analog time reading helps develop important abstract, perceptual, and cognitive skills badly needed in a modern, digital world.

Analog Clocks are Everywhere

Analog clocks are particularly noticeable in public places such as town squares, train stations, airports, and sports stadiums. Schools, offices, and factories also place analog clocks in prominent places where they can be easily read from a distance. Where else have you seen analog clocks?

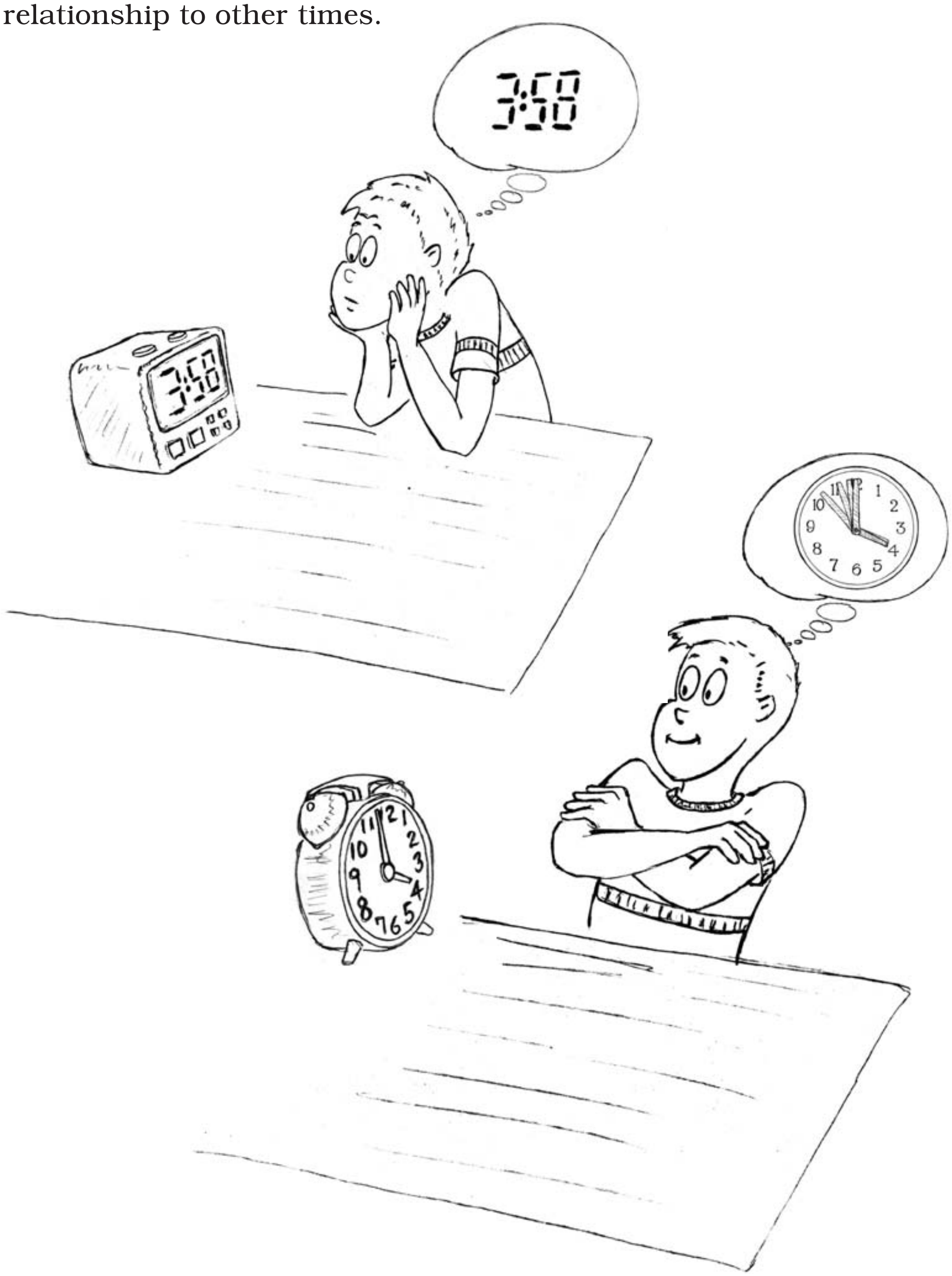






Seeing Meaning

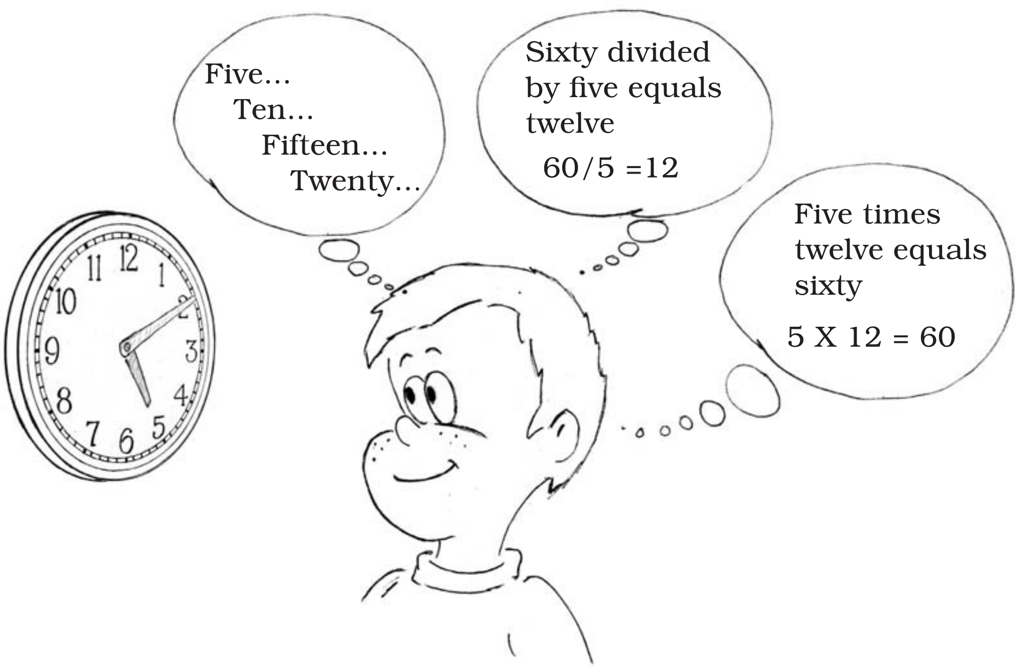
Analog clocks have more meaning than digital ones. When we look at an analog clock, we see not only the current time but also its relationship to other times.



