Dr. Philippe J.S. De Brouwer

History of innovation

Quantititive Methods

March 12, 2024

1 A Subjective Selection from History

Mesopotamia 2,000 BCE

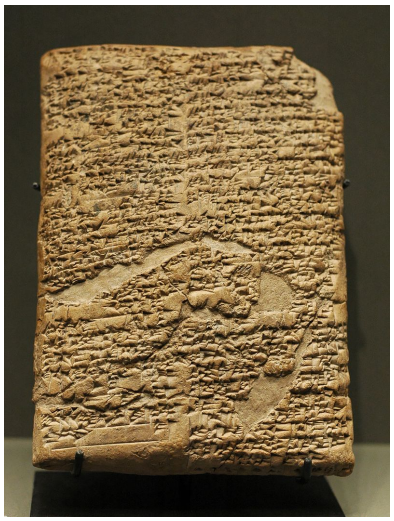

Figure 1: *The Hammurabi Code (Law 100) describes interest-bearing loans. Comissioned by Hammurabi, the king of Babylon (ca. 1792–1750 BCE) – source: wikimedia. org*

Banking's Early Beginnings

The origins of banking can be traced back to ancient Mesopotamia, around 2000 BCE, where the first known form of lending took place. Temples, often considered the earliest banks, served as repositories for valuable items and grain, and priests would lend these resources to local farmers and merchants. The temples were also responsible for keeping records of these transactions, giving birth to the concept of bookkeeping.

In ancient Greece, the concept of banking further evolved with the establishment of moneylenders and private depositories. Around 600 BCE, the Greek city-state of Athens introduced the first standardized coinage system, which facilitated trade and contributed to the growth of banking activities. The Romans, too, played a significant role in the development of banking. They established a network of banks throughout their empire and introduced financial innovations such as bills of exchange, which allowed for the transfer of funds between different locations.

Jesus of Nazareth flips over tables and whips money changers and merchants

Figure 2: *Christ driving the money changers from the temple by Jan Sanders van Hemessen. – source wikimedia. org*

The cleansing of the Temple narrative tells of Jesus expelling the merchants and the money changers from the Temple and is recounted in all four canonical gospels of the New Testament. The scene is a common motif in Christian art.

In this account, Jesus and his disciples travel to Jerusalem for Passover, where Jesus expels the merchants and consumers from the temple, accusing them of turning it into "a den of thieves" (in the Synoptic Gospels) and "a house of trade" (in the Gospel of John) through their commercial activities.

The narrative occurs near the end of the Synoptic Gospels (at Matthew 21:12–17, Mark 11:15–19, and Luke 19:45–48) and near the start of the Gospel of John (at John 2:13–16). Some scholars believe that these refer to two separate incidents, given that the Gospel of John also includes more than one Passover.

Liber Abaci: progress from mathematics

Figure 3: *"Liber Abaci" (1202) by Leonardo di Pisa (posthumously Fibonacci) introduces the Modus Indorum, the Hindu–Arabic numeral system (base-10 notations) in section 1. In section 2 the advantages for business problems: currency conversions, profit and interest calculations - foto American Mathematical Society.*

First Bankers: The Knights Templar

Figure 4: *The Knights Templar: from poverty and devotion to military elite, richness and international banking (1120 – 1307)*

Medieval and Renaissance Europe

The fall of the Roman Empire in the 5th century led to a decline in banking activities, but they re-emerged in medieval Europe during the 12th and 13th centuries. The Knights Templar, a religious military order, provided secure storage for valuables and facilitated the transfer of funds for pilgrims traveling to the Holy Land. Their financial network laid the groundwork for modern banking practices.

The Italian city-states of Florence, Venice, and Genoa emerged as major

banking centers in the 14th and 15th centuries. The Medici family of Florence, who established the Medici Bank, was instrumental in popularizing the double-entry bookkeeping system, which remains a cornerstone of accounting practices today.

The birth of modern banking is often attributed to the founding of the Bank of Amsterdam in 1609. It functioned as a central bank, stabilizing the value of the local currency and serving as a model for other central banks, such as the Bank of England (1694) and the Sveriges Riksbank (1668).

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Jacques de Molay (c. 1240–1250[1] – 11 or 18 March 1314[2]), also spelled "Molai",[3] was the 23rd and last grand master of the Knights Templar, leading the order sometime before 20 April 1292 until it was dissolved by order of Pope Clement V in 1312.[4][5] Though little is known of his actual life and deeds except for his last years as Grand Master, he is one of the best known Templars.

Jacques de Molay's goal as grand master was to reform the order, and adjust it to the situation in the Holy Land during the waning days of the Crusades. As European support for the Crusades had dwindled, other forces were at work which sought to disband the order and claim the wealth of the Templars as their own. King Philip IV of France, deeply in debt to the Templars, had Molay and many other French Templars arrested in 1307 and tortured into making false confessions. When Molay later retracted his confession, Philip had him burned upon a scaffold on an island in the River Seine in front of Notre-Dame de Paris in March, 1314.[6] Both the sudden end of the centuries-old order of Templars and the dramatic execution of its last leader turned Molay into a legendary figure.

—— The rise and fall of the Knights Templar Dan Jones tells the story of a crack unit of holy hard-men who spent 200 years defending crusaders' interests in the Middle East with unblinking ferocity

"The Knights Templare were able to flight across all terrains. They were the equivalent of the SAS, the Navy SEALS or the French Foreign Legion," says Dan Jones. (Alamy) Dan JonesPublished: June 27, 2019 at 12:35 PMGrab a copy of David Mitchell's latest booked UNRULY when you subscribe to BBC History Magazine

On a cripplingly hot day at the start of July 1187, Saladin, the sultan of Egypt and Syria, stood beside his son al-Afdal and peered across the battlefield towards a red tent on a hill. The sultan's face was pale with worry. The armies before him had been fighting for hours, tortured by near-unbearable heat, dust and smoke, which billowed up from the desert scrub Saladin's own men had set alight. Thousands of men and horses lay dead. The enemy – a vast force led by the Christian king Guy of Jerusalem – was badly battered and falling back, but until the king's red pavilion fell, victory would not be complete.

Al-Afdal, youthful and bullish, cheered every Christian charge that the Muslim army repulsed. Saladin scolded him. "Be quiet!" he said. "We have not beaten them until that tent falls." Moments later, the sultan's angst turned to tearful jubilation. The tent collapsed, King Guy was captured and the battle of Hattin was over. The Christians' holiest relic – a fragment of the True Cross –

was seized. The dead were left to rot where they lay, while the living were led off in disgrace: the lowliest Christian prisoners for slaves, and the more valuable for ransom.

Dan Jones on the Templars and 'Knightfall' The Templars on trial: a very muted inquisition But there was one category of captives who received quite different treatment from all the rest. A reward of 50 dinars was offered to anyone who could present the sultan with a member of the military orders: Hospitallers and Templars. These knights and sergeants were the elite special forces within the armies of the cross. They were the most dedicated and highly trained warriors in the Holy Land. And Saladin had special plans for them.

Band of brothers In 1187 the Order of the Poor Knights and of the Temple of Solomon was about 68 years old. The Order had first been assembled in 1119 at the Church of the Holy Sepulchre in Jerusalem by a French knight called Hugh of Payns. Hugh had travelled to the east around the time that Jerusalem fell to the Christian armies of the First Crusade, and he stayed there: seeking a way to combine his skill as a soldier with his yearning for religious purpose.

With a small number of like-minded men – later accounts said there were nine – Hugh established a brotherhood of religious warriors: skilled fighters who took oaths of chastity and poverty. They dedicated themselves to protecting Christian pilgrims on roads around the holy city, which were menaced by brigands preying on vulnerable travellers touring unfamiliar countryside.

More like this This fraternity of holy hard-men soon gained official recognition. The then-ruler of Jerusalem, Baldwin II, put them up in the al-Aqsa Mosque, which they identified with the biblical temple built by Solomon. This was how the Templars gained their name.

