CATHOLIC MEN OF SCIENCE

LOUIS PASTEUR

(1822-1895)

BY

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(The writer desires to acknowledge his indebtedness to two excellent biographies—*The Life of Pasteur,* by M. René Vallery-Radot (son-in-law of Pasteur), and the volume entitled *Pasteur,* by Professor and Mrs. Percy Frankland, in "The Century Science Series." From one or other of these works most of the facts hereinafter set forth have been obtained.)

Louis Pasteur was born in 1822 at Dôle, a small town in the east of France. His father, Jean-Joseph Pasteur, was a soldier of the great Napoleon, and fought in the Peninsular War. Later on he married and set up in business as a tanner at Dôle.

He seems to have been a most respectable type of old soldier. His language and manners were not those of a retired sergeant; he never spoke of his campaigns, and never entered a café. On Sundays, wearing a military-looking frock-coat, spotlessly clean, and adorned with the showy ribbon of the Legion of Honour, he used to go out walking on the vine-bordered road leading from Arbois to Besançon. Although far from prosperous, he contrived to give his son, Louis, a liberal education. He sent him up to Paris for a while, and afterwards caused him to take his degree (Bachelier-ès-Lettres) at the Royal College of Besançon. Pasteur retained through life the liveliest recollections of all his father had done for him, and gave expression to this gratitude in the following noble words, which form the dedication of one of his scientific works:—

"A la mémoire de mon père, ancien militaire sous le Premier Empire, Chevalier de la Légion d'Honneur.
Plus j'ai avancé en âge, mieux j'ai compris ton amitié et la supériorité de ta raison.
Les efforts que j'ai consacrés à ces études, et à celles qui les ont précédées, sont le fruit de tes exemples et de tes conseils.
Voulant honorer ces pieux souvenirs, je dédie cet ouvrage à ta mémoire."

(To the memory of my father, an old soldier of the First Empire, and a Knight of the Legion of Honour.

The longer I have lived, the better I have understood thy warmth of heart and thy strength of mind.

The labour which I have devoted to these studies, as well as to their forerunners, is the fruit of thy example and of thy counsel.

Desirous of honouring these affectionate remembrances, I dedicate this work to thy memory.)

Pasteur graduated at the age of eighteen, and although his father would have been delighted to see his clever son settled down as professor at the local college, his old schoolmaster saw that he was destined for higher things, and urged him to take out special courses of instruction in mathematics and chemistry, so as to qualify for entrance to the great École Normale of Paris—the training school of French scientists and professors. Louis followed this counsel, and went for the entrance examination in 1842, at the age of twenty.

He qualified for admission, but only passed fifteenth out of twenty-two candidates. Most young men would have been satisfied at passing anyhow. Not so Pasteur. Dissatisfied with this performance, he refused admission, took another year's work, went up again, and this time passed in with fourth place. Meanwhile he supported himself by teaching mathematics at a Paris boarding-school, where he gave private lessons from six to seven in the morning. One wonders what a youth of the present generation would think of these hours. "Do not be anxious about my health and work," he wrote home. "I need hardly get up till 5.45; you see, it is not so early."

It was at this period that Pasteur began to feel an enthusiasm for chemistry. In a letter dated 9th December 1842, he writes: "I attend, at the Sorbonne, the lectures of M. Dumas, a celebrated chemist. You cannot imagine what a crowd of people come to these lectures. The room is immense and always quite full. We have to be there half an hour before the time to get a good place, as you would in a theatre; there is also a good deal of applause; there are always six or seven hundred people."

Our young scientist was not the type of man to take for granted any *dictum* laid down by his teachers, however distinguished. He insisted on verifying everything and working out everything for himself. He was assiduous at his attendance at the chemical laboratory, and was in the habit of trying, on his own account, the experiments described, but not actually done, at the lecture. Thus, for example, when the process of making phosphorus was merely explained but not actually carried out, on account of its being so tedious, Pasteur would not rest content. He bought a quantity of bones at the butcher's and set to work. He burnt them, reduced them to a fine ash, treated this with sulphuric acid, and went through all the other stages of the process. The work took him from four in the morning till nine at night; but what was the labour compared with the joy of possessing sixty grammes of pure phosphorus of his own manufacture!

Endowed by God with such a spirit as this, it was not surprising that Pasteur should be selected by his superiors for promotion. He passed his *Licence* examination, and then the higher one called the *Agrégation* with special distinction in physics and chemistry. This was in 1846. A few months later the Minister of Public Instruction wanted to make him Professor of Physics at a Lycée at Tournon, but his teacher, the eminent Balard (discoverer of bromine), represented that it would be rank folly to bury so promising a talent in the provinces, and succeeded in having the appointment cancelled. Pasteur, left to his laboratory work, at once proceeded to prepare for his final degree of Doctor of Science by undertaking some investigations on the application of crystallography and physics to chemical problems. He prepared a thesis on "The Phenomena relative to the Rotatory Polarization of Liquids," and duly obtained his Doctorate in 1847. His attention became concentrated on the optical properties of certain crystalline substances by virtue of which some of them rotate the plane of polarization to the right, whilst others do so to the left. In 1844 a distinguished German chemist, Mitscherlich, had discovered that the two varieties of tartaric acid possessed different optical properties. (Here I may explain that this is the acid obtained from the crusty deposits called "tartar" in old wine barrels.) The common variety (ordinary tartaric acid) rotates the plane of polarized light to the right, whilst the rarer sort (para-tartaric or racemic acid) possesses no rotatory power. Pasteur, who had been studying crystallography and had acquired skill in the use of the goniometer, was much interested in Mitscherlich's discovery. He prepared a fine set of crystals of tartaric acid and its compounds. He could not understand why it was that the two varieties, though absolutely identical in the nature and number of their atoms and in their crystalline forms, should yet behave differently towards the beam of polarized light. He subjected his crystals to a more minute and painstaking examination than they had ever undergone previously, and succeeded in discovering on the crystals of the optically active tartrate certain minute faces, which had escaped the attention of the most accomplished crystallographers of the day. He then ascertained that the crystals of the optically inactive tartrate were symmetrical—in other words, when looked at in a mirror they gave an image upon which the crystals could be accurately superposed. The crystals of the optically active acid were dis-symmetrical—their mirror-image was not identical with themselves, but they bore the same relation to it *that the right hand bears to the left*. The next thing Pasteur did was to try various ways of crystallizing the optically inactive acid, and he at last found a method by which he obtained two different sorts of crystals, one sort being the optically active variety, already known, whilst the other set were identical with the mirror-image of these, and had never previously been seen. He at once saw that these latter crystals might possess optical properties that would exactly counterbalance those of the optically active ingredient—in other words, that they ought to rotate the plane of polarization to the *left*. Accordingly he carefully picked out the crystals of the new variety, dissolved them and tested them in the polarimeter, whereupon he found, to his joy, that they turned the plane through just the same angle to the left as the others did to the *right*. Pasteur's acute and perspicacious mind instantly grasped the far-reaching importance of his discovery, and, rushing from the laboratory, overcome with emotion, he encountered his friend Bertrand in the corridor, and, embracing him, poured the good news into his sympathetic ears.

