Louis Pasteur—the Crusader for Truth

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LOUIS PASTEUR is regarded as one of the greatest biologists of all time. "In biology it is doubtful that anyone but Aristotle and Darwin can be mentioned in the same breath as him" said Isaac Asimov, a renowned science writer.

Some scientists stand out as individuals worth emulating! They broaden the horizon of human thought, contribute to the store-house of knowledge, become responsible for improving the quality of both material and spiritual life, and above all reflect exemplary conduct, ethics and values in life. Louis Pasteur belongs to this category of scientists. Science was a passion of his life. In his own words "Science ··· it is my life ··· it has brought me deepness of pleasure that I have always known yet never realised." His contributions are immense in the field of chemistry and biology. He laid the foundation of three distinct branches of science—stereochemistry, microbiology, and immunology. His contributions qualitatively improved human condition in the field of agriculture, industry, medicine, surgery and hygiene.

He battled against a host of killer diseases like anthrax, silk worm diseases–pebrine and flacherie, chicken cholera and rabies, developed many life-saving vaccines. He contributed to the development of vital theoretical concepts like germ theory, put an end to the theory of spontaneous generation and was responsible for some of the most important practical applications of modern science—fermentation, pasteurisation etc.

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Each of his contributions became acceptable to the then scientific community only after an arduous struggle unleashed by Pasteur. Many a times he was ridiculed, challenged, and ignored by his 'reputed colleagues', but his method of study was so systematic and his experiments so precise and repeatable that nobody could find a fault in his propositions. He would never make a statement without the support of enough data and experimental evidence. He was a brilliant expermental scientist. He spent days and nights living the problem at hand, became thorough with the situation and once he was convinced of the truth, nothing and nobody could stop him. He welcomed challenges and stood out as a crusader for truth.

At a time when science has become a means of career building, brilliance and intelligence is tested on the basis of the smart information one has gathered, and specialisation and super-specialisation have become the order of the day, when a comprehensive understanding of the natural world is absent, it is imperative that we ponder about the lives of heroes of science who faced challenges of their times, studied the problem comprehensively and emerged victorious. Were they born geniuses? Were they different from all of us? What inspired them to risk their lives and stand by the truth? Why could they do so? How did they leave their footprints on the sands of history? These are the questions that need to be answered and this article is an attempt to delve into these questions with respect to the life of Louis Pasteur.

CHILDHOOD AND FAMILY

Pasteur was born on 27 Dec 1822, in the town of Dole in France. He was the son of a tanner Jean Pasteur who did not have much education, but could instil in young Louis a love for knowledge, hard work and his mother-land. His mother Jeanne Etiennette Roqui was a good natured, practical woman. Pasteur loved his parents and family deeply. In his own words "I was born to a tanner. He was a worker but always eager to learn. He was my first teacher and it was he who inspired in me the love for work, as a direction for my work, instilled in me a love for my country." In a letter to his father later in his life he wrote "You might not remember how important your influence was on developing my mind $\cdots$ It was you who helped me to study natural sciences—undoubtedly because of your own interest in the subject rather than a conviction regarding my aptitude. Enthusiasm and mother's presence of mind were all passed on to me by you. If I have always associated the grandeur of our country it is because of the feelings that you inspired in me." Pasteur had a brother who lived only for a year, and three sisters. In the year 1827, the family moved to a nearby town—Arboris.

Pasteur got his primary education at Ecole Primaire. As a student there was nothing special about Pasteur to speak of his genius. He was more interested in fishing and painting than studies. He was busy drawing portraits of friends, neighbours and family members. His paintings of portraits are exhibited at the Pasteur museum, Paris, even today. His father did not want Louis to pursue a career as an artist, instead he wanted him to be a professor at the college at Arboris.

The Finnish artist Albert Edelfeldt, who painted a famous potrait of Louis Pasteur in his laboratory in 1887 passed the following judgment of Pasteur's portraits "$\cdots$ they are extremely good and drawn with energy, full of character, a little dry in colour, but far superior to the usual work of young people who destine themselves to an artistic career$\cdots$ I am certain that if Monsieur Pas-

Table 1: Chronology of Pasteur's scientific work.

1846–	Discovery of asymetry in the molecules of tartaric acid—crystallography
1855–	Beginning of studies on fermentation
1860-64–	Germ theory of diseases
1861–	Discovery of anaerobic life
1864–	Death blow to theory of spontaneous generation
1865–	Studies on pasteurisation and silk worm diseases
1877–	Beginning of studies on anthrax
1878–	Studies on gangrene, septicemia and childbirth fever
1879–	Studies on chicken cholera, discovery of immunisation
1880–	Studies on rabies.

teur selected art instead of science, France would count today one more able painter . . ."

