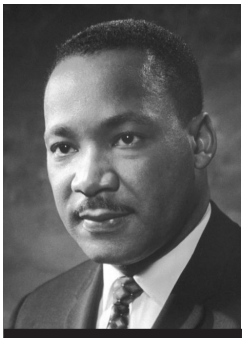
Chapter 1

The Many Faces of Intelligence

Intelligence is like porn, difficult to define, but you know it when you see it.
–Justice Potter Stewart, US Supreme Court (1964)

Where do you see yourself on the intelligence scale? From your first entry through the forbidding doors of your elementary school to the time you graduated high school, you were forming an opinion of your status and your abilities. Your school grades, your IQ tests, and the way you were perceived by your teachers and fellow students all played a role in shaping your perception of your intellectual potential and limitations. This perception, as it evolved, became the most important factor in shaping the trajectory of your life. Your choice of post secondary education, whether at a community college, state college, or prestigious university was heavily influenced by this perception, determining the angle at which your career path was launched. If you perceived yourself as highly intelligent or gifted, this perception probably set your trajectory at a steep angle. However, if you perceived yourself as low on the intellectual scale, there's a good chance that you sold yourself short. While "book smarts" is an invaluable attribute, it is only one face of intelligence; life teaches us that intelligence, like success, has many faces. In the next few pages we will visit several of them.

Intelligence as Articulation and Persuasive Oratory



Martin Luther King Jr.
1929 – 1968

On August 28, 1963, a quarter of a million protestors joined Dr. Martin Luther King Jr. in a march on Washington D.C., demanding equal civil and economic rights for African Americans. The highlight of that event was a speech delivered by Dr. King that would signal the beginning of the end of segregation in the United States.

The night before the march, King had worked frenetically with his speech writer Clarence B. Jones, who had provided him with a summary of ideas that the two men had previously discussed. A few hours later, the man who would become the face of the civil rights movement in America, was delivering his talk from the rapidly prepared draft that had emerged the previous night. Beginning with a reference to the Emancipation Proclamation that Abraham Lincoln had signed 100 years earlier, Dr. King addressed the entire nation:[1]

> *Five score years ago, a great American, in whose symbolic shadow we stand today, signed the Emancipation Proclamation. This momentous decree came as a great beacon light of hope to millions of Negro slaves who had been seared in the flames of withering injustice. It came as a joyous daybreak to end the long night of their captivity.*

After lamenting the inequalities that still remained a century after the emancipation, he emphasized the importance of non-violent civil disobedience, setting a conciliatory, but firm, tone in his call for an end to discrimination. Then, the voice of gospel singer Mahalia Jackson rose from the crowd, "Tell them about the dream, Martin." Dr. King paused as if shifting into high gear and then, seized with a passion that seemed to well up from deep within, he put his written draft aside and embarked upon his "I have a dream" refrain that changed history.

> *I say to you today, my friends, so even though we face the difficulties of today and tomorrow, I still have a dream. It is a dream deeply rooted in the American dream.*
>
> *I have a dream that one day this nation will rise up and live out the true meaning of its creed: "We hold these truths to be self-evident: that all men are created equal."*
>
> *I have a dream that one day on the red hills of Georgia the sons of former slaves and the sons of former slave owners will be able to sit down together at the table of brotherhood.*

I have a dream that one day even the state of Mississippi, a state sweltering with the heat of injustice, sweltering with the heat of oppression, will be transformed into an oasis of freedom and justice.

I have a dream that my four little children will one day live in a nation where they will not be judged by the color of their skin but by the content of their character. I have a dream today.

Then, building on the energy of the tumultuous cheers, he concluded with a joyful vision of a future America:

And when this happens, when we allow freedom to ring, when we let it ring from every village and every hamlet, from every state and every city, we will be able to speed up that day when all of God's children, black men and white men, Jews and Gentiles, Protestants and Catholics, will be able to join hands and sing in the words of the old Negro spiritual, "Free at last! free at last! thank God Almighty, we are free at last!"

King's highly-charged delivery, punctuated with historical allusions, biblical references, and vivid metaphor, galvanized the Civil Rights Movement and sharpened its focus. On July 2, 1964, less than a year after the speech, Lyndon Johnson signed the Civil Rights Act that ended segregation and banned discrimination on the basis of race. King's speech is regarded as one of the greatest in history, not only for its persuasive impact but also for its effect on racial equality in America.

Was Martin Luther King Jr. intelligent? He learned to play the piano at a young age and is reported to have enjoyed opera. At the age of 13, he became assistant manager at one of the *Atlanta Journal* newspaper delivery stations–the youngest to hold such a position. He skipped grade 9, leaping from grade 8 into grade 10 at Booker T. Washington High School. He joined the school debating team and it was soon apparent that he possessed a special affinity for public-speaking. In his junior year, he won first prize in the Negro Elks Club oratorical contest. In that same year, at the age of 15, he passed the entrance examination to Morehouse College and graduated with a B.A. in sociology at age 19. At age 25, he became Dr. Martin Luther King Jr., having completed a Ph.D. in theology.

It was no accident that he rose to prominence. His intelligence was manifest in his creation and delivery of passionate speeches containing highly persuasive metaphors and compelling argumentation–a rare combination of rational thinking combined with interpersonal insight. He honed his skill by studying dictionaries to increase his vocabulary and expand his ability to find the right word to express an idea with eloquence. Clarence P.

