

Super Bowl 50 was an American football game to determine the champion of the National Football League (NFL) for the 2015 season. The American Football Conference (AFC) champion Denver Broncos defeated the National Football Conference (NFC) champion Carolina Panthers 24–10 to earn their third Super Bowl title. The game was played on February 7, 2016, at Levi's Stadium in the San Francisco Bay Area at Santa Clara, California. As this was the 50th Super Bowl, the league emphasized the "golden anniversary" with various gold-themed initiatives, as well as temporarily suspending the tradition of naming each Super Bowl game with Roman numerals (under which the game would have been known as "Super Bowl L"), so that the logo could prominently feature the Arabic numerals 50.

The Panthers finished the regular season with a 15–1 record, and quarterback Cam Newton was named the NFL Most Valuable Player (MVP). They defeated the Arizona Cardinals 49–15 in the NFC Championship Game and advanced to their second Super Bowl appearance since the franchise was founded in 1995. The Broncos finished the regular season with a 12–4 record, and denied the New England Patriots a chance to defend their title from Super Bowl XLIX by defeating them 20–18 in the AFC Championship Game. They joined the Patriots, Dallas Cowboys, and Pittsburgh Steelers as one of four teams that have made eight appearances in the Super Bowl.

The Broncos took an early lead in Super Bowl 50 and never trailed. Newton was limited by Denver's defense, which sacked him seven times and forced him into three turnovers, including a fumble which they recovered for a touchdown. Denver linebacker Von Miller was named Super Bowl MVP, recording five solo tackles, 2½ sacks, and two forced fumbles.

CBS broadcast Super Bowl 50 in the U.S., and charged an average of \$5 million for a 30-second commercial during the game. The Super Bowl 50 halftime show was headlined by the British rock group Coldplay with special guest performers Beyoncé and Bruno Mars, who headlined the Super Bowl XLVII and Super Bowl XLVIII halftime shows, respectively. It was the third-most watched U.S. broadcast ever. In early 2012, NFL Commissioner Roger Goodell stated that the league planned to make the 50th Super Bowl "spectacular" and that it would be "an important game for us as a league".

The league eventually narrowed the bids to three sites: New Orleans' Mercedes-Benz Superdome, Miami's Sun Life Stadium, and the San Francisco Bay Area's Levi's Stadium.

The league announced on October 16, 2012, that the two finalists were Sun Life Stadium and Levi's Stadium. The South Florida/Miami area has previously hosted the event 10 times (tied for most with New Orleans), with the most recent one being Super Bowl XLIV in 2010. The San Francisco Bay Area last hosted in 1985 (Super Bowl XIX), held at Stanford Stadium in Stanford, California, won by the home team 49ers. The Miami bid depended on whether the stadium underwent renovations. However, on May 3, 2013, the Florida legislature refused to approve the funding plan to pay for the renovations, dealing a significant blow to Miami's chances.

On May 21, 2013, NFL owners at their spring meetings in Boston voted and awarded the game to Levi's Stadium. The \$1.2 billion stadium opened in 2014. It is the first Super Bowl held in the San Francisco Bay Area since Super Bowl XIX in 1985, and the first in California since Super Bowl XXXVII took place in San Diego in 2003.

For the third straight season, the number one seeds from both conferences met in the Super Bowl. The Carolina Panthers became one of only ten teams to have completed a regular season with only one loss, and one of only six teams to have acquired a 15–1 record, while the Denver Broncos became one of four teams to have made eight appearances in the Super Bowl. The Broncos made their second Super Bowl appearance in three years, having reached Super Bowl XLVIII, while the Panthers made their second Super Bowl appearance in franchise history, their other appearance being Super Bowl XXXVIII.

Coincidentally, both teams were coached by John Fox in their last Super Bowl appearance prior to Super Bowl 50.

Despite waiving longtime running back DeAngelo Williams and losing top wide receiver Kelvin Benjamin to a torn ACL in the preseason, the Carolina Panthers had their best regular season in franchise history, becoming the seventh team to win at least 15 regular season games since the league expanded to a 16-game schedule in 1978. Carolina started the season 14–0, not only setting franchise records for the best start and the longest single-season winning streak, but also posting the best start to a season by an NFC team in NFL history, breaking the 13–0 record previously shared with the 2009 New Orleans Saints and the 2011 Green Bay Packers. With their NFC-best 15–1 regular season record, the Panthers clinched home-field advantage throughout the NFC playoffs for the first time in franchise history. Ten players were selected to the Pro Bowl (the most in franchise history) along with eight All-Pro selections.

The Panthers offense, which led the NFL in scoring (500 points), was loaded with talent, boasting six Pro Bowl selections. Pro Bowl quarterback Cam Newton had one of his best seasons, throwing for 3,837 yards and rushing for 636, while recording a career-high and league-leading 45 total touchdowns (35 passing, 10 rushing), a career-low 10 interceptions, and a career-best quarterback rating of 99.4. Newton's leading receivers were tight end Greg Olsen, who caught a career-high 77 passes for 1,104 yards and seven touchdowns, and wide receiver Ted Ginn, Jr., who caught 44 passes for 739 yards and 10 touchdowns; Ginn also rushed for 60 yards and returned 27 punts for 277 yards. Other key receivers included veteran Jericho Cotchery (39 receptions for 485 yards), rookie Devin Funchess (31 receptions for 473 yards and five touchdowns), and second-year receiver Corey Brown (31 receptions for 447 yards). The Panthers backfield featured Pro Bowl running back Jonathan Stewart, who led the team with 989 rushing yards and six touchdowns in 13 games, along with Pro Bowl fullback Mike Tolbert, who rushed for 256 yards and caught 18 passes for another 154 yards. Carolina's offensive line also featured two Pro Bowl selections: center Ryan Kalil and guard Trai Turner.

The Panthers defense gave up just 308 points, ranking sixth in the league, while also leading the NFL in interceptions with 24 and boasting four Pro Bowl selections. Pro Bowl defensive tackle Kawann Short led the team in sacks with 11, while also forcing three fumbles and recovering two. Fellow lineman Mario Addison added 6½ sacks. The Panthers line also featured veteran defensive end Jared Allen, a 5-time pro bowler who was the NFL's active career sack leader with 136, along with defensive end Kony Ealy, who had 5 sacks in just 9 starts. Behind them, two of the Panthers three starting linebackers were also selected to play in the Pro Bowl: Thomas Davis and Luke Kuechly. Davis compiled 5½ sacks, four forced fumbles, and four interceptions, while Kuechly led the team in tackles (118) forced two fumbles, and intercepted four passes of his own. Carolina's secondary featured Pro Bowl safety Kurt Coleman, who led the team with a career high seven interceptions, while also racking up 88 tackles and Pro Bowl cornerback Josh Norman, who developed into a shutdown corner during the season and had four interceptions, two of which were returned for touchdowns.

Following their loss in the divisional round of the previous season's playoffs, the Denver Broncos underwent numerous coaching changes, including a mutual parting with head coach John Fox (who had won four divisional championships in his four years as Broncos head coach), and the hiring of Gary Kubiak as the new head coach. Under Kubiak, the Broncos planned to install a run-oriented offense with zone blocking to blend in with quarterback Peyton Manning's shotgun passing skills, but struggled with numerous changes and injuries to the offensive line, as well as Manning having his worst statistical season since his rookie year with the Indianapolis Colts in 1998, due to a plantar fasciitis injury in his heel that he had suffered since the summer, and the simple fact that Manning was getting old, as he turned 39 in the 2015 off-season. Although the team had a 7–0 start, Manning led the NFL in interceptions. In week 10, Manning suffered a partial tear of the plantar fasciitis in his left foot. He set the NFL's all-time record for career passing yards in this game, but was benched after throwing four interceptions in favor of backup quarterback Brock Osweiler, who took over as the starter for most of the remainder of the regular season. Osweiler was injured, however, leading to Manning's return during the Week 17 regular season finale, where the Broncos were losing 13–7 against the 4–11 San Diego Chargers, resulting in Manning re-claiming the starting quarterback position for the playoffs by leading the team to a key 27–20 win that enabled the team to clinch the number one overall AFC seed. Under defensive coordinator Wade Phillips, the Broncos' defense ranked number one in total yards allowed, passing yards allowed and sacks, and like the previous three seasons, the team has continued to set numerous individual, league and franchise records. With the defense carrying the team despite the issues with the offense, the Broncos finished the regular season with a 12–4 record and earned home-field advantage throughout the AFC playoffs. Manning finished the year with a career-low 67.9 passer rating, throwing for 2,249 yards and nine touchdowns, with 17 interceptions. In contrast, Osweiler threw for 1,967 yards, 10 touchdowns and six interceptions for a rating of 86.4. Veteran receiver Demaryius Thomas led the team with 105 receptions for 1,304 yards and six touchdowns, while Emmanuel Sanders caught 76 passes for 1,135 yards and six scores, while adding another 106 yards returning punts. Tight end Owen Daniels was also a big element of the passing game with 46 receptions for 517 yards. Running back C. J. Anderson was the team's leading rusher 863 yards and seven touchdowns, while also catching 25 passes for 183 yards. Running back Ronnie Hillman also made a big impact with 720 yards, five touchdowns, 24 receptions, and a 4.7 yards per carry average. Overall, the offense ranked 19th in scoring with 355 points and did not have any Pro Bowl selections.

The Broncos' defense ranked first in the NFL yards allowed (4,530) for the first time in franchise history, and fourth in points allowed (296). Defensive ends Derek Wolfe and Malik Jackson each had 5½ sacks. Pro Bowl linebacker Von Miller led the team with 11 sacks, forced four fumbles, and recovered three. Linebacker DeMarcus Ware was selected to play in the Pro Bowl for the ninth time in his career, ranking second on the team with 7½ sacks. Linebacker Brandon Marshall led the team in total tackles with 109, while Danny Trevathan ranked second with 102. Cornerbacks Aqib Talib (three interceptions) and Chris Harris, Jr. (two interceptions) were the other two Pro Bowl selections from the defense.

The Panthers beat the Seattle Seahawks in the divisional round, running up a 31–0 halftime lead and then holding off a furious second half comeback attempt to win 31–24, avenging their elimination from a year earlier. The Panthers then blew out the Arizona Cardinals in the NFC Championship Game, 49–15, racking up 487 yards and forcing seven turnovers.

The Broncos defeated the Pittsburgh Steelers in the divisional round, 23–16, by scoring 11 points in the final three minutes of the game. They then beat the defending Super Bowl XLIX champion New England Patriots in the AFC Championship Game, 20–18, by intercepting a pass on New England's 2-point conversion attempt with 17 seconds left on the clock. Despite Manning's problems with interceptions during the season, he didn't throw any in their two playoff games.

Carolina suffered a major setback when Thomas Davis, an 11-year veteran who had already overcome three ACL tears in his career, went down with a broken arm in the NFC Championship Game. Despite this, he insisted he would still find a way to play in the Super Bowl. His prediction turned out to be accurate.

Peyton Manning became the first quarterback ever to lead two different teams to multiple Super Bowls. He is also the oldest quarterback ever to play in a Super Bowl at age 39. The past record was held by John Elway, who led the Broncos to victory in Super Bowl XXXIII at age 38 and is currently Denver's Executive Vice President of Football Operations and General Manager.

This was the first Super Bowl to feature a quarterback on both teams who was the #1 pick in their draft classes. Manning was the #1 selection of the 1998 NFL draft, while Newton was picked first in 2011. The matchup also pits the top two picks of the 2011 draft against each other: Newton for Carolina and Von Miller for Denver. Manning and Newton also set the record for the largest age difference between opposing Super Bowl quarterbacks at 13 years and 48 days (Manning was 39, Newton was 26).

With Rivera having been a linebacker with the Chicago Bears in Super Bowl XX, and Kubiak replacing Elway at the end of the Broncos' defeats in Super Bowls XXI and XXIV, this will be the first Super Bowl in which both head coaches played in the game themselves.

Concerns were raised over whether Levi's Stadium's field was of a high enough quality to host a Super Bowl; during the inaugural season, the field had to be re-sodded multiple times due to various issues, and during a week 6 game earlier in the 2015 season, a portion of the turf collapsed under Baltimore Ravens kicker Justin Tucker, causing him to slip and miss a field goal, although the field has not had any major issues since. As is customary for Super Bowl games played at natural grass stadiums, the NFL re-sodded the field with a new playing surface; a hybrid Bermuda 419 turf. NFL and Atlanta Braves field director Ed Mangan stated that the field was in "great shape" for gameday. However, the turf showed problem throughout the game, with a number of players needing to change their cleats during the game and player slipping during plays all throughout the game.

As the designated home team in the annual rotation between AFC and NFC teams, the Broncos elected to wear their road white jerseys with matching white pants. Elway stated, "We've had Super Bowl success in our white uniforms." The Broncos last wore matching white jerseys and pants in the Super Bowl in Super Bowl XXXIII, Elway's last game as Denver QB, when they defeated the Atlanta Falcons 34–19. In their only other Super Bowl win in Super Bowl XXXII, Denver wore blue jerseys, which was their primary color at the time. They also lost Super Bowl XXI when they wore white jerseys, but they are 0–4 in Super Bowls when wearing orange jerseys, losing in Super Bowl XII, XXII, XXIV, and XLVIII. The only other AFC champion team to have worn white as the designated home team in the Super Bowl was the Pittsburgh Steelers; they defeated the Seattle Seahawks 21–10 in Super Bowl XL 10 seasons prior. The Broncos' decision to wear white meant the Panthers would wear their standard home uniform: black jerseys with silver pants.

The Panthers used the San Jose State practice facility and stayed at the San Jose Marriott. The Broncos practiced at Stanford University and stayed at the Santa Clara Marriott.

On June 4, 2014, the NFL announced that the practice of branding Super Bowl games with Roman

numerals, a practice established at Super Bowl V, would be temporarily suspended, and that the game would be named using Arabic numerals as Super Bowl 50 as opposed to Super Bowl L. The use of Roman numerals will be reinstated for Super Bowl LI. Jaime Weston, the league's vice president of brand and creative, explained that a primary reason for the change was the difficulty of designing an aesthetically pleasing logo with the letter "L" using the standardized logo template introduced at Super Bowl XLV. The logo also deviates from the template by featuring large numerals, colored in gold, behind the Vince Lombardi Trophy, instead of underneath and in silver as in the standard logo.

Various gold-themed promotions and initiatives were held throughout the 2015 NFL season to tie into the "Golden Super Bowl"; gold-tinted logos were implemented across the NFL's properties and painted on fields, the numbering of the 50-yard line on fields was colored gold, and beginning on week 7, all sideline jackets and hats featured gold-trimmed logos. Gold footballs were given to each high school that has had a player or coach appear in the Super Bowl, and "homecoming" events were also held by Super Bowl-winning teams at games.

The annual NFL Experience was held at the Moscone Center in San Francisco. In addition, "Super Bowl City" opened on January 30 at Justin Herman Plaza on The Embarcadero, featuring games and activities that will highlight the Bay Area's technology, culinary creations, and cultural diversity. More than 1 million people are expected to attend the festivities in San Francisco during Super Bowl Week. San Francisco mayor Ed Lee said of the highly visible homeless presence in this area "they are going to have to leave". San Francisco city supervisor Jane Kim unsuccessfully lobbied for the NFL to reimburse San Francisco for city services in the amount of \$5 million.

In addition, there are \$2 million worth of other ancillary events, including a week-long event at the Santa Clara Convention Center, a beer, wine and food festival at Bellomy Field at Santa Clara University, and a pep rally. A professional fundraiser will aid in finding business sponsors and individual donors, but still may need the city council to help fund the event. Additional funding will be provided by the city council, which has announced plans to set aside seed funding for the event.

The game's media day, which was typically held on the Tuesday afternoon prior to the game, was moved to the Monday evening and re-branded as Super Bowl Opening Night. The event was held on February 1, 2016 at SAP Center in San Jose. Alongside the traditional media availabilities, the event featured an opening ceremony with player introductions on a replica of the Golden Gate Bridge.

For the first time, the Super Bowl 50 Host Committee and the NFL have openly sought disabled veteran and lesbian, gay, bisexual and transgender-owned businesses in Business Connect, the Super Bowl program that provides local companies with contracting opportunities in and around the Super Bowl. The host committee has already raised over \$40 million through sponsors including Apple, Google, Yahoo!, Intel, Gap, Chevron, and Dignity Health.

The Super Bowl 50 Host Committee has vowed to be "the most giving Super Bowl ever", and will dedicate 25 percent of all money it raises for philanthropic causes in the Bay Area. The committee created the 50 fund as its philanthropic initiative and focuses on providing grants to aid with youth development, community investment and sustainable environments.

In addition to the Vince Lombardi Trophy that all Super Bowl champions receive, the winner of Super Bowl 50 will also receive a large, 18-karat gold-plated "50". Each digit will weigh 33 lb (15 kg) for a total of 66 lb (30 kg). Like the Lombardi Trophy, the "50" will be designed by Tiffany & Co.

In the United States, the game was televised by CBS, as part of a cycle between the three main broadcast television partners of the NFL. The network's lead broadcast team of Jim Nantz and Phil Simms called the contest, with Tracy Wolfson and Evan Washburn on the sidelines. CBS introduced new features during the telecast, including pylon cameras and microphones along with EyeVision 360—an array of 36 cameras along the upper deck that can be used to provide a 360-degree view of plays and "bullet time" effects. (An earlier version of EyeVision was last used in Super Bowl XXXV; for Super Bowl 50, the cameras were upgraded to 5K resolution.)

On December 28, 2015, ESPN Deportes announced that they had reached an agreement with CBS and the NFL to be the exclusive Spanish-language broadcaster of the game, marking the third dedicated Spanish-language broadcast of the Super Bowl. Unlike NBC and Fox, CBS does not have a Spanish-language outlet of its own that could broadcast the game (though per league policy, a separate Spanish play-by-play call was carried on CBS's second audio program channel for over-the-air viewers). The game was called by ESPN Deportes' Monday Night Football commentary crew of Alvaro Martin and Raul Allegre, and sideline reporter John Sutcliffe. ESPN Deportes broadcast pre-game and post-game

coverage, while Martin, Allegre, and Sutcliffe contributed English-language reports for ESPN's SportsCenter and Mike & Mike.

CBS provided digital streams of the game via CBSSports.com, and the CBS Sports apps on tablets, Windows 10, Xbox One and other digital media players (such as Chromecast and Roku). Due to Verizon Communications exclusivity, streaming on smartphones was only provided to Verizon Wireless customers via the NFL Mobile service. The ESPN Deportes Spanish broadcast was made available through WatchESPN.

As opposed to broadcasts of primetime series, CBS broadcast special episodes of its late night talk shows as its lead-out programs for Super Bowl 50, beginning with a special episode of *The Late Show* with Stephen Colbert following the game. Following a break for late local programming, CBS also aired a special episode of *The Late Late Show* with James Corden.

CBS set the base rate for a 30-second advertisement at \$5,000,000, a record high price for a Super Bowl ad. As of January 26, the advertisements had not yet sold out. CBS mandated that all advertisers purchase a package covering time on both the television and digital broadcasts of the game, meaning that for the first time, digital streams of the game would carry all national advertising in pattern with the television broadcast. This would be the final year in a multi-year contract with Anheuser-Busch InBev that allowed the beer manufacturer to air multiple advertisements during the game at a steep discount. It was also the final year that Doritos, a longtime sponsor of the game, held its "Crash the Super Bowl" contest that allowed viewers to create their own Doritos ads for a chance to have it aired during the game. Nintendo and The Pokémon Company also made their Super Bowl debut, promoting the 20th anniversary of the Pokémon video game and media franchise.

QuickBooks sponsored a "Small Business Big Game" contest, in which Death Wish Coffee had a 30-second commercial aired free of charge courtesy of QuickBooks. Death Wish Coffee beat out nine other contenders from across the United States for the free advertisement.

20th Century Fox, Lionsgate, Paramount Pictures, Universal Studios and Walt Disney Studios paid for movie trailers to be aired during the Super Bowl. Fox paid for *Deadpool*, *X-Men: Apocalypse*, *Independence Day: Resurgence* and *Eddie the Eagle*, Lionsgate paid for *Gods of Egypt*, Paramount paid for *Teenage Mutant Ninja Turtles: Out of the Shadows* and *10 Cloverfield Lane*, Universal paid for *The Secret Life of Pets* and the debut trailer for *Jason Bourne* and Disney paid for *Captain America: Civil War*, *The Jungle Book* and *Alice Through the Looking Glass*.<sup>[citation needed]</sup>

Westwood One will carry the game throughout North America, with Kevin Harlan as play-by-play announcer, Boomer Esiason and Dan Fouts as color analysts, and James Lofton and Mark Malone as sideline reporters. Jim Gray will anchor the pre-game and halftime coverage.

The flagship stations of each station in the markets of each team will carry their local play-by-play calls. In Denver, KOA (850 AM) and KRFX (103.5 FM) will carry the game, with Dave Logan on play-by-play and Ed McCaffrey on color commentary. In North Carolina, WBT (1110 AM) will carry the game, with Mick Mixon on play-by-play and Eugene Robinson and Jim Szoke on color commentary. WBT will also simulcast the game on its sister station WBT-FM (99.3 FM), which is based in Chester, South Carolina. As KOA and WBT are both clear-channel stations, the local broadcasts will be audible over much of the western United States after sunset (for Denver) and the eastern United States throughout the game (for Carolina). In accordance with contractual rules, the rest of the stations in the Broncos and Panthers radio networks will either carry the Westwood One feed or not carry the game at all.

In the United Kingdom, BBC Radio 5 Live and 5 Live Sports Extra will carry the contest. The BBC will carry its own British English broadcast, with Greg Brady, Darren Fletcher and Rocky Boiman on commentary.

In honor of the 50th Super Bowl, the pregame ceremony featured the on-field introduction of 39 of the 43 previous Super Bowl Most Valuable Players. Bart Starr (MVP of Super Bowls I and II) and Chuck Howley (MVP of Super Bowl V) appeared via video, while Peyton Manning (MVP of Super Bowl XLI and current Broncos quarterback) was shown in the locker room preparing for the game. No plans were announced regarding the recognition of Harvey Martin, co-MVP of Super Bowl XII, who died in 2001.

Six-time Grammy winner and Academy Award nominee Lady Gaga performed the national anthem, while Academy Award winner Marlee Matlin provided American Sign Language (ASL) translation.

In late November 2015, reports surfaced stating that "multiple acts" would perform during the halftime show. On December 3, the league confirmed that the show would be headlined by the British rock group Coldplay. On January 7, 2016, Pepsi confirmed to the Associated Press that Beyoncé, who headlined the

Super Bowl XLVII halftime show and collaborated with Coldplay on the single "Hymn for the Weekend", would be making an appearance. Bruno Mars, who headlined the Super Bowl XLVIII halftime show, and Mark Ronson also performed.

Denver took the opening kickoff and started out strong with Peyton Manning completing an 18-yard pass to tight end Owen Daniels and a 22-yard throw to receiver Andre Caldwell. A pair of carries by C. J. Anderson moved the ball up 20 yards to the Panthers 14-yard line, but Carolina's defense dug in over the next three plays. First, linebacker Shaq Thompson tackled Ronnie Hillman for a 3-yard loss. Then after an incompletion, Thomas Davis tackled Anderson for a 1-yard gain on third down, forcing Denver to settle for a 3–0 lead on a Brandon McManus 34-yard field goal. The score marked the first time in the entire postseason that Carolina was facing a deficit.

After each team punted, Panthers quarterback Cam Newton appeared to complete a 24-yard pass Jerricho Cotchery, but the call was ruled an incompletion and upheld after a replay challenge. CBS analyst and retired referee Mike Carey stated he disagreed with the call and felt the review clearly showed the pass was complete. A few plays later, on 3rd-and-10 from the 15-yard line, linebacker Von Miller knocked the ball out of Newton's hands while sacking him, and Malik Jackson recovered it in the end zone for a Broncos touchdown, giving the team a 10–0 lead. This was the first fumble return touchdown in a Super Bowl since Super Bowl XXVIII at the end of the 1993 season.

After a punt from both teams, Carolina got on track with a 9-play, 73-yard scoring drive. Newton completed 4 of 4 passes for 51 yards and rushed twice for 25 yards, while Jonathan Stewart finished the drive with a 1-yard touchdown run, cutting the score to 10–7 with 11:28 left in the second quarter. Later on, Broncos receiver Jordan Norwood received Brad Nortman's short 28-yard punt surrounded by Panthers players, but none of them attempted to make a tackle, apparently thinking Norwood had called a fair catch. Norwood had not done so, and with no resistance around him, he took off for a Super Bowl record 61-yard return before Mario Addison dragged him down on the Panthers 14-yard line. Despite Denver's excellent field position, they could not get the ball into the end zone, so McManus kicked a 33-yard field goal that increased their lead to 13–7.

On Carolina's next possession fullback Mike Tolbert lost a fumble while being tackled by safety Darian Stewart, which linebacker Danny Trevathan recovered on the Broncos 40-yard line. However, the Panthers soon took the ball back when defensive end Kony Ealy tipped a Manning pass to himself and then intercepted it, returning the ball 19 yards to the Panthers 39-yard line with 1:55 left on the clock. The Panthers could not gain any yards with their possession and had to punt. After a Denver punt, Carolina drove to the Broncos 45-yard line. But with 11 seconds left, Newton was sacked by DeMarcus Ware as time expired in the half.

The Panthers seemed primed to score on their opening drive of the second half when Newton completed a 45-yard pass to Ted Ginn Jr. on the Denver 35-yard line on their second offensive play. But the Broncos defense halted the drive on the 26-yard line, and it ended with no points when Graham Gano hit the uprights on a 44-yard field goal attempt. After the miss, Manning completed a pair of passes to Emmanuel Sanders for gains of 25 and 22 yards, setting up McManus' 33-yard field goal that gave the Broncos a 16–7 lead. Carolina got off to another strong start after the kickoff, with Newton completing a 42-yard pass to Corey Brown. But once again they came up empty, this time as a result of a Newton pass that bounced off the hands of Ginn and was intercepted by safety T. J. Ward. Ward fumbled the ball during the return, but Trevathan recovered it to enable Denver to keep possession.

There would be no more scoring in the third quarter, but early in the fourth, the Broncos drove to the Panthers 41-yard line. On the next play, Ealy knocked the ball out of Manning's hand as he was winding up for a pass, and then recovered it for Carolina on the 50-yard line. A 16-yard reception by Devin Funchess and a 12-yard run by Stewart then set up Gano's 39-yard field goal, cutting the Panthers deficit to one score at 16–10. The next three drives of the game would end in punts.

With 4:51 left in regulation, Carolina got the ball on their own 24-yard line with a chance to mount a game-winning drive, and soon faced 3rd-and-9. On the next play, Miller stripped the ball away from Newton, and after several players dove for it, it took a long bounce backwards and was recovered by Ward, who returned it five yards to the Panthers 4-yard line. Although several players dove into the pile to attempt to recover it, Newton did not and his lack of aggression later earned him heavy criticism.

Meanwhile, Denver's offense was kept out of the end zone for three plays, but a holding penalty on cornerback Josh Norman gave the Broncos a new set of downs. Then Anderson scored on a 2-yard touchdown run and Manning completed a pass to Bennie Fowler for a 2-point conversion, giving Denver a

24–10 lead with 3:08 left and essentially putting the game away. Carolina had two more drives, but failed to get a first down on each one.

Manning finished the game 13 of 23 for 141 yards with one interception and zero touchdowns. Sanders was his top receiver with six receptions for 83 yards. Anderson was the game's leading rusher with 90 yards and a touchdown, along with four receptions for 10 yards. Miller had six total tackles (five solo), 2½ sacks, and two forced fumbles. Ware had five total tackles and two sacks. Ward had seven total tackles, a fumble recovery, and an interception. McManus made all four of his field goals, making him perfect on all 11 attempts during the post-season. Newton completed 18 of 41 passes for 265 yards, with one interception. He was also the team's leading rusher with 45 yards on six carries. Brown caught four passes for 80 yards, while Ginn had four receptions for 74. Ealy was the top defensive performer for Carolina with four total tackles, three sacks, a forced fumble, a fumble recovery, and an interception. Defensive End Charles Johnson had four total tackles, a sack, and a forced fumble. Linebacker Luke Kuechly had 11 total tackles, while Thomas Davis had seven, despite playing just two weeks after breaking his right arm in the NFC title game.

Super Bowl 50 featured numerous records from individuals and teams. Denver won despite being massively outgained in total yards (315 to 194) and first downs (21 to 11). Their 194 yards and 11 first downs were both the lowest totals ever by a Super Bowl winning team. The previous record was 244 yards by the Baltimore Ravens in Super Bowl XXXV. Only seven other teams had ever gained less than 200 yards in a Super Bowl, and all of them had lost. The Broncos' seven sacks tied a Super Bowl record set by the Chicago Bears in Super Bowl XX. Kony Ealy tied a Super Bowl record with three sacks. Jordan Norwood's 61-yard punt return set a new record, surpassing the old record of 45 yards set by John Taylor in Super Bowl XXIII. Denver was just 1-of-14 on third down, while Carolina was barely better at 3-of-15. The two teams' combined third down conversion percentage of 13.8 was a Super Bowl low. Manning and Newton had quarterback passer ratings of 56.6 and 55.4, respectively, and their added total of 112 is a record lowest aggregate passer rating for a Super Bowl. Manning became the oldest quarterback ever to win a Super Bowl at age 39, and the first quarterback ever to win a Super Bowl with two different teams, while Gary Kubiak became the first head coach to win a Super Bowl with the same franchise he went to the Super Bowl with as a player.

One of the most famous people born in Warsaw was Maria Skłodowska-Curie, who achieved international recognition for her research on radioactivity and was the first female recipient of the Nobel Prize. Famous musicians include Władysław Szpilman and Frédéric Chopin. Though Chopin was born in the village of Żelazowa Wola, about 60 km (37 mi) from Warsaw, he moved to the city with his family when he was seven months old. Casimir Pulaski, a Polish general and hero of the American Revolutionary War, was born here in 1745.

The Saxon Garden, covering the area of 15.5 ha, was formally a royal garden. There are over 100 different species of trees and the avenues are a place to sit and relax. At the east end of the park, the Tomb of the Unknown Soldier is situated. In the 19th century the Krasiński Palace Garden was remodelled by Franciszek Szanior. Within the central area of the park one can still find old trees dating from that period: maidenhair tree, black walnut, Turkish hazel and Caucasian wingnut trees. With its benches, flower carpets, a pond with ducks on and a playground for kids, the Krasiński Palace Garden is a popular strolling destination for the Varsovians. The Monument of the Warsaw Ghetto Uprising is also situated here. The Łazienki Park covers the area of 76 ha. The unique character and history of the park is reflected in its landscape architecture (pavilions, sculptures, bridges, cascades, ponds) and vegetation (domestic and foreign species of trees and bushes). What makes this park different from other green spaces in Warsaw is the presence of peacocks and pheasants, which can be seen here walking around freely, and royal carps in the pond. The Wilanów Palace Park, dates back to the second half of the 17th century. It covers the area of 43 ha. Its central French-styled area corresponds to the ancient, baroque forms of the palace. The eastern section of the park, closest to the Palace, is the two-level garden with a terrace facing the pond. The park around the Królikarnia Palace is situated on the old escarpment of the Vistula. The park has lanes running on a few levels deep into the ravines on both sides of the palace. There are 13 natural reserves in Warsaw – among others, Bielany Forest, Kabaty Woods, Czerniaków Lake. About 15 kilometres (9 miles) from Warsaw, the Vistula river's environment changes strikingly and features a perfectly preserved ecosystem, with a habitat of animals that includes the otter, beaver and hundreds of bird species. There are also several lakes in Warsaw – mainly the oxbow lakes, like Czerniaków Lake, the lakes in the Łazienki or Wilanów Parks, Kamionek Lake. There are lot of small

lakes in the parks, but only a few are permanent – the majority are emptied before winter to clean them of plants and sediments.

Demographically, it was the most diverse city in Poland, with significant numbers of foreign-born inhabitants. In addition to the Polish majority, there was a significant Jewish minority in Warsaw. According to Russian census of 1897, out of the total population of 638,000, Jews constituted 219,000 (around 34% percent). Warsaw's prewar Jewish population of more than 350,000 constituted about 30 percent of the city's total population. In 1933, out of 1,178,914 inhabitants 833,500 were of Polish mother tongue. World War II changed the demographics of the city, and to this day there is much less ethnic diversity than in the previous 300 years of Warsaw's history. Most of the modern day population growth is based on internal migration and urbanisation.

The University of Warsaw was established in 1816, when the partitions of Poland separated Warsaw from the oldest and most influential Polish academic center, in Kraków. Warsaw University of Technology is the second academic school of technology in the country, and one of the largest in East-Central Europe, employing 2,000 professors. Other institutions for higher education include the Medical University of Warsaw, the largest medical school in Poland and one of the most prestigious, the National Defence University, highest military academic institution in Poland, the Fryderyk Chopin University of Music the oldest and largest music school in Poland, and one of the largest in Europe, the Warsaw School of Economics, the oldest and most renowned economic university in the country, and the Warsaw University of Life Sciences the largest agricultural university founded in 1818.

Another important library – the University Library, founded in 1816, is home to over two million items. The building was designed by architects Marek Budzyński and Zbigniew Badowski and opened on 15 December 1999. It is surrounded by green. The University Library garden, designed by Irena Bajerska, was opened on 12 June 2002. It is one of the largest and most beautiful roof gardens in Europe with an area of more than 10,000 m<sup>2</sup> (107,639.10 sq ft), and plants covering 5,111 m<sup>2</sup> (55,014.35 sq ft). As the university garden it is open to the public every day.

Like many cities in Central and Eastern Europe, infrastructure in Warsaw suffered considerably during its time as an Eastern Bloc economy – though it is worth mentioning that the initial Three-Year Plan to rebuild Poland (especially Warsaw) was a major success, but what followed was very much the opposite. However, over the past decade Warsaw has seen many improvements due to solid economic growth, an increase in foreign investment as well as funding from the European Union. In particular, the city's metro, roads, sidewalks, health care facilities and sanitation facilities have improved markedly.

Today, Warsaw has some of the best medical facilities in Poland and East-Central Europe. The city is home to the Children's Memorial Health Institute (CMHI), the highest-reference hospital in all of Poland, as well as an active research and education center. While the Maria Skłodowska-Curie Institute of Oncology it is one of the largest and most modern oncological institutions in Europe. The clinical section is located in a 10-floor building with 700 beds, 10 operating theatres, an intensive care unit, several diagnostic departments as well as an outpatient clinic. The infrastructure has developed a lot over the past years.

Thanks to numerous musical venues, including the Teatr Wielki, the Polish National Opera, the Chamber Opera, the National Philharmonic Hall and the National Theatre, as well as the Roma and Buffo music theatres and the Congress Hall in the Palace of Culture and Science, Warsaw hosts many events and festivals. Among the events worth particular attention are: the International Frédéric Chopin Piano Competition, the International Contemporary Music Festival Warsaw Autumn, the Jazz Jamboree, Warsaw Summer Jazz Days, the International Stanisław Moniuszko Vocal Competition, the Mozart Festival, and the Festival of Old Music.

Nearby, in Ogród Saski (the Saxon Garden), the Summer Theatre was in operation from 1870 to 1939, and in the inter-war period, the theatre complex also included Momus, Warsaw's first literary cabaret, and Leon Schiller's musical theatre Melodram. The Wojciech Bogusławski Theatre (1922–26), was the best example of "Polish monumental theatre". From the mid-1930s, the Great Theatre building housed the Upti Institute of Dramatic Arts – the first state-run academy of dramatic art, with an acting department and a stage directing department.

Several commemorative events take place every year. Gatherings of thousands of people on the banks of the Vistula on Midsummer's Night for a festival called Wianki (Polish for Wreaths) have become a tradition and a yearly event in the programme of cultural events in Warsaw. The festival traces its roots to a peaceful pagan ritual where maidens would float their wreaths of herbs on the water to predict when they



would be married, and to whom. By the 19th century this tradition had become a festive event, and it continues today. The city council organize concerts and other events. Each Midsummer's Eve, apart from the official floating of wreaths, jumping over fires, looking for the fern flower, there are musical performances, dignitaries' speeches, fairs and fireworks by the river bank.

As interesting examples of expositions the most notable are: the world's first Museum of Posters boasting one of the largest collections of art posters in the world, Museum of Hunting and Riding and the Railway Museum. From among Warsaw's 60 museums, the most prestigious ones are National Museum with a collection of works whose origin ranges in time from antiquity till the present epoch as well as one of the best collections of paintings in the country including some paintings from Adolf Hitler's private collection, and Museum of the Polish Army whose set portrays the history of arms.

A fine tribute to the fall of Warsaw and history of Poland can be found in the Warsaw Uprising Museum and in the Katyń Museum which preserves the memory of the crime. The Warsaw Uprising Museum also operates a rare preserved and operating historic stereoscopic theatre, the Warsaw Fotoplastikon. The Museum of Independence preserves patriotic and political objects connected with Poland's struggles for independence. Dating back to 1936 Warsaw Historical Museum contains 60 rooms which host a permanent exhibition of the history of Warsaw from its origins until today.

The 17th century Royal Ujazdów Castle currently houses Centre for Contemporary Art, with some permanent and temporary exhibitions, concerts, shows and creative workshops. The Centre currently realizes about 500 projects a year. Zachęta National Gallery of Art, the oldest exhibition site in Warsaw, with a tradition stretching back to the mid-19th century organises exhibitions of modern art by Polish and international artists and promotes art in many other ways. Since 2011 Warsaw Gallery Weekend is held on last weekend of September.

Their local rivals, Polonia Warsaw, have significantly fewer supporters, yet they managed to win Ekstraklasa Championship in 2000. They also won the country's championship in 1946, and won the cup twice as well. Polonia's home venue is located at Konwiktorska Street, a ten-minute walk north from the Old Town. Polonia was relegated from the country's top flight in 2013 because of their disastrous financial situation. They are now playing in the 4th league (5th tier in Poland) -the bottom professional league in the National – Polish Football Association (PZPN) structure.

The mermaid (syrenka) is Warsaw's symbol and can be found on statues throughout the city and on the city's coat of arms. This imagery has been in use since at least the mid-14th century. The oldest existing armed seal of Warsaw is from the year 1390, consisting of a round seal bordered with the Latin inscription *Sigillum Civitatis Varsoviensis* (Seal of the city of Warsaw). City records as far back as 1609 document the use of a crude form of a sea monster with a female upper body and holding a sword in its claws. In 1653 the poet Zygmunt Łaskowski asks the question:

The origin of the legendary figure is not fully known. The best-known legend, by Artur Oppman, is that long ago two of Triton's daughters set out on a journey through the depths of the oceans and seas. One of them decided to stay on the coast of Denmark and can be seen sitting at the entrance to the port of Copenhagen. The second mermaid reached the mouth of the Vistula River and plunged into its waters. She stopped to rest on a sandy beach by the village of Warszowa, where fishermen came to admire her beauty and listen to her beautiful voice. A greedy merchant also heard her songs; he followed the fishermen and captured the mermaid.

Tamara de Lempicka was a famous artist born in Warsaw. She was born Maria Górska in Warsaw to wealthy parents and in 1916 married a Polish lawyer Tadeusz Łempicki. Better than anyone else she represented the Art Deco style in painting and art. Nathan Alterman, the Israeli poet, was born in Warsaw, as was Moshe Vilenski, the Israeli composer, lyricist, and pianist, who studied music at the Warsaw Conservatory. Warsaw was the beloved city of Isaac Bashevis Singer, which he described in many of his novels: Warsaw has just now been destroyed. No one will ever see the Warsaw I knew. Let me just write about it. Let this Warsaw not disappear forever, he commented.

In 2012 the Economist Intelligence Unit ranked Warsaw as the 32nd most liveable city in the world. It was also ranked as one of the most liveable cities in Central Europe. Today Warsaw is considered an "Alpha-" global city, a major international tourist destination and a significant cultural, political and economic hub. Warsaw's economy, by a wide variety of industries, is characterised by FMCG manufacturing, metal processing, steel and electronic manufacturing and food processing. The city is a significant centre of research and development, BPO, ITO, as well as of the Polish media industry. The Warsaw Stock Exchange is one of the largest and most important in Central and Eastern Europe. Frontex, the European

Union agency for external border security, has its headquarters in Warsaw. It has been said that Warsaw, together with Frankfurt, London, Paris and Barcelona is one of the cities with the highest number of skyscrapers in the European Union. Warsaw has also been called "Eastern Europe's chic cultural capital with thriving art and club scenes and serious restaurants".

The first historical reference to Warsaw dates back to the year 1313, at a time when Kraków served as the Polish capital city. Due to its central location between the Polish–Lithuanian Commonwealth's capitals of Kraków and Vilnius, Warsaw became the capital of the Commonwealth and of the Crown of the Kingdom of Poland when King Sigismund III Vasa moved his court from Kraków to Warsaw in 1596. After the Third Partition of Poland in 1795, Warsaw was incorporated into the Kingdom of Prussia. In 1806 during the Napoleonic Wars, the city became the official capital of the Grand Duchy of Warsaw, a puppet state of the First French Empire established by Napoleon Bonaparte. In accordance with the decisions of the Congress of Vienna, the Russian Empire annexed Warsaw in 1815 and it became part of the "Congress Kingdom". Only in 1918 did it regain independence from the foreign rule and emerge as a new capital of the independent Republic of Poland. The German invasion in 1939, the massacre of the Jewish population and deportations to concentration camps led to the uprising in the Warsaw ghetto in 1943 and to the major and devastating Warsaw Uprising between August and October 1944. Warsaw gained the title of the "Phoenix City" because it has survived many wars, conflicts and invasions throughout its long history. Most notably, the city required painstaking rebuilding after the extensive damage it suffered in World War II, which destroyed 85% of its buildings. On 9 November 1940, the city was awarded Poland's highest military decoration for heroism, the *Virtuti Militari*, during the Siege of Warsaw (1939).

The city is the seat of a Roman Catholic archdiocese (left bank of the Vistula) and diocese (right bank), and possesses various universities, most notably the Polish Academy of Sciences and the University of Warsaw, two opera houses, theatres, museums, libraries and monuments. The historic city-centre of Warsaw with its picturesque Old Town in 1980 was listed as a UNESCO World Heritage Site. Other main architectural attractions include the Castle Square with the Royal Castle and the iconic King Sigismund's Column, St. John's Cathedral, Market Square, palaces, churches and mansions all displaying a richness of colour and architectural detail. Buildings represent examples of nearly every European architectural style and historical period. Warsaw provides many examples of architecture from the gothic, renaissance, baroque and neoclassical periods, and around a quarter of the city is filled with luxurious parks and royal gardens.

Warsaw's name in the Polish language is *Warszawa*, approximately /v r ɔ v / (also formerly spelled *Warszewa* and *Warszowa*), meaning "belonging to Warsz", Warsz being a shortened form of the masculine name of Slavic origin *Warcisław*; see also etymology of Wrocław. Folk etymology attributes the city name to a fisherman, Wars, and his wife, Sawa. According to legend, Sawa was a mermaid living in the Vistula River with whom Wars fell in love. In actuality, Warsz was a 12th/13th-century nobleman who owned a village located at the modern-day site of Mariensztat neighbourhood. See also the Vršovci family which had escaped to Poland. The official city name in full is *miasto stołeczne Warszawa* (English: "The Capital City of Warsaw"). A native or resident of Warsaw is known as a Varsovian – in Polish *warszawiak* (male), *warszawianka* (female), *warszawiacy* (plural).

The first fortified settlements on the site of today's Warsaw were located in Bródno (9th/10th century) and Jazdów (12th/13th century). After Jazdów was raided by nearby clans and dukes, a new similar settlement was established on the site of a small fishing village called Warszowa. The Prince of Płock, Bolesław II of Masovia, established this settlement, the modern-day Warsaw, in about 1300. In the beginning of the 14th century it became one of the seats of the Dukes of Masovia, becoming the official capital of Masovian Duchy in 1413. 14th-century Warsaw's economy rested on mostly crafts and trade. Upon the extinction of the local ducal line, the duchy was reincorporated into the Polish Crown in 1526. In 1529, Warsaw for the first time became the seat of the General Sejm, permanent from 1569. In 1573 the city gave its name to the Warsaw Confederation, formally establishing religious freedom in the Polish–Lithuanian Commonwealth. Due to its central location between the Commonwealth's capitals of Kraków and Vilnius, Warsaw became the capital of the Commonwealth and the Crown of the Kingdom of Poland when King Sigismund III Vasa moved his court from Kraków to Warsaw in 1596. In the following years the town expanded towards the suburbs. Several private independent districts were established, the property of aristocrats and the gentry, which were ruled by their own laws. Three times between 1655–1658 the city was under siege and three times it was taken and pillaged by the Swedish, Brandenburgian and Transylvanian forces.

Warsaw remained the capital of the Polish–Lithuanian Commonwealth until 1796, when it was annexed by the Kingdom of Prussia to become the capital of the province of South Prussia. Liberated by Napoleon's army in 1806, Warsaw was made the capital of the newly created Duchy of Warsaw. Following the Congress of Vienna of 1815, Warsaw became the centre of the Congress Poland, a constitutional monarchy under a personal union with Imperial Russia. The Royal University of Warsaw was established in 1816.

Warsaw was occupied by Germany from 4 August 1915 until November 1918. The Allied Armistice terms required in Article 12 that Germany withdraw from areas controlled by Russia in 1914, which included Warsaw. Germany did so, and underground leader Piłsudski returned to Warsaw on 11 November and set up what became the Second Polish Republic, with Warsaw the capital. In the course of the Polish-Bolshevik War of 1920, the huge Battle of Warsaw was fought on the eastern outskirts of the city in which the capital was successfully defended and the Red Army defeated. Poland stopped by itself the full brunt of the Red Army and defeated an idea of the "export of the revolution".

After the German Invasion of Poland on 1 September 1939 began the Second World War, Warsaw was defended till September 27. Central Poland, including Warsaw, came under the rule of the General Government, a German Nazi colonial administration. All higher education institutions were immediately closed and Warsaw's entire Jewish population – several hundred thousand, some 30% of the city – herded into the Warsaw Ghetto. The city would become the centre of urban resistance to Nazi rule in occupied Europe. When the order came to annihilate the ghetto as part of Hitler's "Final Solution" on 19 April 1943, Jewish fighters launched the Warsaw Ghetto Uprising. Despite being heavily outgunned and outnumbered, the Ghetto held out for almost a month. When the fighting ended, almost all survivors were massacred, with only a few managing to escape or hide.

By July 1944, the Red Army was deep into Polish territory and pursuing the Germans toward Warsaw. Knowing that Stalin was hostile to the idea of an independent Poland, the Polish government-in-exile in London gave orders to the underground Home Army (AK) to try to seize control of Warsaw from the Germans before the Red Army arrived. Thus, on 1 August 1944, as the Red Army was nearing the city, the Warsaw Uprising began. The armed struggle, planned to last 48 hours, was partially successful, however it went on for 63 days. Eventually the Home Army fighters and civilians assisting them were forced to capitulate. They were transported to PoW camps in Germany, while the entire civilian population was expelled. Polish civilian deaths are estimated at between 150,000 and 200,000.

After World War II, under a Communist regime set up by the conquering Soviets, the "Bricks for Warsaw" campaign was initiated, and large prefabricated housing projects were erected in Warsaw to address the housing shortage, along with other typical buildings of an Eastern Bloc city, such as the Palace of Culture and Science, a gift from the Soviet Union. The city resumed its role as the capital of Poland and the country's centre of political and economic life. Many of the historic streets, buildings, and churches were restored to their original form. In 1980, Warsaw's historic Old Town was inscribed onto UNESCO's World Heritage list.

John Paul II's visits to his native country in 1979 and 1983 brought support to the budding solidarity movement and encouraged the growing anti-communist fervor there. In 1979, less than a year after becoming pope, John Paul celebrated Mass in Victory Square in Warsaw and ended his sermon with a call to "renew the face" of Poland: Let Thy Spirit descend! Let Thy Spirit descend and renew the face of the land! This land! These words were very meaningful for the Polish citizens who understood them as the incentive for the democratic changes.

Warsaw lies in east-central Poland about 300 km (190 mi) from the Carpathian Mountains and about 260 km (160 mi) from the Baltic Sea, 523 km (325 mi) east of Berlin, Germany. The city straddles the Vistula River. It is located in the heartland of the Masovian Plain, and its average elevation is 100 metres (330 ft) above sea level. The highest point on the left side of the city lies at a height of 115.7 metres (379.6 ft) ("Redutowa" bus depot, district of Wola), on the right side – 122.1 metres (400.6 ft) ("Groszówka" estate, district of Wesoła, by the eastern border). The lowest point lies at a height 75.6 metres (248.0 ft) (at the right bank of the Vistula, by the eastern border of Warsaw). There are some hills (mostly artificial) located within the confines of the city – e.g. Warsaw Uprising Hill (121 metres (397.0 ft)), Szcześliwice hill (138 metres (452.8 ft) – the highest point of Warsaw in general).

Warsaw is located on two main geomorphologic formations: the plain moraine plateau and the Vistula Valley with its asymmetrical pattern of different terraces. The Vistula River is the specific axis of Warsaw, which divides the city into two parts, left and right. The left one is situated both on the moraine plateau (10

to 25 m (32.8 to 82.0 ft) above Vistula level) and on the Vistula terraces (max. 6.5 m (21.3 ft) above Vistula level). The significant element of the relief, in this part of Warsaw, is the edge of moraine plateau called Warsaw Escarpment. It is 20 to 25 m (65.6 to 82.0 ft) high in the Old Town and Central district and about 10 m (32.8 ft) in the north and south of Warsaw. It goes through the city and plays an important role as a landmark.

The plain moraine plateau has only a few natural and artificial ponds and also groups of clay pits. The pattern of the Vistula terraces is asymmetrical. The left side consist mainly of two levels: the highest one contains former flooded terraces and the lowest one the flood plain terrace. The contemporary flooded terrace still has visible valleys and ground depressions with water systems coming from the Vistula old – riverbed. They consist of still quite natural streams and lakes as well as the pattern of drainage ditches. The right side of Warsaw has a different pattern of geomorphological forms. There are several levels of the plain Vistula terraces (flooded as well as former flooded once) and only small part and not so visible moraine escarpment. Aeolian sand with a number of dunes parted by peat swamps or small ponds cover the highest terrace. These are mainly forested areas (pine forest).

Warsaw's mixture of architectural styles reflects the turbulent history of the city and country. During the Second World War, Warsaw was razed to the ground by bombing raids and planned destruction. After liberation, rebuilding began as in other cities of the communist-ruled PRL. Most of the historical buildings were thoroughly reconstructed. However, some of the buildings from the 19th century that had been preserved in reasonably reconstructible form were nonetheless eradicated in the 1950s and 1960s (e.g. Leopold Kronenberg Palace). Mass residential blocks were erected, with basic design typical of Eastern bloc countries.

Gothic architecture is represented in the majestic churches but also at the burgher houses and fortifications. The most significant buildings are St. John's Cathedral (14th century), the temple is a typical example of the so-called Masovian gothic style, St. Mary's Church (1411), a town house of Burbach family (14th century), Gunpowder Tower (after 1379) and the Royal Castle Curia Maior (1407–1410). The most notable examples of Renaissance architecture in the city are the house of Baryczko merchant family (1562), building called "The Negro" (early 17th century) and Salwator tenement (1632). The most interesting examples of mannerist architecture are the Royal Castle (1596–1619) and the Jesuit Church (1609–1626) at Old Town. Among the first structures of the early baroque the most important are St. Hyacinth's Church (1603–1639) and Sigismund's Column (1644).

Building activity occurred in numerous noble palaces and churches during the later decades of the 17th century. One of the best examples of this architecture are Krasiński Palace (1677–1683), Wilanów Palace (1677–1696) and St. Kazimierz Church (1688–1692). The most impressive examples of rococo architecture are Czapski Palace (1712–1721), Palace of the Four Winds (1730s) and Visitationist Church (façade 1728–1761). The neoclassical architecture in Warsaw can be described by the simplicity of the geometrical forms teamed with a great inspiration from the Roman period. Some of the best examples of the neoclassical style are the Palace on the Water (rebuilt 1775–1795), Królikarnia (1782–1786), Carmelite Church (façade 1761–1783) and Evangelical Holy Trinity Church (1777–1782). The economic growth during the first years of Congress Poland caused a rapid rise architecture. The Neoclassical revival affected all aspects of architecture, the most notable are the Great Theater (1825–1833) and buildings located at Bank Square (1825–1828).

Exceptional examples of the bourgeois architecture of the later periods were not restored by the communist authorities after the war (like mentioned Kronenberg Palace and Insurance Company Rosja building) or they were rebuilt in socialist realism style (like Warsaw Philharmony edifice originally inspired by Palais Garnier in Paris). Despite that the Warsaw University of Technology building (1899–1902) is the most interesting of the late 19th-century architecture. Some 19th-century buildings in the Praga district (the Vistula's right bank) have been restored although many have been poorly maintained. Warsaw's municipal government authorities have decided to rebuild the Saxon Palace and the Brühl Palace, the most distinctive buildings in prewar Warsaw.

There are also many places commemorating the heroic history of Warsaw. Pawiak, an infamous German Gestapo prison now occupied by a Mausoleum of Memory of Martyrdom and the museum, is only the beginning of a walk in the traces of Heroic City. The Warsaw Citadel, an impressive 19th-century fortification built after the defeat of the November Uprising, was a place of martyr for the Poles. Another important monument, the statue of Little Insurgent located at the ramparts of the Old Town, commemorates the children who served as messengers and frontline troops in the Warsaw Uprising,

while the impressive Warsaw Uprising Monument by Wincenty Kućma was erected in memory of the largest insurrection of World War II.

Other green spaces in the city include the Botanic Garden and the University Library garden. They have extensive botanical collection of rare domestic and foreign plants, while a palm house in the New Orangery displays plants of subtropics from all over the world. Besides, within the city borders, there are also: Pole Mokotowskie (a big park in the northern Mokotów, where was the first horse racetrack and then the airport), Park Ujazdowski (close to the Sejm and John Lennon street), Park of Culture and Rest in Powsin, by the southern city border, Park Skaryszewski by the right Vistula bank, in Praga. The oldest park in Praga, the Praga Park, was established in 1865–1871 and designed by Jan Dobrowolski. In 1927 a zoological garden (Ogród Zoologiczny) was established on the park grounds, and in 1952 a bear run, still open today.

The flora of the city may be considered very rich in species. The species richness is mainly due to the location of Warsaw within the border region of several big floral regions comprising substantial proportions of close-to-wilderness areas (natural forests, wetlands along the Vistula) as well as arable land, meadows and forests. Bielany Forest, located within the borders of Warsaw, is the remaining part of the Masovian Primeval Forest. Bielany Forest nature reserve is connected with Kampinos Forest. It is home to rich fauna and flora. Within the forest there are three cycling and walking trails. Other big forest area is Kabaty Forest by the southern city border. Warsaw has also two botanic gardens: by the Łazienki park (a didactic-research unit of the University of Warsaw) as well as by the Park of Culture and Rest in Powsin (a unit of the Polish Academy of Science).

In 1939, c. 1,300,000 people lived in Warsaw, but in 1945 – only 420,000. During the first years after the war, the population growth was c. 6%, so shortly the city started to suffer from the lack of flats and of areas for new houses. The first remedial measure was the Warsaw area enlargement (1951) – but the city authorities were still forced to introduce residency registration limitations: only the spouses and children of the permanent residents as well as some persons of public importance (like renowned specialists) were allowed to get the registration, hence halving the population growth in the following years. It also bolstered some kind of conviction among Poles that Varsovians thought of themselves as better only because they lived in the capital. Unfortunately this belief still lives on in Poland (although not as much as it used to be) – even though since 1990 there are no limitations to residency registration anymore.

Throughout its existence, Warsaw has been a multi-cultural city. According to the 1901 census, out of 711,988 inhabitants 56.2% were Catholics, 35.7% Jews, 5% Greek orthodox Christians and 2.8% Protestants. Eight years later, in 1909, there were 281,754 Jews (36.9%), 18,189 Protestants (2.4%) and 2,818 Mariavites (0.4%). This led to construction of hundreds of places of religious worship in all parts of the town. Most of them were destroyed in the aftermath of the Warsaw Uprising of 1944. After the war, the new communist authorities of Poland discouraged church construction and only a small number were rebuilt.

The basic unit of territorial division in Poland is a commune (gmina). A city is also a commune – but with the city charter. Both cities and communes are governed by a mayor – but in the communes the mayor is vogt (wójt in Polish), however in the cities – burmistrz. Some bigger cities obtain the entitlements, i.e. tasks and privileges, which are possessed by the units of the second level of the territorial division – counties or powiats. An example of such entitlement is a car registration: a gmina cannot register cars, this is a powiat's task (i.e. a registration number depends on what powiat a car had been registered, not gmina). In this case we say about city county or powiat grodzki. Such cities are for example Lublin, Kraków, Gdańsk, Poznań. In Warsaw, its districts additionally have some of powiat's entitlements – like already mentioned car registration. For example, the district Wola has its own evidence and the district Ursynów – its own (and the cars from Wola have another type of registration number than these from Ursynów). But for instance the districts in Kraków do not have entitlements of powiat, so the registration numbers in Kraków are of the same type for all districts.

Legislative power in Warsaw is vested in a unicameral Warsaw City Council (Rada Miasta), which comprises 60 members. Council members are elected directly every four years. Like most legislative bodies, the City Council divides itself into committees which have the oversight of various functions of the city government. Bills passed by a simple majority are sent to the mayor (the President of Warsaw), who may sign them into law. If the mayor vetoes a bill, the Council has 30 days to override the veto by a two-thirds majority vote.

The mayor of Warsaw is called President. Generally, in Poland, the mayors of bigger cities are called

presidents – i.e. such cities, which have over 100,000 people or these, where already was president before 1990. The first Warsaw President was Jan Andrzej Menich (1695–1696). Between 1975 and 1990 the Warsaw Presidents was simultaneously the Warsaw Voivode. Since 1990 the President of Warsaw had been elected by the City council. In the years of 1994–1999 the mayor of the district Centrum automatically was designated as the President of Warsaw: the mayor of Centrum was elected by the district council of Centrum and the council was elected only by the Centrum residents. Since 2002 the President of Warsaw is elected by all of the citizens of Warsaw.

Warsaw, especially its city centre (Śródmieście), is home not only to many national institutions and government agencies, but also to many domestic and international companies. In 2006, 304,016 companies were registered in the city. Warsaw's ever-growing business community has been noticed globally, regionally, and nationally. MasterCard Emerging Market Index has noted Warsaw's economic strength and commercial center. Moreover, Warsaw was ranked as the 7th greatest emerging market. Foreign investors' financial participation in the city's development was estimated in 2002 at over 650 million euro. Warsaw produces 12% of Poland's national income, which in 2008 was 305.1% of the Polish average, per capita (or 160% of the European Union average). The GDP per capita in Warsaw amounted to PLN 94 000 in 2008 (c. EUR 23 800, USD 33 000). Total nominal GDP of the city in 2010 amounted to 191.766 billion PLN, 111696 PLN per capita, which was 301,1 % of Polish average. Warsaw leads the region of East-Central Europe in foreign investment and in 2006, GDP growth met expectations with a level of 6.1%. It also has one of the fastest growing economies, with GDP growth at 6.5 percent in 2007 and 6.1 percent in the first quarter of 2008.

Warsaw's first stock exchange was established in 1817 and continued trading until World War II. It was re-established in April 1991, following the end of the post-war communist control of the country and the reintroduction of a free-market economy. Today, the Warsaw Stock Exchange (WSE) is, according to many indicators, the largest market in the region, with 374 companies listed and total capitalization of 162 584 mln EUR as of 31 August 2009. From 1991 until 2000, the stock exchange was, ironically, located in the building previously used as the headquarters of the Polish United Workers' Party (PZPR).

The FSO Car Factory was established in 1951. A number of vehicles have been assembled there over the decades, including the Warszawa, Syrena, Fiat 125p (under license from Fiat, later renamed FSO 125p when the license expired) and the Polonez. The last two models listed were also sent abroad and assembled in a number of other countries, including Egypt and Colombia. In 1995 the factory was purchased by the South Korean car manufacturer Daewoo, which assembled the Tico, Espero, Nubia, Tacuma, Leganza, Lanos and Matiz there for the European market. In 2005 the factory was sold to AvtoZAZ, a Ukrainian car manufacturer which assembled there the Chevrolet Aveo. The license for the production of the Aveo expired in February 2011 and has since not been renewed. Currently the company is defunct.

Warsaw (Polish: Warszawa [var ˈava] ( listen); see also other names) is the capital and largest city of Poland. It stands on the Vistula River in east-central Poland, roughly 260 kilometres (160 mi) from the Baltic Sea and 300 kilometres (190 mi) from the Carpathian Mountains. Its population is estimated at 1.740 million residents within a greater metropolitan area of 2.666 million residents, which makes Warsaw the 9th most-populous capital city in the European Union. The city limits cover 516.9 square kilometres (199.6 sq mi), while the metropolitan area covers 6,100.43 square kilometres (2,355.39 sq mi).

The Normans (Norman: Nourmands; French: Normands; Latin: Normanni) were the people who in the 10th and 11th centuries gave their name to Normandy, a region in France. They were descended from Norse ("Norman" comes from "Norseman") raiders and pirates from Denmark, Iceland and Norway who, under their leader Rollo, agreed to swear fealty to King Charles III of West Francia. Through generations of assimilation and mixing with the native Frankish and Roman-Gaulish populations, their descendants would gradually merge with the Carolingian-based cultures of West Francia. The distinct cultural and ethnic identity of the Normans emerged initially in the first half of the 10th century, and it continued to evolve over the succeeding centuries.

The Norman dynasty had a major political, cultural and military impact on medieval Europe and even the Near East. The Normans were famed for their martial spirit and eventually for their Christian piety, becoming exponents of the Catholic orthodoxy into which they assimilated. They adopted the Gallo-Romance language of the Frankish land they settled, their dialect becoming known as Norman, Normaund or Norman French, an important literary language. The Duchy of Normandy, which they formed by treaty with the French crown, was a great fief of medieval France, and under Richard I of

Normandy was forged into a cohesive and formidable principality in feudal tenure. The Normans are noted both for their culture, such as their unique Romanesque architecture and musical traditions, and for their significant military accomplishments and innovations. Norman adventurers founded the Kingdom of Sicily under Roger II after conquering southern Italy on the Saracens and Byzantines, and an expedition on behalf of their duke, William the Conqueror, led to the Norman conquest of England at the Battle of Hastings in 1066. Norman cultural and military influence spread from these new European centres to the Crusader states of the Near East, where their prince Bohemond I founded the Principality of Antioch in the Levant, to Scotland and Wales in Great Britain, to Ireland, and to the coasts of north Africa and the Canary Islands.

The English name "Normans" comes from the French words Normans/Normaniz, plural of Normant, modern French normand, which is itself borrowed from Old Low Franconian Nortmann "Northman" or directly from Old Norse Norðmaðr, Latinized variously as Nortmannus, Normannus, or Nordmannus (recorded in Medieval Latin, 9th century) to mean "Norseman, Viking".

In the course of the 10th century, the initially destructive incursions of Norse war bands into the rivers of France evolved into more permanent encampments that included local women and personal property. The Duchy of Normandy, which began in 911 as a fiefdom, was established by the treaty of Saint-Clair-sur-Epte between King Charles III of West Francia and the famed Viking ruler Rollo, and was situated in the former Frankish kingdom of Neustria. The treaty offered Rollo and his men the French lands between the river Epte and the Atlantic coast in exchange for their protection against further Viking incursions. The area corresponded to the northern part of present-day Upper Normandy down to the river Seine, but the Duchy would eventually extend west beyond the Seine. The territory was roughly equivalent to the old province of Rouen, and reproduced the Roman administrative structure of Gallia Lugdunensis II (part of the former Gallia Lugdunensis).

Before Rollo's arrival, its populations did not differ from Picardy or the Île-de-France, which were considered "Frankish". Earlier Viking settlers had begun arriving in the 880s, but were divided between colonies in the east (Roumois and Pays de Caux) around the low Seine valley and in the west in the Cotentin Peninsula, and were separated by traditional pagii, where the population remained about the same with almost no foreign settlers. Rollo's contingents who raided and ultimately settled Normandy and parts of the Atlantic coast included Danes, Norwegians, Norse–Gaels, Orkney Vikings, possibly Swedes, and Anglo-Danes from the English Danelaw under Norse control.

The descendants of Rollo's Vikings and their Frankish wives would replace the Norse religion and Old Norse language with Catholicism (Christianity) and the Gallo-Romance language of the local people, blending their maternal Frankish heritage with Old Norse traditions and customs to synthesize a unique "Norman" culture in the north of France. The Norman language was forged by the adoption of the indigenous langue d'oïl branch of Romance by a Norse-speaking ruling class, and it developed into the regional language that survives today.

The Normans thereafter adopted the growing feudal doctrines of the rest of France, and worked them into a functional hierarchical system in both Normandy and in England. The new Norman rulers were culturally and ethnically distinct from the old French aristocracy, most of whom traced their lineage to Franks of the Carolingian dynasty. Most Norman knights remained poor and land-hungry, and by 1066 Normandy had been exporting fighting horsemen for more than a generation. Many Normans of Italy, France and England eventually served as avid Crusaders under the Italo-Norman prince Bohemund I and the Anglo-Norman king Richard the Lion-Heart.

Opportunistic bands of Normans successfully established a foothold in Southern Italy (the Mezzogiorno). Probably as the result of returning pilgrims' stories, the Normans entered the Mezzogiorno as warriors in 1017 at the latest. In 999, according to Amatus of Montecassino, Norman pilgrims returning from Jerusalem called in at the port of Salerno when a Saracen attack occurred. The Normans fought so valiantly that Prince Guaimar III begged them to stay, but they refused and instead offered to tell others back home of the prince's request. William of Apulia tells that, in 1016, Norman pilgrims to the shrine of the Archangel Michael at Monte Gargano were met by Melus of Bari, a Lombard nobleman and rebel, who persuaded them to return with more warriors to help throw off the Byzantine rule, which they did.