This observation of Pasteur's, made in 1848, was the first glimpse of mankind into molecular architecture—a study which has for its object the discovery not merely of the numbers and kinds of atoms that go to make up a compound, but their actual arrangement in three-dimensional space It is true that the full consequences of Pasteur's work were not foreseen at the time even by himself. The study of organic chemistry was not then sufficiently advanced. Over twenty years had still to elapse before Wislicenus made a similar observation with regard to lactic acid. Le Bel and van t' Hoff were then able to rear the now majestic edifice of stereo-chemistry upon the foundations laid so far back as 1848 by Pasteur. And all this is not merely barren knowledge. It is fraught with consequences the most important to the human race. Thanks to the accurate conceptions of stereo-chemistry, we can now construct new chemical compounds with the precision of an engineer constructing a machine, and for purposes as definite. We can build up new drugs and foretell what their physiological effects will be. We can secure refreshing sleep, reduce fever, and stay the ravages of some of the worst disease-producing parasites, to the attacks of which our human bodies are liable.

Even though all the consequences of this first discovery of Pasteur's were not at the time foreseen, yet, proceeding as it did from a young man of twenty-five, it excited incredulity in the breasts of many senior men, who had worked for long years in the same field, but with less success. Pasteur's paper was referred for report to the greatest living authority, Biot, who sent for the young man and made him repeat the experiment with materials provided by himself (Biot), and under the most stringent conditions. One glance at the optical instrument proved Pasteur in the right, and the illustrious old scientist, who saw the glory of his years of labour thrown into the shade by his young disciple, grasped him by the hand, and in tones of deep emotion murmured: "My dear boy, I have so loved science all my life through, that this discovery of yours makes my heart throb with joy."

Shortly after this Pasteur lost his mother through apoplexy. He was tenderly attached to her—he could no longer work, but asked for leave of absence, and remained for weeks plunged in grief and incapable of intellectual exertion.

On his return to Paris it was felt that something ought to be done for him, and he was at first sent to teach physics at Dijon. This appointment was not looked upon by Biot and his other scientific friends as sufficiently important for a man of his capacity, and so he was sent to Strasburg (then of course belonging to France) as Professor of Chemistry—a post that suited him well, as the numerous industries of Alsace stood much in need of applied chemistry. Here he became intimate with the family of the President of the College, M. Laurent—an intimacy that proved a turning point in his career, for he proposed to and was accepted by the President's daughter, Mdlle. Marie Laurent. In this important concern Pasteur's insight proved as unerring as it was in other and widely different spheres. The young couple were married on 29th May 1848, and the union proved in every way successful. Madame Pasteur took the deepest interest in her husband's work, shielded him as much as possible from worry, wrote out his daily notes from dictation, and rendered his home life one of unclouded happiness. During the following years everything seemed to smile on him. Three fair children in the home—a sympathetic helpmate to whom he recounted each evening the results of his work during the day, who never scolded him save for not taking enough care of his health, and who was indeed *socia rei humanæ etque divinæ*—such were the elements which, together with acknowledged merit and security from disturbance in his work, made up at this period the life of Pasteur.

To follow his labours during the period of six years which he spent at Strasburg would exceed the limits of this brief memoir. Let it suffice to say that he persevered in his study of dis-symmetrical crystalline compounds, and made the important discovery that right- and left-handed bodies, though chemically identical, are widely different in their behaviour towards living things ; so that fermentative organisms growing in a mixture of such bodies will use up only the right-handed, and reject the left-handed tartaric acid. In this way it is possible to separate the optically active compounds. For these researches Pasteur received in 1856 the Rumford Medal of the Royal Society of England—one of the greatest distinctions in the gift of English science.

After spending three years at Lille, as Professor and Principal of the new Faculty of Science, Pasteur was recalled to Paris to take up the post of Director of Scientific Studies at the École Normale. All the time he could spare from lecturing was devoted to a study of the nature of fermentation. The great German scientist, Liebig, persisted in looking upon the processes of decay, decomposition, and fermentation as of purely physico-chemical character. He considered that the beer yeast was as dead as the wort it fermented. In his own words : " Beer-yeast, and in general all animal and vegetable matters in putrefaction, impart to other bodies the state of decomposition in which they are themselves. The movement which, by the disturbed equilibrium, is impressed on their own elements, is communicated also to the elements of bodies in contact with them." In another oft-quoted passage, Liebig says : " Those who attempt to explain the putrefaction of animal substances by the presence of animacules, argue much in the same way as a child who imagines that he can explain the rapidity of the Rhine's flow by attributing it to the violent agitation caused by the numerous water-wheels at Mayence." Pasteur was led by his own researches boldly to claim for living "animacules" the rôle denied them by Liebig and his followers. He proved, beyond all doubt, that these minute living things oxydized the organic matter in the fluid, and thus caused it to break up into simpler compounds. He discovered a new group of living things called *anærobes*, because they live without air, and showed that they play an important part in the processes of fermentation and putrefaction. At that time, life was thought to be absolutely dependent upon air for its maintenance, and Pasteur's discovery of organisms to which air was a poison, and which could only unfold their activities in its absence, seemed nothing short of a revolution.