The Templars: a brief history Richard I on crusade Papal tax breaks For survival, the brothers relied on charitable handouts, and they quickly became expert at soliciting these – particularly in western Europe, where they built up a large network of profitable estates donated by supporters of the crusading movement. In the 1120s the order was granted a quasi-monastic rule to live by, designed by the Cistercian abbot Bernard of Clairvaux. In the 1130s the pope granted them sweeping tax breaks and an official uniform of white or black tunics emblazoned with a cross.

By the 1140s the Templars had begun to expand their mission of merely providing roadside rescue for pilgrims. In parallel with the Hospitallers, who branched out from providing medical services in Jerusalem to assuming military duties, the Templars manned castles throughout the Holy Land and assisted in raids on Muslim cities such as Damascus.

5 things you (probably) didn't know about the Crusades Crusading for God and gold At the other end of the Mediterranean they had been drafted into the Reconquista: the Christian campaigns for control of the Muslim states of al-Andalus, in southern Spain. The Templars were by now a self-sustaining paramilitary organisation, a crack squad of hardened and dedicated soldiers, able to fight across all terrains and oath-bound to serve God and their brothers. In modern terms, they were the equivalent of the SAS, the Navy SEALS or the French Foreign Legion.

"They were the fiercest fighters of all the Franks." This was the Muslim chronicler Ibn al-Athir's assessment of the Templars. (By 'Franks', he meant the western Christians in the Holy Land.) Ibn al-Athir was around 27 years old in 1187 and, like his contemporary Saladin, he knew just how competent – and dangerous – the Templars could be.

After all, history fairly buzzed with examples. In 1148 the Templars had saved the French armies of the Second Crusade from annihilation. Tens of thousands of ill-disciplined troops led by King Louis VII had tried to cross hostile territory in Asia Minor on foot and horseback, on their way to Syria, where they planned to liberate the city of Edessa. Bedraggled and badly led, they were prey to repeated attacks from Turkish horsemen, who inflicted a particularly terrible defeat on the crusaders at Mount Cadmus, near modern-day Denizli in Turkey. Hundreds were killed and Louis only escaped capture by hiding on a boulder.

Listen — Historian Nicholas Paul explores some little-known aspects of the crusades and their place within medieval history In desperation, the French king handed over military command of the entire expedition to a Templar named Gilbert. He was one of only 50 or so brothers among the vast procession, but Gilbert's leadership was inspired. He divided the pilgrims into battalions, each with a single brother in charge. All the able-bodied were given a crash-course in military conduct, and shown how to hold their shape and discipline under attack. As a result, the French survived the hard trek east, and on arrival in the Holy Land the Templars even raised an emergency loan to keep Louis's troubled campaign afloat.

In the years that followed, the Templars were trusted to defend castles around Gaza in the south, where Christian territory gave way to Egyptian lands. Further north they guarded the passes through the Amanus Mountains, which controlled the routes from Asia Minor into the Christian principality of Antioch. They advised secular leaders on military strategy, but were also pointedly independent, carrying out kidnapping missions and raids of their own as they pleased. Even the Assassins – the shadowy Shia terrorist sect who lived in the Syrian mountains and specialised in spectacular public assassinations of leaders of all faiths – would not touch the Templars, and paid them a fat fee to be left alone.

Templars are going to be executed under look of french king Philippe IV le Bel in 1310, illumination. (Photo by Apic/Getty Images) Templars are going to be executed under look of french king Philippe IV le Bel in 1310, illumination. (Photo by Apic/Getty Images) The Templar Rule, which originally resembled a Cistercian monk's order of daily routine, was heavily revised around 1165 to become more of a military handbook: setting the Templars' battlefield protocols, and emphasising the importance of discipline and obedience. The order's famous black-and-white flag was only to be lowered when the last man defending it was dead. "No brother should leave the field… while there is a piebald banner raised aloft; for if he leaves he will be expelled from the house forever," it read.

When they rode into battle, the Templars sang a psalm: "Not to us, O lord, not to us, but to your name give the glory, for your steadfast love and

faithfulness." The sight and sound of these men charging in their red-crossed white and black cloaks was rightly feared throughout the Holy Land.

Living through the Crusades: 3 poems and songs that reveal how medieval people felt about the holy war Suicidally proud When Saladin's men had finished rounding up Templars and Hospitallers after the battle of Hattin in 1187, around 200 prisoners had been delivered. These included the Templar grand master, Gerard of Ridefort, an impulsive and suicidally proud leader who repeatedly led his men into fights against impossible odds, yet somehow always emerged with his own life. He would do so again now, as Saladin ordered him to be imprisoned and exchanged for the Templars' castle at Gaza.

The rest were not so lucky. Saladin had witnessed the Templars' bravery at first hand several years previously, when the commander of their besieged fortress at Jacob's Ford met his death by deliberately riding headlong into a burning section of the castle. Now, wrote his secretary and biographer Imad al-Din: "He wished to purify land of these... unclean orders, whose practices are useless, who never give up their hostility and who have no use as slaves... He ordered that each would have his head cut off and be erased from the land of the living."

Instead of committing the job to a professional headsman, Saladin asked for volunteers from his religious entourage. Sufis, lawyers and scholars stepped forward for the chance to decapitate an infidel, with predictably gruesome results. Some deaths were swift. Others were painful and slow, as inexperienced clerics hacked away with blunt blades and no technique. Many, wrote Imad al-Din, "proved themselves ridiculous and had to be replaced".

Saladin sent a letter to Baghdad containing news of his extermination of the Christian military orders. "Not one of the Templars survived," he wrote, with satisfaction. And he was very nearly correct.

Listen — Bestselling medieval historian Dan Jones discusses his new book Crusaders, which tells the stories of these religious conflicts through the people who were involved in them The Templars fight back Nearly, but not quite. It took several years for the Templars to rebuild their numbers and their military reputation, but they managed it. When Richard the Lionheart arrived in the Holy Land to lead the Third Crusade in 1191 he revived the order's fortunes, installing new leaders from his own entourage and ensuring that the Templars rode either at the vanguard or rearguard of his army as it marched down the coast from Acre to Jaffa, reclaiming cities Saladin had conquered. He briefly handed the Templars a military dictatorship on Cyprus, although they found the island ungovernable and sold it on. And when Richard left the Holy Land for Europe in 1192, he was said to have travelled incognito, wearing Templar uniform.

The order remained at the military heart of the crusades for another century. In 1218–19 they starred in the Fifth Crusade to Damietta in Egypt, deploying armoured galleys in the water of the Nile Delta, as the Christian armies attempted an amphibious siege of the city. Two generations later they were back again, having helped fund and provision another crusader army with designs on Damietta, this time led by Louis IX of France. Throughout the 13th century,

the Templars continued to be involved in the Reconquista, helping King James I of Aragón to conquer Ibiza and Mallorca between 1229 and 1235, and the kingdom of Valencia by 1244.

Then, at the end of the century, when the Christians were being swept from the Holy Land by an Egyptian slave-soldier regime called the Mamluks, the Templars provided the very last line of defence. Their huge fortress in Acre was the last bastion to hold out against Mamluk forces storming through the breached walls in 1291, in what turned out to be the crusaders' final stand.

In 1307, however, the order was destroyed by a cruel and conniving king of France, Philip IV. Philip used a popular wish for the Templars and Hospitallers to be merged into one military super-order as a pretext for investigating their practices and then confiscating their wealth. Their collapse was swift and dramatic, as the king's lawyers and papal inquisitors accused the brothers of corruption, blasphemy, and sexual crimes. By 1312 the Templars had been disbanded. Their last master, James of Molay, was burned at the stake as a heretic in Paris in 1314.

Other orders survived the decline of crusading. The Hospitallers continued the fight against the church's enemies from a new base on the island of Rhodes, while the German Teutonic Order governed a semi-autonomous state in Prussia for centuries. The Mamluks, who were themselves somewhat like an Islamic military order, ruled Egypt and Syria until they were swept aside by the Ottomans in 1517.