The two most prominent Norman families to arrive in the Mediterranean were descendants of Tancred of Hauteville and the Drengot family, of whom Rainulf Drengot received the county of Aversa, the first Norman toehold in the south, from Duke Sergius IV of Naples in 1030. The Hauteville family achieved princely rank by proclaiming prince Guaimar IV of Salerno "Duke of Apulia and Calabria". He promptly

awarded their elected leader, William Iron Arm, with the title of count in his capital of Melfi. The Drengot family thereafter attained the principality of Capua, and emperor Henry III legally ennobled the Hauteville leader, Drogo, as "dux et magister Italiae comesque Normannorum totius Apuliae et Calabriae" ("Duke and Master of Italy and Count of the Normans of all Apulia and Calabria") in 1047.

From these bases, the Normans eventually captured Sicily and Malta from the Saracens, under the leadership of the famous Robert Guiscard, a Hauteville, and his younger brother Roger the Great Count. Roger's son, Roger II of Sicily, was crowned king in 1130 (exactly one century after Rainulf was "crowned" count) by Antipope Anacletus II. The Kingdom of Sicily lasted until 1194, when it was transferred to the House of Hohenstaufen through marriage. The Normans left their legacy in many castles, such as William Iron Arm's citadel at Squillace, and cathedrals, such as Roger II's Cappella Palatina chapel at Palermo, which dot the landscape and give a wholly distinct architectural flavor to accompany its unique history.

Institutionally, the Normans combined the administrative machinery of the Byzantines, Arabs, and Lombards with their own conceptions of feudal law and order to forge a unique government. Under this state, there was great religious freedom, and alongside the Norman nobles existed a meritocratic bureaucracy of Jews, Muslims and Christians, both Catholic and Eastern Orthodox. The Kingdom of Sicily thus became characterized by Norman, Byzantine Greek, Arab, Lombard and "native" Sicilian populations living in harmony, and its Norman rulers fostered plans of establishing an Empire that would have encompassed Fatimid Egypt as well as the Crusader states in the Levant. One of the great geographical treatises of the Middle Ages, the "Tabula Rogeriana", was written by the Andalusian al-Idrisi for king Roger II of Sicily, and entitled "Kitab Rudjdjar" ("The Book of Roger").

Soon after the Normans began to enter Italy, they entered the Byzantine Empire and then Armenia, fighting against the Pechenegs, the Bulgars, and especially the Seljuk Turks. Norman mercenaries were first encouraged to come to the south by the Lombards to act against the Byzantines, but they soon fought in Byzantine service in Sicily. They were prominent alongside Varangian and Lombard contingents in the Sicilian campaign of George Maniaces in 1038–40. There is debate whether the Normans in Greek service actually were from Norman Italy, and it now seems likely only a few came from there. It is also unknown how many of the "Franks", as the Byzantines called them, were Normans and not other Frenchmen.

One of the first Norman mercenaries to serve as a Byzantine general was Hervé in the 1050s. By then however, there were already Norman mercenaries serving as far away as Trebizond and Georgia. They were based at Malatya and Edessa, under the Byzantine duke of Antioch, Isaac Komnenos. In the 1060s, Robert Crispin led the Normans of Edessa against the Turks. Roussel de Bailleul even tried to carve out an independent state in Asia Minor with support from the local population, but he was stopped by the Byzantine general Alexius Komnenos.

Some Normans joined Turkish forces to aid in the destruction of the Armenians vassal-states of Sassoun and Taron in far eastern Anatolia. Later, many took up service with the Armenian state further south in Cilicia and the Taurus Mountains. A Norman named Oursel led a force of "Franks" into the upper Euphrates valley in northern Syria. From 1073 to 1074, 8,000 of the 20,000 troops of the Armenian general Philaretus Brachamius were Normans—formerly of Oursel—led by Raimbaud. They even lent their ethnicity to the name of their castle: Afranji, meaning "Franks." The known trade between Amalfi and Antioch and between Bari and Tarsus may be related to the presence of Italo-Normans in those cities while Amalfi and Bari were under Norman rule in Italy.

Several families of Byzantine Greece were of Norman mercenary origin during the period of the Comnenian Restoration, when Byzantine emperors were seeking out western European warriors. The Raoulii were descended from an Italo-Norman named Raoul, the Petraliphae were descended from a Pierre d'Aulps, and that group of Albanian clans known as the Maniakates were descended from Normans who served under George Maniaces in the Sicilian expedition of 1038.

Robert Guiscard, an other Norman adventurer previously elevated to the dignity of count of Apulia as the result of his military successes, ultimately drove the Byzantines out of southern Italy. Having obtained the consent of pope Gregory VII and acting as his vassal, Robert continued his campaign conquering the Balkan peninsula as a foothold for western feudal lords and the Catholic Church. After allying himself with Croatia and the Catholic cities of Dalmatia, in 1081 he led an army of 30,000 men in 300 ships landing on the southern shores of Albania, capturing Valona, Kanina, Jericho (Oricum), and reaching Butrint after numerous pillages. They joined the fleet that had previously conquered Corfu and attacked Dyrrachium



from land and sea, devastating everything along the way. Under these harsh circumstances, the locals accepted the call of emperor Alexius I Comnenus to join forces with the Byzantines against the Normans. The Albanian forces could not take part in the ensuing battle because it had started before their arrival. Immediately before the battle, the Venetian fleet had secured a victory in the coast surrounding the city. Forced to retreat, Alexius ceded the command to a high Albanian official named Comiscortes in the service of Byzantium. The city's garrison resisted until February 1082, when Dyrrachium was betrayed to the Normans by the Venetian and Amalfitan merchants who had settled there. The Normans were now free to penetrate into the hinterland; they took Ioannina and some minor cities in southwestern Macedonia and Thessaly before appearing at the gates of Thessalonica. Dissension among the high ranks coerced the Normans to retreat to Italy. They lost Dyrrachium, Valona, and Butrint in 1085, after the death of Robert.

A few years after the First Crusade, in 1107, the Normans under the command of Bohemond, Robert's son, landed in Valona and besieged Dyrrachium using the most sophisticated military equipment of the time, but to no avail. Meanwhile, they occupied Petrela, the citadel of Mili at the banks of the river Deabolis, Gllavenica (Ballsh), Kanina and Jericho. This time, the Albanians sided with the Normans, dissatisfied by the heavy taxes the Byzantines had imposed upon them. With their help, the Normans secured the Arbanon passes and opened their way to Dibra. The lack of supplies, disease and Byzantine resistance forced Bohemond to retreat from his campaign and sign a peace treaty with the Byzantines in the city of Deabolis.

The further decline of Byzantine state-of-affairs paved the road to a third attack in 1185, when a large Norman army invaded Dyrrachium, owing to the betrayal of high Byzantine officials. Some time later, Dyrrachium—one of the most important naval bases of the Adriatic—fell again to Byzantine hands. The Normans were in contact with England from an early date. Not only were their original Viking brethren still ravaging the English coasts, they occupied most of the important ports opposite England across the English Channel. This relationship eventually produced closer ties of blood through the marriage of Emma, sister of Duke Richard II of Normandy, and King Ethelred II of England. Because of this, Ethelred fled to Normandy in 1013, when he was forced from his kingdom by Sweyn Forkbeard. His stay in Normandy (until 1016) influenced him and his sons by Emma, who stayed in Normandy after Cnut the Great's conquest of the isle.

When finally Edward the Confessor returned from his father's refuge in 1041, at the invitation of his half-brother Harthacnut, he brought with him a Norman-educated mind. He also brought many Norman counsellors and fighters, some of whom established an English cavalry force. This concept never really took root, but it is a typical example of the attitudes of Edward. He appointed Robert of Jumièges archbishop of Canterbury and made Ralph the Timid earl of Hereford. He invited his brother-in-law Eustace II, Count of Boulogne to his court in 1051, an event which resulted in the greatest of early conflicts between Saxon and Norman and ultimately resulted in the exile of Earl Godwin of Wessex. In 1066, Duke William I of Normandy conquered England killing King Harold II at the Battle of Hastings. The invading Normans and their descendants replaced the Anglo-Saxons as the ruling class of England. The nobility of England were part of a single Normans culture and many had lands on both sides of the channel. Early Norman kings of England, as Dukes of Normandy, owed homage to the King of France for their land on the continent. They considered England to be their most important holding (it brought with it the title of King—an important status symbol).

Eventually, the Normans merged with the natives, combining languages and traditions. In the course of the Hundred Years' War, the Norman aristocracy often identified themselves as English. The Anglo-Norman language became distinct from the Latin language, something that was the subject of some humour by Geoffrey Chaucer. The Anglo-Norman language was eventually absorbed into the Anglo-Saxon language of their subjects (see Old English) and influenced it, helping (along with the Norse language of the earlier Anglo-Norse settlers and the Latin used by the church) in the development of Middle English. It in turn evolved into Modern English.

The Normans had a profound effect on Irish culture and history after their invasion at Bannow Bay in 1169. Initially the Normans maintained a distinct culture and ethnicity. Yet, with time, they came to be subsumed into Irish culture to the point that it has been said that they became "more Irish than the Irish themselves." The Normans settled mostly in an area in the east of Ireland, later known as the Pale, and also built many fine castles and settlements, including Trim Castle and Dublin Castle. Both cultures intermixed, borrowing from each other's language, culture and outlook. Norman descendants today can

be recognised by their surnames. Names such as French, (De) Roche, Devereux, D'Arcy, Treacy and Lacy are particularly common in the southeast of Ireland, especially in the southern part of County Wexford where the first Norman settlements were established. Other Norman names such as Furlong predominate there. Another common Norman-Irish name was Morell (Murrell) derived from the French Norman name Morel. Other names beginning with Fitz (from the Norman for son) indicate Norman ancestry. These included Fitzgerald, FitzGibbons (Gibbons) dynasty, Fitzmaurice. Other families bearing such surnames as Barry (de Barra) and De Búrca (Burke) are also of Norman extraction.

One of the claimants of the English throne opposing William the Conqueror, Edgar Atheling, eventually fled to Scotland. King Malcolm III of Scotland married Edgar's sister Margaret, and came into opposition to William who had already disputed Scotland's southern borders. William invaded Scotland in 1072, riding as far as Abernethy where he met up with his fleet of ships. Malcolm submitted, paid homage to William and surrendered his son Duncan as a hostage, beginning a series of arguments as to whether the Scottish Crown owed allegiance to the King of England.

Normans came into Scotland, building castles and founding noble families who would provide some future kings, such as Robert the Bruce, as well as founding a considerable number of the Scottish clans. King David I of Scotland, whose elder brother Alexander I had married Sybilla of Normandy, was instrumental in introducing Normans and Norman culture to Scotland, part of the process some scholars call the "Davidian Revolution". Having spent time at the court of Henry I of England (married to David's sister Maud of Scotland), and needing them to wrestle the kingdom from his half-brother Máel Coluim mac Alaxandair, David had to reward many with lands. The process was continued under David's successors, most intensely of all under William the Lion. The Norman-derived feudal system was applied in varying degrees to most of Scotland. Scottish families of the names Bruce, Gray, Ramsay, Fraser, Ogilvie, Montgomery, Sinclair, Pollock, Burnard, Douglas and Gordon to name but a few, and including the later royal House of Stewart, can all be traced back to Norman ancestry.

Even before the Norman Conquest of England, the Normans had come into contact with Wales. Edward the Confessor had set up the aforementioned Ralph as earl of Hereford and charged him with defending the Marches and warring with the Welsh. In these original ventures, the Normans failed to make any headway into Wales.

Subsequent to the Conquest, however, the Marches came completely under the dominance of William's most trusted Norman barons, including Bernard de Neufmarché, Roger of Montgomery in Shropshire and Hugh Lupus in Cheshire. These Normans began a long period of slow conquest during which almost all of Wales was at some point subject to Norman interference. Norman words, such as baron (barwn), first entered Welsh at that time.

The legendary religious zeal of the Normans was exercised in religious wars long before the First Crusade carved out a Norman principality in Antioch. They were major foreign participants in the Reconquista in Iberia. In 1018, Roger de Tosny travelled to the Iberian Peninsula to carve out a state for himself from Moorish lands, but failed. In 1064, during the War of Barbastro, William of Montreuil led the papal army and took a huge booty.

In 1096, Crusaders passing by the siege of Amalfi were joined by Bohemond of Taranto and his nephew Tancred with an army of Italo-Normans. Bohemond was the de facto leader of the Crusade during its passage through Asia Minor. After the successful Siege of Antioch in 1097, Bohemond began carving out an independent principality around that city. Tancred was instrumental in the conquest of Jerusalem and he worked for the expansion of the Crusader kingdom in Transjordan and the region of Galilee.[citation needed]

The conquest of Cyprus by the Anglo-Norman forces of the Third Crusade opened a new chapter in the history of the island, which would be under Western European domination for the following 380 years. Although not part of a planned operation, the conquest had much more permanent results than initially expected.

In April 1191 Richard the Lion-hearted left Messina with a large fleet in order to reach Acre. But a storm dispersed the fleet. After some searching, it was discovered that the boat carrying his sister and his fiancée Berengaria was anchored on the south coast of Cyprus, together with the wrecks of several other ships, including the treasure ship. Survivors of the wrecks had been taken prisoner by the island's despot Isaac Komnenos. On 1 May 1191, Richard's fleet arrived in the port of Limassol on Cyprus. He ordered Isaac to release the prisoners and the treasure. Isaac refused, so Richard landed his troops and took Limassol.

Various princes of the Holy Land arrived in Limassol at the same time, in particular Guy de Lusignan. All declared their support for Richard provided that he support Guy against his rival Conrad of Montferrat. The local barons abandoned Isaac, who considered making peace with Richard, joining him on the crusade, and offering his daughter in marriage to the person named by Richard. But Isaac changed his mind and tried to escape. Richard then proceeded to conquer the whole island, his troops being led by Guy de Lusignan. Isaac surrendered and was confined with silver chains, because Richard had promised that he would not place him in irons. By 1 June, Richard had conquered the whole island. His exploit was well publicized and contributed to his reputation; he also derived significant financial gains from the conquest of the island. Richard left for Acre on 5 June, with his allies. Before his departure, he named two of his Norman generals, Richard de Camville and Robert de Thornham, as governors of Cyprus. While in Limassol, Richard the Lion-Heart married Berengaria of Navarre, first-born daughter of King Sancho VI of Navarre. The wedding was held on 12 May 1191 at the Chapel of St. George and it was attended by Richard's sister Joan, whom he had brought from Sicily. The marriage was celebrated with great pomp and splendor. Among other grand ceremonies was a double coronation: Richard caused himself to be crowned King of Cyprus, and Berengaria Queen of England and Queen of Cyprus as well. The rapid Anglo-Norman conquest proved more important than it seemed. The island occupied a key strategic position on the maritime lanes to the Holy Land, whose occupation by the Christians could not continue without support from the sea. Shortly after the conquest, Cyprus was sold to the Knights Templar and it was subsequently acquired, in 1192, by Guy de Lusignan and became a stable feudal kingdom. It was only in 1489 that the Venetians acquired full control of the island, which remained a Christian stronghold until the fall of Famagusta in 1571.

Between 1402 and 1405, the expedition led by the Norman noble Jean de Bethencourt and the Poitevine Gadifer de la Salle conquered the Canarian islands of Lanzarote, Fuerteventura and El Hierro off the Atlantic coast of Africa. Their troops were gathered in Normandy, Gascony and were later reinforced by Castilian colonists.

Bethencourt took the title of King of the Canary Islands, as vassal to Henry III of Castile. In 1418, Jean's nephew Maciot de Bethencourt sold the rights to the islands to Enrique Pérez de Guzmán, 2nd Count de Niebla.

The customary law of Normandy was developed between the 10th and 13th centuries and survives today through the legal systems of Jersey and Guernsey in the Channel Islands. Norman customary law was transcribed in two customaries in Latin by two judges for use by them and their colleagues: These are the *Très ancien coutumier* (Very ancient customary), authored between 1200 and 1245; and the *Grand coutumier de Normandie* (Great customary of Normandy, originally *Summa de legibus Normanniae in curia laicali*), authored between 1235 and 1245.

Norman architecture typically stands out as a new stage in the architectural history of the regions they subdued. They spread a unique Romanesque idiom to England and Italy, and the encastellation of these regions with keeps in their north French style fundamentally altered the military landscape. Their style was characterised by rounded arches, particularly over windows and doorways, and massive proportions. In England, the period of Norman architecture immediately succeeds that of the Anglo-Saxon and precedes the Early Gothic. In southern Italy, the Normans incorporated elements of Islamic, Lombard, and Byzantine building techniques into their own, initiating a unique style known as Norman-Arab architecture within the Kingdom of Sicily.

In the visual arts, the Normans did not have the rich and distinctive traditions of the cultures they conquered. However, in the early 11th century the dukes began a programme of church reform, encouraging the Cluniac reform of monasteries and patronising intellectual pursuits, especially the proliferation of scriptoria and the reconstitution of a compilation of lost illuminated manuscripts. The church was utilised by the dukes as a unifying force for their disparate duchy. The chief monasteries taking part in this "renaissance" of Norman art and scholarship were Mont-Saint-Michel, Fécamp, Jumièges, Bec, Saint-Ouen, Saint-Evroul, and Saint-Wandrille. These centres were in contact with the so-called "Winchester school", which channeled a pure Carolingian artistic tradition to Normandy. In the final decade of the 11th and first of the 12th century, Normandy experienced a golden age of illustrated manuscripts, but it was brief and the major scriptoria of Normandy ceased to function after the midpoint of the century.

The French Wars of Religion in the 16th century and French Revolution in the 18th successively destroyed much of what existed in the way of the architectural and artistic remnant of this Norman

creativity. The former, with their violence, caused the wanton destruction of many Norman edifices; the latter, with its assault on religion, caused the purposeful destruction of religious objects of any type, and its destabilisation of society resulted in rampant pillaging.

By far the most famous work of Norman art is the Bayeux Tapestry, which is not a tapestry but a work of embroidery. It was commissioned by Odo, the Bishop of Bayeux and first Earl of Kent, employing natives from Kent who were learned in the Nordic traditions imported in the previous half century by the Danish Vikings.

In Britain, Norman art primarily survives as stonework or metalwork, such as capitals and baptismal fonts. In southern Italy, however, Norman artwork survives plentifully in forms strongly influenced by its Greek, Lombard, and Arab forebears. Of the royal regalia preserved in Palermo, the crown is Byzantine in style and the coronation cloak is of Arab craftsmanship with Arabic inscriptions. Many churches preserve sculptured fonts, capitals, and more importantly mosaics, which were common in Norman Italy and drew heavily on the Greek heritage. Lombard Salerno was a centre of ivorywork in the 11th century and this continued under Norman domination. Finally should be noted the intercourse between French Crusaders traveling to the Holy Land who brought with them French artefacts with which to gift the churches at which they stopped in southern Italy amongst their Norman cousins. For this reason many south Italian churches preserve works from France alongside their native pieces.

Normandy was the site of several important developments in the history of classical music in the 11th century. Fécamp Abbey and Saint-Evroul Abbey were centres of musical production and education. At Fécamp, under two Italian abbots, William of Volpiano and John of Ravenna, the system of denoting notes by letters was developed and taught. It is still the most common form of pitch representation in English- and German-speaking countries today. Also at Fécamp, the staff, around which neumes were oriented, was first developed and taught in the 11th century. Under the German abbot Isembard, La Trinité-du-Mont became a centre of musical composition.

At Saint Evroul, a tradition of singing had developed and the choir achieved fame in Normandy. Under the Norman abbot Robert de Grantmesnil, several monks of Saint-Evroul fled to southern Italy, where they were patronised by Robert Guiscard and established a Latin monastery at Sant'Eufemia. There they continued the tradition of singing.

Nikola Tesla (Serbian Cyrillic: Никола Тесла; 10 July 1856 – 7 January 1943) was a Serbian American inventor, electrical engineer, mechanical engineer, physicist, and futurist best known for his contributions to the design of the modern alternating current (AC) electricity supply system.

Tesla gained experience in telephony and electrical engineering before emigrating to the United States in 1884 to work for Thomas Edison in New York City. He soon struck out on his own with financial backers, setting up laboratories and companies to develop a range of electrical devices. His patented AC induction motor and transformer were licensed by George Westinghouse, who also hired Tesla for a short time as a consultant. His work in the formative years of electric power development was involved in a corporate alternating current/direct current "War of Currents" as well as various patent battles.

Tesla went on to pursue his ideas of wireless lighting and electricity distribution in his high-voltage, high-frequency power experiments in New York and Colorado Springs, and made early (1893) pronouncements on the possibility of wireless communication with his devices. He tried to put these ideas to practical use in an ill-fated attempt at intercontinental wireless transmission, his unfinished Wardenclyffe Tower project. In his lab he also conducted a range of experiments with mechanical oscillators/generators, electrical discharge tubes, and early X-ray imaging. He also built a wireless controlled boat, one of the first ever exhibited.

Tesla was renowned for his achievements and showmanship, eventually earning him a reputation in popular culture as an archetypal "mad scientist". His patents earned him a considerable amount of money, much of which was used to finance his own projects with varying degrees of success.:121,154 He lived most of his life in a series of New York hotels, through his retirement. Tesla died on 7 January 1943. His work fell into relative obscurity after his death, but in 1960 the General Conference on Weights and Measures named the SI unit of magnetic flux density the tesla in his honor. There has been a resurgence in popular interest in Tesla since the 1990s.

Tesla was born on 10 July [O.S. 28 June] 1856 into a Serb family in the village of Smiljan, Austrian Empire (modern-day Croatia). His father, Milutin Tesla, was a Serbian Orthodox priest. Tesla's mother, Đuka Tesla (née Mandić), whose father was also an Orthodox priest,:10 had a talent for making home craft tools, mechanical appliances, and the ability to memorize Serbian epic poems. Đuka had never

received a formal education. Nikola credited his eidetic memory and creative abilities to his mother's genetics and influence. Tesla's progenitors were from western Serbia, near Montenegro.:12 Tesla was the fourth of five children. He had an older brother named Dane and three sisters, Milka, Angelina and Marica. Dane was killed in a horse-riding accident when Nikola was five. In 1861, Tesla attended the "Lower" or "Primary" School in Smiljan where he studied German, arithmetic, and religion. In 1862, the Tesla family moved to Gospić, Austrian Empire, where Tesla's father worked as a pastor. Nikola completed "Lower" or "Primary" School, followed by the "Lower Real Gymnasium" or "Normal School." In 1870, Tesla moved to Karlovac, to attend school at the Higher Real Gymnasium, where he was profoundly influenced by a math teacher Martin Sekulić.:32 The classes were held in German, as it was a school within the Austro-Hungarian Military Frontier. Tesla was able to perform integral calculus in his head, which prompted his teachers to believe that he was cheating. He finished a four-year term in three years, graduating in 1873.:33

In 1873, Tesla returned to his birthtown, Smiljan. Shortly after he arrived, Tesla contracted cholera; he was bedridden for nine months and was near death multiple times. Tesla's father, in a moment of despair, promised to send him to the best engineering school if he recovered from the illness (his father had originally wanted him to enter the priesthood).

In 1874, Tesla evaded being drafted into the Austro-Hungarian Army in Smiljan by running away to Tomingaj, near Gračac. There, he explored the mountains in hunter's garb. Tesla said that this contact with nature made him stronger, both physically and mentally. He read many books while in Tomingaj, and later said that Mark Twain's works had helped him to miraculously recover from his earlier illness.

In 1875, Tesla enrolled at Austrian Polytechnic in Graz, Austria, on a Military Frontier scholarship. During his first year, Tesla never missed a lecture, earned the highest grades possible, passed nine exams (nearly twice as many required), started a Serbian culture club, and even received a letter of commendation from the dean of the technical faculty to his father, which stated, "Your son is a star of first rank." Tesla claimed that he worked from 3 a.m. to 11 p.m., no Sundays or holidays excepted. He was "mortified when [his] father made light of [those] hard won honors." After his father's death in 1879, Tesla found a package of letters from his professors to his father, warning that unless he were removed from the school, Tesla would be killed through overwork. During his second year, Tesla came into conflict with Professor Poeschl over the Gramme dynamo, when Tesla suggested that commutators weren't necessary. At the end of his second year, Tesla lost his scholarship and became addicted to gambling. During his third year, Tesla gambled away his allowance and his tuition money, later gambling back his initial losses and returning the balance to his family. Tesla said that he "conquered [his] passion then and there," but later he was known to play billiards in the US. When exam time came, Tesla was unprepared and asked for an extension to study, but was denied. He never graduated from the university and did not receive grades for the last semester.

In December 1878, Tesla left Graz and severed all relations with his family to hide the fact that he dropped out of school. His friends thought that he had drowned in the Mur River. Tesla went to Maribor (now in Slovenia), where he worked as a draftsman for 60 florins a month. He spent his spare time playing cards with local men on the streets. In March 1879, Milutin Tesla went to Maribor to beg his son to return home, but Nikola refused. Nikola suffered a nervous breakdown at around the same time.

On 24 March 1879, Tesla was returned to Gospić under police guard for not having a residence permit. On 17 April 1879, Milutin Tesla died at the age of 60 after contracting an unspecified illness (although some sources say that he died of a stroke). During that year, Tesla taught a large class of students in his old school, Higher Real Gymnasium, in Gospić.

In January 1880, two of Tesla's uncles put together enough money to help him leave Gospić for Prague where he was to study. Unfortunately, he arrived too late to enroll at Charles-Ferdinand University; he never studied Greek, a required subject; and he was illiterate in Czech, another required subject. Tesla did, however, attend lectures at the university, although, as an auditor, he did not receive grades for the courses.

In 1881, Tesla moved to Budapest to work under Ferenc Puskás at a telegraph company, the Budapest Telephone Exchange. Upon arrival, Tesla realized that the company, then under construction, was not functional, so he worked as a draftsman in the Central Telegraph Office instead. Within a few months, the Budapest Telephone Exchange became functional and Tesla was allocated the chief electrician position. During his employment, Tesla made many improvements to the Central Station equipment and claimed to have perfected a telephone repeater or amplifier, which was never patented nor publicly described.

In 1882, Tesla began working for the Continental Edison Company in France, designing and making improvements to electrical equipment. In June 1884, he relocated to New York City:<sup>57–60</sup> where he was hired by Thomas Edison to work at his Edison Machine Works on Manhattan's lower east side. Tesla's work for Edison began with simple electrical engineering and quickly progressed to solving more difficult problems.

Tesla was offered the task of completely redesigning the Edison Company's direct current generators. In 1885, he said that he could redesign Edison's inefficient motor and generators, making an improvement in both service and economy. According to Tesla, Edison remarked, "There's fifty thousand dollars in it for you—if you can do it."<sup>54–57</sup> :<sup>64</sup> This has been noted as an odd statement from an Edison whose company was stingy with pay and who did not have that sort of cash on hand. After months of work, Tesla fulfilled the task and inquired about payment. Edison, saying that he was only joking, replied, "Tesla, you don't understand our American humor."<sup>64</sup> Instead, Edison offered a US\$10 a week raise over Tesla's US\$18 per week salary; Tesla refused the offer and immediately resigned.

After leaving Edison's company Tesla partnered with two businessmen in 1886, Robert Lane and Benjamin Vail, who agreed to finance an electric lighting company in Tesla's name, Tesla Electric Light & Manufacturing. The company installed electrical arc light based illumination systems designed by Tesla and also had designs for dynamo electric machine commutators, the first patents issued to Tesla in the US.

The investors showed little interest in Tesla's ideas for new types of motors and electrical transmission equipment and also seemed to think it was better to develop an electrical utility than invent new systems. They eventually forced Tesla out leaving him penniless. He even lost control of the patents he had generated since he had assigned them to the company in lieu of stock. He had to work at various electrical repair jobs and even as a ditch digger for \$2 per day. Tesla considered the winter of 1886/1887 as a time of "terrible headaches and bitter tears." During this time, he questioned the value of his education.

In late 1886 Tesla met Alfred S. Brown, a Western Union superintendent, and New York attorney Charles F. Peck. The two men were experienced in setting up companies and promoting inventions and patents for financial gain. Based on Tesla's patents and other ideas they agreed to back him financially and handle his patents. Together in April 1887 they formed the Tesla Electric Company with an agreement that profits from generated patents would go  $\frac{1}{3}$  to Tesla,  $\frac{1}{3}$  to Peck and Brown, and  $\frac{1}{3}$  to fund development. They set up a laboratory for Tesla at 89 Liberty Street in Manhattan where he worked on improving and developing new types of electric motors, generators and other devices.

One of the things Tesla developed at that laboratory in 1887 was an induction motor that ran on alternating current, a power system format that was starting to be built in Europe and the United States because of its advantages in long-distance, high-voltage transmission. The motor used polyphase current which generated a rotating magnetic field to turn the motor (a principle Tesla claimed to have conceived in 1882). This innovative electric motor, patented in May 1888, was a simple self-starting design that did not need a commutator, thus avoiding sparking and the high maintenance of constantly servicing and replacing mechanical brushes.

In 1888, the editor of Electrical World magazine, Thomas Commerford Martin (a friend and publicist), arranged for Tesla to demonstrate his alternating current system, including his induction motor, at the American Institute of Electrical Engineers (now IEEE). Engineers working for the Westinghouse Electric & Manufacturing Company reported to George Westinghouse that Tesla had a viable AC motor and related power system — something for which Westinghouse had been trying to secure patents. Westinghouse looked into getting a patent on a similar commutator-less, rotating magnetic field-based induction motor presented in a paper in March 1888 by the Italian physicist Galileo Ferraris, but decided Tesla's patent would probably control the market.

In July 1888, Brown and Peck negotiated a licensing deal with George Westinghouse for Tesla's polyphase induction motor and transformer designs for \$60,000 in cash and stock and a royalty of \$2.50 per AC horsepower produced by each motor. Westinghouse also hired Tesla for one year for the large fee of \$2,000 (\$52,700 in today's dollars) per month to be a consultant at the Westinghouse Electric & Manufacturing Company's Pittsburgh labs.

During that year, Tesla worked in Pittsburgh, helping to create an alternating current system to power the city's streetcars. He found the time there frustrating because of conflicts between him and the other Westinghouse engineers over how best to implement AC power. Between them, they settled on a

60-cycle AC current system Tesla proposed (to match the working frequency of Tesla's motor), although they soon found that, since Tesla's induction motor could only run at a constant speed, it would not work for street cars. They ended up using a DC traction motor instead.

Tesla's demonstration of his induction motor and Westinghouse's subsequent licensing of the patent, both in 1888, put Tesla firmly on the "AC" side of the so-called "War of Currents," an electrical distribution battle being waged between Thomas Edison and George Westinghouse that had been simmering since Westinghouse's first AC system in 1886 and had reached the point of all-out warfare by 1888. This started out as a competition between rival lighting systems with Edison holding all the patents for DC and the incandescent light and Westinghouse using his own patented AC system to power arc lights as well as incandescent lamps of a slightly different design to get around the Edison patent. The acquisition of a feasible AC motor gave Westinghouse a key patent in building a completely integrated AC system, but the financial strain of buying up patents and hiring the engineers needed to build it meant development of Tesla's motor had to be put on hold for a while. The competition resulted in Edison Machine Works pursuing AC development in 1890 and by 1892 Thomas Edison was no longer in control of his own company, which was consolidated into the conglomerate General Electric and converting to an AC delivery system at that point.

In 1893, George Westinghouse won the bid to light the 1893 World's Columbian Exposition in Chicago with alternating current, beating out a General Electric bid by one million dollars. This World's Fair devoted a building to electrical exhibits. It was a key event in the history of AC power, as Westinghouse demonstrated the safety, reliability, and efficiency of a fully integrated alternating current system to the American public. At the Columbian Exposition, under a banner announcing the "Tesla Polyphase System", Tesla demonstrated a series of electrical effects previously performed throughout America and Europe;<sup>76</sup> included using high-voltage, high-frequency alternating current to light a wireless gas-discharge lamp.<sup>79</sup> An observer noted:

In 1893 Richard Dean Adams, who headed up the Niagara Falls Cataract Construction Company sought Tesla's opinion on what system would be best to transmit power generated at the falls. Over several years there had been a series of proposals and open competitions on how best to utilize power generated by the falls with many systems being proposed by several US and European companies including two-phase and three-phase AC, high-voltage DC, and even compressed air. Adams pumped Tesla for information about the current state of all the competing systems. Tesla advised Adams that a two-phased system would be the most reliable and that there was a Westinghouse system to light incandescent bulbs using two-phase alternating current. Based on Tesla's advice and Westinghouse's demonstration that they could build a complete AC system at the Columbian Exposition, a contract for building a two-phase AC generating system at the Niagara Falls was awarded to Westinghouse Electric. A further contract to build the AC distribution system was awarded to General Electric.

The mid 1890s saw the conglomerate General Electric, backed by financier J. P. Morgan, involved in takeover attempts and patent battles with Westinghouse Electric. Although a patent-sharing agreement was signed between the two companies in 1896 Westinghouse was still cash-strapped from the financial warfare. To secure further loans, Westinghouse was forced to revisit Tesla's AC patent, which bankers considered a financial strain on the company (at that point Westinghouse had paid out an estimated \$200,000 in licenses and royalties to Tesla, Brown, and Peck). In 1897, Westinghouse explained his financial difficulties to Tesla in stark terms, saying that if things continue the way they were he would no longer be in control of Westinghouse Electric and Tesla would have to "deal with the bankers" to try to collect future royalties. Westinghouse convinced Tesla to release his company from the licensing agreement over Tesla's AC patents in exchange for Westinghouse Electric purchasing the patents for a lump sum payment of \$216,000; this provided Westinghouse a break from what, due to alternating current's rapid gain in popularity, had turned out to be an overly generous \$2.50 per AC horsepower royalty.

On 30 July 1891, at the age of 35, Tesla became a naturalized citizen of the United States, and established his South Fifth Avenue laboratory, and later another at 46 E. Houston Street, in New York. He lit electric lamps wirelessly at both locations, demonstrating the potential of wireless power transmission. In the same year, he patented the Tesla coil.

Tesla served as a vice president of the American Institute of Electrical Engineers, the forerunner (along with the Institute of Radio Engineers) of the modern-day IEEE, from 1892 to 1894.

Starting in 1894, Tesla began investigating what he referred to as radiant energy of "invisible" kinds after

he had noticed damaged film in his laboratory in previous experiments (later identified as "Roentgen rays" or "X-Rays"). His early experiments were with Crookes tubes, a cold cathode electrical discharge tube. Soon after, much of Tesla's early research—hundreds of invention models, plans, notes, laboratory data, tools, photographs, valued at \$50,000—was lost in the 5th Avenue laboratory fire of March 1895. Tesla is quoted by The New York Times as saying, "I am in too much grief to talk. What can I say?" Tesla may have inadvertently captured an X-ray image—predating, by a few weeks, Wilhelm Röntgen's December 1895 announcement of the discovery of x-rays—when he tried to photograph Mark Twain illuminated by a Geissler tube, an earlier type of gas discharge tube. The only thing captured in the image was the metal locking screw on the camera lens.:134

In March 1896, after hearing of Wilhelm Röntgen's discovery of X-ray and X-ray imaging (radiography), Tesla proceeded to do his own experiments in X-ray imaging, developing a high energy single terminal vacuum tube of his own design that had no target electrode and that worked from the output of the Tesla Coil (the modern term for the phenomenon produced by this device is bremsstrahlung or braking radiation). In his research, Tesla devised several experimental setups to produce X-rays. Tesla held that, with his circuits, the "instrument will ... enable one to generate Roentgen rays of much greater power than obtainable with ordinary apparatus."

Tesla noted the hazards of working with his circuit and single-node X-ray-producing devices. In his many notes on the early investigation of this phenomenon, he attributed the skin damage to various causes. He believed early on that damage to the skin was not caused by the Roentgen rays, but by the ozone generated in contact with the skin, and to a lesser extent, by nitrous acid. Tesla incorrectly believed that X-rays were longitudinal waves, such as those produced in waves in plasmas. These plasma waves can occur in force-free magnetic fields.

At the beginning of 1893 Westinghouse engineer Benjamin Lamme had made great progress developing an efficient version of Tesla's induction motor and Westinghouse Electric started branding their complete polyphase phase AC system as the "Tesla Polyphase System", noting how they believed Tesla's patents gave them patent priority over other AC systems.

Tesla also explained the principles of the rotating magnetic field in an induction motor by demonstrating how to make a copper egg stand on end using a device he constructed known as the Egg of Columbus. On 11 July 1934, the New York Herald Tribune published an article on Tesla, in which he recalled an event that would occasionally take place while experimenting with his single-electrode vacuum tubes; a minute particle would break off the cathode, pass out of the tube, and physically strike him. "Tesla said he could feel a sharp stinging pain where it entered his body, and again at the place where it passed out." In comparing these particles with the bits of metal projected by his "electric gun," Tesla said, "The particles in the beam of force ... will travel much faster than such particles ... and they will travel in concentrations." Tesla's theories on the possibility of the transmission by radio waves go back as far as lectures and demonstrations in 1893 in St. Louis, Missouri, the Franklin Institute in Philadelphia, Pennsylvania, and the National Electric Light Association. Tesla's demonstrations and principles were written about widely through various media outlets. Many devices such as the Tesla Coil were used in the further development of radio.

In 1898, Tesla demonstrated a radio-controlled boat—which he dubbed "teleautomaton"—to the public during an electrical exhibition at Madison Square Garden. The crowd that witnessed the demonstration made outrageous claims about the workings of the boat, such as magic, telepathy, and being piloted by a trained monkey hidden inside. Tesla tried to sell his idea to the U.S. military as a type of radio-controlled torpedo, but they showed little interest. Remote radio control remained a novelty until World War I and afterward, when a number of countries used it in military programs. Tesla took the opportunity to further demonstrate "Teleautomatics" in an address to a meeting of the Commercial Club in Chicago, while he was travelling to Colorado Springs, on 13 May 1899.

In 1900, Tesla was granted patents for a "system of transmitting electrical energy" and "an electrical transmitter." When Guglielmo Marconi made his famous first-ever transatlantic radio transmission in 1901, Tesla quipped that it was done with 17 Tesla patents, though there is little to support this claim. This was the beginning of years of patent battles over radio with Tesla's patents being upheld in 1903, followed by a reverse decision in favor of Marconi in 1904. In 1943, a Supreme Court of the United States decision restored the prior patents of Tesla, Oliver Lodge, and John Stone. The court declared that their decision had no bearing on Marconi's claim as the first to achieve radio transmission, just that since Marconi's claim to certain patents were questionable, he could not claim infringement on those same patents (there



are claims the high court was trying to nullify a World War I claim against the U.S. government by the Marconi Company via simply restoring Tesla's prior patent).

On 17 May 1899, Tesla moved to Colorado Springs, where he would have room for his high-voltage, high-frequency experiments; his lab was located near Foote Ave. and Kiowa St. He chose this location because the polyphase alternating current power distribution system had been introduced there and he had associates who were willing to give him all the power he needed without charging for it. Upon his arrival, he told reporters that he was conducting wireless telegraphy experiments, transmitting signals from Pikes Peak to Paris.[citation needed] The 1978 book *Colorado Springs Notes, 1899–1900* contains descriptions of Tesla's experiments. On 15 June 1899, Tesla performed his first experiments at his Colorado Springs lab; he recorded his initial spark length at five inches long, but very thick and noisy. Tesla investigated atmospheric electricity, observing lightning signals via his receivers. He stated that he observed stationary waves during this time. The great distances and the nature of what Tesla was detecting from lightning storms confirmed his belief that the earth had a resonant frequency.

He produced artificial lightning, with discharges consisting of millions of volts and up to 135 feet long. Thunder from the released energy was heard 15 miles away in Cripple Creek, Colorado. People walking along the street observed sparks jumping between their feet and the ground. Sparks sprang from water line taps when touched. Light bulbs within 100 feet of the lab glowed even when turned off. Horses in a livery stable bolted from their stalls after receiving shocks through their metal shoes. Butterflies were electrified, swirling in circles with blue halos of St. Elmo's fire around their wings.

While experimenting, Tesla inadvertently faulted a power station generator, causing a power outage. In August 1917, Tesla explained what had happened in *The Electrical Experimenter*: "As an example of what has been done with several hundred kilowatts of high frequency energy liberated, it was found that the dynamos in a power house six miles away were repeatedly burned out, due to the powerful high frequency currents set up in them, and which caused heavy sparks to jump through the windings and destroy the insulation!"

During his time at his lab, Tesla observed unusual signals from his receiver which he concluded may be communications from another planet. He mentioned them in a letter to reporter Julian Hawthorne at the *Philadelphia North American* on 8 December 1899 and in a December 1900 letter about possible discoveries in the new century to the Red Cross Society where he referred to messages "from another world" that read "1... 2... 3...". Reporters treated it as a sensational story and jumped to the conclusion Tesla was hearing signals from Mars. He expanded on the signals he heard in a 9 February 1901 *Collier's Weekly* article "Talking With Planets" where he said it had not been immediately apparent to him that he was hearing "intelligently controlled signals" and that the signals could come from Mars, Venus, or other planets. It has been hypothesized that he may have intercepted Marconi's European experiments in July 1899—Marconi may have transmitted the letter S (dot/dot/dot) in a naval demonstration, the same three impulses that Tesla hinted at hearing in Colorado—or signals from another experimenter in wireless transmission.

In 1899, John Jacob Astor IV invested \$100,000 for Tesla to further develop and produce a new lighting system. Instead, Tesla used the money to fund his Colorado Springs experiments.

On 7 January 1900, Tesla left Colorado Springs.[citation needed] His lab was torn down in 1904, and its contents were sold two years later to satisfy a debt.

The Colorado experiments had prepared Tesla for the establishment of the trans-Atlantic wireless telecommunications facility known as Wardencllyffe near Shoreham, Long Island.

Tesla later approached Morgan to ask for more funds to build a more powerful transmitter. When asked where all the money had gone, Tesla responded by saying that he was affected by the Panic of 1901, which he (Morgan) had caused. Morgan was shocked by the reminder of his part in the stock market crash and by Tesla's breach of contract by asking for more funds. Tesla wrote another plea to Morgan, but it was also fruitless. Morgan still owed Tesla money on the original agreement, and Tesla had been facing foreclosure even before construction of the tower began.

In December 1901, Marconi successfully transmitted the letter S from England to Newfoundland, terminating Tesla's relationship with Morgan.[improper synthesis?] Over the next five years, Tesla wrote over 50 letters to Morgan, pleading for and demanding additional funding to complete the construction of Wardencllyffe. Tesla continued the project for another nine months. The tower was erected to its full 187 feet (57 m). In July 1903, Tesla wrote to Morgan that in addition to wireless communication, Wardencllyffe would be capable of wireless transmission of electric power. On 14 October 1904, Morgan finally replied

through his secretary, stating, "It will be impossible for [me] to do anything in the matter," after Tesla had written to Morgan when the financier was meeting with the Archbishop of Canterbury in an attempt to appeal to his Christian spirit.

On his 50th birthday in 1906, Tesla demonstrated his 200 horsepower (150 kilowatts) 16,000 rpm bladeless turbine. During 1910–1911 at the Waterside Power Station in New York, several of his bladeless turbine engines were tested at 100–5,000 hp.

Tesla invented a steam-powered mechanical oscillator—Tesla's oscillator. While experimenting with mechanical oscillators at his Houston Street lab, Tesla allegedly generated a resonance of several buildings. As the speed grew, it is said that the machine oscillated at the resonance frequency of his own building and, belatedly realizing the danger, he was forced to use a sledge hammer to terminate the experiment, just as the police arrived.:162–164 In February 1912, an article—"Nikola Tesla, Dreamer" by Allan L. Benson—was published in *World Today*, in which an artist's illustration appears showing the entire earth cracking in half with the caption, "Tesla claims that in a few weeks he could set the earth's crust into such a state of vibration that it would rise and fall hundreds of feet and practically destroy civilization. A continuation of this process would, he says, eventually split the earth in two."

Tesla theorized that the application of electricity to the brain enhanced intelligence. In 1912, he crafted "a plan to make dull students bright by saturating them unconsciously with electricity," wiring the walls of a schoolroom and, "saturating [the schoolroom] with infinitesimal electric waves vibrating at high frequency. The whole room will thus, Mr. Tesla claims, be converted into a health-giving and stimulating electromagnetic field or 'bath.'" The plan was, at least provisionally approved by then superintendent of New York City schools, William H. Maxwell.

Before World War I, Tesla sought overseas investors. After the war started, Tesla lost the funding he was receiving from his patents in European countries. Eventually, he sold Wardenclyffe for \$20,000 (\$472,500 in today's dollars). In 1917, around the time that the Wardenclyffe Tower was demolished by Boldt to make the land a more viable real estate asset, Tesla received AIEE's highest honor, the Edison Medal. In the August 1917 edition of the magazine *Electrical Experimenter* Tesla postulated that electricity could be used to locate submarines via using the reflection of an "electric ray" of "tremendous frequency," with the signal being viewed on a fluorescent screen (a system that has been noted to have a superficial resemblance to modern radar). Tesla was incorrect in his assumption that high frequency radio waves would penetrate water but Émile Girardeau, who helped develop France's first radar system in the 1930s, noted in 1953 that Tesla's general speculation that a very strong high frequency signal would be needed was correct stating "(Tesla) was prophesying or dreaming, since he had at his disposal no means of carrying them out, but one must add that if he was dreaming, at least he was dreaming correctly.":266

On 6 November 1915, a Reuters news agency report from London had the 1915 Nobel Prize in Physics awarded to Thomas Edison and Nikola Tesla; however, on 15 November, a Reuters story from Stockholm stated the prize that year was being awarded to Sir William Henry Bragg and William Lawrence Bragg "for their services in the analysis of crystal structure by means of X-rays.":245 There were unsubstantiated rumors at the time that Tesla and/or Edison had refused the prize.:245 The Nobel Foundation said, "Any rumor that a person has not been given a Nobel Prize because he has made known his intention to refuse the reward is ridiculous"; a recipient could only decline a Nobel Prize after he is announced a winner.:245 There have been subsequent claims by Tesla biographers that Edison and Tesla were the original recipients and that neither was given the award because of their animosity toward each other; that each sought to minimize the other's achievements and right to win the award; that both refused ever to accept the award if the other received it first; that both rejected any possibility of sharing it; and even that a wealthy Edison refused it to keep Tesla from getting the \$20,000 prize money.:245

In the years after these rumors, neither Tesla nor Edison won the prize (although Edison did receive one of 38 possible bids in 1915 and Tesla did receive one of 38 possible bids in 1937).

In 1928, Tesla received his last patent, U.S. Patent 1,655,114, for a biplane capable of taking off vertically (VTOL aircraft) and then be "gradually tilted through manipulation of the elevator devices" in flight until it was flying like a conventional plane. Tesla thought the plane would sell for less than \$1,000.:251 Although the aircraft was probably impractical, it may be the earliest known design for what became the tiltrotor/tilt-wing concept as well as the earliest proposal for the use of turbine engines in rotor aircraft.[improper synthesis?]

Starting in 1934, the Westinghouse Electric & Manufacturing Company began paying Tesla \$125 per month as well as paying his rent at the Hotel New Yorker, expenses the Company would pay for the rest

of Tesla's life. Accounts on how this came about vary. Several sources say Westinghouse was worried about potential bad publicity surrounding the impoverished conditions their former star inventor was living under. It has been described as being couched in the form of a "consulting fee" to get around Tesla's aversion to accept charity, or by one biographer (Marc Seifer), as a type of unspecified settlement. In 1935, in an annual birthday celebration interview, Tesla announced a method of transmitting mechanical energy with minimal loss over any terrestrial distance, a related new means of communication, and a method of accurately determining the location of underground mineral deposits. In the fall of 1937, after midnight one night, Tesla left the Hotel New Yorker to make his regular commute to the cathedral and the library to feed the pigeons. While crossing a street a couple of blocks from the hotel, Tesla was unable to dodge a moving taxicab and was thrown heavily to the ground. Tesla's back was severely wrenched and three of his ribs were broken in the accident (the full extent of his injuries will never be known; Tesla refused to consult a doctor—an almost lifelong custom). Tesla didn't raise any question as to who was at fault and refused medical aid, only asking to be taken to his hotel via cab. Tesla was bedridden for some months and was unable to continue feeding pigeons from his window; soon, they failed to come. In early 1938, Tesla was able to get up. He at once resumed the pigeon-feeding walks on a much more limited scale, but frequently had a messenger act for him. Later in life, Tesla made claims concerning a "teleforce" weapon after studying the Van de Graaff generator. The press variably referred to it as a "peace ray" or death ray. Tesla described the weapon as capable of being used against ground-based infantry or for anti-aircraft purposes. In 1937, at a luncheon in his honor concerning the death ray, Tesla stated, "But it is not an experiment ... I have built, demonstrated and used it. Only a little time will pass before I can give it to the world." His records indicate that the device is based on a narrow stream of small tungsten pellets that are accelerated via high voltage (by means akin to his magnifying transformer).

During the same year, Tesla wrote a treatise, *The Art of Projecting Concentrated Non-dispersive Energy through the Natural Media*, concerning charged particle beam weapons. Tesla published the document in an attempt to expound on the technical description of a "superweapon that would put an end to all war." This treatise is currently in the Nikola Tesla Museum archive in Belgrade. It describes an open-ended vacuum tube with a gas jet seal that allows particles to exit, a method of charging particles to millions of volts, and a method of creating and directing non-dispersive particle streams (through electrostatic repulsion). Tesla tried to interest the US War Department, the United Kingdom, the Soviet Union, and Yugoslavia in the device.

During the period in which the negotiations were being conducted, Tesla said that efforts had been made to steal the invention. His room had been entered and his papers had been scrutinized, but the thieves, or spies, left empty-handed. He said that there was no danger that his invention could be stolen, for he had at no time committed any part of it to paper; the blueprint for the teleforce weapon was all in his mind. On 7 January 1943, at the age of 86, Tesla died alone in room 3327 of the New Yorker Hotel. His body was later found by maid Alice Monaghan after she had entered Tesla's room, ignoring the "do not disturb" sign that Tesla had placed on his door two days earlier. Assistant medical examiner H.W. Wembly examined the body and ruled that the cause of death had been coronary thrombosis. Tesla's remains were taken to the Frank E. Campbell Funeral Home at Madison Ave. and 81st St. A long-time friend and supporter of Tesla, Hugo Gernsback, commissioned a sculptor to create a death mask, now displayed in the Nikola Tesla Museum.

Two days later, the FBI ordered the Alien Property Custodian to seize Tesla's belongings, even though Tesla was an American citizen. Tesla's entire estate from the Hotel New Yorker and other New York City hotels was transported to the Manhattan Storage and Warehouse Company under the Office of Alien Property (OAP) seal. John G. Trump, a professor at M.I.T. and a well-known electrical engineer serving as a technical aide to the National Defense Research Committee, was called in to analyze the Tesla items in OAP custody. After a three-day investigation, Trump's report concluded that there was nothing which would constitute a hazard in unfriendly hands, stating:

On 10 January 1943, New York City mayor Fiorello La Guardia read a eulogy written by Slovene-American author Louis Adamic live over the WNYC radio while violin pieces "Ave Maria" and "Tamo daleko" were played in the background. On 12 January, two thousand people attended a state funeral for Tesla at the Cathedral of Saint John the Divine. After the funeral, Tesla's body was taken to the Ferncliff Cemetery in Ardsley, New York, where it was later cremated. The following day, a second service was conducted by prominent priests in the Trinity Chapel (today's Serbian Orthodox Cathedral of

Saint Sava) in New York City.

In 1952, following pressure from Tesla's nephew, Sava Kosanović, Tesla's entire estate was shipped to Belgrade in 80 trunks marked N.T. In 1957, Kosanović's secretary Charlotte Muzar transported Tesla's ashes from the United States to Belgrade. The ashes are displayed in a gold-plated sphere on a marble pedestal in the Nikola Tesla Museum.

Tesla obtained around 300 patents worldwide for his inventions. Some of Tesla's patents are not accounted for, and various sources have discovered some that have lain hidden in patent archives. There are a minimum of 278 patents issued to Tesla in 26 countries that have been accounted for. Many of Tesla's patents were in the United States, Britain, and Canada, but many other patents were approved in countries around the globe.:62 Many inventions developed by Tesla were not put into patent protection. Tesla worked every day from 9:00 a.m. until 6:00 p.m. or later, with dinner from exactly 8:10 p.m., at Delmonico's restaurant and later the Waldorf-Astoria Hotel. Tesla would telephone his dinner order to the headwaiter, who also could be the only one to serve him. "The meal was required to be ready at eight o'clock ... He dined alone, except on the rare occasions when he would give a dinner to a group to meet his social obligations. Tesla would then resume his work, often until 3:00 a.m.":283, 286

For exercise, Tesla walked between 8 to 10 miles per day. He squished his toes one hundred times for each foot every night, saying that it stimulated his brain cells.

In an interview with newspaper editor Arthur Brisbane, Tesla said that he did not believe in telepathy, stating, "Suppose I made up my mind to murder you," he said, "In a second you would know it. Now, isn't that wonderful? By what process does the mind get at all this?" In the same interview, Tesla said that he believed that all fundamental laws could be reduced to one.

Near the end of his life, Tesla walked to the park every day to feed the pigeons and even brought injured ones into his hotel room to nurse back to health. He said that he had been visited by a specific injured white pigeon daily. Tesla spent over \$2,000, including building a device that comfortably supported her so her bones could heal, to fix her broken wing and leg. Tesla stated,

Tesla was 6 feet 2 inches (1.88 m) tall and weighed 142 pounds (64 kg), with almost no weight variance from 1888 to about 1926.:292 He was an elegant, stylish figure in New York City, meticulous in his grooming, clothing, and regimented in his daily activities.

Tesla read many works, memorizing complete books, and supposedly possessed a photographic memory.:33 He was a polyglot, speaking eight languages: Serbo-Croatian, Czech, English, French, German, Hungarian, Italian, and Latin.:282 Tesla related in his autobiography that he experienced detailed moments of inspiration. During his early life, Tesla was repeatedly stricken with illness. He suffered a peculiar affliction in which blinding flashes of light would appear before his eyes, often accompanied by visions.:33 Often, the visions were linked to a word or idea he might have come across; at other times they would provide the solution to a particular problem he had encountered. Just by hearing the name of an item, he would be able to envision it in realistic detail.:33 Tesla would visualize an invention in his mind with extreme precision, including all dimensions, before moving to the construction stage, a technique sometimes known as picture thinking. He typically did not make drawings by hand but worked from memory. Beginning in his childhood, Tesla had frequent flashbacks to events that had happened previously in his life.:33

During his second year of study at Graz, Tesla developed a passion for (and became very proficient at) billiards, chess and card-playing, sometimes spending more than 48 hours in a stretch at a gaming table.:43, 301 On one occasion at his laboratory, Tesla worked for a period of 84 hours without sleep or rest.:208 Kenneth Swezey, a journalist whom Tesla had befriended, confirmed that Tesla rarely slept. Swezey recalled one morning when Tesla called him at 3 a.m.: "I was sleeping in my room like one dead ... Suddenly, the telephone ring awakened me ... [Tesla] spoke animatedly, with pauses, [as he] ... work[ed] out a problem, comparing one theory to another, commenting; and when he felt he had arrived at the solution, he suddenly closed the telephone."

Tesla never married; he said his chastity was very helpful to his scientific abilities.:33 However, toward the end of his life, he told a reporter, "Sometimes I feel that by not marrying, I made too great a sacrifice to my work ..." There have been numerous accounts of women vying for Tesla's affection, even some madly in love with him.[citation needed] Tesla, though polite and soft-spoken, did not have any known relationships.

Tesla was asocial and prone to seclude himself with his work. However, when he did engage in a social life, many people spoke very positively and admiringly of Tesla. Robert Underwood Johnson described

him as attaining a "distinguished sweetness, sincerity, modesty, refinement, generosity, and force." His loyal secretary, Dorothy Skeritt, wrote: "his genial smile and nobility of bearing always denoted the gentlemanly characteristics that were so ingrained in his soul." Tesla's friend, Julian Hawthorne, wrote, "seldom did one meet a scientist or engineer who was also a poet, a philosopher, an appreciator of fine music, a linguist, and a connoisseur of food and drink.":80

Tesla was a good friend of Francis Marion Crawford, Robert Underwood Johnson, Stanford White, Fritz Lowenstein, George Scherff, and Kenneth Swezey. In middle age, Tesla became a close friend of Mark Twain; they spent a lot of time together in his lab and elsewhere. Twain notably described Tesla's induction motor invention as "the most valuable patent since the telephone." In the late 1920s, Tesla also befriended George Sylvester Viereck, a poet, writer, mystic, and later, a Nazi propagandist. Tesla occasionally attended dinner parties held by Viereck and his wife.

Tesla could be harsh at times and openly expressed disgust for overweight people, such as when he fired a secretary because of her weight.:110 He was quick to criticize clothing; on several occasions, Tesla directed a subordinate to go home and change her dress.:33

Tesla exhibited a pre-atomic understanding of physics in his writings; he disagreed with the theory of atoms being composed of smaller subatomic particles, stating there was no such thing as an electron creating an electric charge (he believed that if electrons existed at all, they were some fourth state of matter or "sub-atom" that could only exist in an experimental vacuum and that they had nothing to do with electricity).:249 Tesla believed that atoms are immutable—they could not change state or be split in any way. He was a believer in the 19th century concept of an all pervasive "ether" that transmitted electrical energy.

Tesla was generally antagonistic towards theories about the conversion of matter into energy.:247 He was also critical of Einstein's theory of relativity, saying:

Tesla claimed to have developed his own physical principle regarding matter and energy that he started working on in 1892, and in 1937, at age 81, claimed in a letter to have completed a "dynamic theory of gravity" that "[would] put an end to idle speculations and false conceptions, as that of curved space." He stated that the theory was "worked out in all details" and that he hoped to soon give it to the world. Further elucidation of his theory was never found in his writings.:309

Tesla, like many of his era, became a proponent of an imposed selective breeding version of eugenics. His opinion stemmed from the belief that humans' "pity" had interfered with the natural "ruthless workings of nature," rather than from conceptions of a "master race" or inherent superiority of one person over another. His advocacy of it was, however, to push it further. In a 1937 interview, he stated:

In 1926, Tesla commented on the ills of the social subservience of women and the struggle of women toward gender equality, and indicated that humanity's future would be run by "Queen Bees." He believed that women would become the dominant sex in the future.

Tesla made predictions about the relevant issues of a post-World War I environment in a printed article, "Science and Discovery are the great Forces which will lead to the Consummation of the War" (20 December 1914). Tesla believed that the League of Nations was not a remedy for the times and issues.[citation needed]

Tesla was raised an Orthodox Christian. Later in his life, he did not consider himself to be a "believer in the orthodox sense," and opposed religious fanaticism. Despite this, he had a profound respect for both Buddhism and Christianity.

However, his religious views remain uncertain due to other statements that he made. For example, in his article, "A Machine to End War", published in 1937, Tesla stated:

Tesla wrote a number of books and articles for magazines and journals. Among his books are *My Inventions: The Autobiography of Nikola Tesla*, compiled and edited by Ben Johnston; *The Fantastic Inventions of Nikola Tesla*, compiled and edited by David Hatcher Childress; and *The Tesla Papers*. Many of Tesla's writings are freely available on the web, including the article "The Problem of Increasing Human Energy," published in *The Century Magazine* in 1900, and the article "Experiments With Alternate Currents Of High Potential And High Frequency," published in his book *Inventions, Researches and Writings of Nikola Tesla*.

Tesla's legacy has endured in books, films, radio, TV, music, live theater, comics and video games. The impact of the technologies invented or envisioned by Tesla is a recurring theme in several types of science fiction.

On Tesla's 75th birthday in 1931, *Time* magazine put him on its cover. The cover caption "All the world's

his power house" noted his contribution to electrical power generation. He received congratulatory letters from more than 70 pioneers in science and engineering, including Albert Einstein.

Computational complexity theory is a branch of the theory of computation in theoretical computer science that focuses on classifying computational problems according to their inherent difficulty, and relating those classes to each other. A computational problem is understood to be a task that is in principle amenable to being solved by a computer, which is equivalent to stating that the problem may be solved by mechanical application of mathematical steps, such as an algorithm.

A problem is regarded as inherently difficult if its solution requires significant resources, whatever the algorithm used. The theory formalizes this intuition, by introducing mathematical models of computation to study these problems and quantifying the amount of resources needed to solve them, such as time and storage. Other complexity measures are also used, such as the amount of communication (used in communication complexity), the number of gates in a circuit (used in circuit complexity) and the number of processors (used in parallel computing). One of the roles of computational complexity theory is to determine the practical limits on what computers can and cannot do.

Closely related fields in theoretical computer science are analysis of algorithms and computability theory. A key distinction between analysis of algorithms and computational complexity theory is that the former is devoted to analyzing the amount of resources needed by a particular algorithm to solve a problem, whereas the latter asks a more general question about all possible algorithms that could be used to solve the same problem. More precisely, it tries to classify problems that can or cannot be solved with appropriately restricted resources. In turn, imposing restrictions on the available resources is what distinguishes computational complexity from computability theory: the latter theory asks what kind of problems can, in principle, be solved algorithmically.

A computational problem can be viewed as an infinite collection of instances together with a solution for every instance. The input string for a computational problem is referred to as a problem instance, and should not be confused with the problem itself. In computational complexity theory, a problem refers to the abstract question to be solved. In contrast, an instance of this problem is a rather concrete utterance, which can serve as the input for a decision problem. For example, consider the problem of primality testing. The instance is a number (e.g. 15) and the solution is "yes" if the number is prime and "no" otherwise (in this case "no"). Stated another way, the instance is a particular input to the problem, and the solution is the output corresponding to the given input.

To further highlight the difference between a problem and an instance, consider the following instance of the decision version of the traveling salesman problem: Is there a route of at most 2000 kilometres passing through all of Germany's 15 largest cities? The quantitative answer to this particular problem instance is of little use for solving other instances of the problem, such as asking for a round trip through all sites in Milan whose total length is at most 10 km. For this reason, complexity theory addresses computational problems and not particular problem instances.

When considering computational problems, a problem instance is a string over an alphabet. Usually, the alphabet is taken to be the binary alphabet (i.e., the set  $\{0,1\}$ ), and thus the strings are bitstrings. As in a real-world computer, mathematical objects other than bitstrings must be suitably encoded. For example, integers can be represented in binary notation, and graphs can be encoded directly via their adjacency matrices, or by encoding their adjacency lists in binary.

Decision problems are one of the central objects of study in computational complexity theory. A decision problem is a special type of computational problem whose answer is either yes or no, or alternately either 1 or 0. A decision problem can be viewed as a formal language, where the members of the language are instances whose output is yes, and the non-members are those instances whose output is no. The objective is to decide, with the aid of an algorithm, whether a given input string is a member of the formal language under consideration. If the algorithm deciding this problem returns the answer yes, the algorithm is said to accept the input string, otherwise it is said to reject the input.

An example of a decision problem is the following. The input is an arbitrary graph. The problem consists in deciding whether the given graph is connected, or not. The formal language associated with this decision problem is then the set of all connected graphs—of course, to obtain a precise definition of this language, one has to decide how graphs are encoded as binary strings.

A function problem is a computational problem where a single output (of a total function) is expected for every input, but the output is more complex than that of a decision problem, that is, it isn't just yes or no. Notable examples include the traveling salesman problem and the integer factorization problem.

It is tempting to think that the notion of function problems is much richer than the notion of decision problems. However, this is not really the case, since function problems can be recast as decision problems. For example, the multiplication of two integers can be expressed as the set of triples  $(a, b, c)$  such that the relation  $a \times b = c$  holds. Deciding whether a given triple is a member of this set corresponds to solving the problem of multiplying two numbers.

To measure the difficulty of solving a computational problem, one may wish to see how much time the best algorithm requires to solve the problem. However, the running time may, in general, depend on the instance. In particular, larger instances will require more time to solve. Thus the time required to solve a problem (or the space required, or any measure of complexity) is calculated as a function of the size of the instance. This is usually taken to be the size of the input in bits. Complexity theory is interested in how algorithms scale with an increase in the input size. For instance, in the problem of finding whether a graph is connected, how much more time does it take to solve a problem for a graph with  $2n$  vertices compared to the time taken for a graph with  $n$  vertices?

If the input size is  $n$ , the time taken can be expressed as a function of  $n$ . Since the time taken on different inputs of the same size can be different, the worst-case time complexity  $T(n)$  is defined to be the maximum time taken over all inputs of size  $n$ . If  $T(n)$  is a polynomial in  $n$ , then the algorithm is said to be a polynomial time algorithm. Cobham's thesis says that a problem can be solved with a feasible amount of resources if it admits a polynomial time algorithm.

A Turing machine is a mathematical model of a general computing machine. It is a theoretical device that manipulates symbols contained on a strip of tape. Turing machines are not intended as a practical computing technology, but rather as a thought experiment representing a computing machine—anything from an advanced supercomputer to a mathematician with a pencil and paper. It is believed that if a problem can be solved by an algorithm, there exists a Turing machine that solves the problem. Indeed, this is the statement of the Church–Turing thesis. Furthermore, it is known that everything that can be computed on other models of computation known to us today, such as a RAM machine, Conway's Game of Life, cellular automata or any programming language can be computed on a Turing machine. Since Turing machines are easy to analyze mathematically, and are believed to be as powerful as any other model of computation, the Turing machine is the most commonly used model in complexity theory.

A deterministic Turing machine is the most basic Turing machine, which uses a fixed set of rules to determine its future actions. A probabilistic Turing machine is a deterministic Turing machine with an extra supply of random bits. The ability to make probabilistic decisions often helps algorithms solve problems more efficiently. Algorithms that use random bits are called randomized algorithms. A non-deterministic Turing machine is a deterministic Turing machine with an added feature of non-determinism, which allows a Turing machine to have multiple possible future actions from a given state. One way to view non-determinism is that the Turing machine branches into many possible computational paths at each step, and if it solves the problem in any of these branches, it is said to have solved the problem. Clearly, this model is not meant to be a physically realizable model, it is just a theoretically interesting abstract machine that gives rise to particularly interesting complexity classes. For examples, see non-deterministic algorithm.

Many types of Turing machines are used to define complexity classes, such as deterministic Turing machines, probabilistic Turing machines, non-deterministic Turing machines, quantum Turing machines, symmetric Turing machines and alternating Turing machines. They are all equally powerful in principle, but when resources (such as time or space) are bounded, some of these may be more powerful than others.