Arising out of, and closely allied to, these investigations was the great struggle about "spontaneous generation." The question whether life originates spontaneously had been answered in the affirmative by several well-known writers. Readers of the classics will remember Virgil's description of the way in which a swarm of bees can be made to originate from the rotting carcase of a young bull. Nowadays we smile at the crudity of the idea, whilst marvelling at the beauty of the verse in which the old Roman has enshrined it. A still cruder and more laughable assertion was made by Van Helmont, the Belgian physician and alchemist, who actually supplies a recipe for the spontaneous generation of the domestic mouse. His prescription consists in squeezing some soiled linen into the mouth of a vessel containing grains of wheat, whereupon, after the lapse of about twenty-one days, the wheat will be found to have been transformed into mice—adult ones to boot, with both sexes equally represented!

Such mendacious statements had long been discredited as regards the higher forms of life. But in Pasteur's time many scientists were still to be found who maintained that the minuter forms, such as could only be seen with the microscope, made their appearance spontaneously, that is, without arising from pre-existing germs, in decomposing organic infusions, dead bodies and the like. About the middle of the eighteenth century the question had been freely debated, the leaders being two clergymen, our own countryman, Needham, on the side of spontaneous generation, or *generatio æquivoca*, as it was then called, and the Italian, Spallanzani, against it. In Pasteur's time the leading advocate of spontaneous generation was Pouchet, Director of the Natural History Museum in Rouen, who came forward with a paper entitled "A Note on Vegetable and Animal Proto-organisms spontaneously generated in Artificial Air and Oxygen Gas." Pasteur entered the lists against this opinion, and devoted four years to a struggle in which he ultimately proved victorious. He took enormous pains with his experiments, and made some useful discoveries *en route*, so to speak, such as the efficiency of a cotton-wool plug in the neck of a flask as a means of preventing the entrance of air germs. He also invented a flask with a long-drawn-out neck, curved downwards like the bent neck of a swan, known to the present day as Pasteur's flask. By this means he showed that, without any plug at all, a putrescible liquid boiled in such a flask would keep good indefinitely owing to the fact that the air coming in deposited its germs on the moist inside of the curved neck, so that they did not gain access to the fluid. He took a trip to the Alps, bringing with him dozens of flasks charged with putrescible fluid, and with their necks (straight ones this time) drawn into sharp points which were hermetically sealed. He climbed the Montanvert, attended by a guide with a mule carrying the case containing the precious vessels. He opened thirteen of them in the inn, where the air was more or less foul and dusty, and sealed them in a few minutes. Next day he brought twenty more to the Mer de Glace, opened them for a short time, and resealed them with a blow-pipe. Nearly all of the first series went bad, whereas of the twenty opened on the Mer de

Glace, only one became altered. In this way Pasteur showed that it is the presence of dust in the air, and not the air itself, that brings about fermentation. In reply to contrary results recorded by Pouchet, Pasteur was always able to show some flaw in the experiment whereby air germs were allowed to obtain access—in one case, for instance, with the mercury used by Pouchet for closing the mouths of his flasks. In the end, the Academy of Sciences decided in his favour by awarding him the prize in a competition for the best experimental work on spontaneous generation. The affair got into the newspapers; the fashionable crowd in Paris, where the Second Empire was then at the zenith of its glory, became interested, and Pasteur was invited to give a popular lecture on the results of his work. All Paris came to hear the serious-looking man, his face full of quiet energy and reflective force. After giving his audience a glimpse of his laboratory methods and results, he concluded as follows: "And, therefore, gentlemen, I would point to that liquid and say to you, I have taken my drop of water from the immensity of creation, and I have taken it full of the elements suitable for the development of inferior beings. And I wait, I watch, I question it, begging it to recommence for me the beautiful spectacle of the first creation. But it is dumb, dumb since these experiments were begun several years ago; it is dumb because I have kept it from the only thing man cannot produce, from the germs that float in the air; from life, for life is a germ and a germ is life. Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment. . . . No, there is now no circumstance known in which it can be affirmed that microscopic beings came into the world without germs, without parents similar to themselves. Those who affirm it have been duped by illusions, by ill-conducted experiments spoilt by errors, that they either did not perceive or did not know how to avoid."

By the work thus accomplished, with a different object, Pasteur had laid the foundation of the then unthought-of science of bacteriology. The researches thus outlined constitute a turning point in his career. He never went back to the physico-chemical questions that had engrossed his earlier years, but devoted the rest of his active life to the elucidation of biological problems. The study of fermentation led him to inquire into the causes why that process, as industrially conducted, in the manufacture of wine, for example, of beer, of vinegar, not unfrequently "goes wrong," with the result that sour wine, bad beer and vinegar, more like dirty water than anything else, are produced, to the disappointment and loss of the manufacturer. These undesirable results he found to be due to the intrusion and multiplication of extraneous germs in the fermenting mixtures. He found out that by previously heating to about 55° or 60° C. (130–140° F.), most of these objectionable or "wild" organisms could be killed off and the soil left fallow, so to speak, for the rightful or cultivated ferments, which were thus allowed to do their useful work undisturbed. This process of "Pasteurization" still goes by its discoverer's name, and in this country is chiefly practised in the dairy. By pushing the process still further, he found that all microbic life could be killed off—the process we now know as sterilization.

