THE LIFE OF PASTEUR

BY RENÉ VALLERY-RADOT

TRANSLATED FROM THE FRENCH BY
MRS. R. L. DEVONSHIRE

WITH A FOREWORD

BY

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CONTENTS OF VOL. I

FOREWORD

L'homme en ce siècle a pris une connaissance toute nouvelle des ressources de la nature et, par l'application de son intelligence il a commencé à les faire fructifier. Il a refait, par la géologie et la paléontologie, l'histoire de la terre, entraînée elle-même par la grande loi de l'évolution. Il connaît mieux, grâce à Pasteur surtout, les conditions d'existence de son propre organisme et peut entreprendre d'y combattre les causes de destruction.—Monod *L'Europe Contemporaine.*

WHETHER to admire more the man or his method, the life or the work, I leave for the readers of this well-told story to decide. At the request of my friend, Mr. Henry Phipps, a munificent supporter of science, and a man with a keen appreciation of its value in the progress of humanity, I write an introduction to this edition of Mrs. Devonshire's translation of Radot's *Life*. Among the researches that have made the name of Pasteur a household word in the civilised world, three are of the first importance—a knowledge of the true nature of the processes in fermentation—a knowledge of the chief maladies which have scourged man and animals—a knowledge of the measures by which either the body may be protected against these diseases, or the poison neutralised when once within the body.

I.

Our knowledge of disease has advanced in a curiously uniform way. The objective features, the symptoms, naturally first attracted attention. The Greek physicians, Hippocrates, Galen, and Aretaeus, gave excellent accounts of many diseases; for example, the forms of malaria. They knew, too, very well, their modes of termination, and the art of prognosis was studied carefully. But of the actual causes of disease they knew little or nothing, and any glimmerings of truth were

obscured in a cloud of theory. The treatment was haphazard, partly the outcome of experience, partly based upon false theories of the cause of the disease. This may be said to have been the sort of knowledge possessed by the profession until men began to study the "seats and causes" of disease, and to search out the changes *inside* the body, corresponding to the outward symptoms and the external appearances. Morbid anatomy began to be studied, and in the hundred years from 1750 to 1850 such colossal strides were made that we knew well the post-mortem appearances of the more common diseases; the recognition of which was greatly helped by a study of the relation of the pathological appearances with the signs and symptoms. The 19th century may be said to have given us an extraordinarily full knowledge of the changes which disease produces in the solids and fluids of the body. Great advances, too, were made in the treatment of disease. We learned to trust Nature more and drugs less; we got rid (in part) of treatment by theory, and we ceased to have a drug for every symptom. But much treatment was, and still is, irrational, not based on a knowledge of the cause of the disease. In a blundering way many important advances were made, and even specifics were discovered—cinchona, for example, had cured malaria for a hundred and fifty years before Laveran found the cause. At the middle of the last century we did not know much more of the actual causes of the great scourges of the race, the plagues, the fevers and the pestilences, than did the Greeks. Here comes in Pasteur's great work. Before him Egyptian darkness; with his advent a light that brightens more and more as the years give us ever fuller knowledge. The facts that fevers were catching, that epidemics spread, that infection could remain attached to particles of clothing, etc., all gave support to the view that the actual cause was something alive, a *contagium vivum*. It was really a very old view, the germs of which may be found in the Fathers, but which was first clearly expressed—so far as I know—by Frascastorius, a Veronese physician in the 16th century, who spoke of the seeds of contagion passing from

one person to another; and he first drew a parallel between the processes of contagion and the fermentation of wine. This was more than one hundred years before Kircher, Leeuwenhoek, and others, began to use the microscope and to see animalculæ, etc., in water, and so gave a basis for the "infinitely little" view of the nature of disease germs. And it was a study of the processes of fermentation that led Pasteur to the sure ground on which we now stand. Starting as a pure chemist, and becoming interested in the science of crystallography, it was not until his life at Lille, a town with important brewing industries, that Pasteur became interested in the biological side of chemical problems. Many years before it had been noted by Cagniard-Latour that yeast was composed of cells capable of reproducing themselves by a sort of budding, and he made the keen suggestion that it was possibly through some effect of their vegetation that the sugar was transformed. But Liebig's view everywhere prevailed that the ferment was an alterable, organic substance which exercised a catalytic force, transforming the sugar. It was in August, 1857, that Pasteur sent his famous paper on *Lactic Acid Fermentation* to the Lille Scientific Society; and in December of the same year he presented to the Academy of Sciences a paper on *Alcoholic Fermentation*, in which he concluded that the deduplication of sugar into alcohol and carbonic acid is correlevant to a phenomena of life. These studies had the signal effect of diverting the man from the course of his previous more strictly chemical studies. It is interesting to note how slowly these views dislocated the dominant theories of Liebig. More than ten years after their announcement I remember that we had in our chemical lectures the catalytic theory very fully presented.

Out of these researches arose a famous battle which kept Pasteur hard at work for four or five years—the struggle over spontaneous generation. It was an old warfare, but the microscope had revealed a new world, and the experiments on fermentation had lent great weight to the *omne vivum ex ovo* doctrine. The famous Italians, Redi and Spallanzani, had led

the way in their experiments, and the latter had reached the conclusion that there is no vegetable and no animal that has not its own germ. But heterogenesis became the burning question, and Pouchet in France, and Bastian in England, led the opposition to Pasteur. The many famous experiments carried conviction to the minds of scientific men, and destroyed for ever the old belief in spontaneous generation. All along the analogy between disease and fermentation must have been in Pasteur's mind; and then came the suggestion: "What would be most desirable would be to push those studies far enough to prepare the road for a serious research into the origin of various diseases." If the changes in lactic, alcohol and butyric fermentations are due to minute living organisms, why should not the same tiny creatures make the changes which occur in the body in the putrid and suppurative diseases. With an accurate training as a chemist, having been diverted in his studies upon fermentation into the realm of biology, and nourishing a strong conviction of the identity between putrefactive changes of the body and fermentation, Pasteur was well prepared to undertake investigations, which had hitherto been confined to physicians alone.

The first outcome of the researches of Pasteur upon fermentation and spontaneous generation represents a transformation in the practice of surgery, which, it is not too much to say, has been one of the greatest boons ever conferred upon humanity. It had long been recognised that now and again a wound healed without the formation of pus, that is without suppuration, but both spontaneous and operative wounds were almost invariably associated with that change; and, moreover, they frequently became putrid, as it was then called—infected, as we should say; the general system became involved, and the patient died of blood poisoning. So common was this, particularly in old, ill-equipped hospitals, that many surgeons feared to operate, and the general mortality in all surgical cases was very high. Believing that from outside the germs came which caused the decomposition of wounds, just as from the atmosphere the sugar solution got the germs which caused

the fermentation, a young surgeon at Glasgow, Joseph Lister, applied the principles of Pasteur's experiments to their treatment. It may be well here to quote from Lister's original paper in the *Lancet*, 1867 :—"Turning now to the question how the atmosphere produces decomposition of organic substances, we find that a flood of light has been thrown upon this most important subject by the philosophic researches of M. Pasteur, who has demonstrated by thoroughly convincing evidence that it is not to its oxygen or to any of its gaseous constituents that the air owes this property, but to minute particles suspended in it, which are the germs of various low forms of life, long since revealed by the microscope, and regarded as merely accidental concomitants of putrescence, but now shown by Pasteur to be its essential cause, resolving the complex organic compounds into substances of simpler chemical constitution, just as the yeast plant converts sugar into alcohol and carbonic acid." From these beginnings modern surgery took its rise, and the whole subject of wound infection, not only in relation to surgical diseases, but to child-bed fever, forms now one of the most brilliant chapters in the history of Preventive Medicine.

II.

Pasteur was early impressed with the analogies between fermentation and putrefaction and the infectious diseases, and in 1863 he assured the French Emperor that his ambition was "to arrive at the knowledge of the causes of putrid and contagious diseases." After a study upon the diseases of wines, which has had most important practical bearings, an opportunity came of the very first importance, which not only changed the whole course of his career, but had great influence in the development of medical science. A disease of the silkworm had, for some years, ruined one of the most important industries of France, and in 1865 the Government asked Pasteur to give up the laboratory work and teaching, and to devote his whole energies to the task of investigating it. The story of the brilliant success which followed years of application

to the problem will be read with deep interest by every student of science. It was the first of his victories in the application of the experimental methods of a trained chemist to the problems of biology, and it placed his name high in the group of the most illustrious benefactors of practical industries.

The national tragedy of 1870–2 nearly killed Pasteur. He had a terrible pilgrimage to make in search of his son, a sergeant in Bourbaki's force. "The retreat from Moscow cannot have been worse than this," said the *savant*. In October, 1868, he had had a stroke of paralysis, from which he recovered in a most exceptional way, as it seemed to have diminished neither his enthusiasm nor his energy. In a series of studies on the diseases of beer, and on the mode of production of vinegar, he became more and more convinced that these studies on fermentation had given him the key to the nature of the infectious diseases. It is a remarkable fact that the distinguished English philosopher of the seventeenth century, the man who more than anyone else of his century appreciated the importance of the experimental method, Robert Boyle, had said that he who could discover the nature of ferments and fermentation, would be more capable than anyone else of explaining the nature of certain diseases. The studies on spontaneous generation, and Lister's application of the germ theory to the treatment of wounds, had aroused the greatest interest in the medical world, and Villemin, in a series of most brilliant experiments, had demonstrated the infectivity of tuberculosis. An extraordinary opportunity now offered for the study of a widespread epidemic disease, known as anthrax, which in many parts of France killed from 25 to 30 per cent. of the sheep and cattle, and which in parts of Europe had been pandemic, attacking both man and beast. As far back as 1838 minute rods had been noted in the blood of animals which had died from the disease; and in 1863 Devaine thought that these little bodies, which he called bacteridia, were the cause of the disease. In 1876 a young German district physician, Robert Koch, began a career, which in interest and importance rivals that of the subject of this memoir. Koch confirmed in every

point the old researches of Devaine; but he did much more, and for the first time isolated the organism in pure culture outside the body, grew successive generations, showed the remarkable spore formation, and produced the disease artificially in animals by inoculating with the cultures. Pasteur confirmed these results, and in the face of extraordinary opposition succeeded in convincing his opponents. Out of this study came a still more important discovery, namely, that it was possible so to attenuate or weaken the virus or poison that the animal could be inoculated, and have a slight attack, recover, and be protected against the disease. More than eighty years had passed since, on May 14th, 1796, Jenner, with a small bit of virus taken from a cow-pox on the hand of the milkmaid, Sarah Newlme, had vaccinated a child, and thus proved that a slight attack of one disease would protect the body from disease of a similar character. It was an occasion famous in the history of medicine, when, in the spring of 1881, at Melun, at the farmyard of Pouilly le Fort, the final test case was determined, and the flock of vaccinated sheep remained well, while every one of the unvaccinated, inoculated from the same material, had died. It was indeed a great triumph.

The studies on chicken cholera, yellow fever, and on swine plague helped to further the general acceptance of the germ theory. I well remember at the great meeting of the International Congress in 1881, the splendid reception accorded to the distinguished Frenchman, who divided with Virchow the honours of the meeting. Finally came the work upon one of the most dreaded of all diseases—hydrophobia, an infection of a most remarkable character, the germ of which remains undiscovered. The practical results of Pasteur's researches have given us a prophylactic treatment of great efficacy. Before its introduction the only means of preventing the development of the disease was a thorough cauterisation of the disease wound within half an hour after its infliction. Pasteur showed that animals could be made immune to the poison, and devised a method by which the infection conveyed by the bite could be neutralised. Pasteur Institutes for the treatment of hydro-

phobia have been established in different countries, and where the disease is widely prevalent have been of the greatest benefit. Except at the London Congress, the only occasion on which I saw the great master was in 1891 or 1892, when he demonstrated at the Institute to a group of us the technique of the procedure, and then superintended the inoculations of the day. A large number of persons are treated in the course of the year; a good many, of course, have not been bitten by mad dogs; but a very careful classification is made:—

(*a*) Includes persons bitten by dogs proved experimentally to have been mad.

(*b*) Persons bitten by dogs declared to be mad by competent veterinary surgeons.

(*c*) All other cases.

The mortality even in Class A is very slight, though many patients are not brought until late. Incidentally it may be remarked the lesson of this country in its treatment of hydrophobia is one of the most important ever presented in connection with an infectious disease. There are no Pasteur Institutes; there are no cases. Why? The simple muzzling order has prevented the transmission of the disease from dog to dog, and once exterminated in the dog, the possibility of the infection in man had gone. In 1888 the crowning work of Pasteur's life was the establishment of an Institute to serve as a centre of study on contagious disease, and a dispensary for the treatment of hydrophobia, which is to-day the most important single centre of research in the world. The closing years of his life were full of interest in the work of his colleagues and assistants, and he had the great satisfaction of participating, with his assistant Roux, in another great victory over the dread scourge, diphtheria. Before his death in 1895 he had seen his work prosper in a way never before granted to any great discoverer. To no one man has it ever been given to accomplish work of such great importance for the well-being of humanity. As Paul Bert expressed it in the report to the French Government, Pasteur's work constitutes three great discoveries, which may be thus formulated. 1. Each

fermentation is produced by the development of a special microbe.

2. Each infectious disease is produced by the development within the organism of a special microbe.

3. The microbe of an infectious disease culture, under certain detrimental conditions is attenuated in its pathogenic activity; from a virus it has become a vaccine.

In an address delivered in Edinburgh by Sir James Simpson in 1853, in which he extolled the recent advancement of physic, occur these words:—"I do not believe, that, at the present moment, any individual in the profession, who, in surgery or in midwifery, could point out some means of curing —or some prophylactic means of averting by antecedent treatment—the liability to these analogous or identical diseases—viz., surgical or puerperal fever—such a fortunate individual would, I say, make, in relation to surgery and midwifery, a greater and more important discovery than could possibly be attained by any other subject of investigation. Nor does such a result seem hopelessly unattainable." Little did he think that the fulfilment of these words was in the possession of a young Englishman who had just gone to Edinburgh as an assistant to his colleague, Professor Syme. Lister's recognition of the importance of Pasteur's studies led to the fulfilment within this generation of the pious hope expressed by Simpson. In Institutions and Hospitals surgical infection and puerperal fever are things of the past, and for this achievement if for nothing else, the names of Louis Pasteur and Joseph Lister will go down to posterity among those of the greatest benefactors of humanity.

III.

In his growth the man kept pace with the scientist—heart and head held even sway in his life. To many whose estimate of French character is gained from "yellow" literature this story will reveal the true side of a great people, in whom filial piety, brotherly solicitude, generosity, and self-sacrifice are

combined with a rare devotion to country. Was there ever a more charming picture than that of the family at Dôle! Napoleon's old sergeant, Joseph Pasteur, is almost as interesting a character as his illustrious son; and we follow the joys and sorrows of the home with unflagging attention. Rarely has a great man been able to pay such a tribute to his father as that paid by Pasteur:—"For thirty years I have been his constant care, I owe everything to him."

This is a biography for young men of science, and for others who wish to learn what science has done, and may do, for humanity. From it may be gleaned three lessons.

The value of method, of technique, in the hands of a great master has never been better illustrated. Just as Harvey, searching out Nature by way of experiment, opened the way for a study of the functions of the body in health, so did Pasteur, bringing to the problems of biology the same great *organon*, shed a light upon processes the nature of which had defied the analysis of the keenest minds. From Dumas's letter to Pasteur, quoted in Chapter VI., a paragraph may be given in illustration:—"The art of observation and that of experiment are very distinct. In the first case, the fact may either proceed from logical reasons or be mere good fortune; it is sufficient to have some penetration and the sense of truth in order to profit by it. But the art of experimentation leads from the first to the last link of the chain, without hesitation and without a blank, making successive use of Reason, which suggests an alternative, and of Experience, which decides on it, until, starting from a faint glimmer, the full blaze of light is reached." Pasteur had the good fortune to begin with chemistry, and with the science of crystallography, which demanded extraordinary accuracy, and developed that patient persistence so characteristic of all his researches.

In the life of a young man the most essential thing for happiness is the gift of friendship. And here is the second great lesson. As a Frenchman, Pasteur had the devotion that marks the students of that nation to their masters, living and dead. Not the least interesting parts of this work are the

glimpses we get of the great teachers with whom he came in contact. What a model of a scientific man is shown in the character of Biot, so keenly alive to the interests of his young friend, whose brilliant career he followed with the devotion of a second father. One of the most touching incidents recorded in the book relates to Pasteur's election to the Academy of Sciences :—"The next morning when the gates of the Montparnasse cemetery were opened, a woman walked towards Biot's grave with her hands full of flowers. It was Mme. Pasteur who was bringing them to him . . . who had loved Pasteur with so deep an affection." Pasteur looked upon the cult of great men as a great principle in national education. As he said to the students of the University of Edinburgh :—"Worship great men";* and this reverence for the illustrious dead was a dominant element in his character, though the doctrines of Positivism seemed never to have had any attraction for him. A dark shadow in the scientific life is often thrown by a spirit of jealousy, and the habit of suspicious, carping criticism. The hall-mark of a small mind, this spirit should never be allowed to influence our judgment of a man's work, and to young men a splendid example is here offered of a man devoted to his friends, just and generous to his rivals, and patient under many trying contradictions and vexatious oppositions.

And the last great lesson is humility before the unsolved problems of the Universe. Any convictions that might be a comfort in the sufferings of human life had his respectful sympathy. His own creed was beautifully expressed in his eulogy upon *Littré* :—"He who proclaims the existence of the Infinite, and none can avoid it—accumulates in that affirmation more of the supernatural than is to be found in all the miracles of all the religions; for the notion of the Infinite presents that double character that it forces itself upon us and yet is incomprehensible. When this notion seizes upon our understanding, we can but kneel. . . . I see everywhere the inevitable expression of the Infinite in the world; through it,

* A great nation, said Disraeli, is a nation which produces great men.

the supernatural is at the bottom of every heart. The idea of God is a form of the idea of the Infinite. As long as the mystery of the Infinite weighs on human thought, temples will be erected for the worship of the Infinite, whether God is called Brahma, Allah, Jehovah, or Jesus; and on the pavement of those temples, men will be seen kneeling, prostrated, annihilated in the thought of the Infinite." And modern Pantheism has never had a greater disciple, whose life and work set forth the devotion to an ideal—that service to humanity is service to God :—"Blessed is he who carries within himself a God, an ideal, and who obeys it : ideal of art, ideal of science, ideal of the gospel virtues, therein lie the springs of great thoughts and great actions; they all reflect light from the Infinite."

The future belongs to Science. More and more she will control the destinies of the nations. Already she has them in her crucible and on her balances. In her new mission to humanity she preaches a new gospel. In the nineteenth century renaissance she has had great apostles, Darwin, for example, whose gifts of heart and head were in equal measure, but after re-reading for the third or fourth time the *Life of Louis Pasteur*, I am of the opinion, expressed recently by the anonymous writer of a beautiful tribute in the *Spectator*, "that he was the most perfect man who has ever entered the Kingdom of Science."

WILLIAM OSLER.

CHAPTER I

1822—1843

THE origin of even the humblest families can be traced back by persevering search through the ancient parochial registers. Thus the name of Pasteur is to be found written at the beginning of the seventeenth century in the old registers of the Priory of Mouthe, in the province of Franche Comté. The Pasteurs were tillers of the soil, and originally formed a sort of tribe in the small village of Reculfoz, dependent on the Priory, but they gradually dispersed over the country.

The registers of Mièges, near Nozeroy, contain an entry of the marriage of Denis Pasteur and Jeanne David, dated February 9, 1682. This Denis, after whom the line of Pasteur's ancestors follows in an unbroken record, lived in the village of Plénisette, where his eldest son Claude was born in 1683. Denis afterward sojourned for some time in the village of Douay, and ultimately forsaking the valley of Mièges came to Lemuy, where he worked as a miller for Claude François Count of Udressier, a noble descendant of a secretary of the Emperor Charles V.

Lemuy is surrounded by wide plains affording pasture for herds of oxen. In the distance the pine trees of the forest of Joux stand close together, like the ranks of an immense army, their dark masses deepening the azure of the horizon. It was in those widespreading open lands that Pasteur's ancestors lived. Near the church, overshadowed by old beech and lime trees, a tombstone is to be found overgrown with grass. Some members of the family lie under that slab naïvely inscribed: "Here lie, each by the side of the others . . ."

In 1716, in the mill at Lemuy, ruins of which still exist, the marriage contract of Claude Pasteur was drawn up and signed in the presence of Henry Girod, Royal notary of Salins. The father and mother declared themselves unable to write,

but we have the signatures of the affianced couple, Claude Pasteur and Jeanne Belle, affixed to the record of the quaint betrothal oath of the time. This Claude was in his turn a miller at Lemuy, though at his death in 1746 he is only mentioned as a labourer in the parish register. He had eight children, the youngest, whose name was Claude Etienne, and who was born in the village of Supt, a few kilometres from Lemuy, being Louis Pasteur's great-grandfather.

What ambition, what love of adventures induced him to leave the Jura plains to come down to Salins? A desire for independence in the literal sense of the word. According to the custom then still in force in Franche Comté (in contradiction to the name of that province, as Voltaire truly remarks), there were yet some serfs, that is to say, people legally incapable of disposing of their goods or of their persons. They were part of the possessions of a nobleman or of the lands of a convent or monastery. Denis Pasteur and his son had been serfs of the Counts of Udressier. Claude Etienne desired to be freed and succeeded in achieving this at the age of thirty, as is proved by a deed, dated March 20, 1763, drawn up in the presence of the Royal notary, Claude Jarry. Messire Philippe-Marie-François, Count of Udressier, Lord of Ecleux, Cramans, Lemuy and other places, consented "by special grace" to free Claude Etienne Pasteur, a tanner, of Salins, his serf. The deed stipulated that Claude Etienne and his unborn posterity should henceforth be enfranchised from the stain of mortmain. Four gold pieces of twenty-four livres were paid then and there in the mansion of the Count of Udressier by the said Pasteur.

The following year, he married Françoise Lambert. After setting up together a small tannery in the Faubourg Champtave they enjoyed the fairy tale ideal of happiness: they had ten children. The third, Jean Henri, through whom this genealogy continues, was born in 1769. On June 25, 1779, letters giving Claude Etienne Pasteur the freedom of the city of Salins were delivered to him by the Town Council.

Jean Henri Pasteur, in his twentieth year, went to Besançon to seek his fortune as a tanner, but was not successful. His wife, Gabrielle Jourdan, died at the age of twenty, and he married again, but himself died at twenty-seven, leaving one little son by his first marriage, Jean Joseph Pasteur, born March 16, 1791. This child, who was to be

Louis Pasteur's father, was taken charge of by his grandmother at Salins; later on, his father's sisters, one married to a wood merchant named Chamecin, and the other to Philibert Bourgeois, Chamecin's partner, adopted the orphan. He was carefully brought up, but without much learning; it was considered sufficient in those days to be able to read the Emperor's bulletins; the rest did not seem to matter very much. Besides, Jean Joseph had to earn his living at the tanner's trade, which had been his father's and his grandfather's before him.

Jean Joseph was drawn as a conscript in 1811, and went through the Peninsular War in 1812 and 1813. He belonged to the 3rd Regiment of the Line, whose mission was to pursue in the northern Spanish provinces the guerillas of the famous Espoz y Mina. A legend grew round this wonderful man; he was said to make his own gunpowder in the bleak mountain passes; his innumerable partisans were supplied with arms and ammunition by the English cruisers. He dragged women and old men after him, and little children acted as his scouts. Once or twice however, in May, 1812, the terrible Mina was very nearly caught; but in July he was again as powerful as ever. The French had to organize mobile columns to again occupy the coast and establish communications with France. There was some serious fighting. Mina and his followers were incessantly harassing the small French contingent of the 3rd and 4th Regiments, which were almost alone. "How many traits of bravery," writes Tissot, "will remain unknown which on a larger field would have been rewarded and honoured!"

The records of the 3rd Regiment allow us to follow step by step this valiant little troop, and among the rank and file, doing his duty steadily through terrible hardships, that private soldier (a corporal in July, 1812, and a sergeant in October, 1813) whose name was Pasteur. The battalion returned to France at the end of January, 1814. It formed a part of that Leval division which, numbering barely 8,000 men, had to fight at Bar-sur-Aube against an army of 40,000 enemies. The 3rd Regiment was called "brave amongst the brave." "If Napoleon had had none but such soldiers," writes Thiers in his *History of the Consulate and the Empire*, "the result of that great struggle would certainly have been different." The Emperor, touched by so much courage, distributed crosses among the men. Pasteur was made a sergeant-major on March

10, 1814, and received, two days later, the cross of the Legion of Honour.

At the battle of Arcis-sur-Aube (March 21) the Leval division had again to stand against 50,000 men—Russians, Austrians, Bavarians, and Wurtembergers. Pasteur's battalion, the 1st of the 3rd Regiment, came back to St. Dizier and went on by forced marches to Fontainebleau, where Napoleon had concentrated all his forces, arriving on April 4. The battalion was now reduced to eight officers and 276 men. The next day, at twelve o'clock, the Leval division and the remnant of the 7th corps were gathered in the yard of the Cheval Blanc Inn and were reviewed by Napoleon. The attitude of these soldiers, who had heroically fought in Spain and in France, and who were still offering their passionate devotion, gave him a few moments' illusion. Their enthusiasm and acclamations contrasted with the coldness, the reserve, the almost insubordinations of Generals like Ney, Lefebvre, Oudinot and MacDonald, who had just declared that to march on Paris would be folly.

Marmont's defection hastened events; the Emperor, seeing himself forsaken, abdicated. Jean Joseph Pasteur had not, like Captain Coignet, the sad privilege of witnessing the Emperor's farewell, his battalion having been sent into the department of Eure on April 9. On April 23 the white cockade replaced the tricolour.

On May 12, 1814, a royal order gave to the 3rd line Regiment the name of "Régiment Dauphin"; it was reorganized at Douai, where Sergeant-major Pasteur received his discharge from the service. He returned to Besançon with grief and anger in his heart: for him, as for many others risen from the people, Napoleon was a demi-god. Lists of victories, principles of equality, new ideas scattered throughout the nations, had followed each other in dazzling visions. It was a cruel trial for half-pay officers, old sergeants, grenadiers, peasant soldiers, to come down from this imperial epic to every-day monotony, police supervision, and the anxieties of poverty; their wounded patriotism was embittered by feelings of personal humiliation. Jean Joseph resigned himself to his fate and went back to his former trade. The return from Elba was a ray of joy and hope in his obscure life, only to be followed by renewed darkness.

He was living in the Faubourg Champtave a solitary life in accordance with his tastes and character when this solitude was interrupted for an instant. The Mayor of Salins, a knight

of Malta and an ardent royalist, ordered all the late soldiers of Napoleon, the "*brigands de la Loire*" as they were now called, to bring their sabres to the Mairie. Joseph Pasteur reluctantly obeyed; but when he heard that these glorious weapons were destined to police service, and would be used by police agents, further submission seemed to him intolerable. He recognized his own sergeant-major's sabre, which had just been given to an agent, and, springing upon the man, wrested the sword from him. Great excitement ensued—a mixture of indignation, irritation and repressed enthusiasm; the numerous Bonapartists in the town began to gather together. An Austrian regiment was at that time still garrisoned in the town. The Mayor appealed to the colonel, asking him to repress this disobedience; but the Austrian officer refused to interfere, declaring that he both understood and approved the military feelings which actuated the ex-sergeant-major. Pasteur was allowed to keep his sword, and returned home accompanied by sympathizers who were perhaps more noisily enthusiastic than he could have wished.

Having peacefully resumed his work he made the acquaintance of a neighbouring family of gardeners, whose garden faced his tannery on the other bank of the "Furieuse," a river rarely deserving its name. From the steps leading to the water Jean Joseph Pasteur often used to watch a young girl working in the garden at early dawn. She soon perceived that the "old soldier"—very young still; he was but twenty-five years old—was interested in her every movement. Her name was Jeanne Etiennette Roqui.

Her parents, natives of Marnoz, a village about four kilometres from Salins, belonged to one of the most ancient plebeian families of the country. The Salins archives mention a Roqui working in vineyards as far back as 1555, and in 1659 there were Roqui lampmakers and plumbers. The members of this family were in general so much attached to each other that "to love like the Roqui" had become proverbial; their wills and testaments mentioned legacies or gifts from brother to brother, uncle to nephew. In 1815 the father and mother of Jeanne Etiennette were living very quietly in the old Salins faubourg. Their daughter was modest, intelligent and kind; Jean Joseph Pasteur asked for her hand in marriage. They seemed made for each other; the difference in their natures only strengthened their mutual affection: he was reserved,

almost secretive, with a slow and careful mind apparently absorbed in his own inner life; she was very active, full of imagination, and ready enthusiasm.

The young couple migrated to Dôle and settled down in the Rue des Tanneurs. Their first child only lived a few months; in 1818 a little daughter came. Four years later in a small room of their humble home, on Friday, December 27, 1822, at 2 a.m., Louis Pasteur was born.

Two daughters were born later—one at Dôle and the other at Marnoz, in the house of the Roqui. Jean Joseph Pasteur's mother-in-law, now a widow, considering that her great age no longer allowed her to administer her fortune, had divided all she possessed between her son Jean Claude Roqui, a landed proprietor at Marnoz, and Jeanne Etiennette her daughter.

Thus called away from Dôle by family interests, Jean Joseph Pasteur came to live at Marnoz. The place was not very favourable to his trade, though a neighbouring brook rendered the establishment of a tannery possible. The house, though many times altered, still bears the name of "Maison Pasteur." On one of the inner doors the veteran, who had a taste for painting, had depicted a soldier in an old uniform now become a peasant and tilling the soil. This figure stands against a background of grey sky and distant hills; leaning on his spade the man suspends his labours and dreams of past glories. It is easy to criticize the faults in the painting, but the sentimental allegory is full of feeling.

Louis Pasteur's earliest recollections dated from that time; he could remember running joyously along the Aiglepierre road. The Pasteur family did not remain long at Marnoz. A tannery was to let in the neighbourhood by the town of Arbois, near the bridge which crosses the Cuisance, and only a few kilometres from the source of the river. The house, behind its modest frontage, presented the advantage of a yard where pits had been dug for the preparation of the skins. Joseph Pasteur took this little house and settled there with his wife and children.

Louis Pasteur was sent at first to the "Ecole Primaire" attached to the college of Arbois. Mutual teaching was then the fashion; scholars were divided into groups: one child taught the rudiments of reading to others, who then spelt aloud in a sort of sing-song. The master, M. Renaud, went from group to group designating the monitors. Louis soon desired

to possess this title, perhaps all the more so because he was the smallest scholar. But those who would decorate the early years of Louis Pasteur with wonderful legends would be disappointed : when a little later he attended the daily classes at the Arbois college he belonged merely to the category of good average pupils. He took several prizes without much difficulty ; he rather liked buying new lesson books, on the first page of which he proudly wrote his name. His father, who wished to instruct himself as well as to help his son, helped him with his home preparation. During holidays, the boy enjoyed his liberty. Some of his schoolfellows—Vercel, Charrière, Guillemin, Coulon—called for him to come out with them and he followed them with pleasure. He delighted in fishing parties on the Cuisance, and much admired the net throwing of his comrade Jules Vercel. But he avoided bird trapping ; the sight of a wounded lark was painful to him.

