Finding Our Way

6

> *The church says the earth is flat, but I know that it is round, for I have seen the shadow on the moon, and I have more faith in a shadow than in the church*
>
> Ferdinand Magellan (c. 1480–1521)

The Calendar

Perhaps no application is more important to the early developments in mechanics than the production of an accurate calendar. There is a fabulous book that has been written on the subject of the calendar, named appropriately *The Calendar*, by David Ewing Duncan [44]. For the simple reason that his book is all-encompassing, I will not go into great detail herein on this most important subject. I will instead attempt to summarize the evolution of our calendar, especially in sofar as it has impacted the science of mechanics (Figs. 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.17 and 6.18).

Let us begin with what we believe to be the first recorded reference to a calendar, carved on a bone, and discovered in France. This carving has been dated to about 32,000 BCE, and appears to be a lunar based calendar (see Chap. 1).

I will skip over many of the details in between and jump directly to the Egyptian calendar. As early as about 4,000 BCE, the Egyptians appear to have been constructing a solar based calendar that correlated the date of the arrival of the annual flood of the Nile to the day of the year on which Sirius (the Dog Star) rises in the eastern sky, and this evolved into what appears to be the oldest calendar that uses a 365 day period for a revolution of the Earth about the Sun. Other attempts at that time that were based on the Sun's position in the sky were apparently not quite as accurate, and calendars based on lunar motions were even less accurate.

Still later, in 238 BCE Ptolemy III ordered that a leap day be added every 4 years, thus improving the Egyptian calendar to 365.25 days. Unfortunately, this edict did not take hold in Egypt, as the religious clerics persisted in adhering to the 365 day calendar, despite the fact that scientists such as Hipparchus (see Chap. 2) had determined that this was in error.

For the purpose of the current discussion, it is important to recognize that the period of revolution of the Earth about its own axis, the period of revolution of the Moon about the Earth, and the period of revolution of the Earth about the Sun

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Fig. 6.1 Statue of Julius Caesar in the Tuileries, Paris

are all independent of one another. Indeed, each of these can and are affected by motions of other objects in the universe, especially large ones that are close to Earth, and these effects are in most cases caused by gravitational forces.

Fig. 6.2 Portrait of Pope Gregory XIII by Lavinia Fontana

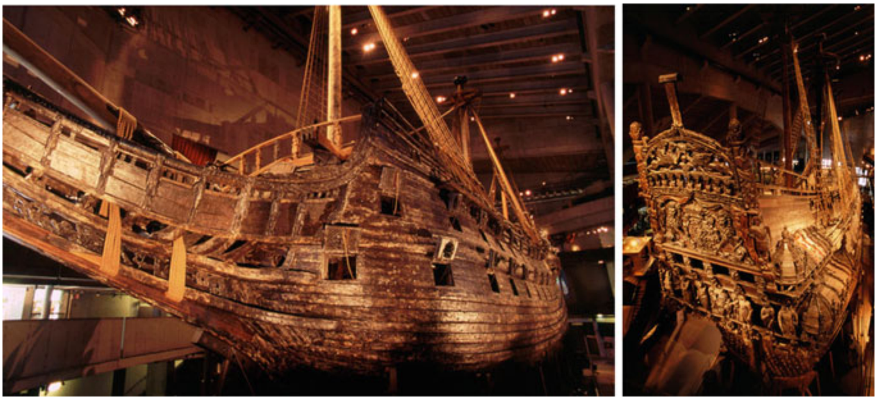


Fig. 6.3 Photos of the Wasa: Bow photo on *left*, stern photo on *right*

On rare occasions, when the Earth or the Moon is impacted by an object, the mechanics of these impacts can also affect the duration of a day or a year. The other spans of time that we humans use are wholly made up by us: a second, an hour, a week, a month, a decade, a millennium, etc. In fact, this is a distinguishing feature of our species compared to all others that we are aware of: *so far as we know, we are the only ones that measure time using a calendar*. This makes the duration of time measurable in an intimate way, which is a good thing. That way we know when we are supposed to report for work, a dinner engagement, or our own wedding, for example. Unfortunately, it may also make us the only species that is aware of our own mortality.

