

# **What in the World Happened?**

## **Perspectives on Man's Historic Accomplishments**

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## Introduction

In 2010 I wrote a paper, “What in the World Happened? - Perspectives on the History of Man,” that reviewed the history of the world, particularly mankind’s history, with the objective of understanding what was happening in various parts of the world in different civilizations during the **same time periods**. I printed a few spiral-bound copies of this paper for my family and a few friends and posted an electronic version on my website, ringbrothershistory.com, to share with whoever else might be interested. I found the project to be fascinating and very educational.

Eight years later, I’m following the same path with this paper, “What in the World Happened? - Perspectives on Man’s Accomplishments.” This paper builds on the foundation of “History of Man” to focus on “Man’s Accomplishments,” trying to identify the absolute best, most important, influential, and enduring of Man’s accomplishments in several categories, discussed in alphabetical order: “art,” “conquerors,” “engineering feats,” “inventions,” “literature,” “mathematics,” “medicine,” “music,” “philosophy,” “religion,” and “science,” with a special category of “women’s accomplishments”. My selection criteria for these categories included: independence, scope, and distribution over a long span of history - dominated by author (me) interest. Several second-level categories are included under “science,” such as “astronomy,” “biology,” “chemistry,” and “earth sciences.” I rejected “culture” and “politics” as categories as being too general.

Even within categories, I’ve reduced the content or scope of the potential discussion, trying to make the project more achievable and focusing on my own interests. So, in two categories (“art” and “music”), I focus on the Western world and virtually ignore everywhere else.<sup>1</sup> In other categories, I simplify by focusing on a subset of possible items, for example limiting “art” to “painting and sculpture,” “literature” to “books,” and “music” to “classical music.”

My sources include such books as: a. *The 100 - A Ranking of the Most Influential Persons in History*, by Michael H. Hart, b. *Art*, by Robert Cumming, c. *Science Firsts*, by Robert E. Adler, d. *Medical Firsts*, also by Robert E. Adler, e. *Classical Music*, edited by John Burrows, f. *The Innovators*, by Walter Isaacson, plus innumerable “top 10” articles by experts in each category.

Again, I’m doing this to expand my personal knowledge, write down what I learn, and share the product with interested people.

There is a **lot** of opinion in this exercise - much of it mine. But, let’s have some fun and get going.

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<sup>1</sup> For the purpose of this project, “Western” includes Europe, the ancient Mediterranean Region, western Russia, and North America.

## **What in the World Happened? Perspectives on Man's Accomplishments**

### **Part 1 - Art**

A definition of "art" that I'm comfortable with is *the expression of human creative and technical skill and imagination, producing works to be appreciated for their beauty or emotional power*. Visual arts include painting, sculpture, architecture, ceramics, textiles, mosaics, jewelry making, stained glass, and more modernly, printmaking, photography, video, film making, crafts, etc. There are also performing arts like music, theater, film, and dance.

"Art" is one of the "Man's Accomplishments" categories for which I decided to limit the discussion. First, I narrowed my field of view to Western art (as many authoritative art books do), including only the ancient Mediterranean Region and Europe, thereby ignoring Asia, Africa, and the Americas. Then, to organize and clarify my thinking, I summarized Western art periods and styles, by noting the characteristics of the art and important innovations or media in each period. Even this limited scope was challenging because there seems to be little agreement among experts on how to define (or group) the various art periods.

Then, following my particular interests, I tried to determine who art experts consider the all-time top-10 "best" painters and sculptors. Again, there was much disagreement among the so-called experts. I ended up selecting the list of visual art expert Neil Collins.<sup>2</sup> He considered such criteria as durability or longevity of the artist's reputation, impact of the artist's work on his contemporaries, current public opinion, artistic technique, and what art museums say. He finally admitted that the decision is a highly subjective, personal matter. His assessment seems reasonable to me, so I present it here, the "Top 10" greatest painters and sculptors of all time in historical order by birthdate.

Finally, I picked a representative artwork from each of these artists and include images to close out this section.

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<sup>2</sup> See Best Artists of All Time - Top 10 Painters, Sculptors, <http://www.visual-arts-cork.com/best-artists-of-all-time.htm>.

*Overview of Western art periods and style.*

<b>Art Period/Style</b>	<b>Characteristics</b>	<b>Innovations/Media</b>
Stone Age 30,000 BC - 2500 BC	Cave paintings, carved fertility goddesses, large standing stone monuments	
Mesopotamian 5000 BC - 539 BC	Ceramics, statues, reliefs, mosaics, large step-pyramid temples	Writing (3400 BC), pottery wheel
Egyptian 3100 BC - 30 BC	Pyramids and tomb painting - focus on afterlife	Pictographic writing, early paints, papyrus
Greek and Hellenistic 850 BC - 31 BC	Idealism: painting, sculpture, architecture styles: Doric, Ionic, Corinthian	
Roman 500 BC - AD 476	Realism: wall paintings, portraiture sculpture, architecture, including the arch	Quill pen
Medieval 500 - 1400	Religious texts embellished with rich colors - often featuring gold and silver, bronze metal work, silver and gold jewelry, fresco and panel painting, tapestry, ceramics, mosaics, naturalistic sculpture, stained glass, coats of arms, domed churches	Paper, tempura, prints
Renaissance 1400 - 1550	Rebirth and expansion of classical Greek and Roman style in art, philosophy, and science. New techniques in perspective, manipulation of light and darkness, more secular art.	Printing press, oil paint, pastels, first use of canvas
Mannerism and Baroque 1527 -1750	Mannerism broke the rules; emphasized emotions. Baroque stressed detail, movement, lighting, and drama in search for beauty. Ornate grandeur.	Modern pencil (1564)
Neoclassicism, Romanticism, Realism 1750 - 1900	Neoclassicism recaptured Greco-Roman grace and grandeur. Romanticism emphasized imagination and individuality. Realism celebrated the working class and peasants.	Photography, watercolors, tube paints, fountain pen
Modern 1865 - 1970	New styles and technical innovations. Impressionism captured fleeting effects of natural light. Fauvism emphasized bright colors. Expressionism evoked emotions. Cubism transposed 3-D reality to flat canvas. Surrealism emphasized dreams and the unconscious. Abstract art abandoned form and absorbed consumerism.	Ballpoint pen, acrylic paint, crayon
Contemporary 1970 -	No central theme. Reworking and mixing of past styles. Growth of commercialism and celebrity.	Computer

*Top 10 Western painters and sculptors in historical order by birthdate.*

No.	Artist	Art Period/Style	Comments
1	<b>Donatello</b> Italian (1386-1466)	Renaissance	Unquestionably the greatest sculptor of the early Renaissance. Complete mastery of sculpture in bronze, stone, wood, and terracotta. Combined realism and powerful emotion.
2	Jan <b>Van Eyck</b> Dutch (1390-1441)	Renaissance	The most renowned painter of the early Northern Renaissance. Noted especially for his pioneering mastery of oil painting, his introduction of a new realism in religious works, and portraiture, and his use of luminous glowing colors.
3	Leonardo <b>da Vinci</b> Italian (1452-1519)	Renaissance	Universal renaissance man: scientist, inventor, philosopher, writer, designer and painter. Innovative and influential oil painting technique. Changed the status of artist from artisan to gentleman.
4	<b>Michelangelo</b> Buonarroti Italian (1475-1564)	Renaissance	The greatest painter, draftsman, and sculptor of all time. World famous sculptures exhibit majesty and power. The artist's Old Testament Sistine Chapel frescoes justifiably rank as the finest body of figurative art in the history of painting.
5	Peter Paul <b>Rubens</b> Flemish (1577-1640)	Baroque	The greatest and most influential figure in Baroque art in Northern Europe. Painted almost every type of subject (notably history and portraits). Also designed tapestries, produced book illustrations and festival decorations, as well as cartoons and sketches for sculptures, metalwork and architecture.
6	<b>Rembrandt</b> van Rijn Dutch (1606-1669)	Baroque	Arguably the greatest painter since the Renaissance. He created prolific, stunning masterpieces in biblical history, portraits, and landscapes.
7	JMW <b>Turner</b> British (1775-1851)	Romanticism	The champion of Romantic landscape and seascape. Portrayed nature in all her moods. Fascinating technical and stylistic innovation, especially in watercolors.
8	Auguste <b>Rodin</b> French (1840-1917)	Modern	Greatest and most influential sculptor of the modern era. A master in the use of clay, plaster, stone, and bronze. He sculpted large set pieces, portraits, nudes, and small models.
9	Claude <b>Monet</b> French (1840-1926)	Impressionism	The true leader of the Impressionists. Lifelong obsession with the depiction of light. He painted the same subject dozens of times, under different light conditions.
10	Pablo <b>Picasso</b> Spanish (1881-1973)	Modern	Probably the most important artist of the 20 <sup>th</sup> century; profound effect on the development of modern and contemporary art. Most important semi-abstract artist and one of the great expressionist painters. He also was a master sculptor, ceramicist, designer, and printmaker.

*Artwork samples from the top-10 Western painters and sculptors.*



Donatello's  
David (c. 1440s)



Van Eyck's  
Man in a Red Turban (1433)



da Vinci's  
Mona Lisa (1510)



Michelangelo's  
David (1501-1504)



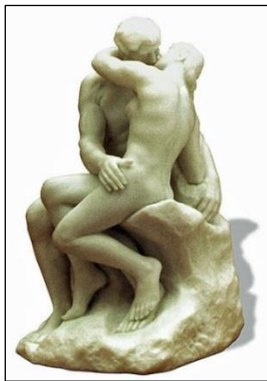
Ruben's  
Samson and Delilah (1609)



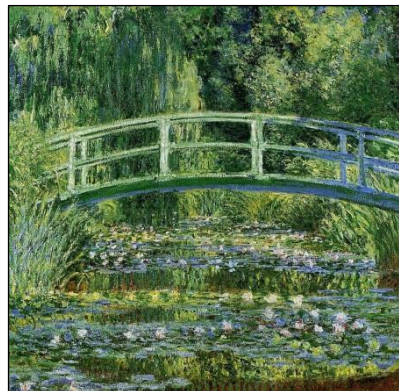
Rembrandt's  
Saskia as Flora (1635)



Turner's  
Rain, Steam and Speed - The Great  
Western Railroad (1840)



Rodin's  
The Kiss (1901-1904)



Monet's  
Water Lilies and Japanese Bridge (1899)



Picasso's  
The Weeping Woman (1937)

**What in the World Happened?  
Perspectives on Man's Accomplishments**

**Part 2 - Conquerors**

Throughout history, aggressive leaders have sought to conquer and control as much territory as possible. Motivated by a desire for power and riches, these conquerors created huge empires that in many cases resulted in the deaths of millions of people. The table below lists the ten greatest conquerors of all time, in terms of territory controlled, in historical order.

*Top 10 conquerors in historical order.*

No.	Conqueror	Conquered Territory	Square Miles	Time Period	Comments
1	Cyrus the Great	Persian Empire: Ancient Near East, much of Southwest and Central Asia	2.09 M	559 BC - 530 BC	United the ancient Middle East into a single state stretching from the Mediterranean Sea to India.
2	Alexander the Great	Macedonian Empire: Macedonia, Persia to India's Indus River, including Syria and Egypt	2.18 M	336 BC - 323 BC	Brought Greek and Middle Eastern civilizations into close contact, leading to Hellenistic Age.
3	Trajan	Roman Empire: Britain, Gaul, Spain, Macedonia, Asia Minor, Judea, Egypt, North Africa	1.90 M	98 - 117	Was emperor when Roman Empire reached its greatest extent.
4	Attila the Hun	Hunnic Empire: Germany to the Ural River and from the Danube River to the Baltic Sea	1.45 M	434 - 453	Pushed Goths west - leading to fall of Roman Empire
5	Mahmud of Ghazni	Ghaznavid Empire: Afghanistan, Iran, Pakistan, northwest India	.68 M	997 - 1030	Established Muslim rule over a substantial part of Indian Sub-Continent.
6	Genghis Khan	Mongol Empire: Substantial part of Central Asia, Russia, and China	4.86 M	1206 - 1227	Largest contiguous land empire in history.
7	Timur	Timurid Empire: Central and Western Asia, parts of Russia, Pakistan, and India	2.15 M	1370 - 1405	Sought to restore Mongol Empire; died just before planned invasion of China.
8	Francisco Pizarro	Inca Empire in South America: Peru, Ecuador, northern Chile, and part of Bolivia	.77 M	1532 - 1541	Conquered Inca empire of 10 million people with a force of 180 men.
9	Napoleon Bonaparte	French Empire: France, Holland, Sweden, Germany, Poland, Italy, and Spain	.72 M	1804 - 1815	Unsuccessfully invaded Egypt and Russia.
10	Adolf Hitler	Third Reich: Europe and North Africa	1.37 M	1933 - 1945	Caused the death of 35 million people.



Except for No. 8 on the list, Francisco Pizarro, all the conquerors operated in Eurasia, which on reflection makes sense since that's where the people were. Over the years, the same lands kept getting reconquered, e.g. Iran.

Conqueror No. 3, Roman Emperor Trajan, is really a special case. He benefited from 600 years of previous Roman territory expansion, and was emperor when it reached its maximum extent in 117.

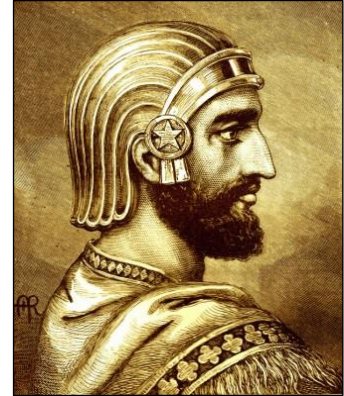
It's hard to imagine such vast territories being under the control of a single person - especially in times of limited transportation and communication. The Mongolian Empire under Genghis Khan, at 4.86 million square miles, was more than 50% larger than the total area of the 48 contiguous states of the United States of America!

A map of Eurasia is included below to help put these conquered territories in today's geographic context. Following the map, short biographies of the ten greatest conquerors are included.