Why did the Templars fall? Part of the answer lies in the weakness of their last master, James of Molay; part in the cruel caprice of Philip IV. But what is seldom noted is that the Templars, for all their wealth and privilege, never established for themselves a geographical base that they could defend against all assaults, even from their own side.

The brothers were famed for their bravery, dedication and piety but these were not enough to save them when Philip IV attacked. Had they established themselves as the rulers of Cyprus when they had the chance in 1191, their history might have been different. But they did not, and the Knights Templars' shocking demise now dominates our memory of an order that was, in its day, better known by Ibn al-Athir's assessment: "The fiercest fighters of all the Franks."

Dan Jones is a historian, TV presenter and author of The Templars. He was a historical advisor for the historical drama Knightfall.

The rise and fall of the Templars 1119: Hugh of Payns and eight other knights band together in Jerusalem, agreeing to protect Christian pilgrims outside the city. They are officially recognised in 1120. Their base is the al-Aqsa mosque, which they call the Temple of Solomon.

1129: The first Templar Rule is written at a church council in Troyes. Templars are committed to a life of celibacy, poverty and military exercise, and banned from knightly frivolities such as hunting with birds or wearing pointed shoes.

1134: Alfonso I 'the Battler', king of Aragon, dies and leaves one third of his kingdom to the Templars, drawing the order into the Reconquista.

1139: Pope Innocent II decrees that the Templars are only answerable to papal authority, and grants them the right to wear the sign of the cross on their chests.

1148: During the Second Crusade to liberate the city of Edessa, the Templars repel Turkish attacks and shepherd a French army all the way to the Holy Land.

1187: On 4 July, Saladin defeats a huge Christian army at the battle of Hattin. He then orders the summary beheading of all Templars captured by his forces.

1191: Richard the Lionheart conquers Cyprus and sells it to the Templars. But the order cannot hold it peacefully and quickly sell it on to Guy of Lusignan, the former king of Jerusalem.

c1200: German author Wolfram von Eschenbach casts Templar-like figures as the defenders of a mysterious item known as the Holy Grail.

1218: Templars join the Fifth Crusade in the Nile Delta, fighting on board armoured galleys.

1291: Mamluk armies attack the last crusader outpost in the city of Acre. The Templar master William of Beaujeu is killed leading the defence.

1307: On Friday 13 October, agents working for King Philip IV arrest every Templar in France. In 1312, the order is disbanded and its property confiscated.

The Medici

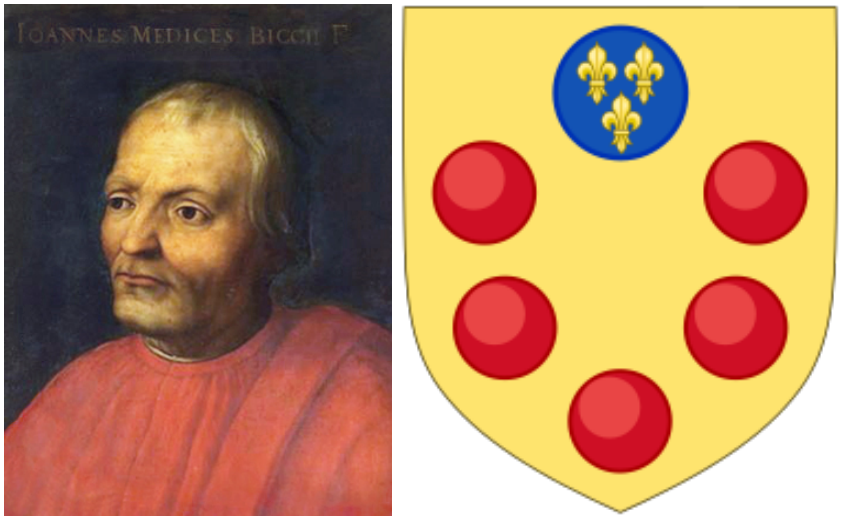


Figure 5: *The Medici Dynasty power and influence beyond comparison through local in Italy - bank created by Giovanni de Medici in the 15th century.*

Shares and stock exchange

Figure 6: *The Amsterdam Stock Exchange: 1602.*

Shakespeare's Merchant of Venice

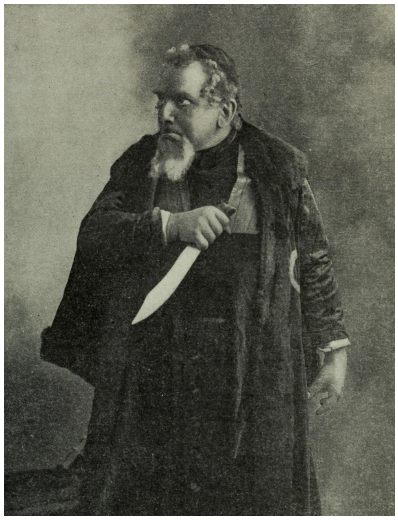


Figure 7: *Ernst von Posart as Shylock in Shakespeare's play "The Merchant of Venice" (ca. 1600). – image* wikimedia. org

Bassanio, a young Venetian of noble rank, wishes to woo the beautiful and wealthy heiress Portia of Belmont. Having squandered his estate, he needs

3,000 ducats to subsidise his expenditures as a suitor. Bassanio approaches his friend Antonio, a wealthy merchant of Venice, who has previously and repeatedly bailed him out. Antonio agrees, but since he is cash-poor – his ships and merchandise are busy at sea to Tripolis, the Indies, Mexico and England – he promises to cover a bond if Bassanio can find a lender, so Bassanio turns to the Jewish moneylender Shylock and names Antonio as the loan's guarantor.

Antonio has already antagonized Shylock through his outspoken antisemitism and because Antonio's habit of lending money without interest forces Shylock to charge lower rates. Shylock is at first reluctant to grant the loan, citing abuse he has suffered at Antonio's hand. He finally agrees to lend the sum to Bassanio without interest upon one condition: if Antonio were unable to repay it at the specified date, Shylock may take a pound of Antonio's flesh. Bassanio does not want Antonio to accept such a risky condition; Antonio is surprised by what he sees as the moneylender's generosity (no "usance" – interest – is asked for), and he signs the contract. With money in hand, Bassanio leaves for Belmont with his friend Gratiano, who has asked to accompany him. Gratiano is a likeable young man, but he is often flippant, overly talkative, and tactless. Bassanio warns his companion to exercise self-control, and the two leave for Belmont.

Meanwhile, in Belmont, Portia is awash with suitors. Her father left a will stipulating that each of her suitors must choose correctly from one of three caskets, made of gold, silver and lead respectively. Whoever picks the right casket wins Portia's hand. The first suitor, the Prince of Morocco, chooses the gold casket, interpreting its slogan, "Who chooseth me shall gain what many men desire", as referring to Portia. The second suitor, the conceited Prince of Aragon, chooses the silver casket, which proclaims, "Who chooseth me shall get as much as he deserves", as he believes he is full of merit. Both suitors leave empty-handed, having rejected the lead casket because of the baseness of its material and the uninviting nature of its slogan, "Who chooseth me must give and hazard all he hath". The last suitor is Bassanio, whom Portia wishes to succeed, having met him before. As Bassanio ponders his choice, members of Portia's household sing a song that says that "fancy" (not true love) is "engend'red in the eyes, / With gazing fed";[2] Bassanio chooses the lead casket and wins Portia's hand.

A depiction of Jessica, from The Graphic Gallery of Shakespeare's Heroines At Venice, Antonio's ships are reported lost at sea, so the merchant cannot repay the bond. Shylock has become more determined to exact revenge from Christians because his daughter Jessica eloped with the Christian Lorenzo and converted. She took a substantial amount of Shylock's wealth with her, as well as a turquoise ring which Shylock had been given by his late wife, Leah. Shylock has Antonio brought before court.