Ever fruitful in bold generalizations, Pasteur now began to ask himself whether disease in man and the higher animals might not, like the so-called maladies of beer, wine, vinegar, etc., be due to the intrusion of minute organisms which, by setting up processes allied to fermentation in the bodies of their victims, could bring about the disturbances of health that we call disease. His first essay in this field was one of peculiar difficulty. It was the investigation of a malady of silkworms called Pébrine, which had assumed serious proportions in 1865, had pulled down the annual revenue from this source by over 100 million francs, and reduced hundreds of formerly prosperous silk cultivators to destitution. Here Pasteur found himself confronted with two separate and distinct maladies, often existing in the same *magnanerie* (the name given to a farm where silkworms are raised). One was the real "pébrine," due to a protozoal organism. The other was "flacherie," due to an actively motile bacillus. With infinite pains he succeeded in disentangling the ravelled skein of morbid phenomena, showed how both maladies might be prevented, and thus earned for himself the eternal gratitude not only of his fellow-countrymen, but also of the foreigner. In 1867 he was awarded the grand prize medal of the Exhibition. In 1868 he received the honorary degree of Doctor of Medicine from the University of Bonn, and a prize of 5000 florins offered by the Austrian Government to the discoverer of the best way of preventing the malady of silkworms. In 1869 our own Royal Society elected him one of its foreign members. More recently (in 1896), the town of Alais, the staple industry of which, silk-raising, profited so largely by his exertions, displayed its gratitude by erecting a statue to its benefactor. It shows us Pasteur in the act of attentively examining a sprig of mulberry covered with cocoons. About this time he applied to the Government for a special grant towards a new laboratory, of which he stood badly in need, and was overjoyed when the Emperor took the matter up and caused the minister concerned to set apart 30,000 francs (£1200) for the purpose.

But Pasteur's life became overfull. His results as regards silkworms were called in question, and he had to do a great deal of additional work in order to confirm them. Moreover, he met with severe domestic bereavement, his father and his two little daughters dying about the same time. When he had to start work after his brief seaside holiday in September 1868, he was struck down with a malady of the gravest kind—paralysis of one side with disturbance of speech. He was most devotedly nursed by his wife, and several of his scientific friends took turns at watching by his bedside. He himself thought that he was going to die, and regretted it; for, as he said, "I should like to have been able to accomplish more for my country." It seemed so hard to die at forty-six in the very midst of his work. To the delight of everyone, his mental powers remained unimpaired, the paralysis gradually relaxed its grip, and he was able to move about once more, though he never fully recovered the use of his limbs.

The Government now decided to confer still further honour on Pasteur by giving him a seat in the Senate. But before this could be done, a catastrophe of appalling suddeness had laid the Second Empire in ruins. The triumphant cohorts of Germany poured like a torrent across the fair land of France. The people turned with fury against the Napoleonic Dynasty, by which they considered themselves as betrayed, and, after the awful convulsions of the Commune, set up the Republican form of government that still holds sway in France. Pasteur was a typical Frenchman, full of the most ardent patriotism. He wished to be enrolled in the *Garde Nationale*, but had to be reminded that a half-paralyzed man is unfit for service. His son went to the war. Pasteur senior tried to go on with his work, but could not. He was overwhelmed by the redoubled calamities that fell upon his unhappy country, and was prevailed upon to quit Paris and retire to Arbois, where he had a little house and vineyard. On learning the news of his country's downfall at Sedan, he took up his pen and wrote the following characteristic letter to his pupil Raulin: "What folly, what blindness there are in the inertia of Austria, Russia, England! What ignorance in our army leaders! We scientists were indeed right when we deplored the poverty of the Department of Public Instruction. There lies the real cause of our misfortunes. It is not with impunity that a great nation is allowed to lose its intellectual standard. . . . We are paying the penalty of fifty years' forgetfulness of science, of its conditions of development, of its immense influence on the life of a great people, and of all that might have assisted the diffusion of light. . . . I cannot go on: all this hurts me. I try to put away all such memories, and also the sight of our terrible distress, in which it seems that a desperate resistance is the only hope we have left. I wish that France may fight to her last man, to her last fortress. I wish that the war may be prolonged until the winter, when, the elements aiding us, all these vandals may perish of cold and distress. Every one of my future works will bear on its title-page the words, 'Hatred to Prussia. Revenge! revenge!'"

In such a frame of mind it is not surprising that Pasteur should have cast about for some means of showing the enemies of his country the view he took of themselves and their proceedings. He bethought him of the diploma of M.D., *honoris causâ*, bestowed on him a few years previously by the University of Bonn—a distinction that had given him much pleasure at the time. "Now," he wrote to the Dean of the Faculty of Medicine at Bonn, "the sight of the parchment is hateful to me. I feel insulted at seeing my name, with the designation *virum clarissimum* which you have conferred upon it, placed under the auspices of a name which is henceforth an object of execration to my country—that of *Rex Gulielmus*. Whilst sincerely expressing my profound respect for you, sir, and for the celebrated professors who have affixed their signatures to the decision of your Faculty, I must obey my conscience by asking you to efface my name from your archives, and to take back your diploma as a token of the indignation inspired in a French scientist by the barbarism and hypocrisy of one who, in order to satisfy his criminal pride, persists in the massacre of two great peoples."

The German's reply was equally characteristic. "Sir—The undersigned, now Principal of the Faculty of Medicine of Bonn, is requested to answer the insult which you have dared to offer to the German nation in the sacred person of its august Emperor, King Wilhelm of Prussia, by sending you the expression of its *entire contempt.*—Maurice Naumann. *P.S.*—Desiring to keep its papers free from taint, the Faculty herewith returns your screed."

Pasteur's rejoinder contained the following passage: "And now, Mr. Principal, after reading over both your letter and mine, I sorrow in my heart to think that men who, like yourself and myself, have spent a lifetime in the pursuit of truth and progress should address each other in such a fashion. This is but one of the results of the character your Emperor has given to this war. You speak to me of *taint.* Mr. Principal, you may be assured that taint will rest until far distant ages on the memory of those who began the bombardment of Paris, when capitulation by famine was inevitable, and who continued this act of savagery after it had become evident to all men that it would not advance by one hour the surrender of the heroic city."

Like his grandfather, Pasteur's son served in the army as a non-commissioned officer, and, as there was no news of him, his father, accompanied by Madame Pasteur and their daughter, set out to look for the boy amongst the scattered remnants of the Eastern Army Corps. After a search as anxious as it was hazardous, they came across the young man and took him across the frontier into Switzerland, where he recovered from an illness due to fatigue and privation. He afterwards rejoined his regiment. Whilst awaiting the moment when he could resume his scientific activities, Pasteur reflected deeply on the causes that had brought about what seemed at the time to be the irretrievable downfall of his beloved country. "The victim of her political instability," he wrote, "France had done nothing to keep up, to propagate, and to develop the progress of science in our land; she has lived on the past, thinking herself great by the scientific discoveries to which she owed her material prosperity, but not perceiving that she was allowing the springs of those discoveries to become dry, whilst neighbouring nations were diverting them to their own benefit and rendering them fruitful by their work, their efforts, and their sacrifices. Whilst Germany was multiplying her universities, establishing between them the most salutary emulation, bestowing honour and consideration on the masters and doctors, creating vast laboratories amply supplied with the most perfect instruments, France, enervated by revolutions, ever seeking for the best form of government, was giving but scanty attention to her establishments for higher education.