*Eurasia was the scene of most of the “conqueror-action” over the centuries.*

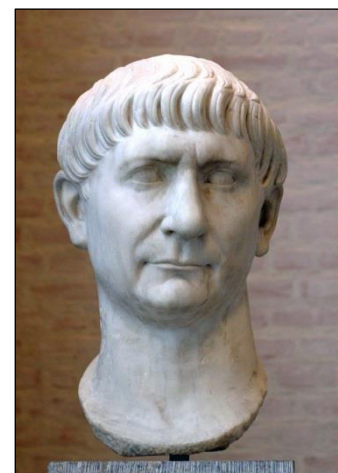
**Cyrus the Great (c. 580 BC - 530 BC).** Cyrus the Great was the founder of the Persian Empire. Starting as a subordinate ruler in southwest Iran, he overthrew - by a remarkable series of victories - three great empires, the Medes, Lydians, and Babylonians, and united most of the ancient Middle East into a single state stretching from the Mediterranean to India. He was regarded as a remarkably humane ruler who respected the customs and religions of the lands he conquered. Cyrus the Great permanently altered the political structure of the ancient world. He died in battle in 530 while fighting the Massagetae along the northeast border of his empire. *For most of the next two centuries, the lands ruled by Persia enjoyed internal peace and prosperity.*



**Alexander the Great (356 BC - 323 BC).** Alexander the Great was born in Pella, the capital city of Macedonia and received a classical Greek education under the tutorship of famed philosopher Aristotle. Alexander's father, King Philip II of Macedon, conquered lands north of Greece and then Greece itself, and was preparing to make war on the mighty Persian Empire when he was assassinated. Twenty-year-old Alexander succeeded to the throne, took over the army, and began 12 years of conquest of the 200-year-old Persian Empire that extended the Macedonian Empire from the Mediterranean to India. He was forced to abandon his plan to invade India when his war-weary troops refused to go on. He was a brilliant military leader and tactician, never losing a battle, defeating much larger forces than his own. Alexander died of a fever at the young age of 32. He had not named a successor; his empire began to fall apart and was eventually divided among his generals. Besides his tactical ability and conquests, Alexander the Great is remembered for spreading Greek culture in the East, marking the beginning of the Hellenistic civilization that followed



**Trajan (53 - 117).** *Rome had been founded as a city in 753 BC, become a Republic in 509 BC, and grew steadily under leaders such as Julius Caesar to become an Empire under Augustus Caesar in 27 BC.* Trajan was born in Spain in 53, gradually rose to prominence in the Roman government, and while Emperor (from 98-117), presided over the greatest military expansion in Roman history, leading the Empire to attain its maximum territorial extent by the time of his death in 117. Trajan is known for his philanthropic rule, overseeing extensive public building programs and implementing social welfare policies. *In 395, Rome split into two empires - the Western Roman Empire ruled from Rome and the Eastern Roman Empire, the Byzantine Empire, with Constantinople the capital. The Western Roman Empire ended in 476 when Rome was defeated by the German Goth Odoacer, starting the Dark Ages in Europe. The Byzantine Empire lasted until 1453, when it fell to the Ottoman Empire.*

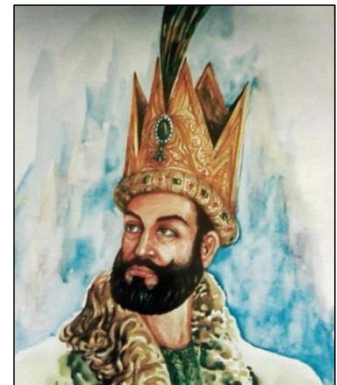


*The Roman Empire was among the most powerful economic, cultural, political, and military forces in the world of its time. It held sway over an estimated 70 million people, about 21% of the world's entire population. Its longevity and vast extent ensured lasting influence of the Latin and Greek language, culture, religion, inventions, architecture, philosophy, law, and forms of government.*

**Attila the Hun (406 - 453).** Attila was the last and most powerful king of the Huns, thought to be a western extension of a group of nomadic tribes from northeastern China and central Asia. The Huns achieved military superiority over their rivals by their readiness for combat, amazing mobility, and weapons like the Hun bow. Attila was a brilliant horseman and military leader, possessed a commanding presence, and held his empire together through the strength of personality. He not only made the Huns the most effective fighting force of the time, but he built a vast empire from virtually nothing in less than ten years. He also unsuccessfully challenged the Roman Empire with invasions of France and the Balkans, and in 452 he invaded to the southwest, engaging the resident Goths (barbarians), pushing them further into Roman territory, which helped lead to the fall of Rome. In much of Western Europe, he is remembered as the epitome of cruelty, but some histories lionize him as a great and noble king. *After he died in 453, his sons tried to hold his empire together, but failed, and it broke apart by 469. Two Gothic kingdoms rose up after the Western Roman Empire crumbled, the Visigoths in Spain and France, and the Ostrogoths in Italy.*

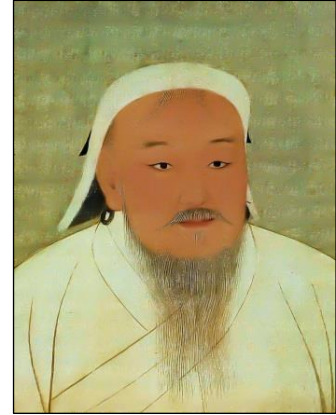


**Mahmud of Ghazni (971 - 1030).** Starting in his birth country Afghanistan, Mahmud first consolidated competing factions there, and then extended his empire to the north, west into most of Iran, and east through Pakistan and regions of northwest India. He was the first Muslim ruler to carry the title Sultan. He is remembered as a hero of Islam by some, and as a defiler of other religion's shrines by others. He turned his hometown, the former provincial city of Ghazni, into one of the leading cities of Central Asia, establishing colleges, laying out gardens, and building mosques, palaces, and caravan overnight stops. Mahmud died of Malaria in 1030; the Ghaznavid Empire was ruled by his successors for 157 years, before being absorbed by surrounding civilizations. *By establishing Muslim rule over a substantial part of the Indian subcontinent, Mahmud permanently changed the nature of subcontinent politics, religion, and culture. Arguably, the partition of India into the Muslim majority and Hindu majority states of Pakistan and India in 1947, was a consequence of his military success.*





**Genghis Khan (c. 1162 - 1227).** Born in Mongolia, Genghis Kahn was the founder of the Mongol Empire. He started by uniting many of the nomadic tribes of northeast Asia, and then seemed to invade and raid in all directions. By the end of his life, the Mongol Empire occupied a substantial portion of Central Asia, Russia, and China. Many people were slaughtered in the course of Genghis Khan's invasions, but he also granted religious freedom to his subjects, abolished torture, encouraged trade and created the first international postal system. Genghis Kahn died in 1227, but his descendants went on to stretch the Mongol Empire across most of Eurasia by conquering and/or creating vassal states out of all of modern day China, Korea, the Caucasus, and substantial portions of modern Eastern Europe and the Middle East. At their peak about 1300, the Mongols controlled the largest contiguous empire in history, over 12 million square miles of land, an area about the size of the continent of Africa, with an estimated population of over 100 million people.<sup>3</sup> The enormous size of the Mongol lands and infighting between potential leaders contributed to the disintegration of the empire. After 1300, the Mongol Empire began splitting into a number of smaller empires that were eventually absorbed by their neighbors or achieved independence on their own. The death toll (by battle, massacre, flooding, and famine) of the Mongol wars of conquest is placed as high as 40 million people by some sources.



**Timur (1336 - 1405).** Born in Central Asia in modern day Uzbekistan, into a tribe of mixed Mongolian and Turkish ancestry, Timur (also known as Tamerlane) rose to become a warlord who vanquished his local rivals. Between 1370 and 1380, Timur seized the rest of Central Asia including Persia. He went on to brutally conquer Western Asia, as well as parts of contemporary Russia, Pakistan, and India. Timur died of a winter illness in 1405 as he prepared to invade China. He is remembered as a vicious conqueror who razed ancient cities to the ground and put entire populations to the sword. He destroyed Bagdad in 1401 and slaughtered 20,000 of its people. On the other hand he is also known as a great patron of the arts, literature, and architecture. Contemporary sources say that Timur's forces killed up to 19 million people during their conquests. The Timurid Empire did not long survive its founder because he rarely bothered to put any government structure in place after he destroyed the existing order.



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<sup>3</sup> The largest non-contiguous empire in history was the British Empire at 13.01 M square miles achieved in 1920.

**Francisco Pizarro (c. 1471 - 1541).** Pizarro was born in Trujillo, Spain and came to the New World as an adventurer in 1502. He lived on Hispaniola (now Haiti and the Dominican Republic) for eight years. In 1513 he was a member of the expedition led by Balboa that crossed Panama to discover the Pacific Ocean. Hearing of great riches of the Inca civilization in Peru, Pizarro mounted expeditions from Panama to Peru in 1524 and 1526 - both unsuccessful due to bad weather, lack of food, and skirmishes with hostile natives in Columbia. In 1532 Pizarro finally succeeded, with a small force of only 180 men by reaching high into the Andes Mountains to



confront the Inca emperor and his force of 40,000 fighters. Pizarro captured the Inca ruler at a parley, and because the Inca Empire was highly centralized, with all authority flowing from the leader, the Incans were unable to effectively react to the invasion. By late 1533, after a few relatively minor battles, Pizarro, with his army expanded to 500 men, “sealed the conquest of Peru.” Remarkably, Pizarro had easily conquered a gold-rich empire of more than three-quarters of a million square miles, extending 2,750 miles along the western coast of South America, with a population of ten million people. Pizarro ruled in Peru until 1541, when he was assassinated by Spanish rivals. Pizarro’s legacy included initiating the decline of Inca culture, instituting Christianity as the religion, reducing much of the local population to serfdom under the Spanish elite, and founding Peru’s capital city of Lima. *Pizarro’s successors withstood Inca resistance until 1572 when the last Inca stronghold was conquered and their last ruler was captured and executed. Pizarro’s Inca conquest was but a part of Spanish conquests in North and South America that by 1790, reached a maximum of 7.72 M square miles.*

**Napoleon Bonaparte (1769 - 1821).** Napoleon was born on the French island of Corsica, trained as an artillery officer, and rose to prominence to lead successful military campaigns against European coalitions arrayed against France. In 1799 he staged a coup and installed himself as First Consul, essentially a military dictatorship, and in 1804 the French Senate proclaimed him as Emperor. In the first decade of the nineteenth century, Napoleon engaged in a series of conflicts with every major European power, securing a dominant position in continental Europe, and maintained the French sphere of influence with extensive alliances and the appointment of friends and family members to rule other European countries as client states. Napoleon’s fortunes turned in 1812 with his unsuccessful invasion of Russia and his military defeat in Germany in 1813, forcing him to abdicate, resulting in his exile to the island of Elba. Less than a year later, he escaped Elba and returned to power, but was



defeated at the Battle of Waterloo in 1815. Napoleon spent the last six years of his life under British supervision on the island of Saint Helena. While he is remembered as a tyrant, he is also remembered for the establishment of the Napoleonic code, which laid the administrative and judicial foundations for much of Western Europe. *In 1803, seeking money to fund his military exploits, Napoleon sold vast French lands in America - the Louisiana Purchase: about 0.82 M square miles - to the United States for fifteen million dollars.*

**Adolf Hitler (1889 - 1945).** Hitler was born in Austria and was a decorated veteran of World War I. He became a politician, joined the National Socialist German Workers (Nazi) Party in 1919, and became its leader 1921. Following his imprisonment for a year (where he wrote *Mein Kampf*, his exposition of his political ideology and future plans for Germany) after a failed coup in 1923, he gained support by promoting German nationalism, anti-Semitism, anti-capitalism, and anti-communism - with charismatic oratory and propaganda. He was appointed chancellor in 1933 and quickly transformed the government into the Third Reich, a single-party dictatorship based on totalitarian and autocratic ideals of National Socialism. He declared a goal of controlling all of Europe. After rearming Germany, in 1939 he invaded Poland, starting World War II. Within three years, Germany and the Axis Powers (Italy, Bulgaria, Romania, and Yugoslavia) occupied most of Europe and most of North Africa. However, with the reversal of the Nazi invasions of the Soviet Union and Egypt in 1942, the Allies (principally the United Kingdom, France, the Soviet Union, and the United States) gained the upper hand. In 1945, Allied armies invaded German-held Europe from all sides, leading to Germany's defeat and surrender on May 7, 1945. Hitler committed suicide a week earlier to avoid capture by the Soviet forces. Adolph Hitler earned the reputation as the most horrible person in history; he systematically murdered as many as 17 million civilians, among them 6 million Jews targeted in the Holocaust. Considering losses in all the battles of World War II, Hitler's total death-count is estimated at 35 million people.



## What in the World Happened? Perspectives on Man's Accomplishments

### Part 3 - Engineering Feats

I adapted a standard definition of “engineering” to use for this project: *The application of scientific and mathematical principles to the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.*

I looked at several lists of the top engineering feats of all time and found quite a bit of disagreement. I tried to identify ten (top 10) projects that were complex, employed many people, were a management challenge, were a technical challenge, and/or required persistence. Most of all, I looked for engineering feats that were important to mankind and/or impressive in their execution.

I ended up choosing twelve projects to talk about, unable to choose only ten. (Most lists of the top twenty or twenty-five projects include these twelve.) My choices for the top twelve engineering feats in history are presented in the table below, in order of their completion date. After the summary table, I'll talk about each project individually.

Don't get too hung up the cost of these projects. It was difficult if not impossible to find accurate, comparative costs with the same cost elements, adjusted to the current year. Just consider them ROM costs.



*Twelve of the greatest engineering feats in history in historical order by completion date.*

<b>No.</b>	<b>Engineering Feat</b>	<b>Where or Who</b>	<b>ROM Cost</b>	<b>Construction Period</b>	<b>Comments</b>
1	Pyramids at Giza	Egypt	unknown	2589-2504 BC	Built as tombs for three Fourth-Dynasty Egyptian kings. One of seven wonders of ancient world. Largest was 481 feet high.
2	Great Wall of China	China	unknown	7 <sup>th</sup> century BC - 16 <sup>th</sup> century AD	Barrier against invasions built across China's northern border. With all its branches, wall is 13,171 miles long.
3	Roman Aqueducts	Rome	unknown	312 BC - 226 AD	Waterways that brought fresh water into Rome for indoor plumbing and sewer system. Eleven separate aqueducts, 260 miles total length.
4	Panama Canal	Panama/U.S.	\$9.9 B	1904-1914	50-mile waterway across Isthmus of Panama that connects the Atlantic Ocean with the Pacific Ocean.
5	Trans-Siberian Railway	Russia	\$28-33 B	1891-1916	Longest railway line in the world at 5,772 miles.
6	Manhattan Project	Los Alamos	\$22 B	1939-1946	World War II research and development effort that produced the first nuclear weapons.
7	Apollo Program	U.S./NASA	\$206 B	1961-1972	Research and development effort to land men on the Moon and return.
8	Chunnel	England-France	\$35 B	1988-1994	32-mile rail tunnel under English Channel linking England and France.
9	Boston Big Dig	Boston	\$15 B	1991-2007	Most expensive highway project in U.S. history; eased downtown congestion. Rerouted I 93 into 1.5-mile tunnel, extended I 90 to Logan International Airport, provided bridge over Charles River.
10	Large Hadron Collider	France-Switzerland	\$4.75 B	1998-2008	World's largest and most powerful particle collider. Lies underground in circular tunnel 17 miles in circumference.
11	Burj Khalifa	Dubai	\$1.5 B	2004-2009	Tallest building in the world at 2,722 feet. 163 floors above ground with 57 elevators.
12	Three Gorges Dam	China	\$40-50 B	1994-2015	World's largest hydroelectric dam; spans Yangtze River; 1.3 miles wide, 600 feet high, with 405 square mile reservoir.



**Pyramids at Giza (2589-2504 BC).** The three pyramids at Giza were built on a rocky plateau on the west bank of the Nile River, near the city of Giza in northern Egypt. The pyramids were constructed over an 85-year period as tombs for the second, fourth, and fifth kings of the Egyptian Fourth Dynasty: Khufu, Khafre, and Menkaure. The first-built and largest of the pyramids (for Khufu), called the Great Pyramid, averaged 756 feet on a side and was (originally) 481 feet high. The second pyramid, built (for Khafre), was slightly smaller (471 feet high) and the third pyramid (for Menkaure) was considerably smaller (218 feet high).

The Great Pyramid is a masterpiece of technical skill and engineering ability. For 3,800 years, it was the tallest man-made structure in the world. Its sides rise at an angle of 52 degrees and are accurately oriented to the four cardinal points of the compass. Approximately 2.3 million blocks of yellowish limestone were cut from quarries, transported to the building site, and assembled to create the pyramid. The stone blocks averaged 2.5 tons in weight, but some weighed as much as 70 tons. The stone blocks may have been moved from the stone quarries by



*Pyramids of Giza, Egypt.*

pulling them over wet sand. The current prevailing construction theory suggests that the Egyptians employed a sloping ramp of brick, earth, and sand that encircled the pyramid under construction, rising as the pyramid rose; stone blocks were hauled up the ramp by means of sledges, rollers, and levers. After the stone blocks were set, the entire outside of the pyramid was covered with a casing of smooth, white limestone. The interior burial chamber was built of huge blocks of granite. The labor force required to construct the Great Pyramid and other two Giza pyramids is estimated at between 20,000 and 100,000 men.

All three pyramids were plundered both internally and externally in ancient and medieval times. Grave goods originally deposited in the burial chambers are missing and the pyramids' outer casings of smooth white limestone have been almost entirely stripped, thereby reducing the size of pyramids about 5%.

**Great Wall of China (7<sup>th</sup> century BC - 16<sup>th</sup> century AD).** The Great Wall of China is a series of walls made of stone, brick, wood, and tamped earth, generally built along an east-to-west line across the historical northern border of China for protection from raids and invasions of nomadic groups from Mongolia. Several walls were built as early as the 7<sup>th</sup> century BC, later joined together and made bigger and stronger - collectively called the Great Wall.