Seeing the hour hand on the **4** and the minute hand approaching the **12** on an analog clock shows directly that the time is very close to and approaching **4:00.** This information is not apparent on a digital clock that is showing **3:58**.

Understanding Numbers

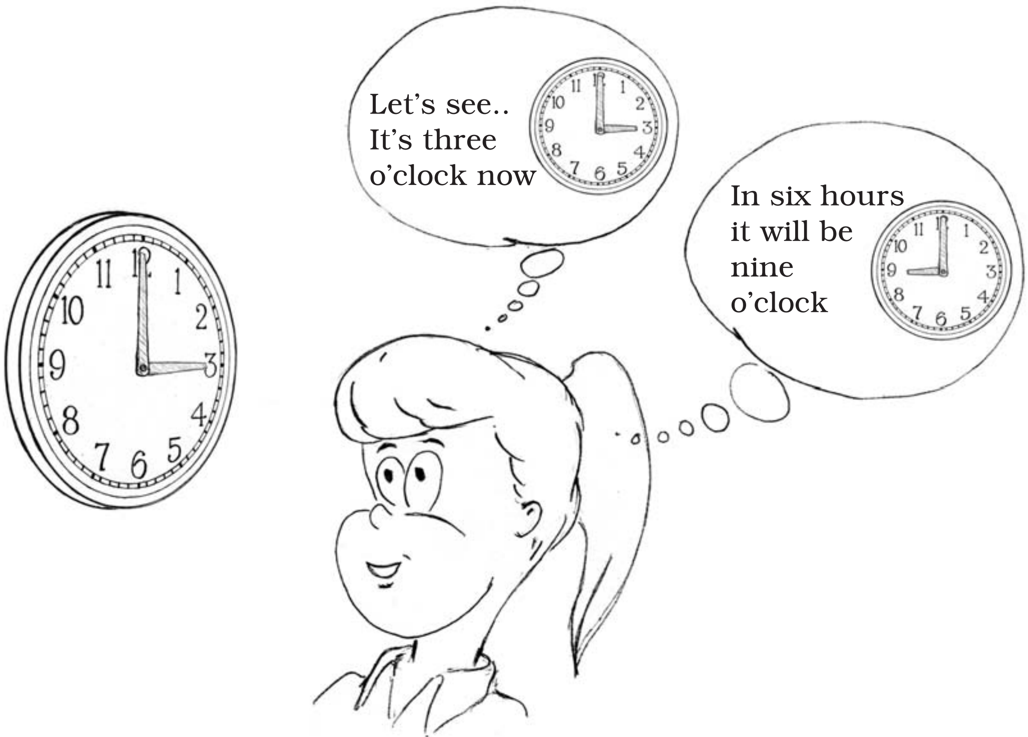
Believe it or not, learning how to tell time also helps one learn arithmetic. Analog clocks give us a vivid understanding of numbers. Specifically, reading analog clocks allows us to become very familiar with multiples of 5. Furthermore, reading an analog clock heightens our perception of angles–the space measured by an arc between the clock's hands.



Can you count quickly by 5's? 5, 10, 15, and so on. The analog clock breaks up the 60 minutes into 12 sections of 5 minutes each. We remember that 12 times 5 is equal to 60 because clocks and watches reinforce this fact.