The doors of Louis Pasteur's home were not usually open except to his schoolboy friends, who, when they did not fetch him away, used to come and play in the tannery yard with remnants of bark, stray bits of iron, etc. Joseph Pasteur, though not considered a proud man, did not easily make friends. 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 (worn very large at that time), he invariably walked out towards the road from Arbois to Besançon. This road passes between vine-planted hills. On the left, on a wooded height above the wide plain towards Dôle, the ruins of the Vadans tower invest the whole landscape with a lingering glamour of heroic times. In these solitary meditations, he dwelt more anxiously on the future than on present difficulties, the latter being of little account in this hard-working family. What would become of this son of his, conscientious and studious, but, though already thirteen years old, with no apparent preference for anything but drawing? The epithet of *artist* given to Louis Pasteur by his Arboisian friends only half pleased the paternal vanity. And yet it is impossible not to be struck by the realism of his first original effort, a very bold pastel drawing. This pastel represents Louis' mother, one morning that she was going to market, with a white cap and a blue and green tartan shawl. Her son insisted on painting

her just as she was. The portrait is full of sincerity and not unlike the work of a conscientious pre-Raphaelite. The powerful face is illumined by a pair of clear straightforward eyes.

Though they did not entertain mere acquaintances, the husband and wife were happy to receive those who seemed to them worthy of affection or esteem by reason of some superiority of the mind or of the heart. In this way they formed a friendship with an old army doctor then practising in the Arbois hospital, Dr. Dumont, a man who studied for the sake of learning and who did a great deal of good while avoiding popularity.

Another familiar friend was a philosopher named Bousson de Mairet. An indefatigable reader, he never went out without a book or pamphlet in his pocket. He spent his life in compiling from isolated facts annals in which the characteristics of the Francs-Comtois, and especially the Arboisians, were reproduced in detail, with labour worthy of a Benedictine monk. He often came to spend a quiet evening with the Pasteur family, who used to question him and to listen to his interesting records of that strange Arboisian race, difficult to understand, presenting as it does a mixture of heroic courage and that slightly ironical good humour which Parisians and Southerners mistake for naïveness. Arboisians never distrust themselves, but are sceptical where others are concerned. They are proud of their local history, and even of their rodomontades.

For instance, on August 4, 1830, they sent an address to the Parisians to express their indignation against the "Ordonnances" [1] and to assure them that all the available population of Arbois was ready to fly to the assistance of Paris. In April, 1834, a lawyer's clerk, passing one evening through Arbois by the coach, announced to a few *gardes nationaux* who were standing about that the Republic was proclaimed at Lyons. Arbois immediately rose in arms; the insurgents armed themselves with guns from the Hôtel de Ville. Louis Pasteur watched the

[1] *Ordonnances du* 26 *Juillet*, 1830. A royal Decree issued by Charles X under the advice of his minister, Prince de Polignac; it was based on a misreading of one of the articles of the Charter of 1814, and dissolved the new Chamber of Deputies before it had even assembled; it suppressed the freedom of the Press and created a new electoral system to the advantage of the royalist party. These *ordonnances* were the cause of the 1830 Revolution, which placed Louis Philippe of Orleans on the Throne. [Trans.]

arrival from Besançon of 200 grenadiers, four squadrons of light cavalry, and a small battery of artillery sent to reduce the rebels. The *sous-préfet* of Poligny having asked the rioters who were their leaders, they answered with one voice, "We are all leaders." A few days later the great, the good news was published in all the newspapers: "Arbois, Lyons, and Paris are pacified." The Arboisians called their neighbours "the Braggarts of Salins," probably with the ingenious intention of turning such a well-deserved accusation from themselves.

Louis Pasteur, whose mind already had a serious bent, preferred to these recent anecdotes such historical records as that of the siege of Arbois under Henry IV, when the Arboisians held out for three whole days against a besieging army of 25,000 men. His childish imagination, after being worked upon by these stories of local patriotism, eagerly seized upon ideals of a higher patriotism, and fed upon the glory of the French people as represented by the conquests of the Empire.

He watched his parents, day by day working under dire necessity and ennobling their weary task by considering their children's education almost as essential as their daily bread; and, as in all things the father and mother took an interest in noble motives and principles, their material life was lightened and illumined by their moral life.

One more friend, the headmaster of Arbois college, M. Romanet, exerted a decisive influence on Louis Pasteur's career. This master, who was constantly trying to elevate the mind and heart of his pupils, inspired Louis with great admiration as well as with respect and gratitude. Romanet considered that whilst instruction doubled a man's value, education, in the highest sense of the word, increased it tenfold. He was the first to discover in Louis Pasteur the hidden spark that had not yet revealed itself by any brilliant success in the hardworking schoolboy. Louis' mind worked so carefully that he was considered slow; he never affirmed anything of which he was not absolutely sure; but with all his strength and caution he also had vivid imaginative faculties.

Romanet, during their strolls round the college playground, took pleasure in awakening with an educator's interest the leading qualities of this young nature—circumspection and enthusiasm. The boy, who had been sitting over his desk

with all-absorbing attention, now listened with sparkling eyes to the kind teacher talking to him of his future and opening to him the prospect of the great *Ecole Normale*.[1]

An officer of the Paris municipal guard, Captain Barbier, who always came to Arbois when on leave, offered to look after Louis Pasteur if he were sent to Paris. But Joseph Pasteur—in spite of all—hesitated to send his son, not yet sixteen years old, a hundred leagues away from home. Would it not be wiser to let him go to Besançon college and come back to Arbois college as professor? What could be more desirable than such a position? Surely Paris and the Ecole Normale were quite unnecessary! The question of money also had to be considered.

"That need not trouble you," said Captain Barbier. "In the Latin Quarter, Impasse des Feuillantines, there is a preparatory school, of which the headmaster, M. Barbet, is a Franc-Comtois. He will do for your son what he has done for many boys from his own country—that is, take him at reduced school fees."

Joseph Pasteur at last allowed himself to be persuaded, and Louis' departure was fixed for the end of October, 1838. He was not going alone: Jules Vercel, his dear school friend, was also going to Paris to work for his "baccalauréat."[2] This youth had a most happy temperament: unambitious, satisfied with each day's work as it came, he took pride and pleasure in the success of others, and especially in that of "Louis," as he then and always fraternally called his friend. The two

[1] *Ecole Normale Supérieure*, under the supervision of the Ministry of Public Instruction and Fine Arts, founded in 1808 by Napoleon I, with the object of training young professors. Candidates must (1) be older than eighteen and younger than twenty-one; (2) pass one written and one vivâ voce examination; (3) be already in possession of their diploma as *bachelier* of science or of letters, according to the branch of studies which they wish to take up; and (4) sign an engagement for ten years' work in public instruction. The professors of the Ecole Normale take the title of *Maître des Conférences*. [Trans.]

[2] Baccalauréat (low Latin *bachalariatus*), first degree taken in a French Faculty; the next is *licence*, and the next *doctorate*. It is much more elementary than a bachelor's degree in an English university. There are two baccalauréats: (1) the baccalauréat *ès lettres* required of candidates for the Faculties of Medicine and of Law, to the Ecole Normale Supérieure and to several public offices; (2) the baccalauréat *ès sciences*, required for admission to the Schools of Medicine and of Pharmacy, to the Ecole Normale Supérieure (scientific section), and the Polytechnic, Military and Foresters' Schools. [Trans.]

boys' friendship went some way to alleviate the natural anxieties felt by both families. The slowness and difficulty of travelling in those days gave to farewells a sort of solemn sadness; they were repeated twenty times whilst the horses were being harnessed and the luggage hoisted on to the coach in the large courtyard of the "Hôtel de la Poste." On that bleak October morning, amidst a shower of rain and sleet, the two lads had to sit under the tarpaulin behind the driver; there were no seats left inside or under the hood. In spite of Vercel's habit of seeing the right side of things and his joy in thinking that in forty-eight hours he, the country boy, would see the wonders of Paris—in spite of Pasteur's brave resolve to make the most of his unexpected opportunities of study, of the now possible entrance into the "Ecole Normale"—both looked with heavy hearts at the familiar scene they were leaving behind them—their homes, the square tower of Arbois church, the heights of the Ermitage in the grey distance.

Every native of Jura, though he affects to feel nothing of the kind, has, at the bottom of his heart, a strong feeling of attachment for the corner of the world where he has spent his childhood; as soon as he forsakes his native soil his thoughts return to it with a painful and persistent charm. The two boys did not take much interest in the towns where the coach stopped to change horses, Dôle, Dijon, Auxerre, Joigny, Sens, Fontainebleau, etc.

When Louis Pasteur reached Paris he did not feel like Balzac's student hero, confidently defying the great city. In spite of the strong will already visible in his pensive features, his grief was too deep to be reasoned away. No one at first suspected this; he was a reserved youth, with none of the desire to talk which leads weak natures to ease their sorrows by pouring them out; but, when all was quiet in the Impasse des Feuillantines and his sleeping comrades could not break in upon his regrets, he would lie awake for hours thinking of his home and repeating the mournful line—

> How endless unto watchful anguish
> Night doth seem.

The students of the Barbet school attended the classes of the Lycée St. Louis. In spite of his willingness and his passionate love of study, Louis was overcome with despair at being away from home. Never was homesickness more acute. "If

I could only get a whiff of the tannery yard," he would say to Jules Vercel, "I feel I should be cured." M. Barbet endeavoured in vain to amuse and turn the thoughts of this lad of fifteen so absorbed in his sorrow. At last he thought it his duty to warn the parents of this state of mind, which threatened to become morbid.

One morning in November Louis Pasteur was told with an air of mystery that he was wanted. "They are waiting for you close by," said the messenger, indicating a small café at the corner of the street. Louis entered and found a man sitting at a small table at the back of the shop, his face in his hands. It was his father. "I have come to fetch you," he said simply. No explanations were necessary; the father and son understood each other's longings.

What took place in Pasteur's mind when he found himself again at Arbois? After the first few days of relief and joy, did he feel, when he went back to Arbois college, any regret, not to say remorse, at not having overcome his homesickness? Was he discouraged by the prospect of a restricted career in that small town? Little is known of that period when his will had been mastered by his feelings; but from the indecision of his daily life we may hazard a guess at the disquieted state of his mind at this time. At the beginning of that year (1839) he returned for a time to his early tastes; he went back to his coloured chalks, left aside for the last eighteen months, ever since one holiday time when he had drawn Captain Barbier, proudly wearing his uniform, and with the high colour of excellent health.

He soon got beyond the powers of his drawing master, M. Pointurier, a good man who does not seem to have seen any scientific possibilities in the art of drawing.

Louis' pastel drawings soon formed a portrait gallery of friends. An old cooper of seventy, Father Gaidot, born at Dôle, but now living at Arbois, had his turn. Gaidot appears in a festive costume, a blue coat and a yellow waistcoat, very picturesque with his wrinkled forehead and close-shaven cheeks. Then there are all the members of a family named Roch. The father and the son are drawn carefully, portraits such as are often seen in country villages; but the two daughters Lydia and Sophia are more delicately pencilled; they live again in the youthful grace of their twenty summers. Then we have a notary, the wide collar of a frock coat framing his rubicund

face; a young woman in white; an old nun of eighty-two in a fluted cap, wearing a white hood and an ivory cross; a little boy of ten in a velvet suit, a melancholy-looking child, not destined to grow to manhood. Pasteur obligingly drew any one who wished to have a portrait. Among all these pastels, two are really remarkable. The first represents, in his official garb, a M. Blondeau, registrar of mortgages, whose gentle and refined features are perfectly delineated. The other is the portrait of a mayor of Arbois, M. Pareau; he wears his silver-embroidered uniform, with a white stock. The cross of the Legion of Honour and the tricolour scarf are discreetly indicated. The whole interest is centred in the smiling face, with hair brushed up *à la* Louis Philippe, and blue eyes harmonizing with a blue ground.

The compliments of this local dignitary and Romanet's renewed counsels at the end of the year—when Pasteur took more school prizes than he could carry—reawakened within him the ambition for the Ecole Normale.

There was no "philosophy" [1] class in the college of Arbois, and a return to Paris seemed formidable. Pasteur resolved to go to the college at Besançon, where he could go on with his studies, pass his baccalauréat and then prepare for the examinations of the Ecole Normale. Besançon is only forty kilometres from Arbois, and Joseph Pasteur was in the habit of going there several times a year to sell some of his prepared skins. This was by far the wisest solution of the problem.

On his arrival at the Royal College of Franche Comté Pasteur found himself under a philosophy master, M. Daunas,

[1] Philosophie class. In French secondary schools or *lycées* the forms or classes, in Pasteur's time, were arranged as follows, starting from the bottom—

1° huitième.
2° septième.
6° sixième (French grammar was begun).
5° cinquième (Latin was begun).
6° quatrième (Greek was begun).
7° troisième.
8° seconde.

9° Mathématiques élémentaires. Rhétorique.
10° Mathématiques spéciales. Philosophie.

The seconde students who intended to pass their *baccalauréat ès sciences* went into the mathématiques élémentaires class, whilst those who were destined for letters or the law entered the rhétorique class, from which they went on to the philosophie class. [Trans.]

who had been a student at the Ecole Normale and was a graduate of the University; he was young, full of eloquence, proud of his pupils, of awakening their faculties and directing their minds. The science master, M. Darlay, did not inspire the same enthusiasm; he was an elderly man and regretted the good old times when pupils were less inquisitive. Pasteur's questions often embarrassed him. Louis' reputation as a painter satisfied him no longer, though the portrait he drew of one of his comrades was exhibited. "All this does not lead to the Ecole Normale," he wrote to his parents in January, 1840. "I prefer a first place at college to 10,000 praises in the course of conversation. . . . We shall meet on Sunday, dear father, for I believe there is a fair on Monday. If we see M. Daunas, we will speak to him of the Ecole Normale. Dear sisters, let me tell you again, work hard, love each other. When one is accustomed to work it is impossible to do without it; besides, everything in this world depends on that. Armed with science, one can rise above all one's fellows. . . . But I hope all this good advice to you is superfluous, and I am sure you spend many moments every day learning your grammar. Love each other as I love you, while awaiting the happy day when I shall be received at the Ecole Normale." Thus was his whole life filled with tenderness as well as with work. He took the degree of "bachelier ès lettres" on August 29, 1840. The three examiners, doctors "ès lettres," put down his answers as "good in Greek on Plutarch and in Latin on Virgil, good also in rhetoric, medicine, history and geography, good in philosophy, very good in elementary science, good in French composition."

At the end of the summer holidays the headmaster of the Royal College of Besançon, M. Répécaud, sent for him and offered him the post of preparation master. Certain administrative changes and an increased number of pupils were the reason of this offer, which proved the master's esteem for Pasteur's moral qualities, his first degree not having been obtained with any particular brilliancy.

The youthful master was to be remunerated from the month of January, 1841. A student in the class of special mathematics, he was his comrades' mentor during preparation time. They obeyed him without difficulty; simple and yet serious-minded, his sense of individual dignity made authority easy to him. Ever thoughtful of his distant home, he strengthened

the influence of the father and mother in the education of his sisters, who had not so great a love of industry as he had. On November 1, 1840—he was not eighteen yet—pleased to hear that they were making some progress, he wrote the following, which, though slightly pedantic, reveals the warmth of his feelings—"My dear parents, my sisters, when I received at the same time the two letters that you sent me I thought that something extraordinary had happened, but such was not the case. The second letter you wrote me gave me much pleasure; it tells me that—perhaps for the first time—my sisters have *willed*. To *will* is a great thing, dear sisters, for Action and Work usually follow Will, and almost always Work is accompanied by success. These three things, Will, Work, Success, fill human existence. Will opens the door to success both brilliant and happy; Work passes these doors, and at the end of the journey Success comes to crown one's efforts. And so, my dear sisters, if your resolution is firm, your task, be it what it may, is already begun; you have but to walk forward, it will achieve itself. If perchance you should falter during the journey, a hand would be there to support you. If that should be wanting, God, who alone could take that hand from you, would Himself accomplish its work. . . . May my words be felt and understood by you, dearest sisters. I impress them on your hearts. May they be your guide. Farewell. Your brother."

The letters he wrote, the books he loved, the friends he chose, bear witness to the character of Pasteur in those days of early youth. As he now felt, after the discouraging trial he had gone through in Paris, that the development of the will should hold the first place in education, he applied all his efforts to the bringing out of this leading force. He was already grave and exceptionally matured; he saw in the perfecting of self the great law of man, and nothing that could assist in that improvement seemed to him without importance. Books read in early life appeared to him to have an almost decisive influence. In his eyes a good book was a good action constantly renewed, a bad one an incessant and irreparable fault.

There lived at that time in Franche Comté an elderly writer, whom Sainte Beuve considered as the ideal of the upright man and of the man of letters. His name was Joseph Droz, and his moral doctrine was that vanity is the cause of many wrecked and aimless lives, that moderation is a form of

wisdom and an element of happiness, and that most men sadden and trouble their lives by causeless worry and agitation. His own life was an example of his precepts of kindliness and patience, and was filled to the utmost with all the good that a pure literary conscience can bestow; he was all benevolence and cordiality. It seemed natural that he should publish one after another numberless editions of his *Essay on the Art of being Happy*.

"I have still," wrote Pasteur to his parents, "that little volume of M. Droz which he was kind enough to lend me. I have never read anything wiser, more moral or more virtuous. I have also another of his works; nothing was ever better written. At the end of the year I shall bring you back these books. One feels in reading them an irresistible charm which penetrates the soul and fills it with the most exalted and generous feelings. There is not a word of exaggeration in what I am writing. Indeed I take his books with me to the services on Sundays to read them, and I believe that in so acting, in spite of all that thoughtless bigotry might say, I am conforming to the very highest religious ideas."

Those ideas Droz might have summarized simply by Christ's words, "Love ye one another." But this was a time of circumlocution. Young people demanded of books, of discourses, of poetry, a sonorous echo of their own secret feelings. In the writings of the Besançon moralist, Pasteur saw a religion such as he himself dreamed of, a religion free from all controversy and all intolerance, a religion of peace, love and devotion.

A little later, Silvio Pellico's *Miei Prigioni* developed in him an emotion which answered to his instinctive sympathy for the sorrows of others. He wrote advising his sisters to read "that interesting work, where you breathe with every page a religious perfume which exalts and ennobles the soul." In read *Miei Prigioni* his sisters would light upon a passage on fraternal love and all the deep feelings which it represents.

"For my sisters," he wrote in another letter, "I bought, a few days ago, a very pretty book; I mean by very pretty something very interesting. It is a little volume which took the Montyon [1] prize a few years ago, and it is called, *Picciola*.

[1] Prix Montyon: a series of prizes founded at the beginning of the nineteenth century by Baron de Montyon, a distinguished philanthropist, and conferred on literary works for their moral worth, and on individuals

How could it have deserved the Montyon prize," he added, with an edifying respect for the decisions of the Academy, "if the reading of it were not of great value?"

"You know," he announced to his parents when his appointment was definitely settled, "that a supplementary master has board and lodging and 300 francs a year!" This sum appeared to him enormous. He added, on January 20: "At the end of this month money will already be owing to me; and yet I assure you I am not really worth it."

Pleased with this situation, though such a modest one, full of eagerness to work, he wrote in the same letter: "I find it an excellent thing to have a room of my own; I have more time to myself, and I am not interrupted by those endless little things that the boys have to do, and which take up a good deal of time. Indeed I am already noticing a change in my work; difficulties are getting smoothed away because I have more time to give to overcoming them; in fact I am beginning to hope that by working as I do and shall continue to do I may be received with a good rank at the Ecole. But do not think that I am overworking myself at all; I take every recreation necessary to my health."

Besides his ordinary work, he had been entrusted with the duty of giving some help in mathematics and physical science to the youths who were reading for their baccalauréat.

As if reproaching himself with being the only member of the family who enjoyed the opportunity of learning, he offered to pay for the schooling of his youngest sister Josephine in a girls' college at Lons-le-Saulnier. He wrote, "I could easily do it by giving private lessons. I have already refused to give some to several boys at 20 or 25 fr. a month. I refused because I have not too much time to give to my work." But he was quite disposed to waive this motive in deference to superior judgment. His parents promised to think over this fraternal wish, without however accepting his generous suggestion, offering even to supplement his small salary of 24 francs a month by a little allowance, in case he wished for a few private lessons to prepare himself more thoroughly for the Ecole Normale. They quite recognized his right to advise;

for acts of private virtue or self-sacrifice. The laureates are chosen every year by the Académie Française, and in this way many obscure heroes are deservedly rewarded, and many excellent books brought to public notice. [Trans.]

and—as he thought that his sister should prepare herself beforehand for the class she was to enter—he wrote to his mother with filial authority, "Josephine should work a good deal until the end of the year, and I would recommend to Mother that she should not continually be sent out on errands; she must have time to work."

Michelet, in his recollections, tells of his hours of intimacy with a college friend named Poinsat, and thus expresses himself: "It was an immense, an insatiable longing for confidences, for mutual revelations." Pasteur felt something of the sort for Charles Chappuis, a *philosophie* student at Besançon college. He was the son of a notary at St. Vit, one of those old-fashioned provincial notaries, who, by the dignity of their lives, their spirit of wisdom, the perpetual preoccupation of their duty, inspired their children with a sense of responsibility. His son had even surpassed his father's hopes. Of this generous, gentle-faced youth there exists a lithograph signed "Louis Pasteur." A book entitled *Les Graveurs du XIX^me^ Siècle* mentions this portrait, giving Pasteur an unexpected form of celebrity. Before the *Graveurs*, the *Guide de l'Amateur des Œuvres d'Art* had already spoken of a pastel drawing discovered in the United States near Boston. It represents another schoolfellow of Pasteur's, who, far from his native land, carefully preserved the portrait of Chappuis as well as his own. Everything that friendship can give in strength and disinterestedness, everything that, according to Montaigne—who knew more about it even that Michelet—"makes souls merge into each other so that the seam which originally joined them disappears," was experienced by Pasteur and Chappuis. Filial piety, brotherly solicitude, friendly confidences—Pasteur knew the sweetness of all these early human joys; the whole of his life was permeated with them. The books he loved added to this flow of generous emotions. Chappuis watched and admired this original nature, which, with a rigid mind made for scientific research and always seeking the proof of everything, yet read Lamartine's *Meditations* with enthusiasm. Differing in this from many science students, who are indifferent to literature—just as some literature students affect to disdain science—Pasteur kept for literature a place apart. He looked upon it as a guide for general ideas. Sometimes he would praise to excess some writer or orator merely because he had found in one page or

in one sentence the expression of an exalted sentiment. It was with Chappuis that he exchanged his thoughts, and together they mapped out a life in common. When Chappuis went to Paris, the better to prepare himself for the Ecole Normale, Pasteur felt an ardent desire to go with him. Chappuis wrote to him with that open spontaneity which is such a charm in youth, "I shall feel as if I had all my Franche Comté with me when you are here." Pasteur's father feared a crisis like that of 1838, and, after hesitating, refused his consent to an immediate departure. "Next year," he said.

In October, 1841, though still combining the functions of master and student, Pasteur resumed his attendance of the classes for special mathematics. But he was constantly thinking of Paris, "Paris, where study is deeper." One of Chappuis' comrades, Bertin, whom Pasteur had met during the holidays, had just entered the Ecole Normale at the head of the list after attending in Paris a class of special mathematics.

"If I do not pass this year," Pasteur wrote to his father on November 7, "I think I should do well to go to Paris for a year. But there is time to think of that and of the means of doing so without spending too much, if the occasion should arise. I see now what great advantage there is in giving two years to mathematics; everything becomes clearer and easier. Of all our class students who tried this year for the Ecole Polytechnique and the Ecole Normale, not a single one has passed, not even the best of them, a student who had already done one year's mathematics at Lyons. The master we have now is very good. I feel sure I shall do a great deal this year."

He was twice second in his class; once he was first in physics. "That gives me hope for later on," he said. He wrote about another mathematical competition, "If I get a good place it will be well deserved, for this work has given me a pretty bad headache; I always do get one, though, whenever we have a competition." Then, fearful of alarming his parents, he hastily adds, "But those headaches never last long, and it is only an hour and a half since we left off."

Anxious to stifle by hard work his growing regrets at not having followed Chappuis to Paris, Pasteur imagined that he might prepare himself for the Ecole Polytechnique as well as for the Ecole Normale. One of his masters, M. Bouché, had led him to hope that he might be successful. "I shall try this

year for both schools," Pasteur wrote to his friend (January 22, 1842). "I do not know whether I am right in deciding to do so. One thing tells me that I am wrong: it is the idea that we might thus be parted; and when I think of that, I firmly believe that I cannot possibly be admitted this year into the Ecole Polytechnique. I feel quite superstitious about it. I have but one pleasure, your letters and those from my family. Oh! do write often, very long letters!"

Chappuis, concerned at this sudden resolve, answered in terms that did credit to his heart and youthful wisdom. "Consult your tastes, think of the present, of the future. You must think of yourself; it is your own fate that you have to direct. There is more glitter on the one side; on the other the gentle quiet life of a professor, a trifle monotonous perhaps, but full of charm for him who knows how to enjoy it. You too appreciated it formerly, and I learned to do so when we thought we should both go the same way. Anyhow, go where you think you will be happy, and think of me sometimes. I hope your father will not blame me. I believe he looks upon me as your evil genius. These last holidays I wanted you to come to me, then I advised you to go to Paris; each time your father created some obstacle! But do what he wishes, and never forget that it is perhaps because he loves you too much that he never does what you ask him."

Pasteur soon thought no more of his Polytechnic fancy, and gave himself up altogether to his preparation for the Ecole Normale. But the study of mathematics seemed to him dry and exhausting. He wrote in April, "One ends by having nothing but figures, formulas and geometrical forms before one's eyes. . . . On Thursday I went out and I read a charming story, which, much to my astonishment, made me weep. I had not done such a thing for years. Such is life."

On August 13, 1842, he went up for his examination (*baccalauréat ès sciences*) before the Dijon Faculty. He passed less brilliantly even than he had done for the *baccalauréat ès lettres*. In chemistry he was only put down as "*médiocre*." On August 26 he was declared admissible to the examinations for the Ecole Normale. But he was only fifteenth out of twenty-two candidates. He considered this too low a place, and resolved to try again the following year. In October, 1842, he started for Paris with Chappuis. On the eve of his departure Louis drew a last pastel, a portrait of his

father. It is a powerful face, with observation and meditation apparent in the eyes, strength and caution in the mouth and chin.

Pasteur arrived at the Barbet Boarding School, no longer a forlorn lad, but a tall student capable of teaching and engaged for that purpose. He only paid one-third of the pupil's fees, and in return had to give to the younger pupils some instruction in mathematics every morning from six to seven. His room was not in the school, but in the same Impasse des Feuillantines; two pupils shared it with him.

"Do not be anxious about my health and work," he wrote to his friends a few days after his arrival. "I need hardly get up till 5.45; you see it is not so very early." He went on outlining the programme of his time. "I shall spend my Thursdays in a neighbouring library with Chappuis, who has four hours to himself on that day. On Sundays we shall walk and work a little together; we hope to do some Philosophy on Sundays, perhaps too on Thursdays; I shall also read some literary works. Surely you must see that I am not homesick this time."

Besides attending the classes of the Lycée St. Louis, he also went to the Sorbonne [1] to hear the Professor, who, after taking Gay-Lussac's place in 1832, had for the last ten years delighted his audience by an eloquence and talent which opened boundless horizons before every mind.

In a letter dated December 9, 1842, Pasteur wrote, "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 great deal of applause; there are always six or seven hundred people."

[1] Sorbonne. Name given to the Paris Faculty of Theology and the buildings in which it was established. It was originally intended by its founder, Robert de Sorbon (who was chaplain to St. Louis, King of France, 1270) as a special establishment to facilitate theological studies for poor students. This college became one of the most celebrated in the world, and produced so many clever theologians that it gave its name to all the members of the Faculty of Theology. It was closed during the Revolution in 1789, and its buildings, which had been restored by Richelieu in the seventeenth century, were given to the Université in 1808. Since 1821 they have been the seat of the Universitarian Academy of Paris, and used for the lectures of the Faculties of Theology, of Letters, and of Sciences. [Trans.]

Under this rostrum, Pasteur became, in his own words, a "disciple" full of the enthusiasm inspired by Dumas.

Happy in this industrious life, he wrote in response to an expression of his parents' provincial uneasiness as to the temptations of the Latin Quarter. "When one wishes to keep straight, one can do so in this place as well as in any other; it is those who have no strength of will that succumb."

He made himself so useful at Barbet's that he was soon kept free of all expense. But the expenses of his Parisian life are set out in a small list made about that time. His father wished him to dine at the Palais Royal on Thursdays and Sundays with Chappuis, and the price of each of those dinners came to a little less than two francs. He had, still with the inseparable Chappuis, gone four times to the theatre and once to the opera. He had also hired a stove for his stone-floored room; for eight francs he had bought some firewood, and also a two-franc cloth for his table, which he said had holes in it, and was not convenient to write on.

At the end of the school year, 1843, he took at the Lycée St. Louis two "Accessits,"[1] and one first prize in physics, and at the "*Concours Général*"[2] a sixth "Accessit" in physics. He was admitted fourth on the list to the Ecole Normale. He then wrote from Arbois to M. Barbet, telling him that on his half-holidays he would give some lessons at the school of the Impasse des Feuillantines as a small token of his gratitude for past kindness. "My dear Pasteur," answered M. Barbet, "I accept with pleasure the offer you have made me to give to my school some of the leisure that you will have during your stay at the Ecole Normale. It will indeed be a means of frequent and intimate intercourse between us, in which we shall both find much advantage."

Pasteur was in such a hurry to enter the Ecole Normale that he arrived in Paris some days before the other students. He solicited permission to come in as another might have begged permission to come out. He was readily allowed to sleep in the empty dormitory. His first visit was to M. Barbet. The Thursday half-holiday, usually from one to seven, was

[1] Accessit. A distinction accorded in French schools to those who have come nearest to obtaining the prize in any given subject. [Trans.]

[2] Concours Général. An open competition held every year at the Sorbonne between the *élite* of the students of all the colleges in France, from the highest classes down to the *quatrième*. [Trans.]

now from one to eight. "There is nothing more simple," he said, "than to come regularly at six o'clock on Thursdays and give the schoolboys a physical science class."

"I am very pleased," wrote his father, "that you are giving lessons at M. Barbet's. He has been so kind to us that I was anxious that you should show him some gratitude; be therefore always most obliging towards him. You should do so, not only for your own sake, but for others; it will encourage him to show the same kindness to other studious young men, whose future might depend upon it."

Generosity, self-sacrifice, kindliness even to unknown strangers, cost not the least effort to the father and son, but seemed to them the most natural thing possible. Just as their little house at Arbois was transformed by a ray of the ideal, the broken down walls of the old Ecole Normale—then a sort of annexe of the Louis Le Grand college, and looking, said Jules Simon, like an old hospital or barracks—reflected within them the ideas and sentiments which inspire useful lives. Joseph Pasteur wrote (Nov. 18, 1843): "The details you give me on the way your work is directed please me very much; everything seems organized so as to produce distinguished scholars. Honour be to those who founded this School." Only one thing troubled him, he mentioned it in every letter. "You know how we worry about your health; you do work so immoderately. Are you not injuring your eyesight by so much night work? Your ambition ought to be satisfied now that you have reached your present position!" He also wrote to Chappuis: "Do tell Louis not to work so much; it is not good to strain one's brain. That is not the way to succeed but to compromise one's health." And with some little irony as to the cogitations of Chappuis the philosopher: "Believe me, you are but poor philosophers if you do not know that one can be happy even as a poor professor in Arbois College."

Another letter, December, 1843, to his son this time: "Tell Chappuis that I have bottled some 1834 bought on purpose to drink the health of the Ecole Normale during the next holidays. There is more wit in those 100 litres than in all the books on philosophy in the world; but, as to mathematical formulæ, there are none, I believe. Mind you tell him that we shall drink the first bottle with him. Remain two good friends."

Pasteur's letters during this first period at the Normale have

been lost, but his biography continues without a break, thanks to the letters of his father. "Tell us always about your studies, about your doings at Barbet's. Do you still attend M. Pouillet's lectures, or do you find that one science hampers the other? I should think not; on the contrary, one should be a help to the other." This observation should be interesting to a student of heredity; the idea casually mentioned by the father was to receive a vivid demonstration in the life-work of the son.