*The Great Wall of China started from Jiayuguan at Ming China's northwest frontier and ended in Hushan on its Manchu/Korean border, crossing nine provinces and municipalities.*

Especially famous is the wall built in 220-206 BC by Qin Shi Huang, the first Emperor of China. From a base of 15 to 50 feet, the Great Wall rose some 15-30 feet high, 20 feet wide, and was topped by ramparts 12 feet or higher; guard towers were distributed at intervals along it. Little of that wall remains. The Great Wall has been rebuilt, maintained, and enhanced over various dynasties; the majority of the existing wall is from the Ming Dynasty (1368-1644). During peak

building periods, over a million men were mobilized for the construction. The entire Wall, with all of its branches, has been carefully measured to be 13,171 miles long.

Apart from defense, other purposes of the Great Wall have included border controls, with duties on goods transported across the border, and regulation of trade and immigration. Furthermore, the defensive characteristics of the Great Wall were enhanced by the construction of troop barracks, garrison stations, and signaling capabilities through smoke or fire. The Great Wall also served as a transportation corridor.

Although a useful deterrent against raids, at several points throughout its history, the Great Wall failed to stop enemies including in 1644 when the Manchu Qing marched through the gates of Shanhai Pass and replaced the most ardent of the wall-building dynasties, the Ming, as rulers of China.

Today the Great Wall is generally recognized as one of the most impressive architectural feats in history. For centuries an object of fascination for foreigners, the Great Wall is now a revered Chinese national symbol and a popular tourist destination.



*The Jinshanling Great Wall is located **87 miles** northeast of Beijing, China. It is the best preserved part of the Great Wall from the Ming Dynasty with many original features.*

**Roman Aqueducts (312 BC - 226 AD).** In one of the greatest engineering achievements in the ancient world, the Romans constructed aqueducts throughout their Empire, to bring water from outside sources into cities and towns. Aqueduct water supplied public baths, latrines, fountains, and private households; it also supported mining operations, milling, farms, and gardens.



*The multiple arches of the Pont du Gard Aqueduct in Roman Gaul (modern day southern France).*

Aqueducts moved water through gravity alone, along a slight overall downward gradient within conduits of stone, brick, or concrete; the steeper the gradient, the faster the flow. Most conduits were buried beneath the ground and followed the contours of the terrain; obstructing peaks were circumvented or, less often, tunneled through. Where valleys or lowlands intervened, the conduit was carried on bridgework, or its contents fed into high-pressure lead, ceramic, or stone pipes and siphoned across. Most aqueduct systems included sedimentation tanks, which helped reduce any water-borne debris.

Sluices and distribution tanks regulated the supply to individual destinations. In cities and towns, the run-off water from aqueducts scoured the drains and sewers.

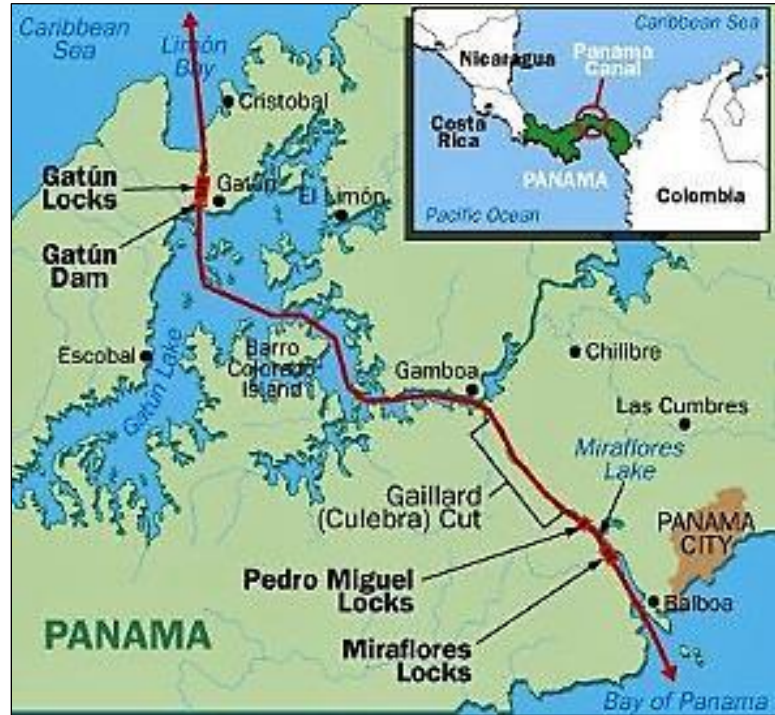
Rome's first aqueduct was built in 312 BC, and supplied a water fountain at the city's cattle market. Five hundred year later, by the 3rd century AD, the city had eleven aqueducts, sustaining a population of over a million people in a water-extravagant economy; most of the water supplied the city's many public baths. Of the approximately 260 miles of aqueducts in the system, only 30 miles consisted of visible, arched structures. Most of Rome's aqueducts drew on springs in the valley plus aquifers and highland rivers, as far as 59 miles from Rome. A complex system of aqueduct junctions, tributary feeds, and distribution tanks supplied every part of the city. The water system was capable of delivering up to one cubic meter of water per person in the city - more than what is commonly available in most cities today. Paid laborers, slaves, and the Roman legions all had parts in building the water system. Most Roman aqueducts proved reliable and durable; some were maintained into the early modern era, and a few are still partly in use.

Cities and towns throughout the Roman Empire emulated this model; at its largest extent, nearly 200 cities were supplied by aqueducts as objects of public interest and civic pride, surpassing the capability of any civilization before or after for nearly another 2,000 years.



### Panama Canal (1904-1914).

The Panama Canal is a man-made 50-mile maritime trade waterway that crosses the Isthmus of Panama to connect the Atlantic Ocean with the Pacific Ocean. To reduce the amount of excavation work required, the canal has locks at each end to lift ships up to Gatun Lake, an artificial lake 85 feet above sea level, and then lower the ships at the other end. The original locks are 110 feet wide in each of two ship lanes. One of the largest and most difficult engineering projects ever undertaken, the Panama Canal shortcut greatly reduces the time for ships to travel between the Atlantic and Pacific Oceans, enabling them to avoid the 7,800-mile, hazardous Cape Horn route around the southernmost tip of South America via the Drake Passage or Strait of Magellan.



*Route of the Panama Canal across the Isthmus of Panama.*

France began work on the canal in 1881, but stopped due to engineering problems and a high worker mortality rate - 22,000 deaths, most from Yellow Fever and Malaria. The United States took over the project in 1904 and opened the canal on August 15, 1914. A total of over 75,000 people worked on the project; at the peak of construction, there were 40,000 workers. According to hospital records,



*Passenger ships emerge from the locks of the Panama Canal.*

5,609 workers died from disease and accidents during the American construction era. A total of 238,845,582 cubic yards of material was excavated in the American effort, including the approach channels at the canal ends. Adding the work by the French, the total excavation was about 268,000,000 cubic yards. The Panama Canal cost the United States about \$375 million (about \$9.4 billion in today's dollars), the most expensive construction project in U.S. history to that time. Of the three

presidents whose terms spanned the construction period, Theodore Roosevelt is most associated with the canal.

The American Society of Civil Engineers has called the Panama Canal one of the seven wonders of the modern world. The canal was a technological marvel and an important strategic and economic asset to the U.S. During World War II, the canal helped restore the devastated United States Pacific Fleet.

The U.S. controlled the canal and surrounding Panama Canal Zone until the 1977 Torrijos-Carter Treaties provided for handover to Panama. After a period of joint American-Panamanian control, in 1999, the canal was taken over by the Panamanian government and is now managed and operated by the government-owned Panama Canal Authority.

Annual traffic has risen from about 1,000 ships in 1914, when the canal opened, to 14,702 vessels in 2008, for a total of 333.7 million tons. By 2012, more than 815,000 vessels had passed through the canal. It takes 11.38 hours to pass through the Panama Canal.

A third ship lane, with an expanded lock width of 180.45 feet, was constructed between September 2007 and May 2016, at an added estimated cost of over \$5 B. The expanded canal began commercial operation on June 26, 2016. The new locks allow transit of larger ships, capable of handling more cargo.

**Trans-Siberian Railway (1891-1916).** The Trans-Siberian Railway, connecting Moscow in western Russia to Vladivostok in the Far East, was built under the supervision of the Russian government. The railway is the longest railway line in the world at 5,772 miles. During its construction, the great railway was a serious drain on the Russian economy and, between 1914 and 1916, on their efforts in World War I. Despite criticism, the Trans-Siberian Railway more than paid for itself during the 20th century, solidifying Moscow's hold on Russia's eastern periphery.



*The original route of the Trans-Siberian Railway from Moscow to Vladivostok.*

The Trans-Siberian Railway crosses eight time zones; passes through 87 cities and small towns, including Moscow, St. Petersburg, Omsk, Irkutsk, Chita, and Vladivostok; and crosses 16 large rivers, including the Volga, Ob, Yenisei, and Amur. An estimated 60-90,000 workers were enlisted to build the railway, many of them soldiers, local laborers, and convicts. In addition to laying track over both mountainous and desert terrain, the labor force had to construct 200 bridges, the longest of which was 1.6 miles long, and 33 tunnels, up to 1.25 miles long. The estimated cost to build the great railway in 1916 U.S. dollars ranges from \$770 million to \$1 billion (approximately \$17-22 B in today's dollars).

Today the Trans-Siberian Railway is a network of railways connecting Moscow with the Russian Far East. The railway encompasses three routes including the Trans-Mongolian (from Moscow to Beijing), the Trans-Manchurian (from Siberia to Beijing), and the original Trans-Siberian route. There are also connecting lines into Mongolia, China, and North Korea. Since 2002 the railway has been fully electrified, incorporating electric locomotives.



*A passenger train of the Trans-Siberian railway.*

The Trans-Siberian railway remains Russia's most important transport link, carrying 30% of its exports every year. The train carries 20,000 containers per year to Europe. In recent years \$11 B has been spent to increase the speed of freight trains to shorten the transport time of cargo.

While the railway does attract plenty of foreign travelers, the majority of its passengers are local Russians traveling on business. Total transit time for passengers over the entire route has improved from over eight days to 6 ½ days.



**Manhattan Project (1939-1946).** The Manhattan Project was a research and development undertaking during World War II that produced the first nuclear weapons. It was led by the United States with the support of the United Kingdom and Canada.

The nuclear age began in 1938, with the discovery of nuclear fission by physicists in Germany. In 1939 American scientists, many of them refugees from fascist regimes in Europe, confirmed the German discovery and convinced the U.S. government that the new phenomenon, that Albert Einstein characterized as “a new and important source of energy,” could lead to the development of very powerful new bombs. Research towards this end began in U.S. laboratories in early 1940. After the U.S. entry into World War II, in 1942 a super-secret U.S. effort was commissioned to develop an atomic bomb. The project was code named “Development of Substitute Materials,” with Major General Leslie Groves as manager. Along the way,

the project absorbed the British counterpart program and became known as the “Manhattan Project.” Nuclear physicist Robert Oppenheimer was assigned to lead the technical effort. More than 30 sites across the United States, the United Kingdom, and Canada participated in the research and development efforts to produce fissionable elements of uranium and plutonium and engineer the world’s first nuclear weapon. In 1943 Los Alamos Laboratory was created, on an isolated mesa at Los Alamos, New Mexico, 34 miles northwest of Santa Fe, to design, build, and test the actual bombs.



*The Los Alamos Laboratory started from existing buildings left over from the area’s days as a school.*

Two types of atomic bombs were developed concurrently. One used a gun-type assembly, in which a “gun” fired a mass of uranium 235 at another mass of uranium 235, creating a supercritical mass. The other type used conventional explosives to compress a sphere of plutonium (implosion) very rapidly to a density sufficient to make it go critical and produce a nuclear explosion.

The Manhattan Project produced three bombs. The first known as “Gadget” employed the implosion plutonium approach and was successfully tested at Trinity site at New Mexico’s Alamogordo Bombing and Gunnery Range, 120 miles south of Albuquerque, on July 16, 1945. The bomb generated an explosive force of 15-20 thousand tons of TNT and produced a crater which measured nearly 2,400 feet across.



*The Trinity test of the Manhattan Project was the first detonation of a nuclear weapon.*

Hoping to avoid horrendous U.S. troop losses in the planned invasion of mainland Japan, and to force Japan's surrender, President Harry Truman approved the use of the two remaining bombs against Japan - to be air-dropped by B-29 bombers. The second bomb, known as "Little Boy," a gun-type uranium device, was detonated over Hiroshima, Japan on August 6, 1945, destroying city and resulting in the immediate or delayed deaths of 66,000 people. When Japan refused to surrender, the third bomb, known as "Fat Man," an implosion plutonium bomb, was detonated over Nagasaki, Japan on August 9, 1945, killing 39,000 people. Japan

surrendered unconditionally on August 15, 1945.<sup>4</sup>

The amazingly complex Manhattan Project grew to employ more than 130,000 people and cost nearly \$22 billion (2016), before being deactivated in 1946. Over 90% of the cost was for building factories and to produce fissile materials, with less than 10% for development and production of the weapons.

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<sup>4</sup> For perspective, there were over 60 million casualties overall during World War II, including 2.5-3.1 million Japanese, and 400,000 Americans.



**Apollo Program (1961-1972).** The Apollo Program, under the management of the U.S. National Aeronautics and Space Administration (NASA), landed 12 humans on the moon and returned them in six lunar landing missions between 1969 and 1972.

President John F. Kennedy, in an address to Congress on May 25, 1961, reacting to recent Russian successes in manned space flight, proposed a national goal of “landing a man on the Moon and returning him safely to Earth” by the end of the 1960s. The Apollo Program that resulted required the most sudden burst of technological creativity and the largest commitment of resources ever made by any nation in peacetime.

After considerable study, a technical approach was established to accomplish the mission: A powerful launch vehicle carrying three astronauts would place a 50-ton spacecraft in a translunar trajectory. The spacecraft would brake on approach to the Moon and go into lunar orbit. The spacecraft would then release a Lunar Module, carrying its own rocket power, to land two astronauts on the Moon, leaving the Command/Service Module orbiting the Moon with the third astronaut. On departure from the Moon, the Lunar Module, leaving part of its structure on the surface, would rocket off the Moon to rendezvous with the Command/Service Module in lunar orbit. The rejoined spacecraft would then launch into a return trajectory to Earth orbit, where the three-man Apollo capsule would separate from the spacecraft and accomplish reentry through Earth’s atmosphere to a safe parachute landing.

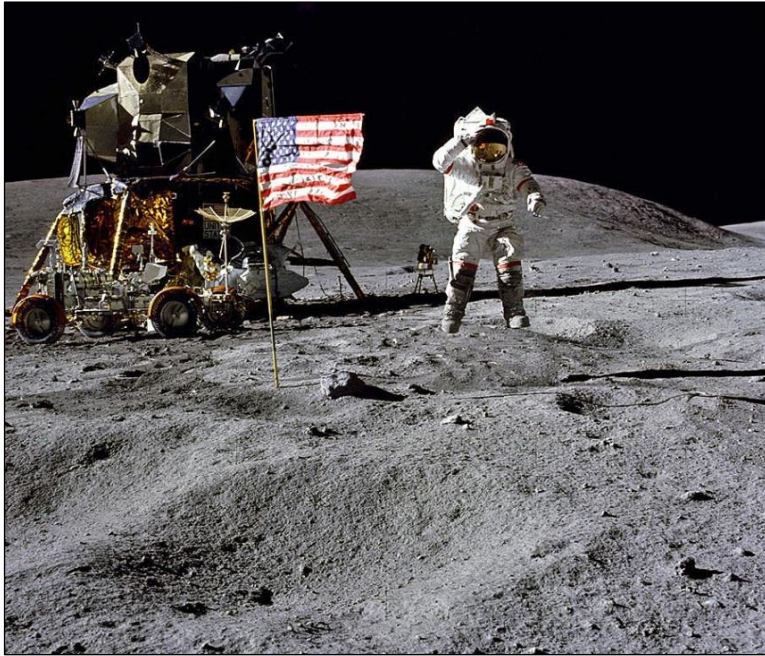


*Apollo 11 Launch from Kennedy Space Center*

Tremendous new facilities to support the program were developed quickly. In July 1960 NASA established the Marshall Space Flight Center in Huntsville, Alabama to design and build the heavy lift Saturn V launch vehicles. In September 1960 the Manned Spacecraft Center was established in Houston, Texas to manage the complex program and also serve as a new Mission Control Center. In November 1962 construction began at Florida’s Cape Canaveral on a new Launch Operations Center that included Launch Complex 39, a Launch Control Center, a Vertical Assembly Building, and an Operations and Checkout Building. (The name of the Launch Center was changed to Kennedy Space Center after President Kennedy was assassinated on November 22, 1963.)