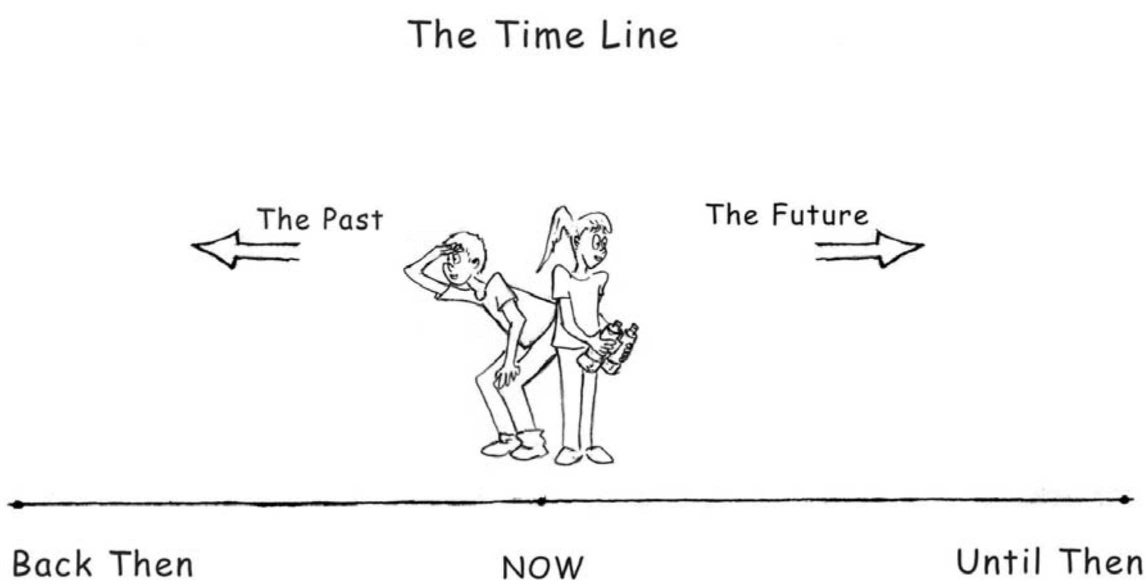
Visual Calculators

Analog clocks can be thought of as visual calculators, which provide direct visual information. Have you ever heard the aphorism "A picture is worth a thousand words?" Pictures, or images in our minds, sometimes fix an idea in a way that words or numbers cannot.



With an analog clock it is easy to imagine what time it would be in, say, six hours, since it is just half way around the dial. There is no need to add or subtract the numbers.

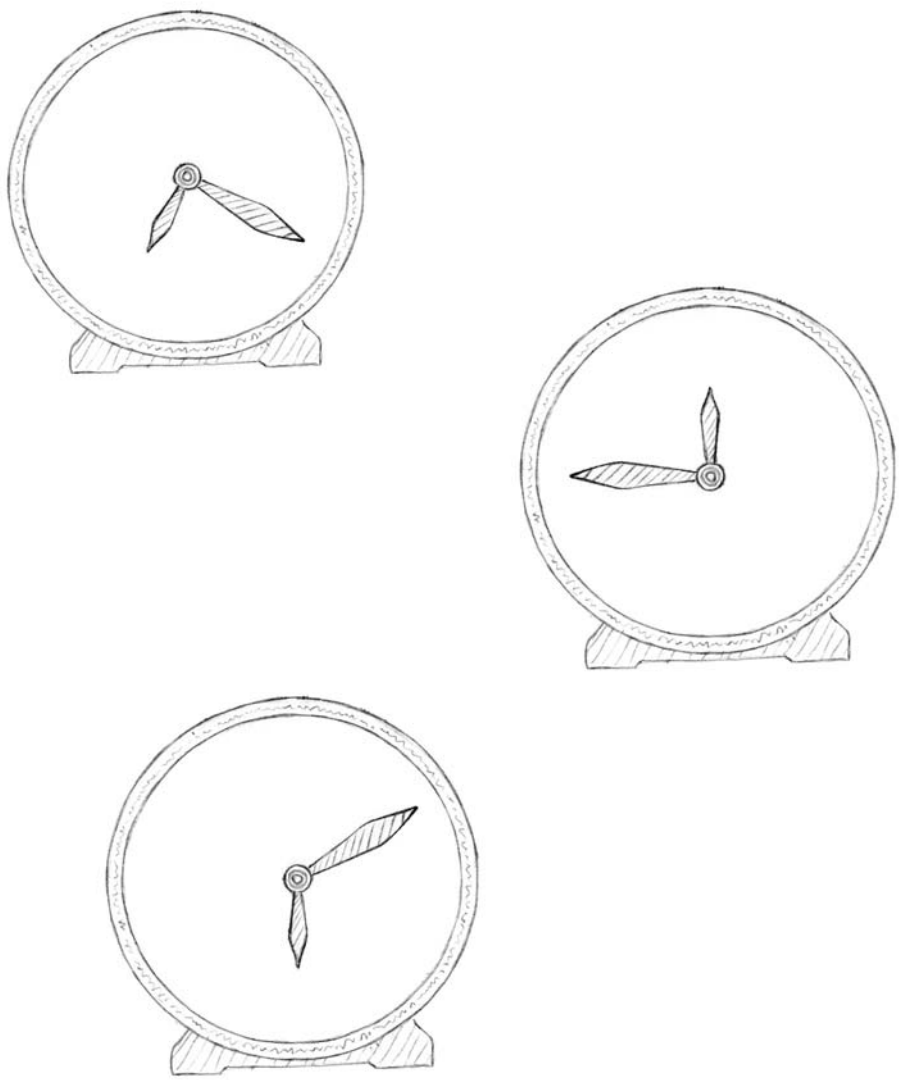
Time and Space
Earlier we noticed our spatial ability to imagine the division of time into equal periods. Analog clocks preserve the important relationship between time and space. All peoples and languages have used spatial terms to describe temporal ideas. For example, the word *then* refers to a particular time. This word comes from the word *thence* meaning from that place.