Many machine models different from the standard multi-tape Turing machines have been proposed in the literature, for example random access machines. Perhaps surprisingly, each of these models can be converted to another without providing any extra computational power. The time and memory consumption of these alternate models may vary. What all these models have in common is that the machines operate deterministically.

However, some computational problems are easier to analyze in terms of more unusual resources. For example, a non-deterministic Turing machine is a computational model that is allowed to branch out to check many different possibilities at once. The non-deterministic Turing machine has very little to do with how we physically want to compute algorithms, but its branching exactly captures many of the mathematical models we want to analyze, so that non-deterministic time is a very important resource in analyzing computational problems.

For a precise definition of what it means to solve a problem using a given amount of time and space, a computational model such as the deterministic Turing machine is used. The time required by a deterministic Turing machine  $M$  on input  $x$  is the total number of state transitions, or steps, the machine makes before it halts and outputs the answer ("yes" or "no"). A Turing machine  $M$  is said to operate within time  $f(n)$ , if the time required by  $M$  on each input of length  $n$  is at most  $f(n)$ . A decision problem  $A$  can be solved in time  $f(n)$  if there exists a Turing machine operating in time  $f(n)$  that solves the problem. Since complexity theory is interested in classifying problems based on their difficulty, one defines sets of problems based on some criteria. For instance, the set of problems solvable within time  $f(n)$  on a deterministic Turing machine is then denoted by  $\text{DTIME}(f(n))$ .

Analogous definitions can be made for space requirements. Although time and space are the most well-known complexity resources, any complexity measure can be viewed as a computational resource. Complexity measures are very generally defined by the Blum complexity axioms. Other complexity measures used in complexity theory include communication complexity, circuit complexity, and decision tree complexity.

The best, worst and average case complexity refer to three different ways of measuring the time complexity (or any other complexity measure) of different inputs of the same size. Since some inputs of size  $n$  may be faster to solve than others, we define the following complexities:

For example, consider the deterministic sorting algorithm quicksort. This solves the problem of sorting a list of integers that is given as the input. The worst-case is when the input is sorted or sorted in reverse order, and the algorithm takes time  $O(n^2)$  for this case. If we assume that all possible permutations of the input list are equally likely, the average time taken for sorting is  $O(n \log n)$ . The best case occurs when each pivoting divides the list in half, also needing  $O(n \log n)$  time.

To classify the computation time (or similar resources, such as space consumption), one is interested in proving upper and lower bounds on the minimum amount of time required by the most efficient algorithm solving a given problem. The complexity of an algorithm is usually taken to be its worst-case complexity, unless specified otherwise. Analyzing a particular algorithm falls under the field of analysis of algorithms. To show an upper bound  $T(n)$  on the time complexity of a problem, one needs to show only that there is a particular algorithm with running time at most  $T(n)$ . However, proving lower bounds is much more difficult, since lower bounds make a statement about all possible algorithms that solve a given problem. The phrase "all possible algorithms" includes not just the algorithms known today, but any algorithm that might be discovered in the future. To show a lower bound of  $T(n)$  for a problem requires showing that no algorithm can have time complexity lower than  $T(n)$ .

Upper and lower bounds are usually stated using the big  $O$  notation, which hides constant factors and smaller terms. This makes the bounds independent of the specific details of the computational model used. For instance, if  $T(n) = 7n^2 + 15n + 40$ , in big  $O$  notation one would write  $T(n) = O(n^2)$ .

Of course, some complexity classes have complicated definitions that do not fit into this framework. Thus, a typical complexity class has a definition like the following:

But bounding the computation time above by some concrete function  $f(n)$  often yields complexity classes that depend on the chosen machine model. For instance, the language  $\{xx \mid x \text{ is any binary string}\}$  can be solved in linear time on a multi-tape Turing machine, but necessarily requires quadratic time in the model of single-tape Turing machines. If we allow polynomial variations in running time, Cobham-Edmonds thesis states that "the time complexities in any two reasonable and general models of computation are polynomially related" (Goldreich 2008, Chapter 1.2). This forms the basis for the complexity class  $P$ , which is the set of decision problems solvable by a deterministic Turing machine within polynomial time. The corresponding set of function problems is  $FP$ .

Many important complexity classes can be defined by bounding the time or space used by the algorithm. Some important complexity classes of decision problems defined in this manner are the following:

Other important complexity classes include  $BPP$ ,  $ZPP$  and  $RP$ , which are defined using probabilistic Turing machines;  $AC$  and  $NC$ , which are defined using Boolean circuits; and  $BQP$  and  $QMA$ , which are defined using quantum Turing machines.  $\#P$  is an important complexity class of counting problems (not decision problems). Classes like  $IP$  and  $AM$  are defined using Interactive proof systems.  $ALL$  is the class of all decision problems.

For the complexity classes defined in this way, it is desirable to prove that relaxing the requirements on (say) computation time indeed defines a bigger set of problems. In particular, although  $\text{DTIME}(n)$  is contained in  $\text{DTIME}(n^2)$ , it would be interesting to know if the inclusion is strict. For time and space



requirements, the answer to such questions is given by the time and space hierarchy theorems respectively. They are called hierarchy theorems because they induce a proper hierarchy on the classes defined by constraining the respective resources. Thus there are pairs of complexity classes such that one is properly included in the other. Having deduced such proper set inclusions, we can proceed to make quantitative statements about how much more additional time or space is needed in order to increase the number of problems that can be solved.

The time and space hierarchy theorems form the basis for most separation results of complexity classes. For instance, the time hierarchy theorem tells us that  $P$  is strictly contained in  $EXPTIME$ , and the space hierarchy theorem tells us that  $L$  is strictly contained in  $PSPACE$ .

Many complexity classes are defined using the concept of a reduction. A reduction is a transformation of one problem into another problem. It captures the informal notion of a problem being at least as difficult as another problem. For instance, if a problem  $X$  can be solved using an algorithm for  $Y$ ,  $X$  is no more difficult than  $Y$ , and we say that  $X$  reduces to  $Y$ . There are many different types of reductions, based on the method of reduction, such as Cook reductions, Karp reductions and Levin reductions, and the bound on the complexity of reductions, such as polynomial-time reductions or log-space reductions.

The most commonly used reduction is a polynomial-time reduction. This means that the reduction process takes polynomial time. For example, the problem of squaring an integer can be reduced to the problem of multiplying two integers. This means an algorithm for multiplying two integers can be used to square an integer. Indeed, this can be done by giving the same input to both inputs of the multiplication algorithm. Thus we see that squaring is not more difficult than multiplication, since squaring can be reduced to multiplication.

This motivates the concept of a problem being hard for a complexity class. A problem  $X$  is hard for a class of problems  $C$  if every problem in  $C$  can be reduced to  $X$ . Thus no problem in  $C$  is harder than  $X$ , since an algorithm for  $X$  allows us to solve any problem in  $C$ . Of course, the notion of hard problems depends on the type of reduction being used. For complexity classes larger than  $P$ , polynomial-time reductions are commonly used. In particular, the set of problems that are hard for  $NP$  is the set of  $NP$ -hard problems. If a problem  $X$  is in  $C$  and hard for  $C$ , then  $X$  is said to be complete for  $C$ . This means that  $X$  is the hardest problem in  $C$ . (Since many problems could be equally hard, one might say that  $X$  is one of the hardest problems in  $C$ .) Thus the class of  $NP$ -complete problems contains the most difficult problems in  $NP$ , in the sense that they are the ones most likely not to be in  $P$ . Because the problem  $P = NP$  is not solved, being able to reduce a known  $NP$ -complete problem,  $\Pi_2$ , to another problem,  $\Pi_1$ , would indicate that there is no known polynomial-time solution for  $\Pi_1$ . This is because a polynomial-time solution to  $\Pi_1$  would yield a polynomial-time solution to  $\Pi_2$ . Similarly, because all  $NP$  problems can be reduced to the set, finding an  $NP$ -complete problem that can be solved in polynomial time would mean that  $P = NP$ .

The complexity class  $P$  is often seen as a mathematical abstraction modeling those computational tasks that admit an efficient algorithm. This hypothesis is called the Cobham–Edmonds thesis. The complexity class  $NP$ , on the other hand, contains many problems that people would like to solve efficiently, but for which no efficient algorithm is known, such as the Boolean satisfiability problem, the Hamiltonian path problem and the vertex cover problem. Since deterministic Turing machines are special non-deterministic Turing machines, it is easily observed that each problem in  $P$  is also member of the class  $NP$ .

The question of whether  $P$  equals  $NP$  is one of the most important open questions in theoretical computer science because of the wide implications of a solution. If the answer is yes, many important problems can be shown to have more efficient solutions. These include various types of integer programming problems in operations research, many problems in logistics, protein structure prediction in biology, and the ability to find formal proofs of pure mathematics theorems. The  $P$  versus  $NP$  problem is one of the Millennium Prize Problems proposed by the Clay Mathematics Institute. There is a US\$1,000,000 prize for resolving the problem.

It was shown by Ladner that if  $P \neq NP$  then there exist problems in  $NP$  that are neither in  $P$  nor  $NP$ -complete. Such problems are called  $NP$ -intermediate problems. The graph isomorphism problem, the discrete logarithm problem and the integer factorization problem are examples of problems believed to be  $NP$ -intermediate. They are some of the very few  $NP$  problems not known to be in  $P$  or to be  $NP$ -complete.

The graph isomorphism problem is the computational problem of determining whether two finite graphs are isomorphic. An important unsolved problem in complexity theory is whether the graph isomorphism problem is in  $P$ ,  $NP$ -complete, or  $NP$ -intermediate. The answer is not known, but it is believed that the

problem is at least not NP-complete. If graph isomorphism is NP-complete, the polynomial time hierarchy collapses to its second level. Since it is widely believed that the polynomial hierarchy does not collapse to any finite level, it is believed that graph isomorphism is not NP-complete. The best algorithm for this problem, due to Laszlo Babai and Eugene Luks has run time  $2O(\sqrt{n \log(n)})$  for graphs with  $n$  vertices. The integer factorization problem is the computational problem of determining the prime factorization of a given integer. Phrased as a decision problem, it is the problem of deciding whether the input has a factor less than  $k$ . No efficient integer factorization algorithm is known, and this fact forms the basis of several modern cryptographic systems, such as the RSA algorithm. The integer factorization problem is in NP and in co-NP (and even in UP and co-UP). If the problem is NP-complete, the polynomial time hierarchy will collapse to its first level (i.e., NP will equal co-NP). The best known algorithm for integer factorization is the general number field sieve, which takes time  $O(e^{(64/9)^{1/3}(n \log 2)^{1/3}(\log(n \log 2))^{2/3}})$  to factor an  $n$ -bit integer. However, the best known quantum algorithm for this problem, Shor's algorithm, does run in polynomial time. Unfortunately, this fact doesn't say much about where the problem lies with respect to non-quantum complexity classes.

Many known complexity classes are suspected to be unequal, but this has not been proved. For instance  $P \neq NP \neq PP \neq PSPACE$ , but it is possible that  $P = PSPACE$ . If  $P$  is not equal to  $NP$ , then  $P$  is not equal to  $PSPACE$  either. Since there are many known complexity classes between  $P$  and  $PSPACE$ , such as  $RP$ ,  $BPP$ ,  $PP$ ,  $BQP$ ,  $MA$ ,  $PH$ , etc., it is possible that all these complexity classes collapse to one class. Proving that any of these classes are unequal would be a major breakthrough in complexity theory.

Along the same lines, co-NP is the class containing the complement problems (i.e. problems with the yes/no answers reversed) of NP problems. It is believed that  $NP$  is not equal to co-NP; however, it has not yet been proven. It has been shown that if these two complexity classes are not equal then  $P$  is not equal to  $NP$ .

Similarly, it is not known if  $L$  (the set of all problems that can be solved in logarithmic space) is strictly contained in  $P$  or equal to  $P$ . Again, there are many complexity classes between the two, such as  $NL$  and  $NC$ , and it is not known if they are distinct or equal classes.

Problems that can be solved in theory (e.g., given large but finite time), but which in practice take too long for their solutions to be useful, are known as intractable problems. In complexity theory, problems that lack polynomial-time solutions are considered to be intractable for more than the smallest inputs. In fact, the Cobham–Edmonds thesis states that only those problems that can be solved in polynomial time can be feasibly computed on some computational device. Problems that are known to be intractable in this sense include those that are EXPTIME-hard. If  $NP$  is not the same as  $P$ , then the NP-complete problems are also intractable in this sense. To see why exponential-time algorithms might be unusable in practice, consider a program that makes  $2^n$  operations before halting. For small  $n$ , say 100, and assuming for the sake of example that the computer does  $10^{12}$  operations each second, the program would run for about  $4 \times 10^{10}$  years, which is the same order of magnitude as the age of the universe. Even with a much faster computer, the program would only be useful for very small instances and in that sense the intractability of a problem is somewhat independent of technological progress. Nevertheless, a polynomial time algorithm is not always practical. If its running time is, say,  $n^{15}$ , it is unreasonable to consider it efficient and it is still useless except on small instances.

What intractability means in practice is open to debate. Saying that a problem is not in  $P$  does not imply that all large cases of the problem are hard or even that most of them are. For example, the decision problem in Presburger arithmetic has been shown not to be in  $P$ , yet algorithms have been written that solve the problem in reasonable times in most cases. Similarly, algorithms can solve the NP-complete knapsack problem over a wide range of sizes in less than quadratic time and SAT solvers routinely handle large instances of the NP-complete Boolean satisfiability problem.

Before the actual research explicitly devoted to the complexity of algorithmic problems started off, numerous foundations were laid out by various researchers. Most influential among these was the definition of Turing machines by Alan Turing in 1936, which turned out to be a very robust and flexible simplification of a computer.

As Fortnow & Homer (2003) point out, the beginning of systematic studies in computational complexity is attributed to the seminal paper "On the Computational Complexity of Algorithms" by Juris Hartmanis and Richard Stearns (1965), which laid out the definitions of time and space complexity and proved the hierarchy theorems. Also, in 1965 Edmonds defined a "good" algorithm as one with running time bounded by a polynomial of the input size.

Earlier papers studying problems solvable by Turing machines with specific bounded resources include John Myhill's definition of linear bounded automata (Myhill 1960), Raymond Smullyan's study of rudimentary sets (1961), as well as Hisao Yamada's paper on real-time computations (1962). Somewhat earlier, Boris Trakhtenbrot (1956), a pioneer in the field from the USSR, studied another specific complexity measure. As he remembers:

Even though some proofs of complexity-theoretic theorems regularly assume some concrete choice of input encoding, one tries to keep the discussion abstract enough to be independent of the choice of encoding. This can be achieved by ensuring that different representations can be transformed into each other efficiently.

In 1967, Manuel Blum developed an axiomatic complexity theory based on his axioms and proved an important result, the so-called, speed-up theorem. The field really began to flourish in 1971 when the US researcher Stephen Cook and, working independently, Leonid Levin in the USSR, proved that there exist practically relevant problems that are NP-complete. In 1972, Richard Karp took this idea a leap forward with his landmark paper, "Reducibility Among Combinatorial Problems", in which he showed that 21 diverse combinatorial and graph theoretical problems, each infamous for its computational intractability, are NP-complete.

The role of teacher is often formal and ongoing, carried out at a school or other place of formal education. In many countries, a person who wishes to become a teacher must first obtain specified professional qualifications or credentials from a university or college. These professional qualifications may include the study of pedagogy, the science of teaching. Teachers, like other professionals, may have to continue their education after they qualify, a process known as continuing professional development. Teachers may use a lesson plan to facilitate student learning, providing a course of study which is called the curriculum.

A teacher's role may vary among cultures. Teachers may provide instruction in literacy and numeracy, craftsmanship or vocational training, the arts, religion, civics, community roles, or life skills.

In some countries, formal education can take place through home schooling. Informal learning may be assisted by a teacher occupying a transient or ongoing role, such as a family member, or by anyone with knowledge or skills in the wider community setting.

Religious and spiritual teachers, such as gurus, mullahs, rabbis, pastors/youth pastors and lamas, may teach religious texts such as the Quran, Torah or Bible.

Teaching may be carried out informally, within the family, which is called homeschooling, or in the wider community. Formal teaching may be carried out by paid professionals. Such professionals enjoy a status in some societies on a par with physicians, lawyers, engineers, and accountants (Chartered or CPA).

A teacher's professional duties may extend beyond formal teaching. Outside of the classroom teachers may accompany students on field trips, supervise study halls, help with the organization of school functions, and serve as supervisors for extracurricular activities. In some education systems, teachers may have responsibility for student discipline.

There are a variety of bodies designed to instill, preserve and update the knowledge and professional standing of teachers. Around the world many governments operate teacher's colleges, which are generally established to serve and protect the public interest through certifying, governing and enforcing the standards of practice for the teaching profession.

The functions of the teacher's colleges may include setting out clear standards of practice, providing for the ongoing education of teachers, investigating complaints involving members, conducting hearings into allegations of professional misconduct and taking appropriate disciplinary action and accrediting teacher education programs. In many situations teachers in publicly funded schools must be members in good standing with the college, and private schools may also require their teachers to be college peoples. In other areas these roles may belong to the State Board of Education, the Superintendent of Public Instruction, the State Education Agency or other governmental bodies. In still other areas Teaching Unions may be responsible for some or all of these duties.

In education, teachers facilitate student learning, often in a school or academy or perhaps in another environment such as outdoors. A teacher who teaches on an individual basis may be described as a tutor.

The objective is typically accomplished through either an informal or formal approach to learning, including a course of study and lesson plan that teaches skills, knowledge and/or thinking skills. Different ways to teach are often referred to as pedagogy. When deciding what teaching method to use teachers consider students' background knowledge, environment, and their learning goals as well as standardized

curricula as determined by the relevant authority. Many times, teachers assist in learning outside of the classroom by accompanying students on field trips. The increasing use of technology, specifically the rise of the internet over the past decade, has begun to shape the way teachers approach their roles in the classroom.

The objective is typically a course of study, lesson plan, or a practical skill. A teacher may follow standardized curricula as determined by the relevant authority. The teacher may interact with students of different ages, from infants to adults, students with different abilities and students with learning disabilities.

Teaching using pedagogy also involve assessing the educational levels of the students on particular skills. Understanding the pedagogy of the students in a classroom involves using differentiated instruction as well as supervision to meet the needs of all students in the classroom. Pedagogy can be thought of in two manners. First, teaching itself can be taught in many different ways, hence, using a pedagogy of teaching styles. Second, the pedagogy of the learners comes into play when a teacher assesses the pedagogic diversity of his/her students and differentiates for the individual students accordingly. For example, an experienced teacher and parent described the place of a teacher in learning as follows: "The real bulk of learning takes place in self-study and problem solving with a lot of feedback around that loop. The function of the teacher is to pressure the lazy, inspire the bored, deflate the cocky, encourage the timid, detect and correct individual flaws, and broaden the viewpoint of all. This function looks like that of a coach using the whole gamut of psychology to get each new class of rookies off the bench and into the game."

Perhaps the most significant difference between primary school and secondary school teaching is the relationship between teachers and children. In primary schools each class has a teacher who stays with them for most of the week and will teach them the whole curriculum. In secondary schools they will be taught by different subject specialists each session during the week and may have ten or more different teachers. The relationship between children and their teachers tends to be closer in the primary school where they act as form tutor, specialist teacher and surrogate parent during the course of the day.

This is true throughout most of the United States as well. However, alternative approaches for primary education do exist. One of these, sometimes referred to as a "platoon" system, involves placing a group of students together in one class that moves from one specialist to another for every subject. The advantage here is that students learn from teachers who specialize in one subject and who tend to be more knowledgeable in that one area than a teacher who teaches many subjects. Students still derive a strong sense of security by staying with the same group of peers for all classes.

Co-teaching has also become a new trend amongst educational institutions. Co-teaching is defined as two or more teachers working harmoniously to fulfill the needs of every student in the classroom.

Co-teaching focuses the student on learning by providing a social networking support that allows them to reach their full cognitive potential. Co-teachers work in sync with one another to create a climate of learning.

Throughout the history of education the most common form of school discipline was corporal punishment. While a child was in school, a teacher was expected to act as a substitute parent, with all the normal forms of parental discipline open to them.

In past times, corporal punishment (spanking or paddling or caning or strapping or birching the student in order to cause physical pain) was one of the most common forms of school discipline throughout much of the world. Most Western countries, and some others, have now banned it, but it remains lawful in the United States following a US Supreme Court decision in 1977 which held that paddling did not violate the US Constitution.

30 US states have banned corporal punishment, the others (mostly in the South) have not. It is still used to a significant (though declining) degree in some public schools in Alabama, Arkansas, Georgia, Louisiana, Mississippi, Oklahoma, Tennessee and Texas. Private schools in these and most other states may also use it. Corporal punishment in American schools is administered to the seat of the student's trousers or skirt with a specially made wooden paddle. This often used to take place in the classroom or hallway, but nowadays the punishment is usually given privately in the principal's office.

Official corporal punishment, often by caning, remains commonplace in schools in some Asian, African and Caribbean countries. For details of individual countries see School corporal punishment.

Currently detention is one of the most common punishments in schools in the United States, the UK, Ireland, Singapore and other countries. It requires the pupil to remain in school at a given time in the

school day (such as lunch, recess or after school); or even to attend school on a non-school day, e.g. "Saturday detention" held at some schools. During detention, students normally have to sit in a classroom and do work, write lines or a punishment essay, or sit quietly.

A modern example of school discipline in North America and Western Europe relies upon the idea of an assertive teacher who is prepared to impose their will upon a class. Positive reinforcement is balanced with immediate and fair punishment for misbehavior and firm, clear boundaries define what is appropriate and inappropriate behavior. Teachers are expected to respect their students; sarcasm and attempts to humiliate pupils are seen as falling outside of what constitutes reasonable discipline.[verification needed] Whilst this is the consensus viewpoint amongst the majority of academics, some teachers and parents advocate a more assertive and confrontational style of discipline.[citation needed] Such individuals claim that many problems with modern schooling stem from the weakness in school discipline and if teachers exercised firm control over the classroom they would be able to teach more efficiently. This viewpoint is supported by the educational attainment of countries—in East Asia for instance—that combine strict discipline with high standards of education.[citation needed]

It's not clear, however that this stereotypical view reflects the reality of East Asian classrooms or that the educational goals in these countries are commensurable with those in Western countries. In Japan, for example, although average attainment on standardized tests may exceed those in Western countries, classroom discipline and behavior is highly problematic. Although, officially, schools have extremely rigid codes of behavior, in practice many teachers find the students unmanageable and do not enforce discipline at all.

Where school class sizes are typically 40 to 50 students, maintaining order in the classroom can divert the teacher from instruction, leaving little opportunity for concentration and focus on what is being taught. In response, teachers may concentrate their attention on motivated students, ignoring attention-seeking and disruptive students. The result of this is that motivated students, facing demanding university entrance examinations, receive disproportionate resources. Given the emphasis on attainment of university places, administrators and governors may regard this policy as appropriate.

Sudbury model democratic schools claim that popularly based authority can maintain order more effectively than dictatorial authority for governments and schools alike. They also claim that in these schools the preservation of public order is easier and more efficient than anywhere else. Primarily because rules and regulations are made by the community as a whole, thence the school atmosphere is one of persuasion and negotiation, rather than confrontation since there is no one to confront. Sudbury model democratic schools' proponents argue that a school that has good, clear laws, fairly and democratically passed by the entire school community, and a good judicial system for enforcing these laws, is a school in which community discipline prevails, and in which an increasingly sophisticated concept of law and order develops, against other schools today, where rules are arbitrary, authority is absolute, punishment is capricious, and due process of law is unknown.

Since teachers can affect how students perceive the course materials, it has been found that teachers who showed enthusiasm towards the course materials and students can affect a positive learning experience towards the course materials. On teacher/course evaluations, it was found that teachers who have a positive disposition towards the course content tend to transfer their passion to receptive students. These teachers do not teach by rote but attempt to find new invigoration for the course materials on a daily basis. One of the difficulties in this approach is that teachers may have repeatedly covered a curriculum until they begin to feel bored with the subject which in turn bores the students as well. Students who had enthusiastic teachers tend to rate them higher than teachers who didn't show much enthusiasm for the course materials.

Teachers that exhibit enthusiasm can lead to students who are more likely to be engaged, interested, energetic, and curious about learning the subject matter. Recent research has found a correlation between teacher enthusiasm and students' intrinsic motivation to learn and vitality in the classroom. Controlled, experimental studies exploring intrinsic motivation of college students has shown that nonverbal expressions of enthusiasm, such as demonstrative gesturing, dramatic movements which are varied, and emotional facial expressions, result in college students reporting higher levels of intrinsic motivation to learn. Students who experienced a very enthusiastic teacher were more likely to read lecture material outside of the classroom.

There are various mechanisms by which teacher enthusiasm may facilitate higher levels of intrinsic motivation. Teacher enthusiasm may contribute to a classroom atmosphere full of energy and enthusiasm

which feed student interest and excitement in learning the subject matter. Enthusiastic teachers may also lead to students becoming more self-determined in their own learning process. The concept of mere exposure indicates that the teacher's enthusiasm may contribute to the student's expectations about intrinsic motivation in the context of learning. Also, enthusiasm may act as a "motivational embellishment"; increasing a student's interest by the variety, novelty, and surprise of the enthusiastic teacher's presentation of the material. Finally, the concept of emotional contagion, may also apply. Students may become more intrinsically motivated by catching onto the enthusiasm and energy of the teacher.[citation needed]

Research shows that student motivation and attitudes towards school are closely linked to student-teacher relationships. Enthusiastic teachers are particularly good at creating beneficial relations with their students. Their ability to create effective learning environments that foster student achievement depends on the kind of relationship they build with their students. Useful teacher-to-student interactions are crucial in linking academic success with personal achievement. Here, personal success is a student's internal goal of improving himself, whereas academic success includes the goals he receives from his superior. A teacher must guide his student in aligning his personal goals with his academic goals. Students who receive this positive influence show stronger self-confidence and greater personal and academic success than those without these teacher interactions.

Students are likely to build stronger relations with teachers who are friendly and supportive and will show more interest in courses taught by these teachers. Teachers that spend more time interacting and working directly with students are perceived as supportive and effective teachers. Effective teachers have been shown to invite student participation and decision making, allow humor into their classroom, and demonstrate a willingness to play.

The way a teacher promotes the course they are teaching, the more the student will get out of the subject matter. The three most important aspects of teacher enthusiasm are enthusiasm about teaching, enthusiasm about the students, and enthusiasm about the subject matter. A teacher must enjoy teaching. If they do not enjoy what they are doing, the students will be able to tell. They also must enjoy being around their students. A teacher who cares for their students is going to help that individual succeed in their life in the future. The teacher also needs to be enthusiastic about the subject matter they are teaching. For example, a teacher talking about chemistry needs to enjoy the art of chemistry and show that to their students. A spark in the teacher may create a spark of excitement in the student as well. An enthusiastic teacher has the ability to be very influential in the young students life.

Misconduct by teachers, especially sexual misconduct, has been getting increased scrutiny from the media and the courts. A study by the American Association of University Women reported that 9.6% of students in the United States claim to have received unwanted sexual attention from an adult associated with education; be they a volunteer, bus driver, teacher, administrator or other adult; sometime during their educational career.

A study in England showed a 0.3% prevalence of sexual abuse by any professional, a group that included priests, religious leaders, and case workers as well as teachers. It is important to note, however, that the British study referenced above is the only one of its kind and consisted of "a random ... probability sample of 2,869 young people between the ages of 18 and 24 in a computer-assisted study" and that the questions referred to "sexual abuse with a professional," not necessarily a teacher. It is therefore logical to conclude that information on the percentage of abuses by teachers in the United Kingdom is not explicitly available and therefore not necessarily reliable. The AAUW study, however, posed questions about fourteen types of sexual harassment and various degrees of frequency and included only abuses by teachers. "The sample was drawn from a list of 80,000 schools to create a stratified two-stage sample design of 2,065 8th to 11th grade students" Its reliability was gauged at 95% with a 4% margin of error. In the United States especially, several high-profile cases such as Debra LaFave, Pamela Rogers, and Mary Kay Letourneau have caused increased scrutiny on teacher misconduct.

Chris Keates, the general secretary of National Association of Schoolmasters Union of Women Teachers, said that teachers who have sex with pupils over the age of consent should not be placed on the sex offenders register and that prosecution for statutory rape "is a real anomaly in the law that we are concerned about." This has led to outrage from child protection and parental rights groups. Fears of being labelled a pedophile or hebephile has led to several men who enjoy teaching avoiding the profession. This has in some jurisdictions reportedly led to a shortage of male teachers.

Teachers face several occupational hazards in their line of work, including occupational stress, which can

negatively impact teachers' mental and physical health, productivity, and students' performance. Stress can be caused by organizational change, relationships with students, fellow teachers, and administrative personnel, working environment, expectations to substitute, long hours with a heavy workload, and inspections. Teachers are also at high risk for occupational burnout.

A 2000 study found that 42% of UK teachers experienced occupational stress, twice the figure for the average profession. A 2012 study found that teachers experienced double the rate of anxiety, depression, and stress than average workers.

There are several ways to mitigate the occupational hazards of teaching. Organizational interventions, like changing teachers' schedules, providing support networks and mentoring, changing the work environment, and offering promotions and bonuses, may be effective in helping to reduce occupational stress among teachers. Individual-level interventions, including stress-management training and counseling, are also used to relieve occupational stress among teachers.

There are many similarities and differences among teachers around the world. In almost all countries teachers are educated in a university or college. Governments may require certification by a recognized body before they can teach in a school. In many countries, elementary school education certificate is earned after completion of high school. The high school student follows an education specialty track, obtain the prerequisite "student-teaching" time, and receive a special diploma to begin teaching after graduation. In addition to certification, many educational institutions especially within the US, require that prospective teachers pass a background check and psychiatric evaluation to be able to teach in classroom. This is not always the case with adult further learning institutions but is fast becoming the norm in many countries as security concerns grow.

Education in Australia is primarily the responsibility of the individual states and territories. Generally, education in Australia follows the three-tier model which includes primary education (primary schools), followed by secondary education (secondary schools/high schools) and tertiary education (universities and/or TAFE colleges).

Teaching in Canada requires a post-secondary degree Bachelor's Degree. In most provinces a second Bachelor's Degree such as a Bachelor of Education is required to become a qualified teacher. Salary ranges from \$40,000/year to \$90,000/yr. Teachers have the option to teach for a public school which is funded by the provincial government or teaching in a private school which is funded by the private sector, businesses and sponsors.

In Germany, teachers are mainly civil servants recruited in special university classes, called Lehramtstudien (Teaching Education Studies). There are many differences between the teachers for elementary schools (Grundschule), lower secondary schools (Hauptschule), middle level secondary schools (Realschule) and higher level secondary schools (Gymnasium). Salaries for teachers depend on the civil servants' salary index scale (Bundesbesoldungsordnung).

Salaries for primary teachers in Ireland depend mainly on seniority (i.e. holding the position of principal, deputy principal or assistant principal), experience and qualifications. Extra pay is also given for teaching through the Irish language, in a Gaeltacht area or on an island. The basic pay for a starting teacher is €27,814 p.a., rising incrementally to €53,423 for a teacher with 25 years service. A principal of a large school with many years experience and several qualifications (M.A., H.Dip., etc.) could earn over €90,000.

Teachers are required to be registered with the Teaching Council; under Section 30 of the Teaching Council Act 2001, a person employed in any capacity in a recognised teaching post - who is not registered with the Teaching Council - may not be paid from Oireachtas funds.

From 2006 Garda vetting has been introduced for new entrants to the teaching profession. These procedures apply to teaching and also to non-teaching posts and those who refuse vetting "cannot be appointed or engaged by the school in any capacity including in a voluntary role". Existing staff will be vetted on a phased basis.

Salaries for Nursery, Primary and Secondary School teachers ranged from £20,133 to £41,004 in September 2007, although some salaries can go much higher depending on experience and extra responsibilities. Preschool teachers may earn £20,980 annually.[citation needed] Teachers in state schools must have at least a bachelor's degree, complete an approved teacher education program, and be licensed.

Many counties offer alternative licensing programs to attract people into teaching, especially for hard-to-fill positions. Excellent job opportunities are expected as retirements, especially among secondary school

teachers, outweigh slowing enrollment growth; opportunities will vary by geographic area and subject taught.[citation needed]

In Scotland, anyone wishing to teach must be registered with the General Teaching Council for Scotland (GTCS). Teaching in Scotland is an all graduate profession and the normal route for graduates wishing to teach is to complete a programme of Initial Teacher Education (ITE) at one of the seven Scottish Universities who offer these courses. Once successfully completed, "Provisional Registration" is given by the GTCS which is raised to "Full Registration" status after a year if there is sufficient evidence to show that the "Standard for Full Registration" has been met.

For the salary year beginning April 2008, unpromoted teachers in Scotland earned from £20,427 for a Probationer, up to £32,583 after 6 years teaching, but could then go on to earn up to £39,942 as they complete the modules to earn Chartered Teacher Status (requiring at least 6 years at up to two modules per year.) Promotion to Principal Teacher positions attracts a salary of between £34,566 and £44,616; Deputy Head, and Head teachers earn from £40,290 to £78,642. Teachers in Scotland can be registered members of trade unions with the main ones being the Educational Institute of Scotland and the Scottish Secondary Teachers' Association.

Education in Wales differs in certain respects from education elsewhere in the United Kingdom. For example, a significant number of students all over Wales are educated either wholly or largely through the medium of Welsh: in 2008/09, 22 per cent of classes in maintained primary schools used Welsh as the sole or main medium of instruction. Welsh medium education is available to all age groups through nurseries, schools, colleges and universities and in adult education; lessons in the language itself are compulsory for all pupils until the age of 16.

Teachers in Wales can be registered members of trade unions such as ATL, NUT or NASUWT and reports in recent years suggest that the average age of teachers in Wales is falling with teachers being younger than in previous years. A growing cause of concern are that attacks on teachers in Welsh schools which reached an all-time high between 2005 and 2010.

In the United States, each state determines the requirements for getting a license to teach in public schools. Teaching certification generally lasts three years, but teachers can receive certificates that last as long as ten years. Public school teachers are required to have a bachelor's degree and the majority must be certified by the state in which they teach. Many charter schools do not require that their teachers be certified, provided they meet the standards to be highly qualified as set by No Child Left Behind. Additionally, the requirements for substitute/temporary teachers are generally not as rigorous as those for full-time professionals. The Bureau of Labor Statistics estimates that there are 1.4 million elementary school teachers, 674,000 middle school teachers, and 1 million secondary school teachers employed in the U.S.

In the past, teachers have been paid relatively low salaries. However, average teacher salaries have improved rapidly in recent years. US teachers are generally paid on graduated scales, with income depending on experience. Teachers with more experience and higher education earn more than those with a standard bachelor's degree and certificate. Salaries vary greatly depending on state, relative cost of living, and grade taught. Salaries also vary within states where wealthy suburban school districts generally have higher salary schedules than other districts. The median salary for all primary and secondary teachers was \$46,000 in 2004, with the average entry salary for a teacher with a bachelor's degree being an estimated \$32,000. Median salaries for preschool teachers, however, were less than half the national median for secondary teachers, clock in at an estimated \$21,000 in 2004. For high school teachers, median salaries in 2007 ranged from \$35,000 in South Dakota to \$71,000 in New York, with a national median of \$52,000. Some contracts may include long-term disability insurance, life insurance, emergency/personal leave and investment options. The American Federation of Teachers' teacher salary survey for the 2006-07 school year found that the average teacher salary was \$51,009. In a salary survey report for K-12 teachers, elementary school teachers had the lowest median salary earning \$39,259. High school teachers had the highest median salary earning \$41,855. Many teachers take advantage of the opportunity to increase their income by supervising after-school programs and other extracurricular activities. In addition to monetary compensation, public school teachers may also enjoy greater benefits (like health insurance) compared to other occupations. Merit pay systems are on the rise for teachers, paying teachers extra money based on excellent classroom evaluations, high test scores and for high success at their overall school. Also, with the advent of the internet, many teachers are now selling their lesson plans to other teachers through the web in order to earn supplemental income, most notably on



There are many forms of spiritual or religious teachers in Christianity, across all three major traditions - (Roman) Catholic, (Eastern) Orthodox Catholic, and Protestant/Non-Denominational, with a stronger tradition of spiritual formation in the more historic and authoritarian/hierarchical Christian traditions with a long tradition of "discernment of spirits", of vocations, and other aspects of spiritual life, especially the Roman and Orthodox Catholic Churches. These positions include: the honoured but informal position of starets or elder - a man (or, less often, woman), often a monastic, considered to be graced by God with certain gifts for the guidance of souls and the detection and correction of prelest (spiritual pride or deception) - who acts as a spiritual guide or father in the Orthodox Catholic tradition, especially Russian Orthodoxy (see Optina Monastery, which had a long line of said starets); the Priest or Confessor in Roman Catholicism, who is often a man in Holy Orders but may be a monastic or other person respected for his spiritual accomplishments or acumen (even the Pope of Rome has a Confessor, who is not always a bishop, and, due to the hierarchical structure of the Roman Church, can not be his equal in authority), which is often a semi-official to official position, as opposed to the unofficial positions of spiritual guides in the Orthodox Catholic and Protestant traditions; and the almost-exclusively informal arrangements (generally formal only in members who are under some form of church discipline) of mentorship (both of adults and children, in the latter case often a youth pastor) in the Protestant and Non-Denominational traditions, which boundaries can be blurred with the more typically Roman "confessor" position in some of the more historic and conservative Reformation Churches, such as some of the Lutheran and Anglican. In keeping with the individualistic nature of most Protestant denominations, the emphasis on being guided in spiritual development is small, with a heavy emphasis placed on heavy reading and personal, Spirit-enlightened interpretation of the Holy Bible.

In The Church of Jesus Christ of Latter-day Saints (LDS Church), the teacher is an office in the Aaronic priesthood, generally conferred on young boys or recent converts, and has little in common with the "spiritual teacher" archetype. The role of "spiritual teacher" may be filled by many individuals in the LDS Church, often a trusted friend, who may hold any office, from Elder to Bishop, or no office at all. The emphasis on spiritual mentorship in the LDS Church is similar to that in the more "low-church" traditions of Protestantism, with a stronger emphasis placed on the husband and father of a family to provide spiritual guidance for all of his family, ideally in consultation with his wife, even if the husband is not a member of the LDS Church, based on interpretation of certain Biblical texts which proclaim the spiritual authority of husbands in marriage. Even Priesthood representatives are expected to defer to the father of the house when in his home. Further, additional spiritual guidance is offered by those holding the office of Patriarch, which is supposed by Latter-day Saints to grant certain gifts of the Spirit, such as the ability to prophesy, to its holders. This guidance is generally offered during a ceremony called the patriarchal blessing. In Hinduism the spiritual teacher is known as a guru, and, in many traditions of Hinduism - especially those common in the West - the emphasis on spiritual mentorship is extremely high, with gurus often exercising a great deal of control over the lives of their disciples.

In Tibetan Buddhism the teachers of Dharma in Tibet are most commonly called a Lama. A Lama who has through phowa and siddhi consciously determined to be reborn, often many times, in order to continue their Bodhisattva vow is called a Tulku.

There are many concepts of teachers in Islam, ranging from mullahs (the teachers at madrassas) to ulemas, who teach of the laws of Islam for the proper way of Islamic living according to the Sunnah and Ahadith, and can render legal verdicts upon matters of Islamic law in accordance with the teaching of one of the Four Schools of Jurisprudence. In the more spiritual or mystical Islamic tradition of Sufism, the position of spiritual teacher and an esoteric (as opposed to exoteric, or actions-oriented, e.g. the Five Pillars of Islam) spirituality and spiritual knowledge takes on a more important dimension, with emphasis on learning from living saints - the highest of which is a Qutb - and of traditions passed down from initiate to initiate, and traceable back to the founder of the order.

Martin Luther (/ lu θ r/ or / lu ð r/; German: [ ma ti n l t ] ( listen); 10 November 1483 – 18 February 1546) was a German professor of theology, composer, priest, former monk and a seminal figure in the Protestant Reformation. Luther came to reject several teachings and practices of the Late Medieval Catholic Church. He strongly disputed the claim that freedom from God's punishment for sin could be purchased with money. He proposed an academic discussion of the power and usefulness of indulgences in his Ninety-Five Theses of 1517. His refusal to retract all of his writings at the demand of Pope Leo X in 1520 and the Holy Roman Emperor Charles V at the Diet of Worms in 1521 resulted in his excommunication by

the Pope and condemnation as an outlaw by the Emperor.

Luther taught that salvation and subsequently eternal life is not earned by good deeds but is received only as a free gift of God's grace through faith in Jesus Christ as redeemer from sin. His theology challenged the authority and office of the Pope by teaching that the Bible is the only source of divinely revealed knowledge from God and opposed sacerdotalism by considering all baptized Christians to be a holy priesthood. Those who identify with these, and all of Luther's wider teachings, are called Lutherans even though Luther insisted on Christian or Evangelical as the only acceptable names for individuals who professed Christ.

His translation of the Bible into the vernacular (instead of Latin) made it more accessible, which had a tremendous impact on the church and German culture. It fostered the development of a standard version of the German language, added several principles to the art of translation, and influenced the writing of an English translation, the Tyndale Bible. His hymns influenced the development of singing in churches. His marriage to Katharina von Bora set a model for the practice of clerical marriage, allowing Protestant clergy to marry.

Martin Luther was born to Hans Luder (or Ludher, later Luther) and his wife Margarethe (née Lindemann) on 10 November 1483 in Eisleben, Saxony, then part of the Holy Roman Empire. He was baptized as a Catholic the next morning on the feast day of St. Martin of Tours. His family moved to Mansfeld in 1484, where his father was a leaseholder of copper mines and smelters and served as one of four citizen representatives on the local council. The religious scholar Martin Marty describes Luther's mother as a hard-working woman of "trading-class stock and middling means" and notes that Luther's enemies later wrongly described her as a whore and bath attendant. He had several brothers and sisters, and is known to have been close to one of them, Jacob. Hans Luther was ambitious for himself and his family, and he was determined to see Martin, his eldest son, become a lawyer. He sent Martin to Latin schools in Mansfeld, then Magdeburg in 1497, where he attended a school operated by a lay group called the Brethren of the Common Life, and Eisenach in 1498. The three schools focused on the so-called "trivium": grammar, rhetoric, and logic. Luther later compared his education there to purgatory and hell.

In 1501, at the age of 19, he entered the University of Erfurt, which he later described as a beerhouse and whorehouse. He was made to wake at four every morning for what has been described as "a day of rote learning and often wearying spiritual exercises." He received his master's degree in 1505.

In accordance with his father's wishes, Luther enrolled in law school at the same university that year but dropped out almost immediately, believing that law represented uncertainty. Luther sought assurances about life and was drawn to theology and philosophy, expressing particular interest in Aristotle, William of Ockham, and Gabriel Biel. He was deeply influenced by two tutors, Bartholomaeus Arnoldi von Usingen and Jodocus Trutfetter, who taught him to be suspicious of even the greatest thinkers and to test everything himself by experience. Philosophy proved to be unsatisfying, offering assurance about the use of reason but none about loving God, which to Luther was more important. Reason could not lead men to God, he felt, and he thereafter developed a love-hate relationship with Aristotle over the latter's emphasis on reason. For Luther, reason could be used to question men and institutions, but not God. Human beings could learn about God only through divine revelation, he believed, and Scripture therefore became increasingly important to him.

He later attributed his decision to an event: on 2 July 1505, he was returning to university on horseback after a trip home. During a thunderstorm, a lightning bolt struck near him. Later telling his father he was terrified of death and divine judgment, he cried out, "Help! Saint Anna, I will become a monk!" He came to view his cry for help as a vow he could never break. He left law school, sold his books, and entered a closed Augustinian cloister in Erfurt on 17 July 1505. One friend blamed the decision on Luther's sadness over the deaths of two friends. Luther himself seemed saddened by the move. Those who attended a farewell supper walked him to the door of the Black Cloister. "This day you see me, and then, not ever again," he said. His father was furious over what he saw as a waste of Luther's education.

Luther dedicated himself to the Augustinian order, devoting himself to fasting, long hours in prayer, pilgrimage, and frequent confession. Luther described this period of his life as one of deep spiritual despair. He said, "I lost touch with Christ the Savior and Comforter, and made of him the jailer and hangman of my poor soul." Johann von Staupitz, his superior, pointed Luther's mind away from continual reflection upon his sins toward the merits of Christ. He taught that true repentance does not involve self-inflicted penances and punishments but rather a change of heart.

In 1507, he was ordained to the priesthood, and in 1508, von Staupitz, first dean of the newly founded

University of Wittenberg, sent for Luther, to teach theology. He received a bachelor's degree in Biblical studies on 9 March 1508, and another bachelor's degree in the Sentences by Peter Lombard in 1509. On 19 October 1512, he was awarded his Doctor of Theology and, on 21 October 1512, was received into the senate of the theological faculty of the University of Wittenberg, having been called to the position of Doctor in Bible. He spent the rest of his career in this position at the University of Wittenberg.

In 1516, Johann Tetzel, a Dominican friar and papal commissioner for indulgences, was sent to Germany by the Roman Catholic Church to sell indulgences to raise money to rebuild St. Peter's Basilica in Rome. Roman Catholic theology stated that faith alone, whether fiduciary or dogmatic, cannot justify man; justification rather depends only on such faith as is active in charity and good works (*fides caritate formata*). The benefits of good works could be obtained by donating money to the church.

On 31 October 1517, Luther wrote to his bishop, Albert of Mainz, protesting the sale of indulgences. He enclosed in his letter a copy of his "Disputation of Martin Luther on the Power and Efficacy of Indulgences", which came to be known as The Ninety-Five Theses. Hans Hillerbrand writes that Luther had no intention of confronting the church, but saw his disputation as a scholarly objection to church practices, and the tone of the writing is accordingly "searching, rather than doctrinaire." Hillerbrand writes that there is nevertheless an undercurrent of challenge in several of the theses, particularly in Thesis 86, which asks: "Why does the pope, whose wealth today is greater than the wealth of the richest Crassus, build the basilica of St. Peter with the money of poor believers rather than with his own money?"

Luther objected to a saying attributed to Johann Tetzel that "As soon as the coin in the coffer rings, the soul from purgatory (also attested as 'into heaven') springs."

He insisted that, since forgiveness was God's alone to grant, those who claimed that indulgences absolved buyers from all punishments and granted them salvation were in error. Christians, he said, must not slacken in following Christ on account of such false assurances.

However, this oft-quoted saying of Tetzel was by no means representative of contemporary Catholic teaching on indulgences, but rather a reflection of his capacity to exaggerate. Yet if Tetzel overstated the matter in regard to indulgences for the dead, his teaching on indulgences for the living was in line with Catholic dogma of the time.

According to scholars Walter Krämer, Götz Trenkler, Gerhard Ritter, and Gerhard Prause, the story of the posting on the door, even though it has settled as one of the pillars of history, has little foundation in truth. The story is based on comments made by Philipp Melanchthon, though it is thought that he was not in Wittenberg at the time.

It was not until January 1518 that friends of Luther translated the 95 Theses from Latin into German and printed and widely copied them, making the controversy one of the first in history to be aided by the printing press. Within two weeks, copies of the theses had spread throughout Germany; within two months, they had spread throughout Europe.

Luther's writings circulated widely, reaching France, England, and Italy as early as 1519. Students thronged to Wittenberg to hear Luther speak. He published a short commentary on Galatians and his Work on the Psalms. This early part of Luther's career was one of his most creative and productive. Three of his best-known works were published in 1520: To the Christian Nobility of the German Nation, On the Babylonian Captivity of the Church, and On the Freedom of a Christian.

From 1510 to 1520, Luther lectured on the Psalms, the books of Hebrews, Romans, and Galatians. As he studied these portions of the Bible, he came to view the use of terms such as penance and righteousness by the Catholic Church in new ways. He became convinced that the church was corrupt in its ways and had lost sight of what he saw as several of the central truths of Christianity. The most important for Luther was the doctrine of justification – God's act of declaring a sinner righteous – by faith alone through God's grace. He began to teach that salvation or redemption is a gift of God's grace, attainable only through faith in Jesus as the Messiah. "This one and firm rock, which we call the doctrine of justification," he wrote, "is the chief article of the whole Christian doctrine, which comprehends the understanding of all godliness."

Luther came to understand justification as entirely the work of God. This teaching by Luther was clearly expressed in his 1525 publication On the Bondage of the Will, which was written in response to On Free Will by Desiderius Erasmus (1524). Luther based his position on predestination on St. Paul's epistle to the Ephesians 2:8–10. Against the teaching of his day that the righteous acts of believers are performed in cooperation with God, Luther wrote that Christians receive such righteousness entirely from outside themselves; that righteousness not only comes from Christ but actually is the righteousness of Christ,

imputed to Christians (rather than infused into them) through faith. "That is why faith alone makes someone just and fulfills the law," he wrote. "Faith is that which brings the Holy Spirit through the merits of Christ." Faith, for Luther, was a gift from God; the experience of being justified by faith was "as though I had been born again." His entry into Paradise, no less, was a discovery about "the righteousness of God" – a discovery that "the just person" of whom the Bible speaks (as in Romans 1:17) lives by faith. He explained his concept of "justification" in the Smalcald Articles:

Luther's rediscovery of "Christ and His salvation" was the first of two points that became the foundation for the Reformation. His railing against the sale of indulgences was based on it.

Archbishop Albrecht of Mainz and Magdeburg did not reply to Luther's letter containing the 95 Theses. He had the theses checked for heresy and in December 1517 forwarded them to Rome. He needed the revenue from the indulgences to pay off a papal dispensation for his tenure of more than one bishopric. As Luther later noted, "the pope had a finger in the pie as well, because one half was to go to the building of St Peter's Church in Rome".

Pope Leo X was used to reformers and heretics, and he responded slowly, "with great care as is proper." Over the next three years he deployed a series of papal theologians and envoys against Luther, which served only to harden the reformer's anti-papal theology. First, the Dominican theologian Sylvester Mazzolini drafted a heresy case against Luther, whom Leo then summoned to Rome. The Elector Frederick persuaded the pope to have Luther examined at Augsburg, where the Imperial Diet was held. There, in October 1518, under questioning by papal legate Cardinal Cajetan Luther stated that he did not consider the papacy part of the biblical Church because historical interpretation of Bible prophecy concluded that the papacy was the Antichrist. The prophecies concerning the Antichrist soon became the center of controversy. The hearings degenerated into a shouting match. More than his writing the 95 Theses, Luther's confrontation with the church cast him as an enemy of the pope. Cajetan's original instructions had been to arrest Luther if he failed to recant, but the legate desisted from doing so. Luther slipped out of the city at night, unbeknownst to Cajetan.

In January 1519, at Altenburg in Saxony, the papal nuncio Karl von Miltitz adopted a more conciliatory approach. Luther made certain concessions to the Saxon, who was a relative of the Elector, and promised to remain silent if his opponents did. The theologian Johann Eck, however, was determined to expose Luther's doctrine in a public forum. In June and July 1519, he staged a disputation with Luther's colleague Andreas Karlstadt at Leipzig and invited Luther to speak. Luther's boldest assertion in the debate was that Matthew 16:18 does not confer on popes the exclusive right to interpret scripture, and that therefore neither popes nor church councils were infallible. For this, Eck branded Luther a new Jan Hus, referring to the Czech reformer and heretic burned at the stake in 1415. From that moment, he devoted himself to Luther's defeat.

On 15 June 1520, the Pope warned Luther with the papal bull (edict) *Exsurge Domine* that he risked excommunication unless he recanted 41 sentences drawn from his writings, including the 95 Theses, within 60 days. That autumn, Johann Eck proclaimed the bull in Meissen and other towns. Karl von Miltitz, a papal nuncio, attempted to broker a solution, but Luther, who had sent the Pope a copy of *On the Freedom of a Christian* in October, publicly set fire to the bull and decretals at Wittenberg on 10 December 1520, an act he defended in *Why the Pope and his Recent Book are Burned and Assertions Concerning All Articles*. As a consequence, Luther was excommunicated by Pope Leo X on 3 January 1521, in the bull *Decet Romanum Pontificem*.

The enforcement of the ban on the 95 Theses fell to the secular authorities. On 18 April 1521, Luther appeared as ordered before the Diet of Worms. This was a general assembly of the estates of the Holy Roman Empire that took place in Worms, a town on the Rhine. It was conducted from 28 January to 25 May 1521, with Emperor Charles V presiding. Prince Frederick III, Elector of Saxony, obtained a safe conduct for Luther to and from the meeting.

Johann Eck, speaking on behalf of the Empire as assistant of the Archbishop of Trier, presented Luther with copies of his writings laid out on a table and asked him if the books were his, and whether he stood by their contents. Luther confirmed he was their author, but requested time to think about the answer to the second question. He prayed, consulted friends, and gave his response the next day:

At the end of this speech, Luther raised his arm "in the traditional salute of a knight winning a bout."

Michael Mullett considers this speech as a "world classic of epoch-making oratory."

Luther refused to recant his writings. He is sometimes also quoted as saying: "Here I stand. I can do no other". Recent scholars consider the evidence for these words to be unreliable, since they were inserted

before "May God help me" only in later versions of the speech and not recorded in witness accounts of the proceedings. However, Mullett suggests that given his nature, "we are free to believe that Luther would tend to select the more dramatic form of words."

Over the next five days, private conferences were held to determine Luther's fate. The Emperor presented the final draft of the Edict of Worms on 25 May 1521, declaring Luther an outlaw, banning his literature, and requiring his arrest: "We want him to be apprehended and punished as a notorious heretic." It also made it a crime for anyone in Germany to give Luther food or shelter. It permitted anyone to kill Luther without legal consequence.

Luther's disappearance during his return trip back to Wittenberg was planned. Frederick III had him intercepted on his way home in the forest near Wittenberg by masked horsemen who were made to appear as armed highwaymen. They escorted Luther to the security of the Wartburg Castle at Eisenach. During his stay at Wartburg, which he referred to as "my Patmos", Luther translated the New Testament from Greek into German and poured out doctrinal and polemical writings. These included a renewed attack on Archbishop Albrecht of Mainz, whom he shamed into halting the sale of indulgences in his episcopates, and a "Refutation of the Argument of Latomus," in which he expounded the principle of justification to Jacobus Latomus, an orthodox theologian from Louvain.

In this work, one of his most emphatic statements on faith, he argued that every good work designed to attract God's favor is a sin. All humans are sinners by nature, he explained, and God's grace (which cannot be earned) alone can make them just. On 1 August 1521, Luther wrote to Melancthon on the same theme: "Be a sinner, and let your sins be strong, but let your trust in Christ be stronger, and rejoice in Christ who is the victor over sin, death, and the world. We will commit sins while we are here, for this life is not a place where justice resides."

In the summer of 1521, Luther widened his target from individual pieties like indulgences and pilgrimages to doctrines at the heart of Church practices. In *On the Abrogation of the Private Mass*, he condemned as idolatry the idea that the mass is a sacrifice, asserting instead that it is a gift, to be received with thanksgiving by the whole congregation. His essay *On Confession, Whether the Pope has the Power to Require It* rejected compulsory confession and encouraged private confession and absolution, since "every Christian is a confessor." In November, Luther wrote *The Judgement of Martin Luther on Monastic Vows*. He assured monks and nuns that they could break their vows without sin, because vows were an illegitimate and vain attempt to win salvation.

In 1521 Luther dealt largely with prophecy, in which he broadened the foundations of the Reformation placing them on prophetic faith. His main interest was centered on the prophecy of the Little Horn in Daniel 8:9–12, 23–25. The antichrist of 2 Thessalonians 2 was identified as the power of the Papacy. So too was the Little Horn of Daniel 7, coming up among the divisions of Rome, explicitly applied.

Luther made his pronouncements from Wartburg in the context of rapid developments at Wittenberg, of which he was kept fully informed. Andreas Karlstadt, supported by the ex-Augustinian Gabriel Zwilling, embarked on a radical programme of reform there in June 1521, exceeding anything envisaged by Luther. The reforms provoked disturbances, including a revolt by the Augustinian friars against their prior, the smashing of statues and images in churches, and denunciations of the magistracy. After secretly visiting Wittenberg in early December 1521, Luther wrote *A Sincere Admonition by Martin Luther to All Christians to Guard Against Insurrection and Rebellion*. Wittenberg became even more volatile after Christmas when a band of visionary zealots, the so-called Zwickau prophets, arrived, preaching revolutionary doctrines such as the equality of man, adult baptism, and Christ's imminent return. When the town council asked Luther to return, he decided it was his duty to act.

Luther secretly returned to Wittenberg on 6 March 1522. He wrote to the Elector: "During my absence, Satan has entered my sheepfold, and committed ravages which I cannot repair by writing, but only by my personal presence and living word." For eight days in Lent, beginning on *Invocavit* Sunday, 9 March, Luther preached eight sermons, which became known as the "*Invocavit* Sermons". In these sermons, he hammered home the primacy of core Christian values such as love, patience, charity, and freedom, and reminded the citizens to trust God's word rather than violence to bring about necessary change.

The effect of Luther's intervention was immediate. After the sixth sermon, the Wittenberg jurist Jerome Schurf wrote to the elector: "Oh, what joy has Dr. Martin's return spread among us! His words, through divine mercy, are bringing back every day misguided people into the way of the truth."

Luther next set about reversing or modifying the new church practices. By working alongside the authorities to restore public order, he signalled his reinvention as a conservative force within the

Reformation. After banishing the Zwickau prophets, he now faced a battle against not only the established Church but also the radical reformers who threatened the new order by fomenting social unrest and violence.

Despite his victory in Wittenberg, Luther was unable to stifle radicalism further afield. Preachers such as Zwickau prophet Nicholas Storch and Thomas Müntzer helped instigate the German Peasants' War of 1524–25, during which many atrocities were committed, often in Luther's name. There had been revolts by the peasantry on a smaller scale since the 15th century. Luther's pamphlets against the Church and the hierarchy, often worded with "liberal" phraseology, now led many peasants to believe he would support an attack on the upper classes in general. Revolts broke out in Franconia, Swabia, and Thuringia in 1524, even drawing support from disaffected nobles, many of whom were in debt. Gaining momentum under the leadership of radicals such as Müntzer in Thuringia and Michael Gaismair in Tyrol, the revolts turned into war.

Luther sympathised with some of the peasants' grievances, as he showed in his response to the Twelve Articles in May 1525, but he reminded the aggrieved to obey the temporal authorities. During a tour of Thuringia, he became enraged at the widespread burning of convents, monasteries, bishops' palaces, and libraries. In *Against the Murderous, Thieving Hordes of Peasants*, written on his return to Wittenberg, he gave his interpretation of the Gospel teaching on wealth, condemned the violence as the devil's work, and called for the nobles to put down the rebels like mad dogs:

Luther justified his opposition to the rebels on three grounds. First, in choosing violence over lawful submission to the secular government, they were ignoring Christ's counsel to "Render unto Caesar the things that are Caesar's"; St. Paul had written in his epistle to the Romans 13:1–7 that all authorities are appointed by God and therefore should not be resisted. This reference from the Bible forms the foundation for the doctrine known as the Divine Right of Kings, or, in the German case, the divine right of the princes. Second, the violent actions of rebelling, robbing, and plundering placed the peasants "outside the law of God and Empire", so they deserved "death in body and soul, if only as highwaymen and murderers." Lastly, Luther charged the rebels with blasphemy for calling themselves "Christian brethren" and committing their sinful acts under the banner of the Gospel.

Without Luther's backing for the uprising, many rebels laid down their weapons; others felt betrayed. Their defeat by the Swabian League at the Battle of Frankenhausen on 15 May 1525, followed by Müntzer's execution, brought the revolutionary stage of the Reformation to a close. Thereafter, radicalism found a refuge in the anabaptist movement and other religious movements, while Luther's Reformation flourished under the wing of the secular powers.

Martin Luther married Katharina von Bora, one of 12 nuns he had helped escape from the Nimbschen Cistercian convent in April 1523, when he arranged for them to be smuggled out in herring barrels. "Suddenly, and while I was occupied with far different thoughts," he wrote to Wenceslaus Link, "the Lord has plunged me into marriage." At the time of their marriage, Katharina was 26 years old and Luther was 41 years old.

On 13 June 1525, the couple was engaged with Johannes Bugenhagen, Justus Jonas, Johannes Apel, Philipp Melanchthon and Lucas Cranach the Elder and his wife as witnesses. On the evening of the same day, the couple was married by Bugenhagen. The ceremonial walk to the church and the wedding banquet were left out, and were made up two weeks later on 27 June.

Some priests and former religious had already married, including Andreas Karlstadt and Justus Jonas, but Luther's wedding set the seal of approval on clerical marriage. He had long condemned vows of celibacy on Biblical grounds, but his decision to marry surprised many, not least Melanchthon, who called it reckless. Luther had written to George Spalatin on 30 November 1524, "I shall never take a wife, as I feel at present. Not that I am insensible to my flesh or sex (for I am neither wood nor stone); but my mind is averse to wedlock because I daily expect the death of a heretic." Before marrying, Luther had been living on the plainest food, and, as he admitted himself, his mildewed bed was not properly made for months at a time.

Luther and his wife moved into a former monastery, "The Black Cloister," a wedding present from the new elector John the Steadfast (1525–32). They embarked on what appeared to have been a happy and successful marriage, though money was often short. Between bearing six children, Hans – June 1526; Elizabeth – 10 December 1527, who died within a few months; Magdalene – 1529, who died in Luther's arms in 1542; Martin – 1531; Paul – January 1533; and Margaret – 1534; Katharina helped the couple earn a living by farming the land and taking in boarders. Luther confided to Michael Stiefel on 11 August

1526: "My Katie is in all things so obliging and pleasing to me that I would not exchange my poverty for the riches of Croesus."

By 1526, Luther found himself increasingly occupied in organising a new church. His Biblical ideal of congregations' choosing their own ministers had proved unworkable. According to Bainton: "Luther's dilemma was that he wanted both a confessional church based on personal faith and experience and a territorial church including all in a given locality. If he were forced to choose, he would take his stand with the masses, and this was the direction in which he moved." From 1525 to 1529, he established a supervisory church body, laid down a new form of worship service, and wrote a clear summary of the new faith in the form of two catechisms. Luther's thought is revolutionary to the extent that it is a theology of the cross, the negation of every affirmation: as long as the cross is at the center, the system building tendency of reason is held in check, and system building does not degenerate into System.

To avoid confusing or upsetting the people, Luther avoided extreme change. He also did not wish to replace one controlling system with another. He concentrated on the church in the Electorate of Saxony, acting only as an adviser to churches in new territories, many of which followed his Saxon model. He worked closely with the new elector, John the Steadfast, to whom he turned for secular leadership and funds on behalf of a church largely shorn of its assets and income after the break with Rome. For Luther's biographer Martin Brecht, this partnership "was the beginning of a questionable and originally unintended development towards a church government under the temporal sovereign". The elector authorised a visitation of the church, a power formerly exercised by bishops. At times, Luther's practical reforms fell short of his earlier radical pronouncements. For example, the Instructions for the Visitors of Parish Pastors in Electoral Saxony (1528), drafted by Melanchthon with Luther's approval, stressed the role of repentance in the forgiveness of sins, despite Luther's position that faith alone ensures justification. The Eisleben reformer Johannes Agricola challenged this compromise, and Luther condemned him for teaching that faith is separate from works. The Instruction is a problematic document for those seeking a consistent evolution in Luther's thought and practice.

In response to demands for a German liturgy, Luther wrote a German Mass, which he published in early 1526. He did not intend it as a replacement for his 1523 adaptation of the Latin Mass but as an alternative for the "simple people", a "public stimulation for people to believe and become Christians." Luther based his order on the Catholic service but omitted "everything that smacks of sacrifice"; and the Mass became a celebration where everyone received the wine as well as the bread. He retained the elevation of the host and chalice, while trappings such as the Mass vestments, altar, and candles were made optional, allowing freedom of ceremony. Some reformers, including followers of Huldrych Zwingli, considered Luther's service too papistic; and modern scholars note the conservatism of his alternative to the Catholic mass. Luther's service, however, included congregational singing of hymns and psalms in German, as well as of parts of the liturgy, including Luther's unison setting of the Creed. To reach the simple people and the young, Luther incorporated religious instruction into the weekday services in the form of the catechism. He also provided simplified versions of the baptism and marriage services.

Luther and his colleagues introduced the new order of worship during their visitation of the Electorate of Saxony, which began in 1527. They also assessed the standard of pastoral care and Christian education in the territory. "Merciful God, what misery I have seen," Luther wrote, "the common people knowing nothing at all of Christian doctrine ... and unfortunately many pastors are well-nigh unskilled and incapable of teaching."

Luther devised the catechism as a method of imparting the basics of Christianity to the congregations. In 1529, he wrote the Large Catechism, a manual for pastors and teachers, as well as a synopsis, the Small Catechism, to be memorised by the people themselves. The catechisms provided easy-to-understand instructional and devotional material on the Ten Commandments, the Apostles' Creed, the Lord's Prayer, baptism, and the Lord's Supper. Luther incorporated questions and answers in the catechism so that the basics of Christian faith would not just be learned by rote, "the way monkeys do it", but understood.

The catechism is one of Luther's most personal works. "Regarding the plan to collect my writings in volumes," he wrote, "I am quite cool and not at all eager about it because, roused by a Saturnian hunger, I would rather see them all devoured. For I acknowledge none of them to be really a book of mine, except perhaps the Bondage of the Will and the Catechism." The Small Catechism has earned a reputation as a model of clear religious teaching. It remains in use today, along with Luther's hymns and his translation of the Bible.

Luther's Small Catechism proved especially effective in helping parents teach their children; likewise the

Larger Catechism was effective for pastors. Using the German vernacular, they expressed the Apostles' Creed in simpler, more personal, Trinitarian language. He rewrote each article of the Creed to express the character of the Father, the Son, or the Holy Spirit. Luther's goal was to enable the catechumens to see themselves as a personal object of the work of the three persons of the Trinity, each of which works in the catechumen's life. That is, Luther depicted the Trinity not as a doctrine to be learned, but as persons to be known. The Father creates, the Son redeems, and the Spirit sanctifies, a divine unity with separate personalities. Salvation originates with the Father and draws the believer to the Father. Luther's treatment of the Apostles' Creed must be understood in the context of the Decalogue (the Ten Commandments) and the Lord's Prayer, which are also part of the Lutheran catechical teaching.