Fig. 6.4 Balancing water pressure and wind (*red*) with ship weight and ballast (*orange*)

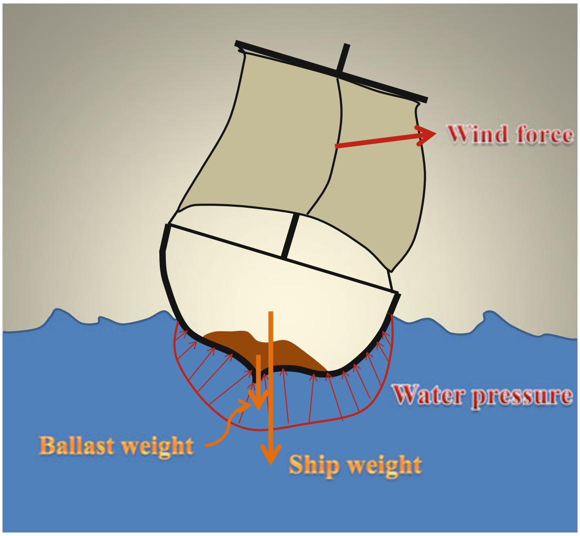


Fig. 6.5 Recreation of L’Anse aux Meadows, Newfoundland

But I digress. Let us get back to the calendar. Let us now jump to the Romans, who possessed the military power to gain control over much of the world by the middle of the first century BCE. Julius Caesar (100-44 BCE) came to power in the