Jones, in an interview with *The Wall Street Journal*, said that his contribution to King's speech came only in the first 7 paragraphs. The rest of the written draft came from King, but the "I have a dream portion," that followed Mahalia Jackson's call, was purely spontaneous. Commenting on the change that came over King as he launched into that portion of the speech, Jones observed:[2]

> *I have never seen him speak the way I saw him on that day…It was as if some cosmic transcendental force came down and occupied his body. It was the same body, the same voice, but the voice had something I had never heard before.*

Oratorical excellence has been celebrated as a form of intelligence since the beginning of the written word. In 725 BCE, the ancient Greek author, Homer wrote:

> *So, the gods don't hand out all their gifts at once, not build and brains and flowing speech to all. One man may fail to impress us with his looks but a god can crown his words with beauty, charm, and men look on with delight when he speaks out.*

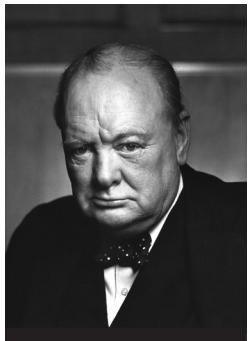
Among those in the ancient world who have displayed this face of intelligence were Pericles, first citizen of Athens, and Cicero, Consul of Rome. Lists of the greatest orators in the 20th century typically include, in addition to Martin Luther King Jr., such spell-binding speakers as John F. Kennedy, Ronald Reagan, Adolph Hitler, and Sir Winston Churchill.

Churchill's epoch-making speeches inspired the British during World War II, while he was Britain's Prime Minister, and are credited with raising British morale through its darkest days. His fluid expression and acerbic wit have been regarded as the model of English usage. In 1963, during a ceremony granting US citizenship to Sir Winston, President John F. Kennedy observed, "Churchill mobilized the English language and sent it into battle.[3]

Yet, throughout his school years, Winston was regarded by his teachers as a poor student and a behavior problem. He did poorly on his tests and barely passed the entrance exams to the prestigious Harrow School. While there, he developed an interest in history and wrote some poems and letters that were published in the school magazine. In spite of his writing prowess, Churchill never felt he was sufficiently educated. "It's a good thing for an uneducated man to read books of quotations," he said, "The quotations when engraved upon the memory give you good thoughts and make you look for more." To this end, he studied the *Bartlett's Familiar Quota-*

tions assiduously and developed a talent for expressing ideas with wit and brevity. Later in life, suggesting that his poor performance at school may have been an advantage, he noted, "By being so long in the lowest form [grade] I gained an immense advantage over the cleverer boys…I got into my bones the essential structure of the normal British sentence–which is a noble thing." Churchill's use of colorful metaphor enabled him to convey lasting images. In describing his disdain for Joseph Stalin and Communism, he explained:[4]

> *Trying to maintain good relations with a Communist is like wooing a crocodile. You do not know whether to tickle it under the chin or beat it over the head. When it opens its mouth, you cannot tell whether it's trying to smile or preparing to eat you up.*



Sir Winston Churchill
1874 – 1965

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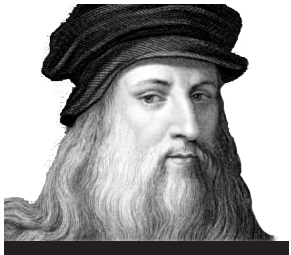
Through his tireless study of language he acquired the turn of phrase so vital to witty discourse. At a reception when Churchill was seated beside a Methodist minister, an attractive young waitress approached with a tray of glasses filled with sherry. Churchill eagerly seized a glass, while the staunch minister, drawing himself into a posture of self-righteous indignation, responded, "Young lady, I'd rather commit adultery than take an intoxicating beverage!" There was a silent pause, and then as the waitress departed, Churchill called out, "Come back miss–I didn't know we had a choice."

Later in life, Churchill's achievements, enhanced by his oratory skills, brought him numerous honorary degrees. On one such occasion, when accepting an honorary Doctor of Law degree, he announced with great humility, "Perhaps no one has ever passed so few examinations and received so many degrees."[5]

There is no simple way to measure intelligence that manifests as oratory brilliance, except by the results it achieves. For Martin Luther King Jr. and Sir Winston Churchill, as with the others noted above, the evidence is clear. Oratory is, indeed, but one of the many different faces of intelligence. While often showcased in politics, it is also manifest in law where masters of persuasion such as Clarence Darrow and William Jenning Bryan (both of Scopes Monkey Trial fame) and Johnny Cochran Jr. and F. Lee Bailey (of the O. J. Simpson trial) combine well-crafted argumentation with powerful delivery to win juries to their point of view. Their intelligence is known mainly through their influence on others.

Intelligence as Creativity

In the 15th and 16th centuries, the Italian Renaissance resurrected learning on a grand scale, beginning in Florence, where the Medici family served as patrons of the arts, and spreading to other city-states, including Venice, Genoa, Rome, Bologna, and Milan. This was the climate in which the creative genius of Leonardo da Vinci, Michelangelo, Raphael (and later Rembrandt and Rubens) came into full blossom. Among various theories as to why this intellectual awakening began in Florence is the suggestion of historian Quentin Skinner that the celebration of genius in art, sculpture, and architecture was an outgrowth of "the remarkable efflorescence of moral, social, and political philosophy" that prevailed there–in short, an environment of free intellectual exploration, often generously supported by wealthy patrons.[6]