Pasteur was hard working, sincere, serious minded, dutiful, eager to assimilate knowledge, and sentimental. The headmaster of the school was very impressed with Pasteur, and wanted him to study in Paris at the Ecole Normale Superieure, the most prestigious University founded to train outstanding students, for careers in higher education in science and humanities. He convinced Pasteur's father to send him to Paris. In October 1838, Pasteur was sent to Paris, to a school in Quartiere Latin, preparatory to Ecole Normale. But Pasteur felt homesick and came back to Arboris to his father. He joined the Royal College of Besancon, but wanted to go back to study at Ecole Normale. Step by step he achieved his goal. In 1840, he won his "Bachelier es lettres." Shortly afterwards he was appointed as an assistant mathematics master at the college. Two years later he went to Paris.

Pasteur qualified for admission to Ecole Normale on Aug 26, 1842. He ranked 15th among the 22 candidates. His physics was judged as 'passable' and chemistry 'mediocre'. Not satisfied with the results, he decided to reappear in the examination next year during which time he attended Jean Baptist Andre Duma's lectures in chemistry as a part of his preparations for the exams. Duma's lectures fascinated Pasteur, which provided a strong foundation in chemistry. His future works would reflect the strong influence, where he approached biological problems from a chemical angle. The next year he got a 4th rank. Till this point, his life's journey does not seem to be any different from that of any of us.

THE RESEARCHER'S JOURNEY BEGINS

Pasteur started his research work at Ecole Normale in chemistry. Since his contributions in research are many and each one is a saga in itself, let us first arrange them in chronology[1] (Table 1). These momentous contributions in science are described in the following sections.

Studies on crystallography

Pasteur spent the first ten years of his research work (1846-1856) studying the ability of organic substances to rotate the plane of polarised light, studying the relation of this property to crystal structure and

[1]The years mentioned here are only to refer to the beginning of the research in various areas. In reality, though they were initiated in these years, each line of research was carried on for a long time, with periods overlapping.

molecular configuration. Senior chemists like Jean Baptist Biot had recorded in 1815 that certain organic molecules like sugar, camphor, tartaric acid, oil of terpentine and some proteins rotated the plane of polarised light in solutions. Another noted German chemist Mitscherlisch had recorded in 1844, that the two forms of tartaric acid and their respective salts tartarate and paratartarate, have the same chemical composition, same crystal shape with the same angles, same specific gravity, same double refraction and therefore the same angles between their optical axes. Their aqueous solutions have the same refraction. But the solution of tartarate rotates the plane of polarisation but paratartarate is optically inactive.

This was the problem Pasteur chose to solve first. Despite Mitscherlisch's claim that the molecules were identical in every aspect, Pasteur was convinced that there had to be some chemical difference between the two substances, and he hoped that he could find the difference in the shape of the crystals. He framed his question properly and set out to test the various possible answers to the question experimentally. Pasteur began a systematic study of the crystals of tartarate and paratartarate that he had carefully prepared. With careful observation, he noticed the small facets on the surface of the tartarate crystals which were missed by the early experimenters. He inferred that there is a link between a crystal's shape and its optical activity.

Now if he could show that paratartarate crystals do not have these facets, that would explain their optically inactive nature. But to his astonishment and disappointment, he found that the paratartarate crystals also showed the small facets similar to tartarate crystals.

Intent on finding some difference he continued his work and found that while in all tartarates crystals the faces were turned towards the right, there were two types of paratartarate crystals: some had faces turned towards the right and some had faces turned towards the left. He carefully separated the two and then examined their solutions separately in a polarimeter. The solution with right handed crystals turned the plane of polarised light to the right and the one with left handed crystals turned the plane of polarised light to the left. When they were mixed together, they did not turn the plane of polarised light, because they nullified each other! The problem that haunted chemists for more than three decades was solved and Pasteur was jubilant. Pasteur was so overcome by emotion that he ran out of the laboratory, embraced one of his assistants and exclaimed "I have just made a great discovery $\cdots$ I am so happy that I am shaking all over and I am unable to set my eyes again on the polarimeter."