Fig. 6.6 Portrait of Marco Polo

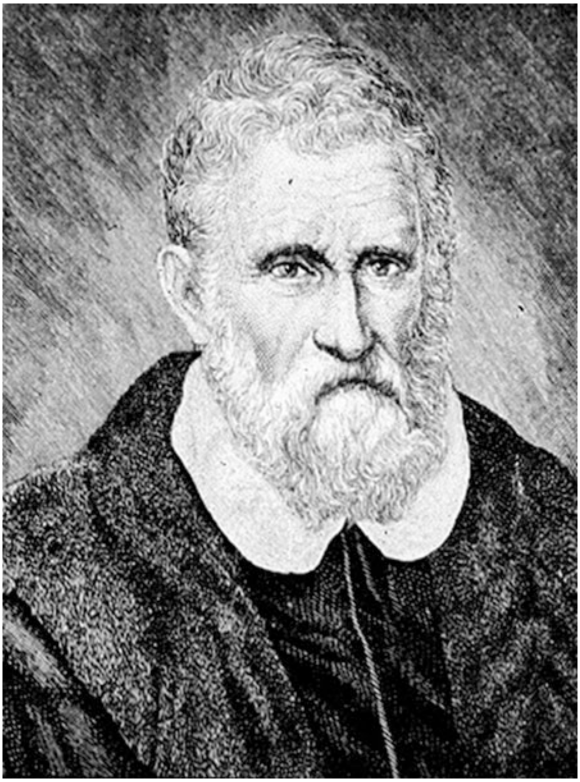


Fig. 6.7 Portrait of Christopher Columbus by Sebastiano del Piombo

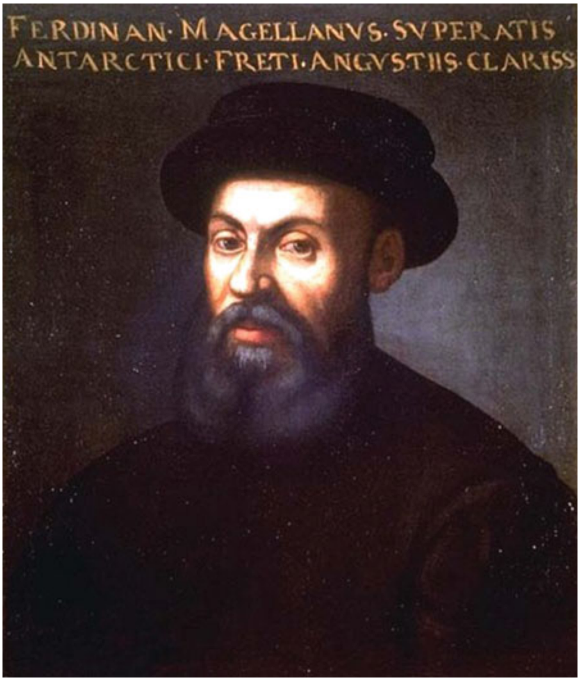


Fig. 6.8 Portrait of Ferdinand Magellan

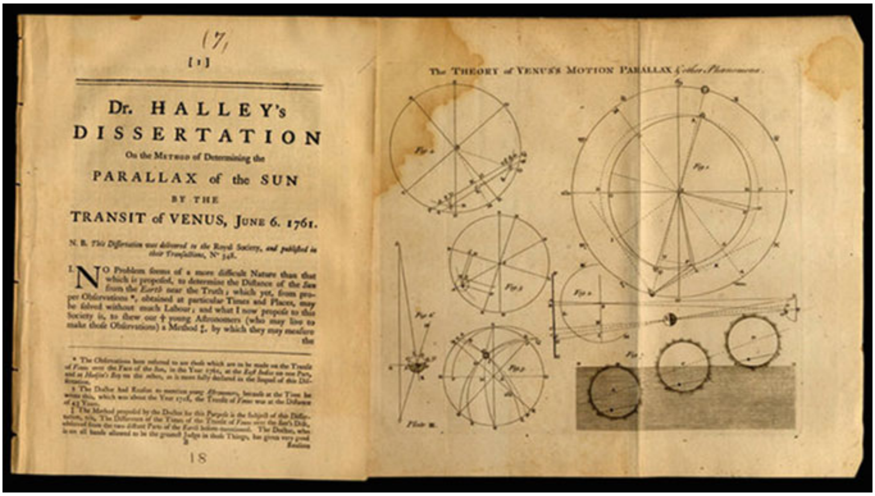
Fig. 6.9 The Victoria, the only ship in Magellan's Fleet to complete the first Circumnavigation of the earth

Fig. 6.10 Portrait of Francis Drake by Marcus Gheeraerts

Fig. 6.11 Portrait of Captain James Cook by Nathaniel Dance-Holland

middle of that century, and he eventually defeated Pompey Magnus (106-48 BCE), the First Man in Rome at the time, at the Battle of Pharsalus (Greece) in 48 BCE, and in so doing he dispatched the last of his enemies within the Roman Republic

Fig. 6.12 Portrait of Edmund Halley by Thomas Murray



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[1]

Dr. HALLEY's
DISSERTATION
On the Method of Determining the
PARALLAX of the SUN
BY THE
TRANSIT of VENUS, June 6. 1761.

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Fig. 6.13 Diagram from Sir Edmund Halley's report to the Royal Society describing how to measure the distance to the Sun using the transit of venus

(at least for the time being). Perhaps fortuitously, Pompey was not killed in the battle, and he made his way to Egypt in hopes of finding refuge there.

Caesar pursued him with two of his (depleted) legions, and upon his arrival in Egypt he was informed that the youthful pharaoh Ptolemy XIII (c. 62–47 BCE) (as opposed to the scientist Ptolemy, who came later) had ordered that Pompey be beheaded upon his arrival in Egypt, and that this order had been duly carried out. Caesar was naturally furious at this revelation (perhaps because he wanted to have this privilege himself), and as a result he was not terribly endeared to the 14-year-old Ptolemy. Perhaps this had something to do with the fact that he fell in with Ptolemy's sister and opponent Cleopatra VII (69-30 BCE).

Fig. 6.14 The Endeavor leaving Whitby Harbor England in 1768

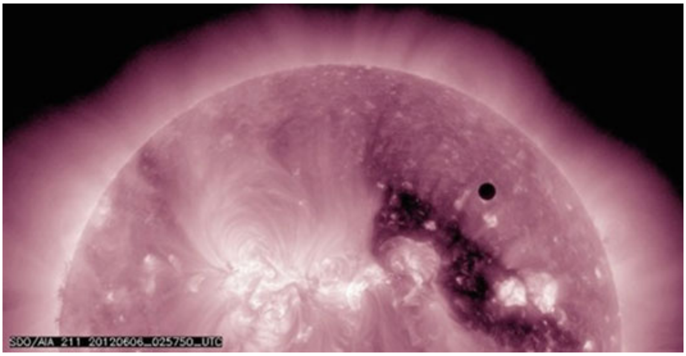

Fig. 6.15 Image of Venus transiting the Sun on June 5, 2012

In due course Caesar patched up the relationship between the two feuding siblings (only briefly), and Cleopatra threw a great party to celebrate this reunion. History tells us that during the party Caesar entered into a conversation with a scientist named Acoreus, who somewhat surreptitiously explained the Egyptian calendar to Caesar. This was apparently the first time that Caesar was informed of this, the most advanced calendar on Earth at the time. And lest it is not already obvious, the Egyptians devised this calendar using mechanics to measure and correlate the motions of the Earth and the Nile River.

Unfortunately, the sibling co-pharaohs could not be made to like each other. Thus, there ensued a civil war in Egypt, forcing Caesar to hang around for several months in Alexandria, long enough for him to sire a child by Cleopatra (named Caesarian). Eventually, Ptolemy was displaced by Caesar (the young pharaoh drowned in the Nile) and Cleopatra took the throne, thus making her the (last) pharaoh (She also later shared the throne briefly with her younger brother Ptolemy XIV (60-44 BCE)).

