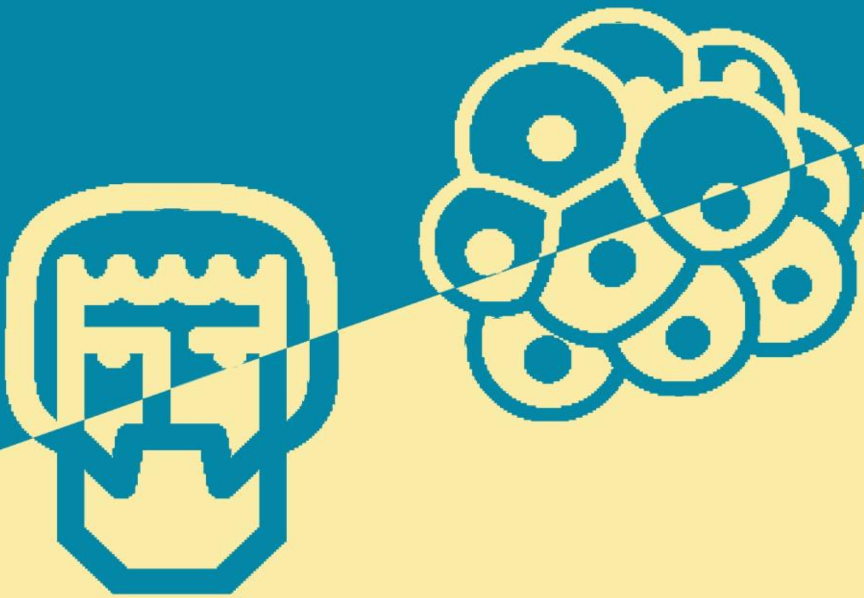
SCIENCE NUGGETS 1

From Aristotle to Stem Cells



RICARDO M. LANTICAN

National Scientist

Science Nuggets 1.
From Aristotle to Stem Cells

Ricardo M. Lantican
National Scientist
National Academy of Science and Technology
Philippines

NAST PHL is an attached agency to the
Department of Science and Technology

ISBN 978-971-8538-94-4

Lantican RM. 2017. **Science Nuggets 1: From Aristotle to Stem Cells**. National Academy of Science and Technology PHL, Manila, Philippines 90 pp.

Published by
National Academy of Science and Technology PHL
DOST Complex, Bicutan, Taguig City, Metro Manila
1631 Philippines
secretariat@nast.ph; http://www.nast.ph
Tel/Fax No.: (632) 837-3170

In charge of publication:
Editor: Academician Evelyn Mae Tecson-Mendoza
NAST staff: Rowena Villapeña-Briones
Cover design: Stephanie Pearl Orendain

Foreword

To the young student and layperson, science is an intimidating subject and is only for those who love mathematics, strange organisms, and chemical equations. They will readily admit that: “Yes! Science is important and useful, but it’s not for me!”

In Science Nuggets, volume 1, National Scientist Ricardo M. Lantican treats the reader to numerous stories about famous scientists, not to tell us how great they are, but how human they are. Science Nuggets, volume 1 will take you on a journey through the history of science, from Aristotle’s theory that Earth is the center of the universe to the advances in stem cell research. Indeed, although NS Lantican talks about scientists with great minds that were ahead of their time, he also tells us that they were also people like you and me. Readers will learn how scientists struggled to challenge the established ideas of their time.

NAST expresses its sincere appreciation to NS Lantican for compiling these science facts and stories that he wrote in Philippine newspapers. We hope that this compilation of his will make people, both young and old, appreciate and participate in science, especially the youth who are the future of our nation. We believe that these compilations will serve as a key contributor for the vision of NAST for our county – “A progressive Philippines anchored on science”.

Acd. Fabian M. Dayrit
Acting President
National Academy of Science and Technology PHL

Preface

This book entitled "Science Nuggets" (in two volumes) is a compilation of articles written by the author and published in Philippine newspapers—The Manila Bulletin (in the column "Educators Speak"), The Philippine Star ("Star Science") and Malaya (Business Section). This publication is intended as informational material on science and technology (S & T) for the general public and most especially the youth.

The science column in The Manila Bulletin was established in 2005 through the initiative of Academician Perla D. Santos Ocampo, then President of NAST (National Academy of Science and Technology) and Academician Brother Andrew Gonzalez.

The creation of the science column was a strategic move to provide a medium for scientists to be heard and articulate their viewpoints on science and country development. The other objective was to provide scientists with greater media exposure to get the public to know and appreciate the role they play in national affairs. The lack of public visibility on the part of the scientists has relegated them to the background, unlike the personalities engaged in showbiz, sports and entertainment who enjoy iconic status.

The NAST undertakes an overall thrust designed to create a science culture that is much needed in the country that would ultimately bring to fruition its vision — "A progressive Philippines anchored on science".

The different chapters of the book cover a wide spectrum of subjects. The articles revolve around three thematic areas: (1) personality profiles of great minds in science; (2) breakthroughs and technological advances that have propelled human progress; and (3) innovative R & D perspectives that can make a better world for humanity. Writing on these topics was a great learning experience on the part of the author.

The author humbly dedicates this book to the youth who have chosen their career path in the sciences.

Ricardo M. Lantican
National Scientist

Acknowledgements

This is to thank the following most sincerely:

- The National Academy of Science and Technology PHL for its support to the publication of this book;
- The late National Scientist Perla D. Santos Ocampo for encouraging NAST members to publish relevant science and opinion articles in mass media platform;
- Colleagues in the Academy, the university and from other sectors who have expressed to the author their support to this endeavor;
- Academician Evelyn Mae Tecson-Mendoza for putting the two volumes in publication form from editing, updating data, to layout;
- NAST PHL Secretariat led by Director Luningning Samarita-Domingo for their assistance in the submission of the articles to the newspapers and in the publication process and, in particular, Ms. Rowena Villapeña-Briones for additional proofreading; and
- Ms. Melissa "Molet" A. Pino for being always ready to help in typing my articles and sending them to NAST on time.

Acknowledgments

pp. 1, 9, 20, 24, 31, 41, 55, 61. Photos and illustrations from Microsoft Clip Art.

p. 15 Photos from the Association Curie et Joliot-Curie, used with permission.

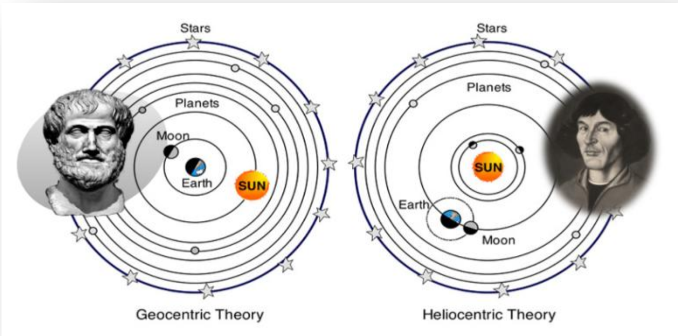
p. 48 Illustration of Watson and Crick, by Rodi de Asis from "Understanding Biotechnology". Used with permission.

p. 65 Mitochondrial DNA inheritance. From the US National Library of Medicine. Free online resource.

p. 70 Illustration of stem cell differentiation by E.M. Tecson-Mendoza.

Cover design by: Stephanie Pearl Orendain

Table of Contents



1.
Great Minds Who Were Ahead of Their Time

Part I

The significance of their original discoveries was not readily grasped and appreciated because the underlying concepts were far too advanced for the scientific and intellectual frame of mind of people during their generation. To be accepted as truth, ideas had to fit into the hub and scheme of things and those that did not, suffered the fate of rejection. Thus, many new discoveries were initially met with skepticism and even derision or ridicule. Worse, some discoveries were considered heretical, if they seriously challenged theological and other well established beliefs. The historical train of events in the growth of civilizations and scientific thoughts is replete with such accounts.

Consequently, discoveries of the past encountered a long lag-time before they were finally accepted and recognized. This would happen only after they had passed the test of time through peer reviews, replication of results by other investigators, verification of supporting evidences or proofs, etc. Once a significant breakthrough in science had been confirmed, a redeeming act by the scientific community usually followed to vindicate the person by conferring rightful acclaim and a meritorious award such as the Nobel Prize. In a number of instances, scientific institutes were named after these illustrious persons.

Many scientific claims that did not pass the rigors of test were considered fraudulent. We have had many accounts of scientific hoaxes especially in the highly competitive world of science of today.

Let me proceed by citing a few illustrative cases of significant discoveries and personages involved and how they were perceived by society during their time.

1. The Geocentric vs the Heliocentric View of the Structure of the Heavens

From the time of Aristotle (384–322 BC) in ancient Greece and Ptolemy (AD 150) of Alexandria, Egypt, up to the period of Copernicus (1473–1543), the "geocentric" or "earth-centered" view of the system of the universe persisted. Aristotle was a Greek scientist and renowned philosopher and teacher to Alexander the Great. Ptolemy, on the other hand, was an Egyptian geographer and astronomer, while Nicolaus Copernicus was a Polish astronomer.

Aristotle believed in a spherical and motionless (non-revolving) earth, and an unchanging universe with Earth at its center. Ptolemy systematized and synthesized the best of the Greek attempts for planetary motions in a treatise, the Almagest. The Ptolemaic hypotheses were more elegant and superior to previous ones. The resulting geocentric system of planets had placed a motionless earth at the center, with the sun, moon and planets revolving around it in circular motions. The Christian world had espoused this concept that was consistent with the centrality of man in the whole of creation as mentioned in biblical texts. As the Italian poet, Dante Alighieri, described it in 1321, the movements of the sun, moon and planets were powered by the Creator.

The geocentric system of planets endured for 1,500 years in the Western world, until it was supplanted by the "heliocentric" or "sun-centered" system of Copernicus, which was published in 1543.

Copernicus realized that there were flaws in the Ptolemaic system which could not provide accurate positions of the sun and the planets. A more acceptable explanation of the planetary motions arose from supposing the sun to be at the center, instead. Copernicus retained the many features of the Ptolemaic concept of planetary movements through their respective "epicycles" or smaller circles, the center of which was revolving in a larger circular orbit around the sun. I guess he did it for strategic reasons of not wanting to rock the boat too much! Copernicus also theorized that the earth was rotating around its axis. This was a radical departure from the Ptolemaic system, which believed that the earth would disintegrate if it did revolve on its axis.

Galileo Galilei (1564–1642), an Italian physicist and astronomer, supported the view of a sun-centered planetary system but discarded the more complicated Copernican-

Ptolemaic concept of planetary movements. He replaced it with a simple circular orbit. Johannes Kepler, another brilliant mathematician and astronomer who followed up on the work of Copernicus, had suggested the correct "elliptical" orbits of planets. He also formulated laws on motions that formed the groundwork of Isaac Newton's discoveries published in 1684. But these new concepts were not considered by Galileo. Galileo had more to show in his observations of the heavenly bodies. With his own designed telescope, he discovered the four satellites or moons of Jupiter. He also saw and described the pockmarks as well as the mountains on the moon's surface.

Copernicus, Kepler and Galileo were all very devout Christians. Copernicus was, in fact, a Canon in the Catholic Church in 1497. He was also brought up by a bishop uncle. When he wrote a pamphlet, the *Commentariolus*, in 1533 describing his sun-centered concepts, which he circulated to several scholars, the reaction was very discouraging. The earth-centered universe was more theologically desirable. Unexpectedly, the response in the Vatican was more positive. In fact, Pope Clement VII and a few bishops and an outside Protestant Professor even approved and urged Copernicus to publish it. He was never under any threat of religious persecution. But Copernicus, for unknown reasons, delayed the publication of his work. It came out in 1543, which he only saw briefly on his deathbed. After his death, his theory remained controversial especially among the Lutherans.

Kepler was an extremely sincere and pious Lutheran. He never suffered any persecution for his avowal of the sun-centered system. Later in 1600, Kepler and his Austrian wife moved to Prague to avoid religious persecution.

Galileo wrote his work on the solar system in 1633 in an elegant language befitting the Rennaisance period. It became highly controversial and he bore the brunt of the wrath of the Roman Catholic Church. He was subjected to a trial by the Italian Inquisition, which found him guilty, condemned him, and compelled him to retract his findings. Galileo expressly stuck to his belief that his system was an alternate interpretation of the biblical texts. He was excommunicated from the Catholic Church and placed under permanent house arrest where he remained till death. In a sense, he was fortunate because other people before him who were charged with heresy were burned at the stakes.

Toward the end of the 20th century, Pope John Paul II issued an extraordinary apology for the Inquisition and rehabilitated Galileo for the "heresy" of espousing the heliocentric theory that the sun, not the earth, was the center of the solar system. In his honor, the four largest Jovian satellites are now called the Galilean moons (orbiting Jupiter) and the spacecraft named Galileo is now successfully orbiting Jupiter.

2. Albert Einstein's "General Theory of Relativity"

It did not earn him a Nobel Prize. Instead, it was Einstein's other work on the "Law of the Photoelectric Effect", that won him the 1921 Nobel Prize in Physics. It was a very significant discovery alright, as the photoelectric effect presaged the invention of solar or photovoltaic cells that are in use today. Pioneered in the 1950s, solar cells convert 15 to 30 percent of the incident light into electricity and power calculators, watches, environmentally conscious homes, orbiting satellites and Martian rovers.