Time events are often spoken of as if they were spatial points on a line. On the Time Line above, Back Then refers to an event that happened in the past. Until Then refers to something that will happen in the future. Our lives themselves are often referred to by poets as a march or journey along a time line marked by different signposts.

Look Mom, No Numbers

Poor lighting, poor eyesight, or large distances make digital watches hard to read. Once you learn to read an analog clock, you can read the time without looking at the numbers. The positions of the hands alone tell you the time. The angle becomes a sign or clue. It contains information for the person who is clock-literate.



Can you tell the time of these three clocks? It's OK if you can't. Ask your parents. Can you tell the time on a clock on the side of a building by reading the location and angle of the hands?

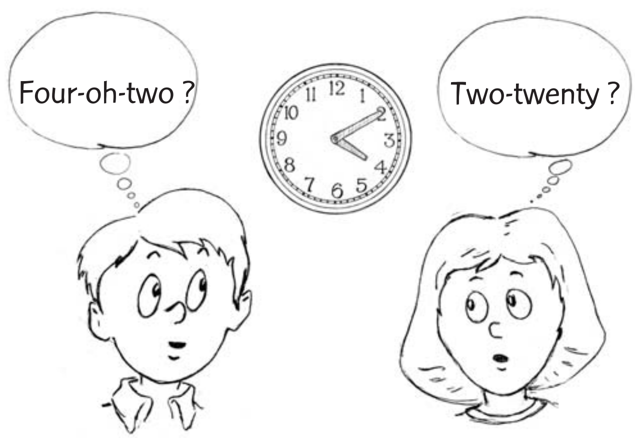
Seven: The Kid Klok

Solving a Problem Creates Another One

While analog clocks have great virtues, they can be improved upon. Adding the minute hand to the analog clock is responsible for the difficulty children have learning to tell time. This new clock with two hands is harder to read, and children have difficulty learning to read it. The space that previously marked only hours now marks minutes as well. It is easy to confuse the two hands and difficult to know what number belongs to each hand.

A Story of Invention

Helping out one day in his son's second grade classroom, one of us was troubled by errors the children made in their lesson on telling time. One child made the typical mistake of reading a clock set at 4:10 as 4:02, another read the same time as 2:20, and 2's were commonly read as "ten".



These errors were not random guesses, but indicated inherent flaws in the design of the clock. The students were asked to read analog time only during their lessons on time, not during the remainder of the school day. None of the students paid attention to the analog clock on the wall.

Like most observant people, but particularly because he was a cognitive and experimental psychologist, Dom was challenged to uncover the nature of the difficulty in reading traditional analog time. He wanted to design a better mousetrap. By employing principles of psychology, cognitive engineering, and observational and experimental evidence, he set out to build a timepiece that made analog time-telling easy to learn.