The operational part of the Apollo Program got off to a horrible start with the first mission, Apollo 1 in 1967. During a prelaunch test, a cabin fire killed the three-man crew. In October 1968, following several unmanned Earth-orbit flights, the program resumed with Apollo 7, a manned Earth-orbit flight. Apollo Missions 8, 9, 10 accomplished increasingly complex tests of mission phases, ending with a dress rehearsal for a Moon landing.

President Kennedy's goal was accomplished on the Apollo 11 mission when astronauts Neil Armstrong and Buzz Aldrin landed their Lunar Module on the Moon on July 20, 1969, and walked on the lunar



*John Young saluting the flag while jumping on Moon's surface during Apollo 16. Lunar Module and a Lunar Rover vehicle are visible in background.*

surface, while Michael Collins remained orbiting the Moon in the Command/Service Module, and all three landed safely back on Earth on July 24. Five subsequent Apollo missions also landed astronauts on the Moon, the last, Apollo 17, in December 1972. In these six spaceflights, twelve men walked on the Moon. (In Apollo 13 the Moon landing was prevented by an oxygen tank explosion on the way to the Moon, but the astronauts were able to get back to Earth safely.)

The Apollo Program ended in 1972. At its peak, the program employed 400,000 people and required the support of over 20,000 industrial firms and universities. The total program cost was \$206 billion in 2016

dollars, including all research and development costs; the procurement of 15 Saturn V rockets, 16 Command/Service Modules, and 12 Lunar Modules; plus program support and management; construction expenses for facilities and their upgrade; and costs for flight operations.

The Apollo Program has been called the greatest technological achievement in human history. The Apollo missions returned a wealth of scientific data including photographs and almost 400 kilograms of lunar samples. Experiments included soil mechanics, meteoroids, seismic, heat flow, lunar ranging, magnetic fields and solar wind experiments. Apollo also stimulated many areas of technology, leading to over 1,800 spin-off products by 2015.

**Chunnel (1988-1994).** The Channel Tunnel, nicknamed the Chunnel, is a 32-mile rail tunnel beneath the English Channel that links France and England. The average depth below the Strait of Dover seabed is 148 feet, with a maximum depth of 250 feet. The tunnel has the longest undersea portion, 23.5 miles, of any tunnel in the world, and since opening in 1994, is considered one the most amazing engineering feats of the 20<sup>th</sup> century.



*The hi-speed railway Chunnel under the English Channel connects with terminals built at Cheriton (near Folkestone) in the United Kingdom, and Coquelles (near*

The Chunnel is really three tunnels, two single-track tunnels for rail traffic and a third, smaller maintenance tunnel. The Chunnel carries high-speed Eurostar passenger trains, the Eurotunnel Shuttle for road vehicles - the largest such transport in the world, and international goods trains at a maximum speed of 99 miles per hour. The Chunnel connects with high-speed railways and automobile highways on both ends, at terminals built at Cheriton (near Folkestone) in the United Kingdom, and Coquelles (near Calais) in France.

Ideas for a cross-channel link appeared as early as 1802, but it wasn't until 1988 - after technology had caught up with dreams, and 20 years of surveying the seabed's chalky geology - that construction began with Eurotunnel<sup>5</sup>, a consortium of British and French corporations and banks, organizing the enormous, successful building effort. The building of the Channel Tunnel began simultaneously from the British and French coasts, with the finished tunnel meeting in the middle. The tunnel was built with three bores, the two main tunnels at 25-foot diameter, and the service tunnel, between them, at 16-foot diameter - connected by cross passages and pressure relief ducts. The service tunnel was used as a pilot tunnel, boring ahead of the two main tunnels to determine the conditions. The digging was done by huge tunnel boring machines (TBMs) which cut through the chalk, collected the debris, and transported the debris behind it using conveyor belts. Then the debris was hauled up to the land surface on each end of the tunnel with railroad wagons (English) or by mixing it with water and pumping it out through a pipeline (French). The tunnel debris was used as fill at the terminal sites and to reclaim land along both coasts. As the TBMs bored through the seabed, the sides of the newly dug tunnels had to be lined with concrete so the tunnel could withstand the intense pressure from above as well as to help waterproof the tunnel. Special lasers and surveying equipment were used to ensure that the British-side and French-side tunnels actually met up in the middle. Construction also included two large train terminals, under-land tunnels from the coasts to the terminals (six miles on the UK side, two miles on the French side), electrical systems, fireproof doors, the ventilation system, and train tracks.

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<sup>5</sup> Now called Getlink, the company still operates the Chunnel today.

Approximately 13,000 skilled and unskilled workers participated in the six-year construction project. Ten workers were killed (eight British, two French) during the construction period between 1987 and 1993. The total cost amounted to about \$35.3 B (2018 U.S. dollars).

Since the opening on May 6, 1994 the Chunnel has faced a few mechanical problems with the trains, three fires, and extremely cold weather - temporarily disrupting operations. Since 1997 people have attempted to enter the UK illegally, creating an ongoing migrant issue on the French side.



*One of Eurotunnel's own locomotives emerging from the Chunnel in France.*

trains just 35 minutes to go between the Continent and England, the tunnel has become serious competition for the ferries that used to dominate such transportation.

Through 2011, more than 265 million passengers, and more than 53 million vehicles - including 16 million heavy goods vehicles - have traveled across the Chunnel's tracks.

Each day, 50 Eurostar trains take passengers between London and either Paris or Brussels, but that's just a fraction of the 450 trains a day that pass through the tunnel carrying trucks, containers, cars, buses, and more. And because it takes



**Boston Big Dig (1991-2007).** The “Big Dig,” officially named the “Central Artery/Tunnel Project,” was accomplished in the city of Boston, and was the largest, most complex, most technologically challenging, and most expensive highway project in U.S. history, at an estimated total cost of over \$15 B. The Big Dig rerouted Boston’s chief north-south highway, Interstate 93, into the underground 1.5-mile Thomas P. O’Neill Jr. Tunnel; constructed the underwater Ted Williams Tunnel, extending Interstate 90 across Boston Harbor to Logan International Airport; built the Leonard P. Zakim Bunker Hill Memorial Bridge, over the Charles River; and built the Rose Kennedy Greenway in the space vacated by the previous I-93 elevated roadway.

The project was developed in response to traffic congestion on Boston’s historically tangled streets which were laid out long before the advent of the automobile. Planning began in 1982; the construction work was carried out between 1991 and 2007. The project was managed by the Massachusetts Turnpike Authority. Design and construction of the Big Dig was supervised by a joint venture of Bechtel Corporation and Parsons Brinckerhoff. Because of the enormous size of the project, the Big Dig was broken up into dozens of



*The construction of O’Neill Underground Tunnel. Tons of dirt were excavated, the tunnel was constructed of concrete, and then overlaid with elements of the Rose Kennedy Greenway.*

subprojects; there were 118 separate construction contracts plus 26 geothermal drilling contracts. At the peak of the project, around the year 2000, there were over 5,000 workers involved in construction.



*Automobile traffic on interstate 93 through the O’Neill Tunnel.*

A few miscellaneous facts: The Big Dig excavated 16 million cubic yards of dirt, enough to fill a stadium to the rim 16 times. The deepest point of the underground highway is 120 feet down, beneath a subway tunnel; in other places the ceiling of the tunnel is the street above. The new underground expressway has 8-10 lanes; the previous elevated highway had just six lanes. The underwater

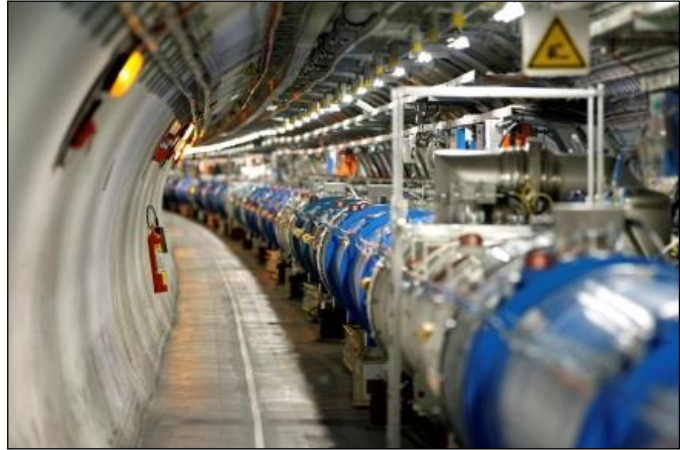
portion (about two-thirds of a mile) of the Ted Williams Tunnel was built using a dozen steel tube sections, each 40 feet in diameter and 300 feet long, which were sunk into a trench 90 feet below the surface of Boston Harbor and connected together. The Leonard P. Zakim Bunker Hill Bridge is the widest

cable-stayed bridge in the world. About 150 cranes were used project wide. The project built six interchanges and 200 bridges.

The Big Dig was plagued with cost overruns, delays, water leaks into the underground tunnels, design flaws (lighting fixtures), charges of poor execution and use of substandard materials (concrete), criminal arrests (fraud), and one death, when a portion of a tunnel ceiling collapsed on an automobile passing underneath.

With all of its problems, the Big Dig significantly reduced traffic congestion and improved mobility in one of America's oldest and most congested major cities.

**Large Hadron Collider (1998-2008).** The Large Hadron Collider (LHC) is the world's largest and most powerful particle collider, the most complex experimental facility ever built, the largest single machine in the world, and is dedicated to the pursuit of fundamental science. It was built by the European Organization for Nuclear Research (CERN) in collaboration with over 10,000 scientists and engineers from 111 countries, as well as hundreds of universities and laboratories. It lies in a circular tunnel 16.5 miles in circumference, as deep as 574 feet beneath the France-Switzerland border near Geneva. Its first research run took place from March 2010 to early 2013 at an energy level about four times the previous world record for a collider. Afterwards, the accelerator was upgraded for two years. It was restarted in early 2015 for its second research run, reaching energy levels seven times higher than any previous machine.



*Inside the underground 16.5-mile long circular collider.*

*Our Universe is believed have started 13.7 billion years ago with an explosion of energy and matter. During these first moments, all the particles and forces that shape our Universe came into existence, defining what we now see. The LHC allows scientists to reproduce the conditions that existed within a billionth of a second after the Big Bang by colliding beams of high energy protons or ions at colossal speeds, close to the speed of light. Analysis of the byproducts of these collisions gives scientists good evidence of the structure of the subatomic world and the laws of nature governing it. Many of these byproducts are produced only by high-energy collisions, and they decay after very short periods of time. Thus many of them are hard or nearly impossible to study in other ways.*

The LHC is ringed with superconducting magnets with a number of accelerating structures to boost the energy of the particles along the way. Inside the accelerator, two high-energy particle beams travel in



*The CERN Control Center manages all collider operations.*

opposite directions in separate beam pipes - two tubes kept at ultrahigh vacuum. They are guided around the accelerator ring by a strong magnet field maintained by the superconducting electromagnets.

All the controls for the accelerator, its services, and technical infrastructure are housed under one roof at the CERN Control Center. From there, the beams inside the LHC are made to collide at four locations around the accelerator ring, corresponding to the positions of four detectors that record the

outcomes of the particles colliding.<sup>6</sup> Another essential part of the LHC, is the Worldwide LHC Computing Grid, the world's largest distributed computing network, comprising over 170 facilities across 36 countries - that is essential to processing the masses of data recorded by the LHC detectors.

The LHC cost a total of \$4.75 B to construct. Since it was declared operational in 2008, the LHC's operating costs have been about \$1 B per year to support a staff of more than 10,000 researchers, engineers, and students. About half of CERN's funding comes from Germany, France, and the UK, while CERN's other 17 member countries contribute the other half of the budget.

In 2012 LHC experiments confirmed the existence of the Higgs Boson particle, an elemental particle that could reshape scientists' understanding of the Universe.

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<sup>6</sup> The LHC was placed underground to shield the detectors from natural radiation



**Burj Khalifa (2004-2009).** Burj Khalifa (Arabic for “Khalifa Tower”) is the tallest building in the world at 2,722 feet (829.2 meters) with 163 above-ground floors. Constructed in downtown Dubai, the largest city in the United Arab Emirates (UAE), the skyscraper was named for the ruler of Abu Dhabi and president of the UAE, Khalifa bin Sayed Al Nahyan.

Burj Khalifa was designed by architect Adrian Smith, then of Skidmore, Owings & Merrill, who also designed the 98-story Trump Tower in Chicago. The design was derived from the Islamic architecture of the region, and resulted in a neo-futurism architectural type. The building was designed for mixed use with 49 office floors and 1,044 residential apartments.

Construction began in 2004; the main contractor was Samsung C&T of South Korea. The foundation of the building is 49 feet deep, supported on 192 reinforced concrete columns (almost five feet in diameter and 141 feet long) sunk into the ground. The tower was built as a six-sided central core with wings. The central core houses 57 elevators and eight escalators, with egress stairs within each of the wings. Principal building materials consisted of steel rebar, reinforced concrete, and aluminum. Double-story mechanical floors were placed every 30 stories or so to house electrical substations, water tanks and pumps, air handling units, and other mechanical equipment. To protect the building from Dubai’s hot summer temperatures, the exterior was covered with reflective materials, including over 28,000 glass panels. A 700-foot spire, containing communication equipment, rises above the top floor. The building includes observation decks on the 124<sup>th</sup>/125<sup>th</sup>, and 148<sup>th</sup> floors plus a restaurant and lounge on the 122<sup>nd</sup> floor.

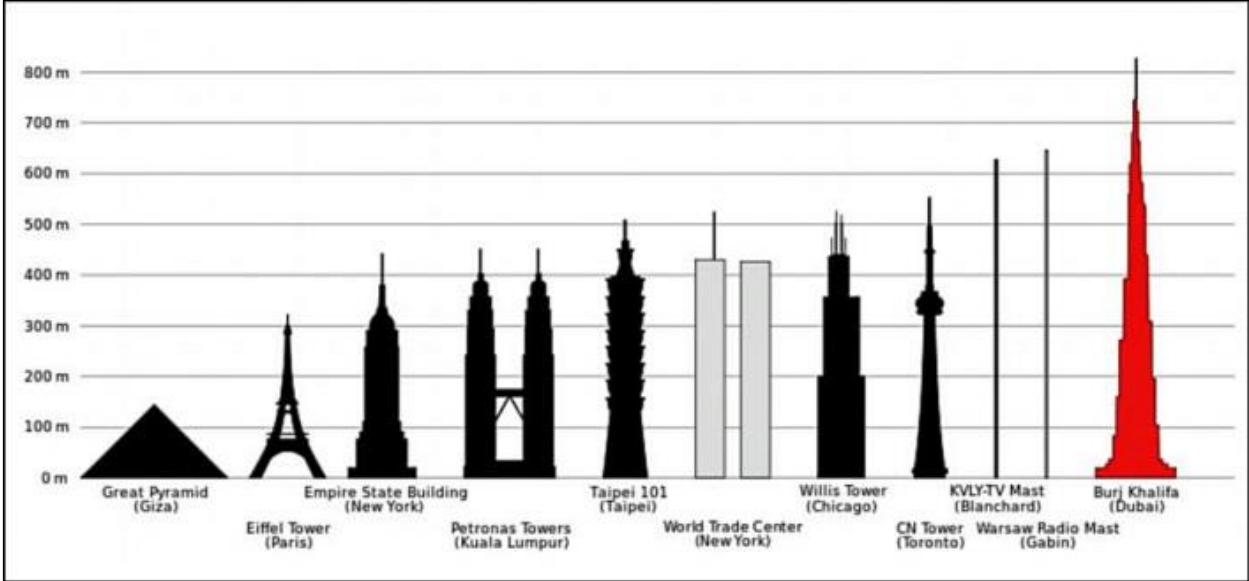
The Dubai fountain was built on the grounds surrounding the Burj Khalifa. The fountain is 246 feet long, illuminated by 6,600 lights and 25 color projectors, and shoots water up to 500 feet in the air, accompanied by a range of classical to contemporary Arab and world music.