Einstein's work on the "General Theory of Relativity" was more profound except that it was a mathematical abstraction that only a handful of physicists could comprehend. It remained a highly controversial issue for sometime. To put it simply, Einstein's theory postulated a "space-time" relationship, that space and time are not separate or independent dimensions but can intertwine to form a warp or distortion. There is no Absolute or Universal Time that all clocks would measure. Relativity also postulates that starlight would swerve or bend measurably as it passes through the heavy gravitational field of the sun. This was first proven right in a solar eclipse in 1919 by a British expedition to West Africa. Subsequent solar eclipses observed at many locations around the world have repeatedly shown that starlight was deflected or bent as the rays passed the sun.

Relativity also states that fast-moving objects "age more slowly" than stationary ones. Each GPS (Global Positioning System) satellite moves along at about 14,000 kilometers per hour, which means that its onboard "atomic clock" (a very precise timepiece) lags the pace of stationary clocks on the earth by about seven microseconds per day. Interplanetary travel, if it ever becomes a reality, will make travelers look younger upon their return to planet Earth!

I am sure scores of ladies will be signing up for interplanetary tours. But wait, relativity also says that gravity exerts a greater relativistic effect on timing. At 20,000 kilometers up, the GPS satellites experience one fourth of the gravitational pull they would on the ground. As a result, onboard atomic clocks run "faster" by 45 microseconds per day!

Einstein's mind was much way ahead of his time. He could have handily won two Nobel Prizes in Physics.

3. The Discovery of Genes as the Units of Inheritance

In 1856, Gregor Johann Mendel, an Austrian biologist and Augustinian monk, carried out hybridization experiments on garden peas in the monastery garden. Out of curiosity, he wanted to investigate the pattern of inheritance of seven plant characters but later he trimmed the number to two. He concentrated on seed shape and color. He did hybridization work between selected parents.

By studying the results of two generations of planting the hybrids, he realized that each of the two seed characters was inherited through elements or discrete particles (now known as genes) from the parents. There was independence of inheritance of the two characters and he theorized the phenomenon of "dominance" versus "recessiveness" in their expression in the segregating hybrid populations. Mendel's observations and theory were phenomenal since there was yet a huge gap of knowledge about the carriers of genes (the chromosomes as we know them now) and the mechanics of reduction-division in the number of chromosomes at the cellular level in the production of sex cells or gametes.

From his experimental observations, Mendel showed that the pattern of inheritance followed the rules of probability and thus, was mathematically predictable. Mendel's findings were presented in 1865 at a scientific society meeting and subsequently published. Ironically, the findings were largely ignored by his fellow scientists especially the biologists who did not think that biological phenomena could relate with mathematical laws. It was only some 40 years after his death that his work was resurrected. But its full value remained unappreciated until the first quarter of the 20^{th} century.

During Mendel's time, Charles Darwin was better known and admired by the scientific community. Darwin did not believe in Mendel's theory of inheritance. On the contrary, Darwin believed that organisms that had adapted themselves to changing environments after undergoing strong selection pressures would pass on the acquired characters to their offsprings. Darwin was inclined to go along with the Lamarckian theory of inheritance of acquired characteristics which was diametrically opposed to Mendel's law. The clash of the two camps would persist for sometime.

2.

Great Minds Who Were Ahead of Their Time

Part II

4. The Continental Drift Theory

Alfred Wegener (1880–1930) was a German meteorologist and geophysicist. He proposed the famous "continental drift theory" in a published paper in 1915 on the origins of continents and oceans. According to the theory, the present continents existed as a single large mass of land, the Pangaea, over 200 million years ago. This supercontinent gradually separated into land masses which drifted to their present position. His theory was ridiculed by the science community. He migrated to Austria since no German university would hire him. He later joined an expedition in the Greenland icecap in 1930 where he perished at the age of 50 years. Wegener's theory was finally accepted in the 1960s and renamed "plate tectonics" that gave geology a single unifying theory that explains the earthquakes, volcanoes and the formation of mountain ranges and ocean basins. Final tribute came to him when an institute in Germany was named after him. Too late the hero.

5. Robert Goddard and Space Rocket Technology.

Rockets have gradually evolved over a long period of time. Rockets then were used solely as weapons of war. In 1232, the Chinese defenders used rockets against the invading Mongols. The Chinese had already possessed the black gunpowder. Rockets were also employed during the European wars in the 1240s. In later years until the 1880s to 1890s, rockets were used as weapons in Europe by the French, Dutch, English and Russian armies. In the war of 1812 in America, the British fired rockets in their unsuccessful attempt to capture Ft McHenry. Francis Scott Key was there to witness the night engagement and wrote the stirring words of the Star Spangled Banner.

Robert Goddard (1882–1945) was a rocket scientist. He was a physics professor at Clark University in Worcester, Massachusetts, U.S.A. He was the first specialist to visualize rockets as a vehicle for space travel. As early as in 1920, Goddard published a little paper on the topic of space travel. Unlike most of his colleagues, Goddard believed rocketry was a viable technology, that "if it is primed with fuel that is powerful enough, one might just be able to reach the moon with it".

The New York Times, in its editorial on January 13, 1920, pounced on Goddard's paper, saying that space travel was impossible since "without atmosphere to push against, a rocket could not move so much of an inch"! The rebuke continued. "Prof. Goddard, it was clear, lacked the knowledge ladled out daily in high schools". Goddard was stung by the ridicule. Since then, he carried on with his rocket research without fanfare.

Goddard's first objective was to improve his rockets to reach high altitudes. He theorized that black powder that had long been the source of power in rocketry must be replaced with fuel that would provide greater propulsion.

Goddard did his experiments with rockets in stages. His first successful rocket was a spindly 10-ft object which he named Nell. He fired it in his aunt's nearby farm and it leaped from the ground and roared into the sky but it only reached an altitude of 41 ft before falling back to the ground only 184 ft away. But Goddard was thrilled with his little success.

As Goddard's Nell rocket grew larger with each new round of research, he felt he needed a larger firing ground. In 1930, with a grant of $100,000 from Harry Guggenheim, Goddard and his wife moved west to Roswell, New Mexico. Over the next nine years, Goddard's Nell rocket grew from 12 ft to 16 ft, to 18 ft and its altitude climbed from 2,000 ft, to 7,500 ft to 9,000 ft. He built his rockets that exceeded the speed of sound. By then, he had replaced the fuel first with kerosene, then with liquid oxygen and gasoline, then with liquid hydrogen. He also theorized that in an airless environment of space, liquid hydrogen must be mixed with liquid oxygen to allow combustion to take place. How prophetic were his words and vision! This is what NASA is using now as rocket propellant.

Meanwhile, in the early 1940s, a contingent of German rocket experts led by Hermann Oberth and Wernher von Braun was working secretly on a rocket in Peenemunde, Germany. Without Goddard knowing it, his rocket design was incorporated into the German version. The final product was the feared V-2 rockets that could carry a heavy load of deadly warheads. A total of 4,000 V-2 rockets were launched to carry out their mission of raining down warheads on Allied targets in France, London and Coventry.

After the surrender of Germany in 1945, 150 German rocket experts and technicians became available to the allies. Wernher von Braun and other experts were brought to America to design powerful rockets for the U.S. space missions. Others moved to Russia, England and France. Thus, the era of space race and exploration began. The first satellite (Sputnik 1) was launched by the USSR and succeeded a year later by Explorer 1 of the U.S. In 1961, USSR's Yuri Gagarin and Alan Shepard of the U.S. became the first human beings to navigate space. In 1967, Apollo 11, launched by Saturn V rocket, enabled the first men to land on the moon. In 1981, the U.S. launched the first space shuttle. All these aerospace developments were the brainchild of Goddard's early vision. Unfortunately, Goddard died in 1945. He was unable to see the realization of his lifetime space obsession.

We end our story with a happy note. After the first moon landing, the New York Times issued another statement, this time humbly regretting the great error that it had committed in its publication 49 years earlier. "It is now definitely established that a rocket can function in a vacuum as well as in an atmosphere". Goddard already knew that all along.

6. Barbara McClintock and the Jumping Genes

McClintock was born in 1902 at Hartford, Connecticut. She enrolled at Cornell University in 1919 and finished her degree with a major in botany. She continued on until she completed her doctorate in cytogenetics. She remained at Cornell as an instructor and undertook research work on the genetic mechanisms of the maize plant.

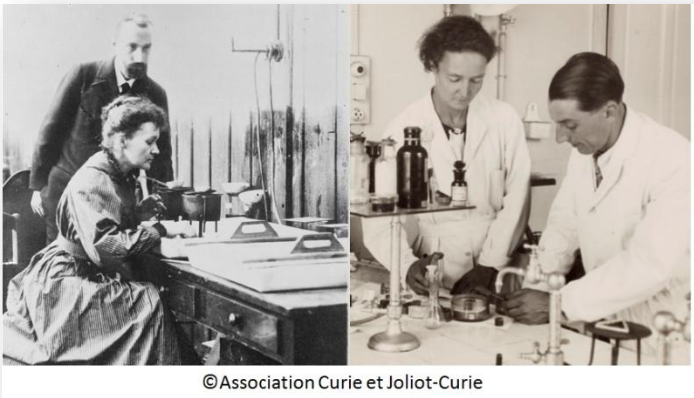
Though she was a topnotched cytogeneticist and an extremely diligent worker, she never obtained a permanent or tenured position, owing probably to gender influences in a male-dominated world, plus the fact that she had established a reputation as an individualist and a sloppily dressed woman. She was always wearing blue jeans instead of a skirt while doing research in the cornfield and even in her lab. But there was a more serious factor— though her scientific abilities were recognized, appreciation of her work tended to be limited due to the advanced and complex nature of her genetic work. She left Cornell in 1931 and held a number of short-term appointments elsewhere until finally, she joined the staff in Cold Spring Harbor Laboratory. While there, she continued her work on the genetics of the maize plant.

She concentrated her work on the variations in pigmentation of corn kernels as influenced by mutation. She particularly noted that the genetic elements controlling pigmentation were unstable and there was this unknown mechanism that switched their expression on and off! She theorized that there were extraneous mobile genes that moved around from chromosome to chromosome in the genome (complete set) of the maize plant. She showed that these mobile or jumping elements had a dominant controlling action on other genes with which they had come in contact during their visitation to different chromosomes. This sounded preposterous to well-grounded geneticists and biologists. They were inclined to believe more in the leaping ability of the Mexican jumping bean. Only three of McClintock's original colleagues at Cornell remained loyal believers in her scientific integrity.

As the world knows it now, there are two mobile genes that work in tandem. One is an "activator" which has a complete sequence of DNA for transposition; the other is a "dissociator" that has no capability for transposition. The activator is independent and can move around whereas the dissociator cannot unless it is accompanied by the former. These mobile genes can intrude into the affairs or control mechanisms of resident genes in the genome.

These mobile genes are technically known as "transposons" which have been detected to operate not only in maize but in bacteria, yeast, other microorganisms and many other plant species. In fact, transposons are now being used in genetic transformation work.

In 1983, the Nobel Prize for Physiology was awarded to Barbara McClintock. I am certain she was impeccably dressed during the glittering awarding ceremonies in Stockholm.



3. A Lineage of Excellence in Science

Intelligence is written in the genetic code of humans. But for it to be expressed creatively, it has to be properly nurtured by the environment. That is how great minds have been molded. Like diamonds, they are forever.

The Nobel Prize Winners

The role of heredity and the environment is best exemplified by people who have descended from a lineage of prominent names in science and reared in a cultured environment.

In 2006, the Nobel Prize in chemistry was awarded to Roger Kornberg for his work on the molecular basis of eukaryotic transcription which involves copying the information in the DNA to a messenger RNA (ribonucleic acid), the genetic messenger that carries out instructions of the DNA code in the synthesis of proteins in the cell. He is the son of Arthur Kornberg who won the Nobel Prize for medicine in 1959. The older Kornberg isolated DNA polymerase I and showed that DNA can be synthesized in the test tube using this enzyme. There have been eight sets of Nobel prizes given to parents and their siblings and two sets for a husband-and-wife team.

The most celebrated case was that of the Curies. Marie and husband Pierre Curie received the 1903 Nobel Prize in physics, jointly with Professor Henri Becquerel, for their discovery of radioactivity. Marie Curie won another Nobel Prize in 1911, this time in chemistry, in recognition of her discovery of the elements radium and polonium.

The Curies had a daughter, Irene, who was married to Frederic Joliot. Both husband and wife (Frederic and Irene) jointly won the Nobel Prize in chemistry in 1935, in recognition of their work on the synthesis of new radioactive elements.

In the case of the Kornbergs and the Curies, it can be speculated that the parent's scientific activities might have provided the environment which motivated the siblings to follow in their footsteps.