Leonardo da Vinci
1452– 1519

Described as the "quintessential Renaissance Man," Leonardo da Vinci–a person compelled by an insatiable curiosity to address the broadest spectrum of intellectual disciplines ever embraced by a human being–became the icon for the polymath. Born out of wedlock in the town of Vinci in Tuscany, and housed by a father who never legitimized him, Leonardo began his life free of the requirement that he become a notary like his father, Piero. This freedom, rare among first-born males, enabled him to pursue his natural interests. At age 14, the family moved to Florence and, while Leonardo had no formal schooling, he did receive informal training in Latin and mathematics–a subject with which he struggled, as he regarded the repetitive rehearsal of arithmetic algorithms and the procedures of algebra to be mind-deadening. His interest in geometry, however, was piqued by his recognition that it underpinned so much of the visual world around him. In one of his famous notebooks he recorded an insight that anticipated the development of modern science by 200 years: "No human inquiry can be a science unless it pursues its path through mathematical exposition and demonstration."

At age 17, Leonardo began a 7-year apprenticeship to the prominent painter and sculptor Verrocchio. Under his tutelage, the young student, by age 20, had achieved status as a master in the Guild of Saint Luke. During this period, he acquired technical skills in drafting, chemistry, metallurgy, plaster casting, leather working, mechanics, and carpentry, in support of his primary focus on sketching, painting, and sculpting.

His relentless curiosity impelled his investigation of projective geometry to capture a 3-dimensional vista on a 2-dimensional canvas. He applied

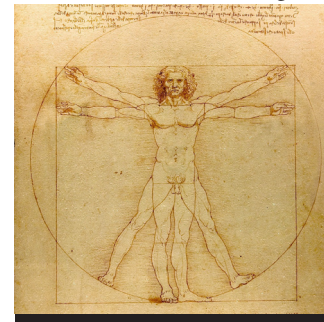
a meticulous study of light and its properties to his paintings so that he could imitate how light casts shadows on the folds of a cascading garment. In his painting titled "The Last Supper" he combined this knowledge with his mastery of the geometric rules of perspective to create the illusion of depth. The result was described by biographer Walter Isaacson as "the most spell-binding narrative painting in history."[7]

Leonardo's extensive dissection of cadavers to study human physiology, enabled him to display the human form in its exact proportions, as depicted in his famous sketch *Vitruvian man*.

In Dan Brown's best-selling novel *The Da Vinci Code*, protagonist Robert Langdon says:[8]

> *Da Vinci was the first to show the human body is literally made of building blocks whose proportional ratios always equal PHI…Measure the distance from the tip of your head to the floor. Then divide that by the distance from your belly button to the floor. Guess what number you get…Yes PHI."*

Fig. 1.1



Vitruvian Man c. 1490

The PHI that Langdon is referring to is the so-called *golden ratio*, a number that is approximately equal to 1.618 and denoted by ϕ. Langdon's statement implies that a person's height is about 1.618 times the distance to their navel from the floor. Landon also asserts that the distance from the shoulder to the fingertips is about 1.618 times the distance from the elbow to the fingertips. However, whether Leonardo used the golden ratio in his construction of vitruvian man and his other paintings is still a matter of debate among scholars. (The mathematical derivation of ϕ is given in my YouTube video at: https://www.youtube.com/watch?v=7TFnMB9RkNM)

From his dissections, Leonardo da Vinci acquired a detailed knowledge of the facial muscles that express specific emotions and observed how their activation is displayed in patterns of light and shadow. This enabled him to paint the enigmatic smile of Mona Lisa that has enchanted generations of people who marvel at the magnitude of his genius.

Mona Lisa c. 1503–1506

Leonardo's unrelenting creativity also found an outlet through technological innovation. He sketched plans for helicopters, flying machines, perpetual motion machines, and a host of other engineering artifacts–some viable and some not.

Biographer Walter Isaacson wrote:[9]

> *What made Leonardo a genius, what set him apart from people who are merely extraordinarily smart, was creativity, the ability to apply imagination to intellect. …What also distinguished Leonardo's genius was its universal nature. The world has produced other thinkers who were more profound or logical, and many who were more practical, but none who was as creative in so many different fields.*

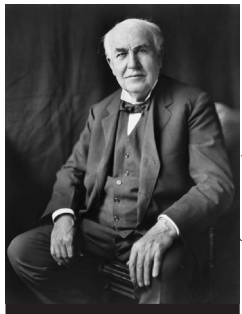
Leonardo's genius came with its own set of anomalies. His quest for perfection was so extreme that he seldom finished a painting, always holding it in reserve with the intention of returning to add yet another stroke or two to improve it. Consequently, to the frustration of his patrons, he seldom finished a painting and rarely on time. On some days, while painting *The Last Supper*, he would mount the scaffold at sunrise and transition into what called the *flow state*, painting continuously until sunset without stopping to eat or drink.[10] On other days, he would merely stare at the painting for an hour or two, analyze it, and depart without executing a single stroke–earning him a reputation as a procrastinator. However, Leonardo justified the behavior as a means of allowing creative ideas to incubate in his brain. Indeed, Leonardo was a creative genius whose intelligence was fed by his curiosity and nourished by the joy of free creation. According to his biographer, Walter Isaacson:[11]

> *Leonardo's genius was a human one, wrought by his own will and ambition. It did not come from being the divine recipient, like Newton or Einstein, of a mind with so much processing power that we mere mortals cannot fathom it…His genius was of the type we can understand, even take lessons from. It was based on skills we can aspire to improve in ourselves, such as curiosity and intense observation.*

The Renaissance signaled a rekindling of human creativity, exploding not only in the arts, but also in music, literature, mathematics, and science. As Copernicus, Galileo, and ultimately, Newton, laid the foundations of modern science, they paved the way for the industrial revolution and the invention of a wide variety of technologies.