There were some problems in construction of the Burj Khalifa that delayed the project about a year from its original completion goal of late 2008. There were changes to finishes; apartment design changes; and problems with marble flooring, the top floors sanitation system, broken glasswork, and poorly done artwork. There were also problems with the primary workforce, migrants from South Asia, who complained about low wages and the practice of confiscating passports until duties were completed.

The exterior of the Burj Khalifa was completed in December 2009, with the building officially opening on January 4, 2010. It took 22 million man-hours to complete the job. Total cost was \$1.5 B in U.S. dollars.



*The Burj Khalifa skyscraper in Dubai UAE.*



*Burj Khalifa height compared to other notable manmade structures*

**Three Gorges Dam (1994-2015).** The Three Gorges Dam, spanning the Yangtze River in central China, is the world's largest hydroelectric dam based on generating capacity. The dam contains 32 main turbines that can generate 700 MW of power each, while two smaller generators of 50 MW each provide electricity to run the plant - for a total of 22,500 MW.



*The Three Gorges Dam is located along the Yangtze River in central China.*

The dam is 1.3 miles wide, over 600 feet in height, and has a reservoir that stretches over 400 square miles. The reservoir helps control flooding in the Yangtze River basin and allows 10,000-ton ocean freighters to sail into the interior of China six months of the year.

The idea of a Three Gorges Dam was first proposed in 1914, but it wasn't until 1994, after 75 years of political struggles and technology improvements, that construction on the dam started. The dam body



*The Three Gorges Dam*

was completed in 2006, the heaviest concrete structure ever built at 144 billion tons. The last of the main 6,000-ton water turbines in the underground plant began production in 2012, with the ship lift completed in December 2015. The ship lift is a series of five locks, where ships can ascend or descend up to 371 feet in about 40 minutes. From various incomplete project sources, I estimate the total cost of the Three Gorges Dam project at \$40-50 billion in today's U.S. dollars.

There is no denying the Three Gorges Dam's significance to China's economic growth, but its construction created new problems for the country. Building the dam flooded archaeological and cultural sites and displaced 1.3 million people when over a hundred towns were submerged. Also the dam is causing significant ecological changes, including the endangerment and extinction of many plant and animal species, and increased risk of landslides on resettled lands due to soil erosion.

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**Part 4 - Inventions**

This definition of "inventions" worked for me: *A unique or novel device, composition, or process. It may be an improvement upon a machine or product or a new process for creating an object or result.*

I looked at lists of the top inventions of all time, trying to choose ten, with emphasis on those that changed the world. Again, I found a lot of variation and disagreement, but this category is something I know a little about, so it was easier to apply my own background and biases.

In order to keep the list to the "top 10," I had to eliminate the "wheel" as one of my selections. So, I'll just mention here that around 3500 BC, someone figured out how to mount wheels at the end of axels, thereby inventing wheeled vehicles that of course are vital our way of life, along with countless other applications of the wheel. I also eliminated broad categories like refrigeration, plumbing, medicine, and communication, and natural phenomenon like electricity.

Anyway, my list of the Top 10 inventions of all time appears in the table below, in historical order by creation year. Sometimes the inventor is unknown, or the invention is due to the creative efforts of many people. At other times, the person who deserves credit for the invention was in dispute at the time; for those cases I tried to use the judgement of history.

I end this discussion of "inventions" with images of the inventors, if appropriate.

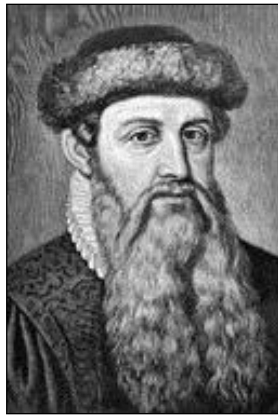
*Top 10 inventions of all time in historical order by creation year.*

<b>No.</b>	<b>Invention</b>	<b>Inventor</b>	<b>Comments</b>
1	Paper 105	Cai Lun China 48-121	Han Dynasty court official standardized paper making materials (recipe) and process - using the bark of trees, remnants of hemp, rags of cloth and fishing nets. Precursors included papyrus (Egypt) and amate (Mexico).
2	Compass c. 1040	Song Dynasty China 960-1279	Invented as a device for divination as early as the Han Dynasty, c. 206 BC, using lodestone, a naturally occurring magnetic ore of iron. Used for maritime navigation by 1040 - enabling mariners to navigate safely far from land, increasing sea trade, and contributing to the Age of Discovery.
3	Printing Press c. 1439	Johannes Gutenberg Germany c. 1400-1468	Adapting existing technologies, Gutenberg invented a mechanized system to precisely and rapidly create and set metal movable type for printing - exponentially increasing printing press speed, leading to the rapid and widespread dissemination of knowledge for the first time in history.
4	Telephone 1875	Alexander Graham Bell United States 1847-1922	Though several other inventors did pioneering work on "electronic voice transmission," Scotland-born Bell is credited with inventing and patenting the first practical telephone. The invention quickly took off and revolutionized global business and communication.
5	Automobile 1885	Karl Benz Germany 1844-1929	Early versions of the automobile were powered by steam (1769) and hydrogen (1808). Experimenting with gasoline-powered internal combustion engines began in 1870. Benz built the first gasoline-powered "production" automobile - patented in 1886. In 1913 Henry Ford began mass producing the Ford Model T to sell at reasonable prices, changing the way the world's population lived and traveled.
6	Radio 1895	Guglielmo Marconi Italy 1874-1937	In 1864 England's theoretical physicist James Maxwell predicted mathematically the existence of radio waves. In 1884 Serbian-American scientist Nikola Tesla invented the induction (Tesla) coil, essential to sending and receiving radio waves. In 1887 German physicist Heinrich Hertz proved the physical existence of radio waves. In 1894 Italian physicist Guglielmo Marconi began to experiment on radio; by 1895 he was transmitting radio waves more than a mile, and was granted a patent for radio in 1897. Radio performance improved with technology; in 1906 Canadian inventor Reginal Fessenden initiated the first radio transmission of the human voice and in 1916 American inventor Lee de Forest set up an experimental radio station in New York City - and as they say, the rest is history.

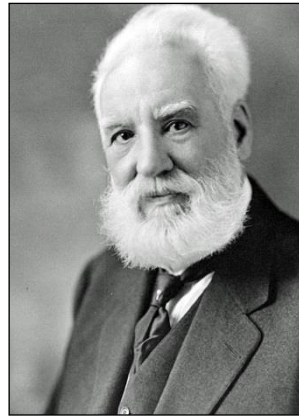
7	Airplane 1903	Orville Wright (1871-1948) Wilbur Wright (1867-1912) United States	Successful manned glider flights began in 1849. Steam-powered flights were attempted unsuccessfully in 1886 and 1894. The first controlled, sustained, heavier-than-air gasoline-powered flights were accomplished by bicycle-maker brothers Orville and Wilber Wright. Innovations include a three-axis control system, wind tunnel testing of airfoils, light-weight aluminum internal combustion engine, and propellers to push the aircraft through the air. Technology improved quickly to improve performance for both civilian and military applications.
8	Rocket 1926	Robert Goddard United States 1882-1945	The first use of gunpowder-fueled arrows occurred in China, as early as the 10th century. Since then, there was increasing world-wide use of gunpowder-fueled rockets, usually employed as weapons. American inventor Goddard attached a supersonic nozzle to the combustion chamber of a liquid-fuel rocket engine to produce a highly directed hypersonic jet of gas, greatly increasing thrust compared to solid rockets. Two of Goddard's 214 patented inventions - a multi-stage rocket and a liquid-fueled rocket - were important milestones towards space flight.
9	Computer 1945	John Mauchly United States 1907-1980	In 1822 futurist English mathematician Charles Babbage conceived of a machine that would be able to compute tables of numbers. Not until 1936 did English scientist Alan Turing present the basic concept the modern computer. In 1943-1945, based on the work of hundreds of others, University of Pennsylvania Professor John Mauchly (and fellow professor Presper Eckert) built and tested the first general purpose electronic digital computer, called ENIAC (Electronic Numerical Integrator and Calculator). It filled a 20-foot by 40-foot room and had 18,000 vacuum tubes. And look where we are today!
10	Internet Late 1960s	DARPA United States	The Internet (global system of interconnected computer networks) began with concepts for wide area networking in computer science laboratories in the U.S., United Kingdom, and France, followed by an unprecedented creative collaboration of the U.S. Defense Department, Universities, and the private sector - involving hundreds of people. The first workable prototype of the Internet came in the late 1960s with the development of ARPANET (Advance Research Projects Agency Network), managed by computer scientist Lawrence Roberts, using packet switching (data transmission of parts of a message on independent, optimum paths for reassembly later), developed by Roberts, that allowed multiple computers to communicate on a single network. ARPANET led to the development of protocols for internetworking and the full implementation of the Internet in the 1970s. Today the Internet continues to grow, driven by even greater amounts of online information, communication, commerce, entertainment, and social networking.



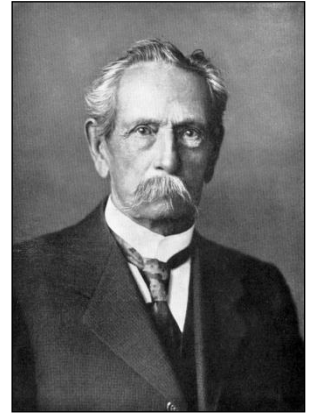
Cai Lun



Johannes Gutenberg



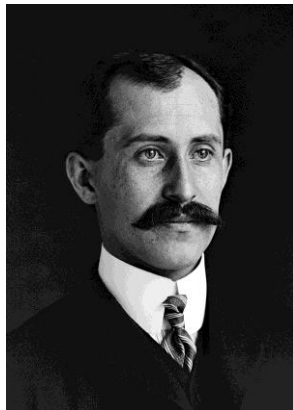
Alexander Graham Bell



Karl Benz



Guglielmo Marconi



Orville Wright



Wilber Wright



Robert Goddard



John Mauchly

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**Part 5 - Literature**

"Literature" is another subject I found difficult to define. Adapting what I read from several sources: *"Literature" is writings - either fiction (fantasy) or nonfiction (factual) - that can be expressed in many forms including novels, short stories, history, biography, essays, poetry, plays, letters, journal/diaries/memoirs, comic books, folklore, and expositions of science, philosophy, etc.* Some sources infer an author's literary goal of permanence and/or universal appeal.

With all this in mind, what I decided to do in this section is to talk about the ten most influential books of all time. Again, I researched "Top 10" lists, found quite a variation, and then applied my own limited knowledge and opinion. My version of the Top Ten Most Influential Books of all Time appears in the following table, in order of the year written (completed).



*The top 10 most influential books of all time in historical order.*

<b>No.</b>	<b>Book</b>	<b>Author</b>	<b>Year Written</b>	<b>Comments</b>
1	The Republic	Plato Greece	380 BC	Socrates dialogues about the meaning of justice, identifying ethical and political issues in teaching about life. (See Part 9 for Plato's contribution to Philosophy.)
2	Holy Bible - King James Version	Over 40 Middle East	1600 BC - 100 AD	Compilation of stories that describe creation, genealogy, persecution and freedom of certain groups, creation of God's laws for man in the Ten Commandments, the coming of Jesus Christ, his teaching as recounted from stories told by his Apostles, and his crucifixion and resurrection.
3	The Qur'an	Muhammad Arabia (present day Saudi Arabia)	609 - 631	Muslims believe this series of divine messages was revealed by God to Muhammad with guidance for mankind, emphasizing moral significance of historical events.
4	The Complete Works	Shakespeare England	1594 - 1634	Centuries later, Shakespeare's plays are still by far the most studied and performed in the English speaking world and beyond.
5	The Wealth of Nations	Adam Smith Scotland	1776	The foundation of economics, the origin of statistical econometrics, and the intellectual cradle of capitalism.
6	The Rights of Man	Thomas Paine America	1791	Written to defend the French Revolution - an inspiration for democracy. Addresses poverty, inequality, and welfare - that are still hotly debated today.
7	On the Origin of the Species	Charles Darwin England	1859	The theory of evolution by natural selection. No scientific book ever published has been so widely and vigorously discussed by scientists and laymen alike. (See Part 11 for Darwin's contribution to Science.)
8	The Communist Manifesto	Karl Marx and Friedrich Engels Germany	1888	Theory and practice of revolutionary movements. How capitalism of the day would be replaced by socialism and finally by communism.
9	The Meaning of Relativity	Albert Einstein Germany	1922	Explains special relativity (light) and general relativity (gravity). Theories transformed theoretical physics and astronomy. (See Part 11 for Einstein's contribution to Science.)
10	A Brief History of Time	Stephen Hawking America	1988	Explains the 13.7B - year astronomical history of the universe from the Big Bang to today.

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**Part 6 - Mathematics**

Of the many definitions of “mathematics” that I found, here is the one that makes most sense to me:

*Mathematics is the abstract science of number, quantity, and space. Mathematics may be studied on its own (pure mathematics), or as it is applied to other disciplines such as physics and engineering (applied mathematics).*

First of all, I tried to identify the all-time “top 10” mathematicians. This was one of the hardest of man’s accomplishment categories to choose a “top 10” for; there are all kinds of expert lists and all kinds of disagreement. So again, my biases and opinions prevailed in my list of the top ten greatest mathematicians of all time shown in the following table, in order of birthdate.

Note that Albert Einstein is not included on my list. He was without question one of the greatest physicists of all time and will be prominently discussed under the “science” category in Part 11. Einstein was a mathematician, however; he pioneered the application of tensor calculus to physics and invented the Einstein summation notation to simplify expressions of vectors, matrices, and general tensors.

Following the “Top 10” list of mathematicians, I include an image of each of them.