Luther had published his German translation of the New Testament in 1522, and he and his collaborators completed the translation of the Old Testament in 1534, when the whole Bible was published. He continued to work on refining the translation until the end of his life. Others had translated the Bible into German, but Luther tailored his translation to his own doctrine. When he was criticised for inserting the word "alone" after "faith" in Romans 3:28, he replied in part: "[T]he text itself and the meaning of St. Paul urgently require and demand it. For in that very passage he is dealing with the main point of Christian doctrine, namely, that we are justified by faith in Christ without any works of the Law. ... But when works are so completely cut away – and that must mean that faith alone justifies – whoever would speak plainly and clearly about this cutting away of works will have to say, 'Faith alone justifies us, and not works'." Luther's translation used the variant of German spoken at the Saxon chancellery, intelligible to both northern and southern Germans. He intended his vigorous, direct language to make the Bible accessible to everyday Germans, "for we are removing impediments and difficulties so that other people may read it without hindrance."

Published at a time of rising demand for German-language publications, Luther's version quickly became a popular and influential Bible translation. As such, it made a significant contribution to the evolution of the German language and literature. Furnished with notes and prefaces by Luther, and with woodcuts by Lucas Cranach that contained anti-papal imagery, it played a major role in the spread of Luther's doctrine throughout Germany. The Luther Bible influenced other vernacular translations, such as William Tyndale's English Bible (1525 forward), a precursor of the King James Bible.

Luther was a prolific hymn-writer, authoring hymns such as "Ein feste Burg ist unser Gott" ("A Mighty Fortress Is Our God"), based on Psalm 46, and "Vom Himmel hoch, da komm ich her" ("From Heaven Above to Earth I Come"), based on Luke 2:11–12. Luther connected high art and folk music, also all classes, clergy and laity, men, women and children. His tool of choice for this connection was the singing of German hymns in connection with worship, school, home, and the public arena. He often accompanied the sung hymns with a lute, later recreated as the waldzither that became a national instrument of Germany in the 20th century.

Luther's hymns were frequently evoked by particular events in his life and the unfolding Reformation. This behavior started with his learning of the execution of Johann Esch and Heinrich Voes, the first individuals to be martyred by the Roman Catholic Church for Lutheran views, prompting Luther to write the hymn "Ein neues Lied wir heben an" ("A new song we raise"), which is generally known in English by John C. Messenger's translation by the title and first line "Flung to the Heedless Winds" and sung to the tune *Ibstone* composed in 1875 by Maria C. Tiddeman.

Luther's 1524 creedal hymn "Wir glauben all an einen Gott" ("We All Believe in One True God") is a three-stanza confession of faith prefiguring Luther's 1529 three-part explanation of the Apostles' Creed in the Small Catechism. Luther's hymn, adapted and expanded from an earlier German creedal hymn, gained widespread use in vernacular Lutheran liturgies as early as 1525. Sixteenth-century Lutheran hymnals also included "Wir glauben all" among the catechetical hymns, although 18th-century hymnals tended to label the hymn as Trinitarian rather than catechetical, and 20th-century Lutherans rarely use the hymn because of the perceived difficulty of its tune.

Luther's 1538 hymnic version of the Lord's Prayer, "Vater unser im Himmelreich", corresponds exactly to Luther's explanation of the prayer in the Small Catechism, with one stanza for each of the seven prayer petitions, plus opening and closing stanzas. The hymn functioned both as a liturgical setting of the Lord's Prayer and as a means of examining candidates on specific catechism questions. The extant manuscript shows multiple revisions, demonstrating Luther's concern to clarify and strengthen the text and to provide an appropriately prayerful tune. Other 16th- and 20th-century versifications of the Lord's Prayer have adopted Luther's tune, although modern texts are considerably shorter.



Luther wrote "Aus tiefer Not schrei ich zu dir" ("From depths of woe I cry to you") in 1523 as a hymnic version of Psalm 130 and sent it as a sample to encourage evangelical colleagues to write psalm-hymns for use in German worship. In a collaboration with Paul Speratus, this and seven other hymns were published in the *Achtliederbuch*, the first Lutheran hymnal. In 1524 Luther developed his original four-stanza psalm paraphrase into a five-stanza Reformation hymn that developed the theme of "grace alone" more fully. Because it expressed essential Reformation doctrine, this expanded version of "Aus tiefer Not" was designated as a regular component of several regional Lutheran liturgies and was widely used at funerals, including Luther's own. Along with Erhart Hegenwalt's hymnic version of Psalm 51, Luther's expanded hymn was also adopted for use with the fifth part of Luther's catechism, concerning confession.

Luther wrote "Ach Gott, vom Himmel sieh darein" ("Oh God, look down from heaven"). "Nun komm, der Heiden Heiland" (Now come, Savior of the gentiles), based on *Veni redemptor gentium*, became the main hymn (*Hauptlied*) for Advent. He transformed *A solus ortus cardine* to "Christum wir sollen loben schon" ("We should now praise Christ") and *Veni Creator Spiritus* to "Komm, Gott Schöpfer, Heiliger Geist" ("Come, Holy Spirit, Lord God"). He wrote two hymns on the Ten Commandments, "Dies sind die heiligen Zehn Gebot" and "Mensch, willst du leben seliglich". His "Gelobet seist du, Jesu Christ" ("Praise be to You, Jesus Christ") became the main hymn for Christmas. He wrote for Pentecost "Nun bitten wir den Heiligen Geist", and adopted for Easter "Christ ist erstanden" (Christ is risen), based on *Victimae paschali laudes*. "Mit Fried und Freud ich fahr dahin", a paraphrase of *Nunc dimittis*, was intended for Purification, but became also a funeral hymn. He paraphrased the *Te Deum* as "Herr Gott, dich loben wir" with a simplified form of the melody. It became known as the German *Te Deum*.

Luther's 1541 hymn "Christ unser Herr zum Jordan kam" ("To Jordan came the Christ our Lord") reflects the structure and substance of his questions and answers concerning baptism in the *Small Catechism*. Luther adopted a preexisting Johann Walter tune associated with a hymnic setting of Psalm 67's prayer for grace; Wolf Heintz's four-part setting of the hymn was used to introduce the Lutheran Reformation in Halle in 1541. Preachers and composers of the 18th century, including J. S. Bach, used this rich hymn as a subject for their own work, although its objective baptismal theology was displaced by more subjective hymns under the influence of late-19th-century Lutheran pietism.

Luther's hymns were included in early Lutheran hymnals and spread the ideas of the Reformation. He supplied four of eight songs of the First Lutheran hymnal *Achtliederbuch*, 18 of 26 songs of the *Erfurt Enchiridion*, and 24 of the 32 songs in the first choral hymnal with settings by Johann Walter, *Eyn geystlich Gesangk Buchleyn*, all published in 1524.

Luther's hymns inspired composers to write music. Johann Sebastian Bach included several verses as chorales in his cantatas and based chorale cantatas entirely on them, namely *Christ lag in Todes Banden*, BWV 4, as early as possibly 1707, in his second annual cycle (1724 to 1725) *Ach Gott, vom Himmel sieh darein*, BWV 2, *Christ unser Herr zum Jordan kam*, BWV 7, *Nun komm, der Heiden Heiland*, BWV 62, *Gelobet seist du, Jesu Christ*, BWV 91, and *Aus tiefer Not schrei ich zu dir*, BWV 38, later *Ein feste Burg ist unser Gott*, BWV 80, and in 1735 *Wär Gott nicht mit uns diese Zeit*, BWV 14.

In contrast to the views of John Calvin and Philipp Melancthon, throughout his life Luther maintained that it was not false doctrine to believe that a Christian's soul sleeps after it is separated from the body in death; and, accordingly, he disputed traditional interpretations of some Bible passages, such as the parable of the rich man and Lazarus. This also led Luther to reject the idea of torments for the saints: "It is enough for us to know that souls do not leave their bodies to be threatened by the torments and punishments of hell, but enter a prepared bedchamber in which they sleep in peace." He also rejected the existence of Purgatory, which involved Christian souls undergoing penitential suffering after death. He affirmed the continuity of one's personal identity beyond death. In his *Smalcald Articles*, he described the saints as currently residing "in their graves and in heaven."

The Lutheran theologian Franz Pieper observed that Luther's teaching about the state of the Christian's soul after death differed from the later Lutheran theologians such as Johann Gerhard. Lessing (1755) had earlier reached the same conclusion in his analysis of Lutheran orthodoxy on this issue.

Luther's *Commentary on Genesis* contains a passage which concludes that "the soul does not sleep (*anima non sic dormit*), but wakes (*sed vigilat*) and experiences visions". Francis Blackburne in 1765 argued that John Jortin misread this and other passages from Luther, while Gottfried Fritschel pointed out in 1867 that it actually refers to the soul of a man "in this life" (*homo enim in hac vita*) tired from his daily labour (*defatigus diurno labore*) who at night enters his bedchamber (*sub noctem intrat in cubiculum*

suum) and whose sleep is interrupted by dreams.

In October 1529, Philip I, Landgrave of Hesse, convoked an assembly of German and Swiss theologians at the Marburg Colloquy, to establish doctrinal unity in the emerging Protestant states. Agreement was achieved on fourteen points out of fifteen, the exception being the nature of the Eucharist – the sacrament of the Lord's Supper—an issue crucial to Luther.

The theologians, including Zwingli, Melancthon, Martin Bucer, and Johannes Oecolampadius, differed on the significance of the words spoken by Jesus at the Last Supper: "This is my body which is for you" and "This cup is the new covenant in my blood" (1 Corinthians 11:23–26). Luther insisted on the Real Presence of the body and blood of Christ in the consecrated bread and wine, which he called the sacramental union, while his opponents believed God to be only spiritually or symbolically present. Zwingli, for example, denied Jesus' ability to be in more than one place at a time but Luther stressed the omnipresence of his human nature. According to transcripts, the debate sometimes became confrontational. Citing Jesus' words "The flesh profiteth nothing" (John 6.63), Zwingli said, "This passage breaks your neck". "Don't be too proud," Luther retorted, "German necks don't break that easily. This is Hesse, not Switzerland." On his table Luther wrote the words "Hoc est corpus meum" ("This is my body") in chalk, to continually indicate his firm stance.

Despite the disagreements on the Eucharist, the Marburg Colloquy paved the way for the signing in 1530 of the Augsburg Confession, and for the formation of the Schmalkaldic League the following year by leading Protestant nobles such as John of Saxony, Philip of Hesse, and George, Margrave of Brandenburg-Ansbach. The Swiss cities, however, did not sign these agreements.

Some scholars have asserted that Luther taught that faith and reason were antithetical in the sense that questions of faith could not be illuminated by reason. He wrote, "All the articles of our Christian faith, which God has revealed to us in His Word, are in presence of reason sheerly impossible, absurd, and false." and "[That] Reason in no way contributes to faith. [...] For reason is the greatest enemy that faith has; it never comes to the aid of spiritual things." However, though seemingly contradictorily, he also wrote in the latter work that human reason "strives not against faith, when enlightened, but rather furthers and advances it", bringing claims he was a fideist into dispute. Contemporary Lutheran scholarship, however, has found a different reality in Luther. Luther rather seeks to separate faith and reason in order to honor the separate spheres of knowledge that each applies to. Bernhard Lohse, for example, has demonstrated in his classic work "Fides und Ratio" that Luther ultimately sought to put the two together. More recently, Hans-Peter Grosshans has demonstrated that Luther's work on Biblical Criticism stresses the need for external coherence in the right exegetical method. This means that for Luther it is more important that the Bible is reasonable according to the reality outside of the scriptures than that the Bible makes sense to itself, that it has internal coherence. The right tool for understanding the world outside of the Bible for Luther is none other than reason, which for him is the field of science, philosophy, history and empirical observation. Here a different picture is presented of a Luther who deeply valued both faith and reason, and held them in dialectical partnership. Luther's concern thus in separating them is honoring their different epistemological spheres.

In 1523, Luther wrote that Jesus Christ was born a Jew which discouraged mistreatment of the Jews and advocated their conversion by proving that the Old Testament could be shown to speak of Jesus Christ. However, as the Reformation continued, Luther began to lose hope in large-scale Jewish conversion to Christianity. In his later years, Luther grew more hostile toward the Jews, writing against them with the kind of venom he had already unleashed on the Anabaptists, Zwinglianism, and the papacy. His 1543 treatise *Von den Juden und ihren Lügen* (On the Jews and Their Lies) took its place among other anti-Jewish literature of the times, although historians acknowledge that this treatise was particularly extreme, even by the standards of sixteenth century Europe. In it, he takes a hardline against Judaism, writing that synagogues and Jewish homes should be destroyed, their money confiscated, and liberty curtailed. These statements and their influence on antisemitism have contributed to his controversial status.

At the time of the Marburg Colloquy, Suleiman the Magnificent was besieging Vienna with a vast Ottoman army. Luther had argued against resisting the Turks in his 1518 Explanation of the Ninety-five Theses, provoking accusations of defeatism. He saw the Turks as a scourge sent to punish Christians by God, as agents of the Biblical apocalypse that would destroy the antichrist, whom Luther believed to be the papacy, and the Roman Church. He consistently rejected the idea of a Holy War, "as though our people were an army of Christians against the Turks, who were enemies of Christ. This is absolutely contrary to

Christ's doctrine and name". On the other hand, in keeping with his doctrine of the two kingdoms, Luther did support non-religious war against the Turks. In 1526, he argued in *Whether Soldiers can be in a State of Grace* that national defence is reason for a just war. By 1529, in *On War against the Turk*, he was actively urging Emperor Charles V and the German people to fight a secular war against the Turks. He made clear, however, that the spiritual war against an alien faith was separate, to be waged through prayer and repentance. Around the time of the Siege of Vienna, Luther wrote a prayer for national deliverance from the Turks, asking God to "give to our emperor perpetual victory over our enemies". In 1542, Luther read a Latin translation of the Qur'an. He went on to produce several critical pamphlets on Islam, which he called "Mohammedanism" or "the Turk". Though Luther saw the Muslim faith as a tool of the devil, he was indifferent to its practice: "Let the Turk believe and live as he will, just as one lets the papacy and other false Christians live." He opposed banning the publication of the Qur'an, wanting it exposed to scrutiny.

Early in 1537, Johannes Agricola (1494–1566) – serving at the time as pastor in Luther's birthplace, Eisleben – preached a sermon in which he claimed that God's gospel, not God's moral law (the Ten Commandments), revealed God's wrath to Christians. Based on this sermon and others by Agricola, Luther suspected that Agricola was behind certain anonymous antinomian theses circulating in Wittenberg. These theses asserted that the law is no longer to be taught to Christians but belonged only to city hall. Luther responded to these theses with six series of theses against Agricola and the antinomians, four of which became the basis for disputations between 1538 and 1540. He also responded to these assertions in other writings, such as his 1539 open letter to C. Güttel *Against the Antinomians*, and his book *On the Councils and the Church* from the same year.

In his theses and disputations against the antinomians, Luther reviews and reaffirms, on the one hand, what has been called the "second use of the law," that is, the law as the Holy Spirit's tool to work sorrow over sin in man's heart, thus preparing him for Christ's fulfillment of the law offered in the gospel. Luther states that everything that is used to work sorrow over sin is called the law, even if it is Christ's life, Christ's death for sin, or God's goodness experienced in creation. Simply refusing to preach the Ten Commandments among Christians – thereby, as it were, removing the three letters l-a-w from the church – does not eliminate the accusing law. Claiming that the law – in any form – should not be preached to Christians anymore would be tantamount to asserting that Christians are no longer sinners in themselves and that the church consists only of essentially holy people.

On the other hand, Luther also points out that the Ten Commandments – when considered not as God's condemning judgment but as an expression of his eternal will, that is, of the natural law – also positively teach how the Christian ought to live. This has traditionally been called the "third use of the law." For Luther, also Christ's life, when understood as an example, is nothing more than an illustration of the Ten Commandments, which a Christian should follow in his or her vocations on a daily basis.

The Ten Commandments, and the beginnings of the renewed life of Christians accorded to them by the sacrament of baptism, are a present foreshadowing of the believers' future angel-like life in heaven in the midst of this life. Luther's teaching of the Ten Commandments, therefore, has clear eschatological overtones, which, characteristically for Luther, do not encourage world-flight but direct the Christian to service to the neighbor in the common, daily vocations of this perishing world.

From December 1539, Luther became implicated in the bigamy of Philip I, Landgrave of Hesse, who wanted to marry one of his wife's ladies-in-waiting. Philip solicited the approval of Luther, Melanchthon, and Bucer, citing as a precedent the polygamy of the patriarchs. The theologians were not prepared to make a general ruling, and they reluctantly advised the landgrave that if he was determined, he should marry secretly and keep quiet about the matter. As a result, on 4 March 1540, Philip married a second wife, Margarethe von der Saale, with Melanchthon and Bucer among the witnesses. However, Philip was unable to keep the marriage secret, and he threatened to make Luther's advice public. Luther told him to "tell a good, strong lie" and deny the marriage completely, which Philip did during the subsequent public controversy. In the view of Luther's biographer Martin Brecht, "giving confessional advice for Philip of Hesse was one of the worst mistakes Luther made, and, next to the landgrave himself, who was directly responsible for it, history chiefly holds Luther accountable". Brecht argues that Luther's mistake was not that he gave private pastoral advice, but that he miscalculated the political implications. The affair caused lasting damage to Luther's reputation.

Luther wrote about the Jews throughout his career, though only a few of his works dealt with them directly. Luther rarely encountered Jews during his life, but his attitudes reflected a theological and

cultural tradition which saw Jews as a rejected people guilty of the murder of Christ, and he lived within a local community that had expelled Jews some ninety years earlier. He considered the Jews blasphemers and liars because they rejected the divinity of Jesus, whereas Christians believed Jesus was the Messiah. But Luther believed that all human beings who set themselves against God were equally guilty. As early as 1516, he wrote that many people "are proud with marvelous stupidity when they call the Jews dogs, evildoers, or whatever they like, while they too, and equally, do not realize who or what they are in the sight of God". In 1523, Luther advised kindness toward the Jews in That Jesus Christ was Born a Jew and also aimed to convert them to Christianity. When his efforts at conversion failed, he grew increasingly bitter toward them. In his 2010 book *Bonhoeffer: Pastor, Martyr, Prophet, Spy*, Christian author Eric Metaxas claimed that Luther's attitude towards Jews "unraveled along with his health."

Luther's other major works on the Jews were his 60,000-word treatise *Von den Juden und Ihren Lügen* (On the Jews and Their Lies), and *Vom Schem Hamphoras und vom Geschlecht Christi* (On the Holy Name and the Lineage of Christ), both published in 1543, three years before his death. Luther argued that the Jews were no longer the chosen people but "the devil's people", and referred to them with violent, vile language. Citing Deuteronomy 13, wherein Moses commands the killing of idolaters and the burning of their cities and property as an offering to God, Luther called for a "scharfe Barmherzigkeit" ("sharp mercy") against the Jews "to see whether we might save at least a few from the glowing flames." Luther advocated setting synagogues on fire, destroying Jewish prayerbooks, forbidding rabbis from preaching, seizing Jews' property and money, and smashing up their homes, so that these "envenomed worms" would be forced into labour or expelled "for all time". In Robert Michael's view, Luther's words "We are at fault in not slaying them" amounted to a sanction for murder. "God's anger with them is so intense," Luther concluded, "that gentle mercy will only tend to make them worse, while sharp mercy will reform them but little. Therefore, in any case, away with them!"

Luther spoke out against the Jews in Saxony, Brandenburg, and Silesia. Josel of Rosheim, the Jewish spokesman who tried to help the Jews of Saxony in 1537, later blamed their plight on "that priest whose name was Martin Luther—may his body and soul be bound up in hell!—who wrote and issued many heretical books in which he said that whoever would help the Jews was doomed to perdition." Josel asked the city of Strasbourg to forbid the sale of Luther's anti-Jewish works: they refused initially, but did so when a Lutheran pastor in Hochfelden used a sermon to urge his parishioners to murder Jews. Luther's influence persisted after his death. Throughout the 1580s, riots led to the expulsion of Jews from several German Lutheran states.

Luther was the most widely read author of his generation, and within Germany he acquired the status of a prophet. According to the prevailing view among historians, his anti-Jewish rhetoric contributed significantly to the development of antisemitism in Germany, and in the 1930s and 1940s provided an "ideal underpinning" for the Nazis' attacks on Jews. Reinhold Lewin writes that anybody who "wrote against the Jews for whatever reason believed he had the right to justify himself by triumphantly referring to Luther." According to Michael, just about every anti-Jewish book printed in the Third Reich contained references to and quotations from Luther. Heinrich Himmler wrote admiringly of his writings and sermons on the Jews in 1940. The city of Nuremberg presented a first edition of *On the Jews and their Lies* to Julius Streicher, editor of the Nazi newspaper *Der Stürmer*, on his birthday in 1937; the newspaper described it as the most radically anti-Semitic tract ever published. It was publicly exhibited in a glass case at the Nuremberg rallies and quoted in a 54-page explanation of the Aryan Law by Dr. E.H. Schulz and Dr. R. Frercks.

On 17 December 1941, seven Protestant regional church confederations issued a statement agreeing with the policy of forcing Jews to wear the yellow badge, "since after his bitter experience Luther had already suggested preventive measures against the Jews and their expulsion from German territory." According to Daniel Goldhagen, Bishop Martin Sasse, a leading Protestant churchman, published a compendium of Luther's writings shortly after Kristallnacht, for which Diarmaid MacCulloch, Professor of the History of the Church in the University of Oxford argued that Luther's writing was a "blueprint." Sasse applauded the burning of the synagogues and the coincidence of the day, writing in the introduction, "On 10 November 1938, on Luther's birthday, the synagogues are burning in Germany." The German people, he urged, ought to heed these words "of the greatest antisemite of his time, the warner of his people against the Jews."

At the heart of scholars' debate about Luther's influence is whether it is anachronistic to view his work as a precursor of the racial antisemitism of the Nazis. Some scholars see Luther's influence as limited, and

the Nazis' use of his work as opportunistic. Biographer Martin Brecht points out that "There is a world of difference between his belief in salvation and a racial ideology. Nevertheless, his misguided agitation had the evil result that Luther fatefully became one of the 'church fathers' of anti-Semitism and thus provided material for the modern hatred of the Jews, cloaking it with the authority of the Reformer." Johannes Wallmann argues that Luther's writings against the Jews were largely ignored in the 18th and 19th centuries, and that there was no continuity between Luther's thought and Nazi ideology. Uwe Siemon-Netto agreed, arguing that it was because the Nazis were already anti-Semites that they revived Luther's work. Hans J. Hillerbrand agreed that to focus on Luther was to adopt an essentially ahistorical perspective of Nazi antisemitism that ignored other contributory factors in German history. Similarly, Roland Bainton, noted church historian and Luther biographer, wrote "One could wish that Luther had died before ever [On the Jews and Their Lies] was written. His position was entirely religious and in no respect racial."

Other scholars argue that, even if his views were merely anti-Judaic—that is, opposed to Judaism and its adherence rather than the Jews as an ethnic group—their violence lent a new element to the standard Christian suspicion of Judaism. Ronald Berger writes that Luther is credited with "Germanizing the Christian critique of Judaism and establishing anti-Semitism as a key element of German culture and national identity." Paul Rose argues that he caused a "hysterical and demonizing mentality" about Jews to enter German thought and discourse, a mentality that might otherwise have been absent. Christopher J. Probst in his book *Demonizing the Jews: Luther and the Protestant Church in Nazi Germany* (2012), shows that a large number of German Lutheran clergy and theologians during the Nazi Third Reich used Luther's hostile publications towards the Jews and their Jewish religion to justify at least in part the anti-Semitic policies of the National Socialists.

Some scholars, such as Mark U. Edwards in his book *Luther's Last Battles: Politics and Polemics 1531–46* (1983), suggest that since Luther's increasingly antisemitic views developed during the years his health deteriorated, it is possible they were at least partly the product of a declining state of mind.

Edwards also comments that Luther often deliberately used "vulgarity and violence" for effect, both in his writings condemning the Jews and in diatribes against "Turks" (Muslims) and Catholics.

Since the 1980s, Lutheran Church denominations have repudiated Martin Luther's statements against the Jews and have rejected the use of them to incite hatred against Lutherans. Strommen et al.'s 1970 survey of 4,745 North American Lutherans aged 15–65 found that, compared to the other minority groups under consideration, Lutherans were the least prejudiced toward Jews. Nevertheless, Professor Richard (Dick) Geary, former Professor of Modern History at the University of Nottingham, England, and the author of *Hitler and Nazism* (Routledge 1993), wrote in the journal *History Today* an article on who voted for the Nazis in elections held from 1928–1933, where he claimed that from his research he found that the Nazis gained disproportionately more votes from Protestant than Catholic areas of Germany.

Luther had been suffering from ill health for years, including Ménière's disease, vertigo, fainting, tinnitus, and a cataract in one eye. From 1531 to 1546, his health deteriorated further. The years of struggle with Rome, the antagonisms with and among his fellow reformers, and the scandal which ensued from the bigamy of the Philip of Hesse incident, in which Luther had played a leading role, all may have contributed. In 1536, he began to suffer from kidney and bladder stones, and arthritis, and an ear infection ruptured an ear drum. In December 1544, he began to feel the effects of angina.

His poor physical health made him short-tempered and even harsher in his writings and comments. His wife Katharina was overheard saying, "Dear husband, you are too rude," and he responded, "They are teaching me to be rude." In 1545 and 1546 Luther preached three times in the Market Church in Halle, staying with his friend Justus Jonas during Christmas.

His last sermon was delivered at Eisleben, his place of birth, on 15 February 1546, three days before his death. It was "entirely devoted to the obdurate Jews, whom it was a matter of great urgency to expel from all German territory," according to Léon Poliakov. James Mackinnon writes that it concluded with a "fiery summons to drive the Jews bag and baggage from their midst, unless they desisted from their calumny and their usury and became Christians." Luther said, "we want to practice Christian love toward them and pray that they convert," but also that they are "our public enemies ... and if they could kill us all, they would gladly do so. And so often they do."

Luther's final journey, to Mansfeld, was taken because of his concern for his siblings' families continuing in their father Hans Luther's copper mining trade. Their livelihood was threatened by Count Albrecht of Mansfeld bringing the industry under his own control. The controversy that ensued involved all four

Mansfeld counts: Albrecht, Philip, John George, and Gerhard. Luther journeyed to Mansfeld twice in late 1545 to participate in the negotiations for a settlement, and a third visit was needed in early 1546 for their completion.

The negotiations were successfully concluded on 17 February 1546. After 8 a.m., he experienced chest pains. When he went to his bed, he prayed, "Into your hand I commit my spirit; you have redeemed me, O Lord, faithful God" (Ps. 31:5), the common prayer of the dying. At 1 a.m. he awoke with more chest pain and was warmed with hot towels. He thanked God for revealing his Son to him in whom he had believed. His companions, Justus Jonas and Michael Coelius, shouted loudly, "Reverend father, are you ready to die trusting in your Lord Jesus Christ and to confess the doctrine which you have taught in his name?" A distinct "Yes" was Luther's reply.

An apoplectic stroke deprived him of his speech, and he died shortly afterwards at 2:45 a.m. on 18 February 1546, aged 62, in Eisleben, the city of his birth. He was buried in the Castle Church in Wittenberg, beneath the pulpit. The funeral was held by his friends Johannes Bugenhagen and Philipp Melancthon. A year later, troops of Luther's adversary Charles V, Holy Roman Emperor entered the town, but were ordered by Charles not to disturb the grave.

A piece of paper was later found on which Luther had written his last statement. The statement was in Latin, apart from "We are beggars," which was in German.

In the 1530s and 1540s, printed images of Luther that emphasized his monumental size were crucial to the spread of Protestantism. In contrast to images of frail Catholic saints, Luther was presented as a stout man with a "double chin, strong mouth, piercing deep-set eyes, fleshy face, and squat neck." He was shown to be physically imposing, an equal in stature to the secular German princes with whom he would join forces to spread Lutheranism. His large body also let the viewer know that he did not shun earthly pleasures like drinking—behavior that was a stark contrast to the ascetic life of the medieval religious orders. Famous images from this period include the woodcuts by Hans Brosamer (1530) and Lucas Cranach the Elder and Lucas Cranach the Younger (1546).

Luther is honoured on 18 February with a commemoration in the Lutheran Calendar of Saints and in the Episcopal (United States) Calendar of Saints. In the Church of England's Calendar of Saints he is commemorated on 31 October.

Southern California, often abbreviated SoCal, is a geographic and cultural region that generally comprises California's southernmost 10 counties. The region is traditionally described as "eight counties", based on demographics and economic ties: Imperial, Los Angeles, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura. The more extensive 10-county definition, including Kern and San Luis Obispo counties, is also used based on historical political divisions. Southern California is a major economic center for the state of California and the United States.

The 8- and 10-county definitions are not used for the greater Southern California Megaregion, one of the 11 megaregions of the United States. The megaregion's area is more expansive, extending east into Las Vegas, Nevada, and south across the Mexican border into Tijuana.

Southern California includes the heavily built-up urban area stretching along the Pacific coast from Ventura, through the Greater Los Angeles Area and the Inland Empire, and down to Greater San Diego. Southern California's population encompasses seven metropolitan areas, or MSAs: the Los Angeles metropolitan area, consisting of Los Angeles and Orange counties; the Inland Empire, consisting of Riverside and San Bernardino counties; the San Diego metropolitan area; the Oxnard–Thousand Oaks–Ventura metropolitan area; the Santa Barbara metro area; the San Luis Obispo metropolitan area; and the El Centro area. Out of these, three are heavily populated areas: the Los Angeles area with over 12 million inhabitants, the Riverside–San Bernardino area with over four million inhabitants, and the San Diego area with over 3 million inhabitants. For CSA metropolitan purposes, the five counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura are all combined to make up the Greater Los Angeles Area with over 17.5 million people. With over 22 million people, southern California contains roughly 60 percent of California's population.

To the east is the Colorado Desert and the Colorado River at the border with Arizona, and the Mojave Desert at the border with the state of Nevada. To the south is the Mexico–United States border.

Within southern California are two major cities, Los Angeles and San Diego, as well as three of the country's largest metropolitan areas. With a population of 3,792,621, Los Angeles is the most populous city in California and the second most populous in the United States. To the south and with a population of 1,307,402 is San Diego, the second most populous city in the state and the eighth most populous in the

nation.

Its counties of Los Angeles, Orange, San Diego, San Bernardino, and Riverside are the five most populous in the state and all are in the top 15 most populous counties in the United States.

The motion picture, television, and music industry is centered on the Los Angeles in southern California. Hollywood, a district within Los Angeles, is also a name associated with the motion picture industry. Headquartered in southern California are The Walt Disney Company (which also owns ABC), Sony Pictures, Universal, MGM, Paramount Pictures, 20th Century Fox, and Warner Brothers. Universal, Warner Brothers, and Sony also run major record companies as well.

Southern California is also home to a large home grown surf and skateboard culture. Companies such as Volcom, Quiksilver, No Fear, RVCA, and Body Glove are all headquartered here. Professional skateboarder Tony Hawk, professional surfers Rob Machado, Tim Curran, Bobby Martinez, Pat O'Connell, Dane Reynolds, and Chris Ward, and professional snowboarder Shaun White live in southern California. Some of the world's legendary surf spots are in southern California as well, including Trestles, Rincon, The Wedge, Huntington Beach, and Malibu, and it is second only to the island of Oahu in terms of famous surf breaks. Some of the world's biggest extreme sports events, including the X Games, Boost Mobile Pro, and the U.S. Open of Surfing are all in southern California. Southern California is also important to the world of yachting. The annual Transpacific Yacht Race, or Transpac, from Los Angeles to Hawaii, is one of yachting's premier events. The San Diego Yacht Club held the America's Cup, the most prestigious prize in yachting, from 1988 to 1995 and hosted three America's Cup races during that time. Many locals and tourists frequent the southern California coast for its popular beaches, and the desert city of Palm Springs is popular for its resort feel and nearby open spaces.

"Southern California" is not a formal geographic designation, and definitions of what constitutes southern California vary. Geographically, California's north-south midway point lies at exactly 37° 9' 58.23" latitude, around 11 miles (18 km) south of San Jose; however, this does not coincide with popular use of the term. When the state is divided into two areas (northern and southern California), the term "southern California" usually refers to the ten southern-most counties of the state. This definition coincides neatly with the county lines at 35° 47' 28" north latitude, which form the northern borders of San Luis Obispo, Kern, and San Bernardino counties. Another definition for southern California uses Point Conception and the Tehachapi Mountains as the northern boundary.

Though there is no official definition for the northern boundary of southern California, such a division has existed from the time when Mexico ruled California, and political disputes raged between the Californios of Monterey in the upper part and Los Angeles in the lower part of Alta California. Following the acquisition of California by the United States, the division continued as part of the attempt by several pro-slavery politicians to arrange the division of Alta California at 36 degrees, 30 minutes, the line of the Missouri Compromise. Instead, the passing of the Compromise of 1850 enabled California to be admitted to the Union as a free state, preventing southern California from becoming its own separate slave state. Subsequently, Californios (dissatisfied with inequitable taxes and land laws) and pro-slavery southerners in the lightly populated "Cow Counties" of southern California attempted three times in the 1850s to achieve a separate statehood or territorial status separate from Northern California. The last attempt, the Pico Act of 1859, was passed by the California State Legislature and signed by the State governor John B. Weller. It was approved overwhelmingly by nearly 75% of voters in the proposed Territory of Colorado. This territory was to include all the counties up to the then much larger Tulare County (that included what is now Kings, most of Kern, and part of Inyo counties) and San Luis Obispo County. The proposal was sent to Washington, D.C. with a strong advocate in Senator Milton Latham. However, the secession crisis following the election of Abraham Lincoln in 1860 led to the proposal never coming to a vote.

In 1900, the Los Angeles Times defined southern California as including "the seven counties of Los Angeles, San Bernardino, Orange, Riverside, San Diego, Ventura and Santa Barbara." In 1999, the Times added a newer county—Imperial—to that list.

The state is most commonly divided and promoted by its regional tourism groups as consisting of northern, central, and southern California regions. The two AAA Auto Clubs of the state, the California State Automobile Association and the Automobile Club of Southern California, choose to simplify matters by dividing the state along the lines where their jurisdictions for membership apply, as either northern or southern California, in contrast to the three-region point of view. Another influence is the geographical phrase South of the Tehachapis, which would split the southern region off at the crest of that transverse range, but in that definition, the desert portions of north Los Angeles County and eastern Kern and San

Bernardino Counties would be included in the southern California region due to their remoteness from the central valley and interior desert landscape.

Southern California consists of a heavily developed urban environment, home to some of the largest urban areas in the state, along with vast areas that have been left undeveloped. It is the third most populated megalopolis in the United States, after the Great Lakes Megalopolis and the Northeastern megalopolis. Much of southern California is famous for its large, spread-out, suburban communities and use of automobiles and highways. The dominant areas are Los Angeles, Orange County, San Diego, and Riverside-San Bernardino, each of which is the center of its respective metropolitan area, composed of numerous smaller cities and communities. The urban area is also host to an international metropolitan region in the form of San Diego–Tijuana, created by the urban area spilling over into Baja California. Traveling south on Interstate 5, the main gap to continued urbanization is Camp Pendleton. The cities and communities along Interstate 15 and Interstate 215 are so inter-related that Temecula and Murrieta have as much connection with the San Diego metropolitan area as they do with the Inland Empire. To the east, the United States Census Bureau considers the San Bernardino and Riverside County areas, Riverside-San Bernardino area as a separate metropolitan area from Los Angeles County. While many commute to L.A. and Orange Counties, there are some differences in development, as most of San Bernardino and Riverside Counties (the non-desert portions) were developed in the 1980s and 1990s. Newly developed exurbs formed in the Antelope Valley north of Los Angeles, the Victor Valley and the Coachella Valley with the Imperial Valley. Also, population growth was high in the Bakersfield-Kern County, Santa Maria and San Luis Obispo areas.

Southern California contains a Mediterranean climate, with infrequent rain and many sunny days. Summers are hot and dry, while winters are a bit warm or mild and wet. Serious rain can occur unusually. In the summers, temperature ranges are 90-60's while as winters are 70-50's, usually all of Southern California have Mediterranean climate. But snow is very rare in the Southwest of the state, it occurs on the Southeast of the state.

Southern California consists of one of the more varied collections of geologic, topographic, and natural ecosystem landscapes in a diversity outnumbering other major regions in the state and country. The region spans from Pacific Ocean islands, shorelines, beaches, and coastal plains, through the Transverse and Peninsular Ranges with their peaks, into the large and small interior valleys, to the vast deserts of California.

Each year, the southern California area has about 10,000 earthquakes. Nearly all of them are so small that they are not felt. Only several hundred are greater than magnitude 3.0, and only about 15–20 are greater than magnitude 4.0. The magnitude 6.7 1994 Northridge earthquake was particularly destructive, causing a substantial number of deaths, injuries, and structural collapses. It caused the most property damage of any earthquake in U.S. history, estimated at over \$20 billion.

Many faults are able to produce a magnitude 6.7+ earthquake, such as the San Andreas Fault, which can produce a magnitude 8.0 event. Other faults include the San Jacinto Fault, the Puente Hills Fault, and the Elsinore Fault Zone. The USGS has released a California Earthquake forecast which models Earthquake occurrence in California.

Southern California is divided culturally, politically, and economically into distinctive regions, each containing its own culture and atmosphere, anchored usually by a city with both national and sometimes global recognition, which are often the hub of economic activity for its respective region and being home to many tourist destinations. Each region is further divided into many culturally distinct areas but as a whole combine to create the southern California atmosphere.

As of the 2010 United States Census, southern California has a population of 22,680,010. Despite a reputation for high growth rates, southern California's rate grew less than the state average of 10.0% in the 2000s as California's growth became concentrated in the northern part of the state due to a stronger, tech-oriented economy in the Bay Area and an emerging Greater Sacramento region.

Southern California consists of one Combined Statistical Area, eight Metropolitan Statistical Areas, one international metropolitan area, and multiple metropolitan divisions. The region is home to two extended metropolitan areas that exceed five million in population. These are the Greater Los Angeles Area at 17,786,419, and San Diego–Tijuana at 5,105,768. Of these metropolitan areas, the Los Angeles-Long Beach-Santa Ana metropolitan area, Riverside-San Bernardino-Ontario metropolitan area, and Oxnard-Thousand Oaks-Ventura metropolitan area form Greater Los Angeles; while the El Centro metropolitan area and San Diego-Carlsbad-San Marcos metropolitan area form the Southern Border



Region. North of Greater Los Angeles are the Santa Barbara, San Luis Obispo, and Bakersfield metropolitan areas.

Los Angeles (at 3.7 million people) and San Diego (at 1.3 million people), both in southern California, are the two largest cities in all of California (and two of the eight largest cities in the United States). In southern California there are also twelve cities with more than 200,000 residents and 34 cities over 100,000 in population. Many of southern California's most developed cities lie along or in close proximity to the coast, with the exception of San Bernardino and Riverside.

Southern California's economy is diverse and one of the largest in the United States. It is dominated and heavily dependent upon abundance of petroleum, as opposed to other regions where automobiles not nearly as dominant, the vast majority of transport runs on this fuel. Southern California is famous for tourism and Hollywood (film, television, and music). Other industries include software, automotive, ports, finance, tourism, biomedical, and regional logistics. The region was a leader in the housing bubble 2001–2007, and has been heavily impacted by the housing crash.

Since the 1920s, motion pictures, petroleum and aircraft manufacturing have been major industries. In one of the richest agricultural regions in the U.S., cattle and citrus were major industries until farmlands were turned into suburbs. Although military spending cutbacks have had an impact, aerospace continues to be a major factor.

Southern California is home to many major business districts. Central business districts (CBD) include Downtown Los Angeles, Downtown San Diego, Downtown San Bernardino, Downtown Bakersfield, South Coast Metro and Downtown Riverside.

Within the Los Angeles Area are the major business districts of Downtown Burbank, Downtown Santa Monica, Downtown Glendale and Downtown Long Beach. Los Angeles itself has many business districts including the Downtown Los Angeles central business district as well as those lining the Wilshire Boulevard Miracle Mile including Century City, Westwood and Warner Center in the San Fernando Valley.

The San Bernardino-Riverside area maintains the business districts of Downtown San Bernardino, Hospitality Business/Financial Centre, University Town which are in San Bernardino and Downtown Riverside.

Orange County is a rapidly developing business center that includes Downtown Santa Ana, the South Coast Metro and Newport Center districts; as well as the Irvine business centers of The Irvine Spectrum, West Irvine, and international corporations headquartered at the University of California, Irvine. West Irvine includes the Irvine Tech Center and Jamboree Business Parks.

Downtown San Diego is the central business district of San Diego, though the city is filled with business districts. These include Carmel Valley, Del Mar Heights, Mission Valley, Rancho Bernardo, Sorrento Mesa, and University City. Most of these districts are located in Northern San Diego and some within North County regions.

Southern California is home to Los Angeles International Airport, the second-busiest airport in the United States by passenger volume (see World's busiest airports by passenger traffic) and the third by international passenger volume (see Busiest airports in the United States by international passenger traffic); San Diego International Airport the busiest single runway airport in the world; Van Nuys Airport, the world's busiest general aviation airport; major commercial airports at Orange County, Bakersfield, Ontario, Burbank and Long Beach; and numerous smaller commercial and general aviation airports.

Six of the seven lines of the commuter rail system, Metrolink, run out of Downtown Los Angeles, connecting Los Angeles, Ventura, San Bernardino, Riverside, Orange, and San Diego counties with the other line connecting San Bernardino, Riverside, and Orange counties directly.

Southern California is also home to the Port of Los Angeles, the United States' busiest commercial port; the adjacent Port of Long Beach, the United States' second busiest container port; and the Port of San Diego.

The Tech Coast is a moniker that has gained use as a descriptor for the region's diversified technology and industrial base as well as its multitude of prestigious and world-renowned research universities and other public and private institutions. Amongst these include 5 University of California campuses (Irvine, Los Angeles, Riverside, Santa Barbara, and San Diego); 12 California State University campuses (Bakersfield, Channel Islands, Dominguez Hills, Fullerton, Los Angeles, Long Beach, Northridge, Pomona, San Bernardino, San Diego, San Marcos, and San Luis Obispo); and private institutions such as the California Institute of Technology, Chapman University, the Claremont Colleges (Claremont McKenna

College, Harvey Mudd College, Pitzer College, Pomona College, and Scripps College), Loma Linda University, Loyola Marymount University, Occidental College, Pepperdine University, University of Redlands, University of San Diego, and the University of Southern California.

Professional sports teams in Southern California include teams from the NFL (Los Angeles Rams, San Diego Chargers); NBA (Los Angeles Lakers, Los Angeles Clippers); MLB (Los Angeles Dodgers, Los Angeles Angels of Anaheim, San Diego Padres); NHL (Los Angeles Kings, Anaheim Ducks); and MLS (LA Galaxy).

From 2005 to 2014, there were two Major League Soccer teams in Los Angeles — the LA Galaxy and Chivas USA — that both played at the StubHub Center and were local rivals. However, Chivas were suspended following the 2014 MLS season, with a second MLS team scheduled to return in 2018.

College sports are also popular in southern California. The UCLA Bruins and the USC Trojans both field teams in NCAA Division I in the Pac-12 Conference, and there is a longtime rivalry between the schools. Rugby is also a growing sport in southern California, particularly at the high school level, with increasing numbers of schools adding rugby as an official school sport.

Formed in November 1990 by the equal merger of Sky Television and British Satellite Broadcasting, BSkyB became the UK's largest digital subscription television company. Following BSkyB's 2014 acquisition of Sky Italia and a majority 90.04% interest in Sky Deutschland in November 2014, its holding company British Sky Broadcasting Group plc changed its name to Sky plc. The United Kingdom operations also changed the company name from British Sky Broadcasting Limited to Sky UK Limited, still trading as Sky.

Following a lengthy legal battle with the European Commission, which deemed the exclusivity of the rights to be against the interests of competition and the consumer, BSkyB's monopoly came to an end from the 2007–08 season. In May 2006, the Irish broadcaster Setanta Sports was awarded two of the six Premier League packages that the English FA offered to broadcasters. Sky picked up the remaining four for £1.3bn. In February 2015, Sky bid £4.2bn for a package of 120 premier league games across the three seasons from 2016. This represented an increase of 70% on the previous contract and was said to be £1bn more than the company had expected to pay. The move has been followed by staff cuts, increased subscription prices (including 9% in Sky's family package) and the dropping of the 3D channel.

While BSkyB had been excluded from being a part of the ONdigital consortium, thereby making them a competitor by default, BSkyB was able to join ITV Digital's free-to-air replacement, Freeview, in which it holds an equal stake with the BBC, ITV, Channel 4 and National Grid Wireless. Prior to October 2005, three BSkyB channels were available on this platform: Sky News, Sky Three, and Sky Sports News.

Initially BSkyB provided Sky Travel to the service. However, this was replaced by Sky Three on 31 October 2005, which was itself later re-branded as 'Pick TV' in 2011.

BSkyB initially charged additional subscription fees for using a Sky+ PVR with their service; waiving the charge for subscribers whose package included two or more premium channels. This changed as from 1 July 2007, and now customers that have Sky+ and subscribe to any BSkyB subscription package get Sky+ included at no extra charge. Customers that do not subscribe to BSkyB's channels can still pay a monthly fee to enable Sky+ functions. In January 2010 BSkyB discontinued the Sky+ Box, limited the standard Sky Box to Multiroom upgrade only and started to issue the Sky+HD Box as standard, thus giving all new subscribers the functions of Sky+. In February 2011 BSkyB discontinued the non-HD variant of its Multiroom box, offering a smaller version of the SkyHD box without Sky+ functionality. In September 2007, Sky launched a new TV advertising campaign targeting Sky+ at women. As of 31 March 2008, Sky had 3,393,000 Sky+ users.

BSkyB utilises the VideoGuard pay-TV scrambling system owned by NDS, a Cisco Systems company. There are tight controls over use of VideoGuard decoders; they are not available as stand-alone DVB CAMs (conditional-access modules). BSkyB has design authority over all digital satellite receivers capable of receiving their service. The receivers, though designed and built by different manufacturers, must conform to the same user interface look-and-feel as all the others. This extends to the Personal video recorder (PVR) offering (branded Sky+).

In 2007, BSkyB and Virgin Media became involved in a dispute over the carriage of Sky channels on cable TV. The failure to renew the existing carriage agreements negotiated with NTL and Telewest resulted in Virgin Media removing the basic channels from the network on 1 March 2007. Virgin Media claimed that BSkyB had substantially increased the asking price for the channels, a claim which BSkyB denied, on the basis that their new deal offered "substantially more value" by including HD channels and

Video On Demand content which was not previously carried by cable.

In July 2013, the English High Court of Justice found that Microsoft's use of the term "SkyDrive" infringed on Sky's right to the "Sky" trademark. On 31 July 2013, BSkyB and Microsoft announced their settlement, in which Microsoft will not appeal the ruling, and will rename its SkyDrive cloud storage service after an unspecified "reasonable period of time to allow for an orderly transition to a new brand," plus "financial and other terms, the details of which are confidential". On 27 January 2014, Microsoft announced "that SkyDrive will soon become OneDrive" and "SkyDrive Pro" becomes "OneDrive for Business".

The service started on 1 September 1993 based on the idea from the then chief executive officer, Sam Chisholm and Rupert Murdoch, of converting the company business strategy to an entirely fee-based concept. The new package included four channels formerly available free-to-air, broadcasting on Astra's satellites, as well as introducing new channels. The service continued until the closure of BSkyB's analogue service on 27 September 2001, due to the launch and expansion of the Sky Digital platform. Some of the channels did broadcast either in the clear or soft encrypted (whereby a Videocrypt decoder was required to decode, without a subscription card) prior to their addition to the Sky Multichannels package. Within two months of the launch, BSkyB gained 400,000 new subscribers, with the majority taking at least one premium channel as well, which helped BSkyB reach 3.5 million households by mid-1994. Michael Grade criticized the operations in front of the Select Committee on National Heritage, mainly for the lack of original programming on many of the new channels.

Sky UK Limited (formerly British Sky Broadcasting or BSkyB) is a British telecommunications company which serves the United Kingdom. Sky provides television and broadband internet services and fixed line telephone services to consumers and businesses in the United Kingdom. It is the UK's largest pay-TV broadcaster with 11 million customers as of 2015. It was the UK's most popular digital TV service until it was overtaken by Freeview in April 2007. Its corporate headquarters are based in Isleworth.

On 18 November 2015, Sky announced Sky Q, a range of products and services to be available in 2016. The Sky Q range consists of three set top boxes (Sky Q, Sky Q Silver and Sky Q Mini), a broadband router (Sky Q Hub) and mobile applications. The Sky Q set top boxes introduce a new user interface, Wi-Fi hotspot functionality, Power-line and Bluetooth connectivity and a new touch-sensitive remote control. The Sky Q Mini set top boxes connect to the Sky Q Silver set top boxes with a Wi-Fi or Power-line connection rather than receive their own satellite feeds. This allows all set top boxes in a household to share recordings and other media. The Sky Q Silver set top box is capable of receiving and displaying UHD broadcasts, which Sky will introduce later in 2016.

BSkyB's standard definition broadcasts are in DVB-compliant MPEG-2, with the Sky Movies and Sky Box Office channels including optional Dolby Digital soundtracks for recent films, although these are only accessible with a Sky+ box. Sky+ HD material is broadcast using MPEG-4 and most of the HD material uses the DVB-S2 standard. Interactive services and 7-day EPG use the proprietary OpenTV system, with set-top boxes including modems for a return path. Sky News, amongst other channels, provides a pseudo-video on demand interactive service by broadcasting looping video streams.

When Sky Digital was launched in 1998 the new service used the Astra 2A satellite which was located at the 28.5°E orbital position, unlike the analogue service which was broadcast from 19.2°E. This was subsequently followed by more Astra satellites as well as Eutelsat's Eurobird 1 (now Eutelsat 33C) at 28.5°E), enabled the company to launch a new all-digital service, Sky, with the potential to carry hundreds of television and radio channels. The old position was shared with broadcasters from several European countries, while the new position at 28.5°E came to be used almost exclusively for channels that broadcast to the United Kingdom.

BSkyB launched its HDTV service, Sky+ HD, on 22 May 2006. Prior to its launch, BSkyB claimed that 40,000 people had registered to receive the HD service. In the week before the launch, rumours started to surface that BSkyB was having supply issues with its set top box (STB) from manufacturer Thomson. On Thursday 18 May 2006, and continuing through the weekend before launch, people were reporting that BSkyB had either cancelled or rescheduled its installation. Finally, the BBC reported that 17,000 customers had yet to receive the service due to failed deliveries. On 31 March 2012, Sky announced the total number of homes with Sky+HD was 4,222,000.

On 8 February 2007, BSkyB announced its intention to replace its three free-to-air digital terrestrial channels with four subscription channels. It was proposed that these channels would offer a range of content from the BSkyB portfolio including sport (including English Premier League Football), films, entertainment and news. The announcement came a day after Setanta Sports confirmed that it would

launch in March as a subscription service on the digital terrestrial platform, and on the same day that NTL's services re-branded as Virgin Media. However, industry sources believe BSkyB will be forced to shelve plans to withdraw its channels from Freeview and replace them with subscription channels, due to possible lost advertising revenue.

Provided is a universal Ku band LNB (9.75/10.600 GHz) which is fitted at the end of the dish and pointed at the correct satellite constellation; most digital receivers will receive the free to air channels. Some broadcasts are free-to-air and unencrypted, some are encrypted but do not require a monthly subscription (known as free-to-view), some are encrypted and require a monthly subscription, and some are pay-per-view services. To view the encrypted content a VideoGuard UK equipped receiver (all of which are dedicated to the Sky service, and cannot be used to decrypt other services) needs to be used. Unofficial CAMs are now available to view the service, although use of them breaks the user's contract with Sky and invalidates the user's rights to use the card.

In the autumn of 1991, talks were held for the broadcast rights for Premier League for a five-year period, from the 1992 season. ITV were the current rights holders, and fought hard to retain the new rights. ITV had increased its offer from £18m to £34m per year to keep control of the rights. BSkyB joined forces with the BBC to make a counter bid. The BBC was given the highlights of most of the matches, while BSkyB paying £304m for the Premier League rights, would give them a monopoly of all live matches, up to 60 per year from the 1992 season. Murdoch described sport as a "battering ram" for pay-television, providing a strong customer base. A few weeks after the deal, ITV went to the High Court to get an injunction as it believed their bid details had been leaked before the decision was taken. ITV also asked the Office of Fair Trading to investigate since it believed Rupert Murdoch's media empire via its newspapers had influenced the deal. A few days later neither action took effect, ITV believed BSkyB was telephoned and informed of its £262m bid, and Premier League advised BSkyB to increase its counter bid.

BSkyB has no veto over the presence of channels on their EPG, with open access being an enforced part of their operating licence from Ofcom. Any channel which can get carriage on a suitable beam of a satellite at 28° East is entitled to access to BSkyB's EPG for a fee, ranging from £15–100,000. Third-party channels which opt for encryption receive discounts ranging from reduced price to free EPG entries, free carriage on a BSkyB leased transponder, or actual payment for being carried. However, even in this case, BSkyB does not carry any control over the channel's content or carriage issues such as picture quality. BSkyB's digital service was officially launched on 1 October 1998 under the name Sky Digital, although small-scale tests were carried out before then. At this time the use of the Sky Digital brand made an important distinction between the new service and Sky's analogue services. Key selling points were the improvement in picture and sound quality, increased number of channels and an interactive service branded Open.... now called Sky Active, BSkyB competed with the ONdigital (later ITV Digital) terrestrial offering and cable services. Within 30 days, over 100,000 digiboxes had been sold, which help bolstered BSkyB's decision to give away free digiboxes and minidishes from May 1999.

Virgin Media (re-branded in 2007 from NTL:Telewest) started to offer a high-definition television (HDTV) capable set top box, although from 30 November 2006 until 30 July 2009 it only carried one linear HD channel, BBC HD, after the conclusion of the ITV HD trial. Virgin Media has claimed that other HD channels were "locked up" or otherwise withheld from their platform, although Virgin Media did in fact have an option to carry Channel 4 HD in the future. Nonetheless, the linear channels were not offered, Virgin Media instead concentrating on its Video On Demand service to carry a modest selection of HD content. Virgin Media has nevertheless made a number of statements over the years, suggesting that more linear HD channels are on the way.

BSkyB's direct-to-home satellite service became available in 10 million homes in 2010, Europe's first pay-TV platform in to achieve that milestone. Confirming it had reached its target, the broadcaster said its reach into 36% of households in the UK represented an audience of more than 25m people. The target was first announced in August 2004, since then an additional 2.4m customers had subscribed to BSkyB's direct-to-home service. Media commentators had debated whether the figure could be reached as the growth in subscriber numbers elsewhere in Europe flattened.

The Daily Mail newspaper reported in 2012 that the UK government's benefits agency was checking claimants' "Sky TV bills to establish if a woman in receipt of benefits as a single mother is wrongly claiming to be living alone" – as, it claimed, subscription to sports channels would betray a man's presence in the household. In December, the UK's parliament heard a claim that a subscription to BSkyB was 'often damaging', along with alcohol, tobacco and gambling. Conservative MP Alec Shelbrooke was

proposing the payments of benefits and tax credits on a "Welfare Cash Card", in the style of the Supplemental Nutrition Assistance Program, that could be used to buy only "essentials".

The agreements include fixed annual carriage fees of £30m for the channels with both channel suppliers able to secure additional capped payments if their channels meet certain performance-related targets. Currently there is no indication as to whether the new deal includes the additional Video On Demand and High Definition content which had previously been offered by BSkyB. As part of the agreements, both BSkyB and Virgin Media agreed to terminate all High Court proceedings against each other relating to the carriage of their respective basic channels.

The economy of Victoria is highly diversified: service sectors including financial and property services, health, education, wholesale, retail, hospitality and manufacturing constitute the majority of employment. Victoria's total gross state product (GSP) is ranked second in Australia, although Victoria is ranked fourth in terms of GSP per capita because of its limited mining activity. Culturally, Melbourne is home to a number of museums, art galleries and theatres and is also described as the "sporting capital of Australia". The Melbourne Cricket Ground is the largest stadium in Australia, and the host of the 1956 Summer Olympics and the 2006 Commonwealth Games. The ground is also considered the "spiritual home" of Australian cricket and Australian rules football, and hosts the grand final of the Australian Football League (AFL) each year, usually drawing crowds of over 95,000 people. Victoria includes eight public universities, with the oldest, the University of Melbourne, having been founded in 1853.

Immigrants arrived from all over the world to search for gold, especially from Ireland and China. Many Chinese miners worked in Victoria, and their legacy is particularly strong in Bendigo and its environs. Although there was some racism directed at them, there was not the level of anti-Chinese violence that was seen at the Lambing Flat riots in New South Wales. However, there was a riot at Buckland Valley near Bright in 1857. Conditions on the gold fields were cramped and unsanitary; an outbreak of typhoid at Buckland Valley in 1854 killed over 1,000 miners.

In November 2006, the Victorian Legislative Council elections were held under a new multi-member proportional representation system. The State of Victoria was divided into eight electorates with each electorate represented by five representatives elected by Single Transferable Vote. The total number of upper house members was reduced from 44 to 40 and their term of office is now the same as the lower house members—four years. Elections for the Victorian Parliament are now fixed and occur in November every four years. Prior to the 2006 election, the Legislative Council consisted of 44 members elected to eight-year terms from 22 two-member electorates.

The centre-left Australian Labor Party (ALP), the centre-right Liberal Party of Australia, the rural-based National Party of Australia, and the environmentalist Australian Greens are Victoria's main political parties. Traditionally, Labor is strongest in Melbourne's working class western and northern suburbs, and the regional cities of Ballarat, Bendigo and Geelong. The Liberals' main support lies in Melbourne's more affluent eastern and outer suburbs, and some rural and regional centres. The Nationals are strongest in Victoria's North Western and Eastern rural regional areas. The Greens, who won their first lower house seats in 2014, are strongest in inner Melbourne.

About 61.1% of Victorians describe themselves as Christian. Roman Catholics form the single largest religious group in the state with 26.7% of the Victorian population, followed by Anglicans and members of the Uniting Church. Buddhism is the state's largest non-Christian religion, with 168,637 members as of the most recent census. Victoria is also home of 152,775 Muslims and 45,150 Jews. Hinduism is the fastest growing religion. Around 20% of Victorians claim no religion. Amongst those who declare a religious affiliation, church attendance is low.

Victoria (abbreviated as Vic) is a state in the south-east of Australia. Victoria is Australia's most densely populated state and its second-most populous state overall. Most of its population is concentrated in the area surrounding Port Phillip Bay, which includes the metropolitan area of its capital and largest city, Melbourne, which is Australia's second-largest city. Geographically the smallest state on the Australian mainland, Victoria is bordered by Bass Strait and Tasmania to the south,[note 1] New South Wales to the north, the Tasman Sea to the east, and South Australia to the west.

Prior to European settlement, the area now constituting Victoria was inhabited by a large number of Aboriginal peoples, collectively known as the Koori. With Great Britain having claimed the entire Australian continent east of the 135th meridian east in 1788, Victoria was included in the wider colony of New South Wales. The first settlement in the area occurred in 1803 at Sullivan Bay, and much of what is now Victoria was included in the Port Phillip District in 1836, an administrative division of New South

Wales. Victoria was officially created a separate colony in 1851, and achieved self-government in 1855. The Victorian gold rush in the 1850s and 1860s significantly increased both the population and wealth of the colony, and by the Federation of Australia in 1901, Melbourne had become the largest city and leading financial centre in Australasia. Melbourne also served as capital of Australia until the construction of Canberra in 1927, with the Federal Parliament meeting in Melbourne's Parliament House and all principal offices of the federal government being based in Melbourne.

More than 26,000 square kilometres (10,000 sq mi) of Victorian farmland are sown for grain, mostly in the state's west. More than 50% of this area is sown for wheat, 33% for barley and 7% for oats. A further 6,000 square kilometres (2,300 sq mi) is sown for hay. In 2003–04, Victorian farmers produced more than 3 million tonnes of wheat and 2 million tonnes of barley. Victorian farms produce nearly 90% of Australian pears and third of apples. It is also a leader in stone fruit production. The main vegetable crops include asparagus, broccoli, carrots, potatoes and tomatoes. Last year, 121,200 tonnes of pears and 270,000 tonnes of tomatoes were produced.

Victoria has a written constitution enacted in 1975, but based on the 1855 colonial constitution, passed by the United Kingdom Parliament as the Victoria Constitution Act 1855, which establishes the Parliament as the state's law-making body for matters coming under state responsibility. The Victorian Constitution can be amended by the Parliament of Victoria, except for certain "entrenched" provisions that require either an absolute majority in both houses, a three-fifths majority in both houses, or the approval of the Victorian people in a referendum, depending on the provision.

The Mallee and upper Wimmera are Victoria's warmest regions with hot winds blowing from nearby semi-deserts. Average temperatures exceed 32 °C (90 °F) during summer and 15 °C (59 °F) in winter. Except at cool mountain elevations, the inland monthly temperatures are 2–7 °C (4–13 °F) warmer than around Melbourne (see chart). Victoria's highest maximum temperature since World War II, of 48.8 °C (119.8 °F) was recorded in Hopetoun on 7 February 2009, during the 2009 southeastern Australia heat wave.

Victorian schools are either publicly or privately funded. Public schools, also known as state or government schools, are funded and run directly by the Victoria Department of Education . Students do not pay tuition fees, but some extra costs are levied. Private fee-paying schools include parish schools run by the Roman Catholic Church and independent schools similar to British public schools. Independent schools are usually affiliated with Protestant churches. Victoria also has several private Jewish and Islamic primary and secondary schools. Private schools also receive some public funding. All schools must comply with government-set curriculum standards. In addition, Victoria has four government selective schools, Melbourne High School for boys, MacRobertson Girls' High School for girls, the coeducational schools John Monash Science School, Nossal High School and Suzanne Cory High School, and The Victorian College of the Arts Secondary School. Students at these schools are exclusively admitted on the basis of an academic selective entry test.

Historically, Victoria has been the base for the manufacturing plants of the major car brands Ford, Toyota and Holden; however, closure announcements by all three companies in the 21st century will mean that Australia will no longer be a base for the global car industry, with Toyota's statement in February 2014 outlining a closure year of 2017. Holden's announcement occurred in May 2013, followed by Ford's decision in December of the same year (Ford's Victorian plants—in Broadmeadows and Geelong—will close in October 2016).

Victoria contains many topographically, geologically and climatically diverse areas, ranging from the wet, temperate climate of Gippsland in the southeast to the snow-covered Victorian alpine areas which rise to almost 2,000 m (6,600 ft), with Mount Bogong the highest peak at 1,986 m (6,516 ft). There are extensive semi-arid plains to the west and northwest. There is an extensive series of river systems in Victoria. Most notable is the Murray River system. Other rivers include: Ovens River, Goulburn River, Patterson River, King River, Campaspe River, Loddon River, Wimmera River, Elgin River, Barwon River, Thomson River, Snowy River, Latrobe River, Yarra River, Maribyrnong River, Mitta River, Hopkins River, Merri River and Kiewa River. The state symbols include the pink heath (state flower), Leadbeater's possum (state animal) and the helmeted honeyeater (state bird).

The Victorian Alps in the northeast are the coldest part of Victoria. The Alps are part of the Great Dividing Range mountain system extending east-west through the centre of Victoria. Average temperatures are less than 9 °C (48 °F) in winter and below 0 °C (32 °F) in the highest parts of the ranges. The state's lowest minimum temperature of −11.7 °C (10.9 °F) was recorded at Omeo on 13 June 1965, and again at

Falls Creek on 3 July 1970. Temperature extremes for the state are listed in the table below:

Rail transport in Victoria is provided by several private and public railway operators who operate over government-owned lines. Major operators include: Metro Trains Melbourne which runs an extensive, electrified, passenger system throughout Melbourne and suburbs; V/Line which is now owned by the Victorian Government, operates a concentrated service to major regional centres, as well as long distance services on other lines; Pacific National, CFCL Australia which operate freight services; Great Southern Rail which operates The Overland Melbourne—Adelaide; and NSW TrainLink which operates XPTs Melbourne—Sydney.

Politically, Victoria has 37 seats in the Australian House of Representatives and 12 seats in the Australian Senate. At state level, the Parliament of Victoria consists of the Legislative Assembly (the lower house) and the Legislative Council (the upper house). Victoria is currently governed by the Labor Party, with Daniel Andrews the current Premier. The personal representative of the Queen of Australia in the state is the Governor of Victoria, currently Linda Dessau. Local government is concentrated in 79 municipal districts, including 33 cities, although a number of unincorporated areas still exist, which are administered directly by the state.

On 1 July 1851, writs were issued for the election of the first Victorian Legislative Council, and the absolute independence of Victoria from New South Wales was established proclaiming a new Colony of Victoria. Days later, still in 1851 gold was discovered near Ballarat, and subsequently at Bendigo. Later discoveries occurred at many sites across Victoria. This triggered one of the largest gold rushes the world has ever seen. The colony grew rapidly in both population and economic power. In ten years the population of Victoria increased sevenfold from 76,000 to 540,000. All sorts of gold records were produced including the "richest shallow alluvial goldfield in the world" and the largest gold nugget. Victoria produced in the decade 1851–1860 20 million ounces of gold, one third of the world's output[citation needed].

As of August 2010, Victoria had 1,548 public schools, 489 Catholic schools and 214 independent schools. Just under 540,800 students were enrolled in public schools, and just over 311,800 in private schools. Over 61 per cent of private students attend Catholic schools. More than 462,000 students were enrolled in primary schools and more than 390,000 in secondary schools. Retention rates for the final two years of secondary school were 77 per cent for public school students and 90 per cent for private school students. Victoria has about 63,519 full-time teachers.