Four centuries after the birth of Leonardo DaVinci, another creative genius came into the world–a genius who would express his creativity, not through art, but through invention. On February 11, 1847, Thomas Alva Edison was born in Milan Ohio, the seventh and last child of Samuel Edison Jr. and Nancy Elliot. When Thomas was 7 years old, the family moved to Port Huron, Michigan. By this time he had been in and out of several different schools in Ohio and Michigan on account of a reading disability

that we know today as *dyslexia*. A few months into his first-grade school year, his teacher Reverend G. B. Engle, became frustrated by Edison's learning difficulties and called him "addled." The scorned youngster stormed out of school ending his formal education. Fortunately his mother was a teacher, so Thomas was home-schooled thereafter.



Thomas Alva Edison
1847– 1931

Under his mother's tutelage, Edison became an avid reader, pursuing his natural curiosity through books and chemical experiments. By age 13, he was earning $50 per week selling candy, fruit, and newspapers on the Grand Trunk Railroad run from Port Huron to Detroit. His flair for entrepreneurial enterprise was further evident at age 15 when he wrote and printed, on a small printing press located in a baggage car, *The Grand Trunk Herald*–a newspaper that he sold to the 400 railroad employees. Using money earned from his enterprise, he purchased books on chemistry along with chemicals for experiments that he conducted in his own makeshift baggage car "lab." Years later Edison said that both he and his laboratory were tossed off the train at Smiths Creek, Michigan by an angry train conductor when a chemical experiment went horribly wrong and burst into flame. In 1866, Edison secured a job as telegraph operator at Western Union where he managed the news wire for the Associated Press bureau. He chose to work the night shift, so he would be free to conduct his experiments outside the scrutiny of supervisors. However, he was fired from that job when a lead-acid battery he was exploring leaked sulphuric acid through the floorboards of his second-story lab onto his boss's desk.

Unrelenting in his exploration of chemistry and electricity, he filed in 1869, at the age of 22, his first patent–an electric vote recorder. A few months later, he moved to Elizabeth, New Jersey, living in the basement of an associate, Franklin Pope, with whom he partnered to found *Pope, Edison & Company Electrical Engineers.* The next year, the ambitious entrepreneurs invented the one-wire telegraph, that tracked and printed stock prices and is known today as the *stock ticker*.

By the time he had reached the age of 29 in 1876, Edison had built a facility in Menlo Park, New Jersey, that would eventually become the first industrial research laboratory in the United States. While working relentlessly to perfect the recently-invented telephone, Edison became obsessed with the idea of recording the human voice. Within a year, he developed a primitive phonograph, recording his rendition of the nursery rhyme "Mary had a little lamb."[12] Although he was deaf in one ear and partially deaf in the other–a consequence of scarlet fever in his early childhood–he would bite

into a wooden part of his new phonograph, so that the vibrations would reach the auditory nerve and enable him to hear.

News of his invention spread rapidly throughout the world, bringing him international fame and flocks of visitors, who traveled from afar, to witness a burgeoning new era in electronic devices. Less than two years later, Edison discovered the invention for which he is most remembered–the first commercially viable incandescent light bulb.[13] The first air conditioning system, the motion picture camera, and a host of other life-enhancing innovations followed soon after and Thomas Edison, as the personification of inventive genius, became immortalized as the "Wizard of Menlo Park."

Enamoured with his prolific inventiveness, the industrial world showered him with a wide variety of honors and awards, including his receipt of the American Congressional Gold Medal in 1928. On February 11, 1947 the US Post Office issued a commemorative stamp to celebrate the centenary of Edison's birth, and in 1983, the United States Congress designated Edison's birthday as National Inventor's Day. Then in 1997, a special issue of *Life Magazine* placed Edison first in the list of the "100 Most Important People in the Last 1000 Years."

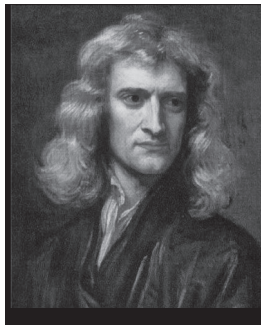
In spite of all the adulation, the Wizard of Menlo Park never professed to have special intellectual powers, famously insisting, "Genius is 1% inspiration and 99% perspiration." His desire to discover and create drove him to work relentlessly toward his goals. A famous photograph of Edison, taken by his wife at his southern laboratory in Fort Myers, Florida shows Edison asleep on his workbench, incubating the information gathered during his conscious state. Though a visionary, Edison was also a pragmatist whose creations, like those of Leonardo da Vinci, were cognitively concrete, focussing on practical devices rather than abstract mathematical models. His powerful intellect found its expression through creative invention.

Intelligence as the Capacity for Abstraction

While the artists, musicians, playwrights and poets were thriving in the freedom of the Renaissance, the mathematicians and scientists were also experiencing a new era of creativity. The invention of the telescope by the German-Dutch lensmaker Hans Lippershey in 1608 was launching a new era in celestial observation. Yet, there was little understanding of the shape of the earth's orbit around the sun or those of the other planets until astronomers Tycho Brahe (Danish) and Johannes Kepler (German) arrived on the scene. A wealth of data gathered by both enabled Kepler to enunciate three laws of planetary motion. The first of these asserted that the planets travel in elliptical orbits around the sun which is located at a focus of each ellipse. Though these laws gave a much more accurate description of the solar system, they

were empirical and it remained for scientists to discover a unifying idea that would show how Kepler's laws of planetary motion could be logically deduced from some overarching principle. Kepler's daunting challenge in communicating his discoveries to the 17th-century world is captured in this insightful Sidney Harris cartoon.