At Belmont, Bassanio receives a letter telling him that Antonio has been unable to repay the loan from Shylock. Portia and Bassanio marry, as do Gratiano and Portia's handmaid Nerissa. Bassanio and Gratiano leave for Venice, with money from Portia, to save Antonio's life by offering the money to Shylock. Unknown to Bassanio and Gratiano, Portia sent her servant, Balthazar, to seek the counsel of Portia's cousin, Bellario, a lawyer, at Padua.

The climax of the play is set in the court of the Duke of Venice. Shylock refuses Bassanio's offer of 6,000 ducats, twice the amount of the loan. He demands his pound of flesh from Antonio. The Duke, wishing to save Antonio but unable to nullify a contract, refers the case to a visitor. He identifies himself as Balthazar, a young male "doctor of the law", bearing a letter of recommendation to the Duke from the learned lawyer Bellario. The doctor is Portia in disguise, and the law clerk who accompanies her is Nerissa, also disguised as a man. As Balthazar, Portia in a famous speech repeatedly asks Shylock to show mercy, advising him that mercy "is twice blest: It blesseth him that gives and him that takes" (Act IV, Sc 1, Line 185). However, Shylock adamantly refuses any compensations and insists on the pound of flesh.

As the court grants Shylock his bond and Antonio prepares for Shylock's knife, Portia deftly appropriates Shylock's argument for "specific performance". She says that the contract allows Shylock to remove only the flesh, not the blood, of Antonio (see quibble). Thus, if Shylock were to shed any drop of Antonio's blood, his "lands and goods" would be forfeited under Venetian laws. She tells him that he must cut precisely one pound of flesh, no more, no less; she advises him that "if the scale do turn, But in the estimation of a hair, Thou diest and all thy goods are confiscate."

Defeated, Shylock consents to accept Bassanio's offer of money for the defaulted bond: first his offer to pay "the bond thrice", which Portia rebuffs, telling him to take his bond, and then merely the principal; but Portia also prevents him from doing this, on the ground that he has already refused it "in the open court". She cites a law under which Shylock, as a Jew and therefore an "alien", having attempted to take the life of a citizen, has forfeited his property, half to the government and half to Antonio, leaving his life at the mercy of the Duke. The Duke spares Shylock's life and says he may remit the forfeiture. Portia says the Duke may waive the state's share, but not Antonio's. Antonio says he is content that the state waive its claim to half Shylock's wealth if he can have his one-half share "in use" until Shylock's death, when the principal would be given to Lorenzo and Jessica. Antonio also asks that "for this favor" Shylock convert to Christianity and bequeath his entire estate to Lorenzo and Jessica. The Duke then threatens to recant his pardon of Shylock's life unless he accepts these conditions. Shylock, re-threatened with death, accepts with the words, "I am content." (IV, i).

Bassanio does not recognise his disguised wife, but offers to give a present to the supposed lawyer. First she declines, but after he insists, Portia requests his ring and Antonio's gloves. Antonio parts with his gloves without a second thought, but Bassanio gives the ring only after much persuasion from Antonio, as earlier in the play he promised his wife never to lose, sell or give it. Nerissa, as the lawyer's clerk, succeeds in likewise retrieving her ring from Gratiano, who does not see through her disguise.

At Belmont, Portia and Nerissa taunt and pretend to accuse their husbands before revealing they were really the lawyer and his clerk in disguise (V). After all the other characters make amends, Antonio learns from Portia that three of his ships were not stranded and have returned safely after all.

Mayer Amschel Rotschild

Figure 8: *Mayer Amschel Rothschild re-invents international banking – The Internationalisation of the bank ca. 1770.*

The Expansion of Banking

The 17th and 18th centuries marked the growth of banking in Europe, with the establishment of banking dynasties such as the Rothschilds and Barings. Joint-stock banks, which allowed investors to buy shares and participate in profits, also began to emerge during this period.

Banking expanded to the New World with the founding of the Bank of New York in 1784 and the First Bank of the United States in 1791. American banking further developed in the 19th century with the creation of state-chartered banks and the establishment of the Federal Reserve System in 1913, which aimed to maintain financial stability and serve as the central banking authority in the United States.

Innovations and the Evolution of Banking

The 19th and 20th centuries saw rapid technological advancements that significantly impacted the banking industry. The introduction of the telegraph in the 1840s enabled faster communication between banks, while the invention of the telephone in the 1870s further revolutionized communication and allowed for the creation of the first wire transfers.

The advent of new technologies, such as ATMs, electronic payments, and online banking, revolutionized the banking industry in the latter half of the 20th century. These innovations made banking more convenient and accessible to consumers, while also improving efficiency and reducing costs for banks.

The globalization of the banking industry in the late 20th century also brought about significant changes, as banks expanded their reach beyond na-

tional borders and began to offer new services such as international payments and currency exchange. Today, we have digital currencies, something bankers of ancient times probably would not have been able to comprehend.

The last piece of the puzzle

Figure 9: *The last piece of the puzzle: energy rich food with the potato. From the end the 16th century (via Spain around 1570, and via the British Isles between 1588 and 1593).*

The Motor: the Scientific Method

Aristotle (384–322 BCE, Greece) can be seen as the father of the scientific method, because of his rigorous logical method which was much more than natural logic. But it is fair to credit Ibn al-Haytham (aka Alhazen — 965–1039, Iraq) to prepare the scientific method for collaborative use. His emphasis on collecting empirical data and reproducibility of results laid the foundation for a scientific method that is much more successful. This method allows people to check each other and confirm or reject previous results.

However both the scientific method and the word "scientist" only came into common use in the 19^{th} century and the scientific method only became the standard method in the 20^{th} century. Therefore, it should not come as a surprise that this became also a period of inventions and development as never seen before.

Indeed, while previous inventions such as fire, agriculture, the wheel, bronze and steel might not have followed explicitly the scientific method they created a society ready to embrace the scientific method and fuel an era of accelerated innovation and expansion. The internal combustion engine, electricity and

magnetism fuelled the economic growth as never seen before. The electronic computer brought us to the 21th century and now a new era of growth is being prepared by big data, machine learning, nanotechnology and –maybe– quantum computing.

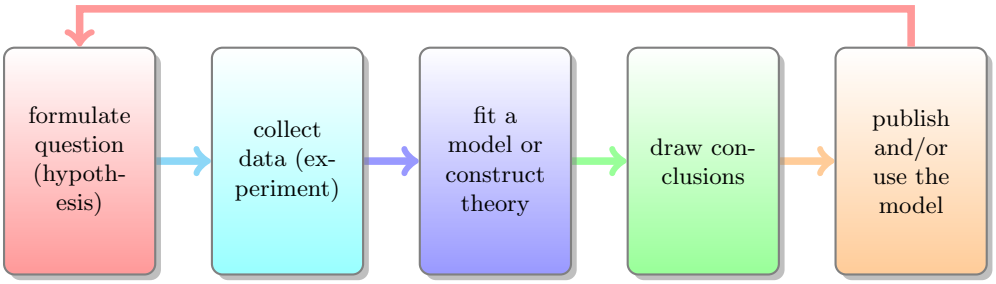


Figure 10: *The steps in the scientific method for the data scientist as commonly in use from the 19th century, long after the work of Ibn al-Haytham (aka Alhazen — 965–1039, Iraq).*

2 The Great Cycles of Capitalism

2.1 The Steam Engine

The steam engine provides power for factories and fuelled unprecedented economic growth