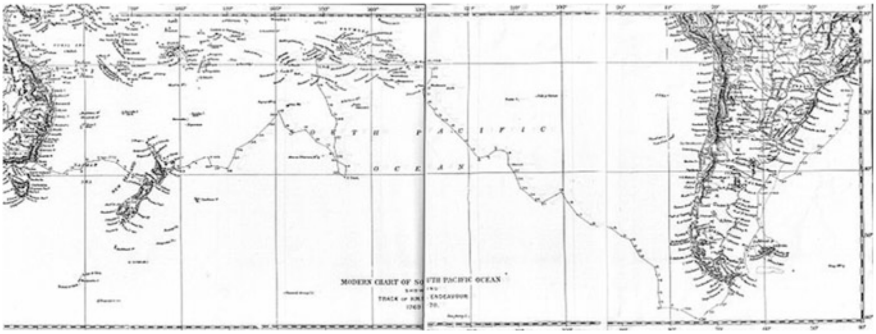

Fig. 6.16 Route of the Endeavor

Fig. 6.17 Captain cook memorial on Kealakekua Bay, Hawaii. *Note* that this is the site where he was killed

Fig. 6.18 Portrait of Joseph Banks by Sir Joshua Reynolds

The point of all of this background information is to explain that due to all of this squabbling Julius Caesar was forced to remain in Egypt for 9 months, and over the last 2 months of his tryst with Cleopatra the pair partook of a languid trip down the Nile. During this cruise he met Cleopatra's astronomer Sosigenes of Alexandria, who explained the Egyptian calendar in further detail. Their 365 day calendar that included a leap day every 4th year seemed to him to be a major improvement over the Roman calendar. Caesar was indeed quite interested in their calendar for reasons that would be obvious if you had lived in Rome at the time.

Somewhat inexplicably, despite their advanced society the Romans had never quite figured out how to handle the calendar. For them, the 1st day of the year was March 1st. The first 6 months of the year were named after the Gods, and the succeeding 4 months were named after numbers: 7 (September), 8 (October), 9 (November), and 10 (December). Their calendar, as originally set up by Romulus (or so the legend went), only contained 10 months. King Numa had added 2 months, Januarius and Ferbruarius, to the calendar in 700 BCE, but they were considered to be the 11th and 12th month of the year. This had brought the total number of days in the lunar based Roman calendar to $12 \times 29.5 = 354$ days (the Moon orbits the Earth about once every 29.5 days).

The remaining approximately 11 days were to be intercalated each year by decree of the Roman Senate. Unfortunately, the Senate had become so dysfunctional in Caesar's time that they had been unable to agree on what day to assign as March 1st, the 1st day of their year. Thus, by the middle of the first century BCE, the Roman calendar had become 2 months out of sync with the seasons, and this was quite obvious to everyone. It was against this backdrop that Caesar learned of the Egyptian calendar.

When he finally managed to clean up the mess in Egypt, Caesar returned to Rome, where he was forthwith made Dictator for 10 years by his own puppet Senate. Acting on his newfound power, he immediately summoned Sosigenes to Rome, along with several other sages on the subject of the calendar. Working together, the group constructed a completely new calendar and Caesar persuaded his puppet government to adopt this new calendar.

Caesar's calendar, called the Julian Calendar today, had 6 months of 31-day duration, interspersed with 6 months of 30 days duration, with the exception that Februarius had 29 days, extended to 30 days every 4th (leap) year. Caesar's final gesture was to change the 1st day of the year to January 1, presumably because it was closest to the winter solstice. The issue of weeks and days of the week was still up in the air, not to be sorted out for nearly 400 years (as described in Chap. 4).

Unfortunately, in order to bring the calendar back into synchrony with the Sun, it was necessary to intercalate a couple of months in the 1st year of the new calendar. Thus, the 1st year of the Julian Calendar had a total of 445 days! That 1st year of 46 BCE was a mess throughout the Roman Empire, especially for moneylenders, who charged interest based on the number of days the money was loaned (just as moneylenders do today!). As a result, they had no idea how much to charge. Still, Romans somehow managed to muddle through, and when January 1st rolled around in the year 45 BCE, the Romans suddenly had the most accurate calendar on Earth.

The following year Caesar was assassinated by members of the Senate on the Ides (15th) of March. Shortly thereafter, the Roman Senate proclaimed him a God (they apparently liked him much more so now that he was dead), subsequently renaming the month Quintilis to Julius in his honor. This wasn't so bad, but to make matters worse, the clerics began intercalating leap days every 3rd year instead of every 4th year, immediately undermining the brilliant work of Caesar's scientific advisors.