As background information about the Nobel Prizes, these have been given annually since 1901, five years after the death of Alfred Nobel. Nobel was a native of Stockholm, Sweden and was trained as an engineer. He was a prolific inventor and one of his inventions was the dynamite. It was a nitroglycerine-based material combined with an absorbent substance so it could be used with reasonable safety. Unfortunately, he lost a younger brother and four other people in a disastrous accidental explosion in 1864. He never married. Nobel, an inventor turned industrialist, established factories all over the world and thus amassed a fortune. He thought he owed it to society that a payback be made so he set up a trust fund of about US$ 9 million. The interest was to be used to reward outstanding individuals who have contributed to the betterment of humanity. Annual awards are given in the areas of physics, chemistry, physiology and medicine, literature and peace. The award in economics was added starting in 1961. The awards are given by the King of Sweden. Every recipient of the Nobel Prize receives a medal and a monetary gift of one-and-a-quarter million US dollars. This is the world's most prestigious award in literature and the sciences.

Other Family Lines

Aside from the Nobel laureates, there were other distinguished scientists who descended from a well known genealogy. We have the case of the Leakey family, in which father Louis, wife Mary and son Richard were all professionally trained along the same disciplinary line and spent some 50 years (in the 20th century) of anthropological and archeological investigations in east Africa. The famous family has made significant contributions to the science of paleoanthropology and in putting Africa as the most likely cradle of early humans.

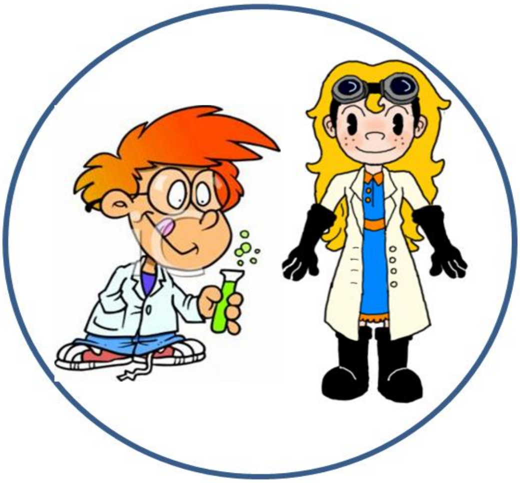
Then there was the illustrious Huxley family that spanned three generations of excellence during the 19th century. Thomas Huxley (1825–1895) was a respected English biologist and university professor. He was a staunch defender of Charles Darwin's theory of evolution and was mistaken as an atheist, although in truth he was a strict believer of the bible and the scriptures. He had two grandsons. One was Sir Julian Huxley, a professor of zoology, a well known humanist, atheist, and science popularizer. The other was Aldous Huxley, a well known biologist, essayist, novelist, and a book writer on human evolution and society.

In the earlier period, there were the Herschels, a father and son astronomers. Sir William Herschel (1738–1822) developed a reflecting telescope and became the discoverer of planet Uranus and greatly added to the knowledge of the solar system, the Milky Way, two satellites of Saturn and the rotation of Saturn's ring. The son, Sir John Frederick William Herschel (1792–1871) extended the astronomical work of his father and discovered numerous nebulae in the interstellar space of the Milky Way.

Another father-and-son combination was the case of the Huygenses. Constantijn Huygens was an accomplished man of science and a brilliant poet. He was said to have carefully planned his son's education in literature, mathematics and music. The son, Christiaan Huygens (1629–1695), became known to have made significant contributions to mathematics, astronomy, optics and mechanics. He was able to adapt the principle of the pendulum to the regulation of clocks to increase their accuracy. He also postulated the wave theory of light.

This father and son relationship is also evident in other fields like sports. Two pairs of father and son players have excelled in the NBA in the US. One pair is that of Joe Bryant who played with the champion team Philadelphia Seventy Sixers in the 1970s and his son, Kobe Bryant, of the Los Angeles Lakers.

The well known "pedigreed" intellectuals enumerated had an assurance of success because they had the genes and they were reared in a cultured environment. They were born with the proverbial silver spoon in their mouths. But these pedigreed individuals constituted only a privileged few. There have been many more scientists of undistinguished descent who rose to prominence on their own due to hardwork and use of their sharp intellect. They were products of varied cultures that have evolved from the four corners of the globe over a long period of time. They did their work in times of peace and war and in a backdrop of ever changing social, economic and political events sweeping across the world. Their divergent ideas and efforts have produced a rippling effect and pushed the frontiers of science to unimaginable heights.



4.
The Human Side in the Lives of Great Scientists

The great men and women of science constitute the fabric of society that has propelled the world to great progress. We revere them for their exceptional talents and scientific achievements. But they are humans too, subject to frailties and quirks of life. I will cite a few specific cases.

Quite a number of our scientists were born from poor families and could not afford a good education. As one example, Michael Faraday (1791–1867), the discoverer of electromagnetic induction and the dynamo, started out at age fourteen as an apprentice to a bookbinder. He was allowed to spend as much time reading books as he did binding them. He was regularly binding the Encyclopedia Britannica which became his source of learning. His interest in science was kindled after attending several public lectures of Sir Humphrey Davy, a well known British chemist and physicist. It was his good fortune to be introduced to Davy, who later hired him as a personal assistant at the Royal Institution in London. This was the starting point of Faraday's illustrious career in science.

On the other extreme, there were those who came from wealthy families. Francis William Aston was one of them. After his graduation from Cambridge University, he did not have to work. He became a pleasure seeker. He became known as the playboy multimillionaire and was a regular surfer in Waikiki beach in Honolulu in 1909. Finally, getting tired of pleasurable living, he decided to apply for a job in Cambridge, where he became an assistant of Sir Joseph John Thomson, the discoverer of the "electron" of atoms. Aston then turned his energies to serious scientific work. He invented and perfected the "mass spectrograph" which could separate and measure atoms and molecular fragments, and, thus, determine their mass. In 1922, Aston won the Nobel Prize in chemistry.

Some scientists were known to be prodigies in early life. Andre-Marie Ampere (1775–1856) who became famous for his work in electro-magnetism, had mastered the field of mathematics at age twelve. Kurt Gödel, a Czech mathematician, was studying math, religion and several languages at age ten. On the other hand, Albert Einstein was not a very good student and did not show any signs of his genius while studying in Munich and later in Switzerland.

Likewise, Sir Isaac Newton's performance in the University of Cambridge was undistinguished.

Many scientists had modest agrarian roots and were helping out in family farm work. But somehow, their inventive instincts prompted them to seek other opportunities elsewhere. Philo Farnsworth, the inventor of the television picture tube, was a young potato farmer in Utah. Henry Ford, the technocrat, never liked farm work. He left his father's farm in Dearborn, Michigan at age sixteen. He walked eight miles to Detroit where he got his first job in a machine shop. He made several transfers to other machine shops and got exposed to building various cars and engines. By 1903, he formed his own Ford Motor Company. By 1908 his Model-T car was out commercially. It was so designed to make it affordable to middle America and became an instant hit. By 1927, more than 15 million cars had been sold, which was one-half the world's output.

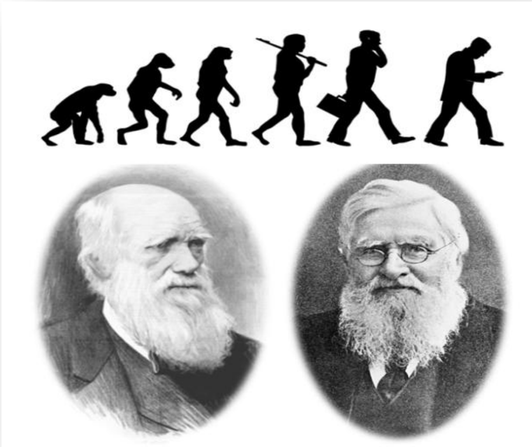
A few of the scientists got too engrossed with their scientific work that they never had time to socialize with women. Newton and Alfred Nobel never got married. It was a different case for Henry Cavendish, the discoverer of hydrogen in 1766 and for whom the Cavendish Laboratory at Cambridge was named. Cavendish had a notorious aversion or dislike for women and he too never got married. But he was an eccentric. In his mansion house, he built a separate stairway for his chamber maid in order to avoid crossing path with him!

Then there is a case of over-indulgence in amorous affairs. Richard Feynman, the American genius in physics in mid-20^{th} century was a ladies' man, good at playing bongos, and was notorious for picking up women in nightclubs and bars.

Many scientists were self-made. Thomas Edison was said to be a poor student in math and coupled with his habitual questioning which evoked displeasure of his teachers, was finally expelled from school. He, therefore, had no formal schooling. At age ten, he had set up a chemical lab at the basement of their home. To buy supplies for his lab, he went to work, selling newspapers and candies at the train station. At age twelve, he set up his own printing press. Due to his various inventions, he became known as the wizard of Menlo Park in New Jersey, USA.

In the case of the famous Wright brothers, Wilbur and Orville, they were self-taught engineers. They were in a bicycle business. They pioneered in building the first flying machine at Kitty Hawk, North Carolina, USA. In 1903, they flew their aircraft which flew a distance of 120 ft in twelve seconds. To improve the aerodynamics and lift of their flying machine, they constructed their own wind tunnel. In 1908, they obtained the contract to manufacture planes for the US army.

Why did I pick the lesser known facts in the lives of our great scientists? It is to remind us that they too were ordinary mortals but who discovered themselves and assiduously put their talents and energies to task to achieve their goals.



5.
Darwin and Wallace on the Theory of Evolution

Charles Robert Darwin (1809–1882) and Alfred Russel Wallace (1823–1913) were British naturalists who simultaneously but independently came up with the theory of evolution based on "natural selection". Both scientists developed their theories based on a large quantity of field observations on plant and animal specimens in two different geographical worlds. Darwin made his field observations at the South American coast with special focus on the Galapagos Islands in 1831–1836 and Alfred Wallace in Sarawak, Borneo, Sulawesi, and the island of Ternate in the Moluccas or Spice Islands, Indonesia.

It was from Ternate Island in Indonesia that Wallace sent his famous paper (dated February, 1858) addressed to Darwin. It was entitled: "On the Tendency of Varieties to Depart Indefinitely from the Original Type". Wallace's paper was a beautifully written scientific treatise which defined the mechanism of the origin of new species. The paper made mention of the idea of the "survival of the fittest" as a result of natural selection. The paper was meant for publication in a prestigious journal but, instead, was scheduled for presentation at the forthcoming meeting of the Linnean Society in London.

Upon receipt of Wallace's paper, Darwin was horrified to learn that it dwelt precisely on the same theory that he had been formulating for sometime. Darwin had spent considerable time of more than twenty years assembling his field notes and information and making refinements to buttress his theory on the origin of species. He agonized over the fact that his life-time work faced imminent ruin. Charles Lyell, a famous geologist and a friend of Darwin, arranged that the independent works of the two scientists be presented. Darwin submitted two of his unpublished excerpts from his writings on the subject. The papers of Darwin and Wallace were read on July 1, 1858 at the Linnean Society meeting in London. Since then, both scientists have been acknowledged as the co-discoverer of the theory of evolution based on natural selection.

A year later in 1859, Darwin published his comprehensive book: "On the Origin of Species by Means of Natural Selection". It was a best-seller. The formulation of the theory of natural selection was adopted from the ideas put forward by the economist Thomas Malthus that human populations tend to grow quickly and thereby overwhelm limited resources. Darwin used the same principle to explain that "favored races are preserved in the struggle for life". It meant that natural selection ensures that more favorable traits of a species endure in successive generations.

Darwin's second publication was "The Descent of Man" released in 1871, which speculated on the evolution of man from primate ancestors.

Darwin's theories on evolution became a hot and highly controversial topic. It provoked outrage from the clergy and religious establishment whose faith is anchored on man's divine creation. Even Darwin's wife, a pious Anglican, experienced a spiritual dilemma on account of her husband's radical and heretical views.

But with time, Darwin achieved an icon status and has been ranked alongside with the all-time greats — Galileo, Copernicus, Newton and Einstein. Wallace, on the other hand, gradually faded from the scene and into obscurity. But not with the Indo-Malay people who believe in Wallace as their real icon and benefactor in establishing the Wallacea area, a designated expanse of islands and seas in the eastern region of Indonesia which has become known as a mega-center of diversity of terrestrial and marine species unique in that part of the world. It is a great preserve that merits global significance in bio-diversity.

Let me provide a personal background and scientific achievements of Darwin and Wallace.

Life of Darwin

Charles Darwin traces his roots from his grandfather, Erasmus Darwin (1731–1802), who had his own thoughts on how life had evolved. Darwin was born into a wealthy family on February 12, 1809. Following his father's desire, Darwin entered medical school but was repulsed by having to cut open human cadavers and never finished his studies. At age 26, Darwin was offered a job as a naturalist and he joined the survey ship, the HMS Beagle, which sailed in 1831 for a five-year around-the-world journey. It was at the Galapagos Islands in South America where he took notice of the finches (birds) varying in beak size in the various islands. It dawned on him twenty years later that the bird's beak size must have changed over the generations to accommodate the differences in the size of seeds or insects consumed on the various islands. These and many other similar observations gained from his field trips formed the basis of his fully formed theory of evolution.

The year 2009 marked the 200^{th} or bicentennial anniversary of the birth of Charles Darwin and the 150^{th} anniversary of his work: The Origin Species. This was a year-long celebration that was observed with dozens of events in at least 10 countries, from England to the city of Darwin, Australia. The Charles Darwin University in Northern Territory, Australia, for example, held a three-day symposium in September 2009, dedicated to the life and legacy of Charles Darwin.