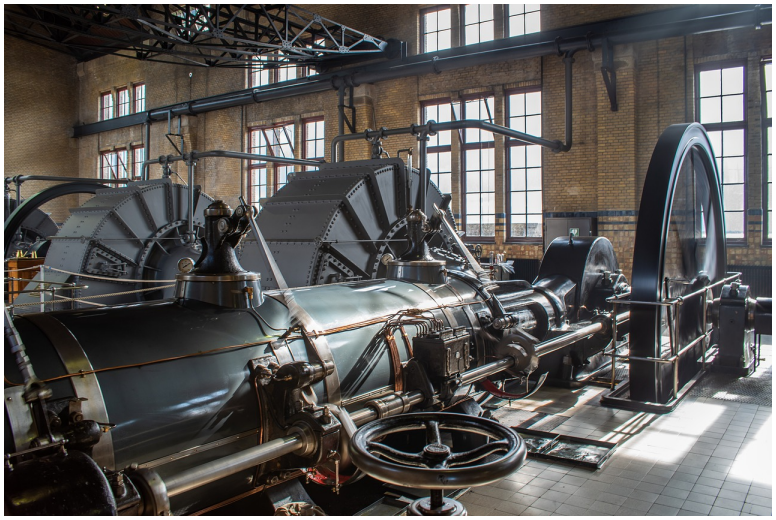


Figure 11: *Steam Engine in factory — image by Kobus van Leer from pixabay. com*

The Steam Engine
Key dates

- Taqi al-Din in 1551 and Giovanni Branca in 1629 describe a steam engine
- Thomas Savery (1698) invents steam pump and in 1712 Thomas Newcomen invents the first practical steam engine
- invention of the steam engine with separate condenser by James Watt in 1765
- Ivan Polzunov (1766) builds the first two-cylinder steam engine
- explosive economic growth since the early 1800s
- The "Panic of 1857", 1866, and "The Panic of 1873", that initiated the "Long Depression"
- Karl Marx writes "Das Kapital" in 1867

2.2 The Train

The Train

Figure 12: *The Train provided reliable mass transport — image Image by Erich Westendarp from pixabay.com*

The Train

Key Dates

- 1804: first train (it pulled 25 tonnes of iron material and 70 people over the distance of 10 miles)
- First commercial steam train (Stephenson's "The Rocket") managed to reach speed of 96 km/h.
- about 40% of the world's cargo go still by train (ecological and efficient)
- end: "The Panic of 1901" and ultimately WWI

2.3 The Internal Combustion Engine, Electricity and Magnetism

The Internal Combustion Engine

Fuelled exponential economic growth and provided individual transport

Figure 13: *The internal combustion engine gave rise to reliable individual transport — image by S. Hermann & F. Richter from pixabay.com*

Electricity and Magnetism

Fuelled exponential economic growth and provided a plethora of applications and appliances

Figure 14: *Electricity and Magnetism provided lightbulbs, radio, and all kinds of powered appliances — image by PublicDomainPictures from pixabay.com*

The Internal Combustion Engine, Electricity and Magnetism

Key Dates

- 1805 Humphry Davy invets the "carbon ark" (electric light)
- 1832: first DC electro-motor (William Sturgeon); 1837
- 1885: first practical gasoline automobile by Karl Benz
- Ford T (since 1908)
- Automation both at home and in the factory due to electricity and magnetism
- end: "Wall Street Crash of 1929", that initiated the "Great Depression" and ultimately WWII.

Automobiles and the Petro-Chemical Industry

Fuelled exponential economic growth

Figure 15: *The petro-chemical industry — image by Frauke Feind from* `pixabay.com`

Automobiles and the Petro-Chemical Industry

Key Dates

- Technological improvements on cars and their production
- First oil wells in USA (1846), Poland (1853), Romania (1857)

- First modern oil well (1854) and first oil refinery (1856) by Ignacy Łukasiewicz
- 1600 BCE: Mesoamericans used natural rubber for balls, bands, and figurines
- 1856: first man-made plastic by Alexander Parkes
- 1872: invention of polyvinyl chloride (PVC)
- 1923: Durite Plastics Inc. produced phenol-furfural resins
- 1930s: production of polystyrene (PS) and PVC by BASF
- 1933: polyethylene discovered by Imperial Chemical Industries (ICI) – Reginald Gibson and Eric Fawcett.
- 1941: polyethylene terephthalate (PET) discovered by Calico Printers' Association (a replacement for glass in many applications)
- 1954: polypropylene by Giulio Natta
- 1957: production of polypropylene
- 1954: expanded polystyrene (building insulation, packaging, and cups) invented by Dow Chemical.
- end: 1973–74 stock market crashes

2.4 The Electronic Computer and the Internet

The Electronic Computer

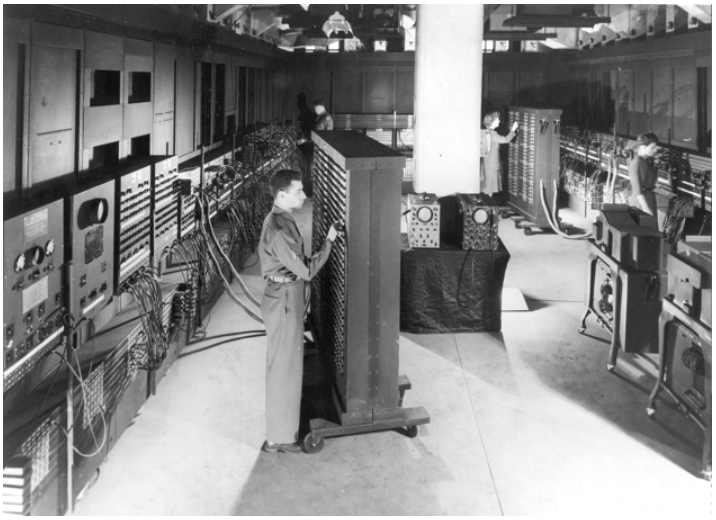


Figure 16: *The ENIAC (Electronic Numerical Integrator and Computer) — image by Unidentified U.S. Army photographer - Public Domain*

ENIAC (Electronic Numerical Integrator and Computer)[1][2] was the first electronic general-purpose computer.[3] It was Turing-complete, digital and able to solve "a large class of numerical problems" through reprogramming.[4][5]

Although ENIAC was designed and primarily used to calculate artillery firing tables for the United States Army's Ballistic Research Laboratory (which later became a part of the Army Research Laboratory),[6][7] its first program was a study of the feasibility of the thermonuclear weapon.[8][9]

ENIAC was completed in 1945 and first put to work for practical purposes on December 10, 1945.[10]

ENIAC was formally dedicated at the University of Pennsylvania on February 15, 1946 and was heralded as a "Giant Brain" by the press.[11] It had a speed on the order of one thousand times faster than that of electro-mechanical machines; this computational power, coupled with general-purpose programmability, excited scientists and industrialists alike. The combination of speed and programmability allowed for thousands more calculations for problems, as ENIAC calculated a trajectory in 30 seconds that took a human 20 hours (allowing one ENIAC hour to displace 2,400 human hours).[12] The completed machine was announced to the public the evening of February 14, 1946 and formally dedicated the next day at the University of Pennsylvania, having cost almost $500,000 (approximately $6,300,000 today). It was formally accepted by the U.S. Army Ordnance Corps in July 1946. ENIAC was shut down on November 9, 1946 for a refurbishment and a memory upgrade, and was transferred to Aberdeen Proving Ground, Maryland in 1947. There, on July 29, 1947, it was turned on and was in continuous operation until 11:45 p.m. on October 2, 1955.