Victoria is the centre of dairy farming in Australia. It is home to 60% of Australia's 3 million dairy cattle and produces nearly two-thirds of the nation's milk, almost 6.4 billion litres. The state also has 2.4 million beef cattle, with more than 2.2 million cattle and calves slaughtered each year. In 2003–04, Victorian commercial fishing crews and aquaculture industry produced 11,634 tonnes of seafood valued at nearly A\$109 million. Blacklipped abalone is the mainstay of the catch, bringing in A\$46 million, followed by southern rock lobster worth A\$13.7 million. Most abalone and rock lobster is exported to Asia.

There are also several smaller freight operators and numerous tourist railways operating over lines which were once parts of a state-owned system. Victorian lines mainly use the 1,600 mm (5 ft 3 in) broad gauge. However, the interstate trunk routes, as well as a number of branch lines in the west of the state have been converted to 1,435 mm (4 ft 8 1/2 in) standard gauge. Two tourist railways operate over 760 mm (2 ft 6 in) narrow gauge lines, which are the remnants of five formerly government-owned lines which were built in mountainous areas.

After the founding of the colony of New South Wales in 1788, Australia was divided into an eastern half named New South Wales and a western half named New Holland, under the administration of the colonial government in Sydney. The first European settlement in the area later known as Victoria was established in October 1803 under Lieutenant-Governor David Collins at Sullivan Bay on Port Phillip. It consisted of 402 people (5 Government officials, 9 officers of marines, 2 drummers, and 39 privates, 5 soldiers' wives, and a child, 307 convicts, 17 convicts' wives, and 7 children). They had been sent from England in HMS Calcutta under the command of Captain Daniel Woodriff, principally out of fear that the French, who had been exploring the area, might establish their own settlement and thereby challenge British rights to the continent.

In 1854 at Ballarat there was an armed rebellion against the government of Victoria by miners protesting against mining taxes (the "Eureka Stockade"). This was crushed by British troops, but the discontents prompted colonial authorities to reform the administration (particularly reducing the hated mining licence fees) and extend the franchise. Within a short time, the Imperial Parliament granted Victoria responsible

government with the passage of the Colony of Victoria Act 1855. Some of the leaders of the Eureka rebellion went on to become members of the Victorian Parliament.

The Premier of Victoria is the leader of the political party or coalition with the most seats in the Legislative Assembly. The Premier is the public face of government and, with cabinet, sets the legislative and political agenda. Cabinet consists of representatives elected to either house of parliament. It is responsible for managing areas of government that are not exclusively the Commonwealth's, by the Australian Constitution, such as education, health and law enforcement. The current Premier of Victoria is Daniel Andrews.

During 2003–04, the gross value of Victorian agricultural production increased by 17% to \$8.7 billion. This represented 24% of national agricultural production total gross value. As of 2004, an estimated 32,463 farms occupied around 136,000 square kilometres (52,500 sq mi) of Victorian land. This comprises more than 60% of the state's total land surface. Victorian farms range from small horticultural outfits to large-scale livestock and grain productions. A quarter of farmland is used to grow consumable crops. Major events also play a big part in tourism in Victoria, particularly cultural tourism and sports tourism. Most of these events are centred on Melbourne, but others occur in regional cities, such as the V8 Supercars and Australian Motorcycle Grand Prix at Phillip Island, the Grand Annual Steeplechase at Warrnambool and the Australian International Airshow at Geelong and numerous local festivals such as the popular Port Fairy Folk Festival, Queenscliff Music Festival, Bells Beach SurfClassic and the Bright Autumn Festival.

Huguenot numbers peaked near an estimated two million by 1562, concentrated mainly in the southern and central parts of France, about one-eighth the number of French Catholics. As Huguenots gained influence and more openly displayed their faith, Catholic hostility grew, in spite of increasingly liberal political concessions and edicts of toleration from the French crown. A series of religious conflicts followed, known as the Wars of Religion, fought intermittently from 1562 to 1598. The wars finally ended with the granting of the Edict of Nantes, which granted the Huguenots substantial religious, political and military autonomy.

A term used originally in derision, Huguenot has unclear origins. Various hypotheses have been promoted. The nickname may have been a combined reference to the Swiss politician Besançon Hugues (died 1532) and the religiously conflicted nature of Swiss republicanism in his time, using a clever derogatory pun on the name Hugues by way of the Dutch word *Huisgenoten* (literally housemates), referring to the connotations of a somewhat related word in German *Eidgenosse* (Confederates as in "a citizen of one of the states of the Swiss Confederacy"). Geneva was John Calvin's adopted home and the centre of the Calvinist movement. In Geneva, Hugues, though Catholic, was a leader of the "Confederate Party", so called because it favoured independence from the Duke of Savoy through an alliance between the city-state of Geneva and the Swiss Confederation. The label Huguenot was purportedly first applied in France to those conspirators (all of them aristocratic members of the Reformed Church) involved in the Amboise plot of 1560: a foiled attempt to wrest power in France from the influential House of Guise. The move would have had the side effect of fostering relations with the Swiss. Thus, Hugues plus *Eidgenosse* by way of *Huisgenoten* supposedly became Huguenot, a nickname associating the Protestant cause with politics unpopular in France.[citation needed]

The availability of the Bible in vernacular languages was important to the spread of the Protestant movement and development of the Reformed church in France. The country had a long history of struggles with the papacy by the time the Protestant Reformation finally arrived. Around 1294, a French version of the Scriptures was prepared by the Roman Catholic priest, Guyard de Moulin. A two-volume illustrated folio paraphrase version based on his manuscript, by Jean de Rély, was printed in Paris in 1487.

Montpellier was among the most important of the 66 "villes de sûreté" that the Edict of 1598 granted to the Huguenots. The city's political institutions and the university were all handed over to the Huguenots. Tension with Paris led to a siege by the royal army in 1622. Peace terms called for the dismantling of the city's fortifications. A royal citadel was built and the university and consulate were taken over by the Catholic party. Even before the Edict of Alès (1629), Protestant rule was dead and the ville de sûreté was no more.[citation needed]

Individual Huguenots settled at the Cape of Good Hope from as early as 1671 with the arrival of François Villion (Viljoen). The first Huguenot to arrive at the Cape of Good Hope was however Maria de la Queillerie, wife of commander Jan van Riebeeck (and daughter of a Walloon church minister), who



arrived on 6 April 1652 to establish a settlement at what is today Cape Town. The couple left for the Far East ten years later. On 31 December 1687 the first organised group of Huguenots set sail from the Netherlands to the Dutch East India Company post at the Cape of Good Hope. The largest portion of the Huguenots to settle in the Cape arrived between 1688 and 1689 in seven ships as part of the organised migration, but quite a few arrived as late as 1700; thereafter, the numbers declined and only small groups arrived at a time.

Barred by the government from settling in New France, Huguenots led by Jessé de Forest, sailed to North America in 1624 and settled instead in the Dutch colony of New Netherland (later incorporated into New York and New Jersey); as well as Great Britain's colonies, including Nova Scotia. A number of New Amsterdam's families were of Huguenot origin, often having emigrated as refugees to the Netherlands in the previous century. In 1628 the Huguenots established a congregation as L'Église française à la Nouvelle-Amsterdam (the French church in New Amsterdam). This parish continues today as L'Eglise du Saint-Esprit, part of the Episcopal (Anglican) communion, and welcomes Francophone New Yorkers from all over the world. Upon their arrival in New Amsterdam, Huguenots were offered land directly across from Manhattan on Long Island for a permanent settlement and chose the harbor at the end of Newtown Creek, becoming the first Europeans to live in Brooklyn, then known as Boschwitz, in the neighborhood now known as Bushwick.

In the early years, many Huguenots also settled in the area of present-day Charleston, South Carolina. In 1685, Rev. Elie Prioleau from the town of Pons in France, was among the first to settle there. He became pastor of the first Huguenot church in North America in that city. After the Revocation of the Edict of Nantes in 1685, several Huguenot families of Norman and Carolingian nobility and descent, including Edmund Bohun of Suffolk England from the Humphrey de Bohun line of French royalty descended from Charlemagne, Jean Postell of Dieppe France, Alexander Pepin, Antoine Poitevin of Orsement France, and Jacques de Bordeaux of Grenoble, immigrated to the Charleston Orange district. They were very successful at marriage and property speculation. After petitioning the British Crown in 1697 for the right to own land in the Baronies, they prospered as slave owners on the Cooper, Ashepoo, Ashley and Santee River plantations they purchased from the British Landgrave Edmund Bellinger. Some of their descendants moved into the Deep South and Texas, where they developed new plantations.

Stadtholder William III of Orange, who later became King of England, emerged as the strongest opponent of king Louis XIV after the French attacked the Dutch Republic in 1672. William formed the League of Augsburg as a coalition to oppose Louis and the French state. Consequently, many Huguenots considered the wealthy and Calvinist Dutch Republic, which led the opposition to Louis XIV, as the most attractive country for exile after the revocation of the Edict of Nantes. They also found many French-speaking Calvinist churches there.

Renewed religious warfare in the 1620s caused the political and military privileges of the Huguenots to be abolished following their defeat. They retained the religious provisions of the Edict of Nantes until the rule of Louis XIV, who progressively increased persecution of them until he issued the Edict of Fontainebleau (1685), which abolished all legal recognition of Protestantism in France, and forced the Huguenots to convert. While nearly three-quarters eventually were killed or submitted, roughly 500,000 Huguenots had fled France by the early 18th century[citation needed].

The Catholic Church in France and many of its members opposed the Huguenots. Some Huguenot preachers and congregants were attacked as they attempted to meet for worship. The height of this persecution was the St. Bartholomew's Day massacre when 5,000 to 30,000 were killed, although there were also underlying political reasons for this as well, as some of the Huguenots were nobles trying to establish separate centers of power in southern France. Retaliating against the French Catholics, the Huguenots had their own militia.

By 1620 the Huguenots were on the defensive, and the government increasingly applied pressure. A series of three small civil wars known as the Huguenot rebellions broke out, mainly in southwestern France, between 1621 and 1629. revolted against royal authority. The uprising occurred a decade following the death of Henry IV, a Huguenot before converting to Catholicism, who had protected Protestants through the Edict of Nantes. His successor Louis XIII, under the regency of his Italian Catholic mother Marie de' Medici, became more intolerant of Protestantism. The Huguenots respond by establishing independent political and military structures, establishing diplomatic contacts with foreign powers, and openly revolting against central power. The rebellions were implacably suppressed by the French Crown.[citation needed]

Approximately one million Protestants in modern France represent some 2% of its population. Most are concentrated in Alsace in northeast France and the Cévennes mountain region in the south, who still regard themselves as Huguenots to this day.[citation needed] A diaspora of French Australians still considers itself Huguenot, even after centuries of exile. Long integrated into Australian society, it is encouraged by the Huguenot Society of Australia to embrace and conserve its cultural heritage, aided by the Society's genealogical research services.

Huguenot immigrants did not disperse or settle in different parts of the country, but rather, formed three societies or congregations; one in the city of New York, another 21 miles north of New York in a town which they named New Rochelle, and a third further upstate in New Paltz. The "Huguenot Street Historic District" in New Paltz has been designated a National Historic Landmark site and contains the oldest street in the United States of America. A small group of Huguenots also settled on the south shore of Staten Island along the New York Harbor, for which the current neighborhood of Huguenot was named. After the revocation of the Edict of Nantes, the Dutch Republic received the largest group of Huguenot refugees, an estimated total of 75,000 to 100,000 people. Amongst them were 200 clergy. Many came from the region of the Cévennes, for instance, the village of Fraissinet-de-Lozère. This was a huge influx as the entire population of the Dutch Republic amounted to ca. 2 million at that time. Around 1700, it is estimated that nearly 25% of the Amsterdam population was Huguenot.[citation needed] In 1705, Amsterdam and the area of West Frisia were the first areas to provide full citizens rights to Huguenot immigrants, followed by the Dutch Republic in 1715. Huguenots intermarried with Dutch from the outset. In this last connection, the name could suggest the derogatory inference of superstitious worship; popular fancy held that Huguon, the gate of King Hugo, was haunted by the ghost of le roi Huguet (regarded by Roman Catholics as an infamous scoundrel) and other spirits, who instead of being in Purgatory came back to harm the living at night. It was in this place in Tours that the prétendus réformés ("these supposedly 'reformed'") habitually gathered at night, both for political purposes, and for prayer and singing psalms. Such explanations have been traced to the contemporary, Reguier de la Plancha (d. 1560), who in *De l'Estat de France* offered the following account as to the origin of the name, as cited by *The Cape Monthly*:

Other evidence of the Walloons and Huguenots in Canterbury includes a block of houses in Turnagain Lane, where weavers' windows survive on the top floor, as many Huguenots worked as weavers. The Weavers, a half-timbered house by the river, was the site of a weaving school from the late 16th century to about 1830. (It has been adapted as a restaurant—see illustration above. The house derives its name from a weaving school which was moved there in the last years of the 19th century, reviving an earlier use.) Others refugees practised the variety of occupations necessary to sustain the community as distinct from the indigenous population. Such economic separation was the condition of the refugees' initial acceptance in the City. They also settled elsewhere in Kent, particularly Sandwich, Faversham and Maidstone—towns in which there used to be refugee churches.

A number of Huguenots served as mayors in Dublin, Cork, Youghal and Waterford in the 17th and 18th centuries. Numerous signs of Huguenot presence can still be seen with names still in use, and with areas of the main towns and cities named after the people who settled there. Examples include the Huguenot District and French Church Street in Cork City; and D'Olier Street in Dublin, named after a High Sheriff and one of the founders of the Bank of Ireland. A French church in Portarlinton dates back to 1696, and was built to serve the significant new Huguenot community in the town. At the time, they constituted the majority of the townspeople.

The exodus of Huguenots from France created a brain drain, as many Huguenots had occupied important places in society. The kingdom did not fully recover for years. The French crown's refusal to allow non-Catholics to settle in New France may help to explain that colony's slow rate of population growth compared to that of the neighbouring British colonies, which opened settlement to religious dissenters. By the time of the French and Indian War (the North American front of the Seven Years' War), a sizeable population of Huguenot descent lived in the British colonies, and many participated in the British defeat of New France in 1759-60.

The pattern of warfare, followed by brief periods of peace, continued for nearly another quarter-century. The warfare was definitively quelled in 1598, when Henry of Navarre, having succeeded to the French throne as Henry IV, and having recanted Protestantism in favour of Roman Catholicism, issued the Edict of Nantes. The Edict reaffirmed Catholicism as the state religion of France, but granted the Protestants equality with Catholics under the throne and a degree of religious and political freedom within their

domains. The Edict simultaneously protected Catholic interests by discouraging the founding of new Protestant churches in Catholic-controlled regions.[citation needed]

The revocation forbade Protestant services, required education of children as Catholics, and prohibited emigration. It proved disastrous to the Huguenots and costly for France. It precipitated civil bloodshed, ruined commerce, and resulted in the illegal flight from the country of hundreds of thousands of Protestants, many of whom became intellectuals, doctors and business leaders in Britain as well as Holland, Prussia, and South Africa. Four thousand emigrated to the North American colonies, where they settled in New York and Virginia, especially. The English welcomed the French refugees, providing money from both government and private agencies to aid their relocation. Those Huguenots who stayed in France became Catholics and were called "new converts".

The first Huguenots to leave France sought freedom from persecution in Switzerland and the Netherlands.[citation needed] A group of Huguenots was part of the French colonisers who arrived in Brazil in 1555 to found France Antarctique. A couple of ships with around 500 people arrived at the Guanabara Bay, present-day Rio de Janeiro, and settled in a small island. A fort, named Fort Coligny, was built to protect them from attack from the Portuguese troops and Brazilian Native Americans. It was an attempt to establish a French colony in South America. The fort was destroyed in 1560 by the Portuguese, who captured part of the Huguenots. The Portuguese threatened the prisoners with death if they did not convert to Catholicism. The Huguenots of Guanabara, as they are now known, produced a declaration of faith to express their beliefs to the Portuguese. This was their death sentence. This document, the Guanabara Confession of Faith, became the first Protestant confession of faith in the whole of the Americas.[citation needed]

Many of the farms in the Western Cape province in South Africa still bear French names. Many families, today mostly Afrikaans-speaking, have surnames indicating their French Huguenot ancestry. Examples include: Blignaut, Cilliers, de Klerk (Le Clercq), de Villiers, du Plessis, Du Preez (Des Pres), du Randt (Durand), du Toit, Duvenhage (Du Vinage), Franck, Fouche, Fourie (Fleurit), Gervais, Giliomee (Guillaume), Gous/Gouws (Gauch), Hugo, Jordaan (Jourdan), Joubert, Kriek, Labuschagne (la Buscagne), le Roux, Lombard, Malan, Malherbe, Marais, Maree, Minnaar (Mesnard), Nel (Nell), Naude', Nortje (Nortier), Pienaar (Pinard), Retief (Retif), Rossouw (Rousseau), Taljaard (Taillard), TerBlanche, Theron, Viljoen (Villion) and Visagie (Visage). The wine industry in South Africa owes a significant debt to the Huguenots, some of whom had vineyards in France, or were brandy distillers, and used their skills in their new home.

Paul Revere was descended from Huguenot refugees, as was Henry Laurens, who signed the Articles of Confederation for South Carolina; Jack Jouett, who made the ride from Cuckoo Tavern to warn Thomas Jefferson and others that Tarleton and his men were on their way to arrest him for crimes against the king; Francis Marion, and a number of other leaders of the American Revolution and later statesmen. The last active Huguenot congregation in North America worships in Charleston, South Carolina, at a church that dates to 1844. The Huguenot Society of America maintains Manakin Episcopal Church in Virginia as an historic shrine with occasional services. The Society has chapters in numerous states, with the one in Texas being the largest.

Some Huguenots settled in Bedfordshire, one of the main centres of the British lace industry at the time. Although 19th century sources have asserted that some of these refugees were lacemakers and contributed to the East Midlands lace industry, this is contentious. The only reference to immigrant lacemakers in this period is of twenty-five widows who settled in Dover, and there is no contemporary documentation to support there being Huguenot lacemakers in Bedfordshire. The implication that the style of lace known as 'Bucks Point' demonstrates a Huguenot influence, being a "combination of Mechlin patterns on Lille ground", is fallacious: what is now known as Mechlin lace did not develop until first half of the eighteenth century and lace with Mechlin patterns and Lille ground did not appear until the end of the 18th century, when it was widely copied throughout Europe.

In Berlin, the Huguenots created two new neighbourhoods: Dorotheenstadt and Friedrichstadt. By 1700, one-fifth of the city's population was French speaking. The Berlin Huguenots preserved the French language in their church services for nearly a century. They ultimately decided to switch to German in protest against the occupation of Prussia by Napoleon in 1806-07. Many of their descendents rose to positions of prominence. Several congregations were founded, such as those of Fredericia (Denmark), Berlin, Stockholm, Hamburg, Frankfurt, Helsinki, and Emden.

After this, Huguenots (with estimates ranging from 200,000 to 1,000,000) fled to surrounding Protestant

countries: England, the Netherlands, Switzerland, Norway, Denmark, and Prussia — whose Calvinist Great Elector Frederick William welcomed them to help rebuild his war-ravaged and underpopulated country. Following this exodus, Huguenots remained in large numbers in only one region of France: the rugged Cévennes region in the south. In the early 18th century, a regional group known as the Camisards who were Huguenots rioted against the Catholic Church in the region, burning churches and killing clergy. It took French troops years to hunt down and destroy all the bands of Camisards, between 1702 and 1709.

In 1564 a group of Norman Huguenots under the leadership of Jean Ribault established the small colony of Fort Caroline on the banks of the St. Johns River in what is today Jacksonville, Florida. The effort was the first at any permanent European settlement in the present-day continental United States, but survived only a short time. A September 1565 French naval attack against the new Spanish colony at St. Augustine failed when its ships were hit by a hurricane on their way to the Spanish encampment at Fort Matanzas. Hundreds of French soldiers were stranded and surrendered to the numerically inferior Spanish forces led by Pedro Menéndez. Menéndez proceeded to massacre the defenseless Huguenots, after which he wiped out the Fort Caroline garrison.

French Huguenots made two attempts to establish a haven in North America. In 1562, naval officer Jean Ribault led an expedition that explored Florida and the present-day Southeastern U.S., and founded the outpost of Charlesfort on Parris Island, South Carolina. The Wars of Religion precluded a return voyage, and the outpost was abandoned. In 1564, Ribault's former lieutenant René Goulaine de Laudonnière launched a second voyage to build a colony; he established Fort Caroline in what is now Jacksonville, Florida. War at home again precluded a resupply mission, and the colony struggled. In 1565 the Spanish decided to enforce their claim to La Florida, and sent Pedro Menéndez de Avilés, who established the settlement of St. Augustine near Fort Caroline. Menéndez' forces routed the French and executed most of the Protestant captives.

In 1700 several hundred French Huguenots migrated from England to the colony of Virginia, where the English Crown had promised them land grants in Lower Norfolk County. When they arrived, colonial authorities offered them instead land 20 miles above the falls of the James River, at the abandoned Monacan village known as Manakin Town, now in Powhatan County. Some settlers landed in present-day Chesterfield County. On 12 May 1705, the Virginia General Assembly passed an act to naturalise the 148 Huguenots still resident at Manakintown. Of the original 390 settlers in the isolated settlement, many had died; others lived outside town on farms in the English style; and others moved to different areas.

Gradually they intermarried with their English neighbors. Through the 18th and 19th centuries, descendants of the French migrated west into the Piedmont, and across the Appalachian Mountains into the West of what became Kentucky, Tennessee, Missouri, and other states. In the Manakintown area, the Huguenot Memorial Bridge across the James River and Huguenot Road were named in their honor, as were many local features, including several schools, including Huguenot High School.

Some Huguenots fought in the Low Countries alongside the Dutch against Spain during the first years of the Dutch Revolt (1568–1609). The Dutch Republic rapidly became a destination for Huguenot exiles. Early ties were already visible in the "Apologie" of William the Silent, condemning the Spanish Inquisition, which was written by his court minister, the Huguenot Pierre L'Oyseleur, lord of Villiers. Louise de Coligny, daughter of the murdered Huguenot leader Gaspard de Coligny, married William the Silent, leader of the Dutch (Calvinist) revolt against Spanish (Catholic) rule. As both spoke French in daily life, their court church in the Prinsenhof in Delft held services in French. The practice has continued to the present day. The Prinsenhof is one of the 14 active Walloon churches of the Dutch Reformed Church. The ties between Huguenots and the Dutch Republic's military and political leadership, the House of Orange-Nassau, which existed since the early days of the Dutch Revolt, helped support the many early settlements of Huguenots in the Dutch Republic's colonies. They settled at the Cape of Good Hope in South Africa and New Netherland in North America.

Both before and after the 1708 passage of the Foreign Protestants Naturalization Act, an estimated 50,000 Protestant Walloons and Huguenots fled to England, with many moving on to Ireland and elsewhere. In relative terms, this was one of the largest waves of immigration ever of a single ethnic community to Britain. Andrew Lortie (born André Lortie), a leading Huguenot theologian and writer who led the exiled community in London, became known for articulating their criticism of the Pope and the doctrine of transubstantiation during Mass.

Following the French Crown's revocation of the Edict of Nantes, many Huguenots settled in Ireland in the

late 17th and early 18th centuries, encouraged by an act of parliament for Protestants' settling in Ireland. Huguenot regiments fought for William of Orange in the Williamite war in Ireland, for which they were rewarded with land grants and titles, many settling in Dublin. Significant Huguenot settlements were in Dublin, Cork, Portarlinton, Lisburn, Waterford and Youghal. Smaller settlements, which included Killeshandra in County Cavan, contributed to the expansion of flax cultivation and the growth of the Irish linen industry.

Prince Louis de Condé, along with his sons Daniel and Osias,[citation needed] arranged with Count Ludwig von Nassau-Saarbrücken to establish a Huguenot community in present-day Saarland in 1604. The Count supported mercantilism and welcomed technically skilled immigrants into his lands, regardless of their religion. The Condés established a thriving glass-making works, which provided wealth to the principality for many years. Other founding families created enterprises based on textiles and such traditional Huguenot occupations in France. The community and its congregation remain active to this day, with descendants of many of the founding families still living in the region. Some members of this community emigrated to the United States in the 1890s.

The bulk of Huguenot émigrés relocated to Protestant European nations such as England, Wales, Scotland, Denmark, Sweden, Switzerland, the Dutch Republic, the Electorate of Brandenburg and Electorate of the Palatinate in the Holy Roman Empire, the Duchy of Prussia, the Channel Islands, and Ireland. They also spread beyond Europe to the Dutch Cape Colony in South Africa, the Dutch East Indies, the Caribbean, and several of the English colonies of North America, and Quebec, where they were accepted and allowed to worship freely.

Some disagree with such double or triple non-French linguistic origins, arguing that for the word to have spread into common use in France, it must have originated in the French language. The "Hugues hypothesis" argues that the name was derived by association with Hugues Capet, king of France, who reigned long before the Reformation. He was regarded by the Gallicans and Protestants as a noble man who respected people's dignity and lives. Janet Gray and other supporters of the hypothesis suggest that the name huguenote would be roughly equivalent to little Hugos, or those who want Hugo.

Other predecessors of the Reformed church included the pro-reform and Gallican Roman Catholics, such as Jacques Lefevre (c. 1455–1536). The Gallicans briefly achieved independence for the French church, on the principle that the religion of France could not be controlled by the Bishop of Rome, a foreign power. During the Protestant Reformation, Lefevre, a professor at the University of Paris, published his French translation of the New Testament in 1523, followed by the whole Bible in the French language in 1530. William Farel was a student of Lefevre who went on to become a leader of the Swiss Reformation, establishing a Protestant government in Geneva. Jean Calvin (John Calvin), another student at the University of Paris, also converted to Protestantism. Long after the sect was suppressed by Francis I, the remaining French Waldensians, then mostly in the Luberon region, sought to join William Farel, Calvin and the Reformation, and Olivetan published a French Bible for them. The French Confession of 1559 shows a decidedly Calvinistic influence. Sometime between 1550 and 1580, members of the Reformed church in France came to be commonly known as Huguenots.[citation needed]

In what became known as the St. Bartholomew's Day Massacre of 24 August – 3 October 1572, Catholics killed thousands of Huguenots in Paris. Similar massacres took place in other towns in the weeks following. The main provincial towns and cities experiencing the Massacre were Aix, Bordeaux, Bourges, Lyons, Meaux, Orleans, Rouen, Toulouse, and Troyes. Nearly 3,000 Protestants were slaughtered in Toulouse alone. The exact number of fatalities throughout the country is not known. On 23–24 August, between about 2,000 and 3,000 Protestants were killed in Paris and between 3,000 and 7,000 more in the French provinces. By 17 September, almost 25,000 Protestants had been massacred in Paris alone. Beyond Paris, the killings continued until 3 October. An amnesty granted in 1573 pardoned the perpetrators.[citation needed]

Louis XIV gained the throne in 1643 and acted increasingly aggressively to force the Huguenots to convert. At first he sent missionaries, backed by a fund to financially reward converts to Catholicism. Then he imposed penalties, closed Huguenot schools and excluded them from favored professions. Escalating, he instituted dragonnades, which included the occupation and looting of Huguenot homes by military troops, in an effort to forcibly convert them. In 1685, he issued the Edict of Fontainebleau, revoking the Edict of Nantes and declaring Protestantism illegal.[citation needed]

New Rochelle, located in the county of Westchester on the north shore of Long Island Sound, seemed to be the great location of the Huguenots in New York. It is said that they landed on the coastline peninsula

of Davenports Neck called "Bauffet's Point" after traveling from England where they had previously taken refuge on account of religious persecution, four years before the revocation of the Edict of Nantes. They purchased from John Pell, Lord of Pelham Manor, a tract of land consisting of six thousand one hundred acres with the help of Jacob Leisler. It was named New Rochelle after La Rochelle, their former strong-hold in France. A small wooden church was first erected in the community, followed by a second church that built of stone. Previous to the erection of it, the strong men would often walk twenty-three miles on Saturday evening, the distance by the road from New Rochelle to New York, to attend the Sunday service. The church was eventually replaced by a third, Trinity-St. Paul's Episcopal Church, which contains heirlooms including the original bell from the French Huguenot Church "Eglise du St. Esperit" on Pine Street in New York City, which is preserved as a relic in the tower room. The Huguenot cemetery, or "Huguenot Burial Ground", has since been recognized as a historic cemetery that is the final resting place for a wide range of the Huguenot founders, early settlers and prominent citizens dating back more than three centuries.

Most of the Huguenot congregations (or individuals) in North America eventually affiliated with other Protestant denominations with more numerous members. The Huguenots adapted quickly and often married outside their immediate French communities, which led to their assimilation. Their descendants in many families continued to use French first names and surnames for their children well into the nineteenth century. Assimilated, the French made numerous contributions to United States economic life, especially as merchants and artisans in the late Colonial and early Federal periods. For example, E.I. du Pont, a former student of Lavoisier, established the Eleutherian gunpowder mills.

One of the most prominent Huguenot refugees in the Netherlands was Pierre Bayle. He started teaching in Rotterdam, where he finished writing and publishing his multi-volume masterpiece, *Historical and Critical Dictionary*. It became one of the 100 foundational texts of the US Library of Congress. Some Huguenot descendants in the Netherlands may be noted by French family names, although they typically use Dutch given names. Due to the Huguenots' early ties with the leadership of the Dutch Revolt and their own participation, some of the Dutch patriciate are of part-Huguenot descent. Some Huguenot families have kept alive various traditions, such as the celebration and feast of their patron Saint Nicolas, similar to the Dutch Sint Nicolaas (Sinterklaas) feast.

The French Protestant Church of London was established by Royal Charter in 1550. It is now located at Soho Square. Huguenot refugees flocked to Shoreditch, London. They established a major weaving industry in and around Spitalfields (see Petticoat Lane and the Tenterground) in East London. In Wandsworth, their gardening skills benefited the Battersea market gardens. The Old Truman Brewery, then known as the Black Eagle Brewery, was founded in 1724. The flight of Huguenot refugees from Tours, France drew off most of the workers of its great silk mills which they had built.[citation needed] Some of these immigrants moved to Norwich, which had accommodated an earlier settlement of Walloon weavers. The French added to the existing immigrant population, then comprising about a third of the population of the city.

Around 1685, Huguenot refugees found a safe haven in the Lutheran and Reformed states in Germany and Scandinavia. Nearly 50,000 Huguenots established themselves in Germany, 20,000 of whom were welcomed in Brandenburg-Prussia, where they were granted special privileges (Edict of Potsdam) and churches in which to worship (such as the Church of St. Peter and St. Paul, Angermünde) by Frederick William, Elector of Brandenburg and Duke of Prussia. The Huguenots furnished two new regiments of his army: the Altpreußische Infantry Regiments No. 13 (Regiment on foot Varenne) and 15 (Regiment on foot Wylich). Another 4,000 Huguenots settled in the German territories of Baden, Franconia (Principality of Bayreuth, Principality of Ansbach), Landgraviate of Hesse-Kassel, Duchy of Württemberg, in the Wetterau Association of Imperial Counts, in the Palatinate and Palatinate-Zweibrücken, in the Rhine-Main-Area (Frankfurt), in modern-day Saarland; and 1,500 found refuge in Hamburg, Bremen and Lower Saxony. Three hundred refugees were granted asylum at the court of George William, Duke of Brunswick-Lüneburg in Celle.

Frederick William, Elector of Brandenburg, invited Huguenots to settle in his realms, and a number of their descendants rose to positions of prominence in Prussia. Several prominent German military, cultural, and political figures were ethnic Huguenot, including poet Theodor Fontane, General Hermann von François, the hero of the First World War Battle of Tannenberg, Luftwaffe General and fighter ace Adolf Galland, Luftwaffe flying ace Hans-Joachim Marseille, and famed U-boat captain Lothar von Arnauld de la Perière. The last Prime Minister of the (East) German Democratic Republic, Lothar de Maizière, is also a

descendant of a Huguenot family, as is the German Federal Minister of the Interior, Thomas de Maizière. Steam engines are external combustion engines, where the working fluid is separate from the combustion products. Non-combustion heat sources such as solar power, nuclear power or geothermal energy may be used. The ideal thermodynamic cycle used to analyze this process is called the Rankine cycle. In the cycle, water is heated and transforms into steam within a boiler operating at a high pressure. When expanded through pistons or turbines, mechanical work is done. The reduced-pressure steam is then condensed and pumped back into the boiler.

The first commercially successful true engine, in that it could generate power and transmit it to a machine, was the atmospheric engine, invented by Thomas Newcomen around 1712. It was an improvement over Savery's steam pump, using a piston as proposed by Papin. Newcomen's engine was relatively inefficient, and in most cases was used for pumping water. It worked by creating a partial vacuum by condensing steam under a piston within a cylinder. It was employed for draining mine workings at depths hitherto impossible, and also for providing a reusable water supply for driving waterwheels at factories sited away from a suitable "head". Water that had passed over the wheel was pumped back up into a storage reservoir above the wheel.

The first full-scale working railway steam locomotive was built by Richard Trevithick in the United Kingdom and, on 21 February 1804, the world's first railway journey took place as Trevithick's unnamed steam locomotive hauled a train along the tramway from the Pen-y-darren ironworks, near Merthyr Tydfil to Abercynon in south Wales. The design incorporated a number of important innovations that included using high-pressure steam which reduced the weight of the engine and increased its efficiency. Trevithick visited the Newcastle area later in 1804 and the colliery railways in north-east England became the leading centre for experimentation and development of steam locomotives.

The Rankine cycle and most practical steam engines have a water pump to recycle or top up the boiler water, so that they may be run continuously. Utility and industrial boilers commonly use multi-stage centrifugal pumps; however, other types are used. Another means of supplying lower-pressure boiler feed water is an injector, which uses a steam jet usually supplied from the boiler. Injectors became popular in the 1850s but are no longer widely used, except in applications such as steam locomotives.

It is a logical extension of the compound engine (described above) to split the expansion into yet more stages to increase efficiency. The result is the multiple expansion engine. Such engines use either three or four expansion stages and are known as triple and quadruple expansion engines respectively. These engines use a series of cylinders of progressively increasing diameter. These cylinders are designed to divide the work into equal shares for each expansion stage. As with the double expansion engine, if space is at a premium, then two smaller cylinders may be used for the low-pressure stage. Multiple expansion engines typically had the cylinders arranged inline, but various other formations were used. In the late 19th century, the Yarrow-Schlick-Tweedy balancing 'system' was used on some marine triple expansion engines. Y-S-T engines divided the low-pressure expansion stages between two cylinders, one at each end of the engine. This allowed the crankshaft to be better balanced, resulting in a smoother, faster-responding engine which ran with less vibration. This made the 4-cylinder triple-expansion engine popular with large passenger liners (such as the Olympic class), but this was ultimately replaced by the virtually vibration-free turbine engine.[citation needed]

In the 1840s and 50s, there were attempts to overcome this problem by means of various patent valve gears with a separate, variable cutoff expansion valve riding on the back of the main slide valve; the latter usually had fixed or limited cutoff. The combined setup gave a fair approximation of the ideal events, at the expense of increased friction and wear, and the mechanism tended to be complicated. The usual compromise solution has been to provide lap by lengthening rubbing surfaces of the valve in such a way as to overlap the port on the admission side, with the effect that the exhaust side remains open for a longer period after cut-off on the admission side has occurred. This expedient has since been generally considered satisfactory for most purposes and makes possible the use of the simpler Stephenson, Joy and Walschaerts motions. Corliss, and later, poppet valve gears had separate admission and exhaust valves driven by trip mechanisms or cams profiled so as to give ideal events; most of these gears never succeeded outside of the stationary marketplace due to various other issues including leakage and more delicate mechanisms.

Lead fusible plugs may be present in the crown of the boiler's firebox. If the water level drops, such that the temperature of the firebox crown increases significantly, the lead melts and the steam escapes, warning the operators, who may then manually suppress the fire. Except in the smallest of boilers the

steam escape has little effect on dampening the fire. The plugs are also too small in area to lower steam pressure significantly, depressurizing the boiler. If they were any larger, the volume of escaping steam would itself endanger the crew.[citation needed]

In 1781 James Watt patented a steam engine that produced continuous rotary motion. Watt's ten-horsepower engines enabled a wide range of manufacturing machinery to be powered. The engines could be sited anywhere that water and coal or wood fuel could be obtained. By 1883, engines that could provide 10,000 hp had become feasible. The stationary steam engine was a key component of the Industrial Revolution, allowing factories to locate where water power was unavailable. The atmospheric engines of Newcomen and Watt were large compared to the amount of power they produced, but high pressure steam engines were light enough to be applied to vehicles such as traction engines and the railway locomotives.

The history of the steam engine stretches back as far as the first century AD; the first recorded rudimentary steam engine being the aeolipile described by Greek mathematician Hero of Alexandria. In the following centuries, the few steam-powered "engines" known were, like the aeolipile, essentially experimental devices used by inventors to demonstrate the properties of steam. A rudimentary steam turbine device was described by Taqi al-Din in 1551 and by Giovanni Branca in 1629. Jerónimo de Ayaz y Beaumont received patents in 1606 for fifty steam powered inventions, including a water pump for draining inundated mines. Denis Papin, a Huguenot refugee, did some useful work on the steam digester in 1679, and first used a piston to raise weights in 1690.

Near the end of the 19th century compound engines came into widespread use. Compound engines exhausted steam in to successively larger cylinders to accommodate the higher volumes at reduced pressures, giving improved efficiency. These stages were called expansions, with double and triple expansion engines being common, especially in shipping where efficiency was important to reduce the weight of coal carried. Steam engines remained the dominant source of power until the early 20th century, when advances in the design of electric motors and internal combustion engines gradually resulted in the replacement of reciprocating (piston) steam engines, with shipping in the 20th-century relying upon the steam turbine.

The final major evolution of the steam engine design was the use of steam turbines starting in the late part of the 19th century. Steam turbines are generally more efficient than reciprocating piston type steam engines (for outputs above several hundred horsepower), have fewer moving parts, and provide rotary power directly instead of through a connecting rod system or similar means. Steam turbines virtually replaced reciprocating engines in electricity generating stations early in the 20th century, where their efficiency, higher speed appropriate to generator service, and smooth rotation were advantages. Today most electric power is provided by steam turbines. In the United States 90% of the electric power is produced in this way using a variety of heat sources. Steam turbines were extensively applied for propulsion of large ships throughout most of the 20th century.

The heat required for boiling the water and supplying the steam can be derived from various sources, most commonly from burning combustible materials with an appropriate supply of air in a closed space (called variously combustion chamber, firebox). In some cases the heat source is a nuclear reactor, geothermal energy, solar energy or waste heat from an internal combustion engine or industrial process. In the case of model or toy steam engines, the heat source can be an electric heating element.

The most useful instrument for analyzing the performance of steam engines is the steam engine indicator. Early versions were in use by 1851, but the most successful indicator was developed for the high speed engine inventor and manufacturer Charles Porter by Charles Richard and exhibited at London Exhibition in 1862. The steam engine indicator traces on paper the pressure in the cylinder throughout the cycle, which can be used to spot various problems and calculate developed horsepower. It was routinely used by engineers, mechanics and insurance inspectors. The engine indicator can also be used on internal combustion engines. See image of indicator diagram below (in Types of motor units section).

With two-cylinder compounds used in railway work, the pistons are connected to the cranks as with a two-cylinder simple at 90° out of phase with each other (quartered). When the double expansion group is duplicated, producing a 4-cylinder compound, the individual pistons within the group are usually balanced at 180°, the groups being set at 90° to each other. In one case (the first type of Vauclain compound), the pistons worked in the same phase driving a common crosshead and crank, again set at 90° as for a two-cylinder engine. With the 3-cylinder compound arrangement, the LP cranks were either set at 90° with the HP one at 135° to the other two, or in some cases all three cranks were set at 120°.[citation needed]



In most reciprocating piston engines, the steam reverses its direction of flow at each stroke (counterflow), entering and exhausting from the cylinder by the same port. The complete engine cycle occupies one rotation of the crank and two piston strokes; the cycle also comprises four events – admission, expansion, exhaust, compression. These events are controlled by valves often working inside a steam chest adjacent to the cylinder; the valves distribute the steam by opening and closing steam ports communicating with the cylinder end(s) and are driven by valve gear, of which there are many types.[citation needed]

Uniflow engines attempt to remedy the difficulties arising from the usual counterflow cycle where, during each stroke, the port and the cylinder walls will be cooled by the passing exhaust steam, whilst the hotter incoming admission steam will waste some of its energy in restoring working temperature. The aim of the uniflow is to remedy this defect and improve efficiency by providing an additional port uncovered by the piston at the end of each stroke making the steam flow only in one direction. By this means, the simple-expansion uniflow engine gives efficiency equivalent to that of classic compound systems with the added advantage of superior part-load performance, and comparable efficiency to turbines for smaller engines below one thousand horsepower. However, the thermal expansion gradient uniflow engines produce along the cylinder wall gives practical difficulties.[citation needed]. The Quasiturbine is a uniflow rotary steam engine where steam intakes in hot areas, while exhausting in cold areas.

An oscillating cylinder steam engine is a variant of the simple expansion steam engine which does not require valves to direct steam into and out of the cylinder. Instead of valves, the entire cylinder rocks, or oscillates, such that one or more holes in the cylinder line up with holes in a fixed port face or in the pivot mounting (trunnion). These engines are mainly used in toys and models, because of their simplicity, but have also been used in full size working engines, mainly on ships where their compactness is valued.[citation needed]

The working fluid in a Rankine cycle can operate as a closed loop system, where the working fluid is recycled continuously, or may be an "open loop" system, where the exhaust steam is directly released to the atmosphere, and a separate source of water feeding the boiler is supplied. Normally water is the fluid of choice due to its favourable properties, such as non-toxic and unreactive chemistry, abundance, low cost, and its thermodynamic properties. Mercury is the working fluid in the mercury vapor turbine. Low boiling hydrocarbons can be used in a binary cycle.

The efficiency of a Rankine cycle is usually limited by the working fluid. Without the pressure reaching supercritical levels for the working fluid, the temperature range the cycle can operate over is quite small; in steam turbines, turbine entry temperatures are typically 565 °C (the creep limit of stainless steel) and condenser temperatures are around 30 °C. This gives a theoretical Carnot efficiency of about 63% compared with an actual efficiency of 42% for a modern coal-fired power station. This low turbine entry temperature (compared with a gas turbine) is why the Rankine cycle is often used as a bottoming cycle in combined-cycle gas turbine power stations.[citation needed]

Steam engines can be said to have been the moving force behind the Industrial Revolution and saw widespread commercial use driving machinery in factories, mills and mines; powering pumping stations; and propelling transport appliances such as railway locomotives, ships, steamboats and road vehicles. Their use in agriculture led to an increase in the land available for cultivation. There have at one time or another been steam-powered farm tractors, motorcycles (without much success) and even automobiles as the Stanley Steamer.

Trevithick continued his own experiments using a trio of locomotives, concluding with the Catch Me Who Can in 1808. Only four years later, the successful twin-cylinder locomotive Salamanca by Matthew Murray was used by the edge railed rack and pinion Middleton Railway. In 1825 George Stephenson built the Locomotion for the Stockton and Darlington Railway. This was the first public steam railway in the world and then in 1829, he built The Rocket which was entered in and won the Rainhill Trials. The Liverpool and Manchester Railway opened in 1830 making exclusive use of steam power for both passenger and freight trains.

A method to lessen the magnitude of this heating and cooling was invented in 1804 by British engineer Arthur Woolf, who patented his Woolf high-pressure compound engine in 1805. In the compound engine, high-pressure steam from the boiler expands in a high-pressure (HP) cylinder and then enters one or more subsequent lower-pressure (LP) cylinders. The complete expansion of the steam now occurs across multiple cylinders and as less expansion now occurs in each cylinder less heat is lost by the steam in each. This reduces the magnitude of cylinder heating and cooling, increasing the efficiency of the engine. By staging the expansion in multiple cylinders, torque variability can be reduced. To derive equal work

from lower-pressure steam requires a larger cylinder volume as this steam occupies a greater volume. Therefore, the bore, and often the stroke, are increased in low-pressure cylinders resulting in larger cylinders.

The main use for steam turbines is in electricity generation (in the 1990s about 90% of the world's electric production was by use of steam turbines) however the recent widespread application of large gas turbine units and typical combined cycle power plants has resulted in reduction of this percentage to the 80% regime for steam turbines. In electricity production, the high speed of turbine rotation matches well with the speed of modern electric generators, which are typically direct connected to their driving turbines. In marine service, (pioneered on the Turbinia), steam turbines with reduction gearing (although the Turbinia has direct turbines to propellers with no reduction gearbox) dominated large ship propulsion throughout the late 20th century, being more efficient (and requiring far less maintenance) than reciprocating steam engines. In recent decades, reciprocating Diesel engines, and gas turbines, have almost entirely supplanted steam propulsion for marine applications.

The Rankine cycle is the fundamental thermodynamic underpinning of the steam engine. The cycle is an arrangement of components as is typically used for simple power production, and utilizes the phase change of water (boiling water producing steam, condensing exhaust steam, producing liquid water)) to provide a practical heat/power conversion system. The heat is supplied externally to a closed loop with some of the heat added being converted to work and the waste heat being removed in a condenser. The Rankine cycle is used in virtually all steam power production applications. In the 1990s, Rankine steam cycles generated about 90% of all electric power used throughout the world, including virtually all solar, biomass, coal and nuclear power plants. It is named after William John Macquorn Rankine, a Scottish polymath.

The historical measure of a steam engine's energy efficiency was its "duty". The concept of duty was first introduced by Watt in order to illustrate how much more efficient his engines were over the earlier Newcomen designs. Duty is the number of foot-pounds of work delivered by burning one bushel (94 pounds) of coal. The best examples of Newcomen designs had a duty of about 7 million, but most were closer to 5 million. Watt's original low-pressure designs were able to deliver duty as high as 25 million, but averaged about 17. This was a three-fold improvement over the average Newcomen design. Early Watt engines equipped with high-pressure steam improved this to 65 million.

Reciprocating piston type steam engines remained the dominant source of power until the early 20th century, when advances in the design of electric motors and internal combustion engines gradually resulted in the replacement of reciprocating (piston) steam engines in commercial usage, and the ascendancy of steam turbines in power generation. Considering that the great majority of worldwide electric generation is produced by turbine type steam engines, the "steam age" is continuing with energy levels far beyond those of the turn of the 19th century.

The first commercial steam-powered device was a water pump, developed in 1698 by Thomas Savery. It used condensing steam to create a vacuum which was used to raise water from below, then it used steam pressure to raise it higher. Small engines were effective though larger models were problematic. They proved only to have a limited lift height and were prone to boiler explosions. It received some use in mines, pumping stations and for supplying water wheels used to power textile machinery. An attractive feature of the Savery engine was its low cost. Bento de Moura Portugal introduced an ingenious improvement of Savery's construction "to render it capable of working itself", as described by John Smeaton in the Philosophical Transactions published in 1751. It continued to be manufactured until the late 18th century. One engine was still known to be operating in 1820.

Around 1800 Richard Trevithick and, separately, Oliver Evans in 1801 introduced engines using high-pressure steam; Trevithick obtained his high-pressure engine patent in 1802. These were much more powerful for a given cylinder size than previous engines and could be made small enough for transport applications. Thereafter, technological developments and improvements in manufacturing techniques (partly brought about by the adoption of the steam engine as a power source) resulted in the design of more efficient engines that could be smaller, faster, or more powerful, depending on the intended application.

Although the reciprocating steam engine is no longer in widespread commercial use, various companies are exploring or exploiting the potential of the engine as an alternative to internal combustion engines. The company Energiprojekt AB in Sweden has made progress in using modern materials for harnessing the power of steam. The efficiency of Energiprojekt's steam engine reaches some 27-30% on

high-pressure engines. It is a single-step, 5-cylinder engine (no compound) with superheated steam and consumes approx. 4 kg (8.8 lb) of steam per kWh.[not in citation given]

Where CHP is not used, steam turbines in power stations use surface condensers as a cold sink. The condensers are cooled by water flow from oceans, rivers, lakes, and often by cooling towers which evaporate water to provide cooling energy removal. The resulting condensed hot water output from the condenser is then put back into the boiler via a pump. A dry type cooling tower is similar to an automobile radiator and is used in locations where water is costly. Evaporative (wet) cooling towers use the rejected heat to evaporate water; this water is kept separate from the condensate, which circulates in a closed system and returns to the boiler. Such towers often have visible plumes due to the evaporated water condensing into droplets carried up by the warm air. Evaporative cooling towers need less water flow than "once-through" cooling by river or lake water; a 700 megawatt coal-fired power plant may use about 3600 cubic metres of make-up water every hour for evaporative cooling, but would need about twenty times as much if cooled by river water.[citation needed]

The centrifugal governor was adopted by James Watt for use on a steam engine in 1788 after Watt's partner Boulton saw one at a flour mill Boulton & Watt were building. The governor could not actually hold a set speed, because it would assume a new constant speed in response to load changes. The governor was able to handle smaller variations such as those caused by fluctuating heat load to the boiler. Also, there was a tendency for oscillation whenever there was a speed change. As a consequence, engines equipped only with this governor were not suitable for operations requiring constant speed, such as cotton spinning. The governor was improved over time and coupled with variable steam cut off, good speed control in response to changes in load was attainable near the end of the 19th century.

The adoption of compounding was common for industrial units, for road engines and almost universal for marine engines after 1880; it was not universally popular in railway locomotives where it was often perceived as complicated. This is partly due to the harsh railway operating environment and limited space afforded by the loading gauge (particularly in Britain, where compounding was never common and not employed after 1930). However, although never in the majority, it was popular in many other countries. The simplest valve gears give events of fixed length during the engine cycle and often make the engine rotate in only one direction. Most however have a reversing mechanism which additionally can provide means for saving steam as speed and momentum are gained by gradually "shortening the cutoff" or rather, shortening the admission event; this in turn proportionately lengthens the expansion period. However, as one and the same valve usually controls both steam flows, a short cutoff at admission adversely affects the exhaust and compression periods which should ideally always be kept fairly constant; if the exhaust event is too brief, the totality of the exhaust steam cannot evacuate the cylinder, choking it and giving excessive compression ("kick back").[citation needed]

Using boiling water to produce mechanical motion goes back over 2000 years, but early devices were not practical. The Spanish inventor Jerónimo de Ayaz y Beaumont obtained the first patent for a steam engine in 1606. In 1698 Thomas Savery patented a steam pump that used steam in direct contact with the water being pumped. Savery's steam pump used condensing steam to create a vacuum and draw water into a chamber, and then applied pressurized steam to further pump the water. Thomas Newcomen's atmospheric engine was the first commercial true steam engine using a piston, and was used in 1712 for pumping in a mine.

A steam turbine consists of one or more rotors (rotating discs) mounted on a drive shaft, alternating with a series of stators (static discs) fixed to the turbine casing. The rotors have a propeller-like arrangement of blades at the outer edge. Steam acts upon these blades, producing rotary motion. The stator consists of a similar, but fixed, series of blades that serve to redirect the steam flow onto the next rotor stage. A steam turbine often exhausts into a surface condenser that provides a vacuum. The stages of a steam turbine are typically arranged to extract the maximum potential work from a specific velocity and pressure of steam, giving rise to a series of variably sized high- and low-pressure stages. Turbines are only efficient if they rotate at relatively high speed, therefore they are usually connected to reduction gearing to drive lower speed applications, such as a ship's propeller. In the vast majority of large electric generating stations, turbines are directly connected to generators with no reduction gearing. Typical speeds are 3600 revolutions per minute (RPM) in the USA with 60 Hertz power, 3000 RPM in Europe and other countries with 50 Hertz electric power systems. In nuclear power applications the turbines typically run at half these speeds, 1800 RPM and 1500 RPM. A turbine rotor is also only capable of providing power when rotating in one direction. Therefore, a reversing stage or gearbox is usually required where power is required in

the opposite direction.[citation needed]

The weight of boilers and condensers generally makes the power-to-weight ratio of a steam plant lower than for internal combustion engines. For mobile applications steam has been largely superseded by internal combustion engines or electric motors. However, most electric power is generated using steam turbine plant, so that indirectly the world's industry is still dependent on steam power. Recent concerns about fuel sources and pollution have incited a renewed interest in steam both as a component of cogeneration processes and as a prime mover. This is becoming known as the Advanced Steam movement.[citation needed]

It is possible to use a mechanism based on a pistonless rotary engine such as the Wankel engine in place of the cylinders and valve gear of a conventional reciprocating steam engine. Many such engines have been designed, from the time of James Watt to the present day, but relatively few were actually built and even fewer went into quantity production; see link at bottom of article for more details. The major problem is the difficulty of sealing the rotors to make them steam-tight in the face of wear and thermal expansion; the resulting leakage made them very inefficient. Lack of expansive working, or any means of control of the cutoff is also a serious problem with many such designs.[citation needed]

The next major step occurred when James Watt developed (1763–1775) an improved version of Newcomen's engine, with a separate condenser. Boulton and Watt's early engines used half as much coal as John Smeaton's improved version of Newcomen's. Newcomen's and Watt's early engines were "atmospheric". They were powered by air pressure pushing a piston into the partial vacuum generated by condensing steam, instead of the pressure of expanding steam. The engine cylinders had to be large because the only usable force acting on them was due to atmospheric pressure.

Steam engines frequently possess two independent mechanisms for ensuring that the pressure in the boiler does not go too high; one may be adjusted by the user, the second is typically designed as an ultimate fail-safe. Such safety valves traditionally used a simple lever to restrain a plug valve in the top of a boiler. One end of the lever carried a weight or spring that restrained the valve against steam pressure. Early valves could be adjusted by engine drivers, leading to many accidents when a driver fastened the valve down to allow greater steam pressure and more power from the engine. The more recent type of safety valve uses an adjustable spring-loaded valve, which is locked such that operators may not tamper with its adjustment unless a seal illegally is broken. This arrangement is considerably safer.[citation needed]

The acme of the horizontal engine was the Corliss steam engine, patented in 1849, which was a four-valve counter flow engine with separate steam admission and exhaust valves and automatic variable steam cutoff. When Corliss was given the Rumford medal the committee said that "no one invention since Watt's time has so enhanced the efficiency of the steam engine". In addition to using 30% less steam, it provided more uniform speed due to variable steam cut off, making it well suited to manufacturing, especially cotton spinning.

The steam engine contributed much to the development of thermodynamic theory; however, the only applications of scientific theory that influenced the steam engine were the original concepts of harnessing the power of steam and atmospheric pressure and knowledge of properties of heat and steam. The experimental measurements made by Watt on a model steam engine led to the development of the separate condenser. Watt independently discovered latent heat, which was confirmed by the original discoverer Joseph Black, who also advised Watt on experimental procedures. Watt was also aware of the change in the boiling point of water with pressure. Otherwise, the improvements to the engine itself were more mechanical in nature. The thermodynamic concepts of the Rankine cycle did give engineers the understanding needed to calculate efficiency which aided the development of modern high-pressure and -temperature boilers and the steam turbine.

One of the principal advantages the Rankine cycle holds over others is that during the compression stage relatively little work is required to drive the pump, the working fluid being in its liquid phase at this point. By condensing the fluid, the work required by the pump consumes only 1% to 3% of the turbine power and contributes to a much higher efficiency for a real cycle. The benefit of this is lost somewhat due to the lower heat addition temperature. Gas turbines, for instance, have turbine entry temperatures approaching 1500 °C. Nonetheless, the efficiencies of actual large steam cycles and large modern gas turbines are fairly well matched.[citation needed]

Other components are often present; pumps (such as an injector) to supply water to the boiler during operation, condensers to recirculate the water and recover the latent heat of vaporisation, and

superheaters to raise the temperature of the steam above its saturated vapour point, and various mechanisms to increase the draft for fireboxes. When coal is used, a chain or screw stoking mechanism and its drive engine or motor may be included to move the fuel from a supply bin (bunker) to the firebox. See: Mechanical stoker

Land-based steam engines could exhaust much of their steam, as feed water was usually readily available. Prior to and during World War I, the expansion engine dominated marine applications where high vessel speed was not essential. It was however superseded by the British invention steam turbine where speed was required, for instance in warships, such as the dreadnought battleships, and ocean liners. HMS Dreadnought of 1905 was the first major warship to replace the proven technology of the reciprocating engine with the then-novel steam turbine.[citation needed]

Virtually all nuclear power plants generate electricity by heating water to provide steam that drives a turbine connected to an electrical generator. Nuclear-powered ships and submarines either use a steam turbine directly for main propulsion, with generators providing auxiliary power, or else employ turbo-electric transmission, where the steam drives a turbo generator set with propulsion provided by electric motors. A limited number of steam turbine railroad locomotives were manufactured. Some non-condensing direct-drive locomotives did meet with some success for long haul freight operations in Sweden and for express passenger work in Britain, but were not repeated. Elsewhere, notably in the U.S.A., more advanced designs with electric transmission were built experimentally, but not reproduced. It was found that steam turbines were not ideally suited to the railroad environment and these locomotives failed to oust the classic reciprocating steam unit in the way that modern diesel and electric traction has done.[citation needed]

The Rankine cycle is sometimes referred to as a practical Carnot cycle because, when an efficient turbine is used, the TS diagram begins to resemble the Carnot cycle. The main difference is that heat addition (in the boiler) and rejection (in the condenser) are isobaric (constant pressure) processes in the Rankine cycle and isothermal (constant temperature) processes in the theoretical Carnot cycle. In this cycle a pump is used to pressurize the working fluid which is received from the condenser as a liquid not as a gas. Pumping the working fluid in liquid form during the cycle requires a small fraction of the energy to transport it compared to the energy needed to compress the working fluid in gaseous form in a compressor (as in the Carnot cycle). The cycle of a reciprocating steam engine differs from that of turbines because of condensation and re-evaporation occurring in the cylinder or in the steam inlet passages.

Oxygen is a chemical element with symbol O and atomic number 8. It is a member of the chalcogen group on the periodic table and is a highly reactive nonmetal and oxidizing agent that readily forms compounds (notably oxides) with most elements. By mass, oxygen is the third-most abundant element in the universe, after hydrogen and helium. At standard temperature and pressure, two atoms of the element bind to form dioxygen, a colorless and odorless diatomic gas with the formula O

2. Diatomic oxygen gas constitutes 20.8% of the Earth's atmosphere. However, monitoring of atmospheric oxygen levels show a global downward trend, because of fossil-fuel burning. Oxygen is the most abundant element by mass in the Earth's crust as part of oxide compounds such as silicon dioxide, making up almost half of the crust's mass.

Many major classes of organic molecules in living organisms, such as proteins, nucleic acids, carbohydrates, and fats, contain oxygen, as do the major inorganic compounds that are constituents of animal shells, teeth, and bone. Most of the mass of living organisms is oxygen as it is a part of water, the major constituent of lifeforms. Oxygen is used in cellular respiration and released by photosynthesis, which uses the energy of sunlight to produce oxygen from water. It is too chemically reactive to remain a free element in air without being continuously replenished by the photosynthetic action of living organisms. Another form (allotrope) of oxygen, ozone (O

3), strongly absorbs UVB radiation and consequently the high-altitude ozone layer helps protect the biosphere from ultraviolet radiation, but is a pollutant near the surface where it is a by-product of smog. At even higher low earth orbit altitudes, sufficient atomic oxygen is present to cause erosion for spacecraft. In the late 17th century, Robert Boyle proved that air is necessary for combustion. English chemist John Mayow (1641–1679) refined this work by showing that fire requires only a part of air that he called spiritus nitroaereus or just nitroaereus. In one experiment he found that placing either a mouse or a lit candle in a closed container over water caused the water to rise and replace one-fourteenth of the air's volume before extinguishing the subjects. From this he surmised that nitroaereus is consumed in both respiration

and combustion.

In the meantime, on August 1, 1774, an experiment conducted by the British clergyman Joseph Priestley focused sunlight on mercuric oxide ( $\text{HgO}$ ) inside a glass tube, which liberated a gas he named "dephlogisticated air". He noted that candles burned brighter in the gas and that a mouse was more active and lived longer while breathing it. After breathing the gas himself, he wrote: "The feeling of it to my lungs was not sensibly different from that of common air, but I fancied that my breast felt peculiarly light and easy for some time afterwards." Priestley published his findings in 1775 in a paper titled "An Account of Further Discoveries in Air" which was included in the second volume of his book titled Experiments and Observations on Different Kinds of Air. Because he published his findings first, Priestley is usually given priority in the discovery.

One of the first known experiments on the relationship between combustion and air was conducted by the 2nd century BCE Greek writer on mechanics, Philo of Byzantium. In his work Pneumatica, Philo observed that inverting a vessel over a burning candle and surrounding the vessel's neck with water resulted in some water rising into the neck. Philo incorrectly surmised that parts of the air in the vessel were converted into the classical element fire and thus were able to escape through pores in the glass. Many centuries later Leonardo da Vinci built on Philo's work by observing that a portion of air is consumed during combustion and respiration.

Highly concentrated sources of oxygen promote rapid combustion. Fire and explosion hazards exist when concentrated oxidants and fuels are brought into close proximity; an ignition event, such as heat or a spark, is needed to trigger combustion. Oxygen is the oxidant, not the fuel, but nevertheless the source of most of the chemical energy released in combustion. Combustion hazards also apply to compounds of oxygen with a high oxidative potential, such as peroxides, chlorates, nitrates, perchlorates, and dichromates because they can donate oxygen to a fire.

Concentrated O

O<sub>2</sub> will allow combustion to proceed rapidly and energetically. Steel pipes and storage vessels used to store and transmit both gaseous and liquid oxygen will act as a fuel; and therefore the design and manufacture of O

O<sub>2</sub> systems requires special training to ensure that ignition sources are minimized. The fire that killed the Apollo 1 crew in a launch pad test spread so rapidly because the capsule was pressurized with pure O<sub>2</sub> but at slightly more than atmospheric pressure, instead of the 1/3 normal pressure that would be used in a mission.[k]

Oxygen is present in the atmosphere in trace quantities in the form of carbon dioxide ( $\text{CO}_2$ )

2). The Earth's crustal rock is composed in large part of oxides of silicon (silica  $\text{SiO}_2$ )

2, as found in granite and quartz), aluminium (aluminium oxide  $\text{Al}_2\text{O}_3$ )

2O

3, in bauxite and corundum), iron (iron(III) oxide  $\text{Fe}_2\text{O}_3$ )

2O

3, in hematite and rust), and calcium carbonate (in limestone). The rest of the Earth's crust is also made of oxygen compounds, in particular various complex silicates (in silicate minerals). The Earth's mantle, of much larger mass than the crust, is largely composed of silicates of magnesium and iron.

John Dalton's original atomic hypothesis assumed that all elements were monatomic and that the atoms in compounds would normally have the simplest atomic ratios with respect to one another. For example, Dalton assumed that water's formula was  $\text{HO}$ , giving the atomic mass of oxygen as 8 times that of hydrogen, instead of the modern value of about 16. In 1805, Joseph Louis Gay-Lussac and Alexander von Humboldt showed that water is formed of two volumes of hydrogen and one volume of oxygen; and by 1811 Amedeo Avogadro had arrived at the correct interpretation of water's composition, based on what is now called Avogadro's law and the assumption of diatomic elemental molecules.[a]

Highly combustible materials that leave little residue, such as wood or coal, were thought to be made mostly of phlogiston; whereas non-combustible substances that corrode, such as iron, contained very little. Air did not play a role in phlogiston theory, nor were any initial quantitative experiments conducted to test the idea; instead, it was based on observations of what happens when something burns, that most common objects appear to become lighter and seem to lose something in the process. The fact that a substance like wood gains overall weight in burning was hidden by the buoyancy of the gaseous combustion products. Indeed, one of the first clues that the phlogiston theory was incorrect was that metals, too, gain weight in rusting (when they were supposedly losing phlogiston).

In this dioxygen, the two oxygen atoms are chemically bonded to each other. The bond can be variously described based on level of theory, but is reasonably and simply described as a covalent double bond that results from the filling of molecular orbitals formed from the atomic orbitals of the individual oxygen atoms, the filling of which results in a bond order of two. More specifically, the double bond is the result of sequential, low-to-high energy, or Aufbau, filling of orbitals, and the resulting cancellation of contributions from the 2s electrons, after sequential filling of the low  $\sigma$  and  $\sigma^*$  orbitals;  $\sigma$  overlap of the two atomic 2p orbitals that lie along the O-O molecular axis and  $\pi$  overlap of two pairs of atomic 2p orbitals perpendicular to the O-O molecular axis, and then cancellation of contributions from the remaining two of the six 2p electrons after their partial filling of the lowest  $\pi$  and  $\pi^*$  orbitals.

Oxygen was discovered independently by Carl Wilhelm Scheele, in Uppsala, in 1773 or earlier, and Joseph Priestley in Wiltshire, in 1774, but Priestley is often given priority because his work was published first. The name oxygen was coined in 1777 by Antoine Lavoisier, whose experiments with oxygen helped to discredit the then-popular phlogiston theory of combustion and corrosion. Its name derives from the Greek roots  $\xi\acute{\upsilon}\varsigma$  oxy's, "acid", literally "sharp", referring to the sour taste of acids and  $-\gamma\epsilon\nu\acute{\eta}\varsigma$  -genes, "producer", literally "begetter", because at the time of naming, it was mistakenly thought that all acids required oxygen in their composition. Common uses of oxygen includes the production cycle of steel, plastics and textiles, brazing, welding and cutting of steels and other metals, rocket propellant, in oxygen therapy and life support systems in aircraft, submarines, spaceflight and diving.

This combination of cancellations and  $\sigma$  and  $\pi$  overlaps results in dioxygen's double bond character and reactivity, and a triplet electronic ground state. An electron configuration with two unpaired electrons as found in dioxygen (see the filled  $\pi^*$  orbitals in the diagram), orbitals that are of equal energy—i.e., degenerate—is a configuration termed a spin triplet state. Hence, the ground state of the  $O_2$  molecule is referred to as triplet oxygen.[b] The highest energy, partially filled orbitals are antibonding, and so their filling weakens the bond order from three to two. Because of its unpaired electrons, triplet oxygen reacts only slowly with most organic molecules, which have paired electron spins; this prevents spontaneous combustion.