CHAPTER II

1844—1849

PASTEUR often spent his leisure moments in the library of the Ecole Normale. Those who knew him at that time remember him as grave, quiet, almost shy. But under these reflective characteristics lay the latent fire of enthusiasm. The lives of illustrious men, of great scientists, of great patriots inspired him with a generous ardour. To this ardour he added a great eagerness of mind; whether studying a book, even a commonplace one—for he was so conscientious that he did not even know what it was to "skim" through a book—or coming away from one of J. B. Dumas' lectures, or writing his student's notes in his small fine handwriting, he was always thirsting to learn more, to devote himself to great researches. There seemed to him no better way of spending a holiday than to be shut up all Sunday afternoon at the Sorbonne laboratory or coaxing a private lesson from the celebrated Barruel, Dumas' curator.

Chappuis—anxious to obey the injunctions of Pasteur's father, who in every letter repeated "Do not let him work too much!" desirous also of enjoying a few hours' outing with his friend—used to wait philosophically, sitting on a laboratory stool, until the experiments were over. Conquered by this patient attitude and reproachful silence Pasteur would take off his apron, saying half angrily, half gratefully, "Well, let us go for a walk." And, when they were out in the street, the same serious subjects of conversation would inevitably crop up—classes, lectures, readings, etc.

One day, in the course of those long talks in the gardens of the Luxembourg, Pasteur carried Chappuis with him very far away from philosophy. He began to talk of tartaric acid and of paratartaric acid. The former had been known since 1770, thanks to the Swedish chemist Scheele, who discovered it in

the thick crusty formations within wine barrels called "tartar"; but the latter was disconcerting to chemists. In 1820 an Alsatian manufacturer, Kestner, had obtained by chance, whilst preparing tartaric acid in his factory at Thann, a very singular acid which he was unable to reproduce in spite of various attempts. He had kept some of it in stock. Gay-Lussac, having visited the Thann factory in 1826, studied this mysterious acid; he proposed to call it *racemic* acid. Berzelius studied it in his turn, and preferred to call it *paratartaric*. Either name may be adopted; it is exactly the same thing: men of letters or in society are equally frightened by the word paratartaric or racemic. Chappuis certainly was when Pasteur repeated to him word for word a paragraph by a Berlin chemist and crystallographer named Mitscherlich. Pasteur had pondered over this paragraph until he knew it by heart; often indeed, absorbed in reading the reports for 1844 of the Académie des Sciences, in the dark room which was then the library of the Ecole Normale, he had wondered if it were possible to get over a difficulty which seemed insurmountable to scientists such as Mitscherlich and Biot. This paragraph related to two saline combinations—tartrate and paratartrate of soda or ammonia—and may be epitomized as follows: in these two substances of similar crystalline form, the nature and number of the atoms, their arrangement and distances are the same. Yet dissolved tartrate rotates the plane of polarized light and paratartrate remains inactive.

Pasteur had the gift of making scientific problems interesting in a few words, even to minds least inclined to that particular line of thought. He rendered his listener's attention very easy; no question surprised him and he never smiled at ignorance. Though Chappuis, absorbed in the series of lectures on philosophy given at that time by Jules Simon, was deep in a train of thought very far away from Mitscherlich's perplexities, he gradually became interested in this optical inactivity of paratartrate, which so visibly affected his friend. Pasteur liked to look back into the history of things, giving in this way a veritable life to his explanations. Thus, à propos of the optical phenomenon which puzzled Mitscherlich, Pasteur was speaking to his friend of crystallized carbonate of lime, called Iceland spar, which presents a double refraction—that is to say: if you look at an object through this crystal, you perceive two reproductions of that object. In describing this, Pasteur was not

giving to Chappuis a vague notion of some piece of crystal in a glass case, but was absolutely evoking a vision of the beautiful crystal, perfectly pure and transparent, brought from Iceland in 1669 to a Danish physicist. Pasteur almost seemed to experience the surprise and emotion of this scientist, when, observing a ray of light through this crystal, he saw it suddenly duplicated. Pasteur also spoke enthusiastically of an officer of Engineers under the First Empire, Etienne Louis Malus. Malus was studying double refraction, and holding in his hands a piece of spar crystal, when, from his room in the Rue de l'Enfer, it occurred to him to observe through the crystal the windows of the Luxembourg Palace, then lighted up by the setting sun. It was sufficient to make the crystal rotate slowly round the visual ray (as on an axis) to perceive the periodic variations in the intensity of the light reflected by the windows. No one had yet suspected that light, after being reflected under certain conditions, would acquire properties quite different from those it had before its reflection. Malus gave the name of polarized light to light thus modified (by reflection in this particular case). Scientists admitted in those days, in the theory of emission, the existence of luminous molecules, and they imagined that these molecules "suffered the same effects simultaneously when they had been reflected on glass at a certain angle. . . . They were all turned in the same direction." Pouillet, speaking of this discovery of Malus in the class on physics that Pasteur attended, explained that the consequent persuasion was "that those molecules had rotatory axes and poles, around which their movements could be accomplished under certain influences."

Pasteur spoke feverishly of his regrets that Malus should have died at thirty-seven in the midst of his researches; of Biot, and of Arago, who became illustrious in the path opened by Malus. He explained to Chappuis that, by means of a polarizing apparatus, it could be seen that certain quartz crystals deflected to the right the plane of polarized light, whilst others caused it to turn to the left. Chappuis also learned that some natural organic material, such as solutions of sugar or of tartaric acid, when placed in such an apparatus, turned to the right the plane of polarization, whilst others, like essence of turpentine or quinine, deflected it to the left; whence the expression "rotatory polarization."

These would seem dry researches, belonging altogether to

the domain of science. And yet, thanks to the saccharimeter, which is a polarizing apparatus, a manufacturer can ascertain the quantity of pure sugar contained in the brown sugar of commerce, and a physiologist can follow the progress of diabetes.

Chappuis, who knew what powers of investigation his friend could bring to bear on the problem enunciated by Mitscherlich, thought with regret that the prospect of such examinations as that for the *licence* and for the *agrégation* did not allow Pasteur to concentrate all his forces on such a special scientific point. But Pasteur was resolved to come back definitely to this subject as soon as he should have become "*docteur ès sciences.*"

When writing to his father he did not dwell upon tartrate and paratartrate; but his ambition was palpable. He was ever eager to do double work, to go up for his examination at the very earliest. "Before being a captain," answered the old sergeant-major, "you must become a lieutenant."

These letters give one the impression of living amongst those lives, perpetually reacting upon each other. The thoughts of the whole family were centred upon the great School, where that son, that brother, was working, in whom the hopes of each were placed. If one of his bulky letters with the large post mark was too long in coming, his father wrote to reproach him gently: "Your sisters were counting the days. Eighteen days, they said! Louis has never kept us waiting so long! Can he be ill? It is a great joy to me," adds the father, "to note your attachment to each other. May it always remain so."

The mother had no time to write much; she was burdened with all the cares of the household and with keeping the books of the business. But she watched for the postman with a tender anxiety increased by her vivid imagination. Her thoughts were ever with the son whom she loved, not with a selfish love, but for himself, sharing his happiness in that he was working for a useful career.

So, between that corner in the Jura and the Ecole Normale, there was a continual exchange of thoughts; the smallest incidents of daily life were related. The father, knowing that he should inform the son of the fluctuations of the family budget, spoke of his more or less successful sales of leathers at the Besançon fair. The son was ever hunting in the progress of industry anything that could tend to lighten the father's heavy handicraft. But though the father declared himself ready to

examine Vauquelin's new tanning process, which obviated the necessity of keeping the skins so long in the pits, he asked himself with scrupulous anxiety whether leathers prepared in that way would last as long as the others. Could he safely guarantee them to the shoemakers, who were unanimous in praising the goods of the little tannery-yard, but alas equally unanimous in forgetting to reward the disinterested tanner by prompt payment? He supplied his family with the necessaries of life: what more did he want? When he had news of his *Normalien* he was thoroughly happy. He associated himself with his son's doings, sharing his enthusiasm over Dumas' lectures, and taking an interest in Pouillet's classes: Pouillet was a Franc-Comtois, and had been a student at the Ecole Normale; he was now Professor of Physics at the Sorbonne and a member of the *Institut*.[1] When Balard, a lecturer at the Ecole, was nominated to the Académie des Sciences, Louis told his father of it with the delight of an admiring pupil.

Like J. B. Dumas, Balard had been an apothecary's pupil. When he spoke of their humble beginnings, Dumas was wont to say rather pompously—"Balard and I were initiated into our scientific life under the same conditions." When, at the age of forty-two, he was made a member of the Institute, Balard could not contain his joy; he was quite a Southerner in his language and gestures, and the adjective *exubérant* might have been invented for him. But this same Southerner, ever on the move as he was, belonged to a special race: he always kept his word. "I was glad to note your pleasure at this nomination," wrote Joseph Pasteur to his son; "it proves

[1] *Institut de France.* Name given collectively to the five following societies—

1. *Académie Française*, founded by Richelieu in 1635 in order to polish and maintain the purity of the French language. It is composed of forty Life members, and publishes from time to time a dictionary which is looked upon as a standard test of correct French.

2. *Académie des Inscriptions et Belles Lettres*, founded by Colbert in 1663.

3. *Académie des Sciences*, also founded by Colbert in 1666. It has published most valuable reports ever since 1699.

4. *Académie des Beaux-Arts*, which includes the Academies of Painting, of Sculpture, of Music, and of Architecture.

5. *Académie des Sciences Morales et Politiques.*

It was in 1795 that these ancient academies, which had been suppressed two years before by the Revolution, were reorganized and combined together to form the *Institut de France.* [Trans.]

that you are grateful to your masters." About that same time the headmaster of Arbois College, M. Romanet, used to read out to the older boys the letters, always full of gratitude, which he received from Louis Pasteur. These letters reflected life in Paris, such as Pasteur understood it—a life of hard work and exalted ambition. M. Romanet, in one of his replies, asked him to become librarian *in partibus* for the college and to choose and procure books on science and literature. The headmaster also begged of the young man some lectures for the *rhétorique* class during the holidays. "It would seem to the boys like an echo of the Sorbonne lectures! And you would speak to us of our great scientific men," added M. Romanet, "amongst whom we shall one day number him who once was one of our best pupils and will ever remain one of our best friends."

A corresponding member of Arbois College, and retained as vacation lecturer, Pasteur now undertook a yet more special task. He had often heard his father deplore his own lack of instruction, and knew well the elder man's desire for knowledge. By a touching exchange of parts, the child to whom his father had taught his alphabet now became his father's teacher; but with what respect and what delicacy did this filial master express himself! "It is in order that you may be able to help Josephine that I am sending you this work to do." He took most seriously his task of tutor by correspondence; the papers he sent were not always easy. His father wrote (Jan. 2, 1845)—"I have spent two days over a problem which I afterwards found quite easy; it is no trifle to learn a thing and teach it directly afterwards." And a month later: "Josephine does not care to rack her brains, she says; however I promise you that you will be pleased with her progress by the next holidays."

The father would often sit up late at night over rules of grammar and mathematical problems, preparing answers to send to his boy in Paris.

Some Arboisians, quite forgotten now, imagined that they would add lustre to the local history. General Baron Delort, a peer of France,[1] aide de camp to Louis Philippe, Grand Cross

[1] *Peers of France.* A supreme Council formed originally of the First Vassals of the Crown; became in 1420 one of the Courts of Parliament. In 1789 the Peerage was suppressed, but reinstated in 1814 by the Restoration, when it again formed part of the Legislative Corps; there were then hereditary peers and life-peers. In 1831 the hereditary

of the Legion of Honour and the first personage in Arbois—where he beguiled his old age by translating Horace—used to go across the Cuisance bridge without so much as glancing at the tannery where the Pasteur family lived. Whilst the general in his thoughts bequeathed to the town of Arbois his books, his papers, his decorations, even his uniform, he was far from foreseeing that the little dwelling by the bridge would one day become the cynosure of all eyes.

Months went by and happy items of news succeeded one another. The *Normalien* was chiefly interested in the transformations of matter, and was practising in order to become capable of assisting in experiments; difficulties only stimulated him. At the chemistry class that he attended, the process of obtaining phosphorus was merely explained, on account of the length of time necessary to obtain this elementary substance; Pasteur, with his patience and desire for proven knowledge, was not satisfied. He therefore bought some bones, burnt them, reduced them to a very fine ash, treated this ash with sulphuric acid, and carefully brought the process to its close. What a triumph it seemed to him when he had in his possession sixty grammes of phosphorus, extracted from bones, which he could put into a phial labelled "phosphorus." This was his first scientific joy.

Whilst his comrades ironically (but with some discernment) called him a "laboratory pillar," some of them, more intent upon their examinations, were getting ahead of him.—M. Darboux, the present "doyen" of the Faculty[1] of Science, finds in the Sorbonne registers that Pasteur was placed 7th at the *licence* examination; two other students having obtained equal marks with him, the jury (Balard, Dumas and Delafosse), mentioned his name after theirs.

Those who care for archives would find in the *Journal Général de l'Instruction Publique* of September 17, 1846, a report of the *agrégation*[2] competition (physical science). Out

peerage was abolished and life-peers were nominated by the King under certain restrictions. This House of Peers was suppressed in 1848, and in 1852 the Senate was instituted in its stead. [Trans.]

[1] *Facultés*, Government establishments for superior studies; there are in France Faculties of Theology, of Law, of Medicine, of Sciences and of Letters, distributed among the larger provincial towns as well as in Paris. The administrator of a faculty is styled *doyen* (dean) and is chosen among the professors. [Trans.]

[2] *Agrégation*. An annual competition for recruiting professors for faculties and secondary schools or *lycées*. A candidate for the *lycées*

of fourteen candidates only four passed and Pasteur was the third. His lessons on physics and chemistry caused the jury to say, "He will make an excellent professor."

Many *Normaliens* of that time fancied themselves called to a destiny infinitely superior to his. Some of them, in later times, used to complacently allude to this momentary superiority when speaking to their pupils. Of all Pasteur's acquaintances Chappuis was the only one who divined the future. "You will see what Pasteur will be," he used to say, with an assurance generally attributed to friendly partiality. Chappuis—Pasteur's confidant—was well aware of his friend's powers of concentration.

Balard also realised this; he had the happy idea of taking the young *agrégé* into his laboratory, and intervened vehemently when the Minister of Public Instruction desired—a few months later—that Pasteur should teach physics in the Tournon Lycée. It would be rank folly, Balard declared, to send 500 kilometres away from Paris a youth who only asked for the modest title of curator, and had no ambition but to work from morning till night, preparing for his doctor's degree. There would be time to send him away later on. It was impossible to resist this torrent of words founded on solid sense. Balard prevailed.

Pasteur was profoundly grateful to him for preserving him from exile to the little town in Ardèche; and, as he added to his Franc-Comtois patience and reflective mind a childlike heart and deep enthusiasm, he was delighted to remain with a master like Balard, who had become celebrated, at the age of twenty-four, as the discoverer of bromin.

At the end of 1846, a newcomer entered Balard's laboratory, a strange delicate-looking man, whose ardent eyes were at the same time proud and yet anxious. This man, a scientist and a poet, was a professor of the Bordeaux Faculty, named Auguste Laurent. Perhaps he had had some friction with his Bordeaux chiefs, possibly he merely wished for a change; at all events, he now desired to live in Paris. Laurent was already known in the scientific world, and had recently been made a correspondent of the Académie des Sciences. He had foreseen and confirmed the theory of substitutions, formulated by Dumas as early as 1834 before the Académie. Dumas had

agrégation must have passed his *licence* examination, and a candidate for the superior *agrégation* must be in possession of his doctorate. [Trans.]

expressed himself thus: "Chlorine possesses the singular power of seizing upon the hydrogen in certain substances, and of taking its place atom by atom."

This theory of substitutions was—according to a simple and vivid comparison of Pasteur's—a way of looking upon chemical bodies as upon "molecular edifices, in which one element could be replaced by another without disturbing the structure of the edifice; as if one were to replace, one by one, every stone of a monument by a new stone." Original researches, new and bold ideas, appealed to Pasteur. But his cautious mind prevented his boldness from leading him into errors, surprises or hasty conclusions. "That is possible," he would say, "but we must look more deeply into the subject."

When asked by Laurent to assist him with some experiments upon certain theories, Pasteur was delighted at this suggested collaboration, and wrote to his friend Chappuis: "Even if the work should lead to no results worth publishing, it will be most useful to me to do practical work for several months with such an experienced chemist."

It was partly due to Laurent, that Pasteur entered more deeply into the train of thought which was to lead him to grapple with Mitscherlich's problem. "One day" (this is a manuscript note of Pasteur's) "one day it happened that M. Laurent—studying, if I mistake not, some tungstate of soda, perfectly crystallized and prepared from the directions of another chemist, whose results he was verifying—showed me through the microscope that this salt, apparently very pure, was evidently a mixture of three distinct kinds of crystals, easily recognizable with a little experience of crystalline forms. The lessons of our modest and excellent professor of mineralogy, M. Delafosse, had long since made me love crystallography; so, in order to acquire the habit of using the goniometer, I began to carefully study the formations of a very fine series of combinations, all very easily crystallized, tartaric acid and the tartrates." He appreciated any favourable influence on his work; we find in the same note: "Another motive urged me to prefer the study of those particular forms. M. de la Provostaye had just published an almost complete work concerning them; this allowed me to compare as I went along my own observations with those, always so precise, of that clever scientist."

Pasteur and Laurent's work in common was interrupted.

Laurent was appointed as Dumas' assistant at the Sorbonne. Pasteur did not dwell upon his own disappointment, but rejoiced to see honour bestowed upon a man whom he thought worthy of the first rank. Some judges have thought that Laurent, in his introductory lesson, was too eager to expound his own ideas; but is not every believer an apostle? When a mind is full of ideas, it naturally overflows. It is probable that Pasteur in Laurent's place would have kept his part as an assistant more in the background. He did not give vent to the slightest criticism, but wrote to Chappuis. "Laurent's lectures are as bold as his writings, and his lessons are making a great sensation amongst chemists." Whether one of criticism or of approbation, this sensation was a living element of success. In order to answer some insinuations concerning Laurent's ambition and constant thirst for change, Pasteur proclaimed in his thesis on chemistry how much he had been "enlightened by the kindly advice of a man so distinguished, both by his talent and by his character."

This essay was entitled "*Researches into the saturation capacity of arsenious acid. A study of the arsenites of potash, soda and ammonia.*" This, to Pasteur's mind, was but schoolboy work. He had not yet, he said, enough practice and experience in laboratory work. "In physics," he wrote to Chappuis, "I shall only present a programme of some researches that I mean to undertake next year, and that I merely indicate in my essay."

This essay on physics was a "*Study of phenomena relative to the rotatory polarization of liquids.*" In it he rendered full homage to Biot, pointing out the importance of a branch of science too much neglected by chemists; he added that it was most useful, in order to throw light upon certain difficult chemical problems, to obtain the assistance of crystallography and physics. "Such assistance is especially needed in the present state of science."

These two essays, dedicated to his father and mother, were read on August 23, 1847. He only obtained one white ball and two red ones for each. "We cannot judge of your essays," wrote his father, in the name of the whole family, "but our satisfaction is no less great. As to a doctor's degree, I was far from hoping as much; all *my* ambition was satisfied with the *agrégation.*" Such was not the case with his son.

"Onwards" was his motto, not from a desire for a diploma, but from an insatiable thirst for knowledge.

After spending a few days with his family and friends, he wanted to go to Germany with Chappuis to study German from morning till night. The prospect of such industrious holidays enchanted him. But he had forgotten a student's debt. "I cannot carry out my project," he sadly wrote, on September 3, 1847; "I am more than ruined by the cost of printing my thesis."

On his return to Paris he shut himself up in the laboratory. "I am extremely happy. I shall soon publish a paper on crystallography." His father writes (December 25, 1847): "We received your letter yesterday; it is absolutely satisfactory, but it could not be otherwise coming from you; you have long, indeed ever, been all satisfaction to me." And in response to his son's intentions of accomplishing various tasks, fully understanding that nothing will stop him: "You are doing right to make for your goal; it was only out of excessive affection that I have often written in another sense. I only feared that you might succumb to your work; so many noble youths have sacrificed their health to the love of science. Knowing you as I do, this was my only anxiety."

After being reproved for excessive work, Louis was reprimanded for too much affection (January 1, 1848). "The presents you sent have just arrived; I shall leave it to your sisters to write their thanks. For my part, I should prefer a thousand times that this money should still be in your purse, and thence to a good restaurant, spent in some good meals that you might have enjoyed with your friends. There are not many parents, my dearest boy, who have to write such things to their son; my satisfaction in you is indeed deeper than I can express." At the end of this same letter, the mother adds in her turn: "My darling boy, I wish you a happy new year. Take great care of your health. . . . Think what a worry it is to me that I cannot be with you to look after you. Sometimes I try to console myself for your absence by thinking how fortunate I am in having a child able to raise himself to such a position as yours is—such a happy position, as it seems to be from your last letter but one." And in a strange sentence, where it would seem that a presentiment of her approaching death made worldly things appear at their true value:

"Whatever happens to you, do not grieve; nothing in life is more than a chimera. Farewell, my son."

On March 20, 1848, Pasteur read to the Académie des Sciences a portion of his treatise on "*Researches on Dimorphism.*" There are some substances which crystallize in two different ways. Sulphur, for instance, gives quite dissimilar crystals according to whether it is melted in a crucible or dissolved in sulphide of carbon. Those substances are called dimorphous. Pasteur, kindly aided by the learned M. Delafosse (with his usual gratefulness he mentions this in the very first pages) had made out a list—as complete as possible—of all dimorphous substances. When M. Romanet, of Arbois College, received this paper he was quite overwhelmed. "It is much too stiff for you," he said with an infectious modesty to Vercel, Charrière, and Coulon, Pasteur's former comrades. Perhaps the head master desired to palliate his own incompetence in the eyes of coming generations, for on the title page of the copy of Pasteur's booklet still to be found in the Arbois library, he wrote this remark, which he signed with his initial R. :—"*Dimorphisme*; this word is not even to be found in the *Dictionnaire de l'Académie*"!! The approbation of several members of the Académie des Sciences compensated for the somewhat summary judgment of M. Romanet, whose good wishes continued to follow the rapid course of his old pupil.

After this very special study, dated at the beginning of 1848, one might imagine the graduate-curator closing his ears to all outside rumours and little concerned with political agitation, but that would be doing him an injustice. Those who witnessed the Revolution of 1848 remember how during the early days France was exalted with the purest patriotism. Pasteur had visions of a generous and fraternal Republic; the words *drapeau* and *patrie* moved him to the bottom of his soul. Lamartine[1] as a politician inspired him with an enthusiastic confidence; he delighted in the sight of a poet leader of men. Many others shared the same illusions. France, as Louis Veuillot has it, made the mistake of choosing her band-master

[1] This celebrated poet took a large share in the Revolution of 1848, when his popularity became enormous. His political talents, however, apart from his wonderful eloquence, were less than mediocre, and he retired into private life within three years.

His "Meditations," "Jocelyn," "Recueillements," etc., etc., are beautiful examples of lyrical poetry, and may be considered as forming part of the literature of the world. [Trans.]

as colonel of the regiment. Enrolled with his fellow students, Pasteur wrote thus to his parents: "I am writing from the Orleans Railway, where as a *garde national*[1] I am stationed. I am glad that I was in Paris during the February days[2] and that I am here still; I should be sorry to leave Paris just now. It is a great and a sublime doctrine which is now being unfolded before our eyes . . . and if it were necessary I should heartily fight for the holy cause of the Republic." "What a transformation of our whole being!" has written one who was then a candidate to the Ecole Normale, already noted by his masters for his good sense, Francisque Sarcey. "How those magical words of liberty and fraternity, this renewal of the Republic, born in the sunshine of our twentieth year, filled our hearts with unknown and absolutely delicious sensations! With what a gallant joy we embraced the sweet and superb image of a people of free men and brethren! The whole nation was moved as we were; like us, it had drunk of the intoxicating cup. The honey of eloquence flowed unceasingly from the lips of a great poet, and France believed, in childlike faith, that his word was efficacious to destroy abuses, cure evils and soothe sorrows."

One day when Pasteur was crossing the Place du Panthéon, he saw a gathering crowd around a wooden erection, decorated with the words: *Autel de la Patrie*. A neighbour told him that pecuniary offerings might be laid upon this altar. Pasteur goes back to the Ecole Normale, empties a drawer of all his savings, and returns to deposit it in thankful hands.

[1] Garde Nationale. A city militia, intended to preserve order and to maintain municipal liberties; it was improvised in 1789, and its first Colonel was General Lafayette, of American Independence fame. Its cockade united the King's white to the Paris colours, blue and red, and thus was inaugurated the celebrated Tricolour.

The National Guard was preserved by the Restoration, but Charles X disbanded it as being dangerously Liberal in its tendencies. It re-formed itself of its own accord in 1830, and helped to overthrow the elder branch of Bourbon. It proved a source of disorder in 1848 and was reorganized under the second Empire, but, having played an active and disastrous part in the Commune (1871), it was disarmed and finally suppressed. [Trans.]

[2] February days. The Republicans had organized a banquet in Paris for February 22, 1848. The Government prohibited it, with the result that an insurrection took place. Barricades were erected and some fighting ensued; on the 24th, the insurgents were masters of the situation. Louis Philippe abdicated (vainly) in favour of his grandson, the Comte de Paris, and fled to England. [Trans.]

"You say," wrote his father on April 28, 1848, "that you have offered to France all your savings, amounting to 150 francs. You have probably kept a receipt of the office where this payment was made, with mention of the date and place?" And considering that this action should be made known, he advises him to publish it in the journal *Le National* or *La Réforme* in the following terms, "Gift to the *Patrie*: 150 francs, by the son of an old soldier of the Empire, Louis Pasteur of the Ecole Normale." He wrote in the same letter, "You should raise a subscription in your school in favour of the poor Polish exiles who have done so much for us; it would be a good deed."

After those days of national exaltation, Pasteur returned to his crystals. He studied tartrates under the influence of certain ideas that he himself liked to expound. Objects considered merely from the point of view of form, may be divided into two great categories. First, those objects which, placed before a mirror, give an image which can be superposed to them: these have a symmetrical plan; secondly, those which have an image which cannot be superposed to them: they are dissymmetrical. A chair, for instance, is symmetrical, or a straight flight of steps. But a spiral staircase is not symmetrical, its own image cannot be laid over it. If it turns to the right, its image turns to the left. In the same way the right hand cannot be superposed to the left hand, a righthand glove does not fit a left hand, and a right hand seen in a mirror gives the image of a left hand.

Pasteur noticed that the crystals of tartaric acid and the tartrates had little faces, which had escaped even the profound observation of Mitscherlich and La Provostaye. These faces, which only existed on one half of the edges or similar angles, constituted what is called a hemihedral form. When the crystal was placed before a glass the image that appeared could not be superposed to the crystal; the comparison of the two hands was applicable to it. Pasteur thought that this aspect of the crystal might be an index of what existed within the molecules, dissymmetry of form corresponding with molecular dissymmetry. Mitscherlich had not perceived that his tartrate presented these little faces, this dissymmetry, whilst his paratartrate was without them, was in fact not hemihedral. Therefore, reasoned Pasteur, the deviation to the right of the plane of polarization produced by tartrate and the optical neutrality

of paratartrates would be explained by a structural law. The first part of these conclusions was confirmed; all the crystals of tartrate proved to be hemihedral. But when Pasteur came to examine the crystals of paratartrate, hoping to find none of them hemihedral, he experienced a keen disappointment. The paratartrate also was hemihedral, but the faces of some of the crystals were inclined to the right, and those of others to the left. It then occurred to Pasteur to take up these crystals one by one and sort them carefully, putting on one side those which turned to the left, and on the other those which turned to the right. He thought that by observing their respective solutions in the polarizing apparatus, the two contrary hemihedral forms would give two contrary deviations; and then, by mixing together an equal number of each kind, as no doubt Mitscherlich had done, the resulting solution would have no action upon light, the two equal and directly opposite deviations exactly neutralizing each other.

With anxious and beating heart he proceeded to this experiment with the polarizing apparatus and exclaimed, "I have it!" His excitement was such that he could not look at the apparatus again; he rushed out of the laboratory, not unlike Archimedes. He met a curator in the passage, embraced him as he would have embraced Chappuis, and dragged him out with him into the Luxembourg garden to explain his discovery. Many confidences have been whispered under the shade of the tall trees of those avenues, but never was there greater or more exuberant joy on a young man's lips. He foresaw all the consequences of his discovery. The hitherto incomprehensible constitution of paratartaric or racemic acid was explained; he differentiated it into righthand tartaric acid, similar in every way to the natural tartaric acid of grapes, and lefthand tartaric acid. These two distinct acids possess equal and opposite rotatory powers which neutralize each other when these two substances, reduced to an aqueous solution, combine spontaneously in equal quantities.

"How often," he wrote to Chappuis (May 5), whom he longed to have with him, "how often have I regretted that we did not both take up the same study, that of physical science. We who so often talked of the future, we did not understand. What splendid work we could have undertaken and would be undertaking now; and what could we not have done united by the same ideas, the same love of science, the same ambition!

I would we were twenty and with the three years of the Ecole before us!" Always fancying that he could have done more, he often had such retrospective regrets. He was impatient to begin new researches, when a sad blow fell upon him—his mother died almost suddenly of apoplexy. "She succumbed in a few hours," he wrote to Chappuis on May 28, "and when I reached home she had already left us. I have asked for a holiday." He could no longer work; he remained steeped in tears and buried in his sorrow. For weeks his intellectual life was suspended.

In Paris, in the scientific world perhaps even more than in any other, everything gets known, repeated, discussed. Pasteur's researches were becoming a subject of conversation. Balard, with his strident voice, spoke of them in the library at the Institute, which is a sort of drawing-room for talkative old Academicians. J. B. Dumas listened gravely; Biot, old Biot, then seventy-four years old, questioned the story with some scepticism. "Are you quite sure?" he would ask, his head a little on one side, his words slow and slightly ironical. He could hardly believe, on first hearing Balard, that a new doctor, fresh from the Ecole Normale, should have overcome a difficulty which had proved too much for Mitscherlich. He did not care for long conversations with Balard, and as the latter continued to extol Pasteur, Biot said, "I should like to investigate that young man's results."

Besides Pasteur's deference for all those whom he looked upon as his teachers, he also felt a sort of general gratitude for their services to Science. Partly from an infinite respect and partly from an ardent desire to convince the old scientist, he wrote on his return to Paris to Biot, whom he did not know personally, asking him for an interview. Biot answered: "I shall be pleased to verify your results if you will communicate them confidentially to me. Please believe in the feelings of interest inspired in me by all young men who work with accuracy and perseverance."

An appointment was made at the Collège de France,[1] where Biot lived. Every detail of that interview remained for ever

[1] Collège de France. An establishment of superior studies founded in Paris by Francis I in 1530, and where public lectures are given on languages, literature, history, mathematics, physical science, etc. It was formerly independent, but is now under the jurisdiction of the Ministry of Public Instruction. [Trans.]

fixed in Pasteur's memory. Biot began by fetching some paratartaric acid. "I have most carefully studied it," he said to Pasteur; "it is absolutely neutral in the presence of polarized light." Some distrust was visible in his gestures and audible in his voice. "I shall bring you everything that is necessary," continued the old man, fetching doses of soda and ammonia. He wanted the salt prepared before his eyes.

After pouring the liquid into a crystallizer, Biot took it into a corner of his room to be quite sure that no one would touch it. "I shall let you know when you are to come back," he said to Pasteur when taking leave of him. Forty-eight hours later some crystals, very small at first, began to form; when there was a sufficient number of them, Pasteur was recalled. Still in Biot's presence, Pasteur withdrew, one by one, the finest crystals and wiped off the mother-liquor adhering to them. He then pointed out to Biot the opposition of their hemihedral character, and divided them into two groups—left and right.