Life of Wallace

Alfred Wallace was born in Wales, England on January 8, 1823 to a middle-class English couple. But with the father's deteriorating finances, Wallace had to leave school at age 14 and had to work for his brother in doing land surveying. Wallace was a voracious reader and he developed a strong desire to learn as much about the sciences of botany, mathematics, zoology, astronomy, and geology. With his exposure in doing survey work all over the English and Welsh countryside and equipped with a probing mind, he developed his interest in natural history.

In 1848, Wallace and a friend, Henry Walter Bates, set off to an expedition to the Amazon to earn a living collecting plant and animal specimens. They spent 4 years in the Amazon rainforest and in one occasion, they went as far as the upper reaches of the Rio Negro where Wallace nearly lost his life. It was during this collection expedition that Wallace began to ponder on species evolution.

After collecting all his specimens and being of poor health, Wallace decided to return home to England. But the ill-fated ship he was on caught fire in the mid-Atlantic and all his valuable collections were lost.

In 1854, Wallace left England again and this time sailed to Malay Archipelago (now Malaysia and Indonesia) for another ambitious collecting expedition. He spent nearly eight years in the region. His first destination was Sarawak, Borneo, where he spent some 15 months, living and working closely with the Dyak people. Then in June, 1856 he set out further to explore other islands—Bali, Lombok, Makassar in Sulawesi, Aru Islands (near New Guinea) and backtracked to Ambon, and finally to Ternate Island in the Moluccas where he established home. In all, Wallace collected a vast number of plant and animal specimens which included beetles, birds, moths, and butterflies. In his travels to the different islands, he observed strange-looking mammals such as the tarsiers (small monkeys), "babirusa" or wild hogs with curly tusks, and the deer-size Anoa, the counterpart of the Philippine tamaraw. He also knew about the Komodo dragons (a huge man-eating monitor lizard) in the Komodo Island.

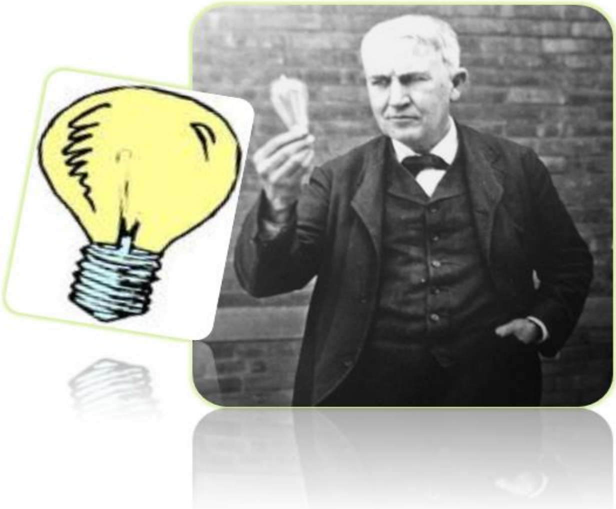
It was in Ternate Island where Wallace finally composed his famous paper on species evolution that he sent to Darwin in 1858.

Wallace became fully aware of the richness and uniqueness or endemism of marine and terrestrial life in that part of eastern Indonesia. He delineated the area with imaginary lines which later became known as the Wallacea region. It included a string of islands starting from Lombok and going eastward in the Flores and Timor Seas, the whole of Sulawesi Island and the Moluccas or Spice Islands which were the center of clove trade with China, Portugal and the Netherlands.

But in recent years, the once pristine forests of Sarawak, Kalimantan and Sulawesi have given way to unrestrained economic activities and human population pressure. These include large commercial logging operations, human settlements for Javanese and other ethnic groups, gold and nickel mining, and conversion to plantation or estate crops, principally oil palm. In the early nineties, Kalimantan forests and peat soils continued smoldering, sending thick smoke to Malaysia and Singapore which disrupted air traffic. Likewise, seagrass and coral reef ecosystems in the Wallacea region have suffered severe damages from over exploitation of fisheries.

With the global concern on the environment, loss of biodiversity and climate change, multi-sectoral and multi-lateral initiatives are underway to rehabilitate wildlife and marine resources in Indonesia. The Indonesian scientific communities such as the Indonesian Academy of Sciences (AIPI), the Indonesian Institute of Sciences (LIPI), the Wallacea Foundation and Conservation International are in the forefront in creating public awareness of the problems by invoking the legacy of Wallace to Indonesia and using it as a strong rallying point or leverage for action.

On December 10–13, 2008, an international conference on Alfred Russel Wallace and the Wallacea which involved the participation of scientists from UK, Netherlands, Italy, Spain, U.S., Australia, New Zealand, Thailand, and the Philippines was undertaken to commemorate the 150^{th} anniversary of the Ternate publication.



6. Serendipity: Accidental Leads Result in Great Discoveries

The scientific revolution has ushered in an exciting era of great technological achievements that have enriched our lives materially and intellectually.

Technological progression in most areas of scientific undertaking occurs at an exponential rate. Take the case of the technological advance in the development of microprocessors for computer and electronic use. The computer chip is just a little bigger than a thumbnail yet it contains an enormous number of transistors (and accompanying capacitors and resistors). When the first microcomputer chip came out in 1971, it contained only 2,300 transistors. In 1982, the number rose to 134,000; in 1985, 275,000; in 1989, 1.2 million; in 1993, 3 million; in 1995, 5.5 million; and in 2005, 592 million. In 2006, Intel's Dual Core Itanium 2 processors had crammed 1.7 billion transistors into that chip! The number of transistors per chip has been doubling every 18–24 months. In 2016, the Intel Broadwell-EP Xeon chip had over 7.2 billion transistors! With the rapid development in microchip technology, microcomputers have acquired awesome computing power, capable of making more than 588 million calculations per second!

The speed of supercomputers is even more mind-boggling! The Tianhe-2 developed by the National University of Defense Technology in central China is capable of sustained computing of 33.86 petaflops per second or 33,860 trillion calculations per second. It was adjudged as the world's fastest supercomputer knocking off from the first spot the US Energy Department's Titan machine which could do 17.59 petaflops per second or 17,590 trillion calculations per second.

We can also cite parallel developments in DNA technology, satellite and spacecraft capability, information technology, nanotechnology, etc., which have made rapid advances in a short span of time. The tools of science have become so precise, and their deep probing has gradually demystified nature's secrets in the biological and physical world.

Things, however, were different during the nascent stage of scientific development in the 19^{th} and the early 20^{th}

century. Though the scientific or experimental method of investigations (based on hypothesis and formal logic) was gaining ground, the empirical method by trial-and-error or hit-and-miss was much in use. "Accidental" discoveries and inventions played a role in providing the impetus for further technological development.

Accidental Discoveries

Many discoveries of the past were known to be a product of accidental observations. To mention a few, we have the following: the discovery of immunity to fowl cholera by Pasteur, of X-rays by Roentgen, of a carbon filament for electric light bulbs by Edison, of the deflection of magnetic needle by an electric current by Oersted, of penicillin by Fleming, of ether as a surgical anesthetic by C. Long, and of the splitting of uranium atoms by thermal neutrons by Hahn.

Let me elaborate on these great accidental discoveries that I have mentioned.

1. **Discovery of the relationship between electricity and magnetism by Danish physicist Hans Christian Oersted in 1820.** This relationship manifested itself when at the end of a lecture at the University of Copenhagen, Oersted accidentally placed a wire conducting a current of electricity to a position parallel to a magnetic needle. He noticed the deflection of the needle. He made follow-up studies based on this accidental observation and established the relationship between electricity and magnetism. Later, Michael Faraday, the inventor of the dynamo, proved not only that an electric current could move

a magnet but also that a moving magnet could produce a current in a wire. Out of this simple beginning arose the vast electrical industry worldwide.

2. **Discovery of the use of ether as surgical anesthetic by C.W. Long.** He observed that persons who inhaled ether for its exhilarating effects felt no pain when injured by fails or blows. In 1842, Long convinced one of his clients who had been using ether for its exhilarating effect to submit to surgery to remove two tumors on his neck. This was the first authenticated case of use of ether for a surgical purpose. This eventually led to the development of more potent anesthetics for varied surgical uses.

3. **Discovery of immunity to animal and human diseases by Louis Pasteur in 1882. Pasteur's discovery began with his work on fowl cholera caused by a bacterium.** On returning from a vacation, his cultures of bacteria appeared to be dead; they failed to produce cholera when fowls were inoculated with them. He then re-inoculated these fowls and some others with new cultures. To his amazement he found that those previously inoculated survived whereas the others died. By following up on this original observation, he discovered that inoculations with weakened or attenuated bacteria could produce immunity. He proceeded to develop immunity against the virulent anthrax disease in humans, and rabies in animals and humans employing the same principle of inoculation with the weakened form of the causal organisms. (Note: the fowl cholera causative agent was named *Pasteurella* in honor of Pasteur).

4. **Discovery of the use of carbon filament for incandescent lights by Thomas Alva Edison in 1879.**

Edison was the most famous and prolific inventor of his time. Before he chanced upon the use of carbon filament, he was experimenting with practically all known substances that by any chance could be used for his electric bulb. The most promising was platinum but it proved commercially impractical because the melting point of the wire and the temperature at which it became incandescent were so nearly alike that a slight increase in the current destroyed the lamp. Thirteen months of ceaseless investigations with various alloys and current regulators followed but proved futile. Then one evening in 1879, sitting alone in his laboratory and mulling over what other substances could, by any possibility, be used for the metal filament, his hand chanced to pick up a pellet of lampblack (a fine soot produced by incomplete combustion of tar) which he unconsciously rolled into a fine thread between his thumb and finger. His attention being briefly focused on it, he was struck with its resemblance to a wire. Like a flash, it occurred to him that past investigators had tried heating it to incandescence with an electric current but burned out rapidly. Edison's carbon filament worked wondrously longer because his bulb was in state of high vacuum. This was the answer! Then a search for the best source of carbon followed. The final success was achieved with the use of a charred cotton thread, sealed in a vacuum so that it would glow without being consumed. The final solution gave way to the use of tungsten. Edison's team then worked out the principles of establishing the generating and distribution system which eventually made electric lights for every home practicable.

5. **Discovery of X-ray technology by Wilhelm Roentgen, a German physicist**. In 1895, Roentgen was experimenting with electron beams in a gas discharge tube. He noticed that a fluorescent screen (a sheet of paper coated

with barium platinum-cyanide) some feet away in his laboratory started to glow when the electron beam was turned on. This response in itself was not so surprising as a fluorescent material normally glows in a reaction to electromagnetic radiation. But Roentgen's tube was surrounded by heavy black cardboard and he assumed that this would have blocked off most of the radiation. Roentgen placed various objects between the tube and the screen and it still glowed. Finally, in desperation, he put his hand in front of the tube and to his surprise, he saw the silhouette of his bones projected in the fluorescent screen!

Roentgen's discovery of the X-ray reached the press and the news became a sensation around the globe. The newspaper reports were accompanied by a photograph showing the silhouette of the bones of his wife's fingers. As the news circulated, scores of women got alarmed that a new gadget with X-ray vision could look through their dresses and make them appear nude in public!

As we know, X-rays are basically the same thing as visible light rays. Both are wavelike forms of electromagnetic radiations carried by energy particles called photons. The difference is that X-rays have a much shorter wavelength and a higher energy level. Our eyes are sensitive to the wavelength of visible light but not to X-ray waves.

X-ray technology has made important contributions in the field of medicine and in research involving quantum mechanics theory, crystallographic imagery, and cosmology. X-ray scanners are also used in detecting minute flaws in heavy metal equipment and in airport security.

6. **Discovery of penicillin by Sir Alexander Fleming in 1928.** He was a medical doctor assigned to the inoculation department of St. Mary's Hospital in London. He

was working on bacterial infections and started to search for substances which could attack infectious bacteria without damaging body tissues or lowering natural defenses.

Fleming's major discovery was made as a result of an accident. For some reason, a culture dish containing samples of *Staphylococcus* bacteria was left uncovered and became contaminated with a green mold. He noted that the mold had dissolved the colonies of *Staphylococcus* and he then took samples of the mold. The mold was found to be highly active against some bacteria but had no effects on others. He identified the mold as *Penicillium notatum* and called the active element penicillin. He was not able to isolate a pure material until two other investigators successfully isolated it in 1940. By 1943, large-scale production of penicillin became a reality and the drug was first used on troops in WW II.

7. **Splitting of uranium atoms in 1938 by two German chemists Otto Hahn and Frits Strassman but who did not realize it then**. When a uranium sample was bombarded with thermal neutrons, several isotopes much lighter that uranium remained. One was barium-140. The results were interpreted as a product of nuclear reaction. Shortly thereafter, two German physicists, Lise Meitner and Otto Frisch then working in Copenhagen undertook a similar study and were able to show that one of the rare isotopes of uranium, uranium-235, was actually split into roughly two equal parts following the capture of slow neutron. They were krypton-94 and barium-139 isotopes which were neutron-rich. The two isotopes promptly ejected neutrons of much higher energy than thermal neutrons, which caused the atomic split. Meitner and Frisch named this breakup nuclear "fission" noting the resultant burst of extra energy.