"The cultivation of science in its highest expression is perhaps even more necessary to the moral condition than to the material prosperity of a nation.

"Great discoveries—the manifestation of thought in art, in science, and in letters—in a word, the disinterested exercise of the mind in every direction and the centre of instruction from which it radiates, introduce into the whole of society that philosophical or scientific spirit, that spirit of discernment, which submits everything to severe reasoning, condemns ignorance, and scatters errors and prejudices. They raise the intellectual level and the moral sense, and, through them, the Divine idea itself is spread abroad and intensified."

Melancholy as were Pasteur's reflections at this sad crisis in his country's fortunes, they would have been incomparably more bitter still had he been aware that, if the consequences of his own researches had been as well understood in France as they were abroad, the lives of many thousands of gallant Frenchmen then dying of their wounds received on the field of battle might have been preserved. Germ-borne diseases, as deadly as they were preventible—suppuration, blood-poisoning, erysipelas, gangrene—were rampant in the French military hospitals, and proved to be veritable scourges which the surgeons, not realizing their true nature, confessed themselves equally unable to cure and to avert. And yet three years had already elapsed since the brilliant young Edinburgh surgeon, Dr. (now Lord) Lister, had laid down those methods of antiseptic treatment which, long years after, he ascribed in the following noble words to the teachings of Pasteur. "Truly," said Lister, addressing Pasteur on the occasion of his jubilee celebration, "there does not exist in the entire world any individual to whom the medical sciences owe more than they do to you. Your researches on fermentation have thrown a powerful beam which has lightened the baleful darkness of surgery, and has transformed the treatment of wounds from a matter of uncertain, and too often dangerous, empiricism into a scientific art of sure beneficence. Thanks to you, surgery has undergone a complete revolution, which has deprived it of its terrors and has extended almost without limit its efficacious power."

Shortly after the war, Pasteur, although not a doctor, was elected a member of the Academy of Medicine. He visited the hospitals and noticed how wounds were bandaged without being properly cleaned, so that foul-smelling pus accumulated in them, and soon produced general blood-poisoning. By the aid of the microscope he pointed out to the half-incredulous surgeons the micro-organisms swarming in the purulent matter, and entered into details as to the precautions necessary to get rid of the germs present in the wound and in the dressings. He prescribed that all instruments should be passed through a flame, and that all the dressings should be heated to a very high temperature, in order to destroy the germs.

The old wrong ideas did not die without a struggle. There were not wanting doctors who resented the intrusion of a mere laboratory scientist, and a non-medical man to boot, into what they regarded as purely professional matters. They scoffed at Pasteur's bacteria and at "laboratory surgery," which, as one of them, Dr. Chassaignac, said, "has destroyed very many animals and saved very few human beings." "Everything," he went on to say, "cannot be resolved into a question of bacteria!" And then, sarcastically, little thinking how near the truth he was, "Typhoid fever, bacterization! Hospital miasma, bacterization!"

Despite these scoffers, Pasteur's ideas, proved as they were up to the hilt by conclusive experiments, carried the day. His merit was now universally recognized, and a bill was introduced into the French Parliament to bestow upon him some substantial token of his country's gratitude. The Government suggested a life annuity of 12,000 francs (£480). "The amount," said the introducer, "is indeed small when compared with the value of the services rendered, . . . but the economic and hygienic results of M. Pasteur's discoveries will presently become so considerable, that the French nation will desire to increase later on its testimony of gratitude towards him, and towards science, of which he is one of the most glorious representatives." Half the amount of the annuity was to go to Pasteur's widow. The bill was passed by 532 votes against 24.

It was at this moment of triumph that Pasteur's attention became definitely concentrated on the nature and causation of disease. By a remarkable, perhaps an unprecedented, transition, the man who had begun by studying the nature and properties of crystals, who had then probed to the bottom the chemical mysteries of the brewer's vat and wine cask, who had spent years in combating the doctrine of spontaneous generation, now found himself engrossed by the problems of infectious disease. Arrived at a period of life (fifty-five) when many men are thinking of retiring from active labours, Pasteur plunged with enthusiasm into the investigation of questions that lay altogether outside his real province, which was that of chemistry and physics. The efficiency and resourcefulness of his experimental work in a department for which his early training might be said—had he been an ordinary man—to have absolutely unfitted him, are certainly calculated to evoke our wonder and admiration.

The first maladies that attracted his attention were those affecting domestic animals, and thus inflicting injury on the agricultural industries of his dear native land. For years a mysterious disease called *charbon*, or splenic fever, had been making havoc among the sheep in the pastoral provinces of Beauce, Brie, Burgundy, and Auvergne. Sheep so stricken often died within a few hours: they drooped their heads, gasped for breath, blood-stained fluid came from their mouths and noses, they fell and died, whilst after death the least cut on the swollen carcase gave issue to black and viscid blood—hence the name "anthrax" (Greek for coal). Nor was the disease confined to sheep. Oxen and horses also suffered, and even man did not escape. Butchers or shepherds who incautiously soiled their hands with blood of the dead animals were often attacked with a hideous swelling called "malignant pustule," which, unless thoroughly cauterized or excised, rapidly produced fatal blood-poisoning.