"So you affirm," said Biot, "that your righthand crystals will deviate to the right the plane of polarization, and your lefthand ones will deviate it to the left?"

"Yes," said Pasteur.

"Well, let me do the rest."

Biot himself prepared the solutions, and then sent again for Pasteur. Biot first placed in the apparatus the solution which should deviate to the left. Having satisfied himself that this deviation actually took place, he took Pasteur's arm and said to him these words, often deservedly quoted: "My dear boy, I have loved Science so much during my life, that this touches my very heart."

"It was indeed evident," said Pasteur himself in recalling this interview, "that the strongest light had then been thrown on the cause of the phenomenon of rotatory polarization and hemihedral crystals; a new class of isomeric substances was discovered; the unexpected and until then unexampled constitution of the racemic or paratartaric acid was revealed; in one word a great and unforeseen road was opened to science."

Biot now constituted himself the sponsor in scientific matters of his new young friend, and undertook to report upon Pasteur's paper entitled: "*Researches on the relations which may exist between crystalline form, chemical composition, and the direction of rotatory power*"—destined for the Académie des Sciences.

Biot did full justice to Pasteur; he even rendered him homage, and—not only in his own name but also in that of his three colleagues, Regnault, Balard, and Dumas—he suggested that the Académie should declare its highest approbation of Pasteur's treatise.

Pasteur did not conceive greater happiness than his laboratory life, and yet the laboratories of that time were very unlike what they are nowadays, as we should see if the laboratories of the Collège de France, of the Sorbonne, of the Ecole Normale had been preserved. They were all that Paris could offer Europe, and Europe certainly had no cause to covet them. Nowadays the most humble college, in the smallest provincial town, would not accept such dens as the State offered (when it offered them any) to the greatest French scientists. Claude Bernard, Magendie's curator, worked at the Collège de France in a regular cellar. Wurtz only had a lumber-room in the attics of the Dupuytren Museum. Henri Sainte Claire Deville, before he became head of the Besançon Faculty, had not even as much; he was relegated to one of the most miserable corners of the Rue Lafarge. J. B. Dumas did not care to occupy the unhealthy room reserved for him at the Sorbonne; his father-in-law, Alexandre Brongniart, having given him a small house in the Rue Cuvier, opposite the Jardin des Plantes, he had had it transformed into a laboratory and was keeping it up at his own expense. He was therefore comfortably situated, but he was exceptionally fortunate. Every scientist who had no private means to draw upon had to choose between the miserable cellars and equally miserable garrets which were all that the State could offer. And yet it was more tempting than a Professor's chair in a College or even in a Faculty, for there one could not give oneself up entirely to one's work.

Nothing would have seemed more natural than to leave Pasteur to his experiments. But his appointment to some definite post could no longer be deferred, in spite of Balard's tumultuous activity. The end of the summer vacation was near, there was a vacancy: Pasteur was made a Professsor of Physics at the Dijon Lycée. The Minister of Public Instruction consented to allow him to postpone his departure until the beginning of November, in order to let him finish some work begun under the eye of Biot, who thought and dreamt of nothing but these new investigations. During thirty years Biot had studied the phenomena of rotatory polarization. He

had called the attention of chemists to these phenomena, but his call had been unheeded. Continuing his solitary labour, he had—in experimenting on cases both simple and complex—studied this molecular rotatory power, without suspecting that this power bore a definite relation to the hemihedral form of some crystals. And now that the old man was a witness of a triumphant sequel to his own researches, now that he had the joy of seeing a young man with a thoughtful mind and an enthusiastic heart working with him, now that the hope of this daily collaboration shed a last ray on the close of his life, Pasteur's departure for Dijon came as a real blow. "If at least," he said, "they were sending you to a Faculty!" He turned his wrath on to the Government officials. "They don't seem to realize that such labours stand above everything else! If they only knew it, two or three such treatises might bring a man straight to the Institut!"

Nevertheless Pasteur had to go. M. Pouillet gave him a letter for a former Polytechnician,[1] now a civil engineer at Dijon, a M. Parandier, in which he wrote—

"M. Pasteur is a most distinguished young chemist. He has just completed some very remarkable work, and I hope it will not be long before he is sent to a first-class Faculty. I need add nothing else about him; I know no more honest, industrious, or capable young man. Help him as much as you can at Dijon; you will not regret it."

Those first weeks away from his masters and from his beloved pursuits seemed very hard to Pasteur. But he was anxious to prove himself a good teacher. This duty appeared to him to be a noble ideal, and to involve a wide responsibility. He felt none of the self satisfaction which is sometimes a source of strength to some minds conscious of their superiority to others. He did not even do himself the justice of feeling that he was

[1] Polytechnician. A student of the Ecole Polytechnique, a military and engineering school under the jurisdiction of the Minister of War, founded in 1794. Candidates for admission must be older than sixteen and younger than twenty, but the limit of age is raised to twenty-five in the case of private soldiers and non-commissioned officers. They must also have passed their *baccalauréat ès lettres* or *ès sciences*—preferably the latter. After two years' residence (compulsory) students pass a leaving examination, and are entered according to their list number as engineers of the Navy, Mines, or Civil Works, or as officers in the military Engineers or in the Artillery; the two last then have to go through one of the military training schools (Ecoles d'Application). [Trans.]

absolutely sure of his subject. He wrote to Chappuis (November 20, 1848): "I find that preparing my lessons takes up a great deal of time. It is only when I have prepared a lesson very carefully that I succeed in making it very clear and capable of compelling attention. If I neglect it at all I lecture badly and become unintelligible."

He had both first and second year pupils; these two classes took up all his time and all his strength. He liked the second class; it was not a very large one. "They all work," Pasteur wrote, "some very intelligently." As to the first year class, what could he do with eighty pupils? The good ones were kept back by the bad. "Don't you think," he wrote, "that it is a mistake not to limit classes to fifty boys at the most? It is with great difficulty that I can secure the attention of all towards the end of the lesson. I have only found one means, which is to multiply experiments at the last moment."

Whilst he was eagerly and conscientiously giving himself up to his new functions—not without some bitterness, for he really was entitled to an appointment in a Faculty, and he could not pursue his favourite studies—his masters were agitating on his behalf. Balard was clamouring to have him as an assistant at the Ecole Normale. Biot was appealing to Baron Thenard. This scientist was then Chairman of the Grand Council of the Université.[1] He had been a pupil of Vauquelin, a friend of Laplace, and a collaborator of Gay-Lussac; he had lectured during thirty years at the Sorbonne, at the Collège de France, and at the Ecole Polytechnique; he could truthfully boast that he had had 40,000 pupils. He was, like J. B. Dumas, a born professor. But, whilst Dumas was always self possessed and dignified in his demeanour, his very smile serious, Thenard, a native of Burgundy, threw his whole personality into his work, a broad smile on his beaming face.

He was now (1848) seventy years old, and the memory of his

[1] *Université.* The celebrated body known as Université de Paris, and instituted by Philippe Auguste in 1200, possessed great privileges from its earliest times. It had the monopoly of teaching and a jurisdiction of its own. It took a share in public affairs on several occasions, and had long struggles to maintain against several religious orders. The Université was suppressed by the Convention, but re-organized by Napoleon I in 1808. It is now subdivided into sixteen *Académies Universitaires*, each of which is administered by a Rector. The title of Grand Master of the Université always accompanies that of Minister of Public Instruction. [Trans.]

teaching, the services rendered to industry by his discoveries, the *éclat* of his name and titles contrasted with his humble origin, all combined to render him more than a Chancellor of the University; he was in fact a sort of Field Marshal of science, and all powerful. Three years previously he had much scandalized certain red-tape officials by choosing three very young men—Puiseux, Delesse, and H. Sainte Claire Deville—as professors for the new Faculty of Science at Besançon. He had accentuated this authoritative measure by making Sante Claire Deville Dean of the Faculty. In the unknown professor of twenty-six, he had divined the future celebrated scientist.

At the end of the year 1848 Pasteur solicited the place of assistant to M. Delesse, who was taking a long leave of absence. This would have brought him near Arbois, besides placing him in a Faculty. He asked for nothing more. Thenard, who had Biot's report in his hands, undertook to transmit to the Minister this modest and natural request. He was opposed by an unexpected argument—the presentation of assistantships belonged to each Faculty. This custom was unknown to Pasteur. Thenard was unable to overcome this routine formality. Pasteur thought that the unanimous opinion of Thenard, Biot, and Pouillet ought to have prevailed. "I can practically do nothing here," he wrote on the sixth of December, thinking of his interrupted studies. "If I cannot go to Besançon, I shall go back to Paris as a curator."

His father, to whom he paid a visit for the new year, persuaded him to look upon things more calmly, telling him that wisdom repudiated too much hurry. Louis deferred to his father's opinion to the extent of writing, on January 2, 1849, to the Minister of Public Instruction, begging him to overlook his request. However, the members of the Institute who had taken up his cause did not intend to be thwarted by minor difficulties. Pasteur's letter was hardly posted when he received an assistantship, not at the Besançon Faculty but at Strasburg, to take the place of M. Persoz, Professor of Chemistry, who was desirous of going to Paris.

Pasteur, on his arrival at Strasburg (January 15) was welcomed by the Professor of Physics, his old school friend, the Franc-Comtois Bertin. "First of all, you are coming to live with me," said Bertin gleefully. "You could not do better; it is a stone's throw from the Faculté." By living with Bertin, Pasteur acquired a companion endowed with a

rare combination of qualities—a quick wit and an affectionate heart. Bertin was too shrewd to be duped, and a malicious twinkle often lit up his kindly expression; with one apparently careless word, he would hit the weak point of the most self satisfied. He loved those who were simple and true, hence his affection for Pasteur. His smiling philosophy contrasted with Pasteur's robust faith and ardent impetuosity. Pasteur admired, but did not often imitate, the peaceful manner with which Bertin, affirming that a disappointment often proved to be a blessing in disguise, accepted things as they came. In order to prove that this was no paradox, Bertin used to tell what had happened to him in 1839, when he was mathematical preparation master at the College of Luxeuil. He was entitled to 200 francs a month, but payment was refused him. This injustice did not cause him to recriminate, but he quietly tendered his resignation. He went in for the Ecole Normale examination, entered the school at the head of the list, and subsequently became Professor of Physics at the Strasburg Faculty. "If it had not been for my former disappointment, I should still be at Luxeuil." He was now perfectly satisfied, thinking that nothing could be better than to be a Professor in a Faculty; but this absence of any sort of ambition did not prevent him from giving his teaching the most scrupulous attention. He prepared his lessons with extreme care, endeavouring to render them absolutely clear. He took great personal interest in his pupils, and often helped them with his advice in the interval between class hours. This excellent man's whole life was spent in working for others, and to be useful was ever to him the greatest satisfaction.

Perhaps Pasteur was stimulated by Bertin's example to give excessive importance to minor matters in his first lessons. He writes: "I gave too much thought to the style of my two first lectures, and they were anything but good; but I think the subsequent ones were more satisfactory, and I feel I am improving." His lectures were well attended, for the numerous industries of Alsace gave to chemistry quite a place by itself.

Everything pleased him in Strasburg save its distance from Arbois. He who could concentrate his thoughts for weeks, for months even, on one subject, who could become as it were a prisoner of his studies, had withal an imperious longing for family life. His rooms in Bertin's house suited him all the

better that they were large enough for him to entertain one of his relations. His father wrote in one of his letters: "You say that you will not marry for a long time, that you will ask one of your sisters to live with you. I could wish it for you and for them, for neither of them wishes for a greater happiness. Both desire nothing better than to look after your comfort; you are absolutely everything to them. One may meet with sisters as good as they are, but certainly with none better."

Louis Pasteur's circle of dear ones was presently enlarged by his intimacy with another family. The new Rector of the Academy of Strasburg, M. Laurent, had arrived in October. He was no relation to the chemist of the same name, and the place he was about to take in Pasteur's life was much greater than that held by Auguste Laurent at the time when they were working together in Balard's laboratory.

After having begun, in 1812, as preparation master in the then Imperial College of Louis le Grand, M. Laurent had become, in 1826, head master of the College of Riom. He found at Riom more tutors than pupils; there were only three boys in the school! Thanks to M. Laurent, those three soon became one hundred and thirty-four. From Riom he was sent to Guéret, then to Saintes, to save a college in imminent danger of disappearing; there were struggles between the former head master and the Mayor, the town refused the subsidies, all was confusion. Peace immediately followed his arrival. "Those who have known him," wrote M. Pierron in the *Revue de l'Instruction Publique*, "will not be surprised at such miracles coming from a man so intelligent and so active, so clever, amiable, and warm-hearted." Wherever he was afterwards sent, at Orleans, Angoulême, Douai, Toulouse, Cahors, he worked the same charm, born of kindness. At Strasburg, he had made of the Académie a home where all the Faculty found a simple and cordial welcome. Madame Laurent was a modest woman who tried to efface herself, but whose exquisite qualities of heart and mind could not remain hidden. The eldest of her daughters was married to M. Zevort, whose name became doubly dear to the Université. The two younger ones, brought up in habits of industry and unselfishness which seemed natural to them, brightened the home by their youthful gaiety.

When Pasteur on his arrival called on this family, he had the feeling that happiness lay there. He had seen at Arbois how, through the daily difficulties of manual labour, his parents looked at life from an exalted point of view, appreciating it from that standard of moral perfection which gives dignity and grandeur to the humblest existence. In this family—of a higher social position than his own—he again found the same high ideal, and, with great superiority of education, the same simple-mindedness. When Pasteur entered for the first time the Laurent family circle, he immediately felt the delightful impression of being in a thoroughly congenial atmosphere; a communion of thoughts and feelings seemed established after the first words, the first looks exchanged between him and his hosts.

In the evening, at the restaurant where most of the younger professors dined, he heard others speak of the kindliness and strict justice of the Rector; and everyone expressed respect for his wonderfully united family.

At one of M. Laurent's quiet evening "at homes," Bertin was saying of Pasteur, "You do not often meet with such a hard worker; no attraction ever can take him away from his work." The attraction now came, however, and it was such a powerful one that, on February 10, only a fortnight after his arrival, Pasteur addressed to M. Laurent the following official letter:—

"SIR,—

"An offer of the greatest importance to me and to your family is about to be made to you on my behalf; and I feel it my duty to put you in possession of the following facts, which may have some weight in determining your acceptance or refusal.

"My father is a tanner in the small town of Arbois in the Jura, my sisters keep house for him, and assist him with his books, taking the place of my mother whom we had the misfortune to lose in May last.

"My family is in easy circumstances, but with no fortune; I do not value what we possess at more than 50,000 francs, and, as for me, I have long ago decided to hand over to my sisters the whole of what should be my share. I have therefore absolutely no fortune. My only means

are good health, some courage, and my position in the Université.

"I left the Ecole Normale two years ago, an *agrégé* in physical science. I have held a Doctor's degree eighteen months, and I have presented to the Académie a few works which have been very well received, especially the last one, upon which a report was made which I now have the honour to enclose.

"This, Sir, is all my present position. As to the future, unless my tastes should completely change, I shall give myself up entirely to chemical research. I hope to return to Paris when I have acquired some reputation through my scientific labours. M. Biot has often told me to think seriously about the Institute; perhaps I may do so in ten or fifteen years' time, and after assiduous work; but this is but a dream, and not the motive which makes me love Science for Science's sake.

"My father will himself come to Strasburg to make this proposal of marriage.

"Accept, Sir, the assurance of my profound respect, etc.

"P.S.—I was twenty-six on December 27."

A definite answer was adjourned for a few weeks. Pasteur, in a letter to Madame Laurent, wrote, "I am afraid that Mlle. Marie may be influenced by early impressions, unfavourable to me. There is nothing in me to attract a young girl's fancy. But my recollections tell me that those who have known me very well have loved me very much."

Of these letters, religiously preserved, fragments like the following have also been obtained. "All that I beg of you, Mademoiselle (he had now been authorised to address himself directly to her) is that you will not judge me too hastily, and therefore misjudge me. Time will show you that below my cold, shy and unpleasing exterior, there is a heart full of affection for you!" In another letter, evidently remorseful at forsaking the laboratory, he says, "I, who did so love my crystals!"

He loved them still, as is proved by an answer from Biot to a proposal of Pasteur's. In order to spare the old man's failing sight, Pasteur had the ingenious idea of cutting out of pieces of cork, with exquisite skill, some models of crystalline types greatly enlarged. He had tinted the edges and faces,

and nothing was easier than to recognize their hemihedral character. "I accept with great pleasure," wrote Biot on April 7, "the offer you make me of sending me a small quantity of your two acids, with models of their crystalline types." He meant the righthand tartaric acid and the left-hand tartaric acid, which Pasteur—not to pronounce too hastily on their identity with ordinary tartaric acid—then called *dextroracemic* and *lævoracemic*.

Pasteur wished to go further; he was now beginning to study the crystallizations of formate of strontian. Comparing them with those of the paratartrates of soda and ammonia, surprised and uneasy at the differences he observed, he once exclaimed, "Ah! formate of strontian, if only I had got you!" to the immense amusement of Bertin, who long afterwards used to repeat this invocation with mock enthusiasm.

Pasteur was about to send these crystals to Biot, but the latter wrote, "Keep them until you have thoroughly investigated them. . . . You can depend on my wish to serve you in every circumstance when my assistance can be of any use to you, and also on the great interest with which you have inspired me."

Regnault and Senarmont had been invited by Biot to examine the valuable samples received from Strasburg, the dextroracemic and lævoracemic acids. Biot wrote to Pasteur, "We might make up our minds to sacrifice a small portion of the two acids in order to reconstitute the racemic, but we doubt whether we should be capable of discerning it with certainty by those crystals when they are formed. You must show it us yourself, when you come to Paris for the holidays. Whilst arranging my chemical treasures, I came upon a small quantity of racemic acid which I thought I had lost. It would be sufficient for the microscopical experiments that I might eventually have to make. So if the small phial of it that you saw here would be useful to you, let me know, and I will willingly send it. In this, as in everything else, you will always find me most anxious to second you in your labours."

This period was all happiness. Pasteur's father and his sister Josephine came to Strasburg. The proposal of marriage was accepted, the father returned to Arbois, Josephine staying behind. She remained to keep house and to share the everyday life of her brother, whom she loved with a mixture of

pride, tenderness and solicitude. In her devoted sisterly generosity, she resigned herself to the thought that her happy dream must be of short duration. The wedding was fixed for May 29.

"I believe," wrote Pasteur to Chappuis, "that I shall be very happy. Every quality I could wish for in a wife I find in her. You will say, 'He is in love!' Yes, but I do not think I exaggerate at all, and my sister Josephine quite agrees with me."

CHAPTER III

1850—1854

From the very beginning Mme. Pasteur not only admitted, but approved, that the laboratory should come before everything else. She would willingly have adopted the typographic custom of the Académie des Sciences Reports, where the word Science is always spelt with a capital S. It was indeed impossible to live with her husband without sharing his joys, anxieties and renewed hopes, as they appeared day by day reflected in his admirable eyes—eyes of a rare grey-green colour like the sparkle of a Ceylon gem. Before certain scientific possibilities, the flame of enthusiasm shone in those deep eyes, and the whole stern face was illumined. Between domestic happiness and prospective researches, Pasteur's life was complete. But this couple, who had now shared everything for more than a year, was to suffer indirectly through the new law on the liberty of teaching.

Devised by some as an effort at compromise between the Church and the University, considered by others as a scope for competition against State education, the law of 1850 brought into the Superior Council of Public Instruction four archbishops or bishops, elected by their colleagues. In each Department[1] an Academy Council was instituted, and, in this parcelling out of University jurisdiction, the right of presence was recognized as belonging to the bishop or his delegate. But all these advantages did not satisfy those who called themselves Catholics before everything else. The rupture between Louis Veuillot on one side and, on the other, Falloux and Montalembert, the principal authors of this law, dates from that time.

[1] *Départements.* The present divisions of French territory, numbering eighty-seven in all. Each department is administered by a *préfet*, and subdivided into *arrondissements*, each of which has a *sous-préfet*. [Trans.]

"What we understood by the liberty of teaching," wrote Louis Veuillot, "was not a share given to the Church, but the destruction of monopoly. . . . No alliance with the University! Away with its books, inspectors, examinations, certificates, diplomas! All that means the hand of the State laid on the liberty of the citizen; it is the breath of incredulity on the younger generation." Confronted by the violent rejection of any attempt at reconciliation and threatened interference with the University on the part of the Church, the Government was trying to secure to itself the whole teaching fraternity.

The primary schoolmasters groaned under the heavy yoke of the prefects. "These deep politicians only know how to dismiss. . . . The rectors will become the valets of the prefects . . ." wrote Pasteur with anger and distress in a letter dated July, 1850. After the primary schools, the attacks now reached the colleges. The University was accused of attending exclusively to Latin verse and Greek translations, and of neglecting the souls of the students. Romieu, who ironically dubbed the University "Alma Parens," and attacked it most bitterly, seemed hardly fitted for the part of justiciary. He was a former pupil of the Ecole Polytechnique, who wrote vaudevilles until he was made a prefect by Louis Philippe. He was celebrated for various tricks which amused Paris and disconcerted the Government, much to the joy of the Prince de Joinville,[1] who loved such mystifications. After the fall of Louis Philippe, Romieu became a totally different personality. He had been supposed to take nothing seriously; he now put a tragic construction on everything. He became a prophet of woe, declaring that "gangrene was devouring the souls of eight year old children." According to him, faith, respect, all was being destroyed; he anathematized Instruction without Education, and stigmatized village schoolmasters as "obscure apostles" charged with "preaching the doctrines of revolt." This violence was partly oratory, but oratory does not minimize violence, it excites it. Every pamphleteer ends by being a bond-slave to his own phraseology.

When Romieu appeared in Strasburg as an Envoy Extraordinary entrusted by the Government with a general inquiry, he found that M. Laurent did not answer to that ideal of a

[1] *Prince de Joinville.* Third son of Louis Philippe, and an Admiral in the French navy. It was he who was sent to fetch Napoleon's remains from St. Helena. [Trans.]

functionary which was entertained by a certain party. M. Laurent had the very highest respect for justice; he distrusted the upstarts whose virtues were very much on the surface; he never decided on the fate of an inferior without the most painstaking inquiry; he did not look on an accidental mistake as an unpardonable fault; he refused to take any immediate and violent measures: all this caused him to be looked upon with suspicion. "The influence of the Rector" (thus ran Romieu's official report) "is hardly, if at all, noticeable. He should be replaced by a safe man."

The Minister of Public Instruction, M. de Parieu, had to bow before the formal wish of the Minister of the Interior, founded upon peremptory arguments of this kind. M. Laurent was offered the post of Rector at Châteauroux, a decided step downward. He refused, left Strasburg, and, with no complaint or recriminations, retired into private life at the age of fifty-five.

It was when this happy family circle was just about to be enlarged that its quiet was thus broken into by this untoward result of political agitation. M. Laurent's youngest daughter soon after became engaged to M. Loir, a professor at the Strasburg Pharmaceutical School, who had been a student at the Ecole Normale, and who ultimately became Dean of the Faculty of Sciences at Lyons. He was then preparing, assisted by Pasteur, his "thesis" for the degree of Doctor of Science In this he announced some new results based on the simultaneous existence of hemihedral crystalline forms and the rotatory power. He wrote, "I am happy to have brought new facts to bear upon the law that M. Pasteur has enunciated."

"Why are you not a professor of physics or chemistry!" wrote Pasteur to Chappuis; "we should work together, and in ten years' time we would revolutionize chemistry. There are wonders hidden in crystallization, and, through it, the inmost construction of substances will one day be revealed. If you come to Strasburg, you *shall* become a chemist; I shall talk to you of nothing but crystals."

The vacation was always impatiently awaited by Pasteur. He was able to work more, and to edit the result of his researches in an extract for the Académie des Sciences. On October 2 his friend received the following letter: "On Monday I presented this year's work to the 'Institut.' I

read a long extract from it, and then gave a vivâ voce demonstration relative to some crystallographic details. This demonstration, which I had been specially desired to give, was quite against the prevailing customs of the Académie. I gave it with my usual delight in that sort of thing, and it was followed with great attention. Fortunately for me, the most influential members of the Académie were present. M. Dumas sat almost facing me. I looked at him several times, and he expressed by an approving nod of his head that he understood and was much interested. He asked me to his house the next day, and congratulated me. He said, amongst other things, that I was a proof that when a Frenchman took up crystallography he knew what he was about, and also that if I persevered, as he felt sure I should, I should become the founder of a school.

"M. Biot, whose kindness to me is beyond all expression, came to me after my lecture and said, 'It is as good as it can possibly be.' On October 14 he will give his report on my work; he declares I have discovered a very California. Do not suppose I have done anything wonderful this year. This is but a satisfactory consequence of preceding work."

In his report (postponed until October 28) Biot was more enthusiastic. He praised the numerous and unforeseen results brought out by Pasteur within the last two years. "He throws light upon everything he touches," he said.

To be praised by Biot was a rare favour; his diatribes were better known. In a secret committee of the Académie des Sciences (January, 1851) the Académie had to pronounce on the merits of two candidates for a professorship at the Collège de France: Balard, a professor of the Faculty of Science, chief lecturer of the Ecole Normale, and Laurent the chemist, who in order to live had been compelled to accept a situation as assayer at the Mint. Biot, with his halting step, arrived at the Committee room and spoke thus: "The title of Member of the Institute is the highest reward and the greatest honour that a French scientist can receive, but it does not constitute a privilege of inactivity that need only be claimed in order to obtain everything. . . . For several years, M. Balard has been in possession of two large laboratories where he might have executed any work dictated to him by his zeal, whilst nearly all M. Laurent's results have been effected by his unaided personal efforts at the cost of heavy sacrifices. If you give the college

vacancy to M. Balard, you will add nothing to the opportunities for study which he already has; but it will take away from M. Laurent the means of work that he lacks and that we have now the opportunity of providing for him. The chemical section, and indeed the whole Academy will easily judge on which side are scientific justice and the interests of future progress."

Biot had this little speech printed and sent a copy of it to Pasteur. The incident led to a warm dispute, and Biot lost his cause. Pasteur wrote to Chappuis, "M. Biot has done everything that was possible to do in order that M. Laurent should win, and the final result is a great grief to him. But really," the younger man added, more indulgent than the old man, and divided between his wishes for Laurent and the fear of the sorrow Balard would have felt, "M. Balard would not have deserved so much misfortune. Think of the disgrace it would have been to him if there had been a second vote favourable to Laurent, especially coming from the Institute of which he is a member." At the end of that campaign, Biot in a fit of misanthropy which excepted Pasteur alone, and knowing that Pasteur had spoken with effusion of their mutual feelings, wrote to him as follows: "I am touched by your acknowledgment of my deep and sincere affection for you, and I thank you for it. But whilst keeping your attachment for me as I preserve mine for you, let me for the future rejoice in it in the secret recesses of my heart and of yours. The world is jealous of friendships however disinterested, and my affection for you is such that I wish people to feel that they honour themselves by appreciating you, rather than that they should know that you love me and that I love you. Farewell. Persevere in your good feelings as in your splendid career, and be happy. Your friend."

The character of Biot, a puzzle to Sainte Beuve, seems easier to understand after reading those letters, written in a small conscientious hand. The great critic wrote: "Who will give us the secret key to Biot's complex nature, to the curiosities, aptitudes, envies, prejudices, sympathies, antipathies, folds and creases of every kind in his character?" Even with no other documents, the history of his relations with Pasteur would throw light upon this nature, not so "complex" after all. From the day when Pasteur worked out his first experiment before Biot, at first suspicious, then astonished and

finally touched to the heart, until the period of absolute mutual confidence and friendship, we see rising before us the image of this true scientist, with his rare independence, his good-will towards laborious men and his mercilessness to every man who, loving not Science for its own sake, looked upon a discovery as a road to fortune, pecuniary or political.

He loved both science and letters, and, now that age had bent his tall form, instead of becoming absorbed in his own recollections and the contemplation of his own labours, he kept his mind open, happy to learn more every day and to anticipate the future of Pasteur.

During the vacation of 1851 Pasteur came to Paris to bring Biot the results of new researches on aspartic and malic acids, and he desired his father to join him in order to efface the sad impression left by his former journey in 1838. Biot and his wife welcomed the father and son as they would have welcomed very few friends. Touched by so much kindness, Joseph Pasteur on his return in June wrote Biot a letter full of gratitude, venturing at the same time to send the only thing it was in his power to offer, a basket of fruit from his garden. Biot answered as follows: "Sir, my wife and I very much appreciate the kind expressions in the letter you have done me the honour of writing me. Our welcome to you was indeed as hearty as it was sincere, for I assure you that we could not see without the deepest interest such a good and honourable father sitting at our modest table with so good and distinguished a son. I have never had occasion to show that excellent young man any feelings but those of esteem founded on his merit, and an affection inspired by his personality. It is the greatest pleasure that I can experience in my old age, to see young men of talent working industriously and trying to progress in a scientific career by means of steady and persevering labour, and not by wretched intriguing. That is what has made your son dear to me, and his affection for me adds yet to his other claims and increases that which I feel for him. We are therefore even with one another. As to your kindness in wishing that I should taste fruit from your garden, I am very grateful for it, and I accept it as cordially as you send it."

Pasteur had also brought Biot some other products—a case full of new crystals. Starting from the external configuration of crystals, he penetrated the individual constitution of their molecular groups, and from this point of departure, he then

had recourse to the resources of chemistry and optics. Biot never ceased to admire the sagacity of the young experimentalist who had turned what had until then been a mere crystallographic character into an element of chemical research.

Equally interested by the general consequences of these studies, so delicate and so precise, M. de Senarmont wished in his turn to examine the crystals. No one approved more fully than he the expressions of the old scientist, who ended in this way his 1851 report: "If M. Pasteur persists in the road he has opened, it may be predicted of him that what he has found is nothing to what he will find." And, delighted to see the important position that Pasteur was taking at Strasburg and the unexpected extension of crystallography, Biot wrote to him: "I have read with much interest the thesis of your brother-in-law, M. Loir. It is well conceived and well written, and he establishes with clearness many very curious facts. M. de Senarmont has also read it with very great pleasure, and I beg you will transmit our united congratulations to your brother-in-law." Biot added, mixing as he was wont family details with scientific ideas: "We highly appreciated your father, the rectitude of his judgment, his firm, calm, simple reason and the enlightened love he bears you."

"My plan of study is traced for this coming year," wrote Pasteur to Chappuis at the end of December. "I am hoping to develop it shortly in the most successful manner. . . . I think I have already told you that I am on the verge of mysteries, and that the veil which covers them is getting thinner and thinner. The nights seem to me too long, yet I do not complain, for I prepare my lectures easily, and often have five whole days a week that I can give up to the laboratory. I am often scolded by Mme. Pasteur, but I console her by telling her that I shall lead her to fame."

He already foresaw the greatness of his work. However he dare not speak of it, and kept his secret, save with the confidante who was now a collaborator, ever ready to act as secretary, watching over the precious health of which he himself took no account, an admirable helpmeet, to whom might be applied the Roman definition, *socia rei humanæ atque divinæ*. Never did life shower more affection upon a man. Everything at that time smiled upon him. Two fair children in the home, great security in his work, no enemies, and the comfort of

receiving the approval and counsel of masters who inspired him with a feeling of veneration.

"At my age," wrote Biot to Pasteur, "one lives only in the interest one takes in those one loves. You are one of the small number who can provide such food for my mind." And alluding in that same letter (December 22, 1851) to four reports successively approved of by Balard, Dumas, Regnault, Chevreul, Senarmont and Thenard : "I was very happy to see, in those successive announcements of ideas of so new and so far-reaching a nature, that you have said—and that we have made you say—nothing that should now be contradicted or objected to in one single point. I still have in my hands the pages of your last paper concerning the optical study of malic acid. I have not yet returned them to you, as I wish to extract from them some results that I shall place to your credit in a paper I am now writing."