To add an interesting sidelight to this landmark discovery, it was the brilliant physicist Enrico Fermi who first discovered in Italy the formation of new radioactive substances by way of bombardment of uranium-92 with slow neutrons and for which the Nobel Prize for Physics was awarded to him in 1938. But there were unexplained results that did not become clear to him at the time.

The idea of atomic fission came to Fermi later when he had emigrated to the US to escape fascism in Italy. The physicist Niels Bohr, who was in constant communication with Meitner and Frisch, visited the US in January 1939 and met with Fermi, Albert Einstein, J.A. Wheeler, and several other physicists. They discussed the new discovery of nuclear fission and the observed tremendous burst in energy. Many questions were raised. Could the energy be unleashed? Can a chain of nuclear reaction (of atomic splitting, release of neutron to split another atom and repeated cycles) be possible and result in one tremendous explosion? There were a host of other questions that needed quick answers. Fermi and his team got organized and conducted a series of experiments using a nuclear reactor which could control or tame unleashed energy from nuclear fission. Soon the needed answers came.

Two kinds of nuclear fuel could be used — uranium-235 or plutonium (which can be derived from uranium-238), which could be produced in the required amount. If a "critical mass" of the nuclear fuel is reached, it can result in a chain reaction and a tremendous explosion. The chain reaction was eventually demonstrated in a reactor using uranium and purified graphite as the energy and moderator of neutron in an experiment conducted at the University of Chicago on December 2, 1942. Based on calculations, less than 100 pounds of either uranium-235 or plutonium-239 could be used as a super explosive per bomb, to give an equivalent 20,000 tons of TNT. A top-secret undertaking code named Manhattan Project soon followed to exploit the fission process. It got the blessings of President Franklin D. Roosevelt after Einstein and a group of physicist met with him. The problem was to produce enough quantities of purified uranium-235 from uranium-238. The production of uranium-235 relied on two physical means of separation: the electromagnetic technique developed at the University of California at Berkeley and the diffusion process devised at Columbia University. A third process known as thermal diffusion was introduced which required less electrical energy.

The first experimental atomic bomb explosion was carried out in Alamogordo air base in Los Alamos New Mexico on July 16, 1945. It was a blinding flash of awesome fury. The fateful events that followed later led to the end of the war in the Pacific, which are now a part of history.

Accidental discoveries, a tribute to the intelligent observer

Accidental discoveries are perceived in a flash of insight by the appreciative and intelligent observer. As Pasteur once said, "chance favors the prepared mind." As another noted scientist has pointed out, "accidental discoveries are only the spark that discharges the gun already loaded". In each case, the discoverer may be looking for something though not precisely that which was discovered. Such discoveries are much like an unusual and difficult catch in a baseball game or an eagle shot in golf. They may have been accidental but would not have been made by an inexperienced player. This was the case with Edison, whose mind was well-focused on an objective and was continuously searching for answers.

Nowadays, scientific research is carried out as a deliberate effort to address a particular objective. It involves careful planning, patience, and critical evaluation of experimental findings. In most instances, the findings lead to new ideas and avenues for more in-depth investigations. Unexpectedly, significant outcomes may arise, which become a part of the database. This is how scientific breakthroughs are arrived at.

Accidental discoveries are referred to as a case of "serendipity", based on Horace Walpole's tale of "The Three Princes of Serendip", whose heroes had the aptitude for making fortunate discoveries accidentally.

7. Intuitive Ideas and Early Scientific Discoveries

Our scientists today are at a very advantageous position. They have access to the latest literature in their field via the Internet. They use the latest state-of-the-art instrumentation and gadgetry. And they are assisted by powerful computers in generating and analyzing complex data.

In contrast, the scientists of old were in a pioneering period. They did not have much to rely on by way of background information that could lead them to new discoveries. Much of the time, they relied on personal intuition or on instinctive feeling or on a flash of insight in coming up with new ideas. Many new ideas seemed to have originated for no apparent reason at all. This may sound unscientific but that was how things were during the early period of scientific development. How was this possible?

How specific ideas were hatched

For some scientists, the ideas just popped up instantaneously at totally unpredictable times without warning and often when their minds were at rest as when they were asleep or nearly so. Sometimes, the circumstances bordered on the bizarre.

Let me relate a few interesting circumstances on how some specific discoveries came about.

The chemist Kekulé, founder of the structure theory of organic chemistry, was dozing off before the fireplace when he suddenly conceived the hexagonal structure of the benzene ring (a six-cornered structure with a carbon and a hydrogen atom at each point). This is one of the most trustworthy generalizations in the history of chemistry. He recalled that in his dream, he saw large and small atoms singly and joined together, flitting like imps before his eyes, "all whirling around in a bewildering dance". Suddenly, a long chain in the form of a snake seized its tail. Immediately awakened, Kekulé began writing the "benzene ring theory".

A.R. Wallace, co-discoverer with Charles Darwin of the principle of natural selection, once remarked that the idea came to him as it did to Darwin in a sudden flash of insight.

Galton, the proponent of "the Ancestral Law of Heredity", once stated that the idea came to him like a flash when he was taking temporary refuge from a storm in a recess by the side of a pathway. He said he forgot everything else for a moment in his delight.

The physicist M. Faraday, who was best known for a brilliant series of experiments on the nature of electricity, was said to have had "an uncanny way of getting at the essential facts by the most direct route, without recourse to intricate theories or mathematical equations". It was not until some 30 years after Faraday that Clark Maxwell was able to express mathematically what Faraday arrived at by intuition.

It has been said that Pasteur's great discoveries were not so much the result of inflexible logic as they were of intuitive vision. According to Pasteur, preconceived theories were like "searchlights that illumine the path of the investigator and serve him as a guide to interrogate nature. They become a danger only if he transforms them into fixed ideas."

The physicist Hermann Helmholtz once made the following remark: "Happy ideas came unexpectedly without effort like and inspiration: they have never come to me when I was at my working table. They came readily during the slow ascent of a hill on a sunny day." Likewise, the idea of wireless telegraphy was said to have flashed intuitively into Marconi's mind while he was vacationing in the Alps.

It was not uncommon for investigators to wake up in the night with the solution of some problems which had troubled them for days, weeks or months. Frederick Grant Banting, the discoverer of insulin, awoke in the night and wrote down on a pad kept by his bedside the outline of one of his important experiments.

Philo Farnsworth was said to have conceived the idea of electronic television in a "moment of inspiration" while he was tilling a potato field back and forth with a horse-drawn harrow. He realized that an electron beam could scan images in the same way that a harrow passes over a swath of land methodically and repeatedly.

Isaac Newton, known for his work on "The Laws of Motion and Gravitation" and co-inventor of calculus, once made the remark that he often solved problems in his dreams. When asked how he made his discoveries, his reply was: "By always thinking about them." He kept the subject constantly before him and waited until the "first dawning opened slowly little by little into a full and clear light".

When the British naturalist Charles Darwin was formulating and writing his concept on the "Theory of Evolution", he was stumped by a problem which he could not reconcile with observed facts. Darwin later recalled: "I can remember the very spot in the country road where, while in my carriage, the solution occurred to me." That spot on the road was later pinpointed and a marker was erected nearby for posterity.

It can be recalled that Darwin, who was appointed a naturalist, joined the British Navy ship HMS Beagle, which sailed in 1831 to survey the South American coast. For almost five years, Darwin spent about two thirds of the time on land, collecting specimens and making observations. His observations on the animal species and the way they varied in the Galapagos Islands became the basis for speculating on their origins.

Intuition and hard work equals great discoveries

In many other circumstances, great ideas and inventions were made intuitively but were complemented by sheer hard work and persistence. Thomas Edison was the consummate and prolific inventor. During his lifetime, over 1000 patents were issued to him or his associates. In the development of his incandescent light bulb, he made thousands of experiments before achieving success with a charred cotton thread, sealed in a vacuum. Edison's most celebrated inventions were the phonograph and the movie camera. He founded his own electric light company, which became the progenitor of General Electric Company (GE). Edison can be remembered for his famous and familiar quote: "invention is 98 percent perspiration and 2 percent inspiration." Who will say that the inspiration did not stem from the perspiration?

Many of the great ideas and discoveries were made in the most unlikely places. We know that the most celebrated scientist, Albert Einstein, wrote two of his three early papers of earth-shaking significance in 1905, while he was working as a clerk in a patent office in Switzerland. The Nobel Prize was awarded to him in 1921 on account of his work on the "law of the photoelectric effect" and not on his more famous treatise on the "general theory of relativity". Nobody understood then what his unified theory on time and space was all about. How about his famous equation: $E = mc^2$? Where did he get all his revolutionary insights? They were initially envisioned at the time while he was thinking about a problem for a doctorate in physics at the University of Zurich but mostly while at work in the patent office.

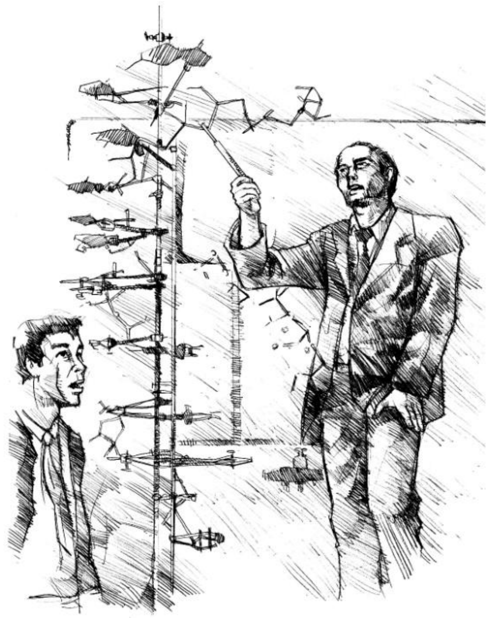
Another interesting case of insightful discovery is that Ernest Ruska, who did significant investigations on the electron microscope in an abandoned bakery in Germany at the height of World War II. Unfortunately for him, it was Reinhold Rudenberg who finally patented the electron microscope in the US and Britain.

Of course, many significant discoveries and inventions have been made in unheralded places even in contemporary times. Steve Jobs, the CEO of Apple and Macintosh computer company, assembled his first commercial model of a computer in his car garage, From very humble beginnings, the computer company has grown to be a world leader and innovator. He is also the maker of the hot-selling iPods. Among his creations are the Apple, iMac, iPod, iTunes, iPhone and iPad.

All these stories should be a reminder to our young and budding Filipino scientists that great discoveries can be made even in the most humble working environment and against overwhelming odds. Moreover, the feeling of personal gratification and fulfillment should be greater, knowing that the benefit can impact on the country's development. This is the true measure of success. Unfortunately, many of our young scientists easily get disillusioned with the dismal state of science and ill-funded R&D in the country. In many instances, our scientists leave the country and try their luck elsewhere. But somehow, we have to break this vicious cycle of low funding and mediocre performance.

We have noted that many great discoveries and inventions of the past were products of creative minds, often borne out of a synaptic flash of brilliance. If Tiger Woods and Michael Jordan would pump their fists after making some spectacular shots, I just wonder how the world's pioneering scientists reacted to their glorious moments of discovery and triumph.

We have one answer in the following story. The Greek mathematician, physicist, and inventor Archimedes (287–212 BC) arrived at the classic principle or law that a body immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the body. He used this principle in solving a problem posed to him— that of detecting the amount of alloy mixed with gold in the crown of the King of Syracuse. He cracked the difficult problem while in his bath and in a momentous outburst, he cried: "Eureka! I have found it." Legend has it that he leaped out of his bath and ran through the streets nude, repeating his exclamation of triumph at the discovery. As we can see, the world's pioneering scientists were also given to extravagant gestures.



8.
Genes and the Genetic Code

In 1856, Gregor Mendel, an Austrian and Augustinian monk, discovered and demonstrated that hereditary traits were determined by particulate units that were handed down from parents to offsprings in an organized pattern. Though the paper was published in 1865, it was largely ignored by the scientific community. Mendel's work was rediscovered in 1900, some 40 years after his death. But its full value remained unappreciated until the first quarter of the 20th century. In 1902, William Bateson, a noted cellular biologist, coined the term "genes" for Mendel's units of inheritance and "genetics" for the discipline relating to its study. Bateson and a host of classical geneticists contributed greatly to the growth of knowledge in genetics.

The Mendelian concept of inheritance provided the basic foundation for the growth of genetics as a science and a practical tool in the improvement of crops and livestock that supports human needs and progress. It was later found necessary to tap ideas from other disciplines to explain the intricacies of heredity. To illustrate, while visual characters like eye color in humans or flower color in plants follow a simple mode of inheritance, other characters like grain yield of crops or body weight and size in humans and livestock follow a more complicated system. This is because such complex characters are controlled by many or multiple genes, each acting in Mendelian fashion and together in a concerted way, plus the fact that gene action is easily influenced and masked by the effects of the environment. There is this joint effect between "nature and nurture" on the manifestation of certain characters.

Statistical and mathematical techniques have been employed to factor out genetic from environmental influences in a continuous variation in populations. Thus, the field of "quantitative genetics" gradually evolved. The knowledge has been useful in directing progress in the development of genetically superior strains of crops and livestock. In like manner, other disciplines like biochemistry and molecular biology have been put in harness to demystify the workings of the gene and the DNA at the molecular level.