On January 4, 1643, the year following the death of Galileo, and one century after the publication of Copernicus' *de Revolutionibus*, a new star of the brightest magnitude entered the cosmos. Isaac Newton, later regarded by historians of mathematics as one of the three greatest mathematicians of all time, was born on a farm in the small hamlet of Woolsthorpe, Lincolnshire, England. He began life as a premature baby–so small that he was not expected to survive. His father had died 3 months prior, and within 3 years, his mother Hannah remarried and moved into the residence of her new husband, Reverend Barnabas Smith. Since the Reverend had no interest in adopting the fledgling Isaac, the young lad was to be raised by his maternal grandparents Ayscough, who resided at the farm and sent him to local day schools. Deprived of a mother and father as well as siblings with whom he could bond, young Isaac was isolated and lonely. Historical records indicate that he became petulant, neurotic, and devoid of the social skills that build friendships.


Isaac Newton 1643–1727

In August 1653, when Isaac was 10 years old, Reverend Smith died, and Hannah returned to the Woolsthorpe farm, bringing a son and two daughters that the Reverend had fathered. Isaac's reunion with his mother lasted less than 2 years, before Isaac was sent to live with apothecary William Clarke, so he could attend the grammar school in Grantham. Adolescence is a time when our species purges those who don't fit within the limited circle of normality. And so it was inevitable that a bully emerged to torment Isaac. One day, the harassment reached a climax when the bully delivered a vicious kick to Isaac's stomach. Encouraged by the schoolmaster, Isaac challenged him to a fair fight. The historical record contains an eyewitness report from a local observer:[14]

> *They went out together into the Church yard…Though Isaac was not so lusty as his antagonist, he had so much more spirit and resolution that he beat him till he declared he would fight no more…[then at the urging of the*

schoolmaster] Isaac pulled him along by the ears & thrust his face against the side of the church.

After this confidence-building conquest, Isaac took a new interest in his studies and soon moved to the top of the class. As his intellectual superiority became evident, resentment by his classmates increased, and Newton became withdrawn. While at Grantham, he spent most of his time alone, creating wooden models and mechanical devices from the stipend his mother provided. When a new windmill was built in the town, Isaac constructed a wooden model, powered by a treadmill and a live mouse, prodded forward by a cob of corn placed above it. Another invention drew comments from the Grantham community, as they gathered in salons and bars. It was a lantern on the end of a kite, that Isaac constructed to illuminate the night sky as its candle burned through a supply of crushed paper. Like Leonardo da Vinci 200 years earlier, and Thomas Edison, 200 years later, Isaac was consumed by his interest in experimenting and inventing–even to the detriment of his schoolwork. Yet, whenever he fell behind, he would rededicate himself and move again to the top of the class.

In late 1659, as Isaac approached the age of 17, his schooling at Grantham came to an end and his mother recalled him to Woolsthorpe to work the farm–a recall that was doomed to fail. Records show that on October 28, 1659, his mother, Hannah, was fined because the unattended sheep consigned to Isaac's supervision had strayed into a neighbor's field and consumed the corn while Isaac, on yet another mental excursion, was building water wheels in a brook. When sent to market to sell the farm produce, Isaac would often bribe a servant to perform the tasks while he sat immersed in a book.

From early on in life, Newton had displayed a remarkable power of concentration and intense focus that would render him entirely unaware of his immediate surroundings. In traveling home from Grantham, to Woolsthorpe by horse, it was necessary to dismount at Spittlegate hill, lead the horse up the steep hill, and then remount at the top. On one occasion, when deep in thought, Isaac dismounted at the bottom of the hill and forgot to remount–unaware that the horse had slipped from his bridle and bolted. On arriving home, bridle in hand, he scratched his head, pondering the whereabouts of his horse.

Eventually, it was recognized that Isaac was unfit for farming. Hannah's brother, the Reverened William Ayscough, and Isaac's teacher, Henry Stokes, urged Hannah to return Isaac to Grantham grammar school to prepare for entrance to university. Mr. Stokes would provide his lodging. The 9 months that Newton had spent at Woolsthorpe had been marked with disputes, quarrels and discord, due in some measure to Isaac's irascible dispo-

sition. The house servants regarded him as lazy, incompetent, and foolish because he so often forgot to eat his meals. The historical record states, that they, "rejoic'd at parting with him, declaring he was fit for nothing but the 'Versity." There was a collective sigh of relief when Isaac left Woolsthrope in the fall of 1660.

In June 1661, Isaac traveled to Cambridge, free at last to pursue his intellectual interests. During the next 3 years, Newton developed a passion for mathematics, mastering Descartes' analytic geometry, Viète's algebra and Oughtred's Clavis (*Key to Mathematics*) in a rapid advance to the frontiers of mathematical knowledge.