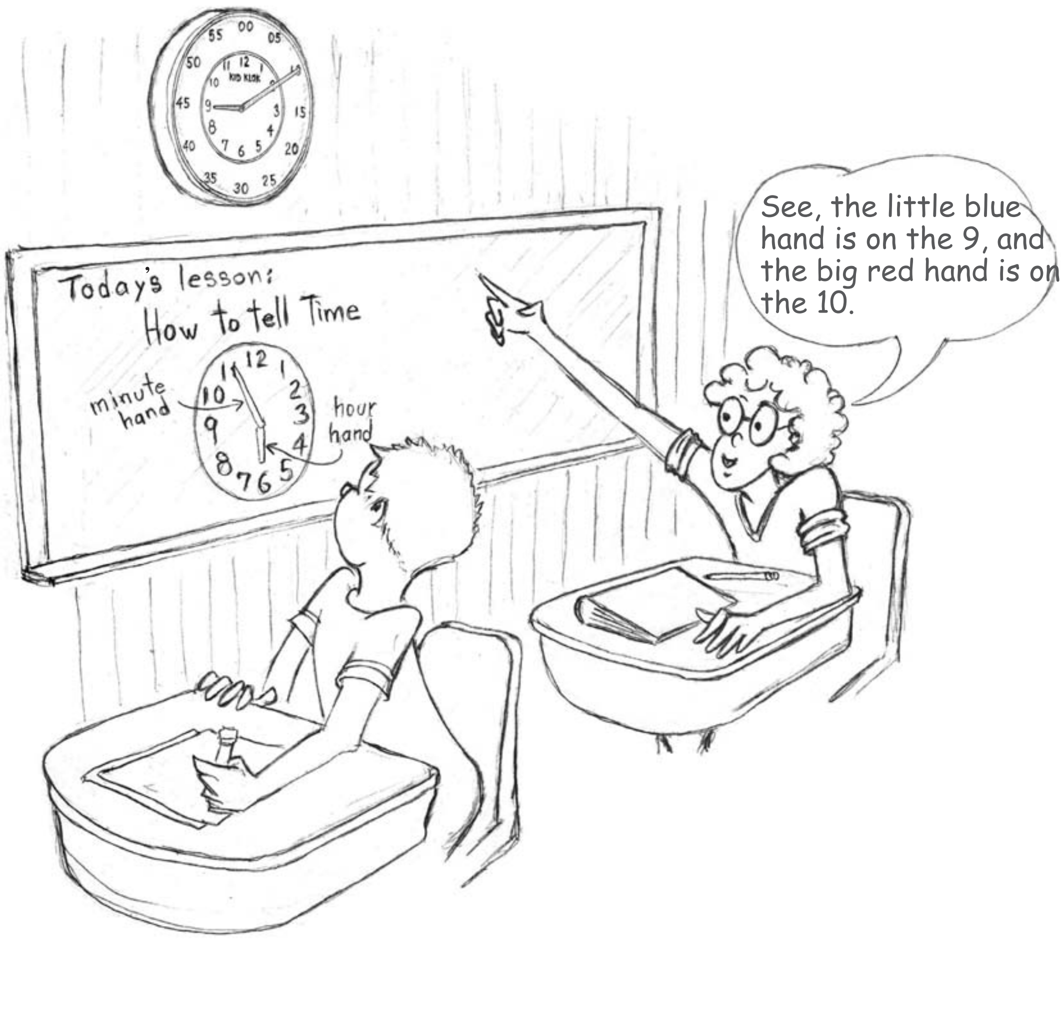
An Easy-to-Read-Clock

Kid Klok was invented to make it easier for kids to learn how to tell time. Reading the analog clock is important, and small changes made the clock much easier to read. Like some very old clocks and timepieces used by engineers on the railroad, both the hour numbers and the minute numbers are on the **Kid Klok**.

The **Kid Klok**, however, links the hands with the numbers by the use of size and color. The hour numbers are in *blue ink*. The *small blue* hour hand goes with these *small blue* numbers. The minute numbers are in red ink. The *large red* minute hand goes with these *large red* numbers.

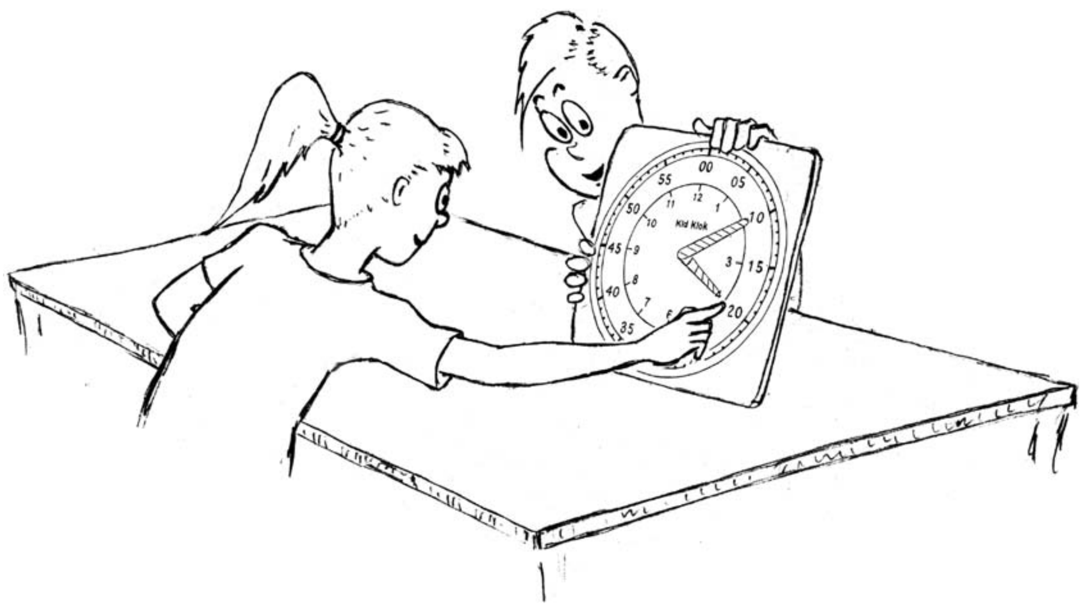
Learning to Tell Analog Time

We've seen that an analog clock has hands that move around a dial. A digital clock shows the time in numbers and without hands. When kids are first learning to tell time they find it very easy to read a digital clock, but have big trouble with an analog clock. The **Kid Klok** solves this problem. Learning to read the **Kid Klok** is a piece of cake, almost as easy as reading a digital clock.