Moore's Law

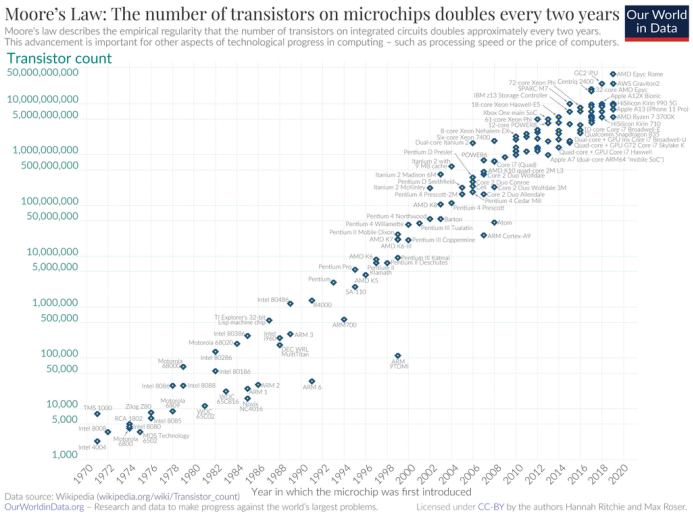


Figure 17: *Moore's Law — image Wikimedia Commons wikipedia. org*

Moore's law is the observation that the number of transistors in a dense integrated circuit doubles about every two years. The observation is named after Gordon Moore, the co-founder of Fairchild Semiconductor and CEO of Intel, whose 1965 paper described a doubling every year in the number of components per integrated circuit,[2] and projected this rate of growth would continue for at least another decade.[3] In 1975,[4] looking forward to the next decade,[5] he revised the forecast to doubling every two years, a compound annual growth rate (CAGR) of 41.4

The doubling period is often misquoted as 18 months because of a prediction by Moore's colleague, Intel executive David House. In 1975, House noted that Moore's revised law of doubling transistor count every 2 years in turn implied that computer chip performance would roughly double every 18 months (with no increase in power consumption).[9] Moore's law is closely related to MOSFET scaling, also known as Dennard scaling,[10] as the rapid scaling and miniaturization of silicon MOSFETs (metal-oxide-semiconductor field-effect transistors, or MOS transistors)[11][12] is the key driving force behind Moore's law.[10][13]

Moore's prediction proved accurate for several decades and has been used in the semiconductor industry to guide long-term planning and to set targets for research and development (R&D).[14] Advancements in digital electronics are strongly linked to Moore's law: quality-adjusted microprocessor prices,[15] memory capacity (RAM and flash), sensors, and even the number and size of pixels in digital cameras.[16] Digital electronics has contributed to world economic growth in the late twentieth and early twenty-first centuries.[17] Moore's law describes a driving force of technological and social change, productivity,

and economic growth.[18][19][20][21]

Moore's law is an observation and projection of a historical trend. It is an empirical relationship and not a physical or natural law. Although the rate held steady from 1975 until around 2012, the rate was faster during the first decade. In general, it is not logically sound to extrapolate from the historical growth rate into the indefinite future. For example, the 2010 update to the International Technology Roadmap for Semiconductors predicted that growth would slow around 2013,[22] and in 2015, Gordon Moore foresaw that the rate of progress would reach saturation: "I see Moore's law dying here in the next decade or so."[23]

Intel stated in 2015 that their pace of advancement has slowed, starting at the 22 nm feature width around 2012, and continuing at 14 nm.[24] Brian Krzanich, the former CEO of Intel, announced, "Our cadence today is closer to two and a half years than two."[25] Intel also stated in 2017 that hyperscaling would be able to continue the trend of Moore's law and offset the increased cadence by aggressively scaling beyond the typical doubling of transistors.[26] Krzanich cited Moore's 1975 revision as a precedent for the current deceleration, which results from technical challenges and is "a natural part of the history of Moore's law".[27][28][29] In the late 2010s, only two semiconductor manufacturers have been able to produce semiconductor nodes that keep pace with Moore's law, TSMC and Samsung Electronics, with 10 nm, 7 nm and 5 nm nodes in production (and plans for 3 nm nodes), whereas the pace has slowed down for Intel and other semiconductor manufacturers.

Clock-speed peeked around 2002

The Computer: Key Dates

- Charles Babbage's Analytical Engine (1930s) and Ada Lovelace's code for it in 1843
- first computers: ABC in 1942, Collossus 1943
- 1946: ENIAC, first programmable general purpose computer
- 1952: IBM sells first mainframe
- 1953: Hard-disk
- 1959: metal–oxide–semiconductor field-effect transistor (MOSFET), invented by Mohamed Atalla and Dawon Kahng
- 1968: Network of Networks (UCLA) with Telnet, FTP, messaging and email — The ARPA-net in 1977 (now "the Internet")
- 1973: C (by Dennis Ritchie in the Bell Labs)
- 1980: DOS
- 1989: WWW is developed and used in CERN

- 1993: IBM Simon (first smart-phone)
- 2000: Nokia 3310
- end: Dot-Com Bubble of 2000 and the 2008 Global Meltdown

3 The Future

3.1 Kondratiev

Kondratiev (1935)

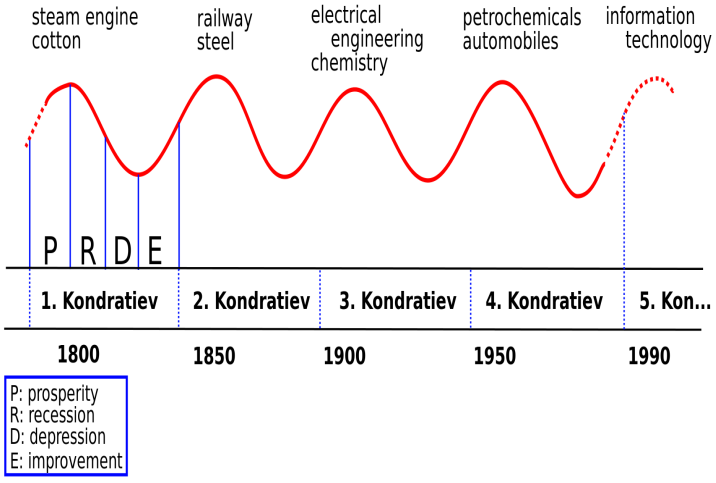


Figure 18: *Kondratiev waves — image By Rursus - Own work, CC BY-SA 3.0,* https://commons.wikimedia.org/w/index.php?curid=7833300.

3.2 The Next Wave

The Next Large Trend Candidates

A. artificial intelligence, machine learning, big data, and robotic process automation;

B. nano technology

C. biotechnology, and

D. quantum computing;

3.2.1 Artificial Intelligence and Machine Learning

AI and ML

Self Driving Cars

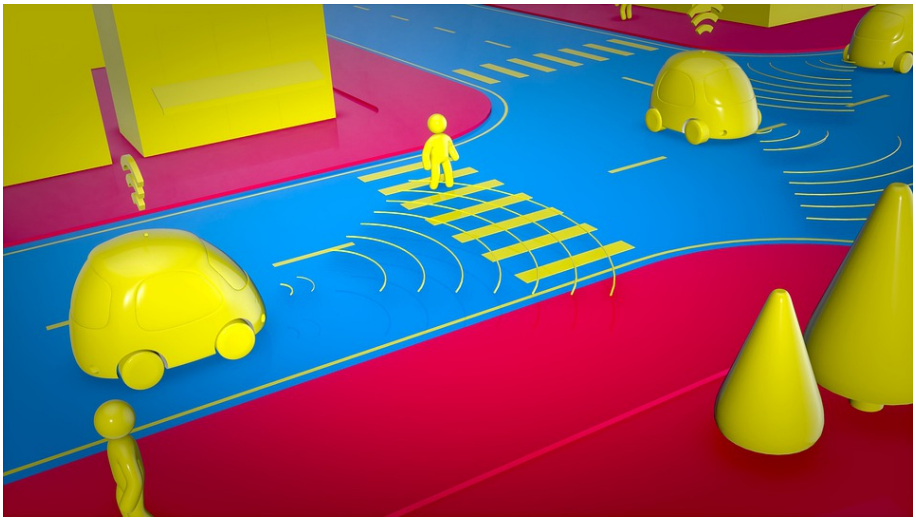


Figure 19: *Self driving cars will become commonplace — image by Julien Tromeur from pixabay.com.*

The Singularity

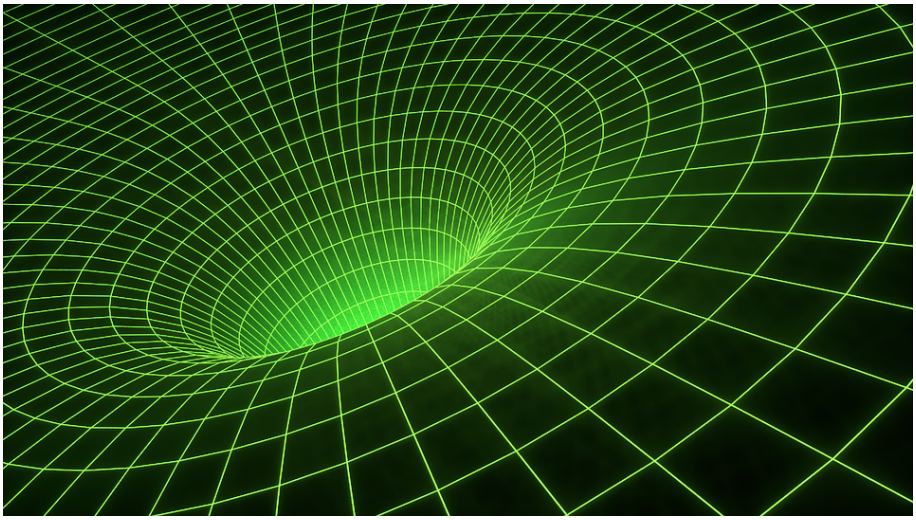


Figure 20: *The singularity occurs when a machine will be able to improve on itself faster and faster — image by Johnson Martin from* `pixabay.com`.