In 1664–65, the bubonic plague was sweeping across England, wiping out about 100,000 people including almost 25% of London's population. Cambridge University, where Newton was now enrolled as a student, was closed. Isaac returned to the farm where he continued to contemplate questions about the movements of the planets, the causes of the tides and the nature of light. The universally accepted assumption at that time was that objects fall toward earth because that is their natural resting place. However, Newton imagined that there was an invisible "attraction" called a "force" that compelled objects toward each other. Formalized in an equation called the *Law of Universal Gravitation*, he was able to explain the cause of the tides–a riddle that had previously defied explanation. The period that spanned the years 1664 through 1666 were Newton's *anni mirabiles* (miracle years). These were the years when he made advances in the study of light, spawned calculus, conceptualized his laws of motion and universal gravitation, and in the process, laid the foundations of theoretical physics. However, it would take two decades of incubation for his insights to hatch into a coherent and polished form. Years later, reflecting on these miracle years, he said, "In those days I was in the prime of my age for invention and minded mathematics and philosophy [physics] more than at any time since."[15]

Newton's solitary nature, together with an excessive sensitivity to criticism had made him reluctant to publish anything. As he expressed in a letter on November 18, 1676:[16]

> *I will resolutely bid adieu to it* [further publication] *except what I do for my private satisfaction, or leave to come out after me* [after my death] *for I see a man must either resolve to put out nothing new, or become a slave to defend it.*

Consequently, by the time he reached 40 years of age, his work was relatively unknown to the scientific community. In 1684, astronomer Sir Edmond Halley (of comet fame) visited Cambridge to ask Newton whether it was possible to derive Kepler's laws from some basic principles. Newton recalled that he had already done so, but hadn't published it. At Halley's

request, Newton sketched his derivation of the laws in a paper titled *On the Motion of Bodies in an Orbit* in which he used differential calculus (originally called *fluxions*) that he had invented during his plague-enforced leave from Cambridge. Recognizing the importance of this discovery, Halley hounded and cajoled Newton to publish all his discoveries about planetary motion in a comprehensive work that Halley would fund. Finally, in 1687 Newton revealed these observations and derivations in a treatise titled, *Philosophiæ Naturalis Principia Mathematica*, known today as *Principia*. This treatise came to be regarded by scientists in the centuries that followed as perhaps, the greatest publication in the history of science.

In deducing Kepler's Laws from basic axioms of physics, Newton's formidable intellect moved science from an organized taxonomy of observed phenomena to a rigorous body of knowledge with predictive capability. In essence, Newton had developed the mathematics of rocket science almost three centuries before a rocket was sent to the moon.

As copies of the *Principia* spread across the Channel to Europe, Newton moved from relative obscurity to demigod status. Revered as the ultimate authority in science, in 1696 at the age of 54, he was appointed Warden of the British Mint. In 1703, he was elected President of the Royal Society, and in 1705, he was knighted by Queen Anne. Sir Isaac Newton lived another 22 years, dying on March 27, 1727 in his eighty-fifth year, having received all the honors that could be bestowed on a human being. When praised for his remarkable achievements, he paid tribute to Descartes, Galileo, Copernicus, Kepler and others with the acknowledgement, "If I have seen further than others, it is by standing upon the shoulders of giants."

Though Newton was the pre-eminent mathematician and scientist of his time, he continued to challenge his assumptions. Never comfortable with his conception of gravitation as a force that acts at a distance, he wrote in a letter to theologian Richard Bentley in 1692:[17]

> *That one body may act upon another at a distance through a vacuum without the mediation of anything else, by and through which their action and force may be conveyed from one another, is to me so great an absurdity that, I believe, no man who has in philosophic matters a competent faculty of thinking could ever fall into it.*

Newton's skepticism about the validity of the assumption that an instantaneously transmitted gravitational force pulls masses together through a flat Euclidean space, was well-founded. By the end of the 19th century, there was a growing body of observational evidence suggesting that one or more of the assumptions underpinning Newtonian physics was flawed.

An Intellectual Giant Emerges in the 20th Century

By Lucien Chavan (1868 - 1942) [Public domain]via Wikimedia Commons

Albert Einstein
1879–1955

In August 1900, a 21-year-old student named Albert Einstein graduated in physics from *Eidgenössische Technische Hochschule* (ETH) in Zurich with a commendable mark of 4.91 out of 6. Since it was customary for students to be offered junior academic appointments upon graduation, Einstein was bitterly disappointed when he was the only one of his graduating friends who was passed over. His independence of thought and his unwillingness to submit to intellectual authority had been perceived as arrogance by his elders, preventing him from winning an academic post.[18] With no means of supporting himself, he desperately sought employment.

On June 16, 1902, after two years of temporary tutoring and teaching jobs, Einstein finally landed a job as an engineer Class III in the Swiss Patent Office in Berne. This "shoemaker's job", as he later described it, engaged him in assessing the viability of inventions submitted for patents. In a letter to his friend Conrad Habicht, he wrote, "[This job gives me] besides eight hours of work…eight hours of idleness plus a whole Sunday."[19] The "idleness" provided by this "shoemaker's job" would give Einstein the freedom to explore the foundations of physics and reconstruct Newton's model of the universe.

In 1905, while still toiling as a clerk in the Patent Office, Einstein was awarded a doctorate by the Zurich Physics Institute for his 21-page dissertation, *A New Definition of Molecular Dimensions*. Though the examining committee had been divided on whether it was "physics" or "mathematics", a final judgment asserted, "[despite] crudeness in style and slips of the pen in the formulas which can and must be overlooked, …, [the paper displays a] thorough mastery of mathematical methods."[20]

Achieving a Ph.D. in physics was a relatively minor accomplishment for Einstein in a year that has become known as his *annus mirabilis* (miracle year). [Recall that Newton's *anni mirabili* also occurred in his mid-twenties.] On March 17, 1905, just three days after he turned 26, Einstein submitted to the physics journal *Annalen der Physik* a paper explaining the photoelectric effect–a paper for which he would eventually receive a Nobel Prize.