It was no longer Biot and Senarmont only who were watching the growing importance of Pasteur's work. At the beginning of the year 1852 the physicist Regnault thought of making Pasteur a corresponding member of the Institute. Pasteur was still under thirty. There was a vacancy in the General Physics section, why not offer it to him? said Regnault, with his usual kindliness. Biot shook his head : "It is to the Chemistry section that he ought to belong." And, with the courage of sincere affection, he wrote to Pasteur, "Your work marks your place in chemistry rather than physics, for in chemistry you are in the front rank of inventors, whilst in physics you have applied processes already known rather than invented new ones. Do not listen to people, who, without knowing the ground, would cause you to desire, and even to hastily obtain, a distinction which would be above your real and recognized claims. . . . Besides, you can see for yourself how much your work of the last four years has raised you in every one's estimation. And that place, which you have made for yourself in the general esteem, has the advantage of not being subject to the fluctuations of the ballot. Farewell, dear friend, write to me when you have time, and be assured that my interest in hard workers is about the only thing which yet makes me wish to live. Your friend."

Pasteur gratefully accepted these wise counsels. In an excess of modesty, he wrote to Dumas that he should not apply

as candidate even if a place for a correspondent were vacant in the Chemistry section. "Do you then believe," answered Dumas with a vivacity very unlike his usual solemn calmness, "do you believe that we are insensible to the glory which your work reflects on French chemistry, and on the Ecole from whence you come? The very day I entered the Ministry, I asked for the Cross[1] for you. I should have had in giving it to you myself a satisfaction which you cannot conceive. I don't know whence the delay and difficulty arise. But what I do know is that you make my blood boil when you speak in your letter of the necessity of leaving a free place in chemistry to the men you mention, one or two excepted. . . . What opinion have you then of our judgment? When there *is* a vacant place, you shall be presented, supported and elected. It is a question of justice and of the great interests of science: we shall make them prevail. . . . When the day comes, there will be means found to do what is required for the interests of science, of which you are one of the firmest pillars, and one of the most glorious hopes. Heartily yours."

"My dear father," wrote Pasteur, sending his father a copy of this letter, "I hope you will be proud of M. Dumas' letter. It surprised me very much. I did not believe that my work deserved such a splendid testimony, though I recognize its great importance."

Thus were associated in Pasteur the full consciousness of his great mental power with an extreme ingenuousness. Instead of the pride and egotism provoked, almost excusably, in so many superior men by excessive strength, his character presented the noblest delicacy.

Another arrangement occurred to Regnault: that he himself should accept the direction of the Sèvres Manufactory, and give up to Pasteur his professorship at the Ecole Polytechnique. Others suggested that Pasteur should become chief lecturer at the Ecole Normale. Rumours of these possibilities reached Strasburg, but Pasteur's thoughts were otherwise absorbed. He was concerned with the manner in which he could modify the crystalline forms of certain substances which, though optically active, did not at the first view present the hemihedral character, and with the possibility of provoking the significant faces by varying the nature of the dissolving agents. Biot was

[1] Of the Legion of Honour.

anxious that he should not be disturbed in these ingenious researches, and advised him to remain at Strasburg in terms as vigorous as any of his previous advice. "As to the accidents which come from or depend on men's caprice, be strong-minded enough to disdain them yet awhile. Do not trouble about anything, but pursue indefatigably your great career. You will be rewarded in the end, the more certainly and unquestionably that you will have deserved it more fully. The time is not far when those who can serve you efficiently will feel as much pride in doing so as shame and embarrassment in not having done so already."

When Pasteur came to Paris in August, for what he might have called his annual pilgrimage, Biot had reserved for him a most agreeable surprise. Mitscherlich was in Paris, where he had come, accompanied by another German crystallographer, G. Rose, to thank the Académie for appointing him a foreign Associate. They both expressed a desire to see Pasteur, who was staying in a hotel in the Rue de Tournon. Biot, starting for his daily walk round the Luxembourg Garden, left this note: "Please come to my house to-morrow at 8 a.m., if possible with your products. M. Mitscherlich and M. Rose are coming at 9 to see them." The interview was lengthy and cordial. In a letter to his father—who now knew a great deal about crystals and their forms, thanks to Pasteur's lucid explanations—we find these words. "I spent two and a half hours with them on Sunday at the Collège de France, showing them my crystals. They were much pleased, and highly praised my work. I dined with them on Tuesday at M. Thenard's; you will like to see the names of the guests: Messrs. Mitscherlich, Rose, Dumas, Chevreul, Regnault, Pelouze, Péligot, C. Prévost, and Bussy. You see I was the only outsider, they are all members of the Académie. . . . But the chief advantage of my meeting these gentlemen is that I have heard from them the important fact that there is a manufacturer in Germany who again produces some racemic acid. I intend to go and see him and his products, so as to study thoroughly that singular substance."

At the time when scientific novels were in fashion, a whole chapter might have been written on Pasteur in search of that acid. In order to understand in a measure his emotion on learning that a manufacturer in Saxony possessed this mysterious acid, we must remember that the racemic acid—

produced for the first time by Kestner at Thann in 1820, through a mere accident in the manufacture of tartaric acid—had suddenly ceased to appear, in spite of all efforts to obtain it again. What then was the origin of it?

Mitscherlich believed that the tartars employed by this Saxony manufacturer came from Trieste. "I shall go to Trieste," said Pasteur; "I shall go to the end of the world. I *must* discover the source of racemic acid, I must follow up the tartars to their origin." Was the acid existent in crude tartars, such as Kestner received in 1820 from Naples, Sicily, or Oporto? This was all the more probable from the fact that from the day when Kestner began to use semi-refined tartars he had no longer found any racemic acid. Should one conclude that it remained stored up in the mother-liquor?

With a feverish impetuosity that nothing could soothe, Pasteur begged Biot and Dumas to obtain for him a mission from the Ministry or the Académie. Exasperated by red tape delays, he was on the point of writing directly to the President of the Republic. "It is a question," he said, "that France should make it a point of honour to solve through one of her children." Biot endeavoured to moderate this excessive impatience. "It is not necessary to set the Government in motion for this," he said, a little quizzically. "The Academy, when informed of your motives might very well contribute a few thousand francs towards researches on the racemic acid." But when Mitscherlich gave Pasteur a letter of recommendation to the Saxony manufacturer, whose name was Fikentscher and who lived near Leipzig, Pasteur could contain himself no longer, and went off, waiting for nothing and listening to no one. His travelling impressions were of a peculiar nature. We will extract passages from a sort of diary addressed to Madame Pasteur so that she might share the emotions of this pursuit. He starts his campaign on the 12th September. "I do not stop at Leipzig, but go on to Zwischau, and then to M. Fikentscher. I leave him at nightfall and go back to him the next morning very early. I have spent all to-day, Sunday, with him. M. Fikentscher is a very clever man, and he has shown me his whole manufactory in every detail, keeping no secrets from me. . . . His factory is most prosperous. It comprises a group of houses which, from a distance. and situated on a height as they are, look almost like a little village.

It is surrounded by 20 hectares[1] of well cultivated ground. All this is the result of a few years' work. As to *the* question, here is a little information that you will keep strictly to yourself for the present. M. Fikentscher obtained racemic acid for the first time about twenty-two years ago. He prepared at that time rather a large quantity. Since then only a very small amount has been formed in the process of manufacture and he has not troubled to preserve it. When he used to obtain most, his tartars came from Trieste. This confirms, though not in every point, what I heard from M. Mitscherlich. Anyhow, here is my plan : Having no laboratory at Zwischau, I have just returned to Leipzig with two kinds of tartars that M. Fikentscher now uses, some of which come from Austria, and some from Italy. M. Fikentscher has assured me that I should be very well received here by divers professors, who know my name very well, he says. To-morrow Monday morning, I will go to the Université and set up in some laboratory or other. I think that in five or six days I shall have finished my examination of these tartars. Then I shall start for Vienna, where I shall stay two or three days and rapidly study Hungarian tartars. . . . Finally I shall go to Trieste, where I shall find tartars of divers countries, notably those of the Levant, and those of the neighbourhood of Trieste itself. On arriving here at M. Fikentscher's I have unfortunately discovered a very regrettable circumstance. It is that the tartars he uses have already been through one process in the country from which they are exported, and this process is such that it evidently eliminates and loses the greater part of the racemic acid. At least I think so. I must therefore go to the place itself. If I had enough money I should go on to Italy; but that is impossible, it will be for next year. I shall give ten years to it if necessary; but it will not be, and I am sure that in my very next letter I shall be able to tell you that I have some good results. For instance, I am almost sure to find a prompt means of testing tartars from the point of view of racemic acid. That is a point of primary importance for my work. I want to go quickly through examining all these different tartars; that will be my first study. . . . M. Fikentscher will take nothing for his products. It is true that I have given him hints and some of my own enthusiasm. He

[1] **Hectare**: French measure of surface, about 2½ acres. [Trans.]

wants to prepare for commercial purposes some *left* tartaric acid, and I have given him all the necessary crystallographic indications. I have no doubt he will succeed."

Leipzig, Wednesday, September 15, 1852. "My dear Marie, I do not want to wait until I have the results of my researches before writing to you again. And yet I have nothing to tell you, for I have not left the laboratory for three days, and I know nothing of Leipzig but the street which goes from the Hôtel de Bavière to the Université. I come home at dusk, dine, and go to bed. I have only received, in M. Erdmann's study, the visit of Professor Hankel, professor of physics of the Leipzig Université, who has translated all my treatises in a German paper edited by M. Erdmann. He has also studied hemihedral crystals, and I enjoyed talking with him. I shall also soon meet the professor of mineralogy, M. Naumann.

"To-morrow only shall I have a first result concerning racemic acid. I shall stay about ten days longer in Leipzig. It is more than I told you, and the reason lies in rather a happy circumstance. M. Fikentscher has kindly written to me and to a firm in Leipzig, and I heard yesterday from the head of that firm that, very likely, they can get me to-morrow some tartars absolutely crude and of the same origin as M. Fikentscher's. The same gentleman has given me some information about a factory at Venice, and will give me a letter of recommendation to a firm in that city, also for Trieste. In this way the journey I proposed to make in that town will not simply be a pleasure trip. . . . I shall write to M. Biot as soon as I have important results. To-day has been a good day, and in about three or four more you will no doubt receive a satisfactory letter."

Leipzig, September 18, 1852. "My dear Marie, the very question which has brought me here is surrounded with very great difficulties. . . . I have only studied one tartar thoroughly since I have been here; it comes from Naples and has been refined once. It contains racemic acid, but in such infinitesimal proportions that it can only be detected by the most delicate process. It is only by manufacture on a very large scale that a certain quantity could be prepared. But I must tell you that the first operation undergone by this tartar must have deprived it almost entirely of racemic acid. Fortunately M. Fikentscher is a most enlightened man, he perfectly understands the importance of this acid and he is

prepared to follow most minutely the indications that I shall give him in order to obtain this singular substance in quantities such that it can again be easily turned into commercial use. I can already conceive the history of this product. M. Kestner must have had at his disposal in 1820 some Neapolitan tartars, as indeed he said he had, and he must have operated on crude tartar. That is the whole secret. . . . But is it certain that almost the whole of the acid is lost in the first manufacture undergone by tartar? I believe it is. But it must be proved. There are at Trieste and at Venice two tartar refineries of which I have the addresses. I also have letters of introduction. I shall examine there (if I find a laboratory) the residual products, and I shall make minute inquiries respecting the places the tartars used in those two cities come from. Finally, I shall procure a few kilogrammes, which I shall carefully study when I get back to France. . . ."

Freiberg, September 23, 1852. "I arrived on the evening of the 21st at Dresden, and I had to wait until eleven the next morning to have my passport *visé*, so I could not start for Freiberg before seven p.m. I took advantage of that day to visit the capital of Saxony, and I can assure you that I saw some admirable things. There is a most beautiful museum containing pictures by the first masters of every school. I spent over four hours in the galleries, noting on my catalogue the pictures I most enjoyed. Those I liked I marked with a cross; but I soon put two, three crosses, according to the degree of my enthusiasm. I even went as far as four.

"I also visited what they call the green vault room, an absolutely unique collection of works of art, gems, jewels . . . then some churches, avenues, admirable bridges across the Elbe. . . .

"I then started for Freiberg at 7. . . . My love of crystals took me first to the learned Professor of mineralogy, Breithaupt, who received me as one would not be received in France. After a short colloquy, he passed into the next room, came back in a black tail-coat with three little decorations in his button hole, and told me he would first present me to the Baron von Beust, Superintendent of Factories, so as to obtain a permit to visit the latter. . . . Then he took me for a walk, talking crystals the whole time. . . ."

P.S.—"Mind you tell M. Biot how I was received; it will please him."

Vienna, September 27, 1852. "Yesterday, Monday morning, I set out to call upon several people. Unfortunately, I hear that Professor Schrotten is at Wiesbaden, at a scientific congress, as well as M. Seybel, a manufacturer of tartaric acid. M. Miller, a merchant for whom I had a letter of recommendation, was kind enough to ask M. Seybel's business manager for permission for me to visit the factory in his absence. He refused, saying he was not authorized. But I did not give in; I asked for the addresses of Viennese professors, and I fortunately came upon that of a very well known scientific man, M. Redtenbacher, who has been kind to me beyond all description. At 6 a.m. he came to my hotel, and we took the train at 7 for the Seybel manufactory, which is at a little distance from Vienna. We were received by the chemist of the factory, who made not the slightest difficulty in introducing us into the sanctuary, and after many questions we ended by being convinced that the famous racemic acid was seen there last winter. . . . I reserve for later many details of great interest, for here they have operated for years on crude tartar. I came away very happy.

"There is another factory of tartaric acid in Vienna. We go there; I repeat through M. Redtenbacher my string of questions. They have seen nothing. I ask to see their products, and I come upon a barrel full of tartaric acid crystals, on the surface of which I think I perceive *the* substance. A first test made with dirty old glasses then and there confirms my doubts; they become a certainty a few moments later at M. Redtenbacher's laboratory. We dine together; then we go back to the factory, where we learn, miraculous to relate, that they are just now embarrassed in their manufacturing process, and, almost certainly, the product which hinders them —though it is in a very small quantity, and they take it for sulphate of potash—is no other than racemic acid. I wish I could give you more details of this eventful day. I was to have left Vienna to-day, but, as you will understand, I shall stay until I have unravelled this question. I have already in the laboratory three kinds of products from the factory. To-morrow night, or the day after, I shall know what to think. . . .

"You remember what I used to say to you and to M. Dumas, that almost certainly the first operation which tartar goes through in certain factories causes it to lose all or nearly all its racemic acid. Well, in the two Viennese factories, it is only

two years since they began to operate on crude tartar, and it is only two years since they first saw the supposed sulphate of potash, the supposed sulphate of magnesia. For, at M. Seybel's, they had taken for sulphate of magnesia the little crystals of racemic acid.

"Shortly, this is as far as I have come—I spare you many details:—

1. "The Naples tartar contains racemic acid.

2. "The Austrian tartar (neighbourhood of Vienna) contains racemic acid.

3. "The tartars of Hungary, Croatia, Carniola contain racemic acid.

4. "The tartar of Naples contains notably more than the latter, for it presents racemic acid even after one refining process, whilst that from Austria and Hungary only presents it when in the crude state.

"I believe it now to be extremely probable that I shall find some racemic acid in French tartars, but in very small quantities; and if it is not detected it is because all the circumstances of the manufacture of tartaric acid are unknown or unappreciated, or because some little precaution is neglected that would preserve it or make it visible.

"You see, dear Marie, how useful was my journey."

"*Vienna, September* 30, 1852. I am not going to Trieste; I shall start for Prague this evening."

"*Prague, October* 1, 1852. Here is a startling piece of news. I arrive in Prague; I settle down in the Hôtel d'Angleterre, have lunch, and call on M. Rochleder, Professor of chemistry, so that he may introduce me to the manufacturer. I go to the chemist of the factory, Dr. Rassmann, for whom I had a letter from M. Redtenbacher, his former master. That letter contained all the questions that I usually make to the manufacturers of tartaric acid.

"Dr. Rassmann hardly took time to read the letter; he saw what it dealt with, and said to me: 'I have long obtained racemic acid. The Paris Pharmaceutical Society offered a prize for whoever manufactured it. It is a product of manufacture; I obtain it with the assistance of tartaric acid.' I took the chemist's hand affectionately, and made him repeat what he had said. Then I added: 'You have made one of the greatest discoveries that it is possible to make in chemistry. Perhaps you do not realise as I do the full importance of it.

But allow me to tell you that, with my ideas, I look upon that discovery as impossible. I do not ask for your secret; I shall await the publication of it with the greatest impatience. So that is really true? You take a kilogramme of pure tartaric acid, and with that you make racemic acid?'

"'Yes,' he said; 'but it is still' . . . and as he had some difficulty in expressing himself, I said: 'It is still surrounded with great difficulties?'

"'Yes, monsieur.'

"Great heavens! what a discovery! if he had really done what he says! But no; it is impossible. There is an abyss to cross, and chemistry is yet too young."

Second letter, same date. "M. Rassmann is mistaken. . . . He has never obtained racemic acid with pure tartaric acid. He does what M. Fikentscher and the Viennese manufacturers do, with slight differences, which confirm the general opinion I expressed in my letter to M. Dumas a few days ago."

That letter, and also another addressed to Biot, indicated that racemic acid was formed in varying quantities in the mother-liquor, which remained after the purification of crude tartars.

"I can at last," Pasteur wrote from Leipzig to his wife, "turn my steps again towards France. I want it; I am very weary."

In an account of this journey in a newspaper called *La Vérité* there was this sentence, which amused everybody, Pasteur included: "Never was treasure sought, never adored beauty pursued over hill and vale with greater ardour."

But the hero of scientific adventures was not satisfied. He had foreseen by the examination of crystalline forms, the correlation between hemihedral dissymmetry and rotatory power; this was, to his mind, a happy foresight. He had afterwards succeeded in separating the racemic acid, inactive on polarized light, into two acids, left and right, endowed with equal but contrary rotatory powers; this was a discovery deservedly qualified as memorable by good judges in those matters. Now he had indicated the mother-liquor as a source of racemic acid, and this was a precious observation that Kestner, who was specially interested in the question, confirmed in a letter to the Académie des Sciences (December, 1852), sending at the same time three large phials of racemic acid, one of which, made of thin glass, broke in Biot's hands. But

a great advance, apparently unrealizable, remained yet to be accomplished. Could not racemic acid be produced by the aid of tartaric acid?

Pasteur himself, as he told the optimist Rassmann, did not believe such a transformation possible. But, by dint of ingenious patience, of trials, of efforts of all sorts, he fancied he was nearing the goal. He wrote to his father: "I am thinking of one thing only, of the hope of a brilliant discovery which seems not very far. But the result I foresee is so extraordinary that I dare not believe it." He told Biot and Senarmont of this hope. Both seemed to doubt. "I advise you," wrote Senarmont, "not to speak until you can say: 'I obtain racemic acid artificially with some tartaric acid, of which I have myself verified the purity; the artificial acid, like the natural, divides itself into equal equivalents of left and right tartaric acids, and those acids have the forms, the optical properties, all the chemical properties of those obtained from the natural acid.' Do not believe that I want to worry you; the scruples I have for you I should have for myself; it is well to be doubly sure when dealing with such a fact." But with Biot, Senarmont was less reserved; he believed the thing done. He said so to Biot, who, prudent and cautious, still desirous of warning Pasteur, wrote to him on May 27, 1853, speaking of Senarmont: "The affection with which your work, your perseverance and your moral character have inspired him makes him desire impossible prodigies for you. My friendship for you is less hastily hopeful and harder to convince. However, enjoy his friendship fully, and be as unreserved with him as you are with me. You can do so in full security; I do not know a stronger character than his. I have said and repeated to him how happy I am to see the affection he bears you. For there will be at least one man who will love you and understand you when I am gone. Farewell; enough sermons for to-day; a man must be as I am, in his eightieth year, to write such long homilies. Fortunately you are accustomed to mine, and do not mind them."

At last, on the first of June, here is the letter announcing the great fact: "My dear father, I have just sent out the following telegram: *Monsieur Biot, Collège de France, Paris. I transform tartaric acid into racemic acid; please inform MM. Dumas and Senarmont.* Here is at last that racemic acid (which I went to seek at Vienna) artificially obtained through

tartaric acid. I long believed that that transformation was impossible. This discovery will have incalculable consequences."

"I congratulate you," answered Biot on the second of June. "Your discovery is now complete. M. de Senarmont will be as delighted as I am. Please congratulate also Mme. Pasteur from me; she must be as pleased as you." It was by maintaining tartrate of cinchonin at a high temperature for several hours that Pasteur had succeeded in transforming tartaric acid into racemic acid. Without entering here into technical details (which are to be found in a report of the Paris Pharmaceutical Society, concerning the prize accorded to Pasteur for the artificial production of racemic acid) it may be added that he had also produced the neutral tartaric acid—that is: with no action on polarized light—which appeared at the expense of racemic acid already formed. There were henceforth four different tartaric acids:—(1) the right or dextro-tartaric acid; (2) the left or lævo-tartaric acid; (3) the combination of the right and the left or racemic acid; and (4) the meso-tartaric acid, optically inactive.

The reports of the Académie des Sciences also contain accounts of occasional discoveries, of researches of all kinds accessory to the history of racemic acid. Thus aspartic acid had caused Pasteur to make a sudden journey from Strasburg to Vendôme. A chemist named Dessaignes—who was municipal receiver of that town, and who found time through sheer love of science for researches on the constitution of divers substances—had announced a fact which Pasteur wished to verify: it turned out to be inaccurate.

One whole sitting of the Académie, the third of January, 1853, was given up to Pasteur's name and growing achievements.

After all this Pasteur came back to Arbois with the red ribbon of the Legion of Honour. He had not won it in the same way as his father had, but he deserved it as fully. Joseph Pasteur, delighting in his illustrious son, wrote effusively to Biot; indeed the old scientist had had his share in this act of justice. Biot answered in the following letter, which is a further revelation of his high and independent ideal of a scientific career.

"Monsieur, your good heart makes out my share to be greater than it is. The splendid discoveries made by your

worthy and excellent son, his devotion to science, his indefatigable perseverance, the conscientious care with which he fulfils the duties of his situation, all this had made his position such that there was no need to solicit for him what he had so long deserved. But one might boldly point out that it would be a real loss to the Order if he were not promptly included within its ranks. That is what I did, and I am very glad to see that the too long delay is now at an end. I wished for this all the more as I knew of your affectionate desire that this act of justice should be done. Allow me to add, however, that in our profession our real distinction depends on us alone, fortunately, and not on the favour or indifference of a minister. In the position that your son has acquired, his reputation will grow with his work, no other help being needed; and the esteem he already enjoys, and which will grow day by day, will be accorded to him, without gainsaying or appeal, by the Grand Jury of scientists of all nations—an absolutely just tribunal, the only one we recognize.

"Allow me to add to my congratulations the expression of the esteem and cordial affection with which you have inspired me."

On his return to Strasburg Pasteur went to live in a house in the Rue des Couples, which suited him as being near the Académie and his laboratory; it also had a garden where his children could play. He was full of projects, and what he called the "spirit of invention" daily suggested some new undertaking. The neighbourhood of Germany, at that time a veritable hive of busy bees, was a fertile stimulant to the French Faculty at Strasburg.

But material means were lacking. When Pasteur received the prize of 1,500 francs given him by the Pharmaceutical Society, he gave up half of it to buying instruments which the Strasburg laboratory was too poor to afford. The resources then placed by the State at his disposal by way of contribution to the expenses of a chemistry class only consisted of 1,200 francs under the heading "class expenses." Pasteur had to pay the wages of his laboratory attendant out of it. Now that he was better provided, thanks to his prize, he renewed his studies on crystals.

Taking up an octahedral crystal, he broke off a piece of it, then replaced it in its mother-liquor. Whilst the crystal was growing larger in every direction by a deposit of crystalline par-

ticles, a very active formation was taking place on the mutilated part; after a few hours the crystal had again assumed its original shape. The healing up of wounds, said Pasteur, might be compared to that physical phenomenon. Claude Bernard, much struck later on by these experiments of Pasteur's and recalling them with much praise, said in his turn—

"These reconstituting phenomena of crystalline redintegration afford a complete comparison with those presented by living beings in the case of a wound more or less deep. In the crystal as in the animal, the damaged part heals, gradually taking back its original shape, and in both cases the reformation of tissue is far more active in that particular part than under ordinary evolutive conditions."

Thus those two great minds saw affinities hidden under facts apparently far apart. Other similarities yet more unexpected carried Pasteur away towards the highest region of speculation. He spoke with enthusiasm of molecular dissymmetry; he saw it everywhere in the universe. These studies in dissymmetry gave birth twenty years later to a new science arising immediately out of his work, viz. stereo-chemistry, or the chemistry of space. He also saw in molecular dissymmetry the influence of a great cosmic cause—

"The universe," he said one day, "is a dissymmetrical whole. I am inclined to think that life, as manifested to us, must be a function of the dissymmetry of the universe and of the consequences it produces. The universe is dissymmetrical; for, if the whole of the bodies which compose the solar system were placed before a glass moving with their individual movements, the image in the glass could not be superposed to the reality. Even the movement of solar life is dissymmetrical. A luminous ray never strikes in a straight line the leaf where vegetable life creates organic matter. Terrestrial magnetism, the opposition which exists between the north and south poles in a magnet, that offered us by the two electricities positive and negative, are but resultants from dissymmetrical actions and movements."

"Life," he said again, "is dominated by dissymmetrical actions. I can even foresee that all living species are primordially, in their structure, in their external forms, functions of cosmic dissymmetry."

And there appeared to him to be a barrier between mineral or artificial products and products formed under the influence

of life. But he did not look upon it as an impassable one, and he was careful to say, "It is a distinction of fact and not of absolute principle." As nature elaborates immediate principles of life by means of dissymmetrical forces, he wished that the chemist should imitate nature, and that, breaking with methods founded upon the exclusive use of symmetrical forces, he should bring dissymmetrical forces to bear upon the production of chemical phenomena. He himself, after using powerful magnets to attempt to introduce a manifestation of dissymmetry into the form of crystals, had had a strong clockwork movement constructed, the object of which was to keep a plant in continual rotatory motion first in one direction then in another. He also proposed to try to keep a plant alive, from its germination under the influence of solar rays reversed by means of a mirror directed by a heliostat.

But Biot wrote to him: "I should like to be able to turn you from the attempts you wish to make on the influence of magnetism on vegetation. M. de Senarmont agrees with me. To begin with, you will spend a great deal on the purchase of instruments with the use of which you are not familiar, and of which the success is very doubtful. They will take you away from the fruitful course of experimental researches which you have followed hitherto, where there is yet so much for you to do, and will lead you from the certain to the uncertain."

"Louis is rather too preoccupied with his experiments," wrote Mme. Pasteur to her father-in-law; "you know that those he is undertaking this year will give us, if they succeed, a Newton or a Galileo."

But success did not come. "My studies are going rather badly," wrote Pasteur in his turn (December 30). "I am almost afraid of failing in all my endeavours this year, and of having no important achievement to record by the end of next year. I am still hoping, though I suppose it was rather mad to undertake what I have undertaken."

Whilst he was thus struggling, an experiment, which for others would have been a mere chemical curiosity, interested him passionately. Recalling one day how his first researches had led him to the study of ferments: "If I place," he said, "one of the salts of racemic acid, paratartrate or racemate of ammonia, for instance, in the ordinary conditions of fermentation, the dextro-tartaric acid alone ferments, the other remains in the liquor. I may say, in passing, that this is the best means

of preparing lævo-tartaric acid. Why does the dextro-tartaric acid alone become putrefied? Because the ferments of that fermentation feed more easily on the right than on the left molecules."

"I have done yet more," he said much later, in a last lecture to the Chemical Society of Paris; "I have kept alive some little seeds of *penicillium glaucum*—that mucor which is to be found everywhere—on the surface of ashes and paratartaric acid and I have seen the lævo-tartaric acid appear . . . "

What seemed to him startling in those two experiments was to find molecular dissymmetry appear as a modifying agent on chemical affinities in a phenomenon of the physiological order.

By an interesting coincidence it was at the very moment when his studies were bringing him towards fermentations that he was called to a country where the local industry was to be the strongest stimulant to his new researches.

CHAPTER IV

1855—1859

In September, 1854, he was made Professor and Dean of the new Faculté des Sciences at Lille. "I need not, Sir," wrote the Minister of Public Instruction, M. Fortoul, in a letter where private feelings were mixed with official solemnity, "recall to your mind the importance which is attached to the success of this new Faculty of Science, situated in a town which is the richest centre of industrial activity in the north of France. By giving you the direction of it, I show the entire confidence which I have placed in you. I am convinced that you will fulfil the hopes which I have founded upon your zeal."

Built at the expense of the town, the Faculté was situated in the Rue des Fleurs. In the opening speech which he pronounced on December 7, 1854, the young Dean expressed his enthusiasm for the Imperial decree of August 22, which brought two happy innovations into the Faculties of Science: (1) The pupils might, for a small annual sum, enter the laboratory and practise the principal experiments carried out before them at the classes; and (2) a new diploma was created. After two years of practical and theoretical study the young men who wished to enter an industrial career could obtain this special diploma and be chosen as foremen or overseers. Pasteur was overjoyed at being able to do useful work in that country of distilleries, and to attract large audiences to the new Faculty. "Where in your families will you find," he said, to excite indolent minds—"where will you find a young man whose curiosity and interest will not immediately be awakened when you put into his hands a potato, when with that potato he may produce sugar, with that sugar alcohol, with that alcohol æther and vinegar? Where is he that will not be happy to tell his family in the evening that he has just been working out an electric telegraph? And, gentlemen, be convinced of this, such studies are seldom if ever forgotten. It is somewhat as if geography were to be taught

by travelling; such geography is remembered because one has seen the places. In the same way your sons will not forget what the air we breathe contains when they have once analysed it, when in their hands and under their eyes the admirable properties of its elements have been resolved."

After stating his wish to be directly useful to these sons of manufacturers and to put his laboratory at their disposal, he eloquently upheld the rights of theory in teaching—

"Without theory, practice is but routine born of habit. Theory alone can bring forth and develop the spirit of invention. It is to you specially that it will belong not to share the opinion of those narrow minds who disdain everything in science which has not an immediate application. You know Franklin's charming saying? He was witnessing the first demonstration of a purely scientific discovery, and people round him said: 'But what is the use of it?' Franklin answered them: 'What is the use of a new-born child?' Yes, gentlemen, what is the use of a new-born child? And yet, perhaps, at that tender age, germs already existed in you of the talents which distinguish you! In your baby boys, fragile beings as they are, there are incipient magistrates, scientists, heroes as valiant as those who are now covering themselves with glory under the walls of Sebastopol. And thus, gentlemen, a theoretical discovery has but the merit of its existence: it awakens hope, and that is all. But let it be cultivated, let it grow, and you will see what it will become.

"Do you know when it first saw the light, this electric telegraph, one of the most marvellous applications of modern science? It was in that memorable year, 1822: Oersted, a Danish physicist, held in his hands a piece of copper wire, joined by its extremities to the two poles of a Volta pile. On his table was a magnetized needle on its pivot, and he suddenly saw (by chance you will say, but chance only favours the mind which is prepared) the needle move and take up a position quite different from the one assigned to it by terrestrial magnetism. A wire carrying an electric current deviates a magnetized needle from its position. That, gentlemen, was the birth of the modern telegraph. Franklin's interlocutor might well have said when the needle moved: 'But what is the use of that?' And yet that discovery was barely twenty years old when it produced by its application the almost supernatural effects of the electric telegraph!"