Caesar's nephew Augustus (nee Octavian) shortly gained power, and he corrected this error. He gained such power in time that the Roman Senate decided to award his name to the month of Sextilis, thus changing it to Augustus. Since the month named in honor of Julius Caesar had 31 days, the Senate deemed that Augustus should be treated equally, therefore awarding him 31 days as well. This of course made the year 1 day too long, so the Senate removed 1 day from the month of Februarius, changing it to 28 days, except for leap years, when it was to have 29 days. As a final gesture, they reversed the 30–31 day order for the last 4 months of the year, thus creating the chaotic order of the number of days in each month that we have today. *This is an example of excellent mechanics being corrupted by politics.* We shall see more examples of this in future chapters.

Interestingly, a number of other people have attempted to have months of the year named after themselves, including several Roman Emperors, but only the months named after Julius and Augustus Caesar survived. All of the other changes were eventually dropped by an unaccepting populace.

So the provinces of the now Roman Empire adopted the Julian Calendar, and things remained that way in the areas that comprised the provinces even after the fall of the Empire in 476 AD. And while the calendar became of little significance during the Middle Ages, when people simply lived from day to day attempting to eke out sufficient sustenance for survival, the Julian Calendar persisted in enough places that it eventually regained prominence across Western Europe as the Renaissance began to unfold in the fourteenth century.

Unfortunately, as we know today, a solar year on Earth does not take 365.25 days. It takes closer to about 365.24219 days. Thus, the Julian Calendar is incorrect by a small but nevertheless significant amount. In order to completely understand this difference, it is important to understand that there is more than one way to measure a year. The obvious version is called a sidereal year. This means of measuring a year determines the length of time that it takes for the Earth to complete one orbit of the Sun. Unfortunately, this means of determining the length of a year is not the most practical one.

There is another year called a solar (also called a tropical) year, and that year is more useful on Earth than is the sidereal year. The solar year is the span of time required for the Sun to return to the same position as seen from Earth (such as the equinox). This may sound like the same thing as the sidereal year, but it is not. The reason that it is not is because of the Earth's precession, as described in Chaps. 1 and 10.

Here is how this difference occurs. The Earth is not only orbiting the Sun and spinning as it does so, it is also wobbling, called precession. This precession was apparently first noticed by Hipparchus (see Chap. 2), although he did not know why it occurred. It was explained by Isaac Newton in *The Principia* (see Chap. 7). The reason for the Earth's precession is that the Sun and the Moon exert gravitational forces on the Earth that cause it to wobble, and this wobble has a period of about 25,772 years. This wobble is called 'precession' because the direction of the rotation of the wobble is in the same direction as the Earth's orbit about the Sun (as opposed to the direction of Earth's spin). Due to this precession the Sun returns to its position in the sky about 20 min before the Earth makes one full orbit of the sun each year.

Now, this 20 min difference can add up over time. In fact, it will add up to 1 year by the time the Earth has completed one complete revolution of its axial wobble, and due to this precession, the Earth will have actually traveled one additional revolution about the Sun. A similar (but slightly different) circumstance occurred in the movie *Around the World in 80 Days*, when the fictional character Phileas Fogg discovers on completing his circumnavigation of the Earth in 81 days that he has actually saved 1 day due to the rotation of the Earth on its axis.

More importantly, the question is—which measure of the length of a year is more practical? The seasons are determined by the Sun's position with respect to Earth, so for the purposes of farming, for example, it makes more sense to use the solar year than the sidereal year. This in itself is reason enough to use the solar year, but it isn't the main reason that the solar year was chosen.

The main reason that the solar year was chosen was because of the description for the date of Easter described in the Bible, which is very complicated, but a simplified version says that Easter falls on the first Sunday after the first full Moon after the vernal equinox. Thus, we use the solar year to measure time on Earth.

More importantly, the Julian Calendar is not quite right. No one is quite sure when folks started realizing that the Julian Calendar was incorrect. We do know that Dionysius Exiguus (c. 470–540), the monk that invented the Anno Domini (AD) dating system (badly, I might add), had some concerns about the date of Easter, but these do not appear to have been related to the error in the Julian Calendar.

As we know from Chap. 4, The Venerable Bede discovered that the Julian Calendar was in error in the early eighth century. However, it appears that the first person to actually complain about the error in the Julian Calendar was none other than Roger Bacon (c.1214–1294). As described in Chap. 4, Bacon was an Oxford educated lecturer who spent most of his career at the Universities of Paris and Oxford.