In one experiment, Lavoisier observed that there was no overall increase in weight when tin and air were heated in a closed container. He noted that air rushed in when he opened the container, which indicated that part of the trapped air had been consumed. He also noted that the tin had increased in weight and that increase was the same as the weight of the air that rushed back in. This and other experiments on combustion were documented in his book *Sur la combustion en général*, which was published in 1777. In that work, he proved that air is a mixture of two gases; 'vital air', which is essential to combustion and respiration, and azote (Gk.  $\zeta\omega\tau\omicron\nu$  "lifeless"), which did not support either. Azote later became nitrogen in English, although it has kept the name in French and several other European languages.

Trioxxygen ( $O_3$ )

3) is usually known as ozone and is a very reactive allotrope of oxygen that is damaging to lung tissue.

Ozone is produced in the upper atmosphere when  $O_2$

2 combines with atomic oxygen made by the splitting of  $O_2$

2 by ultraviolet (UV) radiation. Since ozone absorbs strongly in the UV region of the spectrum, the ozone layer of the upper atmosphere functions as a protective radiation shield for the planet. Near the Earth's surface, it is a pollutant formed as a by-product of automobile exhaust. The metastable molecule tetraoxygen ( $O_4$ )

4) was discovered in 2001, and was assumed to exist in one of the six phases of solid oxygen. It was proven in 2006 that this phase, created by pressurizing  $O_2$

2 to 20 GPa, is in fact a rhombohedral  $O_8$

8 cluster. This cluster has the potential to be a much more powerful oxidizer than either  $O_2$  or  $O_3$

3 and may therefore be used in rocket fuel. A metallic phase was discovered in 1990 when solid oxygen is subjected to a pressure of above 96 GPa and it was shown in 1998 that at very low temperatures, this phase becomes superconducting.

The common allotrope of elemental oxygen on Earth is called dioxygen,  $O_2$

2. It is the form that is a major part of the Earth's atmosphere (see Occurrence).  $O_2$  has a bond length of 121 pm and a bond energy of 498 kJ·mol<sup>−1</sup>, which is smaller than the energy of other double bonds or pairs of single bonds in the biosphere and responsible for the exothermic reaction of  $O_2$  with any organic molecule. Due to its energy content,  $O_2$  is used by complex forms of life, such as animals, in cellular

respiration (see Biological role). Other aspects of  $O_2$  are covered in the remainder of this article.

In 1891 Scottish chemist James Dewar was able to produce enough liquid oxygen to study. The first commercially viable process for producing liquid oxygen was independently developed in 1895 by German engineer Carl von Linde and British engineer William Hampson. Both men lowered the temperature of air until it liquefied and then distilled the component gases by boiling them off one at a time and capturing them. Later, in 1901, oxyacetylene welding was demonstrated for the first time by burning a mixture of acetylene and compressed  $O_2$

2. This method of welding and cutting metal later became common.

Oxygen is more soluble in water than nitrogen is. Water in equilibrium with air contains approximately 1 molecule of dissolved  $O_2$

2 for every 2 molecules of  $N_2$

$O_2$ , compared to an atmospheric ratio of approximately 1:4. The solubility of oxygen in water is temperature-dependent, and about twice as much ( $14.6 \text{ mg}\cdot\text{L}^{-1}$ ) dissolves at  $0^\circ\text{C}$  than at  $20^\circ\text{C}$  ( $7.6 \text{ mg}\cdot\text{L}^{-1}$ ). At  $25^\circ\text{C}$  and 1 standard atmosphere ( $101.3 \text{ kPa}$ ) of air, freshwater contains about 6.04 milliliters (mL) of oxygen per liter, whereas seawater contains about 4.95 mL per liter. At  $5^\circ\text{C}$  the solubility increases to 9.0 mL (50% more than at  $25^\circ\text{C}$ ) per liter for water and 7.2 mL (45% more) per liter for sea water.

Oxygen is the most abundant chemical element by mass in the Earth's biosphere, air, sea and land. Oxygen is the third most abundant chemical element in the universe, after hydrogen and helium. About 0.9% of the Sun's mass is oxygen. Oxygen constitutes 49.2% of the Earth's crust by mass and is the major component of the world's oceans (88.8% by mass). Oxygen gas is the second most common component of the Earth's atmosphere, taking up 20.8% of its volume and 23.1% of its mass (some 1015 tonnes).[d] Earth is unusual among the planets of the Solar System in having such a high concentration of oxygen gas in its atmosphere: Mars (with 0.1%  $O_2$

2 by volume) and Venus have far lower concentrations. The  $O_2$

2 surrounding these other planets is produced solely by ultraviolet radiation impacting oxygen-containing molecules such as carbon dioxide.

By the late 19th century scientists realized that air could be liquefied, and its components isolated, by compressing and cooling it. Using a cascade method, Swiss chemist and physicist Raoul Pierre Pictet evaporated liquid sulfur dioxide in order to liquefy carbon dioxide, which in turn was evaporated to cool oxygen gas enough to liquefy it. He sent a telegram on December 22, 1877 to the French Academy of Sciences in Paris announcing his discovery of liquid oxygen. Just two days later, French physicist Louis Paul Cailletet announced his own method of liquefying molecular oxygen. Only a few drops of the liquid were produced in either case so no meaningful analysis could be conducted. Oxygen was liquified in stable state for the first time on March 29, 1883 by Polish scientists from Jagiellonian University, Zygmunt Wróblewski and Karol Olszewski.

Planetary geologists have measured different abundances of oxygen isotopes in samples from the Earth, the Moon, Mars, and meteorites, but were long unable to obtain reference values for the isotope ratios in the Sun, believed to be the same as those of the primordial solar nebula. Analysis of a silicon wafer exposed to the solar wind in space and returned by the crashed Genesis spacecraft has shown that the Sun has a higher proportion of oxygen-16 than does the Earth. The measurement implies that an unknown process depleted oxygen-16 from the Sun's disk of protoplanetary material prior to the coalescence of dust grains that formed the Earth.

Singlet oxygen is a name given to several higher-energy species of molecular  $O_2$

2 in which all the electron spins are paired. It is much more reactive towards common organic molecules than is molecular oxygen per se. In nature, singlet oxygen is commonly formed from water during photosynthesis, using the energy of sunlight. It is also produced in the troposphere by the photolysis of ozone by light of short wavelength, and by the immune system as a source of active oxygen. Carotenoids in photosynthetic organisms (and possibly also in animals) play a major role in absorbing energy from singlet oxygen and converting it to the unexcited ground state before it can cause harm to tissues.

Paleoclimatologists measure the ratio of oxygen-18 and oxygen-16 in the shells and skeletons of marine organisms to determine what the climate was like millions of years ago (see oxygen isotope ratio cycle). Seawater molecules that contain the lighter isotope, oxygen-16, evaporate at a slightly faster rate than water molecules containing the 12% heavier oxygen-18; this disparity increases at lower temperatures.



During periods of lower global temperatures, snow and rain from that evaporated water tends to be higher in oxygen-16, and the seawater left behind tends to be higher in oxygen-18. Marine organisms then incorporate more oxygen-18 into their skeletons and shells than they would in a warmer climate. Paleoclimatologists also directly measure this ratio in the water molecules of ice core samples that are up to several hundreds of thousands of years old.

Oxygen presents two spectrophotometric absorption bands peaking at the wavelengths 687 and 760 nm. Some remote sensing scientists have proposed using the measurement of the radiance coming from vegetation canopies in those bands to characterize plant health status from a satellite platform. This approach exploits the fact that in those bands it is possible to discriminate the vegetation's reflectance from its fluorescence, which is much weaker. The measurement is technically difficult owing to the low signal-to-noise ratio and the physical structure of vegetation; but it has been proposed as a possible method of monitoring the carbon cycle from satellites on a global scale.

In the triplet form,  $O_2$

2 molecules are paramagnetic. That is, they impart magnetic character to oxygen when it is in the presence of a magnetic field, because of the spin magnetic moments of the unpaired electrons in the molecule, and the negative exchange energy between neighboring  $O_2$

2 molecules. Liquid oxygen is attracted to a magnet to a sufficient extent that, in laboratory demonstrations, a bridge of liquid oxygen may be supported against its own weight between the poles of a powerful magnet.[c]

Reactive oxygen species, such as superoxide ion ( $O_2^{\cdot -}$ )

2) and hydrogen peroxide ( $H_2O_2$ )

2O

2), are dangerous by-products of oxygen use in organisms. Parts of the immune system of higher organisms create peroxide, superoxide, and singlet oxygen to destroy invading microbes. Reactive oxygen species also play an important role in the hypersensitive response of plants against pathogen attack. Oxygen is toxic to obligately anaerobic organisms, which were the dominant form of early life on Earth until  $O_2$

2 began to accumulate in the atmosphere about 2.5 billion years ago during the Great Oxygenation Event, about a billion years after the first appearance of these organisms.

Oxygen condenses at 90.20 K ( $-182.95\text{ }^{\circ}\text{C}$ ,  $-297.31\text{ }^{\circ}\text{F}$ ), and freezes at 54.36 K ( $-218.79\text{ }^{\circ}\text{C}$ ,  $-361.82\text{ }^{\circ}\text{F}$ ). Both liquid and solid  $O_2$

2 are clear substances with a light sky-blue color caused by absorption in the red (in contrast with the blue color of the sky, which is due to Rayleigh scattering of blue light). High-purity liquid  $O_2$

2 is usually obtained by the fractional distillation of liquefied air. Liquid oxygen may also be produced by condensation out of air, using liquid nitrogen as a coolant. It is a highly reactive substance and must be segregated from combustible materials.

Free oxygen also occurs in solution in the world's water bodies. The increased solubility of  $O_2$

2 at lower temperatures (see Physical properties) has important implications for ocean life, as polar oceans support a much higher density of life due to their higher oxygen content. Water polluted with plant nutrients such as nitrates or phosphates may stimulate growth of algae by a process called eutrophication and the decay of these organisms and other biomaterials may reduce amounts of  $O_2$

2 in eutrophic water bodies. Scientists assess this aspect of water quality by measuring the water's biochemical oxygen demand, or the amount of  $O_2$

2 needed to restore it to a normal concentration.

Free oxygen gas was almost nonexistent in Earth's atmosphere before photosynthetic archaea and bacteria evolved, probably about 3.5 billion years ago. Free oxygen first appeared in significant quantities during the Paleoproterozoic eon (between 3.0 and 2.3 billion years ago). For the first billion years, any free oxygen produced by these organisms combined with dissolved iron in the oceans to form banded iron formations. When such oxygen sinks became saturated, free oxygen began to outgas from the oceans 3–2.7 billion years ago, reaching 10% of its present level around 1.7 billion years ago.

The unusually high concentration of oxygen gas on Earth is the result of the oxygen cycle. This biogeochemical cycle describes the movement of oxygen within and between its three main reservoirs on Earth: the atmosphere, the biosphere, and the lithosphere. The main driving factor of the oxygen cycle is photosynthesis, which is responsible for modern Earth's atmosphere. Photosynthesis releases oxygen into the atmosphere, while respiration and decay remove it from the atmosphere. In the present

equilibrium, production and consumption occur at the same rate of roughly 1/2000th of the entire atmospheric oxygen per year.

The other major method of producing O

2 gas involves passing a stream of clean, dry air through one bed of a pair of identical zeolite molecular sieves, which absorbs the nitrogen and delivers a gas stream that is 90% to 93% O

2. Simultaneously, nitrogen gas is released from the other nitrogen-saturated zeolite bed, by reducing the chamber operating pressure and diverting part of the oxygen gas from the producer bed through it, in the reverse direction of flow. After a set cycle time the operation of the two beds is interchanged, thereby allowing for a continuous supply of gaseous oxygen to be pumped through a pipeline. This is known as pressure swing adsorption. Oxygen gas is increasingly obtained by these non-cryogenic technologies (see also the related vacuum swing adsorption).

Oxygen gas can also be produced through electrolysis of water into molecular oxygen and hydrogen. DC electricity must be used: if AC is used, the gases in each limb consist of hydrogen and oxygen in the explosive ratio 2:1. Contrary to popular belief, the 2:1 ratio observed in the DC electrolysis of acidified water does not prove that the empirical formula of water is H<sub>2</sub>O unless certain assumptions are made about the molecular formulae of hydrogen and oxygen themselves. A similar method is the electrocatalytic O

2 evolution from oxides and oxoacids. Chemical catalysts can be used as well, such as in chemical oxygen generators or oxygen candles that are used as part of the life-support equipment on submarines, and are still part of standard equipment on commercial airliners in case of depressurization emergencies. Another air separation technology involves forcing air to dissolve through ceramic membranes based on zirconium dioxide by either high pressure or an electric current, to produce nearly pure O

2 gas.

Oxygen, as a supposed mild euphoric, has a history of recreational use in oxygen bars and in sports. Oxygen bars are establishments, found in Japan, California, and Las Vegas, Nevada since the late 1990s that offer higher than normal O

2 exposure for a fee. Professional athletes, especially in American football, also sometimes go off field between plays to wear oxygen masks in order to get a "boost" in performance. The pharmacological effect is doubtful; a placebo effect is a more likely explanation. Available studies support a performance boost from enriched O

2 mixtures only if they are breathed during aerobic exercise.

Hyperbaric (high-pressure) medicine uses special oxygen chambers to increase the partial pressure of O<sub>2</sub> around the patient and, when needed, the medical staff. Carbon monoxide poisoning, gas gangrene, and decompression sickness (the 'bends') are sometimes treated using these devices. Increased O<sub>2</sub> concentration in the lungs helps to displace carbon monoxide from the heme group of hemoglobin.

Oxygen gas is poisonous to the anaerobic bacteria that cause gas gangrene, so increasing its partial pressure helps kill them. Decompression sickness occurs in divers who decompress too quickly after a dive, resulting in bubbles of inert gas, mostly nitrogen and helium, forming in their blood. Increasing the pressure of O

2 as soon as possible is part of the treatment.

Uptake of O

2 from the air is the essential purpose of respiration, so oxygen supplementation is used in medicine.

Treatment not only increases oxygen levels in the patient's blood, but has the secondary effect of decreasing resistance to blood flow in many types of diseased lungs, easing work load on the heart.

Oxygen therapy is used to treat emphysema, pneumonia, some heart disorders (congestive heart failure), some disorders that cause increased pulmonary artery pressure, and any disease that impairs the body's ability to take up and use gaseous oxygen.

Due to its electronegativity, oxygen forms chemical bonds with almost all other elements to give corresponding oxides. The surface of most metals, such as aluminium and titanium, are oxidized in the presence of air and become coated with a thin film of oxide that passivates the metal and slows further corrosion. Many oxides of the transition metals are non-stoichiometric compounds, with slightly less metal than the chemical formula would show. For example, the mineral FeO (wüstite) is written as Fe<sub>1-x</sub>O, where x is usually around 0.05.

People who climb mountains or fly in non-pressurized fixed-wing aircraft sometimes have supplemental O

2 supplies.[h] Passengers traveling in (pressurized) commercial airplanes have an emergency supply of O

2 automatically supplied to them in case of cabin depressurization. Sudden cabin pressure loss activates chemical oxygen generators above each seat, causing oxygen masks to drop. Pulling on the masks "to start the flow of oxygen" as cabin safety instructions dictate, forces iron filings into the sodium chlorate inside the canister. A steady stream of oxygen gas is then produced by the exothermic reaction.

Oxygen storage methods include high pressure oxygen tanks, cryogenics and chemical compounds. For reasons of economy, oxygen is often transported in bulk as a liquid in specially insulated tankers, since one liter of liquefied oxygen is equivalent to 840 liters of gaseous oxygen at atmospheric pressure and 20 °C (68 °F). Such tankers are used to refill bulk liquid oxygen storage containers, which stand outside hospitals and other institutions with a need for large volumes of pure oxygen gas. Liquid oxygen is passed through heat exchangers, which convert the cryogenic liquid into gas before it enters the building. Oxygen is also stored and shipped in smaller cylinders containing the compressed gas; a form that is useful in certain portable medical applications and oxy-fuel welding and cutting.

Among the most important classes of organic compounds that contain oxygen are (where "R" is an organic group): alcohols (R-OH); ethers (R-O-R); ketones (R-CO-R); aldehydes (R-CO-H); carboxylic acids (R-COOH); esters (R-COO-R); acid anhydrides (R-CO-O-CO-R); and amides (R-C(O)-NR

2). There are many important organic solvents that contain oxygen, including: acetone, methanol, ethanol, isopropanol, furan, THF, diethyl ether, dioxane, ethyl acetate, DMF, DMSO, acetic acid, and formic acid.

Acetone ((CH

3)

2CO) and phenol (C

6H

5OH) are used as feeder materials in the synthesis of many different substances. Other important organic compounds that contain oxygen are: glycerol, formaldehyde, glutaraldehyde, citric acid, acetic anhydride, and acetamide. Epoxides are ethers in which the oxygen atom is part of a ring of three atoms.

The element is found in almost all biomolecules that are important to (or generated by) life. Only a few common complex biomolecules, such as squalene and the carotenes, contain no oxygen. Of the organic compounds with biological relevance, carbohydrates contain the largest proportion by mass of oxygen. All fats, fatty acids, amino acids, and proteins contain oxygen (due to the presence of carbonyl groups in these acids and their ester residues). Oxygen also occurs in phosphate (PO<sub>3</sub>-

4) groups in the biologically important energy-carrying molecules ATP and ADP, in the backbone and the purines (except adenine) and pyrimidines of RNA and DNA, and in bones as calcium phosphate and hydroxylapatite.

Oxygen toxicity to the lungs and central nervous system can also occur in deep scuba diving and surface supplied diving. Prolonged breathing of an air mixture with an O

2 partial pressure more than 60 kPa can eventually lead to permanent pulmonary fibrosis. Exposure to a O

2 partial pressures greater than 160 kPa (about 1.6 atm) may lead to convulsions (normally fatal for divers). Acute oxygen toxicity (causing seizures, its most feared effect for divers) can occur by breathing an air mixture with 21% O

2 at 66 m or more of depth; the same thing can occur by breathing 100% O

2 at only 6 m.

Breathing pure O

2 in space applications, such as in some modern space suits, or in early spacecraft such as Apollo, causes no damage due to the low total pressures used. In the case of spacesuits, the O

2 partial pressure in the breathing gas is, in general, about 30 kPa (1.4 times normal), and the resulting O

2 partial pressure in the astronaut's arterial blood is only marginally more than normal sea-level O

2 partial pressure (for more information on this, see space suit and arterial blood gas).

Oxygen gas (O

2) can be toxic at elevated partial pressures, leading to convulsions and other health problems.[j] Oxygen toxicity usually begins to occur at partial pressures more than 50 kilopascals (kPa), equal to about 50% oxygen composition at standard pressure or 2.5 times the normal sea-level O

2 partial pressure of about 21 kPa. This is not a problem except for patients on mechanical ventilators, since gas supplied through oxygen masks in medical applications is typically composed of only 30%–50%

O

2 by volume (about 30 kPa at standard pressure). (although this figure also is subject to wide variation, depending on type of mask).

The 1973 oil crisis began in October 1973 when the members of the Organization of Arab Petroleum Exporting Countries (OAPEC, consisting of the Arab members of OPEC plus Egypt and Syria) proclaimed an oil embargo. By the end of the embargo in March 1974, the price of oil had risen from US\$3 per barrel to nearly \$12 globally; US prices were significantly higher. The embargo caused an oil crisis, or "shock", with many short- and long-term effects on global politics and the global economy. It was later called the "first oil shock", followed by the 1979 oil crisis, termed the "second oil shock."

The crisis had a major impact on international relations and created a rift within NATO. Some European nations and Japan sought to disassociate themselves from United States foreign policy in the Middle East to avoid being targeted by the boycott. Arab oil producers linked any future policy changes to peace between the belligerents. To address this, the Nixon Administration began multilateral negotiations with the combatants. They arranged for Israel to pull back from the Sinai Peninsula and the Golan Heights. By January 18, 1974, US Secretary of State Henry Kissinger had negotiated an Israeli troop withdrawal from parts of the Sinai Peninsula. The promise of a negotiated settlement between Israel and Syria was enough to convince Arab oil producers to lift the embargo in March 1974.

On August 15, 1971, the United States unilaterally pulled out of the Bretton Woods Accord. The US abandoned the Gold Exchange Standard whereby the value of the dollar had been pegged to the price of gold and all other currencies were pegged to the dollar, whose value was left to "float" (rise and fall according to market demand). Shortly thereafter, Britain followed, floating the pound sterling. The other industrialized nations followed suit with their respective currencies. Anticipating that currency values would fluctuate unpredictably for a time, the industrialized nations increased their reserves (by expanding their money supplies) in amounts far greater than before. The result was a depreciation of the dollar and other industrialized nations' currencies. Because oil was priced in dollars, oil producers' real income decreased. In September 1971, OPEC issued a joint communiqué stating that, from then on, they would price oil in terms of a fixed amount of gold.

This contributed to the "Oil Shock". After 1971, OPEC was slow to readjust prices to reflect this depreciation. From 1947 to 1967, the dollar price of oil had risen by less than two percent per year. Until the oil shock, the price had also remained fairly stable versus other currencies and commodities. OPEC ministers had not developed institutional mechanisms to update prices in sync with changing market conditions, so their real incomes lagged. The substantial price increases of 1973–1974 largely returned their prices and corresponding incomes to Bretton Woods levels in terms of commodities such as gold. On October 6, 1973, Syria and Egypt, with support from other Arab nations, launched a surprise attack on Israel, on Yom Kippur. This renewal of hostilities in the Arab–Israeli conflict released the underlying economic pressure on oil prices. At the time, Iran was the world's second-largest oil exporter and a close US ally. Weeks later, the Shah of Iran said in an interview: "Of course [the price of oil] is going to rise... Certainly! And how!... You've [Western nations] increased the price of the wheat you sell us by 300 percent, and the same for sugar and cement... You buy our crude oil and sell it back to us, refined as petrochemicals, at a hundred times the price you've paid us... It's only fair that, from now on, you should pay more for oil. Let's say ten times more."

In response to American aid to Israel, on October 16, 1973, OPEC raised the posted price of oil by 70%, to \$5.11 a barrel. The following day, oil ministers agreed to the embargo, a cut in production by five percent from September's output and to continue to cut production in five percent monthly increments until their economic and political objectives were met. On October 19, Nixon requested Congress to appropriate \$2.2 billion in emergency aid to Israel, including \$1.5 billion in outright grants. George Lenczowski notes, "Military supplies did not exhaust Nixon's eagerness to prevent Israel's collapse... This [\$2.2 billion] decision triggered a collective OPEC response." Libya immediately announced it would embargo oil shipments to the United States. Saudi Arabia and the other Arab oil-producing states joined the embargo on October 20, 1973. At their Kuwait meeting, OAPEC proclaimed the embargo that curbed exports to various countries and blocked all oil deliveries to the US as a "principal hostile country".

Some of the income was dispensed in the form of aid to other underdeveloped nations whose economies had been caught between higher oil prices and lower prices for their own export commodities, amid shrinking Western demand. Much went for arms purchases that exacerbated political tensions, particularly in the Middle East. Saudi Arabia spent over 100 billion dollars in the ensuing decades for helping spread

its fundamentalist interpretation of Islam, known as Wahhabism, throughout the world, via religious charities such as al-Haramain Foundation, which often also distributed funds to violent Sunni extremist groups such as Al-Qaeda and the Taliban.

In the United States, scholars argue that there already existed a negotiated settlement based on equality between both parties prior to 1973. The possibility that the Middle East could become another superpower confrontation with the USSR was of more concern to the US than oil. Further, interest groups and government agencies more worried about energy were no match for Kissinger's dominance. In the US production, distribution and price disruptions "have been held responsible for recessions, periods of excessive inflation, reduced productivity, and lower economic growth."

The embargo had a negative influence on the US economy by causing immediate demands to address the threats to U.S. energy security. On an international level, the price increases changed competitive positions in many industries, such as automobiles. Macroeconomic problems consisted of both inflationary and deflationary impacts. The embargo left oil companies searching for new ways to increase oil supplies, even in rugged terrain such as the Arctic. Finding oil and developing new fields usually required five to ten years before significant production.

The embargo was not uniform across Europe. Of the nine members of the European Economic Community (EEC), the Netherlands faced a complete embargo, the UK and France received almost uninterrupted supplies (having refused to allow America to use their airfields and embargoed arms and supplies to both the Arabs and the Israelis), while the other six faced partial cutbacks. The UK had traditionally been an ally of Israel, and Harold Wilson's government supported the Israelis during the Six-Day War. His successor, Ted Heath, reversed this policy in 1970, calling for Israel to withdraw to its pre-1967 borders.

Despite being relatively unaffected by the embargo, the UK nonetheless faced an oil crisis of its own - a series of strikes by coal miners and railroad workers over the winter of 1973–74 became a major factor in the change of government. Heath asked the British to heat only one room in their houses over the winter. The UK, Germany, Italy, Switzerland and Norway banned flying, driving and boating on Sundays. Sweden rationed gasoline and heating oil. The Netherlands imposed prison sentences for those who used more than their ration of electricity.

Price controls exacerbated the crisis in the US. The system limited the price of "old oil" (that which had already been discovered) while allowing newly discovered oil to be sold at a higher price to encourage investment. Predictably, old oil was withdrawn from the market, creating greater scarcity. The rule also discouraged development of alternative energies. The rule had been intended to promote oil exploration. Scarcity was addressed by rationing (as in many countries). Motorists faced long lines at gas stations beginning in summer 1972 and increasing by summer 1973.

In 1973, Nixon named William E. Simon as the first Administrator of the Federal Energy Office, a short-term organization created to coordinate the response to the embargo. Simon allocated states the same amount of domestic oil for 1974 that each had consumed in 1972, which worked for states whose populations were not increasing. In other states, lines at gasoline stations were common. The American Automobile Association reported that in the last week of February 1974, 20% of American gasoline stations had no fuel.

To help reduce consumption, in 1974 a national maximum speed limit of 55 mph (about 88 km/h) was imposed through the Emergency Highway Energy Conservation Act. Development of the Strategic Petroleum Reserve began in 1975, and in 1977 the cabinet-level Department of Energy was created, followed by the National Energy Act of 1978.[citation needed] On November 28, 1995, Bill Clinton signed the National Highway Designation Act, ending the federal 55 mph (89 km/h) speed limit, allowing states to restore their prior maximum speed limit.

The energy crisis led to greater interest in renewable energy, nuclear power and domestic fossil fuels. There is criticism that American energy policies since the crisis have been dominated by crisis-mentality thinking, promoting expensive quick fixes and single-shot solutions that ignore market and technology realities. Instead of providing stable rules that support basic research while leaving plenty of scope for entrepreneurship and innovation, congresses and presidents have repeatedly backed policies which promise solutions that are politically expedient, but whose prospects are doubtful.

In 2004, declassified documents revealed that the U.S. was so distraught by the rise in oil prices and being challenged by under-developed countries that they briefly considered military action to forcibly seize Middle Eastern oilfields in late 1973. Although no explicit plan was mentioned, a conversation between

U.S. Secretary of Defense James Schlesinger and British Ambassador to the United States Lord Cromer revealed Schlesinger had told him that "it was no longer obvious to him that the U.S. could not use force." British Prime Minister Edward Heath was so worried by this prospect that he ordered a British intelligence estimate of U.S. intentions, which concluded America "might consider it could not tolerate a situation in which the U.S. and its allies were at the mercy of a small group of unreasonable countries," and that they would prefer a rapid operation to seize oilfields in Saudi Arabia and Kuwait, and possibly Abu Dhabi in military action was decided upon. Although the Soviet response to such an act would likely not involve force, intelligence warned "the American occupation would need to last 10 years as the West developed alternative energy sources, and would result in the 'total alienation' of the Arabs and much of the rest of the Third World."

Although lacking historical connections to the Middle East, Japan was the country most dependent on Arab oil. 71% of its imported oil came from the Middle East in 1970. On November 7, 1973, the Saudi and Kuwaiti governments declared Japan a "nonfriendly" country to encourage it to change its noninvolvement policy. It received a 5% production cut in December, causing a panic. On November 22, Japan issued a statement "asserting that Israel should withdraw from all of the 1967 territories, advocating Palestinian self-determination, and threatening to reconsider its policy toward Israel if Israel refused to accept these preconditions". By December 25, Japan was considered an Arab-friendly state.

The USSR's invasion of Afghanistan was only one sign of insecurity in the region, also marked by increased American weapons sales, technology, and outright military presence. Saudi Arabia and Iran became increasingly dependent on American security assurances to manage both external and internal threats, including increased military competition between them over increased oil revenues. Both states were competing for preeminence in the Persian Gulf and using increased revenues to fund expanded militaries. By 1979, Saudi arms purchases from the US exceeded five times Israel's. Another motive for the large scale purchase of arms from the US by Saudi Arabia was the failure of the Shah during January 1979 to maintain control of Iran, a non-Arabic but largely Shiite Muslim nation, which fell to a theocratic Islamist government under the Ayatollah Ruhollah Khomeini in the wake of the 1979 Iranian Revolution. Saudi Arabia, on the other hand, is an Arab, largely Sunni Muslim nation headed by a near absolutist monarchy. In the wake of the Iranian revolution the Saudis were forced to deal with the prospect of internal destabilization via the radicalism of Islamism, a reality which would quickly be revealed in the seizure of the Grand Mosque in Mecca by Wahhabi extremists during November 1979 and a Shiite revolt in the oil rich Al-Hasa region of Saudi Arabia in December of the same year. In November 2010, Wikileaks leaked confidential diplomatic cables pertaining to the United States and its allies which revealed that the late Saudi King Abdullah urged the United States to attack Iran in order to destroy its potential nuclear weapons program, describing Iran as "a snake whose head should be cut off without any procrastination."

The crisis reduced the demand for large cars. Japanese imports, primarily the Toyota Corona, the Toyota Corolla, the Datsun B210, the Datsun 510, the Honda Civic, the Mitsubishi Galant (a captive import from Chrysler sold as the Dodge Colt), the Subaru DL, and later the Honda Accord all had four cylinder engines that were more fuel efficient than the typical American V8 and six cylinder engines. Japanese imports became mass-market leaders with unibody construction and front-wheel drive, which became de facto standards.

Some buyers lamented the small size of the first Japanese compacts, and both Toyota and Nissan (then known as Datsun) introduced larger cars such as the Toyota Corona Mark II, the Toyota Cressida, the Mazda 616 and Datsun 810, which added passenger space and amenities such as air conditioning, power steering, AM-FM radios, and even power windows and central locking without increasing the price of the vehicle. A decade after the 1973 oil crisis, Honda, Toyota and Nissan, affected by the 1981 voluntary export restraints, opened US assembly plants and established their luxury divisions (Acura, Lexus and Infiniti, respectively) to distinguish themselves from their mass-market brands.

Compact trucks were introduced, such as the Toyota Hilux and the Datsun Truck, followed by the Mazda Truck (sold as the Ford Courier), and the Isuzu-built Chevrolet LUV. Mitsubishi rebranded its Forte as the Dodge D-50 a few years after the oil crisis. Mazda, Mitsubishi and Isuzu had joint partnerships with Ford, Chrysler, and GM, respectively. Later the American makers introduced their domestic replacements (Ford Ranger, Dodge Dakota and the Chevrolet S10/GMC S-15), ending their captive import policy.

An increase in imported cars into North America forced General Motors, Ford and Chrysler to introduce smaller and fuel-efficient models for domestic sales. The Dodge Omni / Plymouth Horizon from Chrysler,

the Ford Fiesta and the Chevrolet Chevette all had four-cylinder engines and room for at least four passengers by the late 1970s. By 1985, the average American vehicle moved 17.4 miles per gallon, compared to 13.5 in 1970. The improvements stayed even though the price of a barrel of oil remained constant at \$12 from 1974 to 1979. Sales of large sedans for most makes (except Chrysler products) recovered within two model years of the 1973 crisis. The Cadillac DeVille and Fleetwood, Buick Electra, Oldsmobile 98, Lincoln Continental, Mercury Marquis, and various other luxury oriented sedans became popular again in the mid-1970s. The only full-size models that did not recover were lower price models such as the Chevrolet Bel Air, and Ford Galaxie 500. Slightly smaller, mid-size models such as the Oldsmobile Cutlass, Chevrolet Monte Carlo, Ford Thunderbird and various other models sold well. Federal safety standards, such as NHTSA Federal Motor Vehicle Safety Standard 215 (pertaining to safety bumpers), and compacts like the 1974 Mustang I were a prelude to the DOT "downsize" revision of vehicle categories. By 1977, GM's full-sized cars reflected the crisis. By 1979, virtually all "full-size" American cars had shrunk, featuring smaller engines and smaller outside dimensions. Chrysler ended production of their full-sized luxury sedans at the end of the 1981 model year, moving instead to a full front-wheel drive lineup for 1982 (except for the M-body Dodge Diplomat/Plymouth Gran Fury and Chrysler New Yorker Fifth Avenue sedans).

OPEC soon lost its preeminent position, and in 1981, its production was surpassed by that of other countries. Additionally, its own member nations were divided. Saudi Arabia, trying to recover market share, increased production, pushing prices down, shrinking or eliminating profits for high-cost producers. The world price, which had peaked during the 1979 energy crisis at nearly \$40 per barrel, decreased during the 1980s to less than \$10 per barrel. Adjusted for inflation, oil briefly fell back to pre-1973 levels. This "sale" price was a windfall for oil-importing nations, both developing and developed.

The Apollo program, also known as Project Apollo, was the third United States human spaceflight program carried out by the National Aeronautics and Space Administration (NASA), which accomplished landing the first humans on the Moon from 1969 to 1972. First conceived during Dwight D. Eisenhower's administration as a three-man spacecraft to follow the one-man Project Mercury which put the first Americans in space, Apollo was later dedicated to President John F. Kennedy's national goal of "landing a man on the Moon and returning him safely to the Earth" by the end of the 1960s, which he proposed in a May 25, 1961, address to Congress. Project Mercury was followed by the two-man Project Gemini (1962–66). The first manned flight of Apollo was in 1968.

Apollo ran from 1961 to 1972, and was supported by the two-man Gemini program which ran concurrently with it from 1962 to 1966. Gemini missions developed some of the space travel techniques that were necessary for the success of the Apollo missions. Apollo used Saturn family rockets as launch vehicles. Apollo/Saturn vehicles were also used for an Apollo Applications Program, which consisted of Skylab, a space station that supported three manned missions in 1973–74, and the Apollo–Soyuz Test Project, a joint Earth orbit mission with the Soviet Union in 1975.

The Apollo program succeeded in achieving its goal of manned lunar landing, despite the major setback of a 1967 Apollo 1 cabin fire that killed the entire crew during a prelaunch test. After the first landing, sufficient flight hardware remained for nine follow-on landings with a plan for extended lunar geological and astrophysical exploration. Budget cuts forced the cancellation of three of these. Five of the remaining six missions achieved successful landings, but the Apollo 13 landing was prevented by an oxygen tank explosion in transit to the Moon, which disabled the command spacecraft's propulsion and life support. The crew returned to Earth safely by using the Lunar Module as a "lifeboat" for these functions.

Apollo set several major human spaceflight milestones. It stands alone in sending manned missions beyond low Earth orbit. Apollo 8 was the first manned spacecraft to orbit another celestial body, while the final Apollo 17 mission marked the sixth Moon landing and the ninth manned mission beyond low Earth orbit. The program returned 842 pounds (382 kg) of lunar rocks and soil to Earth, greatly contributing to the understanding of the Moon's composition and geological history. The program laid the foundation for NASA's current human spaceflight capability, and funded construction of its Johnson Space Center and Kennedy Space Center. Apollo also spurred advances in many areas of technology incidental to rocketry and manned spaceflight, including avionics, telecommunications, and computers.

The Apollo program was conceived during the Eisenhower administration in early 1960, as a follow-up to Project Mercury. While the Mercury capsule could only support one astronaut on a limited Earth orbital mission, Apollo would carry three astronauts. Possible missions included ferrying crews to a space station, circumlunar flights, and eventual manned lunar landings. The program was named after the Greek

god of light, music, and the sun by NASA manager Abe Silverstein, who later said that "I was naming the spacecraft like I'd name my baby." Silverstein chose the name at home one evening, early in 1960, because he felt "Apollo riding his chariot across the Sun was appropriate to the grand scale of the proposed program."

In July 1960, NASA Deputy Administrator Hugh L. Dryden announced the Apollo program to industry representatives at a series of Space Task Group conferences. Preliminary specifications were laid out for a spacecraft with a mission module cabin separate from the command module (piloting and re-entry cabin), and a propulsion and equipment module. On August 30, a feasibility study competition was announced, and on October 25, three study contracts were awarded to General Dynamics/Convair, General Electric, and the Glenn L. Martin Company. Meanwhile, NASA performed its own in-house spacecraft design studies led by Maxime Faget, to serve as a gauge to judge and monitor the three industry designs.

In November 1960, John F. Kennedy was elected president after a campaign that promised American superiority over the Soviet Union in the fields of space exploration and missile defense. Up to the election of 1960, Kennedy had been speaking out against the "missile gap" that he and many other senators felt had formed between the Soviets and themselves due to the inaction of President Eisenhower. Beyond military power, Kennedy used aerospace technology as a symbol of national prestige, pledging to make the US not "first but, first and, first if, but first period." Despite Kennedy's rhetoric, he did not immediately come to a decision on the status of the Apollo program once he became president. He knew little about the technical details of the space program, and was put off by the massive financial commitment required by a manned Moon landing. When Kennedy's newly appointed NASA Administrator James E. Webb requested a 30 percent budget increase for his agency, Kennedy supported an acceleration of NASA's large booster program but deferred a decision on the broader issue.

On April 12, 1961, Soviet cosmonaut Yuri Gagarin became the first person to fly in space, reinforcing American fears about being left behind in a technological competition with the Soviet Union. At a meeting of the US House Committee on Science and Astronautics one day after Gagarin's flight, many congressmen pledged their support for a crash program aimed at ensuring that America would catch up. Kennedy was circumspect in his response to the news, refusing to make a commitment on America's response to the Soviets.

On April 20, Kennedy sent a memo to Vice President Lyndon B. Johnson, asking Johnson to look into the status of America's space program, and into programs that could offer NASA the opportunity to catch up. Johnson responded approximately one week later, concluding that "we are neither making maximum effort nor achieving results necessary if this country is to reach a position of leadership." His memo concluded that a manned Moon landing was far enough in the future that it was likely the United States would achieve it first.

It became clear that managing the Apollo program would exceed the capabilities of Robert R. Gilruth's Space Task Group, which had been directing the nation's manned space program from NASA's Langley Research Center. So Gilruth was given authority to grow his organization into a new NASA center, the Manned Spacecraft Center (MSC). A site was chosen in Houston, Texas, on land donated by Rice University, and Administrator Webb announced the conversion on September 19, 1961. It was also clear NASA would soon outgrow its practice of controlling missions from its Cape Canaveral Air Force Station launch facilities in Florida, so a new Mission Control Center would be included in the MSC.

It also became clear that Apollo would outgrow the Canaveral launch facilities in Florida. The two newest launch complexes were already being built for the Saturn I and IB rockets at the northernmost end: LC-34 and LC-37. But an even bigger facility would be needed for the mammoth rocket required for the manned lunar mission, so land acquisition was started in July 1961 for a Launch Operations Center (LOC) immediately north of Canaveral at Merritt Island. The design, development and construction of the center was conducted by Kurt H. Debus, a member of Dr. Wernher von Braun's original V-2 rocket engineering team. Debus was named the LOC's first Director. Construction began in November 1962. Upon Kennedy's death, President Johnson issued an executive order on November 29, 1963, to rename the LOC and Cape Canaveral in honor of Kennedy.

The LOC included Launch Complex 39, a Launch Control Center, and a 130 million cubic foot (3.7 million cubic meter) Vertical Assembly Building (VAB) in which the space vehicle (launch vehicle and spacecraft) would be assembled on a Mobile Launcher Platform and then moved by a transporter to one of several launch pads. Although at least three pads were planned, only two, designated A and B, were completed in



October 1965. The LOC also included an Operations and Checkout Building (OCB) to which Gemini and Apollo spacecraft were initially received prior to being mated to their launch vehicles. The Apollo spacecraft could be tested in two vacuum chambers capable of simulating atmospheric pressure at altitudes up to 250,000 feet (76 km), which is nearly a vacuum.

Administrator Webb realized that in order to keep Apollo costs under control, he had to develop greater project management skills in his organization, so he recruited Dr. George E. Mueller for a high management job. Mueller accepted, on the condition that he have a say in NASA reorganization necessary to effectively administer Apollo. Webb then worked with Associate Administrator (later Deputy Administrator) Robert Seamans to reorganize the Office of Manned Space Flight (OMSF). On July 23, 1963, Webb announced Mueller's appointment as Deputy Associate Administrator for Manned Space Flight, to replace then Associate Administrator D. Brainerd Holmes on his retirement effective September 1. Under Webb's reorganization, the directors of the Manned Spacecraft Center (Gilruth) Marshall Space Flight Center (von Braun) and the Launch Operations Center (Debus) effectively reported to Mueller. Based on his industry experience on Air Force missile projects, Mueller realized some skilled managers could be found among high-ranking officers in the United States Air Force, so he got Webb's permission to recruit General Samuel C. Phillips, who gained a reputation for his effective management of the Minuteman program, as OMSF program controller. Phillips' superior officer Bernard A. Schriever agreed to loan Phillips to NASA, along with a staff of officers under him, on the condition that Phillips be made Apollo Program Director. Mueller agreed, and Phillips managed Apollo from January 1964, until it achieved the first manned landing in July 1969, after which he returned to Air Force duty.

In early 1961, direct ascent was generally the mission mode in favor at NASA. Many engineers feared that a rendezvous —let alone a docking— neither of which had been attempted even in Earth orbit, would be extremely difficult in lunar orbit. Dissenters including John Houbolt at Langley Research Center emphasized the important weight reductions that were offered by the LOR approach. Throughout 1960 and 1961, Houbolt campaigned for the recognition of LOR as a viable and practical option. Bypassing the NASA hierarchy, he sent a series of memos and reports on the issue to Associate Administrator Robert Seamans; while acknowledging that he spoke "somewhat as a voice in the wilderness," Houbolt pleaded that LOR should not be discounted in studies of the question.

Seamans' establishment of an ad-hoc committee headed by his special technical assistant Nicholas E. Golovin in July 1961, to recommend a launch vehicle to be used in the Apollo program, represented a turning point in NASA's mission mode decision. This committee recognized that the chosen mode was an important part of the launch vehicle choice, and recommended in favor of a hybrid EOR-LOR mode. Its consideration of LOR —as well as Houbolt's ceaseless work— played an important role in publicizing the workability of the approach. In late 1961 and early 1962, members of the Manned Spacecraft Center began to come around to support LOR, including the newly hired deputy director of the Office of Manned Space Flight, Joseph Shea, who became a champion of LOR. The engineers at Marshall Space Flight Center (MSFC) took longer to become convinced of its merits, but their conversion was announced by Wernher von Braun at a briefing in June 1962.

But even after NASA reached internal agreement, it was far from smooth sailing. Kennedy's science advisor Jerome Wiesner, who had expressed his opposition to manned spaceflight to Kennedy before the President took office, and had opposed the decision to land men on the Moon, hired Golovin, who had left NASA, to chair his own "Space Vehicle Panel", ostensibly to monitor, but actually to second-guess NASA's decisions on the Saturn V launch vehicle and LOR by forcing Shea, Seamans, and even Webb to defend themselves, delaying its formal announcement to the press on July 11, 1962, and forcing Webb to still hedge the decision as "tentative".

Wiesner kept up the pressure, even making the disagreement public during a two-day September visit by the President to Marshall Space Flight Center. Wiesner blurted out "No, that's no good" in front of the press, during a presentation by von Braun. Webb jumped in and defended von Braun, until Kennedy ended the squabble by stating that the matter was "still subject to final review". Webb held firm, and issued a request for proposal to candidate Lunar Excursion Module (LEM) contractors. Wiesner finally relented, unwilling to settle the dispute once and for all in Kennedy's office, because of the President's involvement with the October Cuban missile crisis, and fear of Kennedy's support for Webb. NASA announced the selection of Grumman as the LEM contractor in November 1962.

The LOR method had the advantage of allowing the lander spacecraft to be used as a "lifeboat" in the event of a failure of the command ship. Some documents prove this theory was discussed before and

after the method was chosen. A 1964 MSC study concluded, "The LM [as lifeboat] ... was finally dropped, because no single reasonable CSM failure could be identified that would prohibit use of the SPS."

Ironically, just such a failure happened on Apollo 13 when an oxygen tank explosion left the command ship without electrical power. The Lunar Module provided propulsion, electrical power and life support to get the crew home safely.

Maxime Faget's preliminary Apollo design employed a cone-shaped command module, supported by one of several service modules providing propulsion and electrical power, sized appropriately for the space station, cislunar, and lunar landing missions. Once Kennedy's Moon landing goal became official, detailed design began of a Command/Service Module (CSM) in which the crew would spend the entire direct-ascent mission and lift off from the lunar surface for the return trip, after being soft-landed by a larger landing propulsion module. The final choice of lunar orbit rendezvous changed the CSM's role to the translunar ferry used to transport the crew, along with a new spacecraft, the Lunar Excursion Module (LEM, later shortened to Lunar Module, LM) which would take two men to the lunar surface and return them to the CSM.

The Command Module (CM) was the conical crew cabin, designed to carry three astronauts from launch to lunar orbit and back to an Earth ocean landing. It was the only component of the Apollo spacecraft to survive without major configuration changes as the program evolved from the early Apollo study designs. Its exterior was covered with an ablative heat shield, and had its own reaction control system (RCS) engines to control its attitude and steer its atmospheric entry path. Parachutes were carried to slow its descent to splashdown. The module was 11.42 feet (3.48 m) tall, 12.83 feet (3.91 m) in diameter, and weighed approximately 12,250 pounds (5,560 kg).

A cylindrical Service Module (SM) supported the Command Module, with a service propulsion engine and an RCS with propellants, and a fuel cell power generation system with liquid hydrogen and liquid oxygen reactants. A high-gain S-band antenna was used for long-distance communications on the lunar flights. On the extended lunar missions, an orbital scientific instrument package was carried. The Service Module was discarded just before re-entry. The module was 24.6 feet (7.5 m) long and 12.83 feet (3.91 m) in diameter. The initial lunar flight version weighed approximately 51,300 pounds (23,300 kg) fully fueled, while a later version designed to carry a lunar orbit scientific instrument package weighed just over 54,000 pounds (24,000 kg).

North American Aviation won the contract to build the CSM, and also the second stage of the Saturn V launch vehicle for NASA. Because the CSM design was started early before the selection of lunar orbit rendezvous, the service propulsion engine was sized to lift the CSM off of the Moon, and thus was oversized to about twice the thrust required for translunar flight. Also, there was no provision for docking with the Lunar Module. A 1964 program definition study concluded that the initial design should be continued as Block I which would be used for early testing, while Block II, the actual lunar spacecraft, would incorporate the docking equipment and take advantage of the lessons learned in Block I development.

The Lunar Module (LM) was designed to descend from lunar orbit to land two astronauts on the Moon and take them back to orbit to rendezvous with the Command Module. Not designed to fly through the Earth's atmosphere or return to Earth, its fuselage was designed totally without aerodynamic considerations, and was of an extremely lightweight construction. It consisted of separate descent and ascent stages, each with its own engine. The descent stage contained storage for the descent propellant, surface stay consumables, and surface exploration equipment. The ascent stage contained the crew cabin, ascent propellant, and a reaction control system. The initial LM model weighed approximately 33,300 pounds (15,100 kg), and allowed surface stays up to around 34 hours. An Extended Lunar Module weighed over 36,200 pounds (16,400 kg), and allowed surface stays of over 3 days.

Before the Apollo program began, Wernher von Braun and his team of rocket engineers had started work on plans for very large launch vehicles, the Saturn series, and the even larger Nova series. In the midst of these plans, von Braun was transferred from the Army to NASA, and made Director of the Marshall Space Flight Center. The initial direct ascent plan to send the three-man Apollo Command/Service Module directly to the lunar surface, on top of a large descent rocket stage, would require a Nova-class launcher, with a lunar payload capability of over 180,000 pounds (82,000 kg). The June 11, 1962, decision to use lunar orbit rendezvous enabled the Saturn V to replace the Nova, and the MSFC proceeded to develop the Saturn rocket family for Apollo.

The first four Saturn I test flights were launched from LC-34, with only live first stages, carrying dummy

upper stages filled with water. The first flight with a live S-IV was launched from LC-37. This was followed by five launches of boilerplate CSMs (designated AS-101 through AS-105) into orbit in 1964 and 1965. The last three of these further supported the Apollo program by also carrying Pegasus satellites, which verified the safety of the translunar environment by measuring the frequency and severity of micrometeorite impacts.

The Saturn IB was an upgraded version of the Saturn I. The S-IB first stage increased the thrust to 1,600,000 pounds-force (7,120 kN), and the second stage replaced the S-IV with the S-IVB-200, powered by a single J-2 engine burning liquid hydrogen fuel with LOX, to produce 200,000 lbf (890 kN) of thrust. A restartable version of the S-IVB was used as the third stage of the Saturn V. The Saturn IB could send over 40,000 pounds (18,100 kg) into low Earth orbit, sufficient for a partially fueled CSM or the LM. Saturn IB launch vehicles and flights were designated with an AS-200 series number, "AS" indicating "Apollo Saturn" and the "2" indicating the second member of the Saturn rocket family.

The three-stage Saturn V was designed to send a fully fueled CSM and LM to the Moon. It was 33 feet (10.1 m) in diameter and stood 363 feet (110.6 m) tall with its 96,800-pound (43,900 kg) lunar payload. Its capability grew to 103,600 pounds (47,000 kg) for the later advanced lunar landings. The S-IC first stage burned RP-1/LOX for a rated thrust of 7,500,000 pounds-force (33,400 kN), which was upgraded to 7,610,000 pounds-force (33,900 kN). The second and third stages burned liquid hydrogen, and the third stage was a modified version of the S-IVB, with thrust increased to 230,000 lbf (1,020 kN) and capability to restart the engine for translunar injection after reaching a parking orbit.

The Apollo astronauts were chosen from the Project Mercury and Gemini veterans, plus from two later astronaut groups. All missions were commanded by Gemini or Mercury veterans. Crews on all development flights (except the Earth orbit CSM development flights) through the first two landings on Apollo 11 and Apollo 12, included at least two (sometimes three) Gemini veterans. Dr. Harrison Schmitt, a geologist, was the first NASA scientist astronaut to fly in space, and landed on the Moon on the last mission, Apollo 17. Schmitt participated in the lunar geology training of all of the Apollo landing crews. NASA awarded all 32 of these astronauts its highest honor, the Distinguished Service Medal, given for "distinguished service, ability, or courage", and personal "contribution representing substantial progress to the NASA mission". The medals were awarded posthumously to Grissom, White, and Chaffee in 1969, then to the crews of all missions from Apollo 8 onward. The crew that flew the first Earth orbital test mission Apollo 7, Walter M. Schirra, Donn Eisele, and Walter Cunningham, were awarded the lesser NASA Exceptional Service Medal, because of discipline problems with the Flight Director's orders during their flight. The NASA Administrator in October, 2008, decided to award them the Distinguished Service Medals, by this time posthumously to Schirra and Eisele.

Two Block I CSMs were launched from LC-34 on suborbital flights in 1966 with the Saturn IB. The first, AS-201 launched on February 26, reached an altitude of 265.7 nautical miles (492.1 km) and splashed down 4,577 nautical miles (8,477 km) downrange in the Atlantic ocean. The second, AS-202 on August 25, reached 617.1 nautical miles (1,142.9 km) altitude and was recovered 13,900 nautical miles (25,700 km) downrange in the Pacific ocean. These flights validated the Service Module engine and the Command Module heat shield.

After an unmanned LM test flight AS-206, a crew would fly the first Block II CSM and LM in a dual mission known as AS-207/208, or AS-278 (each spacecraft would be launched on a separate Saturn IB.) The Block II crew positions were titled Commander (CDR) Command Module Pilot (CMP) and Lunar Module Pilot (LMP). The astronauts would begin wearing a new Apollo spacesuit, designed to accommodate lunar extravehicular activity (EVA). The traditional visor helmet was replaced with a clear "fishbowl" type for greater visibility, and the lunar surface EVA suit would include a water-cooled undergarment.

Deke Slayton, the grounded Mercury astronaut who became Director of Flight Crew Operations for the Gemini and Apollo programs, selected the first Apollo crew in January 1966, with Grissom as Command Pilot, White as Senior Pilot, and rookie Donn F. Eisele as Pilot. But Eisele dislocated his shoulder twice aboard the KC135 weightlessness training aircraft, and had to undergo surgery on January 27. Slayton replaced him with Chaffee. NASA announced the final crew selection for AS-204 on March 21, 1966, with the backup crew consisting of Gemini veterans James McDivitt and David Scott, with rookie Russell L. "Rusty" Schweickart. Mercury/Gemini veteran Wally Schirra, Eisele, and rookie Walter Cunningham were announced on September 29 as the prime crew for AS-205.

In December 1966, the AS-205 mission was canceled, since the validation of the CSM would be accomplished on the 14-day first flight, and AS-205 would have been devoted to space experiments and

contribute no new engineering knowledge about the spacecraft. Its Saturn IB was allocated to the dual mission, now redesignated AS-205/208 or AS-258, planned for August 1967. McDivitt, Scott and Schweickart were promoted to the prime AS-258 crew, and Schirra, Eisele and Cunningham were reassigned as the Apollo 1 backup crew.

The problems with North American were severe enough in late 1965 to cause Manned Space Flight Administrator George Mueller to appoint program director Samuel Phillips to head a "tiger team" to investigate North American's problems and identify corrections. Phillips documented his findings in a December 19 letter to NAA president Lee Atwood, with a strongly worded letter by Mueller, and also gave a presentation of the results to Mueller and Deputy Administrator Robert Seamans. Meanwhile, Grumman was also encountering problems with the Lunar Module, eliminating hopes it would be ready for manned flight in 1967, not long after the first manned CSM flights.

Grissom, White, and Chaffee decided to name their flight Apollo 1 as a motivational focus on the first manned flight. They trained and conducted tests of their spacecraft at North American, and in the altitude chamber at the Kennedy Space Center. A "plugs-out" test was planned for January, which would simulate a launch countdown on LC-34 with the spacecraft transferring from pad-supplied to internal power. If successful, this would be followed by a more rigorous countdown simulation test closer to the February 21 launch, with both spacecraft and launch vehicle fueled.

The plugs-out test began on the morning of January 27, 1967, and immediately was plagued with problems. First the crew noticed a strange odor in their spacesuits, which delayed the sealing of the hatch. Then, communications problems frustrated the astronauts and forced a hold in the simulated countdown. During this hold, an electrical fire began in the cabin, and spread quickly in the high pressure, 100% oxygen atmosphere. Pressure rose high enough from the fire that the cabin burst and the fire erupted onto the pad area, frustrating attempts to rescue the crew. The astronauts were asphyxiated before the hatch could be opened.

NASA immediately convened an accident review board, overseen by both houses of Congress. While the determination of responsibility for the accident was complex, the review board concluded that "deficiencies existed in Command Module design, workmanship and quality control." At the insistence of NASA Administrator Webb, North American removed Harrison Storms as Command Module program manager. Webb also reassigned Apollo Spacecraft Program Office (ASPO) Manager Joseph Francis Shea, replacing him with George Low.

To remedy the causes of the fire, changes were made in the Block II spacecraft and operational procedures, the most important of which were use of a nitrogen/oxygen mixture instead of pure oxygen before and during launch, and removal of flammable cabin and space suit materials. The Block II design already called for replacement of the Block I plug-type hatch cover with a quick-release, outward opening door. NASA discontinued the manned Block I program, using the Block I spacecraft only for unmanned Saturn V flights. Crew members would also exclusively wear modified, fire-resistant Block II space suits, and would be designated by the Block II titles, regardless of whether a LM was present on the flight or not.

In September 1967, Mueller approved a sequence of mission types which had to be successfully accomplished in order to achieve the manned lunar landing. Each step had to be successfully accomplished before the next ones could be performed, and it was unknown how many tries of each mission would be necessary; therefore letters were used instead of numbers. The A missions were unmanned Saturn V validation; B was unmanned LM validation using the Saturn IB; C was manned CSM Earth orbit validation using the Saturn IB; D was the first manned CSM/LM flight (this replaced AS-258, using a single Saturn V launch); E would be a higher Earth orbit CSM/LM flight; F would be the first lunar mission, testing the LM in lunar orbit but without landing (a "dress rehearsal"); and G would be the first manned landing. The list of types covered follow-on lunar exploration to include H lunar landings, I for lunar orbital survey missions, and J for extended-stay lunar landings.

The delay in the CSM caused by the fire enabled NASA to catch up on man-rating the LM and Saturn V. Apollo 4 (AS-501) was the first unmanned flight of the Saturn V, carrying a Block I CSM on November 9, 1967. The capability of the Command Module's heat shield to survive a trans-lunar reentry was demonstrated by using the Service Module engine to ram it into the atmosphere at higher than the usual Earth-orbital reentry speed. This was followed on April 4, 1968, by Apollo 6 (AS-502) which carried a CSM and a LM Test Article as ballast. The intent of this mission was to achieve trans-lunar injection, followed closely by a simulated direct-return abort, using the Service Module engine to achieve another high-speed

reentry. The Saturn V experienced pogo oscillation, a problem caused by non-steady engine combustion, which damaged fuel lines in the second and third stages. Two S-II engines shut down prematurely, but the remaining engines were able to compensate. The damage to the third stage engine was more severe, preventing it from restarting for trans-lunar injection. Mission controllers were able to use the Service Module engine to essentially repeat the flight profile of Apollo 4. Based on the good performance of Apollo 6 and identification of satisfactory fixes to the Apollo 6 problems, NASA declared the Saturn V ready to fly men, cancelling a third unmanned test.

Apollo 5 (AS-204) was the first unmanned test flight of LM in Earth orbit, launched from pad 37 on January 22, 1968, by the Saturn IB that would have been used for Apollo 1. The LM engines were successfully test-fired and restarted, despite a computer programming error which cut short the first descent stage firing. The ascent engine was fired in abort mode, known as a "fire-in-the-hole" test, where it was lit simultaneously with jettison of the descent stage. Although Grumman wanted a second unmanned test, George Low decided the next LM flight would be manned.

Apollo 8 was planned to be the D mission in December 1968, crewed by McDivitt, Scott and Schweickart, launched on a Saturn V instead of two Saturn IBs. In the summer it had become clear that the LM would not be ready in time. Rather than waste the Saturn V on another simple Earth-orbiting mission, ASPO Manager George Low suggested the bold step of sending Apollo 8 to orbit the Moon instead, deferring the D mission to the next mission in March 1969, and eliminating the E mission. This would keep the program on track. The Soviet Union had sent animals around the Moon on September 15, 1968, aboard Zond 5, and it was believed they might soon repeat the feat with human cosmonauts. The decision was not announced publicly until successful completion of Apollo 7. Gemini veterans Frank Borman and James Lovell, and rookie William Anders captured the world's attention by making 10 lunar orbits in 20 hours, transmitting television pictures of the lunar surface on Christmas Eve, and returning safely to Earth.

The G mission was achieved on Apollo 11 in July 1969 by an all-Gemini veteran crew consisting of Neil Armstrong, Michael Collins and Buzz Aldrin. Armstrong and Aldrin performed the first landing at the Sea of Tranquility at 20:17:40 UTC on July 20, 1969. They spent a total of 21 hours, 36 minutes on the surface, and spent 2 hours, 31 minutes outside the spacecraft, walking on the surface, taking photographs, collecting material samples, and deploying automated scientific instruments, while continuously sending black-and-white television back to Earth. The astronauts returned safely on July 24.

In November 1969, Gemini veteran Charles "Pete" Conrad and rookie Alan L. Bean made a precision landing on Apollo 12 within walking distance of the Surveyor 3 unmanned lunar probe, which had landed in April 1967 on the Ocean of Storms. The Command Module Pilot was Gemini veteran Richard F.

Gordon, Jr. Conrad and Bean carried the first lunar surface color television camera, but it was damaged when accidentally pointed into the Sun. They made two EVAs totaling 7 hours and 45 minutes. On one, they walked to the Surveyor, photographed it, and removed some parts which they returned to Earth.

The contracted batch of 15 Saturn Vs were enough for lunar landing missions through Apollo 20. NASA publicized a preliminary list of eight more planned landing sites, with plans to increase the mass of the CSM and LM for the last five missions, along with the payload capacity of the Saturn V. These final missions would combine the I and J types in the 1967 list, allowing the CMP to operate a package of lunar orbital sensors and cameras while his companions were on the surface, and allowing them to stay on the Moon for over three days. These missions would also carry the Lunar Roving Vehicle (LRV) increasing the exploration area and allowing televised liftoff of the LM. Also, the Block II spacesuit was revised for the extended missions to allow greater flexibility and visibility for driving the LRV.

The success of the first two landings allowed the remaining missions to be crewed with a single veteran as Commander, with two rookies. Apollo 13 launched Lovell, Jack Swigert, and Fred Haise in April 1970, headed for the Fra Mauro formation. But two days out, a liquid oxygen tank exploded, disabling the Service Module and forcing the crew to use the LM as a "life boat" to return to Earth. Another NASA review board was convened to determine the cause, which turned out to be a combination of damage of the tank in the factory, and a subcontractor not making a tank component according to updated design specifications. Apollo was grounded again, for the remainder of 1970 while the oxygen tank was redesigned and an extra one was added.

About the time of the first landing in 1969, it was decided to use an existing Saturn V to launch the Skylab orbital laboratory pre-built on the ground, replacing the original plan to construct it in orbit from several Saturn IB launches; this eliminated Apollo 20. NASA's yearly budget also began to shrink in light of the successful landing, and NASA also had to make funds available for the development of the upcoming

Space Shuttle. By 1971, the decision was made to also cancel missions 18 and 19. The two unused Saturn Vs became museum exhibits at the John F. Kennedy Space Center on Merritt Island, Florida, George C. Marshall Space Center in Huntsville, Alabama, Michoud Assembly Facility in New Orleans, Louisiana, and Lyndon B. Johnson Space Center in Houston, Texas.

The rocks collected from the Moon are extremely old compared to rocks found on Earth, as measured by radiometric dating techniques. They range in age from about 3.2 billion years for the basaltic samples derived from the lunar maria, to about 4.6 billion years for samples derived from the highlands crust. As such, they represent samples from a very early period in the development of the Solar System, that are largely absent on Earth. One important rock found during the Apollo Program is dubbed the Genesis Rock, retrieved by astronauts David Scott and James Irwin during the Apollo 15 mission. This anorthosite rock is composed almost exclusively of the calcium-rich feldspar mineral anorthite, and is believed to be representative of the highland crust. A geochemical component called KREEP was discovered, which has no known terrestrial counterpart. KREEP and the anorthositic samples have been used to infer that the outer portion of the Moon was once completely molten (see lunar magma ocean).

Almost all the rocks show evidence of impact process effects. Many samples appear to be pitted with micrometeoroid impact craters, which is never seen on Earth rocks, due to the thick atmosphere. Many show signs of being subjected to high pressure shock waves that are generated during impact events. Some of the returned samples are of impact melt (materials melted near an impact crater.) All samples returned from the Moon are highly brecciated as a result of being subjected to multiple impact events. In 2009, NASA held a symposium on project costs which presented an estimate of the Apollo program costs in 2005 dollars as roughly \$170 billion. This included all research and development costs; the procurement of 15 Saturn V rockets, 16 Command/Service Modules, 12 Lunar Modules, plus program support and management costs; construction expenses for facilities and their upgrading, and costs for flight operations. This was based on a Congressional Budget Office report, A Budgetary Analysis of NASA's New Vision for Space, September 2004. The Space Review estimated in 2010 the cost of Apollo from 1959 to 1973 as \$20.4 billion, or \$109 billion in 2010 dollars.

Looking beyond the manned lunar landings, NASA investigated several post-lunar applications for Apollo hardware. The Apollo Extension Series (Apollo X,) proposed up to 30 flights to Earth orbit, using the space in the Spacecraft Lunar Module Adapter (SLA) to house a small orbital laboratory (workshop). Astronauts would continue to use the CSM as a ferry to the station. This study was followed by design of a larger orbital workshop to be built in orbit from an empty S-IVB Saturn upper stage, and grew into the Apollo Applications Program (AAP). The workshop was to be supplemented by Apollo Telescope Missions, which would replace the LM's descent stage equipment and engine with a solar telescope observatory. The most ambitious plan called for using an empty S-IVB as an interplanetary spacecraft for a Venus fly-by mission.

The S-IVB orbital workshop was the only one of these plans to make it off the drawing board. Dubbed Skylab, it was constructed complete on the ground rather than in space, and launched in 1973 using the two lower stages of a Saturn V. It was equipped with an Apollo Telescope Mount, the solar telescope that would have been used on the Apollo Telescope Missions. Skylab's last crew departed the station on February 8, 1974, and the station itself re-entered the atmosphere in 1979, by which time it had become the oldest operational Apollo-Saturn component.

In 2008, Japan Aerospace Exploration Agency's SELENE probe observed evidence of the halo surrounding the Apollo 15 Lunar Module blast crater while orbiting above the lunar surface. In 2009, NASA's robotic Lunar Reconnaissance Orbiter, while orbiting 50 kilometers (31 mi) above the Moon, began photographing the remnants of the Apollo program left on the lunar surface, and photographed each site where manned Apollo flights landed. All of the U. S. flags left on the Moon during the Apollo missions were found to still be standing, with the exception of the one left during the Apollo 11 mission, which was blown over during that mission's lift-off from the lunar surface and return to the mission Command Module in lunar orbit; the degree to which these flags retain their original colors remains unknown.

The crew of Apollo 8 sent the first live televised pictures of the Earth and the Moon back to Earth, and read from the creation story in the Book of Genesis, on Christmas Eve, 1968. An estimated one-quarter of the population of the world saw—either live or delayed—the Christmas Eve transmission during the ninth orbit of the Moon. The mission and Christmas provided an inspiring end to 1968, which had been a troubled year for the US, marked by Vietnam War protests, race riots, and the assassinations of civil

rights leader Martin Luther King, Jr., and Senator Robert F. Kennedy.