The small theatre where Pasteur gave his chemistry lessons soon became celebrated in the students' world.

The faults had disappeared with which Pasteur used to reproach himself when he first taught at Dijon and later at Strasburg. He was sure of himself, he was clear in his explanations; the chain of thought, the fitness of words, all was perfect. He made few experiments, but those were decisive. He endeavoured to bring out every observation or comparison they might suggest. The pupil who went away delighted from the class did not suspect the care each of those apparently easy lessons had cost. When Pasteur had carefully prepared all his notes, he used to make a summary of them; he had these summaries bound together afterwards. We may thus sketch the outline of his work; but who will paint the gesture of demonstration, the movement, the grave penetrating voice, the life in short?

After a few months the Minister wrote to M. Guillemin, the rector, that he was much pleased with the success of this Faculty of Sciences at Lille, "which already owes it to the merit of the teaching—solid and brilliant at the same time—of that clever Professor, that it is able to rival the most flourishing Faculties." The Minister felt he must add some official advice: "But M. Pasteur must guard against being carried away by his love for science, and he must not forget that the teaching of the Faculties, whilst keeping up with scientific theory, should, in order to produce useful and far-reaching results, appropriate to itself the special applications suitable to the real wants of the surrounding country."

A year after the inauguration of the new Faculty, Pasteur wrote to Chappuis: "Our classes are very well attended; I have 250 to 300 people at my most popular lectures, and we have twenty-one pupils entered for laboratory experiments. I believe that this year, like last year, Lille holds the first rank for that innovation, for I am told that at Lyons there were but eight entries." It was indeed a success to distance Lyons. "The zeal of all is a pleasure to watch (January, 1856). It reaches that point that four of the professors take the trouble to have their manuscript lessons printed; there are already 120 subscribers for the course of applied mechanics.

"Our building is fortunately completed; it is large and handsome, but will soon become insufficient owing to the progress of practical teaching.

"We are very comfortably settled on the first floor, and I have (on the ground floor immediately below) what I have always wished for, a laboratory where I can go at any time. This week, for instance, the gas remains on, and operations follow their course whilst I am in bed. In this way I try to make up a little of the time which I have to give to the direction of all the rather numerous departments in our Faculties. Add to this that I am a member of two very active societies, and that I have been entrusted, at the suggestion of the Conseil-Général,[1] with the testing of manures for the département of the Nord, a considerable work in this rich agricultural land, but one which I have accepted eagerly, so as to popularize and enlarge the influence of our young Faculty.

"Do not fear lest all this should keep me from the studies I love. I shall not give them up, and I trust that what is already accomplished will grow without my help, with the growth that time gives to everything that has within it the germ of life. Let us all work; that only is enjoyable. I am quoting M. Biot, who certainly is an authority on that subject. You saw the share he took the other day in a great discussion at the Académie des Sciences; his presence of mind, high reasoning powers, and youthfulness were magnificent, and he is eighty-four!"

In a mere study on Pasteur as a scientific man, the way in which he understood his duties as Dean would only be a secondary detail. It is not so here, the very object of this book being to paint what he was in all the circumstances, all the trials of life. Besides his professional obligations, his kindness in leaving his laboratory, however hard the sacrifice, bears witness to an ever present devotion. For instance, he took his pupils round factories and foundries at Aniche, Denain, Valenciennes, St. Omer. In July, 1856, he organized for the same pupils a tour in Belgium. He took them to visit factories, iron foundries, steel and metal works, questioning the foremen with his insatiable curiosity, pleased to induce in his tall students a desire to learn. All returned from these trips with more pleasure in their work; some with the fiery enthusiasm that Pasteur wished to see.

[1] *Conseil-Général de département.* A representative assembly for the general management of each département, somewhat similar to the County Councils in England. [Trans.]

The sentence in his Lille speech, "in the fields of observation, chance only favours the mind which is prepared," was particularly applicable to him. In the summer of 1856 a Lille manufacturer, M. Bigo, had, like many others that same year, met with great disappointments in the manufacture of beetroot alcohol. He came to the young Dean for advice. The prospect of doing a kindness, of communicating the results of his observations to the numerous hearers who crowded the small theatre of the Faculty, and of closely studying the phenomena of fermentation which preoccupied him to such a degree, caused Pasteur to consent to make some experiments. He spent some time almost daily at the factory. On his return to his laboratory—where he only had a student's microscope and a most primitive coke-fed stove—he examined the globules in the fermentation juice, he compared filtered with non-filtered beetroot juice, and conceived stimulating hypotheses often to be abandoned in face of a fact in contradiction with them. Above some note made a few days previously, where a suggested hypothesis had not been verified by fact, he would write: "error," "erroneous," for he was implacable in his criticism of himself.

M. Bigo's son, who studied in Pasteur's laboratory, has summed up in a letter how these accidents of manufacture became a starting point to Pasteur's investigations on fermentation, particularly alcoholic fermentation. "Pasteur had noticed through the microscope that the globules were round when fermentation was healthy, that they lengthened when alteration began, and were quite long when fermentation became lactic. This very simple method allowed us to watch the process and to avoid the failures in fermentation which we used so often to meet with. . . . I had the good fortune to be many times the confidant of the enthusiasms and disappointments of a great man of science." Young Bigo indeed remembered the series of experiments, the numerous observations noted, and how Pasteur, whilst studying the causes of those failures in the distillery, had wondered whether he was not confronted with a general fact, common to all fermentations. Pasteur was on the road to a discovery the consequences of which were to revolutionize chemistry. During months and months he worked to assure himself that he was not a prey to error.

In order to appreciate the importance of the ideas which

from that small laboratory were about to inundate the world, and in order to take account of the effort necessitated to obtain the triumph of a theory which was to become a doctrine, it is necessary to go back to the teachings of that time upon the subject of fermentations. All was darkness, pierced in 1836 by a momentary ray of light. The physicist Cagniard-Latour, studying the ferment of beer called yeast, had observed that that ferment was composed of cells "susceptible of reproduction by a sort of budding, and probably acting on sugar through some effect of their vegetation." Almost at the same time the German doctor Schwann was making analogous observations. However, as the fact seemed isolated, nothing similar being met with elsewhere, Cagniard-Latour's remark was but a curious parenthesis in the history of fermentations.

When such men as J. B. Dumas said that perhaps there might be a sequel to Cagniard-Latour's statement, they emitted the idea so timidly that, in a book *On Contagion* published at Montpellier in 1853, Anglada, the well known author, expressed himself thus—

"M. Dumas, who is an authority, looks upon the act of fermentation as *strange and obscure*; he declares that it gives rise to phenomena the knowledge of which is only tentative at present. Such a competent affirmation is of a nature to discourage those who claim to unravel the mysteries of contagion by the comparative study of fermentation. What is the advantage of explaining one through the other since both are equally mysterious!" This word, *obscure*, was to be found everywhere. Claude Bernard used the same epithet at the Collège de France in March, 1850, to qualify those phenomena.

Four months before the request of the Lille manufacturer, Pasteur himself, preparing on a loose sheet of paper a lesson on fermentation, had written these words: "What does fermentation consist of?—Mysterious character of the phenomenon.—A word on lactic acid." Did he speak in that lesson of his ideas of future experiments? Did he insist upon the mystery he intended to unveil? With his powers of concentration it is probable that he restrained himself and decided to wait another year.

The theories of Berzelius and of Liebig then reigned supreme. To the mind of Berzelius, the Swedish chemist, fermentation was due to contact. It was said that there was a catalytic force. In his opinion, what Cagniard-Latour

believed he had seen, was but "an immediate vegetable principle, which became precipitated during the fermentation of beer, and which, in precipitating, presented forms analogous to the simpler forms of vegetable life, but formation does not constitute life."

In the view of the German chemist Liebig, chemical decomposition was produced by influence: the ferment was an extremely alterable organic substance which decomposed, and in decomposing set in motion, by the rupture of its own elements, the molecules of the fermentative matter; it was the dead portion of the yeast, that which had lived and was being altered, which acted upon the sugar. These theories were adopted, taught, and to be found in all treatises on chemistry.

A vacancy at the Académie des Sciences took Pasteur away from his students for a time and obliged him to go to Paris. Biot, Dumas, Balard and Senarmont had insisted upon his presenting himself in the section of mineralogy. He felt himself unfit for the candidature. He was as incapable of election manœuvres as he was full of his subject when he had to convince an interlocutor or to interest an audience in his works on crystallography. (These works had just procured the bestowal on him of the great Rumford medal, conferred by the London Royal Society.) During this detested canvassing campaign he had one happy day: he was present on February 5, 1857, at the reception of Biot by the Académie Française.

Biot, who had entered the Académie des Sciences fifty-four years earlier, and was now the oldest member of the Institute, took advantage of his great age to distribute, in the course of his speech, a good deal of wise counsel, much applauded by Pasteur from the ranks of the audience. Biot, with his calm irony, aimed this epigram at men of science who disdained letters: "Their science was not the more apparent through their want of literary culture." He ended by remarks which formed a continuation of his last letter to Pasteur's father. Making an appeal to those whose high ambition is to consecrate themselves to pure science, he proudly said: "Perhaps your name, your existence will be unknown to the crowd. But you will be known, esteemed, sought after by a small number of eminent men scattered over the face of the earth, your rivals, your peers in the intellectual Senate of minds; they alone have the right to appreciate you and to assign to you your rank,

a well-merited rank, which no princely will, no popular caprice can give or take away, and which will remain yours as long as you remain faithful to Science, which bestows it upon you."

Guizot, to whom it fell to welcome Biot to the Académie, rendered homage to his independence, to his worship of disinterested research, to his ready counsels. "The events which have overturned everything around you," he said, "have never turned the course of your free and firm judgment, or of your peaceful labours." On that occasion the decline of Biot's life seemed like a beautiful summer evening in the north, before nightfall, when a soft light still envelops all things. No disciple ever felt more emotion than Pasteur when participating in that last joy of his aged master. In Regnault's laboratory, a photograph had been taken of Biot seated with bent head and a weary attitude, but with the old sparkle in his eyes. Biot offered it to Pasteur, saying: "If you place this proof near a portrait of your father, you will unite the pictures of two men who have loved you very much in the same way."

Pasteur, between two canvassing visits, gave himself the pleasure of going to hear a young professor that every one was then speaking of. "I have just been to a lecture by Rigault, at the Collège de France," he wrote on March 6, 1857. "The room is too small, it is a struggle to get in. I have come away delighted; it is a splendid success for the Université, there is nothing to add, nothing to retrench. Fancy a professor in one of the Paris *lycées* making such a début at the Collège de France!"

Pasteur preferred Rigault to St. Marc Girardin. "And Rigault is only beginning!" But, under Rigault's elegance and apparent ease, lurked perpetual constraint. One day that St. Marc Girardin was congratulating him, "Ah," said Rigault, "you do not see the steel corsets that I wear when I am speaking!" That comparison suited his delicate, ingenious, slightly artificial mind, never unrestrained even in simple conversation, at the same time conscientious and self-conscious. He who had once written that "Life is a work of art to be fashioned by a skilful hand if the faculties of the mind are to be fully enjoyed," made the mistake of forcing his nature. He died a few months after that lecture.

Pasteur's enthusiastic lines about Rigault show the joy he felt at the success of others. He did not understand envy, ill-will, or jealousy, and was more than astonished, indeed amazed,

when he came across such feelings. One day that he had read an important paper at the Académie des Sciences, "Would you believe it," he wrote to his father, "I met a Paris Professor of chemistry the very next day, whom I know to have been present, who had indeed come purposely to hear my reading, and he never said a word! I then remembered a saying of M. Biot's: 'When a colleague reads a paper and no one speaks to him about it afterwards, it is because it has been thought well of. . . .'"

The election was at hand. Pasteur wrote (March 11): "My dear father, I am certain to fail." He thought he might count upon twenty votes; thirty were necessary. He resigned himself philosophically. His candidature would at any rate bring his works into greater prominence. In spite of a splendid report by Senarmont, enumerating the successive steps by which Pasteur had risen since his first discoveries concerning the connection between internal structure and external crystalline forms, Pasteur only obtained sixteen votes.

On his return to Lille he set to work with renewed energy; he took up again his study of fermentations, and in particular that of sour milk, called lactic fermentation; he made notes of his experiments day by day; he drew in a notebook the little globules, the tiny bodies that he found in a grey substance sometimes aranged in a zone. Those globules, much smaller than those of yeast, had escaped the observation of chemists and naturalists because it was easy to confound them with other products of lactic fermentation. After isolating and then scattering in a liquid a trace of that grey substance, Pasteur saw some well-characterized lactic fermentation appear. That matter, that grey substance was indeed the ferment.

Whilst all the writings of the chemists who followed in the train of Liebig and Berzelius united in rejecting the idea of an influence of life in the cause of fermentations, Pasteur recognized therein a phenomenon correlative to life. That special lactic yeast, Pasteur could see budding, multiplying, and offering the same phenomena of reproduction as beer yeast.

It was not to the Académie des Sciences, as is generally believed, that Pasteur sent the paper on lactic fermentation, the fifteen pages of which contained such curious and unexpected facts. With much delicacy of feeling, Pasteur made to the Lille Scientific Society this communication (August, 1857) which the Académie des Sciences only saw three months later.

How was it that he desired to leave this Faculty at Lille to which he had rendered such valuable service? The Ecole Normale was going through difficult times. "In my opinion," wrote Pasteur with a sadness that betrayed his attachment to the great school, "of all the objects of care to the authorities, the Ecole Normale should be the first; it is now but the shadow of its former self." He who so often said, "Do not dwell upon things already acquired!" thought that the Lille Faculty was henceforth sure of its future and needed him no longer. Was it not better to come to the assistance of the threatened weak point? At the Ministry of Public Instruction his wish was understood and approved of. Nisard had just been made Director of the Ecole Normale with high and supreme powers; his sub-director of literary studies was M. Jacquinet. The administration was reserved for Pasteur, who was also entrusted with the direction of the scientific studies. To that task were added "the surveillance of the economic and hygienic management, the care of general discipline, intercourse with the families of the pupils and the literary or scientific establishments frequented by them."

The rector of the Lille Faculty announced in these terms the departure of the Dean: "Our Faculty loses a professor and a scientist of the very first order. You have yourselves, gentlemen, been able to appreciate more than once all the vigour and clearness of that mind at once so powerful and so capable."

At the Ecole Normale, Pasteur's labours were not at first seconded by material convenience. The only laboratory in the Rue d'Ulm building was occupied by Henri Sainte Claire Deville who, in 1851, had taken the place of Balard, the latter leaving the Ecole Normale for the Collège de France. Dark rooms, a very few instruments, and a credit of 1,800 francs a year, that was all Sainte Claire Deville had been able to obtain. It would have seemed like a dream to Pasteur. He had to organize his scientific installation in two attics under the roof of the Ecole Normale; he had no assistance of any kind, not even that of an ordinary laboratory attendant. But his courage was not of the kind which evaporates at the first obstacle, and no difficulty could have kept him from work: he climbed the stairs leading to his pseudo-laboratory with all the cheerfulness of a soldier's son. Biot—who had been grieved to see the chemist Laurent working in a sort of cellar, where that scientist's health suffered (he died at forty-three)—was angry that Pasteur should

be relegated to an uninhabitable garret. Neither did he understand the "economic and hygienic surveillance" attributed to Pasteur. He hoped Pasteur would reduce to their just proportions those secondary duties. "They have made him an administrator," he said with mock pomposity; "let them believe that he will administrate." Biot was mistaken. The *de minimis non curat* did not exist for Pasteur.

On one of his agenda leaves, besides subjects for lectures, we find notes such as these: "Catering; ascertain what weight of meat per pupil is given out at the Ecole Polytechnique. Courtyard to be strewn with sand. Ventilation of classroom. Dining hall door to be repaired." Each detail was of importance in his eyes, when the health of the students was in question.

He inaugurated his garret by some work almost as celebrated as that on lactic fermentation. In December, 1857, he presented to the Académie des Sciences a paper on alcoholic fermentation. "I have submitted," he said, "alcoholic fermentation to the method of experimentation indicated in the notes which I recently had the honour of presenting to the Académie. The results of those labours should be put on the same lines, for they explain and complete each other." And in conclusion: "The deduplication of sugar into alcohol and carbonic acid is correlative to a phenomenon of life, an organization of globules . . ."

The reports of the Académie des Sciences for 1858 show how Pasteur recognized complex phenomena in alcoholic fermentation. Whilst chemists were content to say: "So much sugar gives so much alcohol and so much carbonic acid," Pasteur went further. He wrote to Chappuis in June: "I find that alcoholic fermentation is constantly accompanied by the production of glycerine; it is a very curious fact. For instance, in one litre of wine there are several grammes of that product which had not been suspected." Shortly before that he had also recognized the normal presence in alcoholic fermentation of succinic acid. "I should be pursuing the consequences of these facts," he added, "if a temperature of 36° C. did not keep me from my laboratory. I regret to see the longest days in the year lost to me. Yet I have grown accustomed to my attic, and I should be sorry to leave it. Next holidays I hope to enlarge it. You too are struggling against material hindrances in your work; let it stimulate us, my dear fellow, and not discourage us. Our discoveries will have the greater merit."

The year 1859 was given up to examining further facts concerning fermentation. Whence came those ferments, those microscopic bodies, those transforming agents, so weak in appearance, so powerful in reality? Great problems were working in his mind; but he was careful not to propound them hastily, for he was the most timid, the most hesitating of men until he held proofs in his hands. "In experimental science," he wrote, "it is always a mistake not to doubt when facts do not compel you to affirm."

In September he lost his eldest daughter. She died of typhoid fever at Arbois, where she was staying with her grandfather. On December 30 Pasteur wrote to his father: "I cannot keep my thoughts from my poor little girl, so good, so happy in her little life, whom this fatal year now ending has taken away from us. She was growing to be such a companion to her mother and to me, to us all. . . . But forgive me, dearest father, for recalling these sad memories. She is happy; let us think of those who remain and try as much as lies in our power to keep from them the bitterness of this life."

CHAPTER V

1860—1864

On January 30, 1860, the Académie des Sciences conferred on Pasteur the Prize for Experimental Physiology. Claude Bernard, who drew up the report, recalled how much Pasteur's experiments in alcoholic fermentation, lactic fermentation, the fermentation of tartaric acid, had been appreciated by the Académie. He dwelt upon the great physiological interest of the results obtained. "It is," he concluded, "by reason of that physiological tendency in Pasteur's researches, that the Commission has unanimously selected him for the 1859 Prize for Experimental Physiology."

That same January, Pasteur wrote to Chappuis: "I am pursuing as best I can these studies on fermentation which are of great interest, connected as they are with the impenetrable mystery of Life and Death. I am hoping to mark a decisive step very soon by solving, without the least confusion, the celebrated question of spontaneous generation. Already I could speak, but I want to push my experiments yet further. There is so much obscurity, together with so much passion, on both sides, that I shall require the accuracy of an arithmetical problem to convince my opponents by my conclusions. I intend to attain even that."

This progress was depicted to his father in the following letter, dated February 7, 1860—

"I think I told you that I should read a second and last lecture on my old researches on Friday, at the Chemical Society, before several members of the Institute—amongst others, Messrs. Dumas and Claude Bernard. That lecture has had the same success as the first. M. Biot heard about it the next day through some distinguished persons who were in the audience, and sent for me in order to kindly express his great satisfaction.

"After I had finished, M. Dumas, who occupied the chair,

rose and addressed me in these words. After praising the zeal I had brought to this novel kind of teaching at the Society's request, and the *so great penetration I had given proof of, in the course of the work I had just expounded, he added, 'The Académie, sir, rewarded you a few days ago for other profound researches; your audience of this evening will applaud you as one of the most distinguished professors we possess.'*

"All I have underlined was said in those very words by M. Dumas, and was followed by great applause.

"All the students of the scientific section of the Ecole Normale were present; they felt deeply moved and several of them have expressed their emotion to me.

"As for myself, I saw the realization of what I had foreseen. You know how I have always told you confidentially that time would see the growth of my researches on the molecular dissymmetry of natural organic products. Founded as they were on varied notions borrowed from divers branches of science—crystallography, physics, and chemistry—those studies could not be followed by most scientists so as to be fully understood. On this occasion I presented them in the aggregate with some clearness and power and every one was struck by their importance.

"It is not by their form that these two lectures have delighted my hearers, it is by their contents; it is the future reserved to those great results, so unexpected, and opening such entirely new vistas to physiology. I have dared to say so, for at these heights all sense of personality disappears, and there only remains that sense of dignity which is ever inspired by true love of science.

"God grant that by my persevering labours I may bring a little stone to the frail and ill-assured edifice of our knowledge of those deep mysteries of Life and Death where all our intellects have so lamentably failed.

"P.S.—Yesterday I presented to the Academy my researches on spontaneous generation; they seemed to produce a great sensation. More later."

When Biot heard that Pasteur wished to tackle this study of spontaneous generation, he interposed, as he had done seven years before, to arrest him on the verge of his audacious experiments on the part played by dissymmetrical forces in the development of life. Vainly Pasteur, grieved at Biot's disapprobation, explained that this question, in the course of

such researches, had become an imperious necessity; Biot would not be convinced. But Pasteur, in spite of his quasi-filial attachment to Biot, could not stop where he was; he had to go through to the end.

"You will never find your way out," cried Biot.

"I shall try," said Pasteur modestly.

Angry and anxious, Biot wished Pasteur to promise that he would relinquish these apparently hopeless researches. J. B. Dumas, to whom Pasteur related the more than discouraging remonstrances of Biot, entrenched himself behind this cautious phrase—

"I would advise no one to dwell too long on such a subject."

Senarmont alone, full of confidence in the ingenious curiosity of the man who could read nature by dint of patience, said that Pasteur should be allowed his own way.

It is regrettable that Biot—whose passion for reading was so indefatigable that he complained of not finding enough books in the library at the Institute—should not have thought of writing the history of this question of spontaneous generation. He could have gone back to Aristotle, quoted Lucretius, Virgil, Ovid, Pliny. Philosophers, poets, naturalists, all believed in spontaneous generation. Time went on, and it was still believed in. In the sixteenth century, Van Helmont—who should not be judged by that one instance—gave a celebrated recipe to create mice: any one could work that prodigy by putting some dirty linen in a receptacle, together with a few grains of wheat or a piece of cheese. Some time later an Italian, Buonanni, announced a fact no less fantastic: certain timberwood, he said, after rotting in the sea, produced worms which engendered butterflies, and those butterflies became birds.

Another Italian, less credulous, a poet and a physician, Francesco Redi, belonging to a learned society calling itself The Academy of Experience, resolved to carefully study one of those supposed phenomena of spontaneous generation. In order to demonstrate that the worms found in rotten meat did not appear spontaneously, he placed a piece of gauze over the meat. Flies, attracted by the odour, deposited their eggs on the gauze. From those eggs were hatched the worms, which had until then been supposed to begin life spontaneously in the flesh itself. This simple experiment marked some progress. Later on another Italian, a medical professor of

Padua, Vallisneri, recognized that the grub in a fruit is also hatched from an egg deposited by an insect before the development of the fruit.

The theory of spontaneous generation, still losing ground, appeared to be vanquished when the invention of the microscope at the end of the seventeenth century brought fresh arguments to its assistance. Whence came those thousands of creatures, only distinguishable on the slide of the microscope, those infinitely small beings which appeared in rain water as in any infusion of organic matter when exposed to the air? How could they be explained otherwise than through spontaneous generation, those bodies capable of producing 1,000,000 descendants in less than forty-eight hours.

The world of salons and of minor courts was pleased to have an opinion on this question. The Cardinal of Polignac, a diplomat and a man of letters, wrote in his leisure moments a long Latin poem entitled the *Anti-Lucretius*. After scouting Lucretius and other philosophers of the same school, the cardinal traced back to one Supreme Foresight the mechanism and organization of the entire world. By ingenious developments and circumlocutions, worthy of the Abbé Delille, the cardinal, while vaunting the wonders of the microscope, which he called "eye of our eye," saw in it only another prodigy offered us by Almighty Wisdom. Of all those accumulated and verified arguments, this simple notion stood out: "The earth, which contains numberless germs, has not produced them. Everything in this world has its germ or seed."

Diderot, who disseminated so many ideas (since borrowed by many people and used as if originated by them), wrote in some tumultuous pages on nature: "Does living matter combine with living matter? how? and with what result? And what about dead matter?"

About the middle of the eighteenth century the problem was again raised on scientific ground. Two priests, one an Englishman, Needham, and the other an Italian, Spallanzani, entered the lists. Needham, a great partisan of spontaneous generation, studied with Buffon some microscopic animalculæ. Buffon afterwards built up a whole system which became fashionable at that time. The force which Needham found in matter, a force which he called productive or vegetative, and which he regarded as charged with the formation of the organic world, Buffon explained by saying that there are certain primi-

tive and incorruptible parts common to animals and to vegetables. These organic molecules cast themselves into the moulds or shapes which constituted different beings. When one of those moulds was destroyed by death, the organic molecules became free; ever active, they worked the putrefied matter, appropriating to themselves some raw particles and forming, said Buffon, "by their reunion, a multitude of little organized bodies, of which some, like earthworms, and fungi, seem to be fair-sized animals or vegetables, but of which others, in almost infinite numbers, can only be seen through the microscope."

All those bodies, according to him, only existed through spontaneous generation. Spontaneous generation takes place continually and universally after death and sometimes during life. Such was in his view the origin of intestinal worms. And, carrying his investigations further, he added, "The eels in flour paste, those of vinegar, all those so-called microscopic animals, are but different shapes taken spontaneously, according to circumstances, by that ever active matter which only tends to organization."

The Abbé Spallanzani, armed with a microscope, studied these infinitesimal beings. He tried to distinguish them and their mode of life. Needham had affirmed that by enclosing putrescible matter in vases and by placing those vases on warm ashes, he produced animalculæ. Spallanzani suspected: firstly that Needham had not exposed the vases to a sufficient degree of heat to kill the seeds which were inside; and secondly, that seeds could easily have entered those vases and given birth to animalculæ, for Needham had only closed his vases with cork stoppers, which are very porous.

"I repeated that experiment with more accuracy," wrote Spallanzani. "I used hermetically sealed vases. I kept them for an hour in boiling water, and after having opened them and examined their contents within a reasonable time I found not the slightest trace of animalculæ, though I had examined with the microscope the infusions from nineteen different vases."

Thus dropped to the ground, in Spallanzani's eyes, Needham's singular theory, this famous vegetative force, this occult virtue. Yet Needham did not own himself beaten. He retorted that Spallanzani had much weakened, perhaps destroyed, the vegetative force of the infused substances by

leaving his vases in boiling water during an hour. He advised him to try with less heat.

The public took an interest in this quarrel. In an opuscule entitled *Singularities of Nature* (1769), Voltaire, a born journalist, laughed at Needham, whom he turned into an Irish Jesuit to amuse his readers. Joking on this race of so-called eels which began life in the gravy of boiled mutton, he said: "At once several philosophers exclaimed at the wonder and said, 'There is no germ; all is made, all is regenerated by a vital force of nature.' 'Attraction,' said one; 'Organized matter,' said another, 'they are organic molecules which have found their casts.' Clever physicists were taken in by a Jesuit."

In those pages, lightly penned, nothing remained of what Voltaire called "the ridiculous mistake, the unfortunate experiments of Needham, so triumphantly refuted by M. Spallanzani and rejected by whoever has studied nature at all." "It is now demonstrated to sight and to reason that there is no vegetable, no animal but has its own germ." In his *Philosophic Dictionary*, at the word God, "It is very strange," said Voltaire, "that men should deny a creator and yet attribute to themselves the power of creating eels!" The Abbé Needham, meeting with these religious arguments, rather unexpected from Voltaire, endeavoured to prove that the hypothesis of spontaneous generation was in perfect accordance with religious beliefs. But both on Needham's side and on Spallanzani's there was a complete lack of conclusive proofs.

Philosophic argumentation always returned to the fore. As recently as 1846 Ernest Bersot (a moralist who became later a director of the Ecole Normale) wrote in his book on Spiritualism: "The doctrine of spontaneous generation pleases simplicity-loving minds; it leads them far beyond their own expectations. But it is yet only a private opinion, and, were it recognized, its virtue would have to be limited and narrowed down to the production of a few inferior animals."

That doctrine was about to be noisily re-introduced.

On December 20, 1858, a correspondent of the Institute, M. Pouchet, director of the Natural History Museum of Rouen, sent to the Académie des Sciences a *Note on Vegetable and Animal Proto-organisms spontaneously Generated in Artificial Air and in Oxygen Gas*. The note began thus: "At this

time when, seconded by the progress of science, several naturalists are endeavouring to reduce the domain of spontaneous generation or even to deny its existence altogether, I have undertaken a series of researches with the object of elucidating this vexed question." Pouchet, declaring that he had taken excessive precautions to preserve his experiments from any cause of error, proclaimed that he was prepared to demonstrate that "animals and plants could be generated in a medium absolutely free from atmospheric air, and in which, therefore, no germ of organic bodies could have been brought by air."

On one copy of that communication, the opening of a four years' scientific campaign, Pasteur had underlined the passages which he intended to submit to rigorous experimentation. The scientific world was discussing the matter; Pasteur set himself to work.

A new installation, albeit a summary one, allowed him to attempt some delicate experiments. At one of the extremities of the façade of the Ecole Normale, on the same line as the doorkeeper's lodge, a pavilion had been built for the school architect and his clerk. Pasteur succeeded in obtaining possession of this small building, and transformed it into a laboratory. He built a drying stove under the staircase; though he could only reach the stove by crawling on his knees, yet this was better than his old attic. He also had a pleasant surprise —he was given a curator. He had deserved one sooner, for he had founded the institution of *agrégés préparateurs*. Remembering his own desire, on leaving the Ecole Normale, to have a year or two for independent study, he had wished to facilitate for others the obtaining of those few years of research and perhaps inspiration. Thanks to him, five places as laboratory curators were exclusively reserved to Ecole Normale students who had taken their degree (*agrégés*). The first curator who entered the new laboratory was Jules Raulin, a young man with a clear and sagacious mind, a calm and tenacious character, loving difficulties for the sake of overcoming them.

Pasteur began by the microscopic study of atmospheric air. "If germs exist in atmosphere," he said, "could they not be arrested on their way?" It then occurred to him to draw —through an aspirator—a current of outside air through a tube containing a little plug of cotton wool. The current as it passed deposited on this sort of filter some of the solid corpuscles

contained in the air; the cotton wool often became black with those various kinds of dust. Pasteur assured himself that amongst various detritus those dusts presented spores and germs. "There are therefore in the air some organized corpuscles. Are they germs capable of vegetable productions, or of infusions? That is the question to solve." He undertook a series of experiments to demonstrate that the most putrescible liquid remained pure indefinitely if placed out of the reach of atmospheric dusts. But it was sufficient to place in a pure liquid a particle of the cotton-wool filter to obtain an immediate alteration.

A year before starting any discussion Pasteur wrote to Pouchet that the results which he had attained were "not founded on facts of a faultless exactitude. I think you are wrong, not in believing in spontaneous generation (for it is difficult in such a case not to have a preconceived idea), but in affirming the existence of spontaneous generation. In experimental science it is always a mistake not to doubt when facts do not compel affirmation. . . . In my opinion, the question is whole and untouched by decisive proofs. What is there in air which provokes organization? Are they germs? is it a solid? is it a gas? is it a fluid? is it a principle such as ozone? All this is unknown and invites experiment."

After a year's study, Pasteur reached this conclusion: "Gases, fluids, electricity, magnetism, ozone, things known or things occult, there is nothing in the air that is conditional to life, except the germs that it carries."

Pouchet defended himself vigorously. To suppose that germs came from air seemed to him impossible. How many millions of loose eggs or spores would then be contained in a cubic millimetre of atmospheric air?