This experiment marked the beginning of a new branch of science dealing with the study of arrangement of atoms in molecules—stereochemistry. Prof. Ballard,

in whose lab Pasteur was appointed the assistant, was so jubiliant himself that he quickly arranged an appointment with the senior scientist Jean Baptist Biot. Pasteur's finding and his clarity of thought, his conduct and gentle nature moved Biot so much that he took young Pasteur almost like his son.

By the age of twenty seven, he exhibited qualities of a great investigator. He had the independence and audacity to question the validity of statements made by scientists of acknowledged authority. He developed the aptitude of forming bold working hypothesis to be studied with available experimental methods. With industry and thoroughness he developed experimental methods to obtain answers to the questions that he had formulated.

He later studied many more organic molecules like salicylic acid, aspartic acid, malic acid etc., and went a step further in concluding that living organisms produce many asymmetric molecules and therefore they are optically active. This conclusion that he arrived at gave him an edge over his contemporaries, and helped him in solving many biological problems in the later years.

Studies on Fermentation

In 1854, Pasteur joined the Faculty of sciences, Lille, as Dean and Professor of Chemistry. Here he was confronted with the problem of fermentation affecting the breweries. In the summer of 1856, one Mr. Bigot, a distiller and father of one of Pasteur's students, sought Pasteur's help in solving the problem at his factory. Something was going wrong with the process and the alcohol was turning sour. Pasteur went to the distillary, examined the vats, and found that during the brewing process in his distillery, some amount of lactic acid was produced instead of alcohol, which made the wine sour.

The dominant belief held at that time by leading chemists about fermentation was that it was purely a chemical process, and the micro-organism like yeast was only a catalyst. This view was held by giants like Liebig.

Pasteur conducted thorough experimentation, and came up with practical ideas to solve the problem. His experiments indicated three things:
(a) As long as the yeast was living and active. alcohol was produced. The moment lactic acid started being produced, some rod-shaped micro-organisms were found. This means, fermentation is caused by micro-organisms.
(b) Along with alcohol, a lot of other complex organic compounds were found. Therefore, fermentation was not simple breakdown of sugars into simple components as proposed by Lavoisier.
(c) The organic molecules, when studied under the microscope, showed asymmetry and this definitely was due to the living organisms.

Hence, he concluded that fermentation was a direct act of microbes. They did not act just as agents or catalysts but they were the basis of fermentation. The scientific community was not prepared to accept such a drastic shift from the established belief. There were cartoons drawn and circulated in scientific circles which showed a yeast eating sugar and excreting alcohol. Pasteur did not care about these jeerings. He only requested his opponents to come with repeatable experimental evidence to support their claims.

Pasteur's position that micro-organisms cause fermentation enabled him to arrive at a solution to the industrial problem. Pasteur decided that there were in fact two kinds of fermentation, each independent of the other, going on in the vats: alcoholic fermentation due to yeast and lac-

tic acid fermentation due to the a different type of micro-organism. Pasteur discovered and isolated the bacillus, and believed that the air was the source of the contamination. He first tried killing the undesirable micro-organisms with chemicals. Though the method was effective, it disturbed the taste of the alcohol. Finally he struck upon the idea of using heat to destroy the micro-organisms. He proposed heating the alcohol to a temperature of 60-80 degree centigrade for an hour or two and sealing the pack immediately, so that external microbes do not interfere with fermentation. This process came to be known as Pasteurisation, which was applicable not just to beer, alcohol, and wine, but equally to milk, cheese and bread. The method saved the breweries as well as diary industry!

The solution looks simple, but it needs a new outlook—to be sceptical about established authorities, to venture for solutions in unknown areas. And Pasteur did that. He looked at the problem with focus on microbes, and therefore could find a simple solution of the problem by killing the unwanted organisms.

Death blow to theory of spontaneous generation

At that time most scientists believed in the theory of spontaneous generation, which said that the lower animals like insects, worms, maggots and leaches are spontaneously generated out of decaying matter. The theory of spontaneous generation was upheld by many bigwigs in science. Francisco Redi, Lassrado Spallanzani, Franz Schulz, Theodor Schwann and many other biologists of repute fought the spontaneous generation theory with their experiments, but they failed to gain scientific acceptance owing to certain loopholes in their techniques and poor repeatability of the experiments. Pasteur settled the debate with his classic "swan neck bottle" experiment. He accepted a challenge of one of his colleagues and proved the same in the Academy of Sciences.

> "Preconceived ideas are like searchlights which illuminate the path of the experimenter and serve him as a guide to interrogate nature. They become a danger only if he transforms them into fixed ideas ··· the greatest derangement of brain is to believe in something because one wishes it to be so ···"
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> — Louis Pasteur

With very limited equipment and rudimentary knowledge of microbiology, Pasteur continued to solve one problem after another—because of his strict adherance to the scientific method.