The Moon landing data was recorded by a special Apollo TV camera which recorded in a format incompatible with broadcast TV. This resulted in lunar footage that had to be converted for the live television broadcast and stored on magnetic telemetry tapes. During the following years, a magnetic tape shortage prompted NASA to remove massive numbers of magnetic tapes from the National Archives and Records Administration to be recorded over with newer satellite data. Stan Lebar, who led the team that designed and built the lunar television camera at Westinghouse Electric Corporation, also worked with Nafzger to try to locate the missing tapes.

With a budget of \$230,000, the surviving original lunar broadcast data from Apollo 11 was compiled by Nafzger and assigned to Lowry Digital for restoration. The video was processed to remove random noise and camera shake without destroying historical legitimacy. The images were from tapes in Australia, the CBS News archive, and kinescope recordings made at Johnson Space Center. The restored video, remaining in black and white, contains conservative digital enhancements and did not include sound quality improvements.

European Union law is a body of treaties and legislation, such as Regulations and Directives, which have direct effect or indirect effect on the laws of European Union member states. The three sources of European Union law are primary law, secondary law and supplementary law. The main sources of primary law are the Treaties establishing the European Union. Secondary sources include regulations and directives which are based on the Treaties. The legislature of the European Union is principally composed of the European Parliament and the Council of the European Union, which under the Treaties may establish secondary law to pursue the objective set out in the Treaties.

European Union law is applied by the courts of member states and the Court of Justice of the European Union. Where the laws of member states provide for lesser rights European Union law can be enforced by the courts of member states. In case of European Union law which should have been transposed into the laws of member states, such as Directives, the European Commission can take proceedings against the member state under the Treaty on the Functioning of the European Union. The European Court of Justice is the highest court able to interpret European Union law. Supplementary sources of European Union law include case law by the Court of Justice, international law and general principles of European Union law. Although the European Union does not have a codified constitution, like every political body it has laws which "constitute" its basic governance structure. The EU's primary constitutional sources are the Treaty on European Union (TEU) and the Treaty on the Functioning of the European Union (TFEU), which have been agreed or adhered to among the governments of all 28 member states. The Treaties establish the EU's institutions, list their powers and responsibilities, and explain the areas in which the EU can legislate with Directives or Regulations. The European Commission has the initiative to propose legislation. During the ordinary legislative procedure, the Council (which are ministers from member state governments) and the European Parliament (elected by citizens) can make amendments and must give their consent for laws to pass. The Commission oversees departments and various agencies that execute or enforce EU law. The "European Council" (rather than the Council, made up of different government Ministers) is composed of the Prime Ministers or executive Presidents of the member states. It appoints the Commissioners and the board of the European Central Bank. The European Court of Justice is the supreme judicial body which interprets EU law, and develops it through precedent. The Court can review the legality of the EU institutions' actions, in compliance with the Treaties. It can also decide upon claims for breach of EU laws from member states and citizens.

The primary law of the EU consists mainly of the founding treaties, the "core" treaties being the Treaty on European Union (TEU) and the Treaty on the Functioning of the European Union (TFEU). The Treaties contain formal and substantive provisions, which frame policies of the European Union institutions and determine the division of competences between the European Union and its member states. The TEU establishes that European Union law applies to the metropolitan territories of the member states, as well as certain islands and overseas territories, including Madeira, the Canary Islands and the French overseas departments. European Union law also applies in territories where a member state is responsible for external relations, for example Gibraltar and the Åland islands. The TEU allows the European Council to make specific provisions for regions, as for example done for customs matters in Gibraltar and Saint-Pierre-et-Miquelon. The TEU specifically excludes certain regions, for example the Faroe Islands, from the jurisdiction of European Union law. Treaties apply as soon as they enter into force, unless stated otherwise, and are generally concluded for an unlimited period. The TEU provides

that commitments entered into by the member states between themselves before the treaty was signed no longer apply.[vague] All EU member states are regarded as subject to the general obligation of the principle of cooperation, as stated in the TEU, whereby member states are obliged not to take measure which could jeopardise the attainment of the TEU objectives. The Court of Justice of the European Union can interpret the Treaties, but it cannot rule on their validity, which is subject to international law. Individuals may rely on primary law in the Court of Justice of the European Union if the Treaty provisions have a direct effect and they are sufficiently clear, precise and unconditional.

The principal Treaties that form the European Union began with common rules for coal and steel, and then atomic energy, but more complete and formal institutions were established through the Treaty of Rome 1957 and the Maastricht Treaty 1992 (now: TFEU). Minor amendments were made during the 1960s and 1970s. Major amending treaties were signed to complete the development of a single, internal market in the Single European Act 1986, to further the development of a more social Europe in the Treaty of Amsterdam 1997, and to make minor amendments to the relative power of member states in the EU institutions in the Treaty of Nice 2001 and the Treaty of Lisbon 2007. Since its establishment, more member states have joined through a series of accession treaties, from the UK, Ireland, Denmark and Norway in 1972 (though Norway did not end up joining), Greece in 1979, Spain and Portugal 1985, Austria, Finland, Norway and Sweden in 1994 (though again Norway failed to join, because of lack of support in the referendum), the Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia in 2004, Romania and Bulgaria in 2007 and Croatia in 2013. Greenland signed a Treaty in 1985 giving it a special status.

Following the Nice Treaty, there was an attempt to reform the constitutional law of the European Union and make it more transparent; this would have also produced a single constitutional document. However, as a result of the referendum in France and the referendum in the Netherlands, the 2004 Treaty establishing a Constitution for Europe never came into force. Instead, the Lisbon Treaty was enacted. Its substance was very similar to the proposed constitutional treaty, but it was formally an amending treaty, and – though it significantly altered the existing treaties – it did not completely replace them.

The European Commission is the main executive body of the European Union. Article 17(1) of the Treaty on European Union states the Commission should "promote the general interest of the Union" while Article 17(3) adds that Commissioners should be "completely independent" and not "take instructions from any Government". Under article 17(2), "Union legislative acts may only be adopted on the basis of a Commission proposal, except where the Treaties provide otherwise." This means that the Commission has a monopoly on initiating the legislative procedure, although the Council is the "de facto catalyst of many legislative initiatives". The Parliament can also formally request the Commission to submit a legislative proposal but the Commission can reject such a suggestion, giving reasons. The Commission's President (currently an ex-Luxembourg Prime Minister, Jean-Claude Juncker) sets the agenda for the EU's work. Decisions are taken by a simple majority vote, usually through a "written procedure" of circulating the proposals and adopting if there are no objections.[citation needed] Since Ireland refused to consent to changes in the Treaty of Lisbon 2007, there remains one Commissioner for each of the 28 member states, including the President and the High Representative for Foreign and Security Policy (currently Federica Mogherini). The Commissioners (and most importantly, the portfolios they will hold) are bargained over intensively by the member states. The Commissioners, as a block, are then subject to a qualified majority vote of the Council to approve, and majority approval of the Parliament. The proposal to make the Commissioners be drawn from the elected Parliament, was not adopted in the Treaty of Lisbon. This means Commissioners are, through the appointment process, the unelected subordinates of member state governments.

Commissioners have various privileges, such as being exempt from member state taxes (but not EU taxes), and having immunity from prosecution for doing official acts. Commissioners have sometimes been found to have abused their offices, particularly since the Santer Commission was censured by Parliament in 1999, and it eventually resigned due to corruption allegations. This resulted in one main case, *Commission v Edith Cresson* where the European Court of Justice held that a Commissioner giving her dentist a job, for which he was clearly unqualified, did in fact not break any law. By contrast to the ECJ's relaxed approach, a Committee of Independent Experts found that a culture had developed where few Commissioners had 'even the slightest sense of responsibility'. This led to the creation of the European Anti-fraud Office. In 2012 it investigated the Maltese Commissioner for Health, John Dalli, who quickly resigned after allegations that he received a €60m bribe in connection with a Tobacco Products



Directive. Beyond the Commission, the European Central Bank has relative executive autonomy in its conduct of monetary policy for the purpose of managing the euro. It has a six-person board appointed by the European Council, on the Council's recommendation. The President of the Council and a Commissioner can sit in on ECB meetings, but do not have voting rights.

While the Commission has a monopoly on initiating legislation, the European Parliament and the Council of the European Union have powers of amendment and veto during the legislative process. According to the Treaty on European Union articles 9 and 10, the EU observes "the principle of equality of its citizens" and is meant to be founded on "representative democracy". In practice, equality and democracy are deficient because the elected representatives in the Parliament cannot initiate legislation against the Commission's wishes, citizens of smallest countries have ten times the voting weight in Parliament as citizens of the largest countries, and "qualified majorities" or consensus of the Council are required to legislate. The justification for this "democratic deficit" under the Treaties is usually thought to be that completion integration of the European economy and political institutions required the technical coordination of experts, while popular understanding of the EU developed and nationalist sentiments declined post-war. Over time, this has meant the Parliament gradually assumed more voice: from being an unelected assembly, to its first direct elections in 1979, to having increasingly more rights in the legislative process. Citizens' rights are therefore limited compared to the democratic polities within all European member states: under TEU article 11 citizens and associations have the rights such as publicising their views and submit an initiative that must be considered by the Commission with one million signatures. TFEU article 227 contains a further right for citizens to petition the Parliament on issues which affect them. Parliament elections, take place every five years, and votes for Members of the European Parliament in member states must be organised by proportional representation or a single transferable vote. There are 750 MEPs and their numbers are "degressively proportional" according to member state size. This means - although the Council is meant to be the body representing member states - in the Parliament citizens of smaller member states have more voice than citizens in larger member states. MEPs divide, as they do in national Parliaments, along political party lines: the conservative European People's Party is currently the largest, and the Party of European Socialists leads the opposition. Parties do not receive public funds from the EU, as the Court of Justice held in *Parti écologiste "Les Verts" v Parliament* that this was entirely an issue to be regulated by the member states. The Parliament's powers include calling inquiries into maladministration or appoint an Ombudsman pending any court proceedings. It can require the Commission respond to questions and by a two-thirds majority can censure the whole Commission (as happened to the Santer Commission in 1999). In some cases, the Parliament has explicit consultation rights, which the Commission must genuinely follow. However its role participation in the legislative process still remains limited because no member can actually or pass legislation without the Commission and Council, meaning power ("kratia") is not in the hands of directly elected representatives of the people ("demos"): in the EU it is not yet true that "the administration is in the hands of the many and not of the few."

The second main legislative body is the Council, which is composed of different ministers of the member states. The heads of government of member states also convene a "European Council" (a distinct body) that the TEU article 15 defines as providing the 'necessary impetus for its development and shall define the general political directions and priorities'. It meets each six months and its President (currently former Poland Prime Minister Donald Tusk) is meant to 'drive forward its work', but it does not itself 'legislative functions'. The Council does this: in effect this is the governments of the member states, but there will be a different minister at each meeting, depending on the topic discussed (e.g. for environmental issues, the member states' environment ministers attend and vote; for foreign affairs, the foreign ministers, etc.). The minister must have the authority to represent and bind the member states in decisions. When voting takes place it is weighted inversely to member state size, so smaller member states are not dominated by larger member states. In total there are 352 votes, but for most acts there must be a qualified majority vote, if not consensus. TEU article 16(4) and TFEU article 238(3) define this to mean at least 55 per cent of the Council members (not votes) representing 65 per cent of the population of the EU: currently this means around 74 per cent, or 260 of the 352 votes. This is critical during the legislative process.

To make new legislation, TFEU article 294 defines the "ordinary legislative procedure" that applies for most EU acts. The essence is there are three readings, starting with a Commission proposal, where the Parliament must vote by a majority of all MEPs (not just those present) to block or suggest changes, and the Council must vote by qualified majority to approve changes, but by unanimity to block Commission

amendment. Where the different institutions cannot agree at any stage, a "Conciliation Committee" is convened, representing MEPs, ministers and the Commission to try and get agreement on a joint text: if this works, it will be sent back to the Parliament and Council to approve by absolute and qualified majority. This means, legislation can be blocked by a majority in Parliament, a minority in the Council, and a majority in the Commission: it is harder to change EU law than stay the same. A different procedure exists for budgets. For "enhanced cooperation" among a sub-set of at least member states, authorisation must be given by the Council. Member state governments should be informed by the Commission at the outset before any proposals start the legislative procedure. The EU as a whole can only act within its power set out in the Treaties. TEU articles 4 and 5 state that powers remain with the member states unless they have been conferred, although there is a debate about the Kompetenz-Kompetenz question: who ultimately has the "competence" to define the EU's "competence". Many member state courts believe they decide, other member state Parliaments believe they decide, while within the EU, the Court of Justice believes it has the final say.

The judicial branch of the EU has played an important role in the development of EU law, by assuming the task of interpreting the treaties, and accelerating economic and political integration. Today the Court of Justice of the European Union (CJEU) is the main judicial body, within which there is a higher European Court of Justice (commonly abbreviated as ECJ) that deals with cases that contain more public importance, and a General Court that deals with issues of detail but without general importance. There is also a Civil Service Tribunal to deal with EU staff issues, and then a separate Court of Auditors. Under the Treaty on European Union article 19(2) there is one judge from each member state, 28 at present, who are supposed to "possess the qualifications required for appointment to the highest judicial offices" (or for the General Court, the "ability required for appointment to high judicial office"). A president is elected by the judges for three years. Under TEU article 19(3) is to be the ultimate court to interpret questions of EU law. In fact, most EU law is applied by member state courts (the English Court of Appeal, the German Bundesgerichtshof, the Belgian Cour du travail, etc.) but they can refer questions to the EU court for a preliminary ruling. The CJEU's duty is to "ensure that in the interpretation and application of the Treaties the law is observed", although realistically it has the ability to expand and develop the law according to the principles it deems to be appropriate. Arguably this has been done through both seminal and controversial judgments, including *Van Gend en Loos*, *Mangold v Helm*, and *Kadi v Commission*. Since its founding, the EU has operated among an increasing plurality of national and globalising legal systems. This has meant both the European Court of Justice and the highest national courts have had to develop principles to resolve conflicts of laws between different systems. Within the EU itself, the Court of Justice's view is that if EU law conflicts with a provision of national law, then EU law has primacy. In the first major case in 1964, *Costa v ENEL*, a Milanese lawyer, and former shareholder of an energy company, named Mr Costa refused to pay his electricity bill to Enel, as a protest against the nationalisation of the Italian energy corporations. He claimed the Italian nationalisation law conflicted with the Treaty of Rome, and requested a reference be made to both the Italian Constitutional Court and the Court of Justice under TFEU article 267. The Italian Constitutional Court gave an opinion that because the nationalisation law was from 1962, and the treaty was in force from 1958, Costa had no claim. By contrast, the Court of Justice held that ultimately the Treaty of Rome in no way prevented energy nationalisation, and in any case under the Treaty provisions only the Commission could have brought a claim, not Mr Costa. However, in principle, Mr Costa was entitled to plead that the Treaty conflicted with national law, and the court would have a duty to consider his claim to make a reference if there would be no appeal against its decision. The Court of Justice, repeating its view in *Van Gend en Loos*, said member states "albeit within limited spheres, have restricted their sovereign rights and created a body of law applicable both to their nationals and to themselves" on the "basis of reciprocity". EU law would not "be overridden by domestic legal provisions, however framed... without the legal basis of the community itself being called into question." This meant any "subsequent unilateral act" of the member state inapplicable. Similarly, in *Amministrazione delle Finanze v Simmenthal SpA*, a company, Simmenthal SpA, claimed that a public health inspection fee under an Italian law of 1970 for importing beef from France to Italy was contrary to two Regulations from 1964 and 1968. In "accordance with the principle of the precedence of Community law," said the Court of Justice, the "directly applicable measures of the institutions" (such as the Regulations in the case) "render automatically inapplicable any conflicting provision of current national law". This was necessary to prevent a "corresponding denial" of Treaty "obligations undertaken unconditionally and irrevocably by member states", that could "imperil the very

foundations of the" EU. But despite the views of the Court of Justice, the national courts of member states have not accepted the same analysis.

Generally speaking, while all member states recognise that EU law takes primacy over national law where this agreed in the Treaties, they do not accept that the Court of Justice has the final say on foundational constitutional questions affecting democracy and human rights. In the United Kingdom, the basic principle is that Parliament, as the sovereign expression of democratic legitimacy, can decide whether it wishes to expressly legislate against EU law. This, however, would only happen in the case of an express wish of the people to withdraw from the EU. It was held in *R (Factortame Ltd) v Secretary of State for Transport* that "whatever limitation of its sovereignty Parliament accepted when it enacted the European Communities Act 1972 was entirely voluntary" and so "it has always been clear" that UK courts have a duty "to override any rule of national law found to be in conflict with any directly enforceable rule of Community law." More recently the UK Supreme Court noted that in *R (HS2 Action Alliance Ltd) v Secretary of State for Transport*, although the UK constitution is uncodified, there could be "fundamental principles" of common law, and Parliament "did not either contemplate or authorise the abrogation" of those principles when it enacted the European Communities Act 1972. The view of the German Constitutional Court from the *Solange I* and *Solange II* decisions is that if the EU does not comply with its basic constitutional rights and principles (particularly democracy, the rule of law and the social state principles) then it cannot override German law. However, as the nicknames of the judgments go, "so long as" the EU works towards the democratisation of its institutions, and has a framework that protects fundamental human rights, it would not review EU legislation for compatibility with German constitutional principles. Most other member states have expressed similar reservations. This suggests the EU's legitimacy rests on the ultimate authority of member states, its factual commitment to human rights, and the democratic will of the people.

While constitutional law concerns the European Union's governance structure, administrative law binds EU institutions and member states to follow the law. Both member states and the Commission have a general legal right or "standing" (*locus standi*) to bring claims against EU institutions and other member states for breach of the treaties. From the EU's foundation, the Court of Justice also held that the Treaties allowed citizens or corporations to bring claims against EU and member state institutions for violation of the Treaties and Regulations, if they were properly interpreted as creating rights and obligations. However, under Directives, citizens or corporations were said in 1986 to not be allowed to bring claims against other non-state parties. This meant courts of member states were not bound to apply an EU law where a national rule conflicted, even though the member state government could be sued, if it would impose an obligation on another citizen or corporation. These rules on "direct effect" limit the extent to which member state courts are bound to administer EU law. All actions by EU institutions can be subject to judicial review, and judged by standards of proportionality, particularly where general principles of law, or fundamental rights are engaged. The remedy for a claimant where there has been a breach of the law is often monetary damages, but courts can also require specific performance or will grant an injunction, in order to ensure the law is effective as possible.

Although it is generally accepted that EU law has primacy, not all EU laws give citizens standing to bring claims: that is, not all EU laws have "direct effect". In *Van Gend en Loos v Nederlandse Administratie der Belastingen* it was held that the provisions of the Treaties (and EU Regulations) are directly effective, if they are (1) clear and unambiguous (2) unconditional, and (3) did not require EU or national authorities to take further action to implement them. *Van Gend en Loos*, a postal company, claimed that what is now TFEU article 30 prevented the Dutch Customs Authorities charging tariffs, when it imported urea-formaldehyde plastics from Germany to the Netherlands. After a Dutch court made a reference, the Court of Justice held that even though the Treaties did not "expressly" confer a right on citizens or companies to bring claims, they could do so. Historically, international treaties had only allowed states to have legal claims for their enforcement, but the Court of Justice proclaimed "the Community constitutes a new legal order of international law". Because article 30 clearly, unconditionally and immediately stated that no quantitative restrictions could be placed on trade, without a good justification, *Van Gend en Loos* could recover the money it paid for the tariff. EU Regulations are the same as Treaty provisions in this sense, because as TFEU article 288 states, they are 'directly applicable in all Member States'. Moreover, member states comes under a duty not to replicate Regulations in their own law, in order to prevent confusion. For instance, in *Commission v Italy* the Court of Justice held that Italy had breached a duty under the Treaties, both by failing to operate a scheme to pay farmers a premium to slaughter cows (to

reduce dairy overproduction), and by reproducing the rules in a decree with various additions.

"Regulations," held the Court of Justice, "come into force solely by virtue of their publication" and implementation could have the effect of "jeopardizing their simultaneous and uniform application in the whole of the Union." On the other hand, some Regulations may themselves expressly require implementing measures, in which case those specific rules should be followed.

While the Treaties and Regulations will have direct effect (if clear, unconditional and immediate), Directives do not generally give citizens (as opposed to the member state) standing to sue other citizens. In theory, this is because TFEU article 288 says Directives are addressed to the member states and usually "leave to the national authorities the choice of form and methods" to implement. In part this reflects that directives often create minimum standards, leaving member states to apply higher standards. For example, the Working Time Directive requires that every worker has at least 4 weeks paid holidays each year, but most member states require more than 28 days in national law. However, on the current position adopted by the Court of Justice, citizens have standing to make claims based on national laws that implement Directives, but not from Directives themselves. Directives do not have so called "horizontal" direct effect (i.e. between non-state parties). This view was instantly controversial, and in the early 1990s three Advocate Generals persuasively argued that Directives should create rights and duties for all citizens. The Court of Justice refused, but there are five large exceptions.

First, if a Directive's deadline for implementation is not met, the member state cannot enforce conflicting laws, and a citizen may rely on the Directive in such an action (so called "vertical" direct effect). So, in *Pubblico Ministero v Ratti* because the Italian government had failed to implement a Directive 73/173/EEC on packaging and labelling solvents by the deadline, it was estopped from enforcing a conflicting national law from 1963 against Mr Ratti's solvent and varnish business. A member state could "not rely, as against individuals, on its own failure to perform the obligations which the Directive entails." Second, a citizen or company can invoke a Directive, not just in a dispute with a public authority, but in a dispute with another citizen or company. So, in *CIA Security v Signalson and Securitel* the Court of Justice held that a business called CIA Security could defend itself from allegations by competitors that it had not complied with a Belgian decree from 1991 about alarm systems, on the basis that it had not been notified to the Commission as a Directive required. Third, if a Directive gives expression to a "general principle" of EU law, it can be invoked between private non-state parties before its deadline for implementation. This follows from *Kücükdeveci v Swedex GmbH & Co KG* where the German Civil Code §622 stated that the years people worked under the age of 25 would not count towards the increasing statutory notice before dismissal. Ms Kücükdeveci worked for 10 years, from age 18 to 28, for Swedex GmbH & Co KG before her dismissal. She claimed that the law not counting her years under age 25 was unlawful age discrimination under the Employment Equality Framework Directive. The Court of Justice held that the Directive could be relied on by her because equality was also a general principle of EU law. Third, if the defendant is an emanation of the state, even if not central government, it can still be bound by Directives. In *Foster v British Gas plc* the Court of Justice held that Mrs Foster was entitled to bring a sex discrimination claim against her employer, British Gas plc, which made women retire at age 60 and men at 65, if (1) pursuant to a state measure, (2) it provided a public service, and (3) had special powers. This could also be true if the enterprise is privatised, as it was held with a water company that was responsible for basic water provision.

Fourth, national courts have a duty to interpret domestic law "as far as possible in the light of the wording and purpose of the directive". Textbooks (though not the Court itself) often called this "indirect effect". In *Marleasing SA v La Comercial SA* the Court of Justice held that a Spanish Court had to interpret its general Civil Code provisions, on contracts lacking cause or defrauding creditors, to conform with the First Company Law Directive article 11, that required incorporations would only be nullified for a fixed list of reasons. The Court of Justice quickly acknowledged that the duty of interpretation cannot contradict plain words in a national statute. But, fifth, if a member state has failed to implement a Directive, a citizen may not be able to bring claims against other non-state parties, but can sue the member state itself for failure to implement the law. So, in *Francovich v Italy*, the Italian government had failed to set up an insurance fund for employees to claim unpaid wages if their employers had gone insolvent, as the Insolvency Protection Directive required. Francovich, the former employee of a bankrupt Venetian firm, was therefore allowed to claim 6 million Lira from the Italian government in damages for his loss. The Court of Justice held that if a Directive would confer identifiable rights on individuals, and there is a causal link between a member state's violation of EU and a claimant's loss, damages must be paid. The fact that the

incompatible law is an Act of Parliament is no defence.

The principles of European Union law are rules of law which have been developed by the European Court of Justice that constitute unwritten rules which are not expressly provided for in the treaties but which affect how European Union law is interpreted and applies. In formulating these principles, the courts have drawn on a variety of sources, including: public international law and legal doctrines and principles present in the legal systems of European Union member states and in the jurisprudence of the European Court of Human Rights. Accepted general principles of European Union Law include fundamental rights (see human rights), proportionality, legal certainty, equality before the law and subsidiarity.

Proportionality is recognised one of the general principles of European Union law by the European Court of Justice since the 1950s. According to the general principle of proportionality the lawfulness of an action depends on whether it was appropriate and necessary to achieve the objectives legitimately pursued.

When there is a choice between several appropriate measures the least onerous must be adopted, and any disadvantage caused must not be disproportionate to the aims pursued. The principle of proportionality is also recognised in Article 5 of the EC Treaty, stating that "any action by the Community shall not go beyond what is necessary to achieve the objectives of this Treaty".

The concept of legal certainty is recognised one of the general principles of European Union law by the European Court of Justice since the 1960s. It is an important general principle of international law and public law, which predates European Union law. As a general principle in European Union law it means that the law must be certain, in that it is clear and precise, and its legal implications foreseeable, specially when applied to financial obligations. The adoption of laws which will have legal effect in the European Union must have a proper legal basis. Legislation in member states which implements European Union law must be worded so that it is clearly understandable by those who are subject to the law. In European Union law the general principle of legal certainty prohibits Ex post facto laws, i.e. laws should not take effect before they are published. The doctrine of legitimate expectation, which has its roots in the principles of legal certainty and good faith, is also a central element of the general principle of legal certainty in European Union law. The legitimate expectation doctrine holds that and that "those who act in good faith on the basis of law as it is or seems to be should not be frustrated in their expectations".

Fundamental rights, as in human rights, were first recognised by the European Court of Justice in the late 60s and fundamental rights are now regarded as integral part of the general principles of European Union law. As such the European Court of Justice is bound to draw inspiration from the constitutional traditions common to the member states. Therefore, the European Court of Justice cannot uphold measures which are incompatible with fundamental rights recognised and protected in the constitutions of member states. The European Court of Justice also found that "international treaties for the protection of human rights on which the member states have collaborated or of which they are signatories, can supply guidelines which should be followed within the framework of Community law."

None of the original treaties establishing the European Union mention protection for fundamental rights. It was not envisaged for European Union measures, that is legislative and administrative actions by European Union institutions, to be subject to human rights. At the time the only concern was that member states should be prevented from violating human rights, hence the establishment of the European Convention on Human Rights in 1950 and the establishment of the European Court of Human Rights. The European Court of Justice recognised fundamental rights as general principle of European Union law as the need to ensure that European Union measures are compatible with the human rights enshrined in member states' constitution became ever more apparent. In 1999 the European Council set up a body tasked with drafting a European Charter of Human Rights, which could form the constitutional basis for the European Union and as such tailored specifically to apply to the European Union and its institutions. The Charter of Fundamental Rights of the European Union draws a list of fundamental rights from the European Convention on Human Rights and Fundamental Freedoms, the Declaration on Fundamental Rights produced by the European Parliament in 1989 and European Union Treaties.

The 2007 Lisbon Treaty explicitly recognised fundamental rights by providing in Article 6(1) that "The Union recognises the rights, freedoms and principles set out in the Charter of Fundamental Rights of the European Union of 7 December 2000, as adopted at Strasbourg on 12 December 2007, which shall have the same legal value as the Treaties." Therefore, the Charter of Fundamental Rights of the European Union has become an integral part of European Union law, codifying the fundamental rights which were previously considered general principles of European Union law. In effect, after the Lisbon Treaty, the Charter and the Convention now co-exist under European Union law, though the former is enforced by the

European Court of Justice in relation to European Union measures, and the latter by the European Court of Human Rights in relation to measures by member states.

The Social Chapter is a chapter of the 1997 Treaty of Amsterdam covering social policy issues in European Union law. The basis for the Social Chapter was developed in 1989 by the "social partners" representatives, namely UNICE, the employers' confederation, the European Trade Union Confederation (ETUC) and CEEP, the European Centre of Public Enterprises. A toned down version was adopted as the Social Charter at the 1989 Strasbourg European Council. The Social Charter declares 30 general principles, including on fair remuneration of employment, health and safety at work, rights of disabled and elderly, the rights of workers, on vocational training and improvements of living conditions. The Social Charter became the basis for European Community legislation on these issues in 40 pieces of legislation. The Social Charter was subsequently adopted in 1989 by 11 of the then 12 member states. The UK refused to sign the Social Charter and was exempt from the legislation covering Social Charter issues unless it agreed to be bound by the legislation. The UK subsequently was the only member state to veto the Social Charter being included as the "Social Chapter" of the 1992 Maastricht Treaty - instead, an Agreement on Social Policy was added as a protocol. Again, the UK was exempt from legislation arising from the protocol, unless it agreed to be bound by it. The protocol was to become known as "Social Chapter", despite not actually being a chapter of the Maastricht Treaty. To achieve aims of the Agreement on Social Policy the European Union was to "support and complement" the policies of member states. The aims of the Agreement on Social Policy are:

Following the election of the UK Labour Party to government in 1997, the UK formally subscribed to the Agreement on Social Policy, which allowed it to be included with minor amendments as the Social Chapter of the 1997 Treaty of Amsterdam. The UK subsequently adopted the main legislation previously agreed under the Agreement on Social Policy, the 1994 Works Council Directive, which required workforce consultation in businesses, and the 1996 Parental Leave Directive. In the 10 years following the 1997 Treaty of Amsterdam and adoption of the Social Chapter the European Union has undertaken policy initiatives in various social policy areas, including labour and industry relations, equal opportunity, health and safety, public health, protection of children, the disabled and elderly, poverty, migrant workers, education, training and youth.

EU Competition law has its origins in the European Coal and Steel Community (ECSC) agreement between France, Italy, Belgium, the Netherlands, Luxembourg and Germany in 1951 following the second World War. The agreement aimed to prevent Germany from re-establishing dominance in the production of coal and steel as members felt that its dominance had contributed to the outbreak of the war. Article 65 of the agreement banned cartels and article 66 made provisions for concentrations, or mergers, and the abuse of a dominant position by companies. This was the first time that competition law principles were included in a plurilateral regional agreement and established the trans-European model of competition law. In 1957 competition rules were included in the Treaty of Rome, also known as the EC Treaty, which established the European Economic Community (EEC). The Treaty of Rome established the enactment of competition law as one of the main aims of the EEC through the "institution of a system ensuring that competition in the common market is not distorted". The two central provisions on EU competition law on companies were established in article 85, which prohibited anti-competitive agreements, subject to some exemptions, and article 86 prohibiting the abuse of dominant position. The treaty also established principles on competition law for member states, with article 90 covering public undertakings, and article 92 making provisions on state aid. Regulations on mergers were not included as member states could not establish consensus on the issue at the time.

Today, the Treaty of Lisbon prohibits anti-competitive agreements in Article 101(1), including price fixing. According to Article 101(2) any such agreements are automatically void. Article 101(3) establishes exemptions, if the collusion is for distributional or technological innovation, gives consumers a "fair share" of the benefit and does not include unreasonable restraints that risk eliminating competition anywhere (or compliant with the general principle of European Union law of proportionality). Article 102 prohibits the abuse of dominant position, such as price discrimination and exclusive dealing. Article 102 allows the European Council to regulations to govern mergers between firms (the current regulation is the Regulation 139/2004/EC). The general test is whether a concentration (i.e. merger or acquisition) with a community dimension (i.e. affects a number of EU member states) might significantly impede effective competition. Articles 106 and 107 provide that member state's right to deliver public services may not be obstructed, but that otherwise public enterprises must adhere to the same competition principles as

companies. Article 107 lays down a general rule that the state may not aid or subsidise private parties in distortion of free competition and provides exemptions for charities, regional development objectives and in the event of a natural disaster.

While the concept of a "social market economy" was only introduced into EU law in 2007, free movement and trade were central to European development since the Treaty of Rome 1957. According to the standard theory of comparative advantage, two countries can both benefit from trade even if one of them has a less productive economy in all respects. Like in other regional organisations such as the North American Free Trade Association, or the World Trade Organisation, breaking down barriers to trade, and enhancing free movement of goods, services, labour and capital, is meant to reduce consumer prices. It was originally theorised that a free trade area had a tendency to give way to a customs union, which led to a common market, then monetary union, then union of monetary and fiscal policy, political and eventually a full union characteristic of a federal state. In Europe, however, those stages were considerably mixed, and it remains unclear whether the "endgame" should be the same as a state, traditionally understood. In practice free trade, without standards to ensure fair trade, can benefit some people and groups within countries (particularly big business) much more than others, but will burden people who lack bargaining power in an expanding market, particularly workers, consumers, small business, developing industries, and communities. The Treaty on the Functioning of the European Union articles 28 to 37 establish the principle of free movement of goods in the EU, while articles 45 to 66 require free movement of persons, services and capital. These so-called "four freedoms" were thought to be inhibited by physical barriers (e.g. customs), technical barriers (e.g. differing laws on safety, consumer or environmental standards) and fiscal barriers (e.g. different Value Added Tax rates). The tension in the law is that the free movement and trade is not supposed to spill over into a licence for unrestricted commercial profit. The Treaties limit free trade, to prioritise other values such as public health, consumer protection, labour rights, fair competition, and environmental improvement. Increasingly the Court of Justice has taken the view that the specific goals of free trade are underpinned by the general aims of the treaty for improvement of people's well being.

Free movement of goods within the European Union is achieved by a customs union, and the principle of non-discrimination. The EU manages imports from non-member states, duties between member states are prohibited, and imports circulate freely. In addition under the Treaty on the Functioning of the European Union article 34, 'Quantitative restrictions on imports and all measures having equivalent effect shall be prohibited between Member States'. In *Procureur du Roi v Dassonville* the Court of Justice held that this rule meant all "trading rules" that are "enacted by Member States" which could hinder trade "directly or indirectly, actually or potentially" would be caught by article 34. This meant that a Belgian law requiring Scotch whisky imports to have a certificate of origin was unlikely to be lawful. It discriminated against parallel importers like Mr Dassonville, who could not get certificates from authorities in France, where they bought the Scotch. This "wide test", to determine what could potentially be an unlawful restriction on trade, applies equally to actions by quasi-government bodies, such as the former "Buy Irish" company that had government appointees. It also means states can be responsible for private actors. For instance, in *Commission v France* French farmer vigilantes were continually sabotaging shipments of Spanish strawberries, and even Belgian tomato imports. France was liable for these hindrances to trade because the authorities 'manifestly and persistently abstained' from preventing the sabotage. Generally speaking, if a member state has laws or practices that directly discriminate against imports (or exports under TFEU article 35) then it must be justified under article 36. The justifications include public morality, policy or security, "protection of health and life of humans, animals or plants", "national treasures" of "artistic, historic or archaeological value" and "industrial and commercial property." In addition, although not clearly listed, environmental protection can justify restrictions on trade as an overriding requirement derived from TFEU article 11. More generally, it has been increasingly acknowledged that fundamental human rights should take priority over all trade rules. So, in *Schmidberger v Austria* the Court of Justice held that Austria did not infringe article 34 by failing to ban a protest that blocked heavy traffic passing over the A13, Brenner Autobahn, en route to Italy. Although many companies, including Mr Schmidberger's German undertaking, were prevented from trading, the Court of Justice reasoned that freedom of association is one of the 'fundamental pillars of a democratic society', against which the free movement of goods had to be balanced, and was probably subordinate. If a member state does appeal to the article 36 justification, the measures it takes have to be applied proportionately. This means the rule must be pursue a legitimate aim and (1) be suitable to achieve the aim, (2) be necessary, so that a less

restrictive measure could not achieve the same result, and (3) be reasonable in balancing the interests of free trade with interests in article 36.

Often rules apply to all goods neutrally, but may have a greater practical effect on imports than domestic products. For such "indirect" discriminatory (or "indistinctly applicable") measures the Court of Justice has developed more justifications: either those in article 36, or additional "mandatory" or "overriding" requirements such as consumer protection, improving labour standards, protecting the environment, press diversity, fairness in commerce, and more: the categories are not closed. In the most famous case *Rewe-Zentral AG v Bundesmonopol für Branntwein*, the Court of Justice found that a German law requiring all spirits and liqueurs (not just imported ones) to have a minimum alcohol content of 25 per cent was contrary to TFEU article 34, because it had a greater negative effect on imports. German liqueurs were over 25 per cent alcohol, but *Cassis de Dijon*, which *Rewe-Zentrale AG* wished to import from France, only had 15 to 20 per cent alcohol. The Court of Justice rejected the German government's arguments that the measure proportionately protected public health under TFEU article 36, because stronger beverages were available and adequate labelling would be enough for consumers to understand what they bought. This rule primarily applies to requirements about a product's content or packaging. In *Walter Rau Lebensmittelwerke v De Smedt PVBA* the Court of Justice found that a Belgian law requiring all margarine to be in cube shaped packages infringed article 34, and was not justified by the pursuit of consumer protection. The argument that Belgians would believe it was butter if it was not cube shaped was disproportionate: it would "considerably exceed the requirements of the object in view" and labelling would protect consumers "just as effectively". In a 2003 case, *Commission v Italy* Italian law required that cocoa products that included other vegetable fats could not be labelled as "chocolate". It had to be "chocolate substitute". All Italian chocolate was made from cocoa butter alone, but British, Danish and Irish manufacturers used other vegetable fats. They claimed the law infringed article 34. The Court of Justice held that a low content of vegetable fat did not justify a "chocolate substitute" label. This was derogatory in the consumers' eyes. A 'neutral and objective statement' was enough to protect consumers. If member states place considerable obstacles on the use of a product, this can also infringe article 34. So, in a 2009 case, *Commission v Italy*, the Court of Justice held that an Italian law prohibiting motorcycles or mopeds pulling trailers infringed article 34. Again, the law applied neutrally to everyone, but disproportionately affected importers, because Italian companies did not make trailers. This was not a product requirement, but the Court reasoned that the prohibition would deter people from buying it: it would have "a considerable influence on the behaviour of consumers" that "affects the access of that product to the market". It would require justification under article 36, or as a mandatory requirement. In contrast to product requirements or other laws that hinder market access, the Court of Justice developed a presumption that "selling arrangements" would be presumed to not fall into TFEU article 34, if they applied equally to all sellers, and affected them in the same manner in fact. In *Keck and Mithouard* two importers claimed that their prosecution under a French competition law, which prevented them selling *Picon* beer under wholesale price, was unlawful. The aim of the law was to prevent cut throat competition, not to hinder trade. The Court of Justice held, as "in law and in fact" it was an equally applicable "selling arrangement" (not something that alters a product's content) it was outside the scope of article 34, and so did not need to be justified. Selling arrangements can be held to have an unequal effect "in fact" particularly where traders from another member state are seeking to break into the market, but there are restrictions on advertising and marketing. In *Konsumentombudsmannen v De Agostini* the Court of Justice reviewed Swedish bans on advertising to children under age 12, and misleading commercials for skin care products. While the bans have remained (justifiable under article 36 or as a mandatory requirement) the Court emphasised that complete marketing bans could be disproportionate if advertising were "the only effective form of promotion enabling [a trader] to penetrate" the market. In *Konsumentombudsmannen v Gourmet AB* the Court suggested that a total ban for advertising alcohol on the radio, TV and in magazines could fall within article 34 where advertising was the only way for sellers to overcome consumers' "traditional social practices and to local habits and customs" to buy their products, but again the national courts would decide whether it was justified under article 36 to protect public health. Under the Unfair Commercial Practices Directive, the EU harmonised restrictions on restrictions on marketing and advertising, to forbid conduct that distorts average consumer behaviour, is misleading or aggressive, and sets out a list of examples that count as unfair. Increasingly, states have to give mutual recognition to each other's standards of regulation, while the EU has attempted to harmonise minimum ideals of best practice. The attempt to raise standards is hoped to avoid a regulatory "race to



the bottom", while allowing consumers access to goods from around the continent. Since its foundation, the Treaties sought to enable people to pursue their life goals in any country through free movement. Reflecting the economic nature of the project, the European Community originally focused upon free movement of workers: as a "factor of production". However, from the 1970s, this focus shifted towards developing a more "social" Europe. Free movement was increasingly based on "citizenship", so that people had rights to empower them to become economically and socially active, rather than economic activity being a precondition for rights. This means the basic "worker" rights in TFEU article 45 function as a specific expression of the general rights of citizens in TFEU articles 18 to 21. According to the Court of Justice, a "worker" is anybody who is economically active, which includes everyone in an employment relationship, "under the direction of another person" for "remuneration". A job, however, need not be paid in money for someone to be protected as a worker. For example, in *Steymann v Staatssecretaris van Justitie*, a German man claimed the right to residence in the Netherlands, while he volunteered plumbing and household duties in the Bhagwan community, which provided for everyone's material needs irrespective of their contributions. The Court of Justice held that Mr Steymann was entitled to stay, so long as there was at least an "indirect quid pro quo" for the work he did. Having "worker" status means protection against all forms of discrimination by governments, and employers, in access to employment, tax, and social security rights. By contrast a citizen, who is "any person having the nationality of a Member State" (TFEU article 20(1)), has rights to seek work, vote in local and European elections, but more restricted rights to claim social security. In practice, free movement has become politically contentious as nationalist political parties have manipulated fears about immigrants taking away people's jobs and benefits (paradoxically at the same time). Nevertheless, practically "all available research finds little impact" of "labour mobility on wages and employment of local workers".

The Free Movement of Workers Regulation articles 1 to 7 set out the main provisions on equal treatment of workers. First, articles 1 to 4 generally require that workers can take up employment, conclude contracts, and not suffer discrimination compared to nationals of the member state. In a famous case, the *Belgian Football Association v Bosman*, a Belgian footballer named Jean-Marc Bosman claimed that he should be able to transfer from R.F.C. de Liège to USL Dunkerque when his contract finished, regardless of whether Dunkerque could afford to pay Liège the habitual transfer fees. The Court of Justice held "the transfer rules constitute[d] an obstacle to free movement" and were unlawful unless they could be justified in the public interest, but this was unlikely. In *Groener v Minister for Education* the Court of Justice accepted that a requirement to speak Gaelic to teach in a Dublin design college could be justified as part of the public policy of promoting the Irish language, but only if the measure was not disproportionate. By contrast in *Angonese v Cassa di Risparmio di Bolzano SpA* a bank in Bolzano, Italy, was not allowed to require Mr Angonese to have a bilingual certificate that could only be obtained in Bolzano. The Court of Justice, giving "horizontal" direct effect to TFEU article 45, reasoned that people from other countries would have little chance of acquiring the certificate, and because it was "impossible to submit proof of the required linguistic knowledge by any other means", the measure was disproportionate. Second, article 7(2) requires equal treatment in respect of tax. In *Finanzamt Köln Altstadt v Schumacker* the Court of Justice held that it contravened TFEU art 45 to deny tax benefits (e.g. for married couples, and social insurance expense deductions) to a man who worked in Germany, but was resident in Belgium when other German residents got the benefits. By contrast in *Weigel v Finanzlandesdirektion für Vorarlberg* the Court of Justice rejected Mr Weigel's claim that a re-registration charge upon bringing his car to Austria violated his right to free movement. Although the tax was "likely to have a negative bearing on the decision of migrant workers to exercise their right to freedom of movement", because the charge applied equally to Austrians, in absence of EU legislation on the matter it had to be regarded as justified. Third, people must receive equal treatment regarding "social advantages", although the Court has approved residential qualifying periods. In *Hendrix v Employee Insurance Institute* the Court of Justice held that a Dutch national was not entitled to continue receiving incapacity benefits when he moved to Belgium, because the benefit was "closely linked to the socio-economic situation" of the Netherlands. Conversely, in *Geven v Land Nordrhein-Westfalen* the Court of Justice held that a Dutch woman living in the Netherlands, but working between 3 and 14 hours a week in Germany, did not have a right to receive German child benefits, even though the wife of a man who worked full-time in Germany but was resident in Austria could. The general justifications for limiting free movement in TFEU article 45(3) are "public policy, public security or public health", and there is also a general exception in article 45(4) for "employment in the public service".

Citizenship of the EU has increasingly been seen as a "fundamental" status of member state nationals by the Court of Justice, and has accordingly increased the number of social services that people can access wherever they move. The Court has required that higher education, along with other forms of vocational training, should be more access, albeit with qualifying periods. In *Commission v Austria* the Court held that Austria was not entitled to restrict places in Austrian universities to Austrian students to avoid "structural, staffing and financial problems" if (mainly German) foreign students applied for places because there was little evidence of an actual problem.

As well as creating rights for "workers" who generally lack bargaining power in the market, the Treaty on the Functioning of the European Union also protects the "freedom of establishment" in article 49, and "freedom to provide services" in article 56. In *Gebhard v Consiglio dell'Ordine degli Avvocati e Procuratori di Milano* the Court of Justice held that to be "established" means to participate in economic life "on a stable and continuous basis", while providing "services" meant pursuing activity more "on a temporary basis". This meant that a lawyer from Stuttgart, who had set up chambers in Milan and was censured by the Milan Bar Council for not having registered, was entitled to bring a claim under for establishment freedom, rather than service freedom. However, the requirements to be registered in Milan before being able to practice would be allowed if they were non-discriminatory, "justified by imperative requirements in the general interest" and proportionately applied. All people or entities that engage in economic activity, particularly the self-employed, or "undertakings" such as companies or firms, have a right to set up an enterprise without unjustified restrictions. The Court of Justice has held that both a member state government and a private party can hinder freedom of establishment, so article 49 has both "vertical" and "horizontal" direct effect. In *Reyners v Belgium* the Court of Justice held that a refusal to admit a lawyer to the Belgian bar because he lacked Belgian nationality was unjustified. TFEU article 49 says states are exempt from infringing others' freedom of establishment when they exercise "official authority", but this did an advocate's work (as opposed to a court's) was not official. By contrast in *Commission v Italy* the Court of Justice held that a requirement for lawyers in Italy to comply with maximum tariffs unless there was an agreement with a client was not a restriction. The Grand Chamber of the Court of Justice held the Commission had not proven that this had any object or effect of limiting practitioners from entering the market. Therefore, there was no *prima facie* infringement freedom of establishment that needed to be justified.

In 2006, a toxic waste spill off the coast of Côte d'Ivoire, from a European ship, prompted the Commission to look into legislation against toxic waste. Environment Commissioner Stavros Dimas stated that "Such highly toxic waste should never have left the European Union". With countries such as Spain not even having a crime against shipping toxic waste, Franco Frattini, the Justice, Freedom and Security Commissioner, proposed with Dimas to create criminal sentences for "ecological crimes". The competence for the Union to do this was contested in 2005 at the Court of Justice resulting in a victory for the Commission. That ruling set a precedent that the Commission, on a supranational basis, may legislate in criminal law – something never done before. So far, the only other proposal has been the draft intellectual property rights directive. Motions were tabled in the European Parliament against that legislation on the basis that criminal law should not be an EU competence, but was rejected at vote. However, in October 2007, the Court of Justice ruled that the Commission could not propose what the criminal sanctions could be, only that there must be some.

The "freedom to provide services" under TFEU article 56 applies to people who give services "for remuneration", especially commercial or professional activity. For example, in *Van Binsbergen v Bestuur van de Bedrijfvereniging voor de Metaalnijverheid* a Dutch lawyer moved to Belgium while advising a client in a social security case, and was told he could not continue because Dutch law said only people established in the Netherlands could give legal advice. The Court of Justice held that the freedom to provide services applied, it was directly effective, and the rule was probably unjustified: having an address in the member state would be enough to pursue the legitimate aim of good administration of justice. The Court of Justice has held that secondary education falls outside the scope of article 56, because usually the state funds it, though higher education does not. Health care generally counts as a service. In *Geraets-Smits v Stichting Ziekenfonds* Mrs Geraets-Smits claimed she should be reimbursed by Dutch social insurance for costs of receiving treatment in Germany. The Dutch health authorities regarded the treatment unnecessary, so she argued this restricted the freedom (of the German health clinic) to provide services. Several governments submitted that hospital services should not be regarded as economic, and should not fall within article 56. But the Court of Justice held health was a "service" even though the

government (rather than the service recipient) paid for the service. National authorities could be justified in refusing to reimburse patients for medical services abroad if the health care received at home was without undue delay, and it followed "international medical science" on which treatments counted as normal and necessary. The Court requires that the individual circumstances of a patient justify waiting lists, and this is also true in the context of the UK's National Health Service. Aside from public services, another sensitive field of services are those classified as illegal. *Josemans v Burgemeester van Maastricht* held that the Netherlands' regulation of cannabis consumption, including the prohibitions by some municipalities on tourists (but not Dutch nationals) going to coffee shops, fell outside article 56 altogether. The Court of Justice reasoned that narcotic drugs were controlled in all member states, and so this differed from other cases where prostitution or other quasi-legal activity was subject to restriction. If an activity does fall within article 56, a restriction can be justified under article 52 or overriding requirements developed by the Court of Justice. In *Alpine Investments BV v Minister van Financiën* a business that sold commodities futures (with Merrill Lynch and another banking firms) attempted to challenge a Dutch law that prohibiting cold calling customers. The Court of Justice held the Dutch prohibition pursued a legitimate aim to prevent "undesirable developments in securities trading" including protecting the consumer from aggressive sales tactics, thus maintaining confidence in the Dutch markets. In *Omega Spielhallen GmbH v Bonn* a "laserdrome" business was banned by the Bonn council. It bought fake laser gun services from a UK firm called Pulsar Ltd, but residents had protested against "playing at killing" entertainment. The Court of Justice held that the German constitutional value of human dignity, which underpinned the ban, did count as a justified restriction on freedom to provide services. In *Liga Portuguesa de Futebol v Santa Casa da Misericórdia de Lisboa* the Court of Justice also held that the state monopoly on gambling, and a penalty for a Gibraltar firm that had sold internet gambling services, was justified to prevent fraud and gambling where people's views were highly divergent. The ban was proportionate as this was an appropriate and necessary way to tackle the serious problems of fraud that arise over the internet. In the Services Directive a group of justifications were codified in article 16 that the case law has developed.

In regard to companies, the Court of Justice held in *R (Daily Mail and General Trust plc) v HM Treasury* that member states could restrict a company moving its seat of business, without infringing TFEU article 49. This meant the Daily Mail newspaper's parent company could not evade tax by shifting its residence to the Netherlands without first settling its tax bills in the UK. The UK did not need to justify its action, as rules on company seats were not yet harmonised. By contrast, in *Centros Ltd v Erhvervs-og Selkabsstyrelsen* the Court of Justice found that a UK limited company operating in Denmark could not be required to comply with Denmark's minimum share capital rules. UK law only required £1 of capital to start a company, while Denmark's legislature took the view companies should only be started up if they had 200,000 Danish krone (around €27,000) to protect creditors if the company failed and went insolvent. The Court of Justice held that Denmark's minimum capital law infringed Centros Ltd's freedom of establishment and could not be justified, because a company in the UK could admittedly provide services in Denmark without being established there, and there were less restrictive means of achieving the aim of creditor protection. This approach was criticised as potentially opening the EU to unjustified regulatory competition, and a race to the bottom in standards, like in the US where the state Delaware attracts most companies and is often argued to have the worst standards of accountability of boards, and low corporate taxes as a result. Similarly in *Überseering BV v Nordic Construction GmbH* the Court of Justice held that a German court could not deny a Dutch building company the right to enforce a contract in Germany on the basis that it was not validly incorporated in Germany. Although restrictions on freedom of establishment could be justified by creditor protection, labour rights to participate in work, or the public interest in collecting taxes, denial of capacity went too far: it was an "outright negation" of the right of establishment. However, in *Cartesio Oktató és Szolgáltató bt* the Court of Justice affirmed again that because corporations are created by law, they are in principle subject to any rules for formation that a state of incorporation wishes to impose. This meant that the Hungarian authorities could prevent a company from shifting its central administration to Italy while it still operated and was incorporated in Hungary. Thus, the court draws a distinction between the right of establishment for foreign companies (where restrictions must be justified), and the right of the state to determine conditions for companies incorporated in its territory, although it is not entirely clear why.

The Amazon rainforest (Portuguese: Floresta Amazônica or Amazônia; Spanish: Selva Amazónica, Amazonía or usually Amazonia; French: Forêt amazonienne; Dutch: Amazoneregenwoud), also known in English as Amazonia or the Amazon Jungle, is a moist broadleaf forest that covers most of the Amazon

basin of South America. This basin encompasses 7,000,000 square kilometres (2,700,000 sq mi), of which 5,500,000 square kilometres (2,100,000 sq mi) are covered by the rainforest. This region includes territory belonging to nine nations. The majority of the forest is contained within Brazil, with 60% of the rainforest, followed by Peru with 13%, Colombia with 10%, and with minor amounts in Venezuela, Ecuador, Bolivia, Guyana, Suriname and French Guiana. States or departments in four nations contain "Amazonas" in their names. The Amazon represents over half of the planet's remaining rainforests, and comprises the largest and most biodiverse tract of tropical rainforest in the world, with an estimated 390 billion individual trees divided into 16,000 species.

Following the Cretaceous–Paleogene extinction event, the extinction of the dinosaurs and the wetter climate may have allowed the tropical rainforest to spread out across the continent. From 66–34 Mya, the rainforest extended as far south as 45°. Climate fluctuations during the last 34 million years have allowed savanna regions to expand into the tropics. During the Oligocene, for example, the rainforest spanned a relatively narrow band. It expanded again during the Middle Miocene, then retracted to a mostly inland formation at the last glacial maximum. However, the rainforest still managed to thrive during these glacial periods, allowing for the survival and evolution of a broad diversity of species.

During the mid-Eocene, it is believed that the drainage basin of the Amazon was split along the middle of the continent by the Purus Arch. Water on the eastern side flowed toward the Atlantic, while to the west water flowed toward the Pacific across the Amazonas Basin. As the Andes Mountains rose, however, a large basin was created that enclosed a lake; now known as the Solimões Basin. Within the last 5–10 million years, this accumulating water broke through the Purus Arch, joining the easterly flow toward the Atlantic.

There is evidence that there have been significant changes in Amazon rainforest vegetation over the last 21,000 years through the Last Glacial Maximum (LGM) and subsequent deglaciation. Analyses of sediment deposits from Amazon basin paleolakes and from the Amazon Fan indicate that rainfall in the basin during the LGM was lower than for the present, and this was almost certainly associated with reduced moist tropical vegetation cover in the basin. There is debate, however, over how extensive this reduction was. Some scientists argue that the rainforest was reduced to small, isolated refugia separated by open forest and grassland; other scientists argue that the rainforest remained largely intact but extended less far to the north, south, and east than is seen today. This debate has proved difficult to resolve because the practical limitations of working in the rainforest mean that data sampling is biased away from the center of the Amazon basin, and both explanations are reasonably well supported by the available data.

NASA's CALIPSO satellite has measured the amount of dust transported by wind from the Sahara to the Amazon: an average 182 million tons of dust are windblown out of the Sahara each year, at 15 degrees west longitude, across 1,600 miles (2,600 km) over the Atlantic Ocean (some dust falls into the Atlantic), then at 35 degrees West longitude at the eastern coast of South America, 27.7 million tons (15%) of dust fall over the Amazon basin, 132 million tons of dust remain in the air, 43 million tons of dust are windblown and falls on the Caribbean Sea, past 75 degrees west longitude.

For a long time, it was thought that the Amazon rainforest was only ever sparsely populated, as it was impossible to sustain a large population through agriculture given the poor soil. Archeologist Betty Meggers was a prominent proponent of this idea, as described in her book *Amazonia: Man and Culture in a Counterfeit Paradise*. She claimed that a population density of 0.2 inhabitants per square kilometre (0.52/sq mi) is the maximum that can be sustained in the rainforest through hunting, with agriculture needed to host a larger population. However, recent anthropological findings have suggested that the region was actually densely populated. Some 5 million people may have lived in the Amazon region in AD 1500, divided between dense coastal settlements, such as that at Marajó, and inland dwellers. By 1900 the population had fallen to 1 million and by the early 1980s it was less than 200,000.

The first European to travel the length of the Amazon River was Francisco de Orellana in 1542. The BBC's *Unnatural Histories* presents evidence that Orellana, rather than exaggerating his claims as previously thought, was correct in his observations that a complex civilization was flourishing along the Amazon in the 1540s. It is believed that the civilization was later devastated by the spread of diseases from Europe, such as smallpox. Since the 1970s, numerous geoglyphs have been discovered on deforested land dating between AD 0–1250, furthering claims about Pre-Columbian civilizations. Ondemar Dias is accredited with first discovering the geoglyphs in 1977 and Alceu Ranzi with furthering their discovery after flying over Acre. The BBC's *Unnatural Histories* presented evidence that the Amazon

rainforest, rather than being a pristine wilderness, has been shaped by man for at least 11,000 years through practices such as forest gardening and terra preta.

Terra preta (black earth), which is distributed over large areas in the Amazon forest, is now widely accepted as a product of indigenous soil management. The development of this fertile soil allowed agriculture and silviculture in the previously hostile environment; meaning that large portions of the Amazon rainforest are probably the result of centuries of human management, rather than naturally occurring as has previously been supposed. In the region of the Xingu tribe, remains of some of these large settlements in the middle of the Amazon forest were found in 2003 by Michael Heckenberger and colleagues of the University of Florida. Among those were evidence of roads, bridges and large plazas. The region is home to about 2.5 million insect species, tens of thousands of plants, and some 2,000 birds and mammals. To date, at least 40,000 plant species, 2,200 fishes, 1,294 birds, 427 mammals, 428 amphibians, and 378 reptiles have been scientifically classified in the region. One in five of all the bird species in the world live in the rainforests of the Amazon, and one in five of the fish species live in Amazonian rivers and streams. Scientists have described between 96,660 and 128,843 invertebrate species in Brazil alone.

The biodiversity of plant species is the highest on Earth with one 2001 study finding a quarter square kilometer (62 acres) of Ecuadorian rainforest supports more than 1,100 tree species. A study in 1999 found one square kilometer (247 acres) of Amazon rainforest can contain about 90,790 tonnes of living plants. The average plant biomass is estimated at  $356 \pm 47$  tonnes per hectare. To date, an estimated 438,000 species of plants of economic and social interest have been registered in the region with many more remaining to be discovered or catalogued. The total number of tree species in the region is estimated at 16,000.

The rainforest contains several species that can pose a hazard. Among the largest predatory creatures are the black caiman, jaguar, cougar, and anaconda. In the river, electric eels can produce an electric shock that can stun or kill, while piranha are known to bite and injure humans. Various species of poison dart frogs secrete lipophilic alkaloid toxins through their flesh. There are also numerous parasites and disease vectors. Vampire bats dwell in the rainforest and can spread the rabies virus. Malaria, yellow fever and Dengue fever can also be contracted in the Amazon region.

Deforestation is the conversion of forested areas to non-forested areas. The main sources of deforestation in the Amazon are human settlement and development of the land. Prior to the early 1960s, access to the forest's interior was highly restricted, and the forest remained basically intact. Farms established during the 1960s were based on crop cultivation and the slash and burn method. However, the colonists were unable to manage their fields and the crops because of the loss of soil fertility and weed invasion. The soils in the Amazon are productive for just a short period of time, so farmers are constantly moving to new areas and clearing more land. These farming practices led to deforestation and caused extensive environmental damage. Deforestation is considerable, and areas cleared of forest are visible to the naked eye from outer space.

Between 1991 and 2000, the total area of forest lost in the Amazon rose from 415,000 to 587,000 square kilometres (160,000 to 227,000 sq mi), with most of the lost forest becoming pasture for cattle. Seventy percent of formerly forested land in the Amazon, and 91% of land deforested since 1970, is used for livestock pasture. Currently, Brazil is the second-largest global producer of soybeans after the United States. New research however, conducted by Leydimere Oliveira et al., has shown that the more rainforest is logged in the Amazon, the less precipitation reaches the area and so the lower the yield per hectare becomes. So despite the popular perception, there has been no economical advantage for Brazil from logging rainforest zones and converting these to pastoral fields.

The needs of soy farmers have been used to justify many of the controversial transportation projects that are currently developing in the Amazon. The first two highways successfully opened up the rainforest and led to increased settlement and deforestation. The mean annual deforestation rate from 2000 to 2005 (22,392 km<sup>2</sup> or 8,646 sq mi per year) was 18% higher than in the previous five years (19,018 km<sup>2</sup> or 7,343 sq mi per year). Although deforestation has declined significantly in the Brazilian Amazon between 2004 and 2014, there has been an increase to the present day.

Environmentalists are concerned about loss of biodiversity that will result from destruction of the forest, and also about the release of the carbon contained within the vegetation, which could accelerate global warming. Amazonian evergreen forests account for about 10% of the world's terrestrial primary productivity and 10% of the carbon stores in ecosystems—of the order of  $1.1 \times 10^{11}$  metric tonnes of

carbon. Amazonian forests are estimated to have accumulated  $0.62 \pm 0.37$  tons of carbon per hectare per year between 1975 and 1996.

One computer model of future climate change caused by greenhouse gas emissions shows that the Amazon rainforest could become unsustainable under conditions of severely reduced rainfall and increased temperatures, leading to an almost complete loss of rainforest cover in the basin by 2100. However, simulations of Amazon basin climate change across many different models are not consistent in their estimation of any rainfall response, ranging from weak increases to strong decreases. The result indicates that the rainforest could be threatened through the 21st century by climate change in addition to deforestation.

As indigenous territories continue to be destroyed by deforestation and ecocide, such as in the Peruvian Amazon indigenous peoples' rainforest communities continue to disappear, while others, like the Urarina continue to struggle to fight for their cultural survival and the fate of their forested territories. Meanwhile, the relationship between non-human primates in the subsistence and symbolism of indigenous lowland South American peoples has gained increased attention, as have ethno-biology and community-based conservation efforts.

The use of remote sensing for the conservation of the Amazon is also being used by the indigenous tribes of the basin to protect their tribal lands from commercial interests. Using handheld GPS devices and programs like Google Earth, members of the Trio Tribe, who live in the rainforests of southern Suriname, map out their ancestral lands to help strengthen their territorial claims. Currently, most tribes in the Amazon do not have clearly defined boundaries, making it easier for commercial ventures to target their territories.

To accurately map the Amazon's biomass and subsequent carbon related emissions, the classification of tree growth stages within different parts of the forest is crucial. In 2006 Tatiana Kuplich organized the trees of the Amazon into four categories: (1) mature forest, (2) regenerating forest [less than three years], (3) regenerating forest [between three and five years of regrowth], and (4) regenerating forest [eleven to eighteen years of continued development]. The researcher used a combination of Synthetic aperture radar (SAR) and Thematic Mapper (TM) to accurately place the different portions of the Amazon into one of the four classifications.

In 2005, parts of the Amazon basin experienced the worst drought in one hundred years, and there were indications that 2006 could have been a second successive year of drought. A July 23, 2006 article in the UK newspaper The Independent reported Woods Hole Research Center results showing that the forest in its present form could survive only three years of drought. Scientists at the Brazilian National Institute of Amazonian Research argue in the article that this drought response, coupled with the effects of deforestation on regional climate, are pushing the rainforest towards a "tipping point" where it would irreversibly start to die. It concludes that the forest is on the brink of being turned into savanna or desert, with catastrophic consequences for the world's climate.

In 2010 the Amazon rainforest experienced another severe drought, in some ways more extreme than the 2005 drought. The affected region was approximate 1,160,000 square miles (3,000,000 km<sup>2</sup>) of rainforest, compared to 734,000 square miles (1,900,000 km<sup>2</sup>) in 2005. The 2010 drought had three epicenters where vegetation died off, whereas in 2005 the drought was focused on the southwestern part. The findings were published in the journal Science. In a typical year the Amazon absorbs 1.5 gigatons of carbon dioxide; during 2005 instead 5 gigatons were released and in 2010 8 gigatons were released.

Ctenophora (/t n f r /; singular ctenophore, / t n f r / or / ti n f r /; from the Greek κτείς kteis 'comb' and φέρω phero 'carry'; commonly known as comb jellies) is a phylum of animals that live in marine waters worldwide.

Their most distinctive feature is the 'combs' – groups of cilia which they use for swimming – they are the largest animals that swim by means of cilia. Adults of various species range from a few millimeters to 1.5 m (4 ft 11 in) in size. Like cnidarians, their bodies consist of a mass of jelly, with one layer of cells on the outside and another lining the internal cavity. In ctenophores, these layers are two cells deep, while those in cnidarians are only one cell deep. Some authors combined ctenophores and cnidarians in one phylum, Coelenterata, as both groups rely on water flow through the body cavity for both digestion and respiration. Increasing awareness of the differences persuaded more recent authors to classify them as separate phyla.

Almost all ctenophores are predators, taking prey ranging from microscopic larvae and rotifers to the adults of small crustaceans; the exceptions are juveniles of two species, which live as parasites on the salps on which adults of their species feed. In favorable circumstances, ctenophores can eat ten times

their own weight in a day. Only 100–150 species have been validated, and possibly another 25 have not been fully described and named. The textbook examples are cydippids with egg-shaped bodies and a pair of retractable tentacles fringed with tentilla ("little tentacles") that are covered with colloblasts, sticky cells that capture prey. The phylum has a wide range of body forms, including the flattened, deep-sea platyctenids, in which the adults of most species lack combs, and the coastal beroids, which lack tentacles and prey on other ctenophores by using huge mouths armed with groups of large, stiffened cilia that act as teeth. These variations enable different species to build huge populations in the same area, because they specialize in different types of prey, which they capture by as wide a range of methods as spiders use.

Most species are hermaphrodites—a single animal can produce both eggs and sperm, meaning it can fertilize its own egg, not needing a mate. Some are simultaneous hermaphrodites, which can produce both eggs and sperm at the same time. Others are sequential hermaphrodites, in which the eggs and sperm mature at different times. Fertilization is generally external, although platyctenids' eggs are fertilized inside their parents' bodies and kept there until they hatch. The young are generally planktonic and in most species look like miniature cydippids, gradually changing into their adult shapes as they grow. The exceptions are the beroids, whose young are miniature beroids with large mouths and no tentacles, and the platyctenids, whose young live as cydippid-like plankton until they reach near-adult size, but then sink to the bottom and rapidly metamorphose into the adult form. In at least some species, juveniles are capable of reproduction before reaching the adult size and shape. The combination of hermaphroditism and early reproduction enables small populations to grow at an explosive rate.