A Fun Spelling

We spell the word clock as **Klok** to show that it is special. Can you think of other words that are spelled funny? For example: Phabulous Phoods for Fabulous Foods, Olde Thyme Shoppe for Old Time Shop, and U-Haul for You Haul. Ask your parents for other examples.



Kid Klok

You can interact with the Kid Klok at
http://mambo.ucsc.edu/psl/dwm/kk.html
It can be purchased at
http://www.franklinclock.com/kkclock.htm

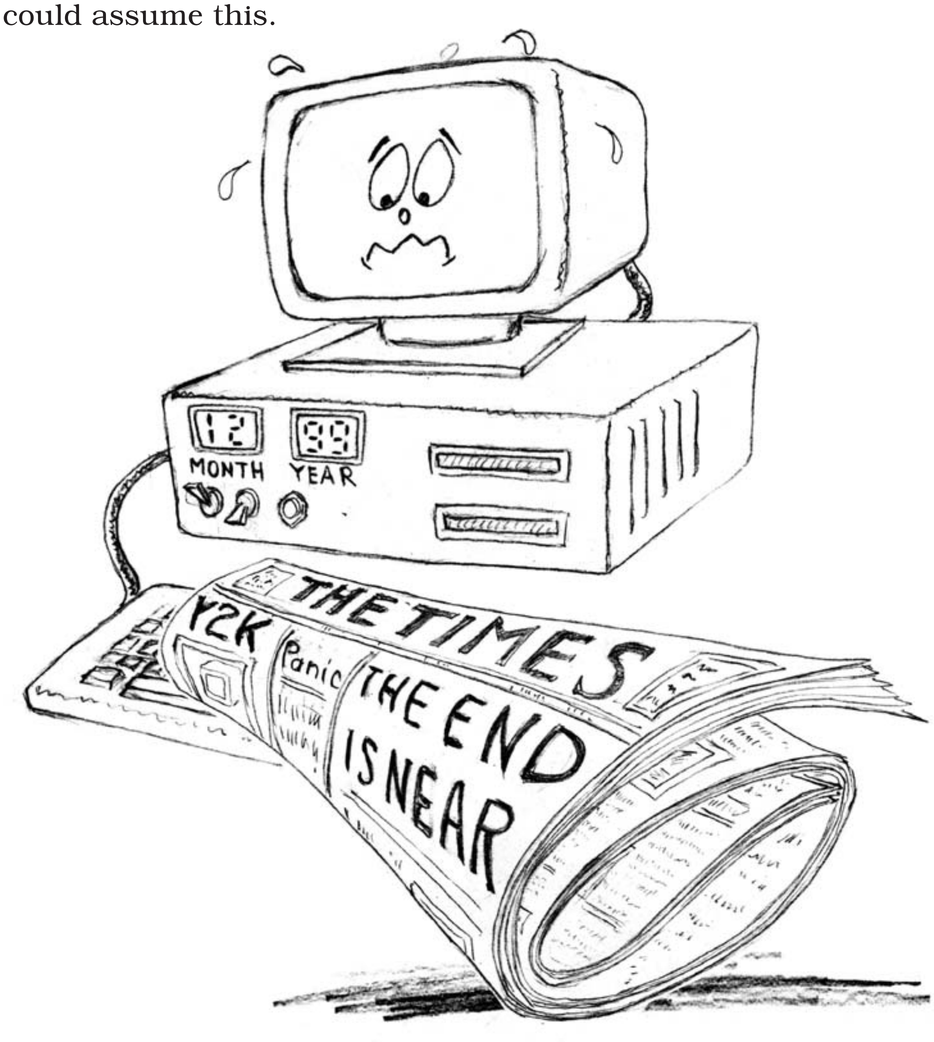
A Fun Lesson

In the lesson, the student sets the little blue hand on the 4 and the big red hand on the 10. This time is **4:10 (four ten).** He or she tells the time by first reading the small blue number that goes with the small blue hand as the hour and the large red number that goes with the large red hand as the minute. Notice that the 5 on the minute dial is written as 05 so that it can be read in the normal way as oh-five.