*The ten greatest mathematicians of all time in historical order by birthdate.*

No.	Mathematician	Comments
1	<b>Euclid</b> Greece and Egypt 322 - 275 BC	Father of Geometry. Founded the school of mathematics in Alexandria. His book, <i>The Elements</i> , introduced the idea of axioms and theorems; used as a textbook for 2,000 years; still the basis of high school geometry.
2	<b>Archimedes</b> Greece and Sicily 287 - 212 BC	Greatest of ancient mathematicians - key contributions to algebra and geometry. Formulated laws that explained levers and pulleys. Famous for the law of specific gravity, known as "Archimedes Principle." Ahead of his time - anticipated calculus. Designed weapons used in Second Punic War.
3	Leonardo <b>Bigollo</b> Italy 1170 - 1245	Most talented mathematician of the Middle Ages. Introduced Hindu-Arabic numerals, including the decimal system to Europe, replacing Roman numerals - enabling math calculations; led to Renaissance and scientific revolution. Known today as <b>Fibonacci</b> , after the sequence of integers he documented that are observed in biological systems and that have applications across mathematics.
4	Rene <b>Descartes</b> France 1596 - 1650	Father of modern mathematics. Developed Cartesian Geometry, the standard graph, and introduced superscripts to denote exponents. Prepared ground for modern calculus. Also a philosopher (I think, therefore I am) and a physicist (conservation of momentum) - one of most influential thinkers in history.
5	Isaac <b>Newton</b> England 1642 - 1747	Father of Calculus, the most important achievement of modern mathematics, the essential tool without which most of the subsequent progress in modern science would have been impossible. Important advances in analytic geometry; developed Binomial Theorem, polar coordinates, power series for exponential and trigonometric functions. (See Part 11 for Newton's contributions to Science.)
6	Gottfried W. <b>Leibniz</b> Germany 1646 - 1716	Co-developer of Calculus - introduced modern standard notation. Math innovations include geometric envelopes and binary number system. Anticipated cybernetics and information theory. Self-taught mathematician - also a philosopher, lawyer, historian, diplomat, and renowned inventor.
7	Leonard <b>Euler</b> Switzerland 1707 - 1783	Most prolific mathematician in history. Pioneered modern trigonometry, calculus of variations, graph theory, functions, and number theory. Introduced symbols, " $\Sigma$ " for summation, " $e$ " for the base of natural logarithms, " $\pi$ " for the ratio of a circle's circumference to its diameter, and notation for imaginary numbers.
8	Carl Friedrich <b>Gauss</b> Germany 1777 - 1855	Prince of Mathematics - most brilliant mathematician who ever lived. Known for Fundamental Theorem of Algebra, number theory, statistics (Gaussian distribution), differential geometry, foundations of topology, measurement of electromagnetism, comet orbit calculations, Gaussian gravitational constant, map theory, and the invention of the heliotrope.
9	G. F. Bernhard <b>Riemann</b> Germany 1826 - 1866	Student of Gauss. Revolutionary contributions to topology, complex analysis, and number theory. Masterpieces include Riemann integral, differential geometry, tensor analysis, non-Euclidean geometry, theory of functions, and especially the theory of manifolds. Set the stage for Einstein's Theory of Relativity.
10	John <b>von Neumann</b> Hungary 1903 - 1957	One of most prolific geniuses in history. Pioneered the use of models in set theory; invented game theory. Worked in analysis, operator theory, matrix theory, numerical analysis, ergodic theory, continuous geometry, statistics, and topology. Also, major contributions to quantum physics, economics, and computer science.



Euclid



Archimedes



Leonardo Bigollo



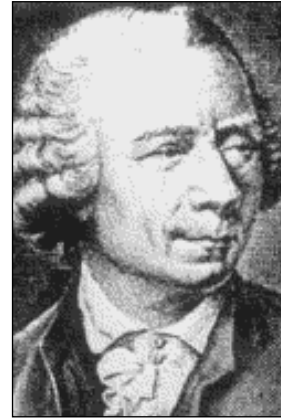
Rene Descartes



Isaac Newton



G. W. Leibniz



Leonard Euler



C. F. Gauss



G. F. Bernard Riemann



John von Neumann

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**Part 7 - Medicine**

I was unable to find a definition of "medicine" inclusive enough for my purposes. So for this project, I'm defining "medicine" to be: *The science or practice of the understanding, diagnosis, treatment, and prevention of disease or other health problems - includes surgery and psychological issues.*

I did find a good source for (Western) medical history, Robert Adler's book, *Medical Firsts - From Hippocrates to the Human Genome.*

The Greek physician Hippocrates laid the foundation for modern medicine over two millennia ago in about 400 BC. As Adler says,

"Ancient medicine was a hit-and-miss affair rooted in pagan ritual and magic. ... It was Hippocrates who took medicine out the realm of myth and superstition and established it on a scientific footing. So powerful was his idea of relying on the direct and systematic observation of nature to reveal the causes and cures of diseases that virtually every medical advance since then can be traced directly back to it.

"The most dramatic expression of the ethical focus of Hippocrates teaching is found in the famous Hippocratic Oath, versions of which many medical students still swear to today. Although it's twenty-four hundred years old, the oath is the direct source of the ethical and personal care that continues to distinguish physicians and medical professionals at their best."

Adler documents 27 of the most important medical firsts in history since Hippocrates. Seeking a "top 10" to write about, I was again unsuccessful, but did finally pick 12 that I believe illustrate the impressive medical innovation path over the years. The following table lists these medical firsts in historical order.



*Twelve of the greatest medical firsts of all time in historical order.*

<b>No.</b>	<b>Medical First</b>	<b>Year</b>	<b>Individuals</b>	<b>Comments</b>
1	Understanding Blood Circulation	1628	William Harvey (1578-1656)	Ended 2,000 years of dogma and speculation. Revolutionized physiology.
2	Smallpox Vaccination	1796	Edward Jenner (1749-1823)	Led to eradication in 1970s of smallpox that had killed 500 million people.
3	Discovery of Anesthesia	1846	William Morton (1819-1868)	Used ether as first surgical anesthesia in operation at Massachusetts General Hospital.
4	Germ Theory of Disease	1860-1864	Louis Pasteur (1822-1895)	Experiments proved that specific microbes cause infectious disease. (See Part 11 for Pasteur's contributions to Science.)
5	Discovery of Viruses	1892	Dmitri Ivanosky (1864-1920)	First virus discovered in experiments on tobacco. Many other contributors over many years to identify viruses as infectious agents that replicate only inside living cells.
6	Discovery of X-rays	1895	Wilhelm Conrad Roentgen (1845-1923)	X-rays illuminate the innermost secrets of the human body. Digitized 3-D images by 1972.
7	Psychoanalysis	1895-1900	Sigmund Freud (1856-1939)	Persuaded world to appreciate subconscious mind. Developed psychoanalytic theory.
8	Penicillin	1928	Alexander Fleming (1881-1955)	Discovered accidentally from mold on petri dishes. First broad-spectrum antibiotic - revolution in medicine.
9	Birth Control	1954	Gregory Pincus (1913-1997)	Birth control activist Margaret Sanger hired Pincus to develop oral contraceptive. Approved by FDA in 1960.
10	Organ Transplantation	1967	Christiaan Barnard (1922-2001)	First successful heart transplant in 1967 followed kidney transplants beginning in 1951. Heart-lung machine and immune-suppressing drugs were enablers.
11	In Vitro Fertilization	1978	Robert Edwards (1925-2013) Patrick Steptoe (1913-1988)	World's first "test tube" baby delivered in 1978 - giving millions of women gift of fertility. Edward's foresaw use of embryonic stem cells to cure diseases and grow replacement organs.
12	Defining the Human Genome	1953	Francis Crick (1916-2004) James Watson (1928 - )	In 1953 Crick and Watson identified double helix arrangement of DNA molecule that contains the instructions an organism needs to develop, live and reproduce - found inside every cell, and passed down from parents to children. Then followed 50 years of efforts by many to map the genetic content of DNA (human genome) - declared complete in 2003.

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### Part 8 - Music

I found a definition of “music” that I like: *Vocal or instrument sounds (or both) combined to produce beauty of form, harmony, and expression of emotion.*

I'm limiting this discussion to Western World classical music. I used as my guide, the book, *Classical Music*, with general editor John Burrows. Once again I researched “Top 10” all-time composer lists, and once again found disagreement. I decided to use the reasonably-stated and well-defended assessment of Listverse Ltd., available at <http://listverse.com/2009/12/17/top-15-greatest-composers-of-all-time/>. I moved Tchaikovsky up from 12<sup>th</sup> on this list to 10<sup>th</sup>, replacing Giuseppe Verdi, simply because Tchaikovsky is probably **my** favorite composer. (Other “Top 10” lists had Tchaikovsky ranked as high as 8<sup>th</sup>.)

Following the organization of editor Burrows, I first summarized the characteristics of Western classical music by musical period, including the most important composers of the period. That summary is presented in the following table. Then comes “my” Top 10 listing of composers and a summary of what they are known for. Next are images of the composers, and finally I present a list of links to the internet, where you can listen to “best of” music for each composer.

*Overview of Western classical music periods.*

<b>Musical Period</b>	<b>Characteristics</b>	<b>Most Important Composers</b>
Early Music 1000-1600	Music of the Middle Ages and Renaissance. Church music dominated - single melodic line Gregorian chants evolved to multiple melodic line music with instrument accompaniment for masses and hymns. Vocal secular music included madrigals and songs generally accompanied by a lute or small instrument ensemble. Instrumental pieces were popular for dancing.	Pope Gregory - Gregorian chants; Giovanni Pierluigi da Palestrina - sacred music; Claudio Monteverdi - defined the transition to Baroque music, laid the groundwork for opera.
Baroque 1600-1750	Opera was born. Instrumental music flourished. Development of the sonata, concerto (single solo instrument), and concerto grosso (small group of solo performers). Important instruments were the keyboard, particularly the harpsichord, organ, lute, violin, and bassoon. The orchestra evolved. Distinctive national styles evolved.	Antonio Vivaldi, Johann Sebastian <b>Bach</b> , George Frideric Handel.
Classical 1750-1820	Instrumental music became most popular form - sonata, symphony, and concerto. New and simpler musical style - clarity, restraint, balance. Growth of public concerts. Orchestra expanded to accommodate expanded musical visions. Professional musicians. Operas produced for the general public in their native languages (vice only Italian).	Wolfgang Amadeus <b>Mozart</b> , Franz Josef Haydn, Ludwig van <b>Beethoven</b> (early years).
Romantic 1810-1920	Music became more expressive, emotional, and instinctive - celebrated nature for inspiration. Originality of paramount importance. More complex, often much longer, works - much of it with nationalistic fervor. Heyday of the virtuoso performer - particularly pianists, violinists, and singers.	Ludwig van <b>Beethoven</b> , Franz <b>Schubert</b> , Felix Mendelssohn, Frederic <b>Chopin</b> , Robert <b>Schumann</b> , Richard <b>Wagner</b> , Franz <b>Liszt</b> , Peter <b>Tchaikovsky</b> , Johannes <b>Brahms</b> , Johann Strauss Jr., Giuseppe Verdi, Antoni Dvorak, Nikolay Rimsky-Korsakov, Gustav Mahler, Claude Debussy, Giacomo Puccini, Maurice Ravel.
Modern 1900-	New freedom and wide experimentation with new musical styles and forms that challenged the accepted rules of music of earlier periods - influenced by ideological, social, and technological changes. The invention of musical amplification and electronic instruments, the synthesizer, recording, radio, headphones, computers, smart phones, etc., contributed to a revolution in music listening.	George Gershwin, Sergei Rachmaninoff, Bela Bartok, Arnold Schoenberg, Arthur Honegger, Igor Stravinsky, Irving Berlin, Aaron Copland, Leonard Bernstein, John Cage, Karlheinz Stockhausen.

*Top 10 Western composers in historical order by birthdate.*

No.	Composer	Comments
1	Johann Sebastian Bach Germany 1685-1750	Largely unappreciated in his lifetime, Bach is considered by many today as the greatest composer of music who ever lived. Bach wrote universal masterpieces in every genre including the six finest concerto grossi ever written, nicknamed the "Brandenburg Concertos." His sacred work masterpiece, Mass in b minor, is arguably the single greatest work of music of all time, in any genre, in any style. He is the greatest of all composers because of the intellectual depth of his music, the technical demand, and the artistic beauty.
2	Wolfgang Amadeus Mozart Austria 1756-1791	The most gifted musical genius in history, the most famous genius of any field in history, and the person who perfected classical music. He wrote 41 symphonies, 27 piano concertos, a large amount of chamber music, 23 operas, 18 sonatas for piano, 36 for violin and cello, church sonatas, organ pieces, 18 masses, four horn concertos, 20 string quartets, serenades, and many others. He was the supreme composer of melody and lyrical quality in music history. He also was one of the finest pianists to ever live, and equally adept at the violin.
3	Ludwig van Beethoven Germany 1770-1827	The inventor of Romantic music. His finest and most unique works include his 3 <sup>rd</sup> to 9 <sup>th</sup> symphonies, his last three of five piano concertos, his violin concerto, the finest ever written, his chamber music, especially his string quartets, the last six of which are universally considered to be among the greatest musical works in history. Beethoven's 5 <sup>th</sup> Symphony begins with the single most famous melody in music history. And he achieved all this despite being completely deaf for the last 25 years of his life.
4	Franz Schubert Germany 1797-1828	The greatest songwriter of all time, and the second greatest master of melodic, lyrical composition - optimistic music. He wrote approximately 650 songs in the short 15 years of his career. Schubert also wrote masses, symphonies, sonatas, ballets, string quartets, and operas. His finest works are his 8 <sup>th</sup> and 9 <sup>th</sup> symphonies, his Trout piano Quintet, ballet music to Rosamunde, Marche Militaire, and some of his songs like, Gretchen at the Spinning Wheel, the Eri-King, and Nact und Traume.
5	Robert Schumann Germany 1810-1846	Perhaps the most elusive composer of the Romantic period; his music is at turns fanciful, introspective, and bombastic. Daringly original, he was a genius in all genres, producing masterpiece symphonies, especially his 3 <sup>rd</sup> "the Rhenish," his chamber music, especially his Piano Quintet, and his Piano Concerto in A Minor, maybe the finest ever written. He is also well regarded for his huge quantity of vocal music.
6	Frederic Chopin Poland 1810-1849	Exiled by revolution, one of the premier composers for the piano who ever lived. Chopin's melodic genius is superlative in all respects - most notable are his ballades, etudes, sonatas, mazurkas, waltzes, nocturnes, preludes, and impromptus. Chopin was the most innovative composer for all of these genre except the sonata. A national hero, his music announced the liberation of his native Poland and still accompanies international statesmen to their graves.

7	Franz Liszt Hungary 1811-1886	The central figure of the Romantic movement. The greatest pianist of all time. He wrote hundreds of short pieces, songs, preludes, etudes, two piano concertos, and symphonic poems. He was an all-around master of every genre in which he composed. Many of his piano works are very technically demanding and hard to play. As famous for his life as for his music, he worked tirelessly to promote the work of his colleagues (including Chopin), and to teach subsequent generations of pianists and composers.
8	Richard Wagner Germany 1813-1883	Wagner reinvented opera as - a unified work of art combining poetry, drama, music, song and painting. He wrote both text and music, and superintended staging and performance as his own director and conductor. His finest masterpieces are Tannhauser, Lohengrin, containing the world famous "Here comes the Bride" theme, Tristan und Isolde, which some consider his finest achievement, Die Meistersinger von Nurnberg, Parsifal, and his gargantuan four-opera cycle Der Ring des Nibelungen. Wagner's music is often used today as background for films.
9	Johannes Brahms Germany 1833-1897	Perhaps the last great composer in the Classical tradition. His music is powerfully affecting and an important influence on the development of 20 <sup>th</sup> century music. He composed masterpieces in all genres except opera. He wrote four symphonies, all outstanding, a German Requiem, his finest work, and one of the greatest violin concertos in history. He was a superb fugue composer.
10	Peter Ilyitch Tchaikovsky Russia 1840-1893	One of the finest orchestrators and one of the supreme melody writers in all of music. Tchaikovsky is the all-time master of ballet - all three world famous: Nutcracker, Swan Lake, and Sleeping Beauty. He wrote two operatic masterpieces and six symphonies. Tchaikovsky was also a master of the concerto and wrote three piano concertos, the first of which is one the most famous in history, and a masterpiece Violin Concerto. To the public at large, Tchaikovsky is perhaps most famous for his rousing "Overture to 1812."