Bacon was apparently really smart, probably too smart for his own good. He ended up getting into quite a bit of trouble, and part of his trouble may have come about due to the fact that he had figured out that the Julian Calendar was in error, by about 9 days by his judgment, at the time he lived. So Bacon complained to the Pope that Easter was being celebrated on the wrong day because he knew how to calculate the date of the equinox. He subsequently got into trouble, and though the record is not very clear as to why, he appears to have been imprisoned for many years, perhaps at least in part because he complained about the calendar, which was nothing more than an issue in mechanics. Meanwhile, nobody paid too much attention to his complaints at the time (the late thirteenth century).

Eventually, however, the errors in the Julian Calendar became impossible to ignore (since the seasons did not agree with the calendar). Thus, in 1577 Pope Gregory XIII convened a scientific commission to develop an improved calendar. By that time more accurate instruments were available for measuring the position of the Earth with respect to the Sun, and the scientific commission used mechanics to determine that the Earth revolves about the Sun every 365.242 days, and they recommended that every year that is exactly divisible by four is a leap year, except for years that are exactly divisible by 100; with the exception that the centurial years that are exactly divisible by 400 are still leap years. For example, the year 1900 was not a leap year, but the year 2000 was a leap year.

This corrected the calendar to within one part in one million of the actual period of the Earth, thus improving things for a long time to come; that is, unless the Earth gets struck by a really big meteorite. Such an enormous impact would invariably change the Earth's orbital period (the duration of a year) about the Sun, as well as its rate of spin (the duration of a day). But then it won't matter, because there won't be any humans left on Earth anyway.

On February 24, 1582 Pope Gregory issued a papal bull altering the calendar to what is today termed the Gregorian Calendar. In order to correct the amount that the Julian Calendar had become in error by that point in time, he decreed that the commission's leap year formula be followed, and he also decreed that *on March 11 of that year the calendar be immediately advanced by 10 days to March 21*! Thus, if you were born between March 11 and 21, you missed a birthday that year!

This development didn't sit too well with a lot of people. In many villages it took years for the word to arrive. Others, such as the whole of England, were in the midst of the Protestant Reformation, and they didn't choose to follow any of the Pope's orders, so they ignored his papal bull. Thus, for many years lots of people had no idea what day it was!

In England Queen Elizabeth was generally in favor of the change, but the Archbishop of Canterbury protested (naturally!), with the result that they didn't accept the Gregorian Calendar until the year 1752, by which time it was necessary to remove 11 days from the calendar (instead of the ten ordered in the papal bull). Thus, for a period of nearly two centuries, if you wanted to have two birthdays in 1 year, all you had to do was celebrate it in France, and travel to England, making sure that you arrived there within 10 days.

This sort of nonsense was prevalent all over Western Europe, as well as other parts of the world until the Gregorian Calendar was finally accepted by the last holdout (China) in 1949. So while we can say that humankind is the only species that has invented our own units of time, it hasn't always been easy to agree on implementation. I would be remiss if I did not point out the obvious: all of this chaos resulted from nothing more than an exercise in mechanics.

The Explorers

In my view explorers deserve a special nod with respect to the science of mechanics, especially those who traveled by ship. There are a number of reasons for this assertion. First, ships are in and of themselves complicated structural entities that engender a variety of issues associated with mechanics. Second, the stability of a ship is by no means guaranteed during a voyage, as evidenced by the enormous number of ships resting on the bottom of the Earth's lakes, seas, and oceans today, and ship stability involves mechanics. Third, navigating a ship across vast bodies of water involves considerable understanding of mechanics.

The Wasa

My favorite example of a sunken ship is the Wasa (pronounced *Vasa*), a Swedish warship that sank in a light breeze on her maiden voyage in 1628, less than 2 km from her moorings in Stockholm harbor. The ship sank because there was insufficient ballast to resist the force of the wind and water pressure, and the ship listed to one side, thereby allowing water to rush in through the gun ports. This is a problem in mechanics.

There she lay for nearly 350 years, until Anders Franzén (1918–1993) discovered the wreck and convinced the Swedish government to float the ship in 1961. After many years of salvage and reconstruction, the ship went on public display at the Wasa Museum in Stockholm in 1987. The salvage process involved many projects based in mechanics. This museum should be visited by anyone who is interested not only in mechanics, but also in understanding the hardships that the great explorers of the past suffered in order to discover new lands.

Ship stability involves balancing the effects of wind, water pressure, ship weight, and ballast in such a way as to ensure that the water level remains below the deck of the ship. Otherwise, water may rush in and scuttle the ship. This is a rather complicated problem in mechanics. Today we can monitor ship stability by using Newton's Second Law (see Chap. 7), but until recent times ship stability was accomplished strictly by experimental means.