Discovery of the Structure of DNA

In 1953, James Watson and Francis Crick, working in Cambridge using x-ray diffraction photographs taken by Maurice Wilkins and Rosalind Franklin discovered the double-helix structure of DNA (deoxyribonucleic acid). This was 100 years later from the time of Mendel's discovery. For this great achievement, the Nobel Prize was awarded to the three persons, excluding Rosalind Franklin, who had earlier died of ovarian cancer before the time of the award. Mention should also be made that the well known chemist, Linus Pauling, a two-time Nobel Prize winner and whose expertise was on the nature of chemical bonds and its application in understanding the structure of complex substances, was doing similar exploratory work on the exact nature of DNA. But his work led him to an erroneous hypothesis that three strands, rather than the double helix, were involved. He, therefore, missed out.

The double helix structure of DNA is nature's neat system of ensuring that in the process of replication in cells, the resulting daughter DNA molecules become the exact copies of the parental DNA helix.

The structure of DNA can be visualized as two polynucleotide chains wrapped around each other to form the double helix. The two chains constitute the spine or backbone which are made up of alternate molecules of sugar and phosphate. In between the inner spaces of the two helical chains are numerous pairs of "bases", which are flat molecules stacked on top of each other like a pile of hotcakes. They are attached to the sugar molecules of opposite strands. We can compare the double helix to a spiral stairway, with the sugar-phosphate links as the backbone and the paired bases as the crosspieces or steps of the stair.

There are four bases, each being a nitrogen-containing ring structure: (1) adenine (A); (2) guanine (G); (3) thymine (T); and (4) (C). The pairing of the bases is very specific: A bonds only with T and C only with G. Other pairing combinations, while possible, result in the paired molecules being either too large or too small to fit snugly in between the spaces of the helical chains. Thus, one of the strands is complementary to the other. The paired bases are linked tightly by hydrogen bonds.

It is the sequence of the paired bases in the DNA stairway that encodes the genetic information and is organized in terms of a large number of units or genes. The number of paired bases is extremely large, which in humans number about three billion. The bases AT and CG are like written musical notes that create great musical compositions.

Each gene is a discrete segment of the DNA with a base sequence that encodes the amino acid sequence of a polypeptide or protein molecule. The biological information carried by each gene is made available to the cell by a process known as "transcription", which directs the synthesis of a "messenger RNA" molecule of complementary sequence, and sent outside of the cell nucleus. The RNA, in turn, directs the synthesis of a polypeptide or protein in the cell, whose amino acid sequence is determined by the base sequence of the RNA. This process is known as "translation". The functioning of cells is dependent on the coordinated activity of many proteins which include enzymes that catalyze reactions, hormones, transporting materials like hemoglobin, structural elements like muscles, etc. The biological information contained within the genes acts as a blueprint or set of instructions for synthesizing the proteins in the cell at the correct time and in the correct place.

Genes and Chromosomes

Higher forms of organisms have a very long chain of DNA that represents their genetic identity. In humans, the three billion base pairs of DNA are coiled and distributed in 23 pairs of chromosomes. If these DNA materials in chromosomes are unwound and joined end to end, they will measure more than six feet in length! It is also amazing how this complex DNA mass can be recopied with great precision during cell division and multiplication. In reality, however, accidents do occur in the process and about 10,000 bases can be lost per cell per day. However, nature has provided a built-in repair mechanism so that only about 3 base pair mistakes actually happen.

There is also a protective mechanism for individual chromosomes. The ends of chromosomes are protected by a cap known as "telomeres". This protection is necessary because chromosomal ends have the potential to recombine with other DNA sequences and if this happens, there will be a disruption of genome integrity. A telomerase enzyme in cells is responsible for restoring the length of telomeres. With aging, the supply of telomerase may become inadequate and the telomeres can become worn out. Some medical biologists relate this erratic chromosomal condition to rapid cellular multiplication called "apoptosis" and the occurrence of cancers in elderly.

Number and Size of Genes

Humans have about 20,000 genes arranged in 23 pairs of chromosomes. Rice has 17,000 to 23,000 genes in 12 pairs of chromosomes; corn has 32,000 genes in 10 pairs of chromosomes. Lower forms of organisms have a lower number of genes — 19,000 in nematodes (microscopic worms), 13,600 in fruit flies and 2,300 in yeasts.

The average size of genes in humans contains at least 1,200 base pairs. This represents an average size of protein that is made up of 400 amino acids.

Recombinant DNA Technology

In 1972, Stanley Cohen of Stanford University and Herbert Boyer of the University of California San Francisco (UCSF) agreed to work together which led to the invention of recombinant DNA technology which was officially announced in 1973 in a publication in the PNAS, and patented in 1984. The patent covered "method and compositions that are provided for replication and expression of exogenous genes in microorganisms." With this method, a gene is inserted into a plasmid or viral DNA resulting into a modified plasmid which is then inserted into cells of microorganism by transformation. Transformed cells or those with the modified plasmids are capable of replicating the inserted gene and expressing it to produce medical or other useful proteins.

By 1976, the race to produce human insulin by this new method of recombinant DNA technology was on!

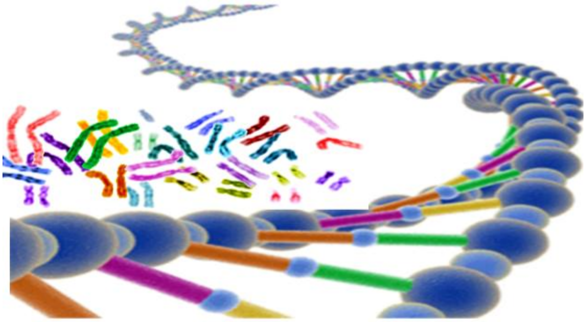
Boyer partnered with Robert Swanson, who had a degree in biochemistry and management from MIT, and formed Genentech starting with a capital of US$1,000! Their competitors were scientists from Harvard and from the UCSF. Their strategy differed from the latter two. Instead of cloning the human insulin gene, Genentech perfected first the synthesis of somatostatin gene using its known amino acid sequence as basis; afterwards Genentech successfully synthesized the human insulin gene. Then, in September 1978, Genentech announced the production of human insulin by recombinant DNA technology. "The development of human insulin demonstrates the viability of using recombinant DNA technology to produce products with practical application", exclaimed Robert Swanson, president of Genentech. It is much cheaper compared to the insulin that is extracted from the pancreas of pigs and cows.

Production of other drugs like the human growth hormone, interferon and hepatitis B virus vaccine (produced in yeast) using the same recombinant DNA technique followed starting in mid -1980s. Presently, there are more than 400 biotech health products in the market.

Recombinant DNA technology has found wide applications in the improvement of crops and animals. The technology is based on knowledge that the genetic codes for protein synthesis are universal and are transferable from one form of organism to another. Transgenic plants and animals with desirable properties such as resistance to pests, diseases and herbicides have been developed and commercialized worldwide.

As of 2015, 180 million hectares were planted to transgenic crops or biotech crops by 17 to 18 million farmers, 90% of whom were small farmers, in 28 countries—20 developing and 8 industrial. Among the health products now produced using recombinant DNA technology are human insulin, hepatitis vaccine, growth hormone, interferon, erythropoietin and many others. Over 90% of industrial enzymes like proteases, amylases, phytases, cellulases, etc. are produced by recombinant DNA technology. Researches are ongoing in the production of transgenic plants and animals that may serve as bioreactors for the production of medicinals or protein pharmaceuticals.

Thus, with the unraveling of how genes function and mastery of handling them, mankind has widened its arsenal and edge in the fight against hunger, malnutrition, and diseases.



9.
The Human Genome Profile

The human genome refers to all the DNA and genes that characterize the human species that are stored in 23 pairs of chromosomes. Humans possess over 3 billion DNA "base" pairs of hereditary material. The total number of genes in humans has been estimated at 20,000, much lower than the early estimates of 40,000 to 60,000. The biological information encoded in these genes serves as a blueprint or software that provides a set of instructions for synthesizing the proteins in the cell at the correct time, in the correct place, and in the right quantity. The kind of protein that is synthesized is determined by the sequence and length of the two nitrogen-bearing base pairs designated by biochemical letters AT and CG along the DNA helix. Proteins perform most of life's functions and make up the majority of cellular structures. They are large and complex molecules made up of smaller repeating subunits called amino acids. There are 20 different amino acids that genes can synthesize to form the kinds of protein that cells require.

The Human Genome Project (HGP)

The HGP was conceived to sequence the 3 billion DNA bases or nucleotides in order to establish the identity and specific location of all human genes. It was an international 13-year effort that was formally launched in 1990 and completed in 2003 at a cost of more than US$ 3 billion. Francis Collins who was the former director of the U.S. National Human Genome Research Institute headed a multinational team of 2,400 scientists who co-mapped the entire genetic blueprint.

The method used in DNA sequencing relied on the technology pioneered by Fred Sanger, the Nobel Prize winner who first synthesized the insulin gene. Though highly reliable, the Sanger method was meticulously time-consuming and expensive to undertake. It took more than a decade to complete the genome project and at a very high cost. A new generation of sequencing machines is now available that can do the work at unprecedented speed and low cost. J. Craig Venter, a former physiologist of the U.S. National Institute of Health and who was actively involved in the human genome project, is the proponent of the high-speed approach to DNA sequencing in collaboration with private equipment manufacturers like the Roche Diagnostics. With earlier-generation sequencing machines, Craig Venter's genome was subjected to analysis at a cost of only $70 million and completed in just a few years. With the rapid-sequencing technology using the 454 Life Sciences Genome Analyzer, it took just two months for a handful of scientists to sequence the DNA of James Watson and at a cost of less than $1.0 million. The goal is to reduce the cost of sequencing further to just a few thousand dollars and make it readily affordable.

A parallel development in the genetic revolution is the invention of the "gene copying machine" which undertakes a "polymerase chain reaction" (PCR) analysis of genes. Specific target DNA sequences corresponding to genes or fragments of genes are copied or amplified over a million times in a simple enzyme reaction involving nucleotide primers, the four bases, and the polymerase enzyme. The PCR is used extensively in the study and manipulation of genes. It has many applications throughout biology and medicine and has made important contributions to the study of inherited diseases. Other applications are in forensic science and biotechnology.

Startling Revelations about the Human Genome

With better understanding on how genes function and the profile of the human genome, some startling facts have been uncovered.

1. Though the human genomic content is extremely large, the functional genes that are involved in hereditary transmission comprise only about 2% of the genome. The remainder or 98% consists of noncoding regions constituted by elements known as tandem or interspersed repeats (or satellite DNA), pseudogenes, and other large chunks of DNA. Much of these noncoding sequences are relics of the evolutionary past but conserved within the human species. They are collectively referred to as "junk" DNA that seemingly serves no present-day purpose. However, there are strong indications that they

serve functions that are not fully understood but which relate to providing chromosomal structural integrity and in regulating where and when proteins are to be synthesized. The vast quantity of sequence information whose functions remain unknown is currently a major subject of scientific inquiry.

2. The human genome is 95% identical to the decoded chimpanzee genome. The remaining 5% is what makes humans different in terms of body shape, bipedalism, brain size, shape of skull and face, size of canine teeth, opposable thumbs, and of course, loss of tail.

3. Humans and mice share 90% of their genes (not the genome). This is the reason why many genetic and physiologic studies are conducted on mice. Paul Allen, the Microsoft billionaire, has supported a $ 140 million project to study the human brain and as a stand-in, the mouse-brain genome has been analyzed.

4. While almost all (99.9%) nucleotide bases are exactly the same in all people, there is "one-tenth of a single percent" of DNA in which no two persons will be alike. This is the basis for "DNA fingerprinting". There are certain types of small "repetitive sequences" that are highly variable from one person to another. Short tandem repeat (STR) technology of nuclear DNA has been in use to distinguish one profile from another. Thirteen (13) specific STR regions or loci have been identified. The odds that two individuals will have the same 13-loci DNA profile is about one in a billion. Using only five to six of the 13 loci for analysis and comparison is conclusive enough to warrant a decision. The use of STR technology is very useful in crime investigations and in establishing paternity and other family relationships.

The Human Genome and the Study of Genetic Disorder

One important spin-off of the human genome study is in facilitating the characterization of the molecular nature of genetic disorders that are controlled by single genes. It will also enhance the capability to map or locate these genes in their respective chromosome. There are about 2,200 known disorders that are caused by single genes. One example is "cystic fibrosis", a disease of the lungs that is caused by multiple mutations of a gene.

Aside from single-gene related diseases, there are other genetic disorders that are caused by genetic variants in combination with appropriate environmental factors such as diet and air quality. Though their effects are not clear-cut, there are genetic variants that are associated with common disease conditions such as diabetes, asthma, obesity and cancer.

With the identity of such disease-causing genes, they can be used as therapeutic targets and genetic biomarkers that will be useful in discovering new drugs. Another use of the human genome information is in providing increased opportunities for genetic testing of people for gene-related disorders and improved treatment. Parents can be screened for hereditary conditions and be given appropriate counseling on the consequences, the probability that it will be inherited in the offspring, and what precautionary measures to take. Another use of genetic testing is in pediatric medicine in which newborn infants are screened for congenital metabolic disorders, followed by early treatment.