Bach



Mozart



Beethoven



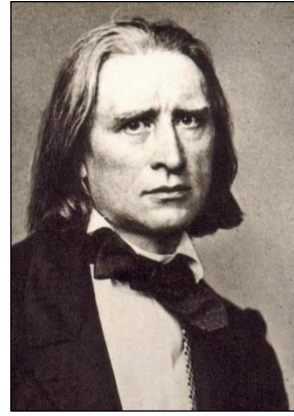
Schubert



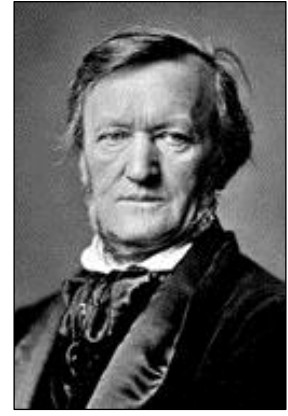
Schumann



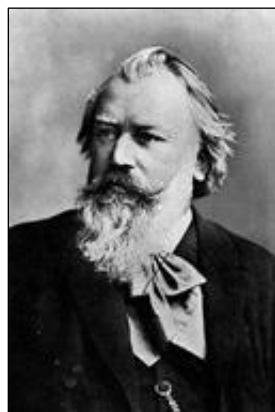
Chopin



Liszt



Wagner



Brahms



Tchaikovsky

*Listen to the “best of” music from each composer at these URLs.*

Bach:

<https://www4.bing.com/videos/search?q=directly+playable+bach+music&view=detail&mid=212AEFCC2C043CA7E15D212AEFCC2C043CA7E15D&FORM=VIRE>

Mozart:

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Beethoven:

<https://www4.bing.com/videos/search?q=directly+playable+best+of+beethoven+music&view=detail&mid=1149B0D17BE5FBD476CB1149B0D17BE5FBD476CB&FORM=VIRE>

Schubert:

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Schumann:

<https://www.youtube.com/watch?v=GRxofEmo3HA>

Chopin:

<https://www.bing.com/videos/search?q=directly+playable+best+of+chopin+music&view=detail&mid=642F3FBEE7B2E25E5150642F3FBEE7B2E25E5150&FORM=VIRE>

Liszt:

<https://www.youtube.com/watch?v=3-8DA29LBHw>

Wagner:

<https://www.youtube.com/watch?v=4i0TnNI6U-w>

Brahms:

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Tchaikovsky:

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**What in the World Happened?  
Perspectives on Man's Accomplishments**

**Part 9 - Philosophy**

*Philosophy is the study of existence, knowledge, values, reason, mind, and language.* The term was probably coined by Greek philosopher Pythagoras (c. 570-495 BC).

I focused on Western philosophers, thereby omitting such prominent people as China's Confucius and Lao Tzu.

Once again I scoured available "Top 10" lists for the greatest philosophers of all time. And again, I found many, all different. So I went back to one of my basic references, the book, *The Hundred - A Ranking of the Most Influential Persons in History*, by Michael Hart. I took the six philosophers listed in that book and "salted" in four others, prominent in the "Top 10" lists, to come up with my list of ten. The following table lists and comments on my selection of *Top 10 Western philosophers of all time in historical order by birthdate*.

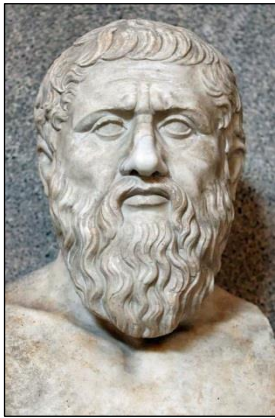
After the table I include an image of each philosopher.

*Top 10 Western philosophers of all time in historical order by birthdate.*

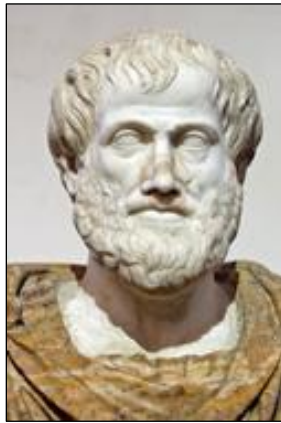
No.	Philosopher	Comments
1	<p style="text-align: center;"><b>Plato</b> Greece 427-347 BC</p>	<p>Taught by Aristotle, Plato represents the starting point of Western political philosophy and much of our ethical and metaphysical thought. His speculations on these subjects, documented in 36 books, have been read and studied for over 2,300 years. Plato's <i>The Republic</i> is regarded by many as one of the "Top 10" most influential books in history. About 387 BC, Plato founded an Academy of Learning in Athens, which continued in operation for over 900 years. Plato was also the first major philosopher, and for a long time, virtually the only one, to suggest the basic equality of the sexes. (See Part 5 for discussion of Plato's <i>The Republic</i>.)</p>
2	<p style="text-align: center;"><b>Aristotle</b> Greece 384-322 BC</p>	<p>The greatest philosopher (and scientist) of the ancient world. He is generally considered the founder of logic as a branch of philosophy. He authored 170 books, writing on logic, ethics, metaphysics, psychology, economics, theology, politics, rhetoric, aesthetics, education, poetry, barbarian customs, and the Athenian constitution. His work was a major influence on Islamic philosophy, and for centuries, his writings dominated European thought. Aristotle attended Plato's Academy for 20 years and tutored the future Alexander the Great for several years. (See Part 11 for Aristotle's contributions to Science.)</p>
3	<p style="text-align: center;"><b>St. Augustine</b> Algeria 354-430</p>	<p>The greatest theologian of his era, during the decline of Rome. His writings profoundly influenced Christian doctrines and attitudes throughout the Middle Ages and still have influence today. He introduced the concept of predestination. His views on salvation, sex, original sin, and many other points were influential. His arguments on the importance of the Church led to others concluding that temporal rulers should be subordinate to the Pope. Many later Catholic theologians, such as Aquinas, were strongly influenced by him.</p>
4	<p style="text-align: center;">St. Thomas <b>Aquinas</b> Italy 1225-1274</p>	<p>Famous for his theological writings and particularly for his <i>Summa Theologica</i>, perhaps the most authoritative statement of Catholic theological doctrine ever produced. His views on ethics, natural law, metaphysics, and political theory have been debated for centuries. Aquinas attempted to synthesize the philosophy of Aristotle with the principles of Christianity. The Catholic Church honors Thomas Aquinas as a saint and regards his teachings as a required program of study for those studying for the priesthood.</p>
5	<p style="text-align: center;">Rene <b>Descartes</b> France 1596-1650</p>	<p>Referred to as "the Father of Modern Philosophy." Also known as a scientist (laws of refraction and reflection) and mathematician (created analytic geometry with his Cartesian coordinate system). He advocated dualism, the power of the mind over the body; his most famous statement, now practically the motto of existentialism, "I think therefore I am," proving the existence of one's mind. He rejected perception as unreliable and considered deduction (reason) the only reliable method for examining, proving, and disproving anything.</p>
6	<p style="text-align: center;">John <b>Locke</b> England 1632-1704</p>	<p>The first writer to put together in coherent form the basics of constitutional democracy. His ideas - as expressed in <i>Two Treatises of Government</i> - strongly influenced the founding fathers of the United States, as well as leaders of the French Enlightenment. In another essay, <i>A Letter Concerning Toleration</i>, Locke argues for religious tolerance in government. His most famous philosophical work, <i>An Essay on Human Understanding</i>, discusses the origin, nature, and limits of human knowledge - greatly influencing philosophers who followed like, Hume and Kant.</p>

7	<b>David Hume</b> Scotland 1711-1776	Philosopher, economist, historian, and essayist. Undoubtedly the most important philosopher who wrote in English. He rejected the possibility of certainty in knowledge, positing that all human knowledge is founded solely in experience (empiricism). He believed that only natural laws and forces operate in the world. He held that passion rather than reason governs human behavior. He opposed the teleological argument (intelligent design) for God's existence. Hume was also a sentimentalist who held that ethics are based on emotion or sentiment rather than abstract moral principle. During the 20 <sup>th</sup> century, Hume, more than any other philosopher, influenced the spirit and tenor of English-language philosophy, which was generally empirical, naturalistic, anti-metaphysical, and analytic, and which prized clarity and logical rigor.
8	<b>Jean-Jacques Rousseau</b> Switzerland 1712-1778	A philosopher, writer (novels), and composer (two operas). He was an important factor in the rise of Romanticism in literature and had great influence on education, emphasizing the importance of a child's learning through experience. His political philosophy influenced the Enlightenment across Europe, as well as the French Revolution and the overall development of political and educational thought. His views are dominated by a passion for equality in society and a feeling that the existing structure of society is unjust, e.g. private property. Rousseau is considered one of the forerunners of modern Socialism and Communism.
9	<b>Immanuel Kant</b> Germany 1724-1804	Central figure in modern philosophy. He synthesized early modern rationalism and empiricism, set the terms for much of 19 <sup>th</sup> and 20 <sup>th</sup> century philosophy, and continues today to influence metaphysics, epistemology, ethics, political philosophy, and aesthetics. The fundamental idea of Kant's philosophy is human autonomy, arguing that human understanding is the source of the general laws of nature that structure all our experience, and that human reason gives itself moral law, which is our basis for belief in God, freedom, and immortality. Kant was one of the earliest exponents of the idea that perpetual peace could be secured through universal democracy and international cooperation.
10	<b>G. W. F. Hegel</b> Germany 1770-1831	An important figure of German idealism, the idea that "the rational alone is real." He is perhaps most well-known for his teleological (doctrine of design and purpose) account of history, arguing that all history is progressing towards a perfect state of being. His philosophy of spirit conceptually integrates psychology, the state, history, art, religion, and philosophy. He influenced all the great philosophers of the 19 <sup>th</sup> century, including Marx and Nietzsche, and was important to existentialism and the beginning of psychoanalysis.





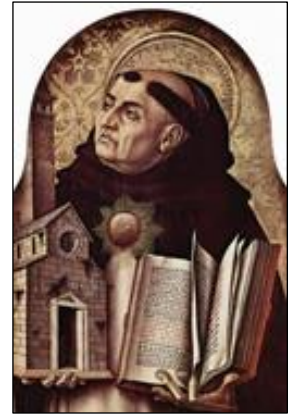
Plato



Aristotle



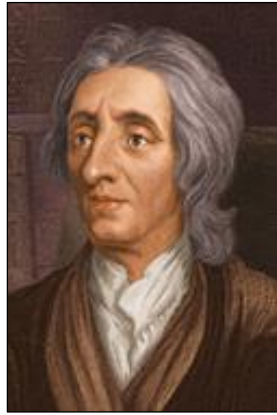
St. Augustine



St. Aquinas



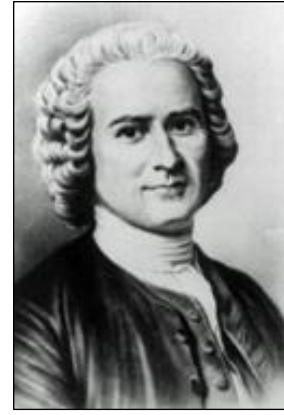
Rene Descartes



John Locke



David Hume



Jean-Jacques Rousseau



Immanuel Kant



G.W.F. Hegel

## What in the World Happened? Perspectives on Man's Accomplishments

### Part 10 - Religion

Religion has always been important to mankind, from Stone Age man's belief in mysticism through magic-endowed shamans; to fertility gods; to early civilization gods of agriculture, sun, moon, stars; to multiple Greek and Roman gods responsible for daily activities, and the environment - such as gods of war, hunting, farming, wisdom, love, the sea, etc. - with human attributes attributed to all of them.

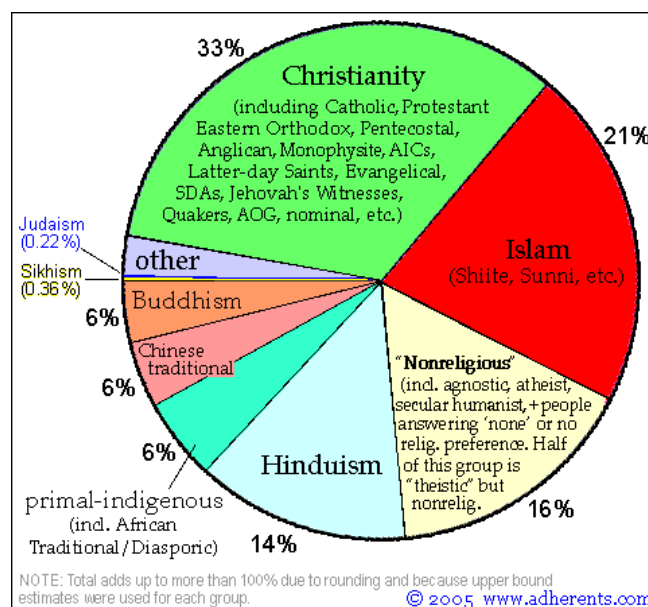
I looked for a reasonable definition of "religion" that would serve for today's world - religions which were founded after the Ancient World ended. I came up with: *A set of beliefs concerning the cause, nature, and purpose of the universe, especially when considered as the creation of a superhuman agency or agencies, usually involving devotional and ritual observances, and often containing a moral code governing the conduct of human affairs.*

I looked for a resource that discussed the history of the world's major religions and also put size (number of adherents) into context. The only source I found was "Major Religions Ranked by Size" at Adherents.com, dating from 2005. This website shows a religion-size "pie chart" and discusses the history of each religion.

I include the "pie chart" below. You may be surprised (as I was) at the "big size" of Christianity and the "small size" of Judaism.

Next I provide a table discussing today's major world religions in historical order by year established.

*Major religions of the world by number of adherents.*



Major religions of today's world in historical order by year established.

No.	Religion	Year Started	No. Adherents Today	Comments
1	Hinduism	4000-2500 BC	900 million	Origin traced to Indus Valley. Belief in the unity of everything, called Brahman. We are part of God and can rejoin with him if enlightened through multiple life cycle and reincarnation experiences. Enlightenment measured by karma, the accumulation of one's good and bad deeds. Hindus follow a strict caste system which determines the standing of each person.
2	Judaism	2000 BC	14 million	Jews believe in one creator to be worshiped as absolute ruler of the universe. He monitors people's activities, rewards good deeds, punishes evil. The Torah was revealed to Moses and cannot be changed though God does communicate through prophets. Jews believe in the inherent goodness of the world, that they are God's chosen people, and that the Messiah will arrive in the future to lead them.
3	Buddhism	560-490 BC	376 million	Developed out of the teachings of Siddhartha Gautama who in 535 BC assumed the title of Buddha. He promoted a balanced (between indulgence and restraint) approach to life as the path to enlightenment. After his death, his teachings were collected in the Tripitaka. Buddhists believe in reincarnation and after many life cycles, if a person releases their attachment to desire and self, can attain Nirvana. Buddhists do not believe in a God, the need for a savior, prayer, or eternal life after death.
4	Christianity	30	2.1 billion	Started as a breakaway sect of Judaism. Jesus, conceived through the Holy Spirit, revealed that he was the son of God, sent to Earth to save humanity from our sins. He performed many miracles during his travels and related many of his teachings in the form of parables, like "love thy neighbor" and "turn the other cheek." He was crucified for his teachings, rose from the dead, and told his disciples to spread his message. Christians believe in original sin and that Jesus was fully human and fully God, and is part of the Holy Trinity: God the Father, His Son, and the Holy Spirit. Christians believe in heaven and that those who sincerely repent their sins before God, will be saved and join Him in heaven. Christians believe that the Holy Bible contains the revelations of God and is the guiding holy text of the Christian religion.
5	Islam	622	1.5 billion	Founded by Muhammad the Prophet in Mecca. The two sacred texts are the Qur'an, the words of Allah "the one true God," as given to Muhammad, and the Hadith, a collection of Muhammad's sayings. Muslims believe in one creator, who is just, omnipotent, and merciful, and in Satan who drives people to sin, and that all unbelievers and sinners will spend eternity in Hell. Muslims who sincerely repent and submit to God will achieve a state of sinlessness and go to Paradise after death. The duties of all Muslims, the Five Pillars of Islam, specify rules for recitation, prayer, donations, fasting, and pilgrimages. Alcohol, drugs, and gambling should be avoided, and they reject racism.