"What will be the outcome of this giant's struggle?" grandiloquently wrote an editor of the *Moniteur Scientifique* (April, 1860). Pouchet answered this anonymous writer by advising him to accept the doctrine of spontaneous generation adopted of old by so many "men of genius." Pouchet's principal disciple was a lover of science and of letters, M. Nicolas Joly, an *agrégé* of natural science, doctor of medicine, and professor of physiology at Toulouse. He himself had a pupil, Charles Musset, who was preparing a thesis for his doctor's degree under the title: *New Experimental Researches on Heterogenia, or Spontaneous Generation.* By the words

heterogenia or spontaneous generation Joly and Musset agreed in affirming that "they did not mean a creation out of nothing, but the production of a new organized being, lacking parents, and of which the primordial elements are drawn from ambient organic matter."

Thus supported, Pouchet multiplied objections to the views of Pasteur, who had to meet every argument. Pasteur intended to narrow more and more the sphere of discussion. It was an ingenious operation to take the dusts from a cotton-wool filter, to disseminate them in a liquid, and thus to determine the alteration of that liquid; but the cotton wool itself was an organic substance and might be suspected. He therefore substituted for the cotton wool a plug of asbestos fibre, a mineral substance. He invented little glass flasks with a long curved neck; he filled them with an alterable liquid, which he deprived of germs by ebullition; the flask was in communication with the outer air through its curved tube, but the atmospheric germs were deposited in the curve of the neck without reaching the liquid; in order that alteration should take place, the vessel had to be inclined until the point where the liquid reached the dusts in the neck.

But Pouchet said, "How could germs contained in the air be numerous enough to develop in every organic infusion? Such a crowd of them would produce a thick mist as dense as iron." Of all the difficulties this last seemed to Pasteur the hardest to solve. Could it not be that the dissemination of germs was more or less thick according to places? "Then," cried the heterogenists, "there would be sterile zones and fecund zones, a most convenient hypothesis, indeed!" Pasteur let them laugh whilst he was preparing a series of flasks reserved for divers experiments. If spontaneous generation existed, it should invariably occur in vessels filled with the same alterable liquid. "Yet it is ever possible," affirmed Pasteur, "to take up in certain places a notable though limited volume of ordinary air, having been submitted to no physical or chemical change, and still absolutely incapable of producing any alteration in an eminently putrescible liquor." He was ready to prove that nothing was easier than to increase or to reduce the number either of the vessels where productions should appear or of the vessels where those productions should be lacking. After introducing into a series of flasks of a capacity of 250 cubic centimetres a very easily corrupted liquid, such as yeast

water, he submitted each flask to ebullition. The neck of those vessels was ended off in a vertical point. Whilst the liquid was still boiling, he closed, with an enameller's lamp, the pointed opening through which the steam had rushed out, taking with it all the air contained in the vessel. Those flasks were indeed calculated to satisfy both partisans or adversaries of spontaneous generation. If the extremity of the neck of one of these vessels was suddenly broken, all the ambient air rushed into the flask, bringing in all the suspended dusts; the bulb was closed again at once with the assistance of a jet of flame. Pasteur could then carry it away and place it in a temperature of 25–30° C., quite suitable for the development of germs and mucors.

In those series of tests some flasks showed some alteration, others remained pure, according to the place where the air had been admitted. During the beginning of the year 1860 Pasteur broke his bulb points and enclosed ordinary air in many different places, including the cellars of the Observatory of Paris. There, in that zone of an invariable temperature, the absolutely calm air could not be compared to the air he gathered in the yard of the same building. The results were also very different: out of ten vessels opened in the cellar, closed again and placed in the stove, only one showed any alteration; whilst eleven others, opened in the yard, all yielded organized bodies.

In a letter to his father (June, 1860), Pasteur wrote: "I have been prevented from writing by my experiments, which continue to be very curious. But it is such a wide subject that I have almost too many ideas of experiments. I am still being contradicted by two naturalists, M. Pouchet of Rouen and M. Joly of Toulouse. But I do not waste my time in answering them; they may say what they like, truth is on my side. They do not know how to experiment; it is not an easy art; it demands, besides certain natural qualities, a long practice which naturalists have not generally acquired nowadays."

When the long vacation approached, Pasteur, who intended to go on a voyage of experiments, laid in a store of glass flasks. He wrote to Chappuis, on August 10, 1860: "I fear from your letter that you will not go to the Alps this year. . . . Besides the pleasure of having you for a guide, I had hoped to utilize your love of science by offering you the modest part of curator. It is by some study of air on heights afar from habitations and vegetation that I want to conclude my work on so-called spon-

taneous generation. The real interest of that work for me lies in the connection of this subject with that of ferments which I shall take up again November."

Pasteur started for Arbois, taking with him seventy-three flasks; he opened twenty of them not very far from his father's tannery, on the road to Dôle, along an old road, now a path which leads to the mount of the Bergère. The vine labourers who passed him wondered what this holiday tourist could be doing with all those little phials; no one suspected that he was penetrating one of nature's greatest secrets. "What would you have?" merrily said his old friend, Jules Vercel; "it amuses him!" Of those twenty vessels, opened some distance away from any dwelling, eight yielded organized bodies.

Pasteur went on to Salins and climbed Mount Poupet, 850 metres above the sea-level. Out of twenty vessels opened, only five were altered. Pasteur would have liked to charter a balloon in order to prove that the higher you go the fewer germs you find, and that certain zones absolutely pure contain none at all. It was easier to go into the Alps.

He arrived at Chamonix on September 20, and engaged a guide to make the ascent of the Montanvert. The very next morning this novel sort of expedition started. A mule carried the case of thirty-three vessels, followed very closely by Pasteur, who watched over the precious burden and walked alongside of precipices supporting the case with one hand so that it should not be shaken.

When the first experiments were started an incident occurred. Pasteur has himself related this fact in his report to the Académie. "In order to close again the point of the flasks after taking in the air, I had taken with me an eolipyle spirit-lamp. The dazzling whiteness of the ice in the sunlight was such that it was impossible to distinguish the jet of burning alcohol, and as moreover that was slightly moved by the wind, it never remained on the broken glass long enough to hermetically seal my vessel. All the means I might have employed to make the flame visible and consequently directable would inevitably have given rise to causes of error by spreading strange dusts into the air. I was therefore obliged to bring back to the little inn of Montanvert, unsealed, the flasks which I had opened on the glacier."

The inn was a sort of hut, letting in wind and rain. The thirteen open vessels were exposed to all the dusts in the room

where Pasteur slept; nearly all of them presented alterations.

In the meanwhile the guide was sent to Chamonix where a tinker undertook to modify the lamp in view of the coming experiment.

The next morning, twenty flasks, which have remained celebrated in the world of scientific investigators, were brought to the Mer de Glace. Pasteur gathered the air with infinite precautions; he used to enjoy relating these details to those people who call everything easy. After tracing with a steel point a line on the glass, careful lest dusts should become a cause of error, he began by heating the neck and fine point of the bulb in the flame of the little spirit-lamp. Then raising the vessel above his head, he broke the point with steel nippers, the long ends of which had also been heated in order to burn the dusts which might be on their surface and which would have been driven into the vessel by the quick inrush of the air. Of those twenty flasks, closed again immediately, only one was altered. "If all the results are compared that I have obtained until now," he wrote, on March 5, 1880, when relating this journey to the Académie, "it seems to me that it can be affirmed that the dusts suspended in atmospheric air are the exclusive origin, the necessary condition of life in infusions."

And in an unnoticed little sentence, pointing already then to the goal he had in view, "What would be most desirable would be to push those studies far enough to prepare the road for a serious research into the origin of various diseases." The action of those little beings, agents not only of fermentation but also of disorganization and putrefaction, already dawned upon him.

While Pasteur was going from the Observatoire cellars to the Mer de Glace, Pouchet was gathering air on the plains of Sicily, making experiments on Etna, and on the sea. He saw everywhere, he wrote, "air equally favourable to organic genesis, whether surcharged with detritus in the midst of our populous cities, or taken on the summit of a mountain, or on the sea, where it offers extreme purity. With a cubic decimetre of air, taken where you like, I affirm that you can ever produce legions of microzoa."

And the heterogenists proclaimed in unison that "everywhere, strictly everywhere, air is constantly favourable to life." Those who followed the debate nearly all leaned towards

Pouchet. "I am afraid," wrote a scientific journalist in *La Presse* (1860), "that the experiments you quote, M. Pasteur, will turn against you. . . . The world into which you wish to take us is really too fantastic. . . ."

And yet some adversaries should have been struck by the efforts of a mind which, while marching forward to establish new facts, was ever seeking arguments against itself, and turned back to strengthen points which seemed yet weak. In November, Pasteur returned to his studies on fermentations in general and lactic fermentation in particular. Endeavouring to bring into evidence the animated nature of the lactic ferment, and to indicate the most suitable surroundings for the self-development of that ferment, he had come across some complications which hampered the purity and the progress of that culture. Then he had perceived another fermentation, following upon lactic fermentation and known as butyric fermentation. As he did not immediately perceive the origin of this butyric acid—which causes the bad smell in rancid butter—he ended by being struck by the inevitable coincidence between the (then called) infusory animalculæ and the production of this acid.

"The most constantly repeated tests," he wrote in February, 1861, "have convinced me that the transformation of sugar, mannite and lactic acid into butyric acid is due exclusively to those Infusories, and they must be considered as the real butyric ferment." Those vibriones that Pasteur described as under the shape of small cylindric rods with rounded ends, sliding about, sometimes in a chain of three or four articles, he sowed in an appropriate medium, as he sowed beer yeast. But, by a strange phenomenon, "those infusory animalculæ," he said, "live and multiply indefinitely, without requiring the least quantity of air. And not only do they live without air, but air actually kills them. It is sufficient to send a current of atmospheric air during an hour or two through the liquor where those vibriones were multiplying to cause them all to perish and thus to arrest butyric fermentation, whilst a current of pure carbonic acid gas passing through that same liquor hindered them in no way. Thence this double proposition," concluded Pasteur; "the butyric ferment is an infusory; that infusory lives without free oxygen." He afterwards called anaërobes those beings which do not require air, in opposition to the name of aërobes given to other microscopic beings who require air to live.

Biot, without knowing all the consequences of these studies, had not been long in perceiving that he had been far too sceptical, and that physiological discoveries of the very first rank would be the outcome of researches on so-called spontaneous generation. He would have wished, before he died, not only that Pasteur should be the unanimously selected candidate for the 1861 Zecker prize in the Chemistry Section, but also that his friend, forty-eight years younger than himself, should be a member of the Institute. At the beginning of 1861, there was one vacancy in the Botanical Section. Biot took advantage of the researches pursued by Pasteur within the last three years, to say and to print that he should be nominated as a candidate. "I can hear the commonplace objection: he is a chemist, a physicist, not a professional botanist. . . . But that very versatility, ever active and ever successful, should be a title in his favour. . . . Let us judge of men by their works and not by the destination more or less wide or narrow that they have marked out for themselves. Pasteur made his début before the Académie in 1848, with the remarkable treatise which contained by implication the resolution of the paratartaric acid into its two components, right and left. He was then twenty-six; the sensation produced is not forgotten. Since then, during the twelve years which followed, he has submitted to your appreciation twenty-one papers, the last ten relating to vegetable physiology. All are full of new facts, often very unexpected, several very far reaching, not one of which has been found inaccurate by competent judges. If to-day, by your suffrage, you introduce M. Pasteur into the Botanical Section, as you might safely have done for Théodore de Saussure or Ingenhousz, you will have acquired for the Académie and for that particular section an experimentalist of the same order as those two great men."

Balard, who in this academic campaign made common cause with Biot, was also making efforts to persuade several members of the Botanical Section. He was walking one day in the Luxembourg with Moquin-Tandon, pouring out, in his rasping voice, arguments in favour of Pasteur. "Well," said Moquin-Tandon, "let us go to Pasteur's, and if you find a botanical work in his library I shall put him on the list." It was a witty form given to the scruples of the botanists. Pasteur only had twenty-four votes; Duchartre was elected.

The study of a microscopic fungus, capable by itself of

transforming wine into vinegar, the bringing to light of the action of that mycoderma, endowed with the power of taking oxygen from air and fixing it upon alcohol, thus transforming the latter into acetic acid; the most ingenious experiments to demonstrate the absolute and exclusive power of the little plant, all gave reason to Biot's affirmation that such skill in the observation of inferior vegetables equalled any botanist's claim. Pasteur, showing that the interpretations of the causes which act in the formation of vinegar were false, and that alone the microscopic fungus did everything, was constantly dwelling on this power of the infinitesimally small. "Mycoderma," he said, "can bring the action of combustion of the oxygen in air to bear on a number of organic materia. If microscopic beings were to disappear from our globe, the surface of the earth would be encumbered with dead organic matter and corpses of all kinds, animal and vegetable. It is chiefly they who give to oxygen its powers of combustion. Without them, life would become impossible because death would be incomplete."

Pasteur's ideas on fermentation and putrefaction were being adopted by disciples unknown to him. "I am sending you," he wrote to his father, "a treatise on fermentation, which was the subject of a recent competition at the Montpellier Faculty. This work is dedicated to me by its author, whom I do not know at all, a circumstance which shows that my results are spreading and exciting some attention.

"I have only read the last pages, which have pleased me; if the rest is the same, it is a very good *résumé*, entirely conceived in the new direction of my labours, evidently well understood by this young doctor.

"M. Biot is very well, only suffering a little from insomnia. He has, fortunately for his health, finished that great account of my former results which will be the greatest title I can have to the esteem of scientists."

Biot died without having realized his last wish, which was to have Pasteur for a colleague. It was only at the end of the year 1862 that Pasteur was nominated by the Mineralogical Section for the seat of Senarmont. This new candidature did not go without a hitch. In his study on tartrates, Pasteur, as will be remembered, had discovered that their crystalline forms were hemihedral. When he examined the characteristic faces, he held the crystal in a particular way and said: "It is hemihedral on the right side." A German mineralogist, named

Rammelsberg, holding the crystal in the opposite direction, said: "It is hemihedral on the left side." It was a mere matter of conventional orientation; nothing was changed in the scientific results announced by Pasteur. But some adversaries made a weapon of that inverted crystal; not a dangerous weapon, thought Pasteur at first, fancying that a few words would clear the misunderstanding. But the campaign persisted, with insinuations, murmurs, whisperings. When Pasteur saw this simple difference in the way the crystal was held stigmatised as a cause of error, he desired to cut short this quarrel made in Germany. He then had with him no longer Raulin, but M. Duclaux, who was beginning his scientific life. M. Duclaux remembers one day when Pasteur, seeing that incontrovertible arguments were required, sent for a cabinet maker with his tools. He superintended the making of a complete wooden set of the crystalline forms of tartrates, a gigantic set, such as Gulliver might have seen in Brobdingnag if he had studied geometrical forms in that island. A coating of coloured paper finished the work; green paper marked the hemihedral face. A member of the Philomathic Society, Pasteur asked the Society to give up the meeting of November 8, 1862, to the discussion of that subject. Several of his colleagues vainly endeavoured to dissuade him from that intention; Pasteur hearkened to no one. He took with him his provision of wooden crystals, and gave a vivid and impassioned lecture. "If you know the question," he asked his adversaries, "where is your conscience? If you know it not, why meddle with it?" And with one of his accustomed sudden turns, "What is all this?" he added. "One of those incidents to which we all, more or less, are exposed by the conditions of our career; no bitterness remains behind. Of what account is it in the presence of those mysteries, so varied, so numerous, that we all, in divers directions, are working to clear? It is true I have had recourse to an unusual means of defending myself against attacks not openly published, but I think that means was safe and loyal, and deferential towards you. And," he added, thinking of Biot and Senarmont, "will you have my full confession? You know that I had during fifteen years the inestimable advantage of the intercourse of two men who are no more, but whose scientific probity shone as one of the beacons of the Académie des Sciences. Before deciding on the course I have now followed, I questioned my memory and

endeavoured to revive their advice, and it seemed to me that they would not have disowned me."

M. Duclaux said about this meeting: "Pasteur has since then won many oratorical victories. I do not know of a greater one than that deserved by that acute and penetrating improvisation. He was still much heated as we were walking back to the Rue d'Ulm, and I remember making him laugh by asking him why, in the state of mind he was in, he had not concluded by hurling his wooden crystals at his adversaries' heads."

On December 8, 1862, Pasteur was elected a member of the Académie des Sciences; out of sixty voters he received thirty-six suffrages.

The next morning, when the gates of the Montparnasse cemetery were opened, a woman walked towards Biot's grave with her hands full of flowers. It was Mme. Pasteur who was bringing them to him who lay there since February 5, 1862, and who had loved Pasteur with so deep an affection.

A letter picked up at a sale of autographs, one of the last Biot wrote, gives a finishing touch to his moral portrait. It is addressed to an unknown person discouraged with this life. "Sir,—The confidence you honour me with touches me. But I am not a physician of souls. However, in my opinion, you could not do better than seek remedies to your moral suffering in work, religion, and charity. A useful work taken up with energy and persevered in will revive by occupation the forces of your mind. Religious feelings will console you by inspiring you with patience. Charity manifested to others will soften your sorrows and teach you that you are not alone to suffer in this life. Look around you, and you will see afflicted ones more to be pitied than yourself. Try to ease their sufferings; the good you will do to them will fall back upon yourself and will show you that a life which can thus be employed is not a burden which cannot, which must not be borne."

On his entering the Académie des Sciences, Balard and Dumas advised Pasteur to let alone his wooden crystals and to continue his studies on ferments. He undertook to demonstrate that "the hypothesis of a phenomenon of mere contact is not more admissible than the opinion which placed the ferment character exclusively in dead albuminoid matter. Whilst continuing his researches on beings which could live without air, he tried, as he went along, à propos of spontaneous generation, to find some weak point in his work. Until now the

liquids he had used, however alterable they were, had been brought up to boiling point. Was there not some new and decisive experiment to make? Could he not study organic matter as constituted by life and expose to the contact of air deprived of its germs some fresh liquids, highly putrescible, such as blood and urine? Claude Bernard, joining in these experiments of Pasteur's, himself took some blood from a dog. This blood was sealed up in a glass phial, with every condition of purity, and the phial remained in a stove constantly heated up to 30° C. from March 3 until April 20, 1862, when Pasteur laid it on the Académie table. The blood had suffered no sort of putrefaction; neither had some urine treated in the same way. "The conclusions to which I have been led by my first series of experiments," said Pasteur before the Académie, "are therefore applicable in all cases to organic substances."

While studying putrefaction, which is itself but a fermentation applied to animal materia, while showing the marvellous power of the infinitesimally small, he foresaw the immensity of the domain he had conquered, as will be proved by the following incident. Some time after the Académie election, in March, 1863, the Emperor, who took an interest in all that took place in the small laboratory of the Rue d'Ulm, desired to speak with Pasteur. J. B. Dumas claimed the privilege of presenting his former pupil, and the interview took place at the Tuileries. Napoleon questioned Pasteur with a gentle, slightly dreamy insistence. Pasteur wrote the next day: "I assured the Emperor that all my ambition was to arrive at the knowledge of the causes of putrid and contagious diseases."

In the meanwhile, the chapter on ferments was not yet closed; Pasteur was attracted by studies on wine. At the beginning of the 1863 holidays, just before starting for Arbois, he drew up this programme with one of his pupils: "From the 20th to the 30th (August) preparation in Paris of all the vessels, apparatus, products, that we must take. September 1, departure for the Jura; installation; purchase of the products of a vineyard. Immediate beginning of tests of all kinds. We shall have to hurry; grapes do not keep long."

Whilst he was preparing this vintage tour, which he intended to make with three "Normaliens," Duclaux, Gernez and Lechartier, the three heterogenists, Pouchet, Joly and Musset, proposed to use that same time in fighting Pasteur on his own ground. They started from Bagnères-de-Luchon

followed by several guides and taking with them all kinds of provisions and some little glass flasks with a slender pointed neck. They crossed the pass of Venasque without incident, and decided to go further, to the Rencluse. Some isard-stalkers having come towards the strange-looking party, they were signalled away; even the guides were invited to stand aside. It was necessary to prevent any dusts from reaching the bulbs, which were thus opened at 8 p.m. at a height of 2,083 metres. But eighty-three metres higher than the Montanvert did not seem to them enough, they wished to go higher. "We shall sleep on the mountain," said the three scientists. Fatigue and bitter cold, they withstood everything with the courage inspired by a problem to solve. The next morning they climbed across that rocky chaos, and at last reached the foot of one of the greatest glaciers of the Maladetta, 3,000 metres above the sea-level. "A very deep narrow crevasse," says Pouchet, "seemed to us the most suitable place for our experiments." Four phials (filled with a decoction of hay) were opened and sealed again with precautions that Pouchet considered as exaggerated.

Pouchet, in his merely scientific report, does not relate the return journey, yet more perilous than the ascent. At one of the most dangerous places, Joly slipped, and would have rolled into a precipice, but for the strength and presence of mind of one of the guides. All three at last came back to Luchon, forgetful of dangers run, and glorying at having reached 1,000 metres higher than Pasteur. They triumphed when they saw alteration in their flasks! "Therefore," said Pouchet, "the air of the Maladetta, and of high mountains in general, is not incapable of producing alteration in an eminently putrescible liquor; therefore heterogenia or the production of a new being devoid of parents, but formed at the expense of ambient organic matter, is for us a reality."

The Academy of Sciences was taking more and more interest in this debate. In November, 1863, Joly and Musset expressed a wish that the Academy should appoint a Commission, before whom the principal experiments of Pasteur and of his adversaries should be repeated. On this occasion Flourens expressed his opinion thus: "I am blamed in certain quarters for giving no opinion on the question of spontaneous generation. As long as my opinion was not formed, I had

nothing to say. It is now formed, and I give it : M. Pasteur's experiments are decisive. If spontaneous generation is real, what is required to obtain animalculæ? Air and putrescible liquor. M. Pasteur puts air and putrescible liquor together and nothing happens. Therefore spontaneous generation is not. To doubt further is to misunderstand the question."

Already in the preceding year, the Académie itself had evidenced its opinion by giving Pasteur the prize of a competition proposed in these terms : " To attempt to throw some new light upon the question of so-called spontaneous generation by well-conducted experiments." Pasteur's treatise on *Organized Corpuscles existing in Atmosphere* had been unanimously preferred. Pasteur might have entrenched himself behind the suffrages of the Academy, but begged it, in order to close those incessant debates, to appoint the Commission demanded by Joly and Musset.

The members of the Commission were Flourens, Dumas, Brongniart, Milne-Edwards, and Balard. Pasteur wished that the discussion should take place as soon as possible, and it was fixed for the first fortnight in March. But Pouchet, Joly and Musset asked for a delay on account of the cold. " We consider that it might compromise, perhaps prevent, our results, to operate in a temperature which often goes below zero even in the south of France. How do we know that it will not freeze in Paris between the first and fifteenth of March? " They even asked the Commission to adjourn experiments until the summer. " I am much surprised," wrote Pasteur, " at the delay sought by Messrs. Pouchet, Joly and Musset; it would have been easy with a stove to raise the temperature to the degree required by those gentlemen. For my part I hasten to assure the Academy that I am at its disposal, and that in summer, or in any other season, I am ready to repeat my experiments."

Some evening scientific lectures had just been inaugurated at the Sorbonne; such a subject as spontaneous generation was naturally on the programme. When Pasteur entered the large lecture room of the Sorbonne on April 7, 1864, he must have been reminded of the days of his youth, when crowds came, as to a theatrical performance, to hear J. B. Dumas speak. Dumas' pupil, now a master, in his turn found a still greater crowd invading every corner. Amongst the professors and students, such celebrities as Duruy,

Alexandre Dumas senior, George Sand, Princess Mathilde, were being pointed out. Around them, the inevitable "smart" people who must see everything and be seen everywhere, without whom no function favoured by fashion would be complete; in short what is known as the "Tout Paris." But this "Tout Paris" was about to receive a novel impression, probably a lasting one. The man who stood before this fashionable audience was not one of those speakers who attempt by an insinuating exordium to gain the good graces of their hearers; it was a grave-looking man, his face full of quiet energy and reflective force. He began in a deep, firm voice, evidently earnestly convinced of the greatness of his mission as a teacher: "Great problems are now being handled, keeping every thinking man in suspense; the unity or multiplicity of human races; the creation of man 1,000 years or 1,000 centuries ago, the fixity of species, or the slow and progressive transformation of one species into another; the eternity of matter; the idea of a God unnecessary. Such are some of the questions that humanity discusses nowadays."

He had now, he continued, entered upon a subject accessible to experimentation, and which he had made the object of the strictest and most conscientious studies. Can matter organize itself? Can living beings come into the world without having been preceded by beings similar to them? After showing that the doctrine of spontaneous generation had gradually lost ground, he explained how the invention of the microscope had caused it to reappear at the end of the seventeenth century, "in the face of those beings, so numerous, so varied, so strange in their shapes, the origin of which was connected with the presence of all dead vegetable and animal matter in a state of disorganization." He went on to say how Pouchet had taken up this study, and to point out the errors that this new partisan of an old doctrine had committed, errors difficult to recognize at first. With perfect clearness and simplicity, Pasteur explained how the dusts which are suspended in air contain germs of inferior organized beings and how a liquid preserved, by certain precautions, from the contact of these germs can be kept indefinitely, giving his audience a glimpse of his laboratory methods.

"Here," he said, "is an infusion of organic matter, as limpid as distilled water, and extremely alterable. It has been

prepared to-day. To-morrow it will contain animalculæ, little infusories, or flakes of mouldiness.

"I place a portion of that infusion into a flask with a long neck, like this one. Suppose I boil the liquid and leave it to cool. After a few days, mouldiness or animalculæ will develop in the liquid. By boiling, I destroyed any germs contained in the liquid or against the glass; but that infusion being again in contact with air, it becomes altered, as all infusions do. Now suppose I repeat this experiment, but that, before boiling the liquid, I draw (by means of an enameller's lamp) the neck of the flask into a point, leaving, however, its extremity open. This being done, I boil the liquid in the flask, and leave it to cool. Now the liquid of this second flask will remain pure not only two days, a month, a year, but three or four years—for the experiment I am telling you about is already four years old, and the liquid remains as limpid as distilled water. What difference is there, then, between those two vases? They contain the same liquid, they both contain air, both are open! Why does one decay and the other remain pure? The only difference between them is this: in the first case, the dusts suspended in air and their germs can fall into the neck of the flask and arrive into contact with the liquid, where they find appropriate food and develop; thence microscopic beings. In the second flask, on the contrary, it is impossible, or at least extremely difficult, unless air is violently shaken, that dusts suspended in air should enter the vase; they fall on its curved neck. When air goes in and out of the vase through diffusions or variations of temperature, the latter never being sudden, the air comes in slowly enough to drop the dusts and germs that it carries at the opening of the neck or in the first curves.

"This experiment is full of instruction; for this must be noted, that everything in air save its dusts can easily enter the vase and come into contact with the liquid. Imagine what you choose in the air—electricity, magnetism, ozone, unknown forces even, all can reach the infusion. Only one thing cannot enter easily, and that is dust, suspended in air. And the proof of this is that if I shake the vase violently two or three times, in a few days it contains animalculæ or mouldiness. Why? because air has come in violently enough to carry dust with it.

"And, therefore, gentlemen, I could 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 appropriated

to 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 which 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."

The public enthusiastically applauded these words, which ended the lecture :

" 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."

In the meanwhile, besides public lectures and new studies, Pasteur succeeded in " administering " the Ecole Normale in the most complete sense of the word. His influence was such that students acquired not a taste but a passion for study; he directed each one in his own line, he awakened their instincts. It was already through his wise inspiration that five " Normaliens agrégés " should have the chance of the five curators' places; but his solicitude did not stop there. If some disappointment befell some former pupil, still in that period of youth which doubts nothing or nobody, he came vigorously to his assistance; he was the counsellor of the future. A few letters will show how he understood his responsibility.

A Normalien, Paul Dalimier, received 1st at the *agrégation* of Physics in 1858, afterwards Natural History curator at the Ecole, and who, having taken his doctor's degree, asked to be sent to a Faculty, was ordered to go to the Lycée of Chaumont.

In the face of this almost disgrace he wrote a despairing letter to Pasteur. He could do nothing more, he said, his career was ruined. " My dear sir," answered Pasteur, " I much regret that I could not see you before your departure for Chaumont. But here is the advice which I feel will be useful to you. Do not manifest your just displeasure; but attract attention from the very first by your zeal and talent. In a word, aggravate, by your fine discharge of your new duties, the injustice which has been committed. The discouragement expressed in your

last letter is not worthy of a man of science. Keep but three objects before your eyes : your class, your pupils and the work you have begun. . . . Do your duty to the best of your ability. without troubling about the rest."

Pasteur undertook the rest himself. He went to the Ministry to complain of the injustice and unfairness, from a general point of view, of that nomination.

" Sir," answered the Chaumont exile, " I have received your kind letter. My deep respect for every word of yours will guarantee my intention to follow your advice. I have given myself up entirely to my class. I have found here a Physics cabinet in a deplorable state, and I have undertaken to reorganise it."

He had not time to finish : justice was done, and Paul Dalimier was made *maître des conférences* at the Ecole Normale. He died at twenty-eight.

The wish that masters and pupils should remain in touch with each other after the three years at the Ecole Normale had already in 1859 inspired Pasteur to write a report on the desirableness of an annual report entitled, *Scientific Annals of the Ecole Normale.*

The initiative of pregnant ideas often is traced back to France. But, through want of tenacity, she allows those same ideas to fall into decay and they are taken up by other nations, transplanted, developed, until they come back unrecognized to their mother country. Germany had seen the possibilities of such a publication as Pasteur's projected *Annals.* Renan wrote about that time to the editors of the *Revue Germanique,* a Review intended to draw France and Germany together : " In France, nothing is made public until achieved and ripened. In Germany, a work is given out provisionally, not as a teaching, but as an incitement to think, as a ferment for the mind."

Pasteur felt all the power of that intellectual ferment. In the volume entitled *Centenary of the Ecole Normale*, M. Gernez has recalled Pasteur's enthusiasm when he spoke of those *Annals.* Was it not for former pupils, away in the provinces, a means of collaborating with their old masters and of keeping in touch with Paris?

It was in June, 1864, that Pasteur presented the first number of this publication to the Académie des Sciences. M. Gernez, who was highly thought of by Pasteur, has not related in the *Centenary* that the book opened with some of his own

researches on the rotatory power of certain liquids and their steam.

At that same time, the heterogenists had at last placed themselves at the disposal of the Académie and were invited to meet Pasteur before the Natural History Commission at M. Chevreul's laboratory. "I affirm," said Pasteur, "that in any place it is possible to take up from the ambient atmosphere a determined volume of air containing neither egg nor spore and producing no generation in putrescible solutions." The Commission declared that, the whole contest bearing upon one simple fact, one experiment only should take place. The heterogenists wanted to recommence a whole series of experiments, thus reopening the discussion. The Commission refused, and the heterogenists, unwilling to concede the point, retired from the field, repudiating the arbiters that they had themselves chosen.

And yet Joly had written to the Académie, "If one only of our flasks remains pure, we will loyally own our defeat." A scientist who later became Permanent Secretary of the Académie des Sciences, Jamin, wrote about this conflict: "The heterogenists, however they may have coloured their retreat, have condemned themselves. If they had been sure of the fact—which they had solemnly engaged to prove or to own themselves vanquished,—they would have insisted on showing it, it would have been the triumph of their doctrine."