Then, on May 11, just two months later, he submitted to that same journal another monumental achievement, this time on Brownian motion, explaining how colliding molecules produce the random motion observed when microscopic particles like pollen grains oscillate in water.

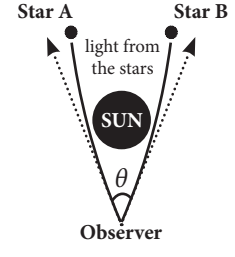
Despite the significance of these two papers, they would eventually be eclipsed in importance by a third containing a revolutionary insight captured in his *Special Theory of Relativity*–an insight that would revolutionize physics irrevocably by challenging Newton's assumption that space and time are absolute. These three papers, any one of which would have earned Einstein a place among the greatest physicists of all time, appeared in the celebrated Volume 17 of *Annalen der Physik* in July 1905.

As if this flurry of papers were not enough, on September 27 of the same year, he submitted yet a fourth paper, an "addendum" to his Special Theory of Relativity which was subsequently published in Volume 18. In it, he derived his famous equation $E = mc^2$ that defines his mass-energy equivalence principle and often serves as an icon for the discoverer himself.[21] His counter intuitive assumption that time is not absolute was met with the same skepticism that Galileo and others had faced when promoting ideas that were perceived to be outrageously radical.

Undaunted by the resistance to his ideas, Einstein in 1907 at age 28, embarked on a journey far more ambitious than his Special Theory. In what has become known as his *General Theory of Relativity*, he challenged Newton's assumption that gravity is a force propagated through a flat Euclidean space, and instead proposed that space is "curved" by the presence of mass. Furthermore, he asserted that this "warp" defines the paths that objects follow as they move through a complex interweaving of space and time, called "spacetime." It would take him the next 10 years to flesh out his original insights, but with help from mathematicians, Grossmann, Minkowski, and Schwarzchild, he was able to express this theory in a coherent set of equations with a predictive power that could be tested. For if indeed, space is warped around large masses such as the sun, we would expect that beams of light from stars would bend as they pass near the sun en route to the earth. Einstein challenged astronomers to make observations that would confirm or contradict his prediction.

Fig. 1.2

The Warp increases the *Apparent* Angular Distance θ



The opportunity to test his theory would come in 1919 when a total solar eclipse would block the sun, making the stars visible during the day. The angular distance between two stars measured during the eclipse, when the sun is flanked by the stars, would be compared with their angular distance at night. Einstein's General Theory of Relativity predicted that the angular distance measured during the eclipse, would be greater than the nighttime angular measure by 1.7 seconds of arc (approximately 0.0005 degrees).

In late April, an expedition, headed by astronomer Sir Arthur Edding-

ton, journeyed to Principe Island off the coast of West Africa, where a full eclipse would be visible. May 29, 1919 arrived, along with heavy rains in the morning that threatened to obscure the eclipse during all or part of the five-minute window when it would occur. However, in the early afternoon, the sky began to clear and by 3:13 p.m. the heavens had opened enough to reveal the sun and some stars. In a frenzied five-minutes, Eddington changed plates on his camera sixteen times before the eclipse ran its course and the sun emerged from behind the moon to erase all the stars. These sixteen photographs were closely-guarded treasures that would validate or disprove Einstein's General Theory of Relativity.

Finally, on November 6, after months of scrutiny, the results of Eddington's expedition were presented at a joint meeting of members of the Royal Society and the Royal Astronomical Society. With all the pomp and circumstance of formal British society, Astronomer Royal, Sir Frank Dyson announced, "After a careful study of the plates, I am prepared to say that there can be no doubt that they confirm Einstein's prediction." J. J. Thomson, discoverer of the electron, asserted, "The result is one of the greatest achievements of human thought."[22]

The day following Dyson's announcement, *The Times* of London front-page headline blazoned:

REVOLUTION IN SCIENCE

NEW THEORY OF THE UNIVERSE

NEWTONIAN IDEAS OVERTHROWN

News of Eddington's verification of Einstein's Theory spread like a tsunami from Europe across the Atlantic, reaching the front page of *The New York Times* on November 10, 1919. A world, weary from the horrors of World War I, welcomed a new era of scientific inquiry and international cooperation. In the days that followed, the tsunami continued across middle America to California, carrying with it the name "Albert Einstein." Science and technology that had been dedicated to the development of weapons was now elevated to the loftier goal of universal enlightenment. Einstein became its champion and an overnight celebrity.

The media elevated Einstein to demigod status, emphasizing the abstruse equations and asserting that only a dozen scientists could comprehend the complicated theory. Einstein himself, with his disheveled appearance, his contemplative pipe, and his unworldly ways became the caricature of genius.

In 1921, Einstein made his first trip to America. A swarm of newspaper reporters greeted him as his ship pulled into the New York harbor and before he could disembark, Einstein found himself embroiled in a press conference. Through an interpreter, he answered the questions with a wit

and twinkle that indicated he was enjoying the attention.

During his speaking tour in America, Einstein packed the Metropolitan Opera House in New York to the rafters, visited Washington D.C. where he met with President Warren G. Harding, and gave lectures in Chicago to overflow crowds. The halo of awe that bordered on reverence accompanied Einstein wherever he went and people flocked to get a glimpse of this eccentric, self-effacing genius. More than 15,000 people attended parades in his honor in Hartford, Connecticut and Cleveland, Ohio.