The Future of Gene Therapy in Humans

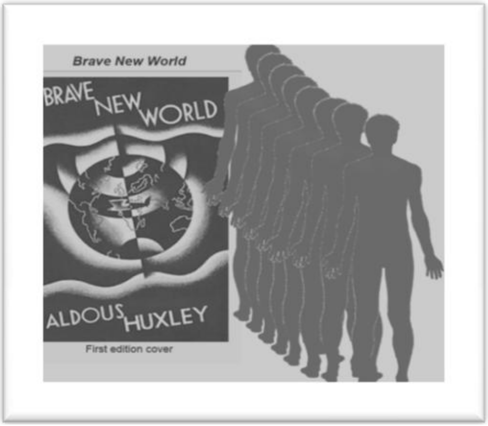
Gene therapy in humans refers to a process in which specific genetic disorders are corrected by replacing defective genes with normal ones through bioengineering techniques.

Thus, people with hereditary diseases can be given engineered genes to cure them. This capability is within the grasp of molecular biologists as it has been done routinely in plants and animals. But in humans, this is viewed as tampering or tinkering with the stuff of life that carries an enormous ethical question.

In reality, the technology is not yet ready because there are basic issues that need answers. For one, natural genes have regulatory mechanisms and what are the assurances that the installed helpful genes will operate within regulatory bounds in terms of action of the new molecular byproduct?

The first attempt at human gene therapy took place in 1980. Two victims of beta-thalassemia, an often fatal disease similar to sickle-cell anemia, were experimented on by having their bone marrow cells removed and subjected to recombinant DNA technology with the normal hemoglobin gene that was lacking. It was hoped that the cells would take up the genes and function normally when injected back into the patients. The results turned out to be inconclusive and the scientist who undertook the process at the University of California was found guilty by the National Institute of Health of violating the regulations concerning the use of recombinant molecules.

After more than three decades, gene therapy has been successfully applied in the treatment of severe combined immune deficiency (SCID), blood disorders, inherited blindness, lipoprotein lipase deficiency among others. It is only a matter of time when gene therapy becomes the way of the future, when the benefits demonstrably outweigh the risks, and finally, when human life triumphs over suffering and death.



10.
Aldous Huxley's Brave New World

Great scientific advances in genetic and molecular biology have given rise to a new and powerful tool known as "genetic engineering" or "recombinant DNA" technology. Genes can be manipulated and transferred at will across biological barriers— from microbial sources to plants, from humans to animals and to microbes for scientific utilitarian purposes.

The creation of genetically modified crops which have been fortified with high resistance or tolerance to pests, diseases and herbicides has steadily gained wide acceptance. In 2015, genetically improved crops of maize, soya beans, cotton, squash, canola, sugar beets and alfalfa occupied more than 180 million hectares worldwide, grown by 17 to 18 million farmers in 28 countries. Annual increments in hectarage have been quite spectacular. In 2006, there were only 101 million hectares.

Genetically-engineered strains of bacteria, yeasts, insect cells and mammalian cells are used in cell cultures to manufacture pharmaceuticals like insulin. More than 400 biotech health products are in the market today.

Genetically-modified plants such as maize, potato, rice, soybean and tomato are being tested to produce pharmaceuticals particularly vaccines for both humans and animals. These include vaccines against pneumonic and bubonic plague, a potato-based vaccine for hepatitis B that protects humans, and an edible rice-based vaccine for human protection to allergenic disorders such as asthma, seasonal allergies and atopic dermatitis.

So far, only two biotech products from animals have been approved and released for commercialization. Atryn, an anticlotting drug from GTC Biotherapeutics, was approved for release by the European Medicines Agency in June 2006 and by the US Food and Drug Administration (FDA) in 2009. Atryn is produced in the milk of transgenic goat. In December 2015, Kanuma, a treatment for a rare disease, lysosomal acid lipase deficiency, was approved by the US FDA. Recombinant lysosomal acid lipase is produced in the egg whites of transgenic chickens.

A number of human blood proteins are now produced using recombinant DNA technology using mammalian cells like Chinese hamster ovary cells; these are: (1) protein C, Factor VIII, and Factor IX, which are clotting agents which hemophiliacs or people suffering from in-born deficiency may seriously lack; (2) "tissue plasminogen activator", a substance that can dissolve blood clots and used in treating patients who have suffered from strokes or heart attacks; (3) alpha-1-antitrypsin, which can be infused in the blood plasma of people suffering from a debilitating form of emphysema, to relieve them of the difficulty in breathing.

Scientific investigations along the area of "human gene therapy" are steadily making progress so that in the foreseeable future, genetic disorders may be corrected by replacing defective genes with normal ones through bio-engineering.

Similarly, advances in stem-cell science are closing in to make regenerative medicine a reality in providing therapies for conditions like diabetes, Parkinson's, Alzheimer's, heart disease and spinal cord injuries.

The creation of synthetic but reproducible DNA is now possible. With knowledge and expertise gained in sequencing the human genome, Craig Venter has assembled 528,970 base pairs into the genome of a fully synthetic bacterium. Such creative capability has tremendous implications in custom-designing microorganisms that can produce biofuels, novel pharmaceuticals, or those that can be useful in bioremediation of polluted soils

As the Nobel Prize Laureate James Watson sums it up, humans now have the capability to create designer genes that can make "all girls look pretty". Of course, this statement was made in jest, because he used to be an avid girl watcher during his student days. But with the advent of the new biology, anything seems possible.

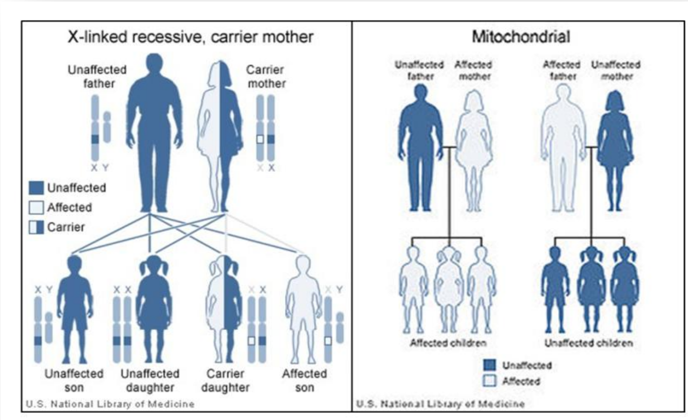
All these common place events in biology were foreseen by Aldous Huxley as early as in the 1930s. He was born on July 26, 1894 in Surrey, England. He was the grandson of Thomas Huxley (1825–1895), a respected English biologist and university professor, and contemporary of Charles Darwin.

Aldous Huxley studied biology at Oxford College but majored in literature. After Oxford, he pursued journalistic work. Huxley wrote four volumes of poetry and 46 novels but one stood out to become a classic. The novel was "Brave New World", a science fiction written in 1932.

The book was written at the time when pastoral England was emerging as an industrializing and urbanizing country. Huxley created a vision of a futuristic society in which the members were dehumanized to conform to strict utilitarian values. It describes a system of mass-rearing of human eggs and embryos in giant hatcheries, cloning of embryos, mental conditioning of babies, etc. Individuals lose their identity and spirituality. The society is structured into castes or classes, each serving a specific utilitarian role.

Brave New World had a strong appeal to the Hippie movement of the sixties, whose own utopian vision was based on non-conformity to authority, free love, psychedelic drugs, unscrubbed looks, and rock music.

Will science and discoveries send humanity to a perilous journey towards Aldous Huxley's world? Not at all, as the world science community has practiced good science all along and adhered to high ethical and moral principles. Research on "stem cells" involving human embryos and "human gene therapy" is governed by a strict code of ethics. Thus, Huxley's vision on human cloning will remain as a fantasy. The creation, release, and commercialization of genetically modified crops and animals have undergone a series of rigid biosafety tests all the way to make certain that the products are safe for human and livestock consumption and that their release will not pose a threat to the environment. So far, not a single negative effect anywhere in the world has been documented and verified.



11 Extra-Chromosomal and Y-Chromosome DNA Test in Humans

In my previous article on human genome, I indicated how DNA tests are used in forensic investigations and in establishing paternity and other family relationships. Such investigative analysis makes use of chromosomal DNA that is confined in the nucleus of cells. But aside from nuclear DNA, humans, animals and plants produce a small fraction of DNA outside the nucleus, in organelles known as "mitochondria". Mitochondria are energy-generating structures which convert and store energy derived from food in a form that cells utilize. This process of energy conversion requires the synthesis of enzymes that are involved in "oxidative phosphorylation". Mitochondrial DNA in humans consists of 16,300 nucleotides or base pairs that constitute about 37-genes. Thirteen (13) of these genes support mitochondrial functions.

Use of Mitochondrial DNA Analysis

Old biological remains such as hair, bones, and teeth lack nucleated cellular DNA for test purposes and instead, mitochondrial DNA (mt DNA) is used. For cases that have gone unsolved for years, mt DNA has been extremely useful.

Take the case of the murdered Nicolas Romanov II, the last emperor of tsarist Russia. During the Russian Revolution of 1917, the Bolsheviks who took power killed Nicolas Romanov II, his consort Alexandra, his brother Michael, 4 daughters, (Olga, Tatiana, Maria, Anastasia), and only son, Alexis. Russian DNA experts conducted a DNA test of the remains of the Romanovs and were able to establish the identity of every member of the deceased royalty.

In another great mystery, the use of DNA tests proved that the son of executed French King Louis XVI and Marie-Antoinette, Louis-Charles, died in prison as a child and did not escape the clutches of the French Revolution as earlier believed. Mitochondrial DNA is passed down only through the maternal line. Thus, all mothers possess the same mitochondrial DNA as their daughters. This is because the mitochondria of each embryo come from the mother's egg cell. The father's sperm contributes only nuclear DNA. Based on the analysis of mitochondrial DNA of fossils and ethnic groups, Rebecca L. Cann and Allan C. Wilson of the University of California reported in 1987 that modern humans from different populations all descended from a single female in Africa who lived about 200,000 years ago. She was named as "Mitochondrial Eve", adopted from the Biblical Eve.

Use of the Male or Y Chromosome Tests in Tracing Early Human Migrations

There are two kinds of sex chromosomes in humans, the X and the Y. Females carry the XX and the males, the XY chromosomes. Thus, the Y chromosome is passed down only by fathers to their sons. The male-transmitted DNA carries tens of millions of nucleotides compared to just 16,500 base pairs in mitochondrial DNA. Genetic markers or DNA sites in the Y chromosome where mutations have occurred and given rise to different human lineages have been used to distinguish one population from another. By examining genetic markers in the Y chromosome from men who live in different parts of the world, molecular biologists have traced the path of ancient migrations.

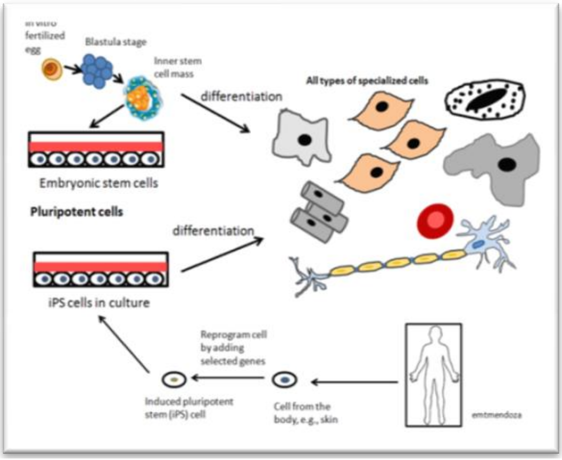
Paleoanthropological discoveries of human fossilized bones and artifacts in different evolutionary stages and use of radioactive carbon-dating techniques have established beyond doubt that early humans originated in East Africa. Modern use of mitochondrial DNA and Y chromosome tests has substantiated the theory that modern humans already walked this earth some 185,000 to 200,000 years ago. This time estimate is arrived at by measuring the rate of mutational change in specific sites in the DNA and using it as a molecular clock. Then about 50,000 years ago, early humans began moving out of Africa in trickles and later in waves in distinct timelines. Their journey spanned different continents and land bridges until, finally, they reached as far as the tip of South America.

Some DNA studies aimed to establish the ancestral origin of different ethnic populations around the globe have yielded interesting insights. For example, tests have indicated that the Siberians, Eskimos, the American Indians and the South American Indians have had a common ancestry. Some Bedouin groups of North Africa and tribes of the Middle East are hypothesized to be the progenitors of the early human settlers in Europe. Some gene pool of Lebanese men can be traced to Christian Crusaders and the Muslims of the Arabian Peninsula. The early Neanderthals, whose fossil remains were unearthed in a Croatian cave and other sites in Spain and France have been carbon-dated to be 40,000 years old. Comparative DNA tests have so far indicated that the Neanderthals reached a genetic dead-end and did not contribute to the genomes of modern humans.

The mitochondrial DNA and Y chromosome tests remain to be highly reliable and a powerful instrument. A $40-million funded organized global study spearheaded by the National Geographic Society, IBM and the Waitt Family Foundation was started in 2005 and collaborated in by 10 regional academic institutions. Known as the Genographic Project, its objective was to gather DNA from up to 100,000 indigenous people worldwide. The project aims to establish human genome relationships and provide details of how people made the journeys to the different parts of the world.