Discovery of anaerobic life

While studying butyric acid fermentation, he observed anaerobic organisms which live in the absence of air. He observed certain micro-organisms preferring to crowd at the middle of the cover slip and shying away from the edges that have some contact with air. This observation led him to conclude that putrefaction or decaying happens because of anaerobic bacteria.

Studies on silk worm diseases

In 1865, he was asked to probe into the silk worm disease that had caused havoc in southern France. At the time when Pasteur began this work, he knew nothing about the silk worm. He had not seen one. But when he was assigned the task of solving the problem, he lived with the problem day and night. The plight of the poor farmers touched him. He made thorough observations, studied the life cycle of the worm,

learnt about methods of rearing the silk moth, observed and recorded the symptoms of the disease. He did his work so well that he surpassed the biologists of his time! He devised experiments based on this study and accordingly concluded that there are three types of diseased worms: worms affected by pebrine—with black corpuscules on the body, worms affected by flacherie—with no specific symptom except that they became sluggish, and worms affected by both. He adopted the egg selection method to isolate the healthy eggs from the diseased ones. At a time when the disease had spread as far and wide as China, and quacks had begun making quick money by selling spurious eggs as healthy ones, Pasteur rejuvenated the dying industry. He supplied healthy eggs to the farmers from his laboratory and suggested various methods of hygienic rearing of the worms which he experimented himself and saved the sericulture industry.

When Pasteur was battling the disease, he was struck hard with three personal tragedies—the death of his beloved father in 1865, the death of two of his loving daughters Camille in August 1865 (aged 2 years) and Cecille in May 1866 (aged 13 years). He completed his work on silk moth in 1869, but he was himself paralysed in october 1868. Despite such emotional trauma, Pasteur kept his work going! He had five children, four daughters and a son. He lost three of his daughters to various diseases. He lost his first daughter Jeanne in Sept 1859 to typhoid fever. This kindled in him an urge to probe into the role of microorganisms in human health. His studies on silk moth gave him the necessary exposure. And he was formulating the principles of germ theory in his agitated mind.

> "Imagination is necessary to give wings to thought at the beginning of experimental investigation of any given subject. But however when the time has come to conclude, and to interpret the facts derived from observation, imagination must submit to factual results of the experiments."
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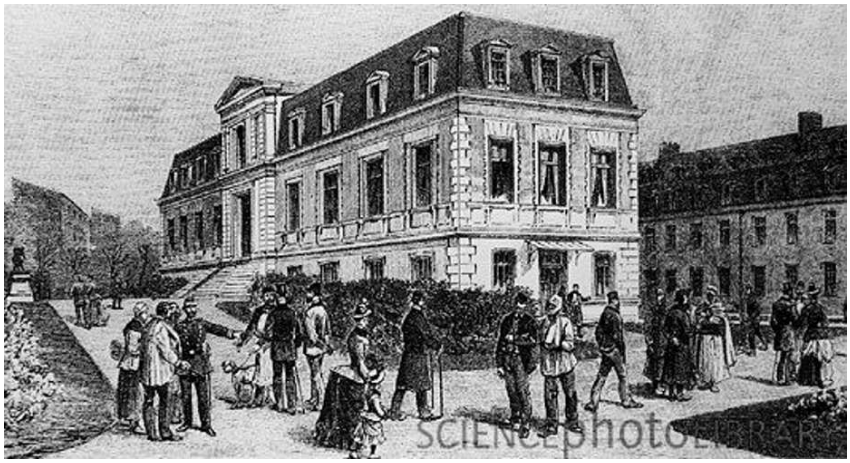
> — Louis Pasteur

Battling the anthrax epidemic

In 1877, he started work on the killer epidemic Anthrax affecting sheep and cattle in the entire Europe. Robert Koch, a German physician, was working on the same disease. He isolated the bacteria, recorded its ability to form spores and studied its life cycle. It took Pasteur to conclusively prove that the bacteria is the killer. Pasteur developed attenuated forms of the bacteria as vaccines and saved the cattle rearing industry. His experimental methods were thorough and scientific. Yet again a lot of physicians challenged Pasteur on his methods. They claimed to have repeated the same experiment and failed. Rasignol, a famous veterinarian who did not accept the germ theory, challenged him for a public demonstration of his experiment. Pasteur readily accepted!