Pythéas

Perhaps the most famous of the ancient explorers is Pythéas (c. 350–285 BCE) [45]. He is the first person known to have sailed to Great Britain from Greece. He is also the first person to have recorded the midnight sun and the polar ice. And he is the first person known to have stated that the tides are caused by the Moon. This is a problem in mechanics, as the motions of the water on the surface of the Earth are profoundly affected by the gravitational pull of the Moon.

The Americas

Most people believe that Columbus discovered the Americas in 1492. However, there is some evidence to the contrary. In 1976 a shipwreck was discovered in the harbor of Guanabara near Rio de Janeiro, Brazil. Subsequent study of the site in 1982 by Robert Marx indicated that numerous amphora found at the site appeared to be of the same style as those used by the Romans in the third century BCE, thus making a circumstantial argument for the discovery of South America by Romans nearly 1,700 years before its previously supposed discovery.

Interestingly, when this discovery was reported in Brazil, many Italian transplants immediately claimed to be citizens of Brazil by force of discovery. Common belief holds that Brazil was discovered by Pedro Cabral (c. 1467–1520) in 1500. As a result, Portuguese citizens receive special treatment when applying for Brazilian citizenship, but Italians do not.

Is it possible that South America was discovered by Romans seventeen centuries earlier than previously held? If so, they were either blown a long way off course, or they must have had some pretty amazing means of measuring their location, a problem in mechanics.

We know today that Polynesians managed to inhabit essentially every inhabitable island in the Pacific Ocean beginning thousands of years ago. Jared Diamond's Pulitzer Prize winning book *Guns, Germs, Steel* explains much dealing with this expansion [46].

Apparently, the last string of islands settled by the Polynesians was the Hawaiian Island chain, which is the most remote land mass on Earth, sometime between 300 and 800 AD. They seem to have accomplished this amazing feat with little more than canoes and a gift for navigation via the stars at night. Here is a truly amazing feat in the study of celestial mechanics.

Although it has not been confirmed, it is also believed that the Polynesians actually discovered South America because sweet potatoes, which are indigenous to South America, can be found in several Polynesian Islands today.

According to Irish legend, St. Brendan of Clonfert (c. 484–577) sailed to North America in the sixth century. However, although there are some pretty tantalizing stone markings in the United States today, there is no extant proof of this voyage.

According to the Icelandic Sagas, Leif Ericson (c. 970–1020) established a colony on the island of Newfoundland in North America around 1000 AD. The settlement is today called L'Anse aux Meadows, thus providing corroboration of Ericson's discovery of the Americas. A careful examination of a map will show that it is possible to navigate around the North Atlantic without having to get too far from land (that is, once you get from Norway to Iceland!). Thus, Ericson's transatlantic navigation may not have required too much mechanics, but he nonetheless deserves mention here for surviving all of that ice, which surely required some appreciation of the mechanics of ice!

Marco Polo

Marco Polo (1254–1324) is by far the most famous of the explorers from the Middle Ages. He apparently traveled from Europe to China and back in 1271–1295. I mention him here because his descriptions of the East had a significant impact on later explorers who decided to sail west to get to the East, a challenging problem in mechanics.

Christopher Columbus

The fall of Constantinople (the last remnant of the Eastern Roman Empire) to the Ottomans in 1453 dealt a severe blow to Venetian trade with the East, from whence had heretofore come prized foodstuffs from the Spice Islands. Acting on the possibility of gaining wealth by sailing west and potentially arriving in the East, if indeed the Earth was a sphere, several explorers proposed voyages to the West in the latter part of the fifteenth century. Of course, as we all know, the first to do so and survive was Christopher Columbus (c. 1451–1506), an Italian sailing under the Spanish flag in 1492. He didn't actually make it to India, but he thought he had, from whence we have the terms "West Indies" and "American Indians."

What makes Columbus' voyage so impressive is that he managed to accomplish it without the aid of a modern day chronometer, a mechanical device that can be used to determine longitude (See Chap. 8). Of course, it was possible to determine latitude by using a sextant (a device for determining the angle of declination, such as of the North Star), but the lateral distance from your home port was strictly guesswork at that time, meaning that no one could determine longitude accurately. In other words, Columbus was lucky!

I am not going to go into detail regarding all of the other famous explorers of that time because you can find the history of exploration in any world history book, but I do want to mention three other explorers from that period due to their importance to the science of mechanics.

Ferdinand Magellan

First and foremost, we simply must mention Ferdinand Magellan (c. 1480–1521), who should be right at the top of anyone's list of explorers. He is the first person to circumnavigate the globe. He didn't actually do it himself, but he sailed west from Spain and made it to a longitude that others had made it to by going east, thereby proving that the Earth is a sphere.