6	Sikhism	1500	23 million	Founded by Shri Guru Nanak Dev Ji in Pakistan. Sikhs believe in a single formless God with many names, who can be known through meditation. Sikhs pray many times each day and are prohibited from worshipping idols or icons. They believe in repeated life cycles, karma, and reincarnation, but reject the caste system. They believe that everyone has equal status in the eyes of God. The Sikh code of conduct and conventions, evolved through the teachings of 10 leaders (gurus) over the years, and was documented in 1931 in the Reht Maryada.
7	Spiritism	1840s	15 million	Founded by the French educator Hippolyte Leon Denizard Rivail. Spiritism postulates that humans are essentially immortal spirits that temporarily inhabit physical bodies for necessary incarnations to attain moral and intellectual improvement. It also asserts that spirits, through passive or active mediumship, may have beneficent or malevolent influence on the physical world. Spiritism has influenced a social movement of healing centers, charity institutions and hospitals in dozens of countries.
8	Juche	1950s	19 million	Official state ideology of North Korea, developed by Kim Il-sung, originally viewed as a variant of Marxism-Leninism. It postulates that “man is the master of his destiny,” that the North Korean masses are to act as the “masters of the revolution and construction” and by becoming self-reliant and strong, a nation can achieve true socialism.
9	Nonreligious	NA	1.1 billion	Includes agnostic, atheist, secular humanist, and people specifying “none” or “no religion.”
10	Chinese Traditional	NA	394 million	Different religious and philosophical traditions that have been influential in China: Chinese folk religion, Confucianism, Taoism, and Buddhism. Most Chinese people believe in some combination of these four traditions.
11	Primal Indigenous	NA	300 million	Belief systems of groups of people scattered over Africa and Asia.
12	African Traditional & Diasporic	NA	100 million	Includes African traditional religions.
13	Other	NA	26.2 million	Includes Baha’i (7 million), Jainism (4.2 million), Shinto (4 million), Cao Dai (4 million), Zoroastrianism (2.6 million), Tenrikyo (2 million), Neo-Paganism (1 million), Unitarian-Universalism (800 thousand), Rastafarianism (600 thousand).

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**Part 11 - Science**

Here is the definition for "science" that I came up with: *The systematic study of the structure and behavior of the physical and natural world, involving postulates, observation, experiment, and/or analysis.*

My sources for the greatest scientists in history included two books: *The 100 - A Ranking of the Most Influential Persons in History*, by Michael H. Hart, and *Science Firsts*, by Robert E. Adler. I also consulted numerous "Top 10" lists to come up with my selection of the Top 10 greatest scientists of all time which I present in the following table in historical order by birth year.

I also want to acknowledge two people not on my list. The first is Greek philosopher Thales (624 -c. 547 BC), who asked the question, "What is the world made of?" and planted the seed that would grow into Western science. The second omission is the Italian Leonard da Vinci (1452-1519), perhaps the most brilliant universal genius that ever lived, but whose actual influence on history, through enduring scientific accomplishments, was comparatively minor. (He is included in Part 1, the discussion of the "Top 10" artists of all time.)

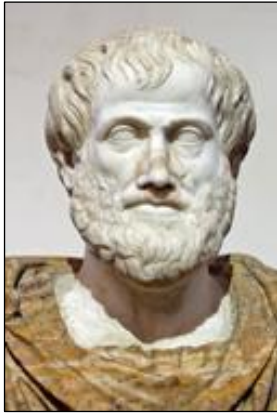
Following the "Top 10" discussion, I included images of each scientist.



*Top 10 greatest scientists of all time in historical order by birth year.*

No.	Scientist	Comments
1	<p style="text-align: center;"><b>Aristotle</b> Greece 384-322 BC</p>	<p>The greatest scientist (and philosopher) of the ancient world. His scientific works constitute a virtual encyclopedia of the scientific knowledge of his day – astronomy, zoology, embryology, geography, geology, physics, anatomy and physiology, botany, chemistry, meteorology, and geometry. He emphasized that the universe’s behavior is subject to rational laws, and that it is worthwhile for us to conduct a systematic inquiry into every aspect of the natural world and use both empirical observations and logical reasoning in forming our conclusions - profoundly influencing Western civilization for centuries. (See Part 9 for Aristotle’s contributions to Philosophy.)</p>
2	<p style="text-align: center;"><b>Galileo Galilei</b> Italy 1564-1642</p>	<p>Probably more responsible for the development of the scientific method (combining mathematical analysis with experimentation) than any other individual. Galileo improved the telescope and was the first to gather evidence that the earth revolves around the sun (Copernican theory). He also confirmed the phases of Venus, discovered Jupiter’s four largest moons, and observed and analyzed sunspots. He studied mechanics with experiments on falling bodies, floating objects, the tides, and the arc of a cannon ball, informally stating the principles later embodied in Newton’s first two laws of motion. He also invented the pendulum clock and developed the first thermometer. <i>Galileo was forced to recant his Copernican theory results by the Catholic Inquisition in Rome, and spent the last eight years of his life under house arrest.</i></p>
3	<p style="text-align: center;"><b>Isaac Newton</b> England 1643-1727</p>	<p>The greatest and most influential scientist who ever lived. He demonstrated that the motions of celestial bodies and objects on Earth are governed by the same set of natural laws: the universal law of gravitation and his three laws of motion (inertia, force, reciprocal action). This work incorporated Galileo’s earlier work and Johannes Kepler’s laws of planetary motion, removing the last doubts about heliocentrism, and laid the groundwork for classical mechanics, which dominated the scientific view of the physical universe for the next three centuries and is the basis for modern engineering. Newton also enunciated the principles of conservation of momentum and angular momentum. In optics, he built the first practical reflecting telescope and developed a theory of color based on observing that a prism decomposes white light into a visible spectrum. He also formulated an empirical law of cooling and studied the speed of sound. (See Part 6 for Newton’s contributions to Mathematics.)</p>
4	<p style="text-align: center;"><b>Charles Darwin</b> England 1809-1882</p>	<p>Based on five years of research as an unpaid naturalist on a voyage to the Pacific Coast of South America, Darwin demonstrated that all species of life have evolved over time from common ancestors through the process he called natural selection. He concluded that variation within species occurs randomly and survival/extinction is determined by the organism’s ability to adapt to its environment. Darwin developed his theory of evolution against a backdrop of disbelief and skepticism; he spent over 20 years carefully assembling the evidence and marshaling the arguments in favor of his hypotheses. His 1859 book <i>On the Origin of the Species</i> established evolution by common descent as the dominant scientific explanation of diversification in nature. No work has so fundamentally changed the way we think about our very being and the world around us. (See Part 5 for a discussion of <i>On The Origin of the Species</i>.)</p>

5	<b>Louis Pasteur</b> France 1822-1895	Most important person in the history of Medicine. Biologist, microbiologist, and chemist who contributed greatly towards the advancement of medical sciences, experimentally confirming the germ theory of disease and developing preventive inoculations for rabies, anthrax and other infectious diseases. He also invented the process of pasteurization to make milk safer to drink, and led the way to the current understanding of a fundamental principle in the structure of organic compounds. Pasteur's incites revolutionized medicine, surgery, and public health. He probably saved more lives than any other person. (See Part 7 for Pasteur's contributions to Medicine.)
6	<b>James Clerk Maxwell</b> England 1831-1879	The greatest theoretical physicist between Newton and Einstein. Formulated four equations (Maxwell Equations) that express the basic laws of electricity and magnetism in a unified theory that have been employed extensively for the past century in both theoretical and applied science. Discovered that oscillating electromagnetic fields produce electromagnetic waves that propagate at different wavelengths and frequencies, including visible light, x-rays, gamma rays, ultraviolet rays, and today's radio and TV signals. Maxwell also made important contributions to astronomical theory and thermodynamics.
7	<b>Nikola Tesla</b> Serbia 1856-1943	Inventor, electrical engineer, mechanical engineer, physicist, and futurist. Designed the alternating current (AC) electrical system that is widely used today, demonstrated its utility and safety in a dispute with Thomas Edison (proponent of direct current), and discovered the rotating magnetic field that is the basis of most AC machinery. He was one of the pioneers of radio, took some of the first X-ray photographs, and constructed the first radio-controlled robots. Tesla also invented the "Tesla coil," an early wireless power transmission device, still used in radio technology.
8	<b>Marie Curie</b> Poland 1867-1934	Physicist and chemist - pioneer in the field of radioactivity. Experimentally explained the phenomenon of radiation and used it to discover two new elements, polonium and radium. Also directed the world's first studies of radioactive isotope treatment of cancer. First female professor at the University of Paris. Only person to win Nobel Prizes in two different sciences, Chemistry and Physics. (See Part 12 for Curie's place in the most influential women list.)
9	<b>Albert Einstein</b> Germany/U.S. 1879-1955	The greatest scientist of the 20 <sup>th</sup> century and one of the supreme intellects of all time. Physicist best known for his Special Theory of Relativity, relating space and time, partially expressed by the world's most famous formula, for mass-energy equivalence, $E=mc^2$ , and his General Theory of Relativity that provided a new theory of gravitation, involving a curved space-time continuum. Einstein also explained the Photoelectric Effect, how many metals emit electrons when light shines on them, having a major impact on the development of quantum theory. He also made many other important contributions, publishing over 300 scientific papers and earning a Nobel Prize for his services to Theoretical Physics.
10	<b>Alan Turing</b> England 1912-1954	Considered to be the father of theoretical computer science and artificial intelligence. Mathematician and logician who also made major contributions to cryptanalysis, philosophy, mathematical biology, and artificial life. During World War II, Turing was instrumental in breaking German codes. Afterwards, he wrote the first complete specification of an electronic-stored-program all-purpose digital computer. He was a founder of artificial intelligence and cognitive science and developed the "Turing test" as a criterion for whether a computer is thinking. <i>In 1952 Turing was prosecuted for (then illegal) homosexuality and accepted chemical castration treatment as an alternative to prison.</i>



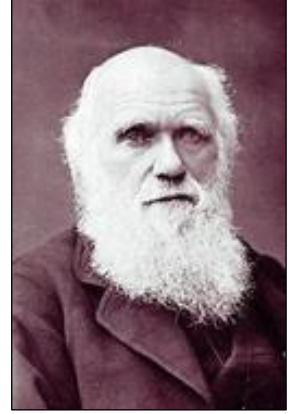
Aristotle



Galileo



Newton



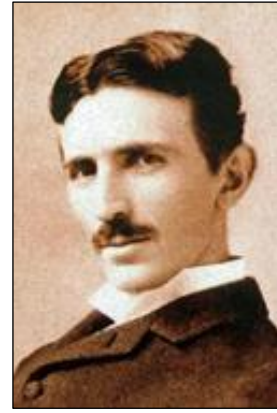
Darwin



Pasteur



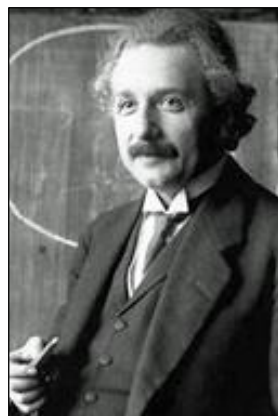
Maxwell



Tesla



Curie



Einstein



Turing

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**Part 12 - Women**

There is only one woman (Marie Curie) included in my entire set of "Top 10" lists so far, so I added this category for completeness.

I checked my go-to source, the book, *The 100 - A Ranking of the Most Influential Persons in History*, by Michael Hart, and picked up three people: Queen Isabella I, Queen Elizabeth I, and the aforementioned Marie Curie. Then, back to research on "Top 10" lists where I found total disagreement. Using my criterion of "enduring influence" I had to eliminate such outstanding woman as Eleanor Roosevelt, Mother Teresa, Amelia Earhart, and Joan of Arc - all of whom were ranked high on multiple lists. So with more of my personal bias than usual, I struggled to come up my version of the Top 10 most influential women of all time, which I present below in historical order by birth year.

As usual, after the list, I include an image of each woman.

*Top 10 most influential women of all time in historical order by birth year.*

No.	Influential Woman	Comments
1	Hatshepsut Egypt 1508-1458 BC	One of the most powerful and successful women in the ancient world as fifth pharaoh of the Eighteenth Dynasty of Ancient Egypt. She ruled longer than any woman in Egyptian history, commissioned many building projects, reestablished trade networks that had been disrupted by Hyksos invaders, and led successful military campaigns in Nubia, the Levant, and Syria.
2	Queen Isabella I Spain 1451-1504	A capable and controversial Spanish ruler whose decisions profoundly influenced the New World for centuries, and indirectly affect millions of people today. She initiated the Spanish Inquisition, targeting Jews and Muslims, to compel religious (Catholic) conformity, and conquered Muslim kingdoms in Spain, forcing Muslims into exile - these efforts stifling the pace of Spain's intellectual development compared to Europe. She is best remembered for sponsoring Christopher Columbus's voyages to the Western Hemisphere, ensuring that most of Central and South America became Spanish colonies and making Spain a World Power.
3	Queen Elizabeth I England 1533-1603	Widely considered to be England's greatest monarch, in a 45-year reign termed the "Elizabethan Era," marked by economic prosperity. She is best remembered for bringing the Renaissance to England, transforming the English court into a center for poets, writers, musicians, and scholars; establishing Protestantism in England; and defeating the Spanish Armada - that started England on the path towards gradually replacing Spain as a World Power.
4	Catherine the Great Russia 1729-1796	Catherine ruled over Russia (world's largest country geographically) as Empress for 34 years - continued the process of Westernizing Russia, by bringing Enlightenment ideas to her country and patronizing the arts; and expanding the empire with two successful major wars against the Ottoman Empire to become the dominant power in southeastern Europe. She desired that Europe should perceive her as an enlightened monarch, while crushing periodic revolts at home.
5	Queen Victoria United Kingdom 1819-1901	Ruled the vast British Empire, the largest in history, spanning six continents, for 63 years. Inspired a world-wide trend known as the "Victorian Era" that influenced conservative religious and social attitudes, fashion, and politics. Contributed to massive political and social reforms in the British Empire, including abolishment of slavery, reducing the length of the working day, and extending the vote to most British men.
6	Susan B. Anthony United States 1820-1906	Social reformer and woman's rights activist who played a pivotal role in the women's suffrage movement. After nearly half a century of organizing, traveling, and making speeches that argued for women's right to vote, in 1920 Congress granted that right by ratifying the Nineteenth Amendment to the U.S. Constitution - colloquially called the Susan B. Anthony amendment. Anthony was also active in movements to abolish slavery, reform education, reduce workweek hours, temperance, and women's rights.
7	Florence Nightingale England 1820-1910	Founder of modern professional nursing, social reformer, and writer. Followed her heroic nursing work during the Crimean War by establishing the world's first secular nursing school in London. Her social reforms included improving healthcare for British society, advocating hunger relief in India, helping to abolish harsh prostitution laws, and expanding acceptable roles for women in the workforce. Her prodigious writings helped spread medical knowledge.

8	Marie Curie Poland 1867-1934	Physicist and chemist - pioneer in the field of radioactivity. Experimentally explained the phenomenon of radiation and used it to discover two new elements, polonium and radium. Also directed the world's first studies of radioactive isotope treatment of cancer. First female professor at the University of Paris. Only person to win Nobel Prizes in two different sciences, Chemistry and Physics. (See Part 11 for Curie's place on Science list.)
9	Margaret Sanger United States 1879-1966	Founder of modern birth control movement - originated the term birth control. Sanger opened the first birth control clinic in the U.S. and established organizations that evolved into the Planned Parenthood Federation of America. Her efforts contributed to several judicial cases that helped legalize contraception in the U.S. She hired Gregory Pincus to develop the first oral contraceptive, approved by the FDA in 1960. Sanger was also a nurse, sex educator, and writer.
10	Rosa Parks United States 1913-2005	African American civil rights activist whom the U.S. Congress called the "Mother of the Modern-Day Civil Rights Movement." In 1955 Parks famously refused to give up her bus seat to make room for a white passenger. This civil disobedience led to the year-long Montgomery Alabama Bus Boycott, the first direct-action campaign of the post war civil rights movement, and also launched Martin Luther King to prominence. Parks became an international icon of resistance to racial segregation.





Hatshepsut



Queen Isabella I



Queen Elizabeth I



Catherine the Great



Queen Victoria



Susan B. Anthony



Florence Nightingale



Marie Curie



Margaret Sanger



Rosa Parks