About the year 1850, Davaine and also Rayer had put under the microscope drops of blood taken from the dying animals, and had seen little transparent motionless rod-like bodies, which were not present in the blood of healthy animals. Their discovery passed unheeded at the time. About the time when Pasteur was thinking of taking up the subject (1876), Robert Koch, then a young country practitioner in a small town of East

Germany, announced that he had succeeded in growing the little rods in the aqueous humour of an ox's eye, had transplanted them from one drop to another, had seen them grow out into long tangled filaments, and form spores somewhat after the manner in which peas form in the pod. Koch likewise showed that by injecting the anthrax rods or bacilli, as they are now called, into guinea-pigs, the disease could be reproduced. The same effect was also produced by feeding animals with material containing the spores. To all these researches it was objected that not the bacilli but some other material derived from the infected animal was the true cause—the bacilli, said the objectors, are only its accompaniment. This view Pasteur successfully refuted. He prepared a series of flasks containing sterilized nutrient broth, and introduced into the first of them, with the usual precautions against accidental contamination, a minute trace of blood from the infected animal. He set it aside in a warm chamber to develop, and next day saw it quite cloudy with flakes consisting of long chains of bacilli. From this turbid liquid he transferred the minutest trace to a second flask, got the same result, and so on from day to day, till, say, ten or twenty flasks had been so inoculated. He then tried the effect of injecting into an animal a few drops of the liquid contained in the last of the flasks, and found that it succumbed to anthrax. The dilution to which the original droplet of blood had been subjected was so inconceivably great that the disease must clearly be attributed to the only thing derived from that blood that persists through the whole series of the flasks, namely, the bacilli: no matter how many flasks were used, five, twenty, or a hundred, the result was always the same. The bacillus and nothing but the bacillus was responsible for the disease.

Further objections were raised. It was pointed out that the blood of animals that never had anthrax, but had been choked or felled and allowed to lie on the ground for a day or two, contained bacteria like those of anthrax, and would cause death, if inoculated.

Pasteur showed that the blood of such animals owed its virulence to another disease germ, superficially resembling that of anthrax, but differing from it in being motile and in its inability to grow in the presence of air. This germ he called *Vibrion Septique.* We now know it under the name, bestowed by Koch, of the *bacillus of malignant œdema.*

The next subject of Pasteur's researches was chicken-cholera. In the blood of the affected fowls he soon discovered what he termed little specks of extreme minuteness. He had some difficulty in getting them to grow outside the body, but at last succeeded in devising a medium that suited them—a broth made of chicken gristle, neutralized with potash and sterilized at a temperature of 110° to 115° C. The smallest drop of such a culture given to a chicken on a few bread crumbs was sufficient to set up the disease. A chance observation made by Pasteur while studying this malady proved to have momentous consequences. During his absence on vacation his cultures were not renewed. On his return, he found that these old cultures had become incapable of causing the disease in its fatal form. Fowls inoculated with them became ill, but recovered. These same fowls, on being injected shortly afterwards with fresh cultures of proved virulence, remained unaffected. Pondering over this, Pasteur began to ask himself whether some reliable way could not be found of so modifying a virulent germ as to convert it into a harmless *vaccine*, inoculation with which would protect the animal from the naturally acquired disease. Accordingly, Pasteur set about experimenting, and at last hit upon the plan of forcing the anthrax germ to grow at a temperature higher than that to which it was accustomed. He found that when cultivated at 108° F. instead of 98°, it soon lost its property of forming spores, and, moreover, when inoculated, failed to kill, but only gave a mild attack which protected against the virulent bacillus. It was on the 28th of February 1881 that Pasteur came forward at the Academie des Sciences with his memorable paper on the Vaccine of Splenic Fever. He showed how the degree of virulence could be exactly graduated, and how it was possible to restore to the modified or "attenuated" bacillus its primitive deadliness.

As usual, his conclusions were at first doubted, his facts were called in question. The editor of one of the veterinary journals, a M. Rossignol, wrote an ironical article poking fun at him. "Microbiolatry," he wrote, "is the fashion; it is a doctrine that must not even be discussed. Henceforth, the germ theory must have precedence of clinical observation. The microbe alone is true, and Pasteur is its prophet." Confident that Pasteur's theories would break down under a practical test on a large scale, Rossignol began an anti-microbe campaign and collected money to procure animals for a test. The programme was drawn up and left Pasteur no loophole of retreat. Sixty sheep were to be procured by the Melun Agricultural Society. Twenty-five of these were to be vaccinated by two inoculations at twelve or fifteen days' interval. Some days later, these twenty-five, and also twenty-five others, were to be inoculated with anthrax culture of high virulence. "The twenty-five unvaccinated sheep will all perish," wrote Pasteur; "the twenty-five vaccinated ones will all survive." These latter were to be compared afterwards with the ten sheep that had undergone no treatment in order to show that the vaccination itself did no harm. There were other conditions which made the test still more stringent, and Pasteur's friends felt uneasy lest he might have committed himself too deeply. "If he succeeds," wrote the veterinary press, "he will have endowed this country with a great benefit, and his adversaries must prepare to follow, chained and prostrate, the chariot of the immortal victor. But he must succeed: such is the price of triumph. Let M. Pasteur not forget that the Tarpeian Rock is near the Capitol."

The experiment was duly carried out in the presence of an immense crowd of witnesses, comprising the civil authorities, delegates from agricultural, medical, and veterinary societies, as well as many journalists. It proved a complete success. Pasteur had a sleepless night owing to some of the vaccinated animals showing a sharp rise of temperature. It was no wonder, considering that they had received a threefold fatal dose! In the event they all recovered, and on the final day the carcases of twenty-two of the unvaccinated sheep were lying side by side in the farmyard, two others were expiring with the characteristic symptoms of splenic fever,[1] whilst all the vaccinated sheep were in perfect health.

Pasteur's triumph was now complete and unquestionable. He found himself the most famous man in France. The Government offered him the Grand Cordon of the Legion of Honour. Pasteur would only accept it on one condition: the red ribbon for his two fellow-workers, Doctors Roux and Chamberland. "What I chiefly wish," wrote he, "is that the discovery should be consecrated by an exceptional distinction to two devoted young men." His condition was at once acceded to, and he and his assistants received the coveted decorations.