Since its launch in 2005, more than 250,000 people have joined the Genographic Project to learn their ancestry, their haplogroups and their personal genetic story. The project has developed a new test kit, called Geno 2.0 Next Generation. It examines a collection of about 300,000 DNA markers that have been selected to provide ancestry-relevant information. The analysis of DNA from a saliva sample consists of identifying thousands of genetic markers on the mitochondrial DNA which are passed on from mother to child, to show direct maternal deep ancestry.

For men, they examine markers on the Y chromosome to reveal direct paternal deep ancestry. Further, more than 250,000 ancestry-informative markers across the genome can reveal the regional affiliation of one's ancestry. (From: https://genographic.nationalgeographic.com/about/)



12.
Rapid Advances in Stem Cell Research

A landmark discovery in cellular biology was made in 1998. "Stem" cells from human embryos were isolated and cultured in the lab for the first time by a team of developmental biologists at the University of Wisconsin-Madison led by James Thomson. The discovery has sparked a great deal of interest in the development of "regenerative" medicine, a highly specialized field geared at treating disorders by replacing and restoring diseased or damaged human body organs.

The nature of embryonic stem cells

Embryonic stem cells are "undifferentiated" cells that constitute the fertilized embryos that are 5 to 7 days old. These beginning cells, still very few in number at 8 to 16, are technically termed "blastocysts". They are the mother of all 300 types of cells that later differentiate to form their respective tissues of the human body — the skin, bone, muscle, heart, liver, blood cells, neural tissues, etc. Embryonic stem cells are known to be "pluripotent": they can convert to any kind and group of cells that form specific body tissues.

Human embryonic stem cells are extracted from surplus embryos created during *in vitro* fertilization (outside the womb) in fertility clinics. Thus, human embryos as sources of stem cells are destroyed. This poses a great ethical dilemma to embryonic cell research. Consequently, federal support for this kind of research in countries like the U.S. has been very restrictive and granted only under certain conditionalities. Further advances in research made headway only when substantial funding was made available from private corporate sources which hold a high stake on medical and drug development.

Stem cells from non-embryonic sources

To sidestep the ethical issues surrounding embryonic stem cells research, efforts have been directed to look for "adult" or "somatic" stem cells that can perform similar functions. Adult stem cells can be found in some tissues which perform the role of maintenance and repair. Somatic stem cells can be derived from umbilical cords, placentas and amniotic fluid associated with pregnancies and births. In adult persons, stem cells are present within various tissues and organ systems which include the bone-marrow, liver, epidermis, retina, skeletal muscle, intestine, brain and elsewhere. Special adult-type stem cells from bone-marrow and from umbilical cord have been isolated which appear to be as flexible as the embryonic type. But in many instances, adult cells are already specialized and their potential to regenerate damaged tissues is very limited: skin cells will only become skin and cartilage cells will only become cartilage. Furthermore, adults do not produce stem cells in many other vital organs of the body.

Another limitation of adult stem cells is the difficulty in culturing them in the lab and their potential to reproduce diminishes with age; producing clinically significant amount of adult stem cells may prove to be difficult. Embryonic stem cells, on the other hand, have a capacity to reproduce indefinitely in the lab and are immortal. Interest switches back to the use of embryonic stem cells which are pluripotent and can be coaxed to develop into virtually any other cell type produced by the human body.

Conversion of skin cells into the embryonic state

For conversion work, the use of skin cells has been explored because of ease of extraction and cloning. The skin conversion procedure is adopted from the pioneering technique employed by the British embryologist Ian Wilmut in cloning a mammary cell of a sheep to a successful reproductive stage which resulted in the birth of Dolly. This was a scientific breakthrough achieved in 1996, which has since been duplicated in reproductive cloning of other farm and domestic animals. In converting the skin cells, a "nuclear transfer" technique is involved in which the skin cell's nucleus is excised or removed surgically and transplanted into an egg cell (from a female donor) that has been emptied of its own nucleus and genetic material. The transformed skin cell behaves like a fertilized egg and acquires an embryonic status, including its pluripotent nature. The next step is cloning of the cell in culture medium in the lab. This conversion of skin cells to an embryonic state has been successfully performed only in mice. But the objective in the mice work is to be able to refine the techniques so that in the end they could find application to human skin cells.

There has been a flurry of research activities around the world in a race to transform human adult cells into embryonic form but with no successful results. Suddenly in February, 2004, Hwang Woo Suk of Seoul National University announced the creation of 16 lines of cloned human embryonic cells in a scientific article published in Nature, a prestigious journal. It astounded the scientific world. But such findings could not be duplicated in other laboratories. It turned out to be a great scientific hoax because the findings were all fraudulent.

To come closer to a link with human cells, a number of investigators have turned to the use of monkey cells. In 2003, Gerald Schatten undertook nuclear transfer work on 716 monkey eggs but they did not produce a single clone. Earlier, a research team led by Shoukhrat Mitalipov in Oregon Health and Science University had been trying reproductive cloning in monkeys and used some 15,000 eggs in the process but all failed. They also explored using skin cells from a nine-year-old rhesus monkey and did similar nuclear transfer work. With the use of more precise surgical techniques, two cell lines were successfully formed, both showing an acquired embryonic pluripotency characteristic. The two cell lines reproduced further into multiple embryos in the lab. The success with monkey skin cells was a step closer in duplicating the feat with human skin cells.

The capability to convert human skin cells to embryonic forms may become a reality sooner than we think. In November 2007, Shinya Yamanaka of the University of Kyoto in Japan announced that his team had created pluripotent cells from human skin without resorting to the conventional use of egg cells. The technique was a more direct route through genetic manipulation of the skin cells. Four transcription factors were introduced directly into the human skin cells and were "reprogrammed" to become an embryo-like cell. Yamanaka's team generated 10 pluripotent lines from a culture of some 50,000 facial skin cells that had been subjected to the four genetic factors. The skin sample originally came from a 36-year old Caucasian woman. Yamanaka repeated the experiment using cells derived from synovial (joint) fluid from a 69-year old man and he obtained similar results. During culture, the converted cells took on the flat shape of embryonic stem cells.

Yamanaka's genetic manipulation technique on human skin cells is very significant for a number of reasons. Firstly, it has bypassed or done away with the use of human egg cells. In the somatic-cell nuclear transfer technique to human egg cells, the success rate in creating embryonic cells is expected to be very low, as was the experience with monkey eggs. Therefore, a very large number of egg cells, probably in a few thousands, would be required. Recruitment of enough number of female donors will not be easy. In undergoing the surgical procedure of egg extraction, donors would encounter discomforts, anxiety, and even health risks. Legal problems on proprietary rights on established cell lines may also crop up in later stages.

The second advantage in the direct usage of skin cells is the ease of the procedure because they proliferate and multiply fast in lab culture. With millions of cells at disposal, success rate in genetic transformation would be high. The third advantage is that with the patient's own skin cells as the pluripotent material for transplantation to the diseased organ, the risk of rejection by the body immune system is eliminated.

There are still some technical hurdles that need to be worked out in genetic transformation work because one of the four genes responsible has been found to cause the formation of tumors in mice, which may also occur in humans. But such genetic factor can be replaced with harmless counterparts. Also, scientists need to understand the factors that lead cells to specialization in order to coax them to become particular types of tissues that will be needed.

Yamanaka's ingenuous work has spurred a lot of excitement along the field globally and many other investigators and laboratories have joined the groundswell of activities. Broadening of the scientific base will eventually lead to medical applications.

In the event that human skin cells become the main source of pluripotent stem cells, it will usher in a new realm in which human organ spare parts will become readily available for transplantation work to replace damaged and diseased tissues. Pluripotent stem cells have the potential to treat and cure a wide array of diseases — Parkinson's, Alzheimer's, diabetes, heart disease, spinal cord injuries, third degree burns, etc.

Today, we are already aware of successes in the use of somatic stem cells for curative purposes. For the last few decades, the use of bone-marrow transplant has been successful in curing leukemia. But the more spectacular development in the treatment of this disease was with the use of stem cells taken from the blood in the umbilical cord of a newly born baby girl, which was given birth to by the mother, who happened to be previously diagnosed with acute leukemia. The mother was later given the bone-marrow transplant and several years later, she was found to be in full remission or free of the disease. Likewise, adult stem cells derived from the olfactory mucosa in the nasal region have been used to successfully treat spinal cord injuries. Stem cells can also be coaxed to develop into insulin-producing islet cells for transplantation to defective pancreas. As we are aware, insulin is necessary so that cells can absorb glucose present in the blood stream. The absence of insulin causes diabetes, an insidious killer.

With rapid developments in stem cell biology, a powerful tool is at hand that will eventually enhance the practice of regenerative medicine. Humankind can now be assured of longer life and healthful living.

Note: Dr. Shinya Yamanaka of Kyoto University received the Nobel Prize in Medicine (with Sir John D. Gurdon) in 2012 for "the discovery that mature cells can be reprogrammed to become pluripotent". Yamanaka's induced pluripotent stem (iPS) cells have become an important tool for modeling and investigating human diseases and screening drugs. Greater challenges in their medical use are in moving the clinical trials for cell therapies.

About the Author

Dr. Ricardo M. Lantican is a member Academician of the National Academy of Science and Technology Philippines elected in 1988 and was conferred the rank and title of National Scientist in 2005.

While National Scientist Lantican is more known for his outstanding scientific contributions in the varietal improvement of leguminous crops such as mungbean, soybean, and peanut which resulted in their improved plant architecture and/or resistance to biotic and abiotic stresses and higher yield, he has also significantly contributed to disseminating science and technology information to the general public through the more than 30 science articles he wrote and published in various newspapers. His topics range from great minds in science, breakthroughs, and technological advances to commentaries on international and national issues related to agriculture, environment and energy, and innovative R and D perspectives.

He obtained his BS in Agriculture from the University of the Philippines (UP) College of Agriculture (CA) based in Los Baños (1954), MS major in Crop Science (1956) from the North Carolina State College and PhD in

Plant Breeding and Genetics (1961) from Iowa State University. Dr. Lantican served UPLB and the government in various capacities: Professor, Director of the Institute of Plant Breeding at UP Los Baños, CA (1979–1984), Director of Research, UPLB (1970–1973; 1984–1987); and Undersecretary for R & D, Department of Science and Technology (1988–1992). Dr. Lantican was appointed as Professor Emeritus upon his retirement in 1998.

About NAST PHL

The National Academy of Science and Technology (NAST) Philippines is the country's highest advisory body to the government and the science community on matters related to science and technology. It also has the mandate to recognize outstanding achievements in science and technology made by Filipino scientists in all fields of science. NAST PHL was established on December 17, 1976 through Presidential Decree (PD) No. 1003-A and became operational in 1978 through PD 1557.

Its Vision for the Country

A progressive Philippines anchored on science

Its Mission

1. To recognize scientists for their exemplary science and technology achievements, and to identify and support emerging scientific talent;
2. To encourage Academy members to continue their own scholarly pursuits;
3. To provide independent advice on the utilization of science, technology, and innovation;
4. To promote a strong science culture in Philippine society; and
5. To link with national academies of science and technology in other countries.

Its Mandate

1. To recognize outstanding achievements in science and technology as well as provide meaningful incentives to those engaged in scientific and technological researches (PD 1003-A);
2. To advise the President and the Cabinet on matters related to science and technology (EO 818);
3. To engage in projects and programs designed to recognize outstanding achievements in science and promote scientific productivity (EO 818);
4. To embark on programs traditionally expected of an academy of science (EO 818); and
5. To promote and preserve science and technology resources of the country through the Philippine Science Heritage Center (RA 9107) which shall serve as the main repository of the country's contributions, achievements, and accomplishments in science and technology.

40 Years of Excellence
National Academy of Science and Technology Philippines
1976 - 2016
IN PURSUIT OF EXCELLENCE

ABOUT THE BOOK

In Science Nuggets, volume 1, National Scientist Ricardo M. Lantican treats the reader to numerous stories about famous scientists, not to tell us how great they are, but how human they are. Science Nuggets, volume 1 will take you on a journey through the history of science, from Aristotle's theory that Earth is the center of the universe to the advances in stem cell research. Indeed, although NS Lantican talks about scientists with great minds that were ahead of their time, he also tells us that they were also people like you and me. Readers will learn how scientists struggled to challenge the established ideas of their time.

—Acd. Fabian M. Dayrit

ABOUT THE AUTHOR

Dr. Ricardo M. Lantican is a member Academician of the National Academy of Science and Technology Philippines elected in 1988 and was conferred the rank and title of National Scientist in 2005.

While National Scientist Lantican is more known for his outstanding scientific contributions in the varietal improvement of leguminous crops such as mungbean, soybean, and peanut which resulted in their improved plant architecture and/or resistance to biotic and abiotic stresses and higher yield, he has also significantly contributed to disseminating science and technology information to the general public through the more than 30 science articles he wrote and published in various newspapers. His topics range from great minds in science, breakthroughs and technological advances to commentaries on international and national issues related to agriculture, environment and energy, and innovative R and D perspectives.

National Academy of Science and Technology Philippines
1976 - 2016
IN PURSUIT OF EXCELLENCE
40 Years of Excellence