AI and ML – Face recognition is possible even when people are maksed

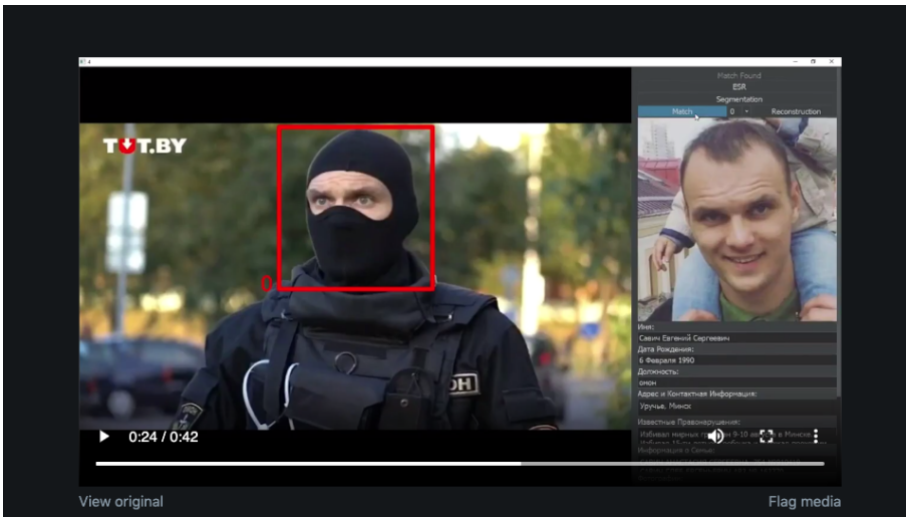


Figure 21: *Police brutality under scrutiny: masked OMON police unmasked by AI.*

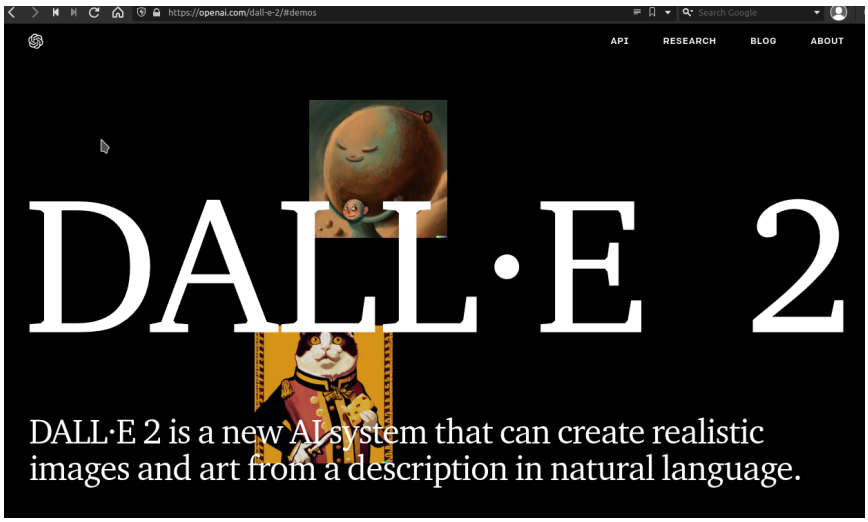


Figure 22: https://openai.com

AIML: Dall-e

AIML: Hypotheses

AIML: Design and Creativity

AIML: Transformational
The success of:

A. Netflix

B. Google: search engine, digital assistant, etc.

C. Uber

D. openAI

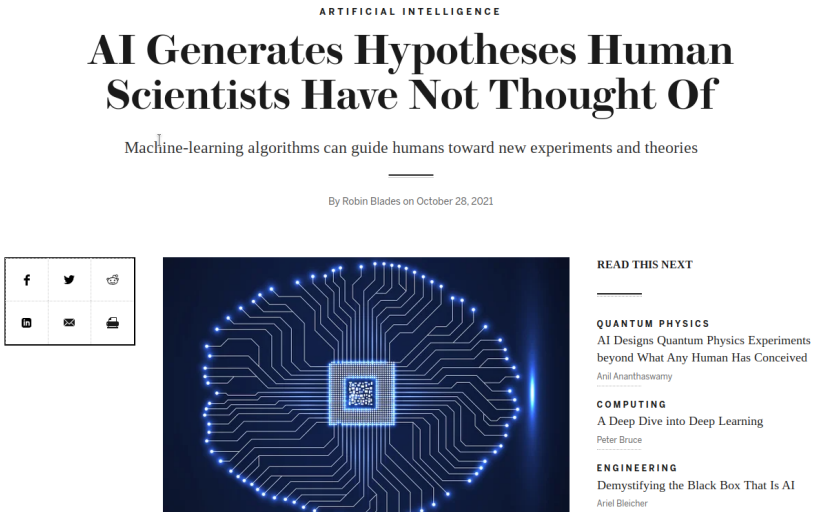
E. Amazon

F. Nvidia

G. etc.

3.2.2 Nano Technology

Nano Technology
Vanta Black or Black 3.0



ARTIFICIAL INTELLIGENCE

AI Generates Hypotheses Human Scientists Have Not Thought Of

Machine-learning algorithms can guide humans toward new experiments and theories

By Robin Blades on October 28, 2021

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QUANTUM PHYSICS
AI Designs Quantum Physics Experiments beyond What Any Human Has Conceived
Anil Ananthaswamy

COMPUTING
A Deep Dive into Deep Learning
Peter Bruce

ENGINEERING
Demystifying the Black Box That Is AI
Ariel Bleicher

Figure 23: *https://www.scientificamerican.com/article/ai-generates-hypotheses-human-scientists-have-not-thought-of/*

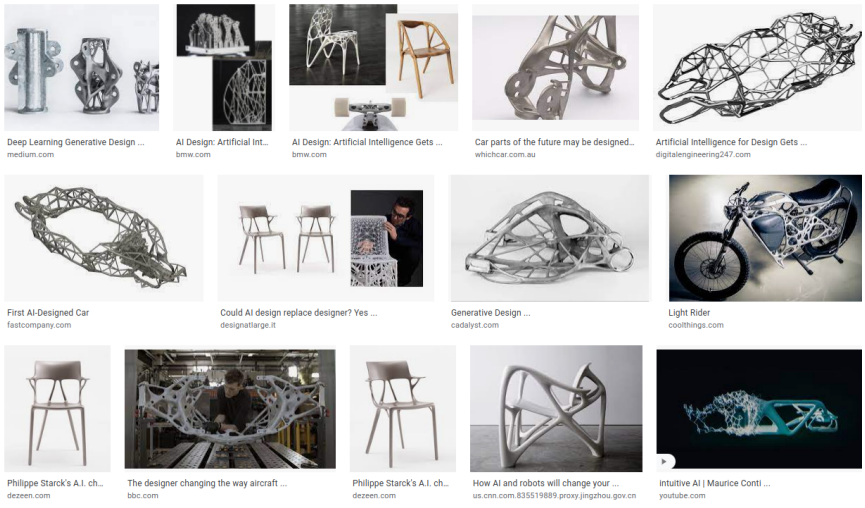

Figure 24: *search on www.google.com "AI designed"*

Figure 26: *Vanta Black and similar coatings use nano technology – source:* https://www.coating.co.uk/vantablack-coating.