The event was widely publicised; the *Times of London* carried the news. The test was to take place in front a great assembly of general public and scientists—both friends and foes! The plan of the experiment by Pasteur's team was as follows. For the experiment, 50 healthy sheep would be chosen. Out of that 25 would be vaccinated, and later inoculated with anthrax bacilli. The other 25 (the control group) would be left unvaccinated but inoculated with anthrax. If Pasteur's theory is correct, the first set should survive, while the second



The Pasteur Institute at the time of inauguration.

While presenting the results of his rabies treatment to the Academy of sciences on March 1, 1886 Pasteur, called for the creation a rabies vaccine center. Pasteur said: "The cure for rabies resulting from dog bites was well founded. There was the need to create a vaccination for rabies." The Academy of Sciences launched an extensive, international public drive for funding the proposed center and it was able to collect 2,586,680 Francs. With the overwhelming response shown by a number of people, it was possible to acquire 11,000 m^2 of land on rue Durot, in Paris. The Institute which bears the name of Pasteur was inaugurated on 14 November 1888 in the presence of French president Sadi Carnot. In his inaugural speech on the occasion, Pasteur said: "$\cdots$ It can be said of the immense building which was constructed that, without exception, each stone stands as a material symbol for generosity. All virtues were combined to raise this work structure$\cdots$ My dear colleagues, maintain the enthusiasm that you showed right from the beginning. At the same time, be extremely strict in monitoring. Do not forward anything that cannot be proved in a simple and decisive manner. Adopt a critical mind. By itself, it cannot encourage ideas nor stimulate anything great. But without it, everything is useless. It always has the last word. When I ask of you in this respect and what you will in turn ask of your disciples in the most difficult part for an inventor$\cdots$" Pasteur became so emotional that he had to ask his son to read out his speech.

set should die.

The animals were assembled at Pouilly le Fort, Melun, on the property of Rasignol, who would monitor the experiment personally. While all his assistants were tensed, Pasteur believed "what succeeded with 14 in the laboratory will succeed with 50 in Melun." On May 5th, 1881, the first vaccination was made and on May 17th the second one. Trial inoculation was made on May 31. June 2nd was the test day. There were lots of sceptics in the crowd. Doctors, veterinarians, farmers, scientists—all had gathered to witness the rare event. When Pasteur arrived on the scene on June 2nd he was received with a loud applause by his assistants Roux, Chamberland, Thuillier and others. The experiment was a grand success and the challenge was won in style. It was a victory to the germ theory of diseases.

On the same lines Pasteur later tackled

chicken cholera, swine fever, osteomyelities, and child birth fever. Pasteur lamented the very poor hygiene practices of the physicians who utterly disregarded the role of microbes in human health. Despite resounding evidence of the existence and mischief potential of the micro-organisms, there were still a large section of doctors who believed that change in the external conditions like temperature, humidity, wind, rain etc.—and not micro-organisms—left human beings susceptible to death. Thousands of women died at the time of child birth in hospitals because the doctors themselves unknowingly carried the staphylococci bacteria from person to person. Septicemia was a common cause of death. Pasteur strongly advocated the necessity of hygienic practices in the medical fraternity. He published pamphlets and distributed among the public. Physicians did not accept his recommendation, because he was a chemist and had no qualification to speak on human health. Still, he was dogged in defence of the truth that he had found by experimental methods.

And finally, Rabies

Keeping such fights alive, Pasteur jumped into yet another danger zone—Rabies! Many argued with him that it was not a major killer, so why attack it. But Pasteur was convinced of the deadly nature of the disease. He had vivid childhood memories of his friends succumbing to the disease. The treatment in those days was to inflict deep burns with red hot iron in the wounded regions. Still death was more or less certain!