Eight: The Future of Time

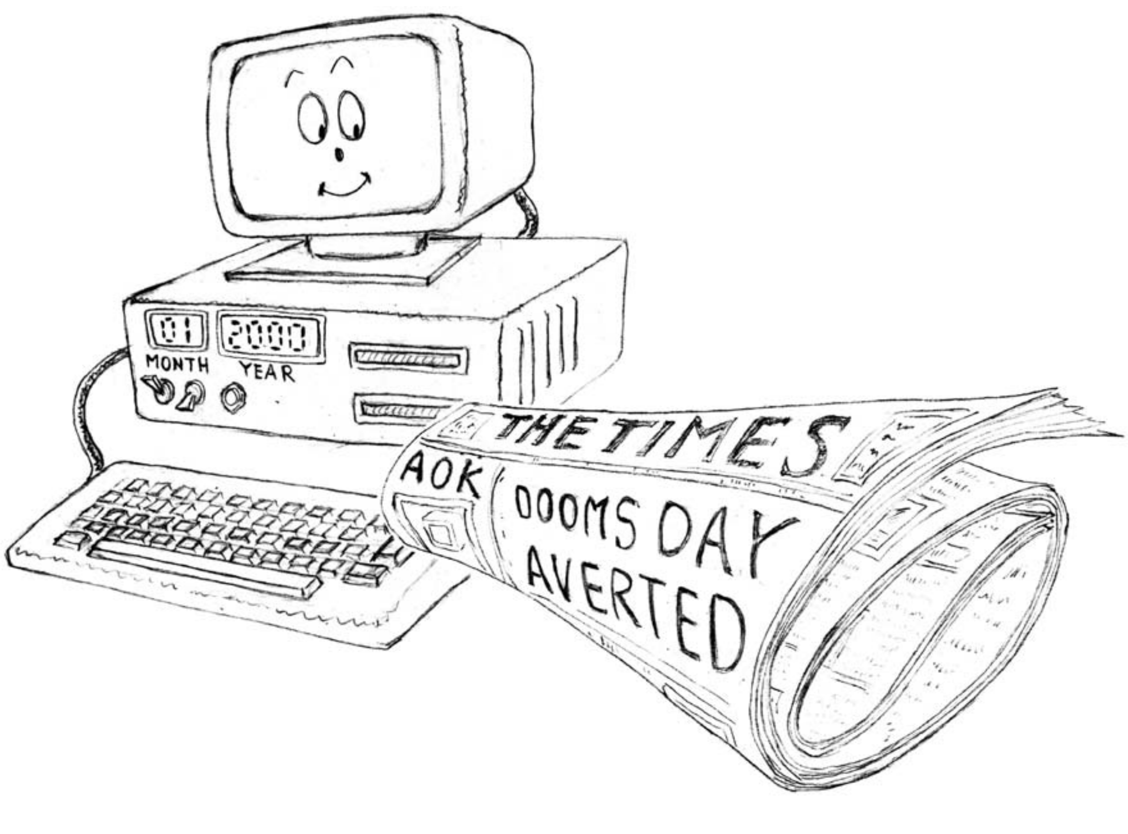
Recording Time: The Year 2000 Glitch

Back in the days when computers were large and cumbersome, it was important to use as little memory as possible to store information. If we wanted to date your birthday in this type of computer, it was natural to eliminate the 19 from the year. All years being entered would begin with 19, and computer users could assume this.



The next century seemed so far off there was no need to worry. But, of course, it arrived, and there was no place in these computers to specify the new century. Had you entered 00 for the year, the computer would interpret it as 1900 rather than the correct year 2000. Our government and our industrial/business communities promised to have the problem corrected in time.

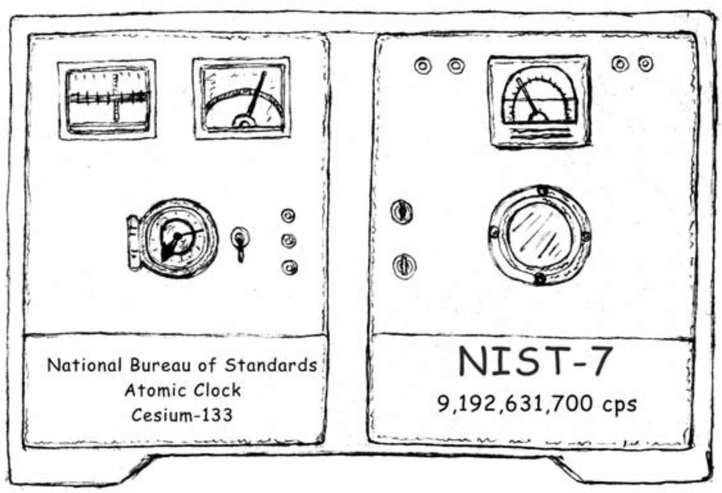
And indeed they did!



Profound Precision

Although we take the clock for granted, it has had a profound effect on all aspects of our life. Clocks govern our behavior in many different ways. Before clocks, a person's behavior was less regular and less predictable. In this age of worldwide communication and interaction, it is difficult to imagine how our society would work without the order imposed by time-keeping.