Passing over many researches, some more, some less successful, that occupied the last two decades of Pasteur's well-filled life, we will conclude with a brief account of his work on hydrophobia, or rabies. The mystery in which this horrible disease was enshrouded had haunted Pasteur's mind for many years. In 1880 he took up work on it, his first material being provided by two mad dogs sent into his laboratory by M. Bourrel, an old army veterinarian, who had long been searching for a remedy

[1] The twenty-fifth unvaccinated sheep died of anthrax a few days later.

for this most justly dreaded of all maladies. One of these dogs had the form known as dumb madness: his jaw hung half opened and paralyzed, his tongue was covered with foam, his eyes full of wistful anguish; the other, suffering from the ordinary or furious madness, made savage darts at anything held out to him, with a rabid glare in his bloodshot eyes, and gave vent to despairing howls. Shortly afterwards, Pasteur learnt from Professor Lannelongue that a child of five years, bitten on the face a month previously, had just been admitted into the Hôpital Trousseau. Pasteur, overmastering his repugnance to the sight of pain, went to see the poor little patient, who presented all the characteristic symptoms—spasms and convulsions, ardent thirst, combined with impossibility of swallowing. After nearly twenty-four hours of agonizing torture, the child died—suffocated by the mucus that filled its mouth. Pasteur's first step was to take from the child a specimen of the saliva, in which the virus of the disease was supposed to be present, and inoculate it into rabbits. They died in less than two days. He examined their blood and found in it a microbe which he isolated and studied. It proved highly virulent; but was it the genuine microbe of hydrophobia? The symptoms it gave rise to were more like those of ordinary blood-poisoning, and the incubation period was much too short. Pasteur cautiously abstained from drawing any conclusion. "I am absolutely ignorant," said he at the Academy of Medicine, "of the connection there may be between this new disease and hydrophobia." He then tried experiments with saliva from persons suffering from other maladies, and even from healthy adults, and often obtained the new disease, "sputum-septicæmia," as it is now called. From this it was clear that he was "on the wrong track"—he had discovered a hitherto unknown disease germ, but not that of hydrophobia. Without being discouraged, Pasteur continued his investigations, at no small risk to himself and his helpers, as may be gathered from the description given by M. Vallery-Radot of what used to take place. "One day, Pasteur, wishing to obtain a little saliva direct from the jaws of a rabid dog, two of Bourrel's assistants undertook to drag a mad bulldog, foaming at the mouth, from its cage; they seized it with a lasso and stretched it on the table. These two men, thus associated with Pasteur in the same danger, with the same calm heroism held the struggling, ferocious animal down with their powerful hands, whilst the scientist, by means of a glass tube held between his lips, drew a few drops of the deadly saliva." They ran a terrible risk. It was all no use. No satisfactory results could be obtained from the saliva. Pasteur then tried the blood, but also in vain. As his experience grew, he gradually became convinced that the true seat of the virus lay in the central nervous system. He tried inoculating with the *medulla oblongata* (part of the brain) taken from a rabid animal, and succeeded in reproducing the disease. At first the injections were made under the skin. This method did not yield uniform results, and so he tried placing the virus directly on the brain. This was accomplished by the operation called trephining, which means that the animal was chloroformed, and a small round piece cut out of its skull. The inoculation was then made directly into the brain, the wound closed up, and the animal allowed to recover. With constant practice this operation came to be performed with such speed and skill that the animal, on regaining consciousness, seemed the same as usual. But after the lapse of about a fortnight it invariably developed hydrophobia and died. The seat of the microbe had now been discovered. This was a great step in advance. But it was followed by as great a disappointment. The microscope revealed no bacillus. The culture-flasks, abundantly inoculated with rabid brain-matter, yielded no growth. The microbe could not be found. (Now, after the lapse of thirty years, we know why it was that Pasteur could not see this microbe, or grow it.) Not being able to cultivate the virus outside the body, Pasteur adopted the only means open to him—he grew it in the brain of living rabbits, transferring it from one that had just died to fresh animals. He noticed that the time that elapsed between inoculation and the outbreak of the symptoms gradually became shorter, until it was at last reduced to seven days. Pasteur called this seven-day virus, *virus fixe,* because it took a fixed time to produce the disease, instead of the variable and inconstant periods taken by the virus procured from ordinary mad dogs as captured in the streets.

This important progress made, Pasteur began to see his way to the final goal—that of immunization. Having found out how to intensify the virus, he now sought for a means of weakening it. The simplest possible plan was that which he had learnt by accident in the case of chicken-cholera, namely, the lapse of time. Accordingly he took the spinal cords of rabbits that had just died of *virus fixe,* suspended them by threads in flasks, the air in which was kept dry by a lump of caustic potash lying at the bottom, and kept them at a constant temperature for days. At intervals he tried the effect of inoculating rabbits with matter from these cords, and found that after a fortnight in the flask all virulence was lost. The shorter the period of drying, the greater the amount of virulence that was retained. Accordingly, Pasteur next proceeded to an immunization experiment. Into a number of dogs he injected first of all some spinal cord that had been kept a fortnight, next day some that had been kept thirteen days, and so on till he was giving them material from rabbits that had only died that very day—the redoubtable *virus fixe.* The dogs so treated remained well, and it was found that they could be bitten by mad companions or even intra-cranially inoculated without contracting the disease. They were absolutely immune against hydrophobia. All this work was carefully watched by a scientific commission specially appointed by the government for the purpose. A place in the park of Villeneuve l'Etang near St. Cloud was set apart for the numerous experimental animals with their kennels and cages. Pasteur was no surgeon, and never operated with his own hands. The difficult operations rendered necessary for these investigations were at first performed by Dr. Roux, and later on by skilled laboratory porters. During the years 1884 and 1885 the work went steadily on. The immediate object was no longer to render a dog immune to rabies *before* being bitten, but to prevent it from acquiring the disease by treatment begun *after* it had been bitten or otherwise inoculated with the virus. This was also successfully accomplished. The path was now at last opened straight to the ultimate goal—the rescue of a human being from this most dreadful of diseases.