Ctenophores may be abundant during the summer months in some coastal locations, but in other places they are uncommon and difficult to find. In bays where they occur in very high numbers, predation by ctenophores may control the populations of small zooplanktonic organisms such as copepods, which might otherwise wipe out the phytoplankton (planktonic plants), which are a vital part of marine food chains. One ctenophore, *Mnemiopsis*, has accidentally been introduced into the Black Sea, where it is blamed for causing fish stocks to collapse by eating both fish larvae and organisms that would otherwise have fed the fish. The situation was aggravated by other factors, such as over-fishing and long-term environmental changes that promoted the growth of the *Mnemiopsis* population. The later accidental introduction of *Beroe* helped to mitigate the problem, as *Beroe* preys on other ctenophores.

Despite their soft, gelatinous bodies, fossils thought to represent ctenophores, apparently with no tentacles but many more comb-rows than modern forms, have been found in lagerstätten as far back as the early Cambrian, about 515 million years ago. The position of the ctenophores in the evolutionary family tree of animals has long been debated, and the majority view at present, based on molecular phylogenetics, is that cnidarians and bilaterians are more closely related to each other than either is to ctenophores. A recent molecular phylogenetics analysis concluded that the common ancestor of all modern ctenophores was cydippid-like, and that all the modern groups appeared relatively recently, probably after the Cretaceous–Paleogene extinction event 66 million years ago. Evidence accumulating since the 1980s indicates that the "cydippids" are not monophyletic, in other words do not include all and only the descendants of a single common ancestor, because all the other traditional ctenophore groups are descendants of various cydippids.

Ctenophores form an animal phylum that is more complex than sponges, about as complex as cnidarians (jellyfish, sea anemones, etc.), and less complex than bilaterians (which include almost all other animals). Unlike sponges, both ctenophores and cnidarians have: cells bound by inter-cell connections and carpet-like basement membranes; muscles; nervous systems; and some have sensory organs. Ctenophores are distinguished from all other animals by having colloblasts, which are sticky and adhere to prey, although a few ctenophore species lack them.

Like sponges and cnidarians, ctenophores have two main layers of cells that sandwich a middle layer of jelly-like material, which is called the mesoglea in cnidarians and ctenophores; more complex animals have three main cell layers and no intermediate jelly-like layer. Hence ctenophores and cnidarians have traditionally been labelled diploblastic, along with sponges. Both ctenophores and cnidarians have a type of muscle that, in more complex animals, arises from the middle cell layer, and as a result some recent text books classify ctenophores as triploblastic, while others still regard them as diploblastic.

Ranging from about 1 millimeter (0.039 in) to 1.5 meters (4.9 ft) in size, ctenophores are the largest non-colonial animals that use cilia ("hairs") as their main method of locomotion. Most species have eight strips, called comb rows, that run the length of their bodies and bear comb-like bands of cilia, called

"ctenes," stacked along the comb rows so that when the cilia beat, those of each comb touch the comb below. The name "ctenophora" means "comb-bearing", from the Greek κτείς (stem-form κτεν-) meaning "comb" and the Greek suffix -φορος meaning "carrying".

For a phylum with relatively few species, ctenophores have a wide range of body plans. Coastal species need to be tough enough to withstand waves and swirling sediment particles, while some oceanic species are so fragile that it is very difficult to capture them intact for study. In addition oceanic species do not preserve well, and are known mainly from photographs and from observers' notes. Hence most attention has until recently concentrated on three coastal genera – Pleurobrachia, Beroë and Mnemiopsis. At least two textbooks base their descriptions of ctenophores on the cydippid Pleurobrachia.

The internal cavity forms: a mouth that can usually be closed by muscles; a pharynx ("throat"); a wider area in the center that acts as a stomach; and a system of internal canals. These branch through the mesoglea to the most active parts of the animal: the mouth and pharynx; the roots of the tentacles, if present; all along the underside of each comb row; and four branches round the sensory complex at the far end from the mouth – two of these four branches terminate in anal pores. The inner surface of the cavity is lined with an epithelium, the gastrodermis. The mouth and pharynx have both cilia and well-developed muscles. In other parts of the canal system, the gastrodermis is different on the sides nearest to and furthest from the organ that it supplies. The nearer side is composed of tall nutritive cells that store nutrients in vacuoles (internal compartments), germ cells that produce eggs or sperm, and photocytes that produce bioluminescence. The side furthest from the organ is covered with ciliated cells that circulate water through the canals, punctuated by ciliary rosettes, pores that are surrounded by double whorls of cilia and connect to the mesoglea.

The outer surface bears usually eight comb rows, called swimming-plates, which are used for swimming. The rows are oriented to run from near the mouth (the "oral pole") to the opposite end (the "aboral pole"), and are spaced more or less evenly around the body, although spacing patterns vary by species and in most species the comb rows extend only part of the distance from the aboral pole towards the mouth. The "combs" (also called "ctenes" or "comb plates") run across each row, and each consists of thousands of unusually long cilia, up to 2 millimeters (0.079 in). Unlike conventional cilia and flagella, which has a filament structure arranged in a 9 + 2 pattern, these cilia are arranged in a 9 + 3 pattern, where the extra compact filament is suspected to have a supporting function. These normally beat so that the propulsion stroke is away from the mouth, although they can also reverse direction. Hence ctenophores usually swim in the direction in which the mouth is pointing, unlike jellyfish. When trying to escape predators, one species can accelerate to six times its normal speed; some other species reverse direction as part of their escape behavior, by reversing the power stroke of the comb plate cilia.

It is uncertain how ctenophores control their buoyancy, but experiments have shown that some species rely on osmotic pressure to adapt to water of different densities. Their body fluids are normally as concentrated as seawater. If they enter less dense brackish water, the ciliary rosettes in the body cavity may pump this into the mesoglea to increase its bulk and decrease its density, to avoid sinking.

Conversely if they move from brackish to full-strength seawater, the rosettes may pump water out of the mesoglea to reduce its volume and increase its density.

The largest single sensory feature is the aboral organ (at the opposite end from the mouth). Its main component is a statocyst, a balance sensor consisting of a statolith, a solid particle supported on four bundles of cilia, called "balancers", that sense its orientation. The statocyst is protected by a transparent dome made of long, immobile cilia. A ctenophore does not automatically try to keep the statolith resting equally on all the balancers. Instead its response is determined by the animal's "mood", in other words the overall state of the nervous system. For example, if a ctenophore with trailing tentacles captures prey, it will often put some comb rows into reverse, spinning the mouth towards the prey.

Cydippid ctenophores have bodies that are more or less rounded, sometimes nearly spherical and other times more cylindrical or egg-shaped; the common coastal "sea gooseberry," Pleurobrachia, sometimes has an egg-shaped body with the mouth at the narrow end, although some individuals are more uniformly round. From opposite sides of the body extends a pair of long, slender tentacles, each housed in a sheath into which it can be withdrawn. Some species of cydippids have bodies that are flattened to various extents, so that they are wider in the plane of the tentacles.

The tentacles of cydippid ctenophores are typically fringed with tentilla ("little tentacles"), although a few genera have simple tentacles without these sidebranches. The tentacles and tentilla are densely covered with microscopic colloblasts that capture prey by sticking to it. Colloblasts are specialized



mushroom-shaped cells in the outer layer of the epidermis, and have three main components: a domed head with vesicles (chambers) that contain adhesive; a stalk that anchors the cell in the lower layer of the epidermis or in the mesoglea; and a spiral thread that coils round the stalk and is attached to the head and to the root of the stalk. The function of the spiral thread is uncertain, but it may absorb stress when prey tries to escape, and thus prevent the colloblast from being torn apart. In addition to colloblasts, members of the genus *Haeckelia*, which feed mainly on jellyfish, incorporate their victims' stinging nematocytes into their own tentacles – some cnidaria-eating nudibranchs similarly incorporate nematocytes into their bodies for defense. The tentilla of *Euplokamis* differ significantly from those of other cydippids: they contain striated muscle, a cell type otherwise unknown in the phylum Ctenophora; and they are coiled when relaxed, while the tentilla of all other known ctenophores elongate when relaxed. *Euplokamis*' tentilla have three types of movement that are used in capturing prey: they may flick out very quickly (in 40 to 60 milliseconds); they can wriggle, which may lure prey by behaving like small planktonic worms; and they coil round prey. The unique flicking is an uncoiling movement powered by contraction of the striated muscle. The wriggling motion is produced by smooth muscles, but of a highly specialized type. Coiling around prey is accomplished largely by the return of the tentilla to their inactive state, but the coils may be tightened by smooth muscle.

There are eight rows of combs that run from near the mouth to the opposite end, and are spaced evenly round the body. The "combs" beat in a metachronal rhythm rather like that of a Mexican wave. From each balancer in the statocyst a ciliary groove runs out under the dome and then splits to connect with two adjacent comb rows, and in some species runs all the way along the comb rows. This forms a mechanical system for transmitting the beat rhythm from the combs to the balancers, via water disturbances created by the cilia.

The Lobata have a pair of lobes, which are muscular, cuplike extensions of the body that project beyond the mouth. Their inconspicuous tentacles originate from the corners of the mouth, running in convoluted grooves and spreading out over the inner surface of the lobes (rather than trailing far behind, as in the Cydippida). Between the lobes on either side of the mouth, many species of lobates have four auricles, gelatinous projections edged with cilia that produce water currents that help direct microscopic prey toward the mouth. This combination of structures enables lobates to feed continuously on suspended planktonic prey.

Lobates have eight comb-rows, originating at the aboral pole and usually not extending beyond the body to the lobes; in species with (four) auricles, the cilia edging the auricles are extensions of cilia in four of the comb rows. Most lobates are quite passive when moving through the water, using the cilia on their comb rows for propulsion, although *Leucothea* has long and active auricles whose movements also contribute to propulsion. Members of the lobate genera *Bathocyroe* and *Ocyropsis* can escape from danger by clapping their lobes, so that the jet of expelled water drives them backwards very quickly. Unlike cydippids, the movements of lobates' combs are coordinated by nerves rather than by water disturbances created by the cilia, yet combs on the same row beat in the same Mexican wave style as the mechanically coordinated comb rows of cydippids and beroids. This may have enabled lobates to grow larger than cydippids and to have shapes that are less egg-like.

The Beroida, also known as Nuda, have no feeding appendages, but their large pharynx, just inside the large mouth and filling most of the saclike body, bears "macrocilia" at the oral end. These fused bundles of several thousand large cilia are able to "bite" off pieces of prey that are too large to swallow whole – almost always other ctenophores. In front of the field of macrocilia, on the mouth "lips" in some species of *Beroe*, is a pair of narrow strips of adhesive epithelial cells on the stomach wall that "zip" the mouth shut when the animal is not feeding, by forming intercellular connections with the opposite adhesive strip. This tight closure streamlines the front of the animal when it is pursuing prey.

The Cestida ("belt animals") are ribbon-shaped planktonic animals, with the mouth and aboral organ aligned in the middle of opposite edges of the ribbon. There is a pair of comb-rows along each aboral edge, and tentilla emerging from a groove all along the oral edge, which stream back across most of the wing-like body surface. Cestids can swim by undulating their bodies as well as by the beating of their comb-rows. There are two known species, with worldwide distribution in warm, and warm-temperate waters: *Cestum veneris* ("Venus' girdle") is among the largest ctenophores – up to 1.5 meters (4.9 ft) long, and can undulate slowly or quite rapidly. *Velamen parallelum*, which is typically less than 20 centimeters (0.66 ft) long, can move much faster in what has been described as a "darting motion".

Most Platyctenida have oval bodies that are flattened in the oral-aboral direction, with a pair of

tentilla-bearing tentacles on the aboral surface. They cling to and creep on surfaces by everting the pharynx and using it as a muscular "foot". All but one of the known platyctenid species lack comb-rows. Platyctenids are usually cryptically colored, live on rocks, algae, or the body surfaces of other invertebrates, and are often revealed by their long tentacles with many sidebranches, seen streaming off the back of the ctenophore into the current.

Almost all species are hermaphrodites, in other words they function as both males and females at the same time – except that in two species of the genus *Ocryopsis* individuals remain of the same single sex all their lives. The gonads are located in the parts of the internal canal network under the comb rows, and eggs and sperm are released via pores in the epidermis. Fertilization is external in most species, but platyctenids use internal fertilization and keep the eggs in brood chambers until they hatch.

Self-fertilization has occasionally been seen in species of the genus *Mnemiopsis*, and it is thought that most of the hermaphroditic species are self-fertile.

Development of the fertilized eggs is direct, in other words there is no distinctive larval form, and juveniles of all groups generally resemble miniature cydippid adults. In the genus *Beroe* the juveniles, like the adults, lack tentacles and tentacle sheaths. In most species the juveniles gradually develop the body forms of their parents. In some groups, such as the flat, bottom-dwelling platyctenids, the juveniles behave more like true larvae, as they live among the plankton and thus occupy a different ecological niche from their parents and attain the adult form by a more radical metamorphosis, after dropping to the sea-floor.

When some species, including *Bathyctena chuni*, *Euplokamis stationis* and *Eurhamphaea vexilligera*, are disturbed, they produce secretions (ink) that luminesce at much the same wavelengths as their bodies. Juveniles will luminesce more brightly in relation to their body size than adults, whose luminescence is diffused over their bodies. Detailed statistical investigation has not suggested the function of ctenophores' bioluminescence nor produced any correlation between its exact color and any aspect of the animals' environments, such as depth or whether they live in coastal or mid-ocean waters.

Almost all ctenophores are predators – there are no vegetarians and only one genus that is partly parasitic. If food is plentiful, they can eat 10 times their own weight per day. While *Beroe* preys mainly on other ctenophores, other surface-water species prey on zooplankton (planktonic animals) ranging in size from the microscopic, including mollusc and fish larvae, to small adult crustaceans such as copepods, amphipods, and even krill. Members of the genus *Haeckelia* prey on jellyfish and incorporate their prey's nematocysts (stinging cells) into their own tentacles instead of colloblasts. Ctenophores have been compared to spiders in their wide range of techniques from capturing prey – some hang motionless in the water using their tentacles as "webs", some are ambush predators like Salticid jumping spiders, and some dangle a sticky droplet at the end of a fine thread, as bolas spiders do. This variety explains the wide range of body forms in a phylum with rather few species. The two-tentacled "cydippid" *Lampea* feeds exclusively on salps, close relatives of sea-squirts that form large chain-like floating colonies, and juveniles of *Lampea* attach themselves like parasites to salps that are too large for them to swallow. Members of the cydippid genus *Pleurobrachia* and the lobate *Bolinopsis* often reach high population densities at the same place and time because they specialize in different types of prey: *Pleurobrachia*'s long tentacles mainly capture relatively strong swimmers such as adult copepods, while *Bolinopsis* generally feeds on smaller, weaker swimmers such as rotifers and mollusc and crustacean larvae. Ctenophores used to be regarded as "dead ends" in marine food chains because it was thought their low ratio of organic matter to salt and water made them a poor diet for other animals. It is also often difficult to identify the remains of ctenophores in the guts of possible predators, although the combs sometimes remain intact long enough to provide a clue. Detailed investigation of chum salmon, *Oncorhynchus keta*, showed that these fish digest ctenophores 20 times as fast as an equal weight of shrimps, and that ctenophores can provide a good diet if there are enough of them around. Beroids prey mainly on other ctenophores. Some jellyfish and turtles eat large quantities of ctenophores, and jellyfish may temporarily wipe out ctenophore populations. Since ctenophores and jellyfish often have large seasonal variations in population, most fish that prey on them are generalists, and may have a greater effect on populations than the specialist jelly-eaters. This is underlined by an observation of herbivorous fishes deliberately feeding on gelatinous zooplankton during blooms in the Red Sea. The larvae of some sea anemones are parasites on ctenophores, as are the larvae of some flatworms that parasitize fish when they reach adulthood.

On the other hand, in the late 1980s the Western Atlantic ctenophore *Mnemiopsis leidyi* was accidentally

introduced into the Black Sea and Sea of Azov via the ballast tanks of ships, and has been blamed for causing sharp drops in fish catches by eating both fish larvae and small crustaceans that would otherwise feed the adult fish. Mnemiopsis is well equipped to invade new territories (although this was not predicted until after it so successfully colonized the Black Sea), as it can breed very rapidly and tolerate a wide range of water temperatures and salinities. The impact was increased by chronic overfishing, and by eutrophication that gave the entire ecosystem a short-term boost, causing the Mnemiopsis population to increase even faster than normal – and above all by the absence of efficient predators on these introduced ctenophores. Mnemiopsis populations in those areas were eventually brought under control by the accidental introduction of the Mnemiopsis-eating North American ctenophore *Beroe ovata*, and by a cooling of the local climate from 1991 to 1993, which significantly slowed the animal's metabolism. However the abundance of plankton in the area seems unlikely to be restored to pre-Mnemiopsis levels. Because of their soft, gelatinous bodies, ctenophores are extremely rare as fossils, and fossils that have been interpreted as ctenophores have been found only in lagerstätten, places where the environment was exceptionally suited to preservation of soft tissue. Until the mid-1990s only two specimens good enough for analysis were known, both members of the crown group, from the early Devonian (Emsian) period. Three additional putative species were then found in the Burgess Shale and other Canadian rocks of similar age, about 505 million years ago in the mid-Cambrian period. All three apparently lacked tentacles but had between 24 and 80 comb rows, far more than the 8 typical of living species. They also appear to have had internal organ-like structures unlike anything found in living ctenophores. One of the fossil species first reported in 1996 had a large mouth, apparently surrounded by a folded edge that may have been muscular. Evidence from China a year later suggests that such ctenophores were widespread in the Cambrian, but perhaps very different from modern species – for example one fossil's comb-rows were mounted on prominent vanes. The Ediacaran *Eoandromeda* could putatively represent a comb jelly. The early Cambrian sessile frond-like fossil *Stromatoveris*, from China's Chengjiang lagerstätte and dated to about 515 million years ago, is very similar to *Vendobionta* of the preceding Ediacaran period. De-Gan Shu, Simon Conway Morris et al. found on its branches what they considered rows of cilia, used for filter feeding. They suggested that *Stromatoveris* was an evolutionary "aunt" of ctenophores, and that ctenophores originated from sessile animals whose descendants became swimmers and changed the cilia from a feeding mechanism to a propulsion system.

The relationship of ctenophores to the rest of Metazoa is very important to our understanding of the early evolution of animals and the origin of multicellularity. It has been the focus of debate for many years. Ctenophores have been purported to be the sister lineage to the Bilateria, sister to the Cnidaria, sister to Cnidaria, Placozoa and Bilateria, and sister to all other animal phyla. A series of studies that looked at the presence and absence of members of gene families and signalling pathways (e.g., homeoboxes, nuclear receptors, the Wnt signaling pathway, and sodium channels) showed evidence congruent with the latter two scenarios, that ctenophores are either sister to Cnidaria, Placozoa and Bilateria or sister to all other animal phyla. Several more recent studies comparing complete sequenced genomes of ctenophores with other sequenced animal genomes have also supported ctenophores as the sister lineage to all other animals. This position would suggest that neural and muscle cell types were either lost in major animal lineages (e.g., Porifera) or that they evolved independently in the ctenophore lineage. However, other researchers have argued that the placement of Ctenophora as sister to all other animals is a statistical anomaly caused by the high rate of evolution in ctenophore genomes, and that Porifera (sponges) is the earliest-diverging animal phylum instead. Ctenophores and sponges are also the only known animal phyla that lack any true hox genes.

Since all modern ctenophores except the beroids have cydippid-like larvae, it has widely been assumed that their last common ancestor also resembled cydippids, having an egg-shaped body and a pair of retractable tentacles. Richard Harbison's purely morphological analysis in 1985 concluded that the cydippids are not monophyletic, in other words do not contain all and only the descendants of a single common ancestor that was itself a cydippid. Instead he found that various cydippid families were more similar to members of other ctenophore orders than to other cydippids. He also suggested that the last common ancestor of modern ctenophores was either cydippid-like or beroid-like. A molecular phylogeny analysis in 2001, using 26 species, including 4 recently discovered ones, confirmed that the cydippids are not monophyletic and concluded that the last common ancestor of modern ctenophores was cydippid-like. It also found that the genetic differences between these species were very small – so small that the relationships between the Lobata, Cestida and Thalassocalycida remained uncertain. This suggests that

the last common ancestor of modern ctenophores was relatively recent, and perhaps was lucky enough to survive the Cretaceous–Paleogene extinction event 65.5 million years ago while other lineages perished. When the analysis was broadened to include representatives of other phyla, it concluded that cnidarians are probably more closely related to bilaterians than either group is to ctenophores but that this diagnosis is uncertain.

Fresno (/ fr zno / FREZ-noh), the county seat of Fresno County, is a city in the U.S. state of California. As of 2015, the city's population was 520,159, making it the fifth-largest city in California, the largest inland city in California and the 34th-largest in the nation. Fresno is in the center of the San Joaquin Valley and is the largest city in the Central Valley, which contains the San Joaquin Valley. It is approximately 220 miles (350 km) northwest of Los Angeles, 170 miles (270 km) south of the state capital, Sacramento, or 185 miles (300 km) south of San Francisco. The name Fresno means "ash tree" in Spanish, and an ash leaf is featured on the city's flag.

In 1872, the Central Pacific Railroad established a station near Easterby's—by now a hugely productive wheat farm—for its new Southern Pacific line. Soon there was a store around the station and the store grew the town of Fresno Station, later called Fresno. Many Millerton residents, drawn by the convenience of the railroad and worried about flooding, moved to the new community. Fresno became an incorporated city in 1885. By 1931 the Fresno Traction Company operated 47 streetcars over 49 miles of track. Before World War II, Fresno had many ethnic neighborhoods, including Little Armenia, German Town, Little Italy, and Chinatown. In 1940, the Census Bureau reported Fresno's population as 94.0% white, 3.3% black and 2.7% Asian. (Incongruously, Chinatown was primarily a Japanese neighborhood and today Japanese-American businesses still remain). During 1942, Pinedale, in what is now North Fresno, was the site of the Pinedale Assembly Center, an interim facility for the relocation of Fresno area Japanese Americans to internment camps. The Fresno Fairgrounds was also utilized as an assembly center.

In September 1958, Bank of America launched a new product called BankAmericard in Fresno. After a troubled gestation during which its creator resigned, BankAmericard went on to become the first successful credit card; that is, a financial instrument that was usable across a large number of merchants and also allowed cardholders to revolve a balance (earlier financial products could do one or the other but not both). In 1976, BankAmericard was renamed and spun off into a separate company known today as Visa Inc.

In the 1970s, the city was the subject of a song, "Walking Into Fresno", written by Hall Of Fame guitarist Bill Aken and recorded by Bob Gallion of the world-famous "WWVA Jamboree" radio and television show in Wheeling, West Virginia. Aken, adopted by Mexican movie actress Lupe Mayorga, grew up in the neighboring town of Madera and his song chronicled the hardships faced by the migrant farm workers he saw as a child. Aken also made his first TV appearance playing guitar on the old country-western show at The Fresno Barn.

Fresno has three large public parks, two in the city limits and one in county land to the southwest. Woodward Park, which features the Shinzen Japanese Gardens, numerous picnic areas and several miles of trails, is in North Fresno and is adjacent to the San Joaquin River Parkway. Roeding Park, near Downtown Fresno, is home to the Fresno Chaffee Zoo, and Rotary Storyland and Playland. Kearney Park is the largest of the Fresno region's park system and is home to historic Kearney Mansion and plays host to the annual Civil War Revisited, the largest reenactment of the Civil War in the west coast of the U.S. Between the 1880s and World War II, Downtown Fresno flourished, filled with electric Street Cars, and contained some of the San Joaquin Valley's most beautiful architectural buildings. Among them, the original Fresno County Courthouse (demolished), the Fresno Carnegie Public Library (demolished), the Fresno Water Tower, the Bank of Italy Building, the Pacific Southwest Building, the San Joaquin Light & Power Building (currently known as the Grand 1401), and the Hughes Hotel (burned down), to name a few.

Fulton Street in Downtown Fresno was Fresno's main financial and commercial district before being converted into one of the nation's first pedestrian malls in 1964. Renamed the Fulton Mall, the area contains the densest collection of historic buildings in Fresno. While the Fulton Mall corridor has suffered a sharp decline from its heyday, the Mall includes some of the finest public art pieces in the country, including the only Pierre-Auguste Renoir piece in the world that one can walk up to and touch. Current plans call for the reopening of the Fulton Mall to automobile traffic. The public art pieces will be restored and placed near their current locations and will feature wide sidewalks (up to 28' on the east side of the

street) to continue with the pedestrian friendly environment of the district.

The neighborhood of Sunnyside is on Fresno's far southeast side, bounded by Chestnut Avenue to the West. Its major thoroughfares are Kings Canyon Avenue and Clovis Avenue. Although parts of Sunnyside are within the City of Fresno, much of the neighborhood is a "county island" within Fresno County. Largely developed in the 1950s through the 1970s, it has recently experienced a surge in new home construction. It is also the home of the Sunnyside Country Club, which maintains a golf course designed by William P. Bell.

The popular neighborhood known as the Tower District is centered around the historic Tower Theatre, which is included on the National List of Historic Places. The theater was built in 1939 and is at Olive and Wishon Avenues in the heart of the Tower District. (The name of the theater refers to a well-known landmark water tower, which is actually in another nearby area). The Tower District neighborhood is just north of downtown Fresno proper, and one-half mile south of Fresno City College. Although the neighborhood was known as a residential area prior, the early commercial establishments of the Tower District began with small shops and services that flocked to the area shortly after World War II. The character of small local businesses largely remains today. To some extent, the businesses of the Tower District were developed due to the proximity of the original Fresno Normal School, (later renamed California State University at Fresno). In 1916 the college moved to what is now the site of Fresno City College one-half mile north of the Tower District.

This vibrant and culturally diverse area of retail businesses and residences experienced a renewal after a significant decline in the late 1960s and 1970s.[citation needed] After decades of neglect and suburban flight, the neighborhood revival followed the re-opening of the Tower Theatre in the late 1970s, which at that time showed second and third run movies, along with classic films. Roger Rocka's Dinner Theater & Good Company Players also opened nearby in 1978,[citation needed] at Olive and Wishon Avenues. Fresno native Audra McDonald performed in the leading roles of Evita and The Wiz at the theater while she was a high school student. McDonald subsequently became a leading performer on Broadway in New York City and a Tony award winning actress. Also in the Tower District is Good Company Players' 2nd Space Theatre.

The neighborhood features restaurants, live theater and nightclubs, as well as several independent shops and bookstores, currently operating on or near Olive Avenue, and all within a few hundred feet of each other. Since renewal, the Tower District has become an attractive area for restaurant and other local businesses. Today, the Tower District is also known as the center of Fresno's LGBT and hipster Communities.; Additionally, Tower District is also known as the center of Fresno's local punk/goth/deathrock and heavy metal community.[citation needed]

The area is also known for its early twentieth century homes, many of which have been restored in recent decades. The area includes many California Bungalow and American Craftsman style homes, Spanish Colonial Revival Style architecture, Mediterranean Revival Style architecture, Mission Revival Style architecture, and many Storybook houses designed by Fresno architects, Hilliard, Taylor & Wheeler. The residential architecture of the Tower District contrasts with the newer areas of tract homes urban sprawl in north and east areas of Fresno.

Homes from the early 20th century line this boulevard in the heart of the historic Alta Vista Tract. The section of Huntington Boulevard between First Street on the west to Cedar Avenue on the east is the home to many large, stately homes. The original development of this area began circa 1910, on 190 acres of what had been an alfalfa field. The Alta Vista Tract, as the land would become known, was mapped by William Stranahan for the Pacific Improvement Corporation, and was officially platted in 1911. The tract's boundaries were Balch Avenue on the south, Cedar Avenue on the east, the rear property line of Platt Avenue (east of Sixth Street) and Platt Avenue (west of Sixth Street) on the north, and First Street on the west. The subdivision was annexed to the City in January 1912, in an election that was the first in which women voted in the community. At the time of its admission to the City, the Alta Vista Tract was uninhabited but landscaped, although the trees had to be watered by tank wagon. In 1914 developers Billings & Meyering acquired the tract, completed street development, provided the last of the necessary municipal improvements including water service, and began marketing the property with fervor. A mere half decade later the tract had 267 homes. This rapid development was no doubt hastened by the Fresno Traction Company right-of-way along Huntington Boulevard, which provided streetcar connections between downtown and the County Hospital.

The "West Side" of Fresno, also often called "Southwest Fresno", is one of the oldest neighborhoods in

the city. The neighborhood lies southwest of the 99 freeway (which divides it from Downtown Fresno), west of the 41 freeway and south of Nielsen Ave (or the newly constructed 180 Freeway), and extends to the city limits to the west and south. The neighborhood is traditionally considered to be the center of Fresno's African-American community. It is culturally diverse and also includes significant Mexican-American and Asian-American (principally Hmong or Laotian) populations.

The neighborhood includes Kearney Boulevard, named after early 20th century entrepreneur and millionaire M. Theo Kearney, which extends from Fresno Street in Southwest Fresno about 20 mi (32 km) west to Kerman, California. A small, two-lane rural road for most of its length, Kearney Boulevard is lined with tall palm trees. The roughly half-mile stretch of Kearney Boulevard between Fresno Street and Thorne Ave was at one time the preferred neighborhood for Fresno's elite African-American families. Another section, Brookhaven, on the southern edge of the West Side south of Jensen and west of Elm, was given the name by the Fresno City Council in an effort to revitalize the neighborhood's image. The isolated subdivision was for years known as the "Dogg Pound" in reference to a local gang, and as of late 2008 was still known for high levels of violent crime.

While many homes in the neighborhood date back to the 1930s or before, the neighborhood is also home to several public housing developments built between the 1960s and 1990s by the Fresno Housing Authority. The US Department of Housing and Urban Development has also built small subdivisions of single-family homes in the area for purchase by low-income working families. There have been numerous attempts to revitalize the neighborhood, including the construction of a modern shopping center on the corner of Fresno and B streets, an aborted attempt to build luxury homes and a golf course on the western edge of the neighborhood, and some new section 8 apartments have been built along Church Ave west of Elm St. Cargill Meat Solutions and Foster Farms both have large processing facilities in the neighborhood, and the stench from these (and other small industrial facilities) has long plagued area residents. The Fresno Chandler Executive Airport is also on the West Side. Due to its position on the edge of the city and years of neglect by developers, is not a true "inner-city" neighborhood, and there are many vacant lots, strawberry fields and vineyards throughout the neighborhood. The neighborhood has very little retail activity, aside from the area near Fresno Street and State Route 99 Freeway (Kearney Palm Shopping Center, built in the late 1990s) and small corner markets scattered throughout.

In the north eastern part of Fresno, Woodward Park was founded by the late Ralph Woodward, a long-time Fresno resident. He bequeathed a major portion of his estate in 1968 to provide a regional park and bird sanctuary in Northeast Fresno. The park lies on the South bank of the San Joaquin River between Highway 41 and Friant Road. The initial 235 acres (0.95 km<sup>2</sup>), combined with additional acres acquired later by the City, brings the park to a sizable 300 acres (1.2 km<sup>2</sup>). Now packed with amenities, Woodward Park is the only Regional Park of its size in the Central Valley. The Southeast corner of the park harbors numerous bird species offering bird enthusiasts an excellent opportunity for viewing. The park has a multi-use amphitheatre that seats up to 2,500 people, authentic Japanese Garden, fenced dog park, two-mile (3 km) equestrian trail, exercise par course, three children's playgrounds, a lake, 3 small ponds, 7 picnic areas and five miles (8 km) of multipurpose trails that are part of the San Joaquin River Parkway's Lewis S. Eaton Trail. When complete, the Lewis S. Eaton trail system will cover 22 miles (35 km) between Highway 99 and Friant Dam. The park's numerous picnic tables make for a great picnic destination and a convenient escape from city life. The park's amphetheatre was renovated in 2010, and has hosted performances by acts such as Deftones, Tech N9ne, and Sevendust as well as numerous others. The park is open April through October, 6am to 10pm and November through March, 6am to 7pm. Woodward Park is home to the annual CIF(California Interscholastic Federation) State Championship cross country meet, which takes place in late November. It is also the home of the Woodward Shakespeare Festival which began performances in the park in 2005.

Formed in 1946, Sierra Sky Park Airport is a residential airport community born of a unique agreement in transportation law to allow personal aircraft and automobiles to share certain roads. Sierra Sky Park was the first aviation community to be built[citation needed] and there are now numerous such communities across the United States and around the world. Developer William Smilie created the nation's first planned aviation community. Still in operation today, the public use airport provides a unique neighborhood that spawned interest and similar communities nationwide.

Fresno is marked by a semi-arid climate (Köppen BSh), with mild, moist winters and hot and dry summers, thus displaying Mediterranean characteristics. December and January are the coldest months, and average around 46.5 °F (8.1 °C), and there are 14 nights with freezing lows annually, with the coldest

night of the year typically bottoming out below 30 °F (−1.1 °C). July is the warmest month, averaging 83.0 °F (28.3 °C); normally, there are 32 days of 100 °F (37.8 °C)+ highs and 106 days of 90 °F (32.2 °C)+ highs, and in July and August, there are only three or four days where the high does not reach 90 °F (32.2 °C). Summers provide considerable sunshine, with July peaking at 97 percent of the total possible sunlight hours; conversely, January is the lowest with only 46 percent of the daylight time in sunlight because of thick tule fog. However, the year averages 81% of possible sunshine, for a total of 3550 hours. Average annual precipitation is around 11.5 inches (292.1 mm), which, by definition, would classify the area as a semidesert. Most of the wind rose direction occurrences derive from the northwest, as winds are driven downward along the axis of the California Central Valley; in December, January and February there is an increased presence of southeastern wind directions in the wind rose statistics. Fresno meteorology was selected in a national U.S. Environmental Protection Agency study for analysis of equilibrium temperature for use of ten-year meteorological data to represent a warm, dry western United States locale.

The official record high temperature for Fresno is 115 °F (46.1 °C), set on July 8, 1905, while the official record low is 17 °F (−8 °C), set on January 6, 1913. The average windows for 100 °F (37.8 °C)+, 90 °F (32.2 °C)+, and freezing temperatures are June 1 thru September 13, April 26 thru October 9, and December 10 thru January 28, respectively, and no freeze occurred between in the 1983/1984 season. Annual rainfall has ranged from 23.57 inches (598.7 mm) in the “rain year” from July 1982 to June 1983 down to 4.43 inches (112.5 mm) from July 1933 to June 1934. The most rainfall in one month was 9.54 inches (242.3 mm) in November 1885 and the most rainfall in 24 hours 3.55 inches (90.2 mm) on November 18, 1885. Measurable precipitation falls on an average of 48 days annually. Snow is a rarity; the heaviest snowfall at the airport was 2.2 inches (0.06 m) on January 21, 1962.

The 2010 United States Census reported that Fresno had a population of 494,665. The population density was 4,404.5 people per square mile (1,700.6/km<sup>2</sup>). The racial makeup of Fresno was 245,306 (49.6%) White, 40,960 (8.3%) African American, 8,525 (1.7%) Native American, 62,528 (12.6%) Asian (3.6% Hmong, 1.7% Indian, 1.2% Filipino, 1.2% Laotian, 1.0% Thai, 0.8% Cambodian, 0.7% Chinese, 0.5% Japanese, 0.4% Vietnamese, 0.2% Korean), 849 (0.2%) Pacific Islander, 111,984 (22.6%) from other races, and 24,513 (5.0%) from two or more races. Hispanic or Latino of any race were 232,055 persons (46.9%). Among the Hispanic population, 42.7% of the total population are Mexican, 0.4% Salvadoran, and 0.4% Puerto Rican. Non-Hispanic Whites were 30.0% of the population in 2010, down from 72.6% in 1970.

There were 158,349 households, of which 68,511 (43.3%) had children under the age of 18 living in them, 69,284 (43.8%) were opposite-sex married couples living together, 30,547 (19.3%) had a female householder with no husband present, 11,698 (7.4%) had a male householder with no wife present. There were 12,843 (8.1%) unmarried opposite-sex partnerships, and 1,388 (0.9%) same-sex married couples or partnerships. 35,064 households (22.1%) were made up of individuals and 12,344 (7.8%) had someone living alone who was 65 years of age or older. The average household size was 3.07. There were 111,529 families (70.4% of all households); the average family size was 3.62.

As of the census of 2000, there were 427,652 people, 140,079 households, and 97,915 families residing in the city. The population density was 4,097.9 people per square mile (1,582.2/km<sup>2</sup>). There were 149,025 housing units at an average density of 1,427.9 square miles (3,698 km<sup>2</sup>). The racial makeup of the city was 50.2% White, 8.4% Black or African American, 1.6% Native American, 11.2% Asian (about a third of which is Hmong), 0.1% Pacific Islander, 23.4% from other races, and 5.2% from two or more races. Hispanic or Latino of any race were 39.9% of the population.

To avoid interference with existing VHF television stations in the San Francisco Bay Area and those planned for Chico, Sacramento, Salinas, and Stockton, the Federal Communications Commission decided that Fresno would only have UHF television stations. The very first Fresno television station to begin broadcasting was KMJ-TV, which debuted on June 1, 1953. KMJ is now known as NBC affiliate KSEE. Other Fresno stations include ABC O&O KFSN, CBS affiliate KGPE, CW affiliate KFRE, FOX affiliate KMPH, MNTV affiliate KAIL, PBS affiliate KVPT, Telemundo O&O KNSO, Univision O&O KFTV, and MundoFox and Azteca affiliate KGMC-DT.

Fresno is served by State Route 99, the main north/south freeway that connects the major population centers of the California Central Valley. State Route 168, the Sierra Freeway, heads east to the city of Clovis and Huntington Lake. State Route 41 (Yosemite Freeway/Eisenhower Freeway) comes into Fresno from Atascadero in the south, and then heads north to Yosemite. State Route 180 (Kings Canyon

Freeway) comes from the west via Mendota, and from the east in Kings Canyon National Park going towards the city of Reedley.

Fresno is the largest U.S. city not directly linked to an Interstate highway. When the Interstate Highway System was created in the 1950s, the decision was made to build what is now Interstate 5 on the west side of the Central Valley, and thus bypass many of the population centers in the region, instead of upgrading what is now State Route 99. Due to rapidly raising population and traffic in cities along SR 99, as well as the desirability of Federal funding, much discussion has been made to upgrade it to interstate standards and eventually incorporate it into the interstate system, most likely as Interstate 9. Major improvements to signage, lane width, median separation, vertical clearance, and other concerns are currently underway.

Passenger rail service is provided by Amtrak San Joaquins. The main passenger rail station is the recently renovated historic Santa Fe Railroad Depot in Downtown Fresno. The Bakersfield-Stockton mainlines of the Burlington Northern Santa Fe Railway and Union Pacific Railroad railroads cross in Fresno, and both railroads maintain railyards within the city; the San Joaquin Valley Railroad also operates former Southern Pacific branchlines heading west and south out of the city. The city of Fresno is planned to serve the future California High Speed Rail.

Starting in the late 1950s, American computer scientist Paul Baran developed the concept Distributed Adaptive Message Block Switching with the goal to provide a fault-tolerant, efficient routing method for telecommunication messages as part of a research program at the RAND Corporation, funded by the US Department of Defense. This concept contrasted and contradicted the theretofore established principles of pre-allocation of network bandwidth, largely fortified by the development of telecommunications in the Bell System. The new concept found little resonance among network implementers until the independent work of Donald Davies at the National Physical Laboratory (United Kingdom) (NPL) in the late 1960s. Davies is credited with coining the modern name packet switching and inspiring numerous packet switching networks in Europe in the decade following, including the incorporation of the concept in the early ARPANET in the United States.

Packet switching contrasts with another principal networking paradigm, circuit switching, a method which pre-allocates dedicated network bandwidth specifically for each communication session, each having a constant bit rate and latency between nodes. In cases of billable services, such as cellular communication services, circuit switching is characterized by a fee per unit of connection time, even when no data is transferred, while packet switching may be characterized by a fee per unit of information transmitted, such as characters, packets, or messages.

Packet mode communication may be implemented with or without intermediate forwarding nodes (packet switches or routers). Packets are normally forwarded by intermediate network nodes asynchronously using first-in, first-out buffering, but may be forwarded according to some scheduling discipline for fair queuing, traffic shaping, or for differentiated or guaranteed quality of service, such as weighted fair queuing or leaky bucket. In case of a shared physical medium (such as radio or 10BASE5), the packets may be delivered according to a multiple access scheme.

Baran developed the concept of distributed adaptive message block switching during his research at the RAND Corporation for the US Air Force into survivable communications networks, first presented to the Air Force in the summer of 1961 as briefing B-265, later published as RAND report P-2626 in 1962, and finally in report RM 3420 in 1964. Report P-2626 described a general architecture for a large-scale, distributed, survivable communications network. The work focuses on three key ideas: use of a decentralized network with multiple paths between any two points, dividing user messages into message blocks, later called packets, and delivery of these messages by store and forward switching.

Starting in 1965, Donald Davies at the National Physical Laboratory, UK, independently developed the same message routing methodology as developed by Baran. He called it packet switching, a more accessible name than Baran's, and proposed to build a nationwide network in the UK. He gave a talk on the proposal in 1966, after which a person from the Ministry of Defence (MoD) told him about Baran's work. A member of Davies' team (Roger Scantlebury) met Lawrence Roberts at the 1967 ACM Symposium on Operating System Principles and suggested it for use in the ARPANET.

In connectionless mode each packet includes complete addressing information. The packets are routed individually, sometimes resulting in different paths and out-of-order delivery. Each packet is labeled with a destination address, source address, and port numbers. It may also be labeled with the sequence number of the packet. This precludes the need for a dedicated path to help the packet find its way to its



destination, but means that much more information is needed in the packet header, which is therefore larger, and this information needs to be looked up in power-hungry content-addressable memory. Each packet is dispatched and may go via different routes; potentially, the system has to do as much work for every packet as the connection-oriented system has to do in connection set-up, but with less information as to the application's requirements. At the destination, the original message/data is reassembled in the correct order, based on the packet sequence number. Thus a virtual connection, also known as a virtual circuit or byte stream is provided to the end-user by a transport layer protocol, although intermediate network nodes only provides a connectionless network layer service.

Connection-oriented transmission requires a setup phase in each involved node before any packet is transferred to establish the parameters of communication. The packets include a connection identifier rather than address information and are negotiated between endpoints so that they are delivered in order and with error checking. Address information is only transferred to each node during the connection set-up phase, when the route to the destination is discovered and an entry is added to the switching table in each network node through which the connection passes. The signaling protocols used allow the application to specify its requirements and discover link parameters. Acceptable values for service parameters may be negotiated. Routing a packet requires the node to look up the connection id in a table. The packet header can be small, as it only needs to contain this code and any information, such as length, timestamp, or sequence number, which is different for different packets.

Both X.25 and Frame Relay provide connection-oriented operations. But X.25 does it at the network layer of the OSI Model. Frame Relay does it at level two, the data link layer. Another major difference between X.25 and Frame Relay is that X.25 requires a handshake between the communicating parties before any user packets are transmitted. Frame Relay does not define any such handshakes. X.25 does not define any operations inside the packet network. It only operates at the user-network-interface (UNI). Thus, the network provider is free to use any procedure it wishes inside the network. X.25 does specify some limited re-transmission procedures at the UNI, and its link layer protocol (LAPB) provides conventional HDLC-type link management procedures. Frame Relay is a modified version of ISDN's layer two protocol, LAPD and LAPB. As such, its integrity operations pertain only between nodes on a link, not end-to-end. Any retransmissions must be carried out by higher layer protocols. The X.25 UNI protocol is part of the X.25 protocol suite, which consists of the lower three layers of the OSI Model. It was widely used at the UNI for packet switching networks during the 1980s and early 1990s, to provide a standardized interface into and out of packet networks. Some implementations used X.25 within the network as well, but its connection-oriented features made this setup cumbersome and inefficient. Frame relay operates principally at layer two of the OSI Model. However, its address field (the Data Link Connection ID, or DLCI) can be used at the OSI network layer, with a minimum set of procedures. Thus, it rids itself of many X.25 layer 3 encumbrances, but still has the DLCI as an ID beyond a node-to-node layer two link protocol. The simplicity of Frame Relay makes it faster and more efficient than X.25. Because Frame relay is a data link layer protocol, like X.25 it does not define internal network routing operations. For X.25 its packet IDs---the virtual circuit and virtual channel numbers have to be correlated to network addresses. The same is true for Frame Relays DLCI. How this is done is up to the network provider. Frame Relay, by virtue of having no network layer procedures is connection-oriented at layer two, by using the HDLC/LAPD/LAPB Set Asynchronous Balanced Mode (SABM). X.25 connections are typically established for each communication session, but it does have a feature allowing a limited amount of traffic to be passed across the UNI without the connection-oriented handshake. For a while, Frame Relay was used to interconnect LANs across wide area networks. However, X.25 and well as Frame Relay have been supplanted by the Internet Protocol (IP) at the network layer, and the Asynchronous Transfer Mode (ATM) and or versions of Multi-Protocol Label Switching (MPLS) at layer two. A typical configuration is to run IP over ATM or a version of MPLS. <Uyless Black, X.25 and Related Protocols, IEEE Computer Society, 1991> <Uyless Black, Frame Relay Networks, McGraw-Hill, 1998> <Uyless Black, MPLS and Label Switching Networks, Prentice Hall, 2001> < Uyless Black, ATM, Volume I, Prentice Hall, 1995> ARPANET and SITA HLN became operational in 1969. Before the introduction of X.25 in 1973, about twenty different network technologies had been developed. Two fundamental differences involved the division of functions and tasks between the hosts at the edge of the network and the network core. In the datagram system, the hosts have the responsibility to ensure orderly delivery of packets. The User Datagram Protocol (UDP) is an example of a datagram protocol. In the virtual call system, the network guarantees sequenced delivery of data to the host. This results in a simpler host interface with less

functionality than in the datagram model. The X.25 protocol suite uses this network type.

AppleTalk was a proprietary suite of networking protocols developed by Apple Inc. in 1985 for Apple Macintosh computers. It was the primary protocol used by Apple devices through the 1980s and 90s. AppleTalk included features that allowed local area networks to be established ad hoc without the requirement for a centralized router or server. The AppleTalk system automatically assigned addresses, updated the distributed namespace, and configured any required inter-network routing. It was a plug-n-play system.

The CYCLADES packet switching network was a French research network designed and directed by Louis Pouzin. First demonstrated in 1973, it was developed to explore alternatives to the early ARPANET design and to support network research generally. It was the first network to make the hosts responsible for reliable delivery of data, rather than the network itself, using unreliable datagrams and associated end-to-end protocol mechanisms. Concepts of this network influenced later ARPANET architecture.

DECnet is a suite of network protocols created by Digital Equipment Corporation, originally released in 1975 in order to connect two PDP-11 minicomputers. It evolved into one of the first peer-to-peer network architectures, thus transforming DEC into a networking powerhouse in the 1980s. Initially built with three layers, it later (1982) evolved into a seven-layer OSI-compliant networking protocol. The DECnet protocols were designed entirely by Digital Equipment Corporation. However, DECnet Phase II (and later) were open standards with published specifications, and several implementations were developed outside DEC, including one for Linux.

In 1965, at the instigation of Warner Sinback, a data network based on this voice-phone network was designed to connect GE's four computer sales and service centers (Schenectady, Phoenix, Chicago, and Phoenix) to facilitate a computer time-sharing service, apparently the world's first commercial online service. (In addition to selling GE computers, the centers were computer service bureaus, offering batch processing services. They lost money from the beginning, and Sinback, a high-level marketing manager, was given the job of turning the business around. He decided that a time-sharing system, based on Kemney's work at Dartmouth—which used a computer on loan from GE—could be profitable. Warner was right.)

Merit Network, Inc., an independent non-profit 501(c)(3) corporation governed by Michigan's public universities, was formed in 1966 as the Michigan Educational Research Information Triad to explore computer networking between three of Michigan's public universities as a means to help the state's educational and economic development. With initial support from the State of Michigan and the National Science Foundation (NSF), the packet-switched network was first demonstrated in December 1971 when an interactive host to host connection was made between the IBM mainframe computer systems at the University of Michigan in Ann Arbor and Wayne State University in Detroit. In October 1972 connections to the CDC mainframe at Michigan State University in East Lansing completed the triad. Over the next several years in addition to host to host interactive connections the network was enhanced to support terminal to host connections, host to host batch connections (remote job submission, remote printing, batch file transfer), interactive file transfer, gateways to the Tymnet and Telenet public data networks, X.25 host attachments, gateways to X.25 data networks, Ethernet attached hosts, and eventually TCP/IP and additional public universities in Michigan join the network. All of this set the stage for Merit's role in the NSFNET project starting in the mid-1980s.

Telenet was the first FCC-licensed public data network in the United States. It was founded by former ARPA IPTO director Larry Roberts as a means of making ARPANET technology public. He had tried to interest AT&T in buying the technology, but the monopoly's reaction was that this was incompatible with their future. Bolt, Beranack and Newman (BBN) provided the financing. It initially used ARPANET technology but changed the host interface to X.25 and the terminal interface to X.29. Telenet designed these protocols and helped standardize them in the CCITT. Telenet was incorporated in 1973 and started operations in 1975. It went public in 1979 and was then sold to GTE.

Tymnet was an international data communications network headquartered in San Jose, CA that utilized virtual call packet switched technology and used X.25, SNA/SDLC, BSC and ASCII interfaces to connect host computers (servers) at thousands of large companies, educational institutions, and government agencies. Users typically connected via dial-up connections or dedicated async connections. The business consisted of a large public network that supported dial-up users and a private network business that allowed government agencies and large companies (mostly banks and airlines) to build their own dedicated networks. The private networks were often connected via gateways to the public network to

reach locations not on the private network. Tymnet was also connected to dozens of other public networks in the U.S. and internationally via X.25/X.75 gateways. (Interesting note: Tymnet was not named after Mr. Tyme. Another employee suggested the name.)

There were two kinds of X.25 networks. Some such as DATAPAC and TRANSPAC were initially implemented with an X.25 external interface. Some older networks such as TELENET and TYMNET were modified to provide a X.25 host interface in addition to older host connection schemes. DATAPAC was developed by Bell Northern Research which was a joint venture of Bell Canada (a common carrier) and Northern Telecom (a telecommunications equipment supplier). Northern Telecom sold several DATAPAC clones to foreign PTTs including the Deutsche Bundespost. X.75 and X.121 allowed the interconnection of national X.25 networks. A user or host could call a host on a foreign network by including the DNIC of the remote network as part of the destination address.[citation needed]

AUSTPAC was an Australian public X.25 network operated by Telstra. Started by Telecom Australia in the early 1980s, AUSTPAC was Australia's first public packet-switched data network, supporting applications such as on-line betting, financial applications — the Australian Tax Office made use of AUSTPAC — and remote terminal access to academic institutions, who maintained their connections to AUSTPAC up until the mid-late 1990s in some cases. Access can be via a dial-up terminal to a PAD, or, by linking a permanent X.25 node to the network.[citation needed]

Datanet 1 was the public switched data network operated by the Dutch PTT Telecom (now known as KPN). Strictly speaking Datanet 1 only referred to the network and the connected users via leased lines (using the X.121 DNIC 2041), the name also referred to the public PAD service Telepad (using the DNIC 2049). And because the main Videotex service used the network and modified PAD devices as infrastructure the name Datanet 1 was used for these services as well. Although this use of the name was incorrect all these services were managed by the same people within one department of KPN contributed to the confusion.

The Computer Science Network (CSNET) was a computer network funded by the U.S. National Science Foundation (NSF) that began operation in 1981. Its purpose was to extend networking benefits, for computer science departments at academic and research institutions that could not be directly connected to ARPANET, due to funding or authorization limitations. It played a significant role in spreading awareness of, and access to, national networking and was a major milestone on the path to development of the global Internet.

Internet2 is a not-for-profit United States computer networking consortium led by members from the research and education communities, industry, and government. The Internet2 community, in partnership with Qwest, built the first Internet2 Network, called Abilene, in 1998 and was a prime investor in the National LambdaRail (NLR) project. In 2006, Internet2 announced a partnership with Level 3 Communications to launch a brand new nationwide network, boosting its capacity from 10 Gbit/s to 100 Gbit/s. In October, 2007, Internet2 officially retired Abilene and now refers to its new, higher capacity network as the Internet2 Network.

The National Science Foundation Network (NSFNET) was a program of coordinated, evolving projects sponsored by the National Science Foundation (NSF) beginning in 1985 to promote advanced research and education networking in the United States. NSFNET was also the name given to several nationwide backbone networks operating at speeds of 56 kbit/s, 1.5 Mbit/s (T1), and 45 Mbit/s (T3) that were constructed to support NSF's networking initiatives from 1985-1995. Initially created to link researchers to the nation's NSF-funded supercomputing centers, through further public funding and private industry partnerships it developed into a major part of the Internet backbone.

The Very high-speed Backbone Network Service (vBNS) came on line in April 1995 as part of a National Science Foundation (NSF) sponsored project to provide high-speed interconnection between NSF-sponsored supercomputing centers and select access points in the United States. The network was engineered and operated by MCI Telecommunications under a cooperative agreement with the NSF. By 1998, the vBNS had grown to connect more than 100 universities and research and engineering institutions via 12 national points of presence with DS-3 (45 Mbit/s), OC-3c (155 Mbit/s), and OC-12c (622 Mbit/s) links on an all OC-12c backbone, a substantial engineering feat for that time. The vBNS installed one of the first ever production OC-48c (2.5 Gbit/s) IP links in February 1999 and went on to upgrade the entire backbone to OC-48c.

The Black Death is thought to have originated in the arid plains of Central Asia, where it then travelled along the Silk Road, reaching Crimea by 1343. From there, it was most likely carried by Oriental rat fleas

living on the black rats that were regular passengers on merchant ships. Spreading throughout the Mediterranean and Europe, the Black Death is estimated to have killed 30–60% of Europe's total population. In total, the plague reduced the world population from an estimated 450 million down to 350–375 million in the 14th century. The world population as a whole did not recover to pre-plague levels until the 17th century. The plague recurred occasionally in Europe until the 19th century.

The plague disease, caused by *Yersinia pestis*, is enzootic (commonly present) in populations of fleas carried by ground rodents, including marmots, in various areas including Central Asia, Kurdistan, Western Asia, Northern India and Uganda. Nestorian graves dating to 1338–39 near Lake Issyk Kul in Kyrgyzstan have inscriptions referring to plague and are thought by many epidemiologists to mark the outbreak of the epidemic, from which it could easily have spread to China and India. In October 2010, medical geneticists suggested that all three of the great waves of the plague originated in China. In China, the 13th century Mongol conquest caused a decline in farming and trading. However, economic recovery had been observed at the beginning of the 14th century. In the 1330s a large number of natural disasters and plagues led to widespread famine, starting in 1331, with a deadly plague arriving soon after. Epidemics that may have included plague killed an estimated 25 million Chinese and other Asians during the 15 years before it reached Constantinople in 1347.

Plague was reportedly first introduced to Europe via Genoese traders at the port city of Kaffa in the Crimea in 1347. After a protracted siege, during which the Mongol army under Jani Beg was suffering from the disease, the army catapulted the infected corpses over the city walls of Kaffa to infect the inhabitants. The Genoese traders fled, taking the plague by ship into Sicily and the south of Europe, whence it spread north. Whether or not this hypothesis is accurate, it is clear that several existing conditions such as war, famine, and weather contributed to the severity of the Black Death.

From Italy, the disease spread northwest across Europe, striking France, Spain, Portugal and England by June 1348, then turned and spread east through Germany and Scandinavia from 1348 to 1350. It was introduced in Norway in 1349 when a ship landed at Askøy, then spread to Bjørgvin (modern Bergen) and Iceland. Finally it spread to northwestern Russia in 1351. The plague was somewhat less common in parts of Europe that had smaller trade relations with their neighbours, including the Kingdom of Poland, the majority of the Basque Country, isolated parts of Belgium and the Netherlands, and isolated alpine villages throughout the continent.

The plague struck various countries in the Middle East during the pandemic, leading to serious depopulation and permanent change in both economic and social structures. As it spread to western Europe, the disease entered the region from southern Russia also. By autumn 1347, the plague reached Alexandria in Egypt, probably through the port's trade with Constantinople, and ports on the Black Sea. During 1347, the disease travelled eastward to Gaza, and north along the eastern coast to cities in Lebanon, Syria and Palestine, including Ashkelon, Acre, Jerusalem, Sidon, Damascus, Homs, and Aleppo. In 1348–49, the disease reached Antioch. The city's residents fled to the north, most of them dying during the journey, but the infection had been spread to the people of Asia Minor.[citation needed] Gasquet (1908) claimed that the Latin name *atra mors* (Black Death) for the 14th-century epidemic first appeared in modern times in 1631 in a book on Danish history by J.I. Pontanus: "*Vulgo & ab effectu atram mortem vocatibant.*" ("Commonly and from its effects, they called it the black death"). The name spread through Scandinavia and then Germany, gradually becoming attached to the mid 14th-century epidemic as a proper name. In England, it was not until 1823 that the medieval epidemic was first called the Black Death.

Medical knowledge had stagnated during the Middle Ages. The most authoritative account at the time came from the medical faculty in Paris in a report to the king of France that blamed the heavens, in the form of a conjunction of three planets in 1345 that caused a "great pestilence in the air". This report became the first and most widely circulated of a series of plague tracts that sought to give advice to sufferers. That the plague was caused by bad air became the most widely accepted theory. Today, this is known as the Miasma theory. The word 'plague' had no special significance at this time, and only the recurrence of outbreaks during the Middle Ages gave it the name that has become the medical term. The dominant explanation for the Black Death is the plague theory, which attributes the outbreak to *Yersinia pestis*, also responsible for an epidemic that began in southern China in 1865, eventually spreading to India. The investigation of the pathogen that caused the 19th-century plague was begun by teams of scientists who visited Hong Kong in 1894, among whom was the French-Swiss bacteriologist Alexandre Yersin, after whom the pathogen was named *Yersinia pestis*. The mechanism by which *Y.*

pestis was usually transmitted was established in 1898 by Paul-Louis Simond and was found to involve the bites of fleas whose midguts had become obstructed by replicating *Y. pestis* several days after feeding on an infected host. This blockage results in starvation and aggressive feeding behaviour by the fleas, which repeatedly attempt to clear their blockage by regurgitation, resulting in thousands of plague bacteria being flushed into the feeding site, infecting the host. The bubonic plague mechanism was also dependent on two populations of rodents: one resistant to the disease, which act as hosts, keeping the disease endemic, and a second that lack resistance. When the second population dies, the fleas move on to other hosts, including people, thus creating a human epidemic.

The historian Francis Aidan Gasquet wrote about the 'Great Pestilence' in 1893 and suggested that "it would appear to be some form of the ordinary Eastern or bubonic plague". He was able to adopt the epidemiology of the bubonic plague for the Black Death for the second edition in 1908, implicating rats and fleas in the process, and his interpretation was widely accepted for other ancient and medieval epidemics, such as the Justinian plague that was prevalent in the Eastern Roman Empire from 541 to 700 CE.

Other forms of plague have been implicated by modern scientists. The modern bubonic plague has a mortality rate of 30–75% and symptoms including fever of 38–41 °C (100–106 °F), headaches, painful aching joints, nausea and vomiting, and a general feeling of malaise. Left untreated, of those that contract the bubonic plague, 80 percent die within eight days. Pneumonic plague has a mortality rate of 90 to 95 percent. Symptoms include fever, cough, and blood-tinged sputum. As the disease progresses, sputum becomes free flowing and bright red. Septicemic plague is the least common of the three forms, with a mortality rate near 100%. Symptoms are high fevers and purple skin patches (purpura due to disseminated intravascular coagulation). In cases of pneumonic and particularly septicemic plague, the progress of the disease is so rapid that there would often be no time for the development of the enlarged lymph nodes that were noted as buboes.

In October 2010, the open-access scientific journal PLoS Pathogens published a paper by a multinational team who undertook a new investigation into the role of *Yersinia pestis* in the Black Death following the disputed identification by Drancourt and Raoult in 1998. They assessed the presence of DNA/RNA with Polymerase Chain Reaction (PCR) techniques for *Y. pestis* from the tooth sockets in human skeletons from mass graves in northern, central and southern Europe that were associated archaeologically with the Black Death and subsequent resurgences. The authors concluded that this new research, together with prior analyses from the south of France and Germany, ". . . ends the debate about the etiology of the Black Death, and unambiguously demonstrates that *Y. pestis* was the causative agent of the epidemic plague that devastated Europe during the Middle Ages".

The study also found that there were two previously unknown but related clades (genetic branches) of the *Y. pestis* genome associated with medieval mass graves. These clades (which are thought to be extinct) were found to be ancestral to modern isolates of the modern *Y. pestis* strains *Y. p. orientalis* and *Y. p. medievalis*, suggesting the plague may have entered Europe in two waves. Surveys of plague pit remains in France and England indicate the first variant entered Europe through the port of Marseille around November 1347 and spread through France over the next two years, eventually reaching England in the spring of 1349, where it spread through the country in three epidemics. Surveys of plague pit remains from the Dutch town of Bergen op Zoom showed the *Y. pestis* genotype responsible for the pandemic that spread through the Low Countries from 1350 differed from that found in Britain and France, implying Bergen op Zoom (and possibly other parts of the southern Netherlands) was not directly infected from England or France in 1349 and suggesting a second wave of plague, different from those in Britain and France, may have been carried to the Low Countries from Norway, the Hanseatic cities or another site. The results of the Haensch study have since been confirmed and amended. Based on genetic evidence derived from Black Death victims in the East Smithfield burial site in England, Schuenemann et al. concluded in 2011 "that the Black Death in medieval Europe was caused by a variant of *Y. pestis* that may no longer exist." A study published in Nature in October 2011 sequenced the genome of *Y. pestis* from plague victims and indicated that the strain that caused the Black Death is ancestral to most modern strains of the disease.

The plague theory was first significantly challenged by the work of British bacteriologist J. F. D. Shrewsbury in 1970, who noted that the reported rates of mortality in rural areas during the 14th-century pandemic were inconsistent with the modern bubonic plague, leading him to conclude that contemporary accounts were exaggerations. In 1984 zoologist Graham Twigg produced the first major work to challenge

the bubonic plague theory directly, and his doubts about the identity of the Black Death have been taken up by a number of authors, including Samuel K. Cohn, Jr. (2002), David Herlihy (1997), and Susan Scott and Christopher Duncan (2001).

It is recognised that an epidemiological account of the plague is as important as an identification of symptoms, but researchers are hampered by the lack of reliable statistics from this period. Most work has been done on the spread of the plague in England, and even estimates of overall population at the start vary by over 100% as no census was undertaken between the time of publication of the Domesday Book and the year 1377. Estimates of plague victims are usually extrapolated from figures from the clergy. In addition to arguing that the rat population was insufficient to account for a bubonic plague pandemic, sceptics of the bubonic plague theory point out that the symptoms of the Black Death are not unique (and arguably in some accounts may differ from bubonic plague); that transference via fleas in goods was likely to be of marginal significance; and that the DNA results may be flawed and might not have been repeated elsewhere, despite extensive samples from other mass graves. Other arguments include the lack of accounts of the death of rats before outbreaks of plague between the 14th and 17th centuries; temperatures that are too cold in northern Europe for the survival of fleas; that, despite primitive transport systems, the spread of the Black Death was much faster than that of modern bubonic plague; that mortality rates of the Black Death appear to be very high; that, while modern bubonic plague is largely endemic as a rural disease, the Black Death indiscriminately struck urban and rural areas; and that the pattern of the Black Death, with major outbreaks in the same areas separated by 5 to 15 years, differs from modern bubonic plague—which often becomes endemic for decades with annual flare-ups.

A variety of alternatives to the *Y. pestis* have been put forward. Twigg suggested that the cause was a form of anthrax, and Norman Cantor (2001) thought it may have been a combination of anthrax and other pandemics. Scott and Duncan have argued that the pandemic was a form of infectious disease that characterise as hemorrhagic plague similar to Ebola. Archaeologist Barney Sloane has argued that there is insufficient evidence of the extinction of a large number of rats in the archaeological record of the medieval waterfront in London and that the plague spread too quickly to support the thesis that the *Y. pestis* was spread from fleas on rats; he argues that transmission must have been person to person. However, no single alternative solution has achieved widespread acceptance. Many scholars arguing for the *Y. pestis* as the major agent of the pandemic suggest that its extent and symptoms can be explained by a combination of bubonic plague with other diseases, including typhus, smallpox and respiratory infections. In addition to the bubonic infection, others point to additional septicemic (a type of "blood poisoning") and pneumonic (an airborne plague that attacks the lungs before the rest of the body) forms of the plague, which lengthen the duration of outbreaks throughout the seasons and help account for its high mortality rate and additional recorded symptoms. In 2014, scientists with Public Health England announced the results of an examination of 25 bodies exhumed from the Clerkenwell area of London, as well as of wills registered in London during the period, which supported the pneumonic hypothesis. The most widely accepted estimate for the Middle East, including Iraq, Iran and Syria, during this time, is for a death rate of about a third. The Black Death killed about 40% of Egypt's population. Half of Paris's population of 100,000 people died. In Italy, the population of Florence was reduced from 110–120 thousand inhabitants in 1338 down to 50 thousand in 1351. At least 60% of the population of Hamburg and Bremen perished, and a similar percentage of Londoners may have died from the disease as well. Interestingly while contemporary reports account of mass burial pits being created in response to the large numbers of dead, recent scientific investigations of a burial pit in Central London found well-preserved individuals to be buried in isolated, evenly spaced graves, suggesting at least some pre-planning and Christian burials at this time. Before 1350, there were about 170,000 settlements in Germany, and this was reduced by nearly 40,000 by 1450. In 1348, the plague spread so rapidly that before any physicians or government authorities had time to reflect upon its origins, about a third of the European population had already perished. In crowded cities, it was not uncommon for as much as 50% of the population to die. The disease bypassed some areas, and the most isolated areas were less vulnerable to contagion. Monks and priests were especially hard hit since they cared for victims of the Black Death.