Although Magellan was killed by natives in the Spice Islands, a (very) few of his crew continued sailing westward and actually made it all the way back to their home port in Sevilla. This has been noted by some historians as the beginning of the modern era, and his accomplishment as the greatest one in human history.

Why is this considered so great a feat? To understand that, you will need to read a book detailing his voyage. I personally recommend *Over the Edge of the World* by Laurence Bergreen [47]. Therein you will find out that Magellan overcame almost incomprehensible geographical and meteorological hurdles (most notably, navigating the Straits of Magellan), mutiny by his own sailors, and near starvation in the middle of the Pacific to accomplish this amazing feat that required considerable mechanics. But most important of all, Magellan's voyage finally established beyond a doubt that the Earth is a sphere.

Francis Drake

So incomprehensibly difficult was Magellan's voyage that it was not duplicated until almost 60 years later, and in between several voyages failed (with great loss of life). Indeed, the next person to circumnavigate the Earth was Sir Francis Drake (1540–1596). If you go to California, you will find him to be quite a hero. That is because he discovered the West Coast of North America, including California.

I am quite certain that there are a multitude of reasons why Captain Drake deserves recognition in a book on mechanics. I choose to employ this one. He explored the Eastern side of the "ring of fire," where many active volcanoes and earthquake-prone faults exist. And as we will see in Chap. 11, these are problems related to mechanics.

Captain James Cooke

The last oceanic explorer that I want to mention is Captain James Cook (1728–1779). He is my personal favorite for several reasons. First and foremost, his expeditions were expressly for the purpose of extending our knowledge of science. There are several other reasons.

As described in Richard Hough's book *Captain James Cook* [48], Captain Cook commanded three voyages to the South Pacific in the latter third of the eighteenth century. The first was perhaps the most important to the science of mechanics.

Here is a great story in the history of mechanics, indeed of all science. It seems that in 1663 the Scottish mathematician James Gregory had posited that using measurements at widely separated points on Earth, the distance to the Sun could be determined using parallax during the transit of Venus. Acting on this suggestion, the English scientist Edmund Halley (1656–1742) wrote a paper to the Royal Society in 1716 describing how parallax could be used to make this all-important calculation. Unfortunately, Halley did not live to see the next transit of Venus, since the transit of Venus only occurs twice (at an 8-year interval, due to retrograde planetary motion relative to Earth) in a little more than a century.

When the long awaited approaching transit of Venus came in 1761, it was expected by the scientific community that this long-sought distance would be measured. Unfortunately, the several expeditions that were sent out were either blocked by clouds or were not sufficiently far apart to measure the distance to either Venus or the Sun.

Thus, when the second transit in the 100-year cycle occurred in 1769, the English were prepared, sending one expedition to Hudson Bay in Northern Canada, and the other to Tahiti, under the command of Captain Cook on the ship Endeavor.

Captain Cook and the crew of his ship (including the soon-to-be world famous botanist Joseph Banks (1743–1820)) measured the transit of Venus from Point Venus on the island of Tahiti on June 3–4, 1769, thus providing the necessary measurements to determine that the Sun is approximately 149.60×10^6 km (93,000,000 mi, now called one astronomical unit) from Earth.

Still later in April 1770, Cook became the first European explorer to land in Australia, at Botany Bay. The Endeavor eventually circled the Earth, completing its mission, and in so doing becoming perhaps the most successful scientific expedition on this planet in history.

Captain Cook was to lead two more expeditions to the South Pacific. By the time he was killed by natives on the West Coast of The Big Island of Hawaii in 1779, he had charted and seen more of the Earth than anyone in the history of our planet up to that point in time.

Incidentally, Joseph Banks would later play a significant role in the history of mechanics, elected as president of the British Royal Society in 1778. As described in *The Age of Wonder* by Richard Holmes [49], Banks exercised a profound influence over British science for the remainder of his life. This included many achievements in the science of mechanics.

If you want to know just how significant these developments in world exploration are, you need to go on a deep sea fishing expedition in an open boat on a day with sea state IV. First of all, the mechanics of motion will very likely make you as sick as a dog (whatever that actually means!). The explorers endured this sickening weather often, sometimes for days on end. Second, while you are onboard ship try to guess the time of day without a watch. It is necessary to know the time of day in order to know your longitude. Without longitude, you have no idea how far east or west you have progressed.

Once you are out of sight of land, you will know the feeling of true terror. Being out of sight of land on the high seas can be completely disorienting. And yet, these amazingly courageous individuals succeeded in discovering most of the world before the invention of the chronometer (see Chap. 8). And had they not mapped the world using mechanics, it is hard to imagine where we would be today.