Nano Technology
Graphene

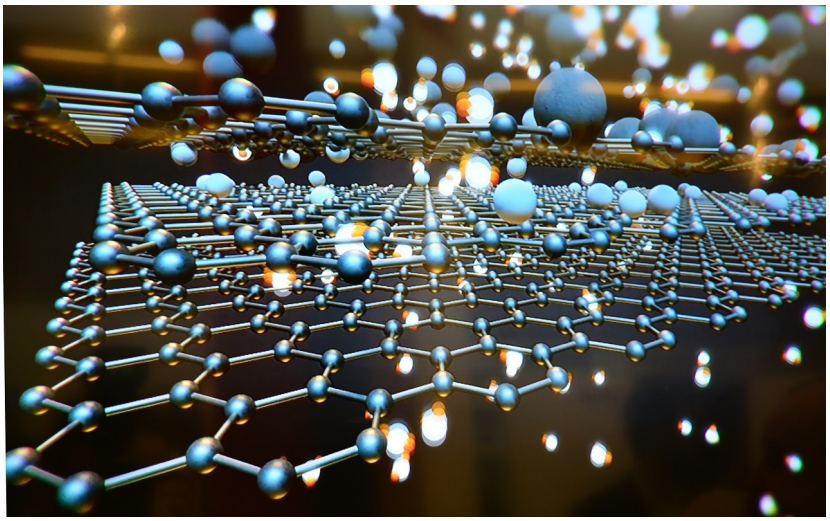

Figure 27: *Graphene — image: Image by seagul from* pixabay.com.

Nano Technology

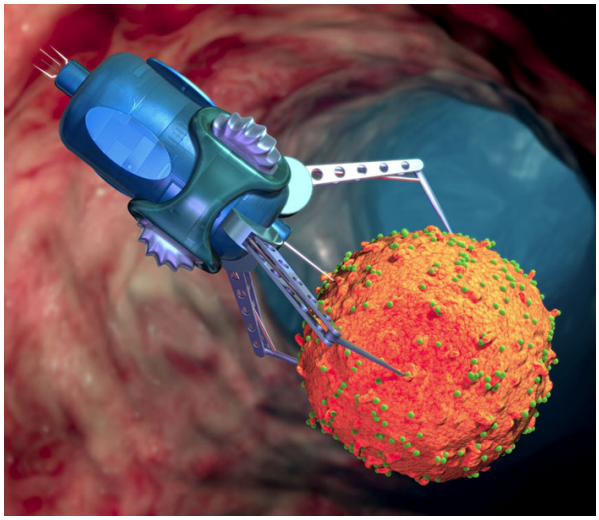

Figure 28: *Nano robots — source:* https://www.yaabot.com/23051/nano-robots-medicine-miniscule-wonders/.

3.2.3 Biotechnology

Biotechnology and genetic manipulation is as old as farming: more than 10,000 years

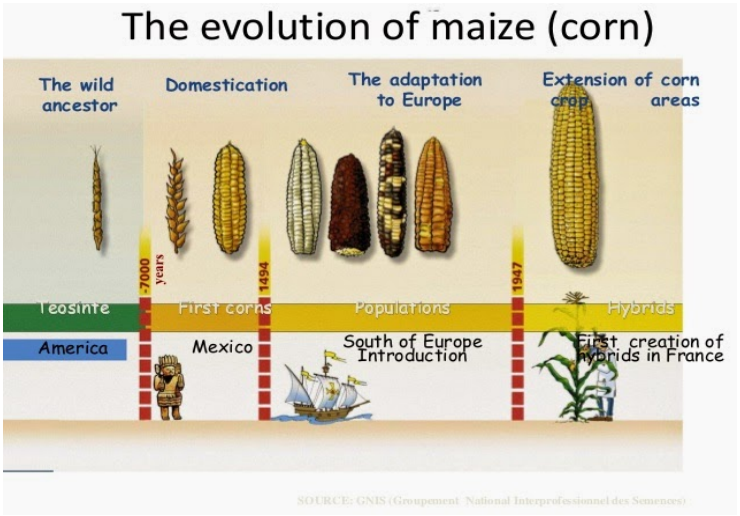

Figure 29: *the guided evolution of corn — source: unknown.*

Biotech

What

- Recombinant DNA
- Cloning
- Stem Cell Therapy
- Designer Drugs
- Genomics & genetic engineering

Why

- less pesticides, $C0_2$, etc.
- better and more crops
- better plant and animal health
- better human health

The Holy Grail

Figure 30: *The holy grail of Biotechnology — source: unknown.*

3.2.4 Quantum Computing

Quantum Computing

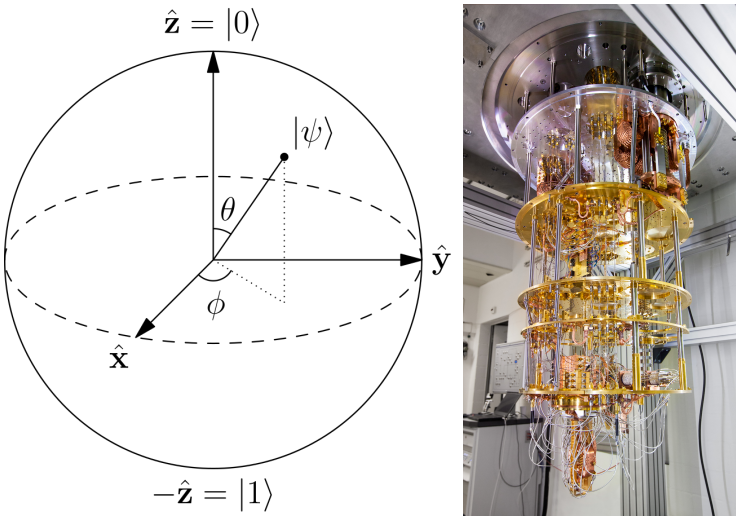

Figure 31: *Quantum Computers. – Source: Wikimedia*

Potential of Quantum Computers
Quantum Computers do not violate the Church-Turing Thesis, but ...

- Adiabatic Optimization (D-Wave)
  - optimizations
  - ... but there is also the Quantum Monte-Carlo (QMC) technique for classical computers
- Shor's Alogorithm (1994): factor numbers
  - break most of today's encryption
  - ... including today's blockchain technology
- Lov Grover's (1996): invert functions without prior knowledge of the function
  - searching in unstructured data
- Solve large linear systems
  - solve ODE and PDE systems
  - regressions
  - machine learning

4 Conclusions

Conclusions

A. The next wave of exponential growth is taking off, and

B. while mathematics always was an enabler, for the first time it **is** mathematics (AI) that propels this growth.

C. Therefore we should consider:

   (a) contributing to the development of AI,

   (b) the applications of AI, but also

   (c) invest even more in understanding and controlling AI, learning from AI, malevolent AI, ethics, societal organisation and purpose of humans, the future of humanity and a post-human era, etc.

D. Prepare for the next wave: of quantum computing with a focus on error correction, optimization methods, quantum robust encryption, QKD, etc.

Nomenclature

AI artificial intelligence

AIML artificial intelligence and machine learning

BASF Badische Anilin und Soda Fabrik

BCE before common era

$C0_2$ carbon dioxide

DOS disc operating system

ENIAC Electronic Numerical Integrator and Computer

FTP file transfer protocol

IBM International Business Machines Corporation

ML machine learning

MOSFET metal–oxide–semiconductor field-effect transistor

OMON Special Purpose Mobile Unit – Russian and Belarusian police force

PS polystyrene

PVC polyvinyl chloride

UCLA The University of California, Los Angeles

WWI World War I

WWW world wide web