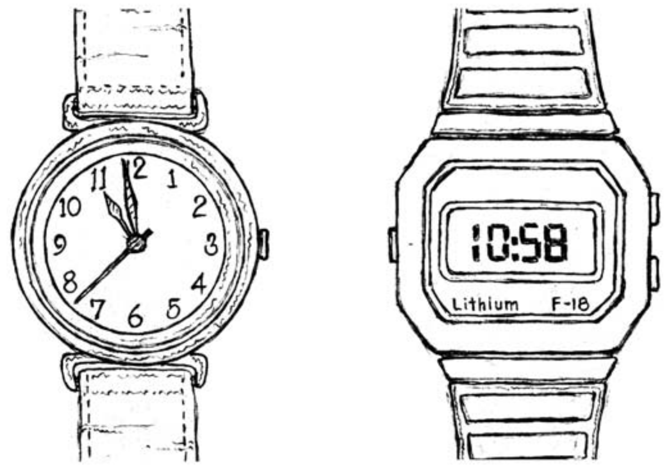
Although clocks are usually cheap, the United States invested three million dollars in a timepiece to serve as our universal standard. This clock, the NIST-7, is protected inside a climate-controlled room at the foot of the Rocky Mountains. As can be seen in the illustration, it looks nothing like the other time-keepers throughout history.



It is accurate to within one second every six million years. It achieves such precision by counting the vibrations of atoms, which are nature's fundamental units of matter. Some Cesium-133, a metallic element, is heated to boil off some individual atoms, which are then accelerated through microwave fields. It turns out that the outermost electron of this heated atom vibrates (oscillates) at an extremely regular rate. Detectors are set up to count these vibrations. And even more impressive is that they are vibrating at 9,192,631,770 times per second.

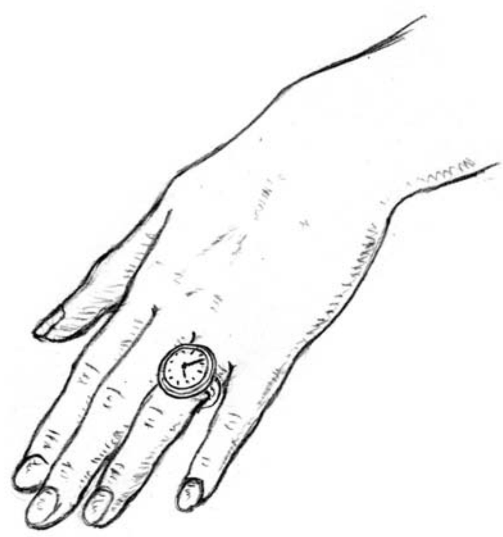
Little Clocks

A watch can be thought of as a clock that a person wears on his or her body. The word watch comes from the Anglo-Saxon word *waeccan* meaning “to watch” or “to keep track of.”



Miniature Watches

As you know, computers are getting smaller and smaller at a fantastic rate. The technology used in computers can also be used in clocks and watches. Already there are watches small enough to be worn as rings on your finger.



Shakespeare's Time

Perhaps the best closure we can provide to the future of time is to acknowledge Shakespeare's great insight into the ages played out in human experience. We end with these lines from Shakespere's famous play *Macbeth*. Read them aloud, and listen to how the measured pace of the words seem to tick like a clock.

> Tomorrow, and tomorrow, and tomorrow
> Creeps in this petty pace from day to day,
> To the last syllable of recorded time...

By making an effort to see, hear, and do in order to understand, each of us will be applauded for an outstanding performance. What do you now understand about time, and what more do you want to learn?

GET READY TO LEARN ABOUT TIME

HAVE YOU EVER WONDERED:

HOW ARE CLOCKS MADE?

WHY DO CLOCKS RUN CLOCKWISE?

WHY DO BEARS KNOW WHEN TO WAKE UP?

HOW DO CRABS KNOW WHEN TO CHANGE THEIR COLOR?

WHY ARE THERE TWO HANDS BUT ONLY ONE SET OF NUMBERS ON CLOCKS?

IN THIS BOOK WE INVITE YOU THINK ABOUT THESE AND OTHER MYSTERIES ABOUT TIME.

YOU WILL EXPLORE THE HISTORY OF TIME AND ITS PLACE IN NATURE.

YOU WILL LOOK INSIDE CLOCKS TO SEE HOW THEY WORK.

THE ILLUSTRATIONS, GAMES, AND PUZZLES GUARANTEE AN EXCITING ADVENTURE.

IN READING THIS BOOK, YOU WILL LEARN MANY FUN FACTS ABOUT TIME.

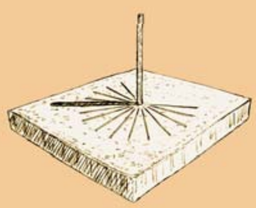
YOU WILL FIND OUT WHY TRADITIONAL CLOCKS ARE HARD TO READ, AND

HOW LEARNING TO TELL TIME CAN BE MADE A PIECE OF CAKE.

THIS BOOK WILL CHALLENGE YOU TO THINK, PROVOKE YOUR IMAGINATION, AND

GUIDE EXPERIMENTATION WITH SOMETHING WE OFTEN TAKE FOR GRANTED: TIME.

THE AUTHORS ARE EXPERTS IN THE PSYCHOLOGY AND PHYSICS OF TIME AND LITERATURE. THEY HAVEN'T STARRED IN MOVIES, BEEN FEATURED IN VIDEO GAMES, OR EVEN APPEARED ON TELEVISION. IF YOU BUY THIS BOOK, HOWEVER, THEY JUST MIGHT.



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