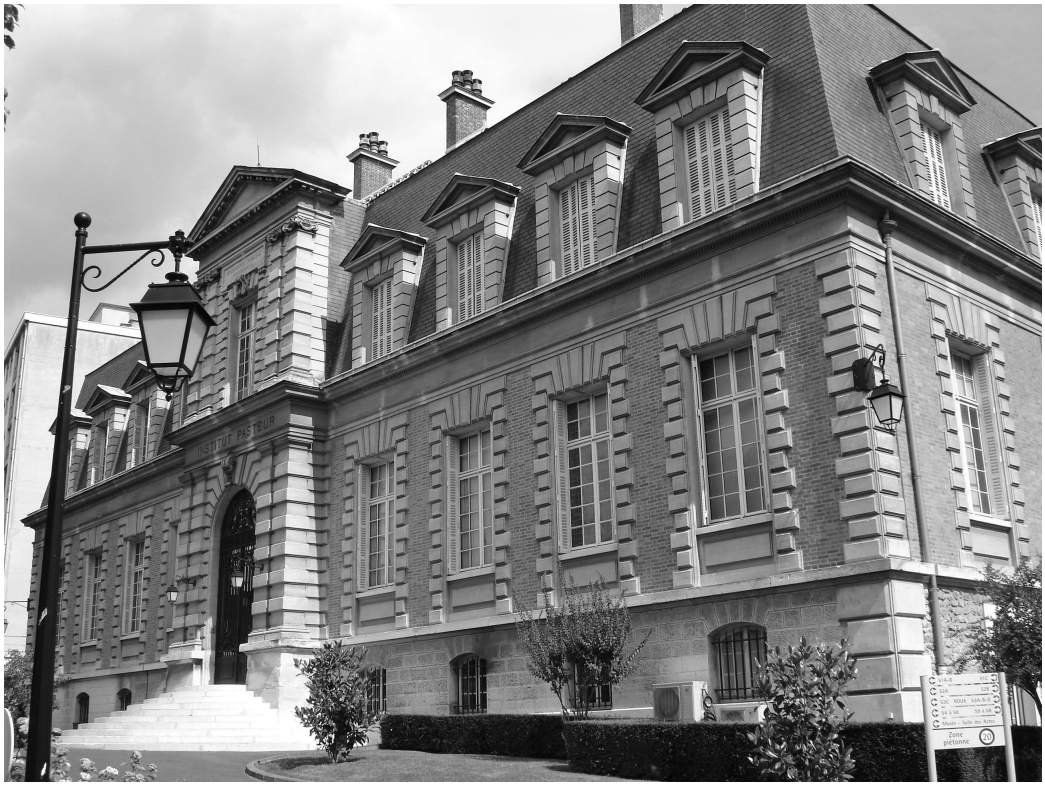
In December 1880, Pasteur decided to study rabies. He extracted the inoculum from the saliva of a dead child, used rabbits and dogs to culture the virus. The method of extraction of sample known in those days was drawing the saliva from infected animals by suction through mouth. This was an extremely dangerous procedure. Very slight carelessness on the part of the experimenter would cost him his life. Pasteur prepared vaccines from the dried spinal cords of infected animals. Even as he was perfecting his technique he was forced to test it on human beings, a feat if unsuccessful would land Pasteur in deep legal trouble.

Joseph Meister, aged 9, was brought from Alsace to Pasteur on July 6th 1885, he was bitten by a rabid dog on hands, legs and thighs. On July 7th, 60 hours after the dog bite, the boy was vaccinated with higher and higher doses for 12 days, finally on July 16th he received an inoculation with the virulent cord. Joseph Meister exhibited no symptoms of the disease and returned to Alsace healthy, carrying deep love and gratitude for Pasteur. Pasteur too loved the boy deeply and insisted on keeping him posted about his whereabouts and health. He later became a gate keeper of the Pasteur institute, fifty five years later when Pasteur was no more. He decided to guard the crypt of Louis Pasteur. He considered it a great honour. But when the Germans invaded France in 1940, they compelled him to open the gates of the crypt, unable to resist the invaders and bear any damage to the crypt Meister committed suicide in front of the crypt. This incident bears testimony to the love Pasteur enjoyed.

Pasteur had himself vaccinated 2490 people against rabies!

Pasteur was a great experimental scientist who was driven by the passion for science and humanity. He laid down some of the important principles for scientists.

Pasteur was a great humanist. He never filed any patents for his inventions, his only purpose in life was to be of use to mankind and to improve the quality of life. Pasteur was a great patriot but he was not a fanatic. “Science knows no country, because knowledge belongs to humanity, and is the torch



The Pasteur Institute today.

which illuminates the world" wrote Pasteur. "Science is the highest personification of a nation because that nation will remain the first which carries the furthest the work of thought and intelligence."

Pasteur died on September 28, 1895. The French government honoured him with a national funeral on October 5 1895. Thousands of people gathered and joined the funeral. People were seen crying, shedding tears of gratitude for the man who changed the lives of millions of people across the world. It is not in France alone that Pasteur became a legendary hero. Scientific institutes, broad avenues, even provinces and villages carries his name all over the world. There are around 60 Pasteur Institutes across the world working on various diseases. His love for humanity will remain etched in people's minds. This is how he left his footprints on the sands of history!

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