On his second visit to America, Albert and his wife Elsa were invited to the black-tie premiere of Charlie Chaplin's famous film *City Lights*. As Chaplin and Einstein entered the theater to thunderous applause, Chaplin observed, "They cheer me because they all understand me, and they cheer you because no one understands you."[23]

Gradually, the new superstar was eclipsing Edison as the icon for genius. What Edison had achieved was understandable to the layman. What Einstein had achieved was incomprehensible. When Einstein was in Boston, a reporter challenged him with a question taken from the famous Edison test, that the Wizard of Menlo Park had used to screen new hires, "Dr. Einstein, what is the speed of sound?"

Einstein responded, "I don't carry such information in my mind since it is readily available in books." The reporter persisted, "Mr. Edison contends that a college education is of little value." Einstein responded, "The value of a college education is not the learning of many facts but the training of the mind to think."[24] A decade later, when Edison was interviewed on his 84th birthday, he was asked what he thought of Einstein's Theory of Relativity. He responded, "I don't think anything of Einstein's Theory of Relativity because I don't understand it."[25] A few months after that interview, Edison passed away, virtually replaced as the ultimate icon for genius by the eccentric, disheveled, unworldly scientist who saw the universe through the lens of abstruse mathematics embedded in four-dimensions.

Epilog

Many inferences about high intelligence can be drawn from the six biographical snapshots presented in this chapter, and more will be drawn in future chapters. However, the intent of these snapshots is to share with you the idea that intelligence has many different faces, that may manifest in eloquent oratory, creative inventiveness, abstract theorizing, or wise judgment–snapshots for the last of these to be provided in chapter 17.

To the ancient Greeks, intelligence possessed as many faces as their panoply of gods. *Nous* was the capacity for understanding abstract concepts; *phronesis* was wisdom in judgment, and *metis* was the word to describe the kind of shrewdness that we might refer to today as "street smarts."

While these different dimensions of intelligence share common characteristics, it was recognized that they were evident in different people to different degrees.

Since intelligence is a multi-faceted attribute, attempts to rank individuals by their level of intelligence depends significantly on the metric used, if indeed there is one. The question, "Who was smarter, Albert Einstein or Thomas Edison?" has no meaning until we agree on a basis for comparison. Though Edison was highly intelligent and a genius at invention, he had minimal training in formal mathematics and therefore, little hope of fully understanding the Theory of Relativity. Conversely, Einstein, as theoretician, had little interest in performing experiments or embarking upon entrepreneurial ventures. Therefore, while both men were very intelligent, comparing their intelligence requires an examination of their individual thought processes, actions, and accomplishments. Edison was the preeminent inventive genius, while Einstein was superbly gifted in abstract conceptualization.

Though lionized as a genius, Albert Einstein recognized that his brilliance in theoretical physics did not transfer to *all* other domains. When Chaim Weizmann, the first President of Israel died, Einstein was invited to become his successor. The revered scientist refused, stating that he lacked the natural aptitude for social interaction that would be required in such a political position.[26] He felt his exceptional problem solving skills in physics would not easily transfer to this other context and compensate for his lack of experience in managing human affairs. We are fortunate that Einstein was not the Prime Minister of England during World War II and that Churchill was not commissioned to reconceptualize a theory of gravitation.

In the year 2000, Albert Einstein, widely celebrated as the quintessential genius, was selected by *Time Magazine*, not as the person of the year, but as the PERSON OF THE CENTURY! Among others being considered for having "the greatest impact on this century, for better or worse," were Mahatma Gandhi, Adolph Hitler, Franklin Roosevelt, Bill Gates, Nelson Mandela, and Martin Luther King Jr. These people displayed different arrays of intellectual attributes, yet the selection committee of journalists picked Einstein. Choosing a "greatest impact" created a lot of controversy, because comparing the influence of people in different domains requires a judgment about the relative importance of each domain. Journalist Charles Krauthammer suggested that Winston Churchill, rather than Einstein, deserved the accolade, asserting, "If Einstein hadn't lived, the ideas he produced might have been delayed. But take away Churchill's stand in 1940, and fascism might well have triumphed."[27] Similarly, comparing the intelligence of those who display different faces of cognition is fraught with the same judgment difficulties as choosing which of several people in vastly different pursuits have made the biggest impact.

The shaded box below presents, under the title "Myth," the popular misconception that intelligence is a unidimensional attribute (like height) that can rank people from most to least intelligent. A more accurate depiction of intelligence is given under the title "Truth." While the information in this chapter provides only anecdotal evidence of this "truth;" evidence from research will be forthcoming in subsequent chapters.

Myth: Intelligence is a one-dimensional trait that can rank individuals in a hierarchy such that any two people can be compared, and the more intelligent of the two will be able to perform more effectively in *all* domains that require cognitive skills.[28]

Truth: Intelligence is a multi-dimensional human trait that consists of a composite of cognitive abilities including, among others, the following capacities:

- to learn new ideas,
- to solve complex problems,
- to draw valid inferences,
- to articulate ideas clearly and persuasively,
- to exercise prudent judgment.

Each individual possesses these capacities in different degrees, so in different domains individuals may compare differently in terms of who demonstrates intellectual superiority.

Furthermore, each of these cognitive abilities in an individual changes throughout life, peaking and declining at different times and rates.