In July 1885 a suitable case presented itself in the person of a little Alsatian peasant-boy, Joseph Meister, who, on his way to school, had been knocked down and terribly bitten by a furious dog, pronounced rabid by the veterinary surgeon. The wounds (fourteen in number) had not been cauterized till twelve hours afterwards, and then only with carbolic acid. In the opinion of all, the poor little fellow was doomed to the most agonizing of all deaths. Pasteur felt and expressed the deepest anxiety as to the advisability of trying his new method of immunization on a human being. He consulted the eminent nerve specialist, Vulpian, who examined the boy himself and decided, in conjunction with Dr. Grancher, one of Pasteur's collaborators, that not a moment was to be lost. They started, therefore, by injecting material fourteen days old and quite devoid of virulence. The little boy, who had been screaming with terror beforehand, soon dried his tears on finding that he had only to suffer a slight pin prick. As days passed on, and Pasteur found himself doing a thing never before done in the history of the human race—deliberately administering to an innocent child the virus of the most deadly of all known diseases—his anxiety became terrible. He had a series of sleepless nights. But there was no drawing back now. Each day a number of fresh rabbits were inoculated with the cords used for the boy, so as to test their virulence. At last, on the twelfth day, he was treated with the dreaded *virus fixe*. At the same time, some of the same cord was given to a number of rabbits, all of which developed hydrophobia on the seventh day. *The boy remained well.* It was the surest test of the successful immunity conferred on the patient. Pasteur had conquered the terrors of hydrophobia!

When the news was spread, people who had been bitten by rabid dogs began to pour in from all sides, foreigners as well as Frenchmen. Doctors came also, desirous of studying the method. The "service" of hydrophobia became the principal business of the day. Everything was done systematically. Names, dates when bitten, history of the patient, and *post-mortem* examination of the dog were all entered up, and patients were carefully classified, so as to avoid any possibility of receiving a wrong virus, which might prove fatal. There was an occasional failure. A girl, aged ten, who had been severely bitten on the head *thirty-seven days beforehand*, was brought up. Pasteur looked on the case as hopeless, on account of the time that had elapsed since the bite, but allowed himself to be persuaded to give the treatment. The child returned to school, but shortly afterwards was seized with breathlessness and convulsions. She could swallow nothing. Pasteur sat by her deathbed, and as he went down the staircase, burst into tears.

Despite occasional failures, which were mostly due to the treatment having been begun too late, the success of the Pasteur method was phenomenal. Out of his first 350 patients only one succumbed, the little girl just mentioned. The most reliable statistics up to the introduction of the Pasteur treatment showed a mortality of at least 16 per cent. from the bite of rabid dogs, so that at least fifty-five lives had been saved from the most agonizing of deaths. Pasteur concluded his paper on the subject before the Academy of Medicine by the suggestion that a vaccine establishment should be set up for carrying on this important work, and others of a cognate character, on a large scale. The project was warmly applauded, money flowed in from all sides, and the magnificent Institution called after Pasteur was built, endowed, and equipped with every requirement needed, not only for the work of hydrophobia, but for researches on every variety of infectious disease, and indeed on microbic life in general. Here his disciples and fellow-workers, Roux, Duclaux, Grancher, Chamberland, Metchnikoff, and many others, found suitable accommodation for the investigations that have thrown so much light on the causation and prevention of disease. The Institut Pasteur was formally opened on 14th November 1888, the occasion being made a great public function, at which our hero may be said to have attained the pinnacle of glory.

His life-work was now accomplished. He entered the Institute that bears his name, already ill and weary. During the years that followed he supervised and directed the labours of his colleagues, but did little more original work himself.

The beginning of the end was in November 1894, when he was seized with a uræmic attack. In broken health he lingered on, tenderly watched over by his wife, children, and grandchildren, till the following September, and then he died. One of his hands rested in that of Madame Pasteur, whilst the other held a crucifix.

The Government decreed him a public funeral at Notre Dame, where his body was temporarily laid to rest. All that is mortal of him now reposes in a beautiful mausoleum, erected at the Institute by his family. The marble arches on either side of the sarcophagus bear inscriptions recording his chief discoveries, whilst beyond it is an apsidal chapel containing a white marble altar. Above the staircase leading to the chapel are inscribed the following words, taken from the oration he delivered at his reception into the Academy of Science:—

"Heureux celui qui porte en soi un dieu, un idéal de beauté, et qui lui obéit—idéal de l'art, idéal de la science, idéal de la patrie, idéal des vertus de l'Evangile."

(Happy he who bears within himself a deity, an ideal of beauty, and who obeys its dictates—an ideal of art, an ideal of science, an ideal of patriotism, an ideal of the virtues of the Gospel.)

Pasteur lived and died a devout Catholic, and in erecting this beautiful monument to his memory, his family took care that it should give expression to the religious side of his nature. The mosaics with which the tomb is decorated comprise angelic figures of Faith, Hope, Charity, and Science. Above the altar we see the descending figure of a dove representing the Holy Spirit, and on either side the Greek letters A and Ω.

As a man of science, Pasteur claimed absolute liberty of research; but, unlike so many others who get carried away by their speculations, he clung to the rock of objectivity and never attempted to penetrate into primary causes. Whilst, on occasion, making no secret of his repugnance for insolent unbelief and barren irony, he seldom gave expression in public to the ideals which inspired his inner life. The following is one of the few passages in which he alluded to those cherished beliefs and hopes. It is taken from a speech on Spontaneous Generation, delivered in 1874 at the Academy of Science:

"I must not be understood to imply that in my beliefs and in the conduct of my life, I only take account of acquired science; even if I would, I could not do so, for I should then have to strip myself of a part of myself. There are two men in each of us: the scientist—he who starts with a clear field and desires to rise to the knowledge of Nature, through observation, experiment, and reasoning; and the man of sentiment, the man of belief, the man who mourns his dead children and who cannot, alas! prove that he will see them again, but who believes that he will, and lives in that hope: the man who will not die like a microbe, but who feels that the force that is within him cannot die. The two domains are distinct, and woe to him who tries to let them trespass on each other in the so imperfect state of human knowledge." In the words of his son-in-law, M. Vallery-Radot: "With the spiritual sentiment which caused him to claim for the inner moral life the same liberty as for scientific research, he could not understand certain givers of easy explanations, who affirm that matter has organized itself, and who, considering as perfectly simple the spectacle of the universe of which the earth is but an infinitesimal part, are in no wise moved by the Infinite Power who created the worlds. With his whole heart he proclaimed the immortality of the soul."

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