The heterogenists appealed to the public. A few days after their defeat, Joly gave a lecture at the Faculty of Medicine. He called the trial, as decided on by the Commission, a "circus competition"; he was applauded by those who saw other than scientific questions in the matter. The problem was now coming down from mountains and laboratories into the arena of society discussions. If all comes from a germ, people said, whence came the first germ? We must bow before that mystery, said Pasteur; it is the question of the origin of all things, and absolutely outside the domain of scientific research. But an invincible curiosity exists amongst most men which cannot admit that science should have the wisdom to content itself with the vast space between the beginning of the world and the unknown future. Many people transform a question of fact into a question of faith. Though Pasteur had brought into his researches a solely scientific preoccupation, many people approved or blamed him as the defender of a religious cause.

Vainly had he said, "There is here no question of religion, philosophy, atheism, materialism, or spiritualism. I might even add that they do not matter to me as a scientist. It is a question of fact; when I took it up I was as ready to be convinced by experiments that spontaneous generation exists as I am now persuaded that those who believe it are blindfolded."

It might have been thought that Pasteur's arguments were in support of a philosophical theory! It seemed impossible to those whose ideas came from an ardent faith, from the influence of their surroundings, from personal pride or from interested calculations to understand that a man should seek truth for its own sake and with no other object than to proclaim it. Hostilities were opened, journalists kept up the fire. A priest, the Abbé Moigno spoke of converting unbelievers through the proved non-existence of spontaneous generation. The celebrated novelist, Edmond About, took up Pouchet's cause with sparkling irony. "M. Pasteur preached at the Sorbonne amidst a concert of applause which must have gladdened the angels."

Thus, among the papers and reviews of that time we can follow the divers ideas brought out by these discussions. Guizot, then almost eighty, touched on this problem with the slightly haughty assurance of one conscious of having given much thought to his beliefs and destiny. "Man has not been formed through spontaneous generation, that is by a creative and organizing force inherent in matter; scientific observation daily overturns that theory, by which, moreover, it is impossible to explain the first appearance upon the earth of man in his complete state." And he praised "M. Pasteur, who has brought into this question the light of his scrupulous criticism."

Nisard was a wondering witness of what took place in the small laboratory of the Ecole Normale. Ever preoccupied by the relations between science and religion, he heard with some surprise Pasteur saying modestly, "Researches on primary causes are not in the domain of Science, which only recognizes facts and phenomena which it can demonstrate."

Pasteur did not disinterest himself from the great problems which he called the eternal subjects of men's solitary meditations. But he did not admit the interference of religion with science any more than that of science with religion.

His eagerness during a conflict was only equalled by his absolute forgetfulness after the conflict was over. He answered some one who, years later, reminded him of that past so full of attacks and praises. "A man of science should think of what will be said of him in the following century, not of the insults or the compliments of one day."

Pasteur, anxious to regain lost time, hurried to return to his studies on wine. "Might not the diseases of wines," he said at the Académie des Sciences in January, 1864, "be caused by organized ferments, microscopic vegetations, of which the germs would develop when certain circumstances of temperature, of atmospheric variations, of exposure to air, would favour their evolution or their introduction into wines? . . . I have indeed reached this result that the alterations of wines are co-existent with the presence and multiplication of microscopic vegetations." Acid wines, bitter wines, "ropy" wines, sour wines, he had studied them all with a microscope, his surest guide in recognizing the existence and form of the evil.

As he had more particularly endeavoured to remedy the cause of the acidity which often ruins the Jura red or white wines in the wood, the town of Arbois, proud of its celebrated rosy and tawny wines, placed an impromptu laboratory at his disposal during the holidays of 1864; the expenses were all to be covered by the town. "This spontaneous offer from a town dear to me for so many reasons," answered Pasteur to the Mayor and Town Council, "does too much honour to my modest labours, and the way in which it is made covers me with confusion." He refused it however, fearing that the services he might render should not be proportionate to the generosity of the Council. He preferred to camp out with his curators in an old coffee room at the entrance of the town, and they contented themselves with apparatus of the most primitive description, generally made by some local tinker or shoeing smith.

The problem consisted, in Pasteur's view, in opposing the development of organized ferments or parasitic vegetations, causes of the diseases of wines. After some fruitless endeavours to destroy all vitality in the germs of these parasites, he found that it was sufficient to keep the wine for a few moments at a temperature of 50° C. to 60° C. "I have also ascertained that wine was never altered by that preliminary operation, and as nothing prevents it afterwards from under-

going the gradual action of the oxygen in the air—the only cause, as I think, of its improvement with age—it is evident that this process offers every advantage."

It seems as if that simple and practical means, applicable to every quality of wine, now only had to be tried. But not so. Every progress is opposed by prejudice, petty jealousies, indolence even. A devoted obstinacy is required in order to overcome this opposition. Pasteur's desire was that his country should benefit by his discovery. An Englishman had written to him: "People are astonished in France that the sale of French wines should not have become more extended here since the Commercial Treaties. The reason is simple enough. At first we eagerly welcomed those wines, but we soon had the sad experience that there was too much loss occasioned by the diseases to which they are subject."

Pasteur was in the midst of those discussions, experimental sittings, etc., when J. B. Dumas suddenly asked of him the greatest of sacrifices, that of leaving the laboratory.

CHAPTER VI

1865—1870

An epidemic was ruining in terrible proportions the industry of the cultivation of silkworms. J. B. Dumas had been desired, as Senator, to draw up a report on the wishes of over 3,500 proprietors in sericicultural departments, all begging the public authorities to study the question of the causes of the protracted epidemic. Dumas was all the more preoccupied as to the fate of sericiculture that he himself came from one of the stricken departments. He was born on July 14, 1800, in one of the back streets of the town of Alais, to which he enjoyed returning as a celebrated scientist and a dignitary of the Empire. He gave much attention to all the problems which interested the national prosperity and considered that the best judges in these matters were the men of science. He well knew the conscientious tenacity—besides other characteristics—which his pupil and friend brought into any undertaking, and anxiously urged him to undertake this study. "Your proposition," wrote Pasteur in a few hurried lines, "throws me into a great perplexity; it is indeed most flattering and the object is a high one, but it troubles and embarrasses me! Remember, if you please, that I have never even touched a silkworm. If I had some of your knowledge on the subject I should not hesitate; it may even come within the range of my present studies. However, the recollection of your many kindnesses to me would leave me bitter regrets if I were to decline your pressing invitation. Do as you like with me." On May 17, 1865, Dumas wrote: "I attach the greatest value to seeing your attention fixed on the question which interests my poor country; the distress is beyond anything you can imagine."

Before his departure for Alais, Pasteur had read an essay on the history of the silkworm, published by one of his col-

leagues, Quatrefages, born like Dumas in the Gard. Quatrefages attributed to an Empress of China the first knowledge of the art of utilizing silk, more than 4,000 years ago. The Chinese, in possession of the precious insect, had jealously preserved the monopoly of its culture, even to the point of making it a capital offence to take beyond the frontiers of the Empire the eggs of the silkworm. A young princess, 2,000 years later, had the courage to infringe this law for love of her betrothed, whom she was going to join in the centre of Asia, and also through the almost equally strong desire to continue her fairy-like occupation after her marriage.

Pasteur appreciated the pretty legend, but was more interested in the history of the acclimatizing of the mulberry tree. From Provence Louis XI took it to Touraine : Catherine de Medici planted it in Orléanais. Henry IV had some mulberry trees planted in the park at Fontainebleau and in the Tuileries where they succeeded admirably. He also encouraged a *Treatise on the Gathering of Silk* by Olivier de Serres. This earliest agricultural writer in France was much appreciated by the king, in spite of the opposition of Sully, who did not believe in this new fortune for France. Documentary evidence is lacking as to the development of the silk industry.

From 1700 to 1788, wrote Quatrefages, France produced annually about 6,000,000 kilogrammes of cocoons. This was decreased by one-half under the Republic; wool replaced silk perhaps from necessity, perhaps from affectation.

Napoleon I restored that luxury. The sericicultural industry prospered from the Imperial Epoch until the reign of Louis Philippe, to such an extent as to reach in one year a total of 20,000,000 kilogrammes of cocoons, representing 100,000,000 francs. The name of Tree of Gold given to the mulberry, had never been better deserved.

Suddenly all these riches fell away. A mysterious disease was destroying the nurseries. "Eggs, worms, chrysalides, moths, the disease may manifest itself in all the organs," wrote Dumas in his report to the Senate. "Whence does it come? how is it contracted? No one knows. But its invasion is recognized by little brown or black spots." It was therefore called "corpuscle disease"; it was also designated as "*gattine*" from the Italian *gattino*, kitten; the sick worms held up their heads and put out their hooked feet like cats about

to scratch. But of all those names, that of "pébrine" adopted by Quatrefages was the most general. It came from the patois word *pébré* (pepper). The spots on the diseased worms were, in fact, rather like pepper grains.

The first symptoms had been noticed by some in 1845, by others in 1847. But in 1849 it was a disaster. The South of France was invaded. In 1853, seed had to be procured from Lombardy. After one successful year the same disappointments recurred. Italy was attacked, also Spain and Austria. Seed was procured from Greece, Turkey, the Caucasus, but the evil was still on the increase; China itself was attacked, and, in 1864, it was only in Japan that healthy seed could be found.

Every hypothesis was suggested, atmospheric conditions, degeneration of the race of silkworms, disease of the mulberry tree, etc.—books and treatises abounded, but in vain.

When Pasteur started for Alais (June 16, 1865), entrusted with this scientific mission by the Minister of Agriculture, his mind saw but that one point of interrogation, "What caused these fatal spots?" On his arrival he sympathetically questioned the Alaisians. He received confused and contradictory answers, indications of chimerical remedies; some cultivators poured sulphur or charcoal powder on the worms, some mustard meal or castor sugar; ashes and soot were used, quinine powders, etc. Some cultivators preferred liquids, and syringed the mulberry leaves with wine, rum or absinthe. Fumigations of chlorine, of coal tar, were approved by some and violently objected to by others. Pasteur, more desirous of seeking the origin of the evil than of making a census of these remedies, unceasingly questioned the nursery owners, who invariably answered that it was something like the plague or cholera. Some worms languished on the frames in their earliest days, others in the second stage only, some passed through the third and fourth moultings, climbed the twig and spun their cocoon. The chrysalis became a moth, but that diseased moth had deformed antennæ and withered legs, the wings seemed singed. Eggs (technically called seed) from those moths were inevitably unsuccessful the following year. Thus, in the same nursery, in the course of the two months that a larva takes to become a moth, the pébrine disease was alternately sudden or insidious: it burst out or disappeared, it hid itself within the chrysalis and reappeared in the moth or the eggs of a moth

which had seemed sound. The discouraged Alaisians thought that nothing could overcome pébrine.

Pasteur did not admit such resignation. But he began by one aspect only of the problem. He resolved to submit those corpuscles of the silkworm which had been observed since 1849 to microscopical study. He settled down in a small *magnanerie* near Alais; two series of worms were being cultivated. The first set was full grown; it came from some Japanese seed guaranteed as sound, and had produced very fine cocoons. The cultivator intended to keep the seed of the moths to compensate himself for the failure of the second set, also of Japanese origin, but not officially guaranteed. The worms of this second series were sickly and did not feed properly. And yet these worms, seen through the microscope, only exceptionally presented corpuscles; whilst Pasteur was surprised to find some in almost every moth or chrysalis from the prosperous nursery. Was it then elsewhere than in the worms that the secret of the pébrine was to be found?

Pasteur was interrupted in the midst of his experiments by a sudden blow. Nine days after his arrival, a telegram called him to Arbois: his father was very ill. He started, full of anguish, remembering the sudden death of his mother before he had had time to reach her, and that of Jeanne, his eldest daughter, who had also died far away from him in the little house at Arbois. His sad presentiment oppressed him during the whole of the long journey, and was fully justified; he arrived to find, already in his coffin, the father he so dearly loved and whose name he had made an illustrious one.

In the evening, in the empty room above the tannery, Pasteur wrote: "Dear Marie, dear children, the dear grandfather is no more; we have taken him this morning to his last resting place, close to little Jeanne's. In the midst of my grief I have felt thankful that our little girl had been buried there. . . . Until the last moment I hoped I should see him again, embrace him for the last time . . . but when I arrived at the station I saw some of our cousins all in black, coming from Salins; it was only then that I understood that I could but accompany him to the grave.

"He died on the day of your first communion, dear Cécile; those two memories will remain in your heart, my poor child. I had a presentiment of it when that very morning, at the hour when he was struck down, I was asking you to pray for

the grandfather at Arbois. Your prayers will have been acceptable unto God, and perhaps the dear grandfather himself knew of them and rejoiced with dear little Jeanne over Cécile's piety.

"I have been thinking all day of the marks of affection I have had from my father. For thirty years I have been his constant care, I owe everything to him. When I was young he kept me from bad company and instilled into me the habit of working and the example of the most loyal and best-filled life. He was far above his position both in mind and in character. . . . You did not know him, dearest Marie, at the time when he and my mother were working so hard for the children they loved, for me especially, whose books and schooling cost so much. . . . And the touching part of his affection for me is that it never was mixed with ambition. You remember that he would have been pleased to see me the headmaster of Arbois College? He foresaw that advancement would mean hard work, perhaps detrimental to my health. And yet I am sure that some of the success in my scientific career must have filled him with joy and pride; his son! his name! the child he had guided and cherished! My dear father, how thankful I am that I could give him some satisfaction!

"Farewell, dearest Marie, dear children. We shall often talk of the dear grandfather. How glad I am that he saw you all again a short time ago, and that he lived to know little Camille. I long to see you all, but must go back to Alais, for my studies would be retarded by a year if I could not spend a few days there now.

"I have some ideas on this disease, which is indeed a scourge for all those southern departments. The one *arrondissement* of Alais has lost an income of 120,000,000 francs during the last fifteen years. M. Dumas is a million times right; it must be seen to, and I am going to continue my experiments. I am writing to M. Nisard to have the admission examinations in my absence, which can easily be done."

Nisard wrote to him (June 19): "My dear friend, I heard of your loss, and I sympathize most cordially with you. . . . Take all the time necessary to you. You are away in the service of science, probably of humanity. Everything will be done according to your precise indications. I foresee no difficulty . . . everything is going on well at the Ecole.

In spite of your reserve—which is a part of your talent—I see that you are on the track, as M. Biot would have said, and that you will have your prey. Your name will stand next to that of Olivier de Serres in the annals of sericiculture."

On his return to Alais Pasteur went back to his observations with his scientific ardour and his customary generous eagerness to lighten the burden of others. He wrote in the introduction to his *Studies on Silkworm Disease* the following heartfelt lines—

"A traveller coming back to the Cévennes mountains after an absence of fifteen years would be saddened to see the change wrought in that countryside within such a short time. Formerly he might have seen robust men breaking up the rock to build terraces against the side and up to the summit of each mountain; then planting mulberry trees on these terraces. These men, in spite of their hard work, were then bright and happy, for ease and contentment reigned in their homes.

"Now the mulberry plantations are abandoned, the 'golden tree' no longer enriches the country, faces once beaming with health and good humour are now sad and drawn. Distress and hunger have succeeded to comfort and happiness."

Pasteur thought with sorrow of the sufferings of the Cévenol populations. The scientific problem was narrowing itself down. Faced by the contradictory facts that one successful set of cocoons had produced corpuscled moths, while an apparently unsuccessful set of worms showed neither corpuscles nor spots, he had awaited the last period of these worms with an impatient curiosity. He saw, amongst those which had started spinning, some which as yet showed no spots and no corpuscles. But corpuscles were abundant in the chrysalides, those especially which were in full maturity, on the eve of becoming moths; and none of the moths were free from them. Perhaps the fact that the disease appeared in the chrysalis and moth only explained the failures of succeeding series. "It was a mistake," wrote Pasteur (June 26, 1865), "to look for the symptom, the corpuscle, exclusively in the eggs or the worms; either might carry in themselves the germ of the disease, without presenting distinct and microscopically visible corpuscles. The evil developed itself chiefly in the chrysalides and the moths, it was there that it should chiefly be sought. There should be an infallible means of procuring healthy seed by having recourse to moths free from corpuscles.

This idea was like a searchlight flashed into the darkness. Pasteur thus formulated his hypothesis: "Every moth containing corpuscles must give birth to diseased seed. If a moth only has a few corpuscles, its eggs will provide worms without any, or which will only develop them towards the end of their life. If the moth is much infected, the disease will show itself in the earliest stages of the worm, either by corpuscles or by other unhealthy symptoms."

Pasteur studied hundreds of moths under the microscope. Nearly all, two or three couples excepted, were corpuscled, but that restricted quantity was increased by a precious gift. Two people, who had heard Pasteur ventilate his theories, brought him five moths born of a local race of silkworms and nurtured in the small neighbouring town of Anduze in the Turkish fashion, i.e. without any of the usual precautions consisting in keeping the worms in nurseries heated at an equal temperature. Everything having been tried, this system had also had its turn, without any appreciable success. By a fortunate circumstance, four out of those five moths were healthy.

Pasteur looked forward to the study in comparisons that the following spring would bring when worms were hatched both from the healthy and the diseased seed. In the meanwhile, only a few of the Alaisians, including M. Pagès, the Mayor, and M. de Lachadenède, really felt any confidence in these results. Most of the other silkworm cultivators were disposed to criticize everything, without having the patience to wait for results. They expressed much regret that the Government should choose a "mere chemist" for those investigations instead of some zoologist or silkworm cultivator. Pasteur only said, "Have patience."

He returned to Paris, where fresh sorrow awaited him: Camille, his youngest child, only two years old, was seriously ill. He watched over her night after night, spending his days at his task in the laboratory, and returning in the evening to the bedside of his dying child. During that same period he was asked for an article on Lavoisier by J. B. Dumas, who had been requested by the Government to publish his works.

"No one," wrote Dumas to Pasteur—"has read Lavoisier with more attention than you have; no one can judge of him better. . . . The chance which caused me to be born before you has placed me in communication with surroundings and with men in whom I have found the ideas and feelings which

have guided me in this work. But, had it been yours, I should have allowed no one else to be the first in drawing the world's attention to it. It is from this motive, also from a certain conformity of tastes and of principles which has long made you dear to me, that I now ask you to give up a few hours to Lavoisier."

"My dear and illustrious master," answered Pasteur (July 18, 1865), "in the face of your letter and its expressions of affectionate confidence, I cannot refuse to submit to you a paper which you must promise to throw away if it should not be exactly what you want. I must also ask you to grant me much time, partly on account of my inexperience, and partly on account of the fatigue both mental and bodily imposed on me by the illness of our dear child."

Dumas replied: "Dear friend and colleague, I thank you for your kind acquiescence in Lavoisier's interests, which might well be your own, for no one at this time represents better than you do his spirit and method,—a method in which reasoning had more share than anything else.

"The art of observation and that of experimentation are very distinct. In the first case, the fact may either proceed from logical reasons or be mere good fortune; it is sufficient to have some penetration and the sense of truth in order to profit by it. But the art of experimentation leads from the first to the last link of the chain, without hesitation and without a blank, making successive use of Reason, which suggests an alternative, and of Experience, which decides on it, until, starting from a faint glimmer, the full blaze of light is reached. Lavoisier made this art into a method, and you possess it to a degree which always gives me a pleasure for which I am grateful to you.

"Take your time. Lavoisier has waited seventy years! It is a century since his first results were produced! What are weeks and months?

"I feel for you with all my heart! I know how heartrending are those moments by the deathbed of a suffering child. I hope and trust this great sorrow will be spared you, as indeed you deserve that it should be."

The promise made by Dumas to give to France an edition of Lavoisier's works dated very far back. It was in May, 1836, in one of his eloquent lectures at the Collège de France, that Dumas had declared his intention of raising a scientific monu-

ment to the memory of this, perhaps the greatest of all French scientists. He had hoped that a Bill would be passed by the Government of Louis Philippe decreeing that this edition of Lavoisier's works would be produced at the expense of the State. But the usual obstacles and formalities came in the way. Governments succeeded each other, and it was only in 1861 that Dumas obtained the decree he wished for and that the book appeared.

Certainly Pasteur knew and admired as much as any one the discoveries of Lavoisier. But, in the presence of the series of labours accomplished, in spite of many other burdens, during that life cut off in its prime by the Revolutionary Tribunal (1792), labours collated for the first time by Dumas, Pasteur was filled with a new and vivid emotion. His logic in reasoning and his patience in observing nature had in no wise diminished the impetuous generosity of his feelings; a beautiful book, a great discovery, a brilliant exploit or a humble act of kindness would move him to tears. Concerning such a man as Lavoisier, Pasteur's curiosity became a sort of worship. He would have had the history of such a life spread everywhere. "Though one discovery always surpasses another, and though the chemical and physical knowledge accumulated since his time has gone beyond all Lavoisier's dreams," wrote Pasteur, "his work, like that of Newton and a few other rare spirits, will remain ever young. Certain details will age, as do the fashions of another time, but the foundation, the method, constitute one of those great aspects of the human mind, the majesty of which is only increased by years. . . ."

Pasteur's article appeared in the *Moniteur* and was much praised by the celebrated critic Sainte Beuve, whose literary lectures were often attended by Pasteur, between 1857 and 1861. The chronological order that we are following in this history of Pasteur's life allows us to follow the ideas and feelings with which he lived his life of hard daily work combined with daily devotion to others. Joys and sorrows can be chronicled, thanks to the confidences of those who loved him. His fame is indeed part of the future, but the tenderness which he inspired revives the memories of the past.

In September, 1865, little Camille died. Pasteur took the tiny coffin to Arbois and went back to his work. A letter written in November alludes to the depth of his grief.

It was à propos of a candidature to the Académie des

Sciences, Sainte Beuve was asked to help that of a young friend of his, Charles Robin. Robin occupied a professor's chair specially created for him at the *Faculté de Médecine*; he had made a deep microscopical study of the tissues of living bodies, of cellular life, of all which constitutes histology. He was convinced that outside his own studies, numerous questions would fall more and more into the domain of experimentation, and he believed that the faith in spiritual things could not "stand the struggle against the spirit of the times, wholly turned to positive things." He did not, like Pasteur, understand the clear distinction between the scientist on the one hand and the man of sentiment on the other, each absolutely independent. Neither did he imitate the reserve of Claude Bernard who did not allow himself to be pressed by any urgent questioner into enrolment with either the believers or the unbelievers, but answered: "When I am in my laboratory, I begin by shutting the door on materialism and on spiritualism; I observe facts alone; I seek but the scientific conditions under which life manifests itself." Robin was a disciple of Auguste Comte, and proclaimed himself a Positivist, a word which for superficial people was the equivalent of materialist. The same efforts which had succeeded in keeping Littré out of the Académie Française in 1863 were now attempted in order to keep Robin out of the Académie des Sciences in 1865.

Sainte Beuve, whilst studying medicine, had been a Positivist; his quick and impressionable nature had then turned to a mysticism which had inspired him to pen some fine verses. He had now returned to his former philosophy, but kept an open mind, however, criticism being for him not the art of dictating, but of understanding, and he was absolutely averse to irrelevant considerations when a candidature was in question.

The best means with Pasteur, who was no diplomat, was to go straight to the point. Sainte Beuve therefore wrote to him: "Dear Sir, will you allow me to be indiscreet enough to solicit your influence in favour of M. Robin, whose work I know you appreciate?

"M. Robin does not perhaps belong to the same philosophical school as you do; but it seems to me—from an outsider's point of view—that he belongs to the same scientific school. If he should differ essentially—whether in metaphysics or otherwise—would it not be worthy of a great scientist

to take none but positive work into account? Nothing more, nothing less.

"Forgive me; I have much resented the injustice towards you of certain newspapers, and I have sometimes asked myself if there were not some simple means of showing up all that nonsense, and of disproving those absurd and ill-intentioned statements. If M. Robin deserves to be of the Académie why should he not attain to it through you? . . .

"My sense of gratitude towards you for those four years during which you have done me the honour of including such a man as you are in my audience, also a feeling of friendship, are carrying me too far. I intended to mention this to you the other day at the Princess's; she had wished me to do so, but I feel bolder with a pen. . . ."

The Princess in question was Princess Mathilde. Her salon, a rendezvous of men of letters, men of science and artists, was a sort of second Academy which consoled Théophile Gautier for not belonging to the other. Sainte Beuve prided himself on being, so to speak, honorary secretary to this accomplished and charming hostess.

Pasteur answered by return of post. "Sir and illustrious colleague, I feel strongly inclined towards M. Robin, who would represent a new scientific element at the Academy—the microscope applied to the study of the human organism. I do not trouble about his philosophical school save for the harm it may do to his work. . . . I confess frankly, however, that I am not competent on the question of our philosophical schools. Of M. Comte I have only read a few absurd passages; of M. Littré I only know the beautiful pages you were inspired to write by his rare knowledge and some of his domestic virtues. My philosophy is of the heart and not of the mind, and I give myself up, for instance, to those feelings about eternity which come naturally at the bedside of a cherished child drawing its last breath. At those supreme moments, there is something in the depths of our souls which tells us that the world may be more than a mere combination of phenomena proper to a mechanical equilibrium brought out of the chaos of the elements simply through the gradual action of the forces of matter. I admire them all, our philosophers! We have experiments to straighten and modify our ideas, and we constantly find that nature is other than we had imagined. They, who are always guessing, how can they know! . . ."

Sainte Beuve was probably not astonished at Pasteur's somewhat hasty epithet applied to Auguste Comte, whom he had himself defined as "an obscure, abstruse, often diseased brain." After Robin's election he wrote to his "dear and learned colleague"—

"I have not allowed myself to thank you for the letter, so beautiful, if I may say so, so deep and so exalted in thought, which you did me the honour of writing in answer to mine. Nothing now forbids me to tell you how deeply I am struck with your way of thinking and with your action in this scientific matter."

That "something in the depths of our souls" of which Pasteur spoke in his letter to Sainte Beuve, was often perceived in his conversation; absorbed as he was in his daily task, he yet carried in himself a constant aspiration towards the Ideal, a deep conviction of the reality of the Infinite and a trustful acquiescence in the Mystery of the universe.

During the last term of the year 1865, he turned from his work for a time in order to study cholera. Coming from Egypt, the scourge had lighted on Marseilles, then on Paris, where it made in October more than two hundred victims per day; it was feared that the days of 1832 would be repeated, when the deaths reached twenty-three per 1,000. Claude Bernard, Pasteur, and Sainte Claire Deville went into the attics of the Lariboisière hospital, above a cholera ward.

"We had opened," said Pasteur, "one of the ventilators communicating with the ward; we had adapted to the opening a glass tube surrounded by a refrigerating mixture, and we drew the air of the ward into our tube, so as to condense into it as many as we could of the products of the air in the ward."

Claude Bernard and Pasteur afterwards tried blood taken from patients, and many other things; they were associated in those experiments, which gave no result. Henri Sainte Claire Deville once said to Pasteur, "Studies of that sort require much courage." "What about duty?" said Pasteur simply, in a tone, said Deville afterwards, worth many sermons. The cholera did not last long; by the end of the autumn all danger had disappeared.

Napeoleon the Third loved science, and found in it a sense of assured stability which politics did not offer him. He de-

sired Pasteur to come and spend a week at the Palace of Compiègne.

The very first evening a grand reception took place. The diplomatic world was represented by M. de Budberg, ambassador of Russia, and the Prussian ambassador, M. de Goltz. Among the guests were: Dr. Longet, celebrated for his researches and for his *Treatise on Physiology*, a most original physician, whose one desire was to avoid patients and so have more time for pure science; Jules Sandeau, the tender and delicate novelist, with his somewhat heavy aspect of a captain in the Garde Nationale; Paul Baudry, the painter, then in the flower of his youth and radiant success; Paul Dubois, the conscientious artist of the *Chanteur Florentin* exhibited that very year; the architect, Viollet le Duc, an habitué of the palace. The Emperor drew Pasteur aside towards the fireplace, and the scientist soon found himself instructing his Sovereign, talking about ferments and molecular dissymmetry.

Pasteur was congratulated by the courtiers on the favour shown by this immediate confidential talk, and the Empress sent him word that she wished him to talk with her also. Pasteur remembered this conversation, an animated one, a little disconnected, chiefly about animalculæ, infusories and ferments. When the guests returned to the immense corridor into which the rooms opened, each with the name of the guests on the door, Pasteur wrote to Paris for his microscope and for some samples of diseased wines.

The next morning a stag hunt was organized; riders in handsome costumes, open carriages drawn by six horses and containing guests, entered the forest; a stag was soon brought to bay by the hounds. In the evening, after dinner, there was a torchlight procession in the great courtyard. Amid a burst of trumpets, the footmen in state livery, standing in a circle, held aloft the flaming torches. In the centre, a huntsman held part of the carcase of the stag and waved it to and fro before the greedy eyes of the hounds, who, eager to hurl themselves upon it, and now restrained by a word, then let loose, and again called back all trembling at their discomfiture, were at length permitted to rush upon and devour their prey.

The next day offered another item on the programme, a visit to the castle of Pierrefonds, marvellously restored by

Viollet le Duc at the expense of the Imperial purse. Pasteur, who, like the philosopher, might have said, "I am never bored but when I am being entertained," made his arrangements so that the day should not be entirely wasted. He made an appointment for his return with the head butler, hoping to find a few diseased wines in the Imperial cellar. That department, however, was so well administered that he was only able to find seven or eight suspicious-looking bottles. The tall flunkeys, who scarcely realized the scientific interest offered by a basketful of wine bottles, watched Pasteur more or less ironically as he returned to his room, where he had the pleasure of finding his microscope and case of instruments sent from the Rue d'Ulm. He remained upstairs, absorbed as he would have been in his laboratory, in the contemplation of a drop of bitter wine revealing the tiny mycoderma which caused the bitterness.

In the meanwhile some of the other guests were gathered in the smoking room, smilingly awaiting the Empress's five o'clock tea, whilst others were busy with the preparations for the performance of Racine's *Plaideurs*, which Provost, Regnier, Got, Delaunay, Coquelin, and Mademoiselle Jouassain were going to act that very evening in the theatre of the palace.

On the Sunday, at 4 p.m., he was received privately by their Majesties, for their instruction and edification. He wrote in a letter to a friend: "I went to the Emperor with my microscope, my wine samples, and all my paraphernalia. When I was announced, the Emperor came up to meet me and asked me to come in. M. Conti, who was writing at a table, rose to leave the room, but was invited to stay. Then he fetched the Empress, and I began to show their Majesties various objects under the microscope and to explain them; it lasted a whole hour."

The Empress had been much interested, and wished that her five o'clock friends—who were waiting in the room where tea was served—should also acquire some notions of these studies. She merrily took up the microscope, laughing at her new occupation of laboratory attendant, and arrived thus laden in the drawing-room, much to the surprise of her privileged guests. Pasteur came in behind her, and gave a short and simple account of a few general ideas and precise discoveries.

In the same way, the preceding week, Le Verrier[1] had spoken of his planet, and Dr. Longet had given a lecture on the circulation of the blood. That butterfly world of the Court, taking a momentary interest in scientific things, did not foresee that the smallest discovery made in the poor laboratory of the Rue d'Ulm would leave a more lasting impression than the fêtes of the Tuileries of Fontainebleau and of Compiègne.

In the course of their private interview, Napoleon and Eugénie manifested some surprise that Pasteur should not endeavour to turn his discoveries and their applications to a source of legitimate profit. "In France," he replied, "scientists would consider that they lowered themselves by doing so."

He was convinced that a man of pure science would complicate his life, the order of his thoughts, and risk paralysing his inventive faculties, if he were to make money by his discoveries. For instance, if he had followed up the industrial results of his studies on vinegar, his time would have been too much and too regularly occupied, and he would not have been free for new researches.

"My mind is free," he said. "I am as full of ardour for the new question of silkworm disease as I was in 1863, when I took up the wine question."

What he most wished was to be able to watch the growth of the silkworms from the very first day, and to pursue without interruption this serious study in which the future of France was interested. That, and the desire to have one day a laboratory adequate to the magnitude of his works were his only ambitions. On his return to Paris he obtained leave to go back to Alais.

"My dear Raulin," wrote Pasteur to his former pupil in January, 1866. "I am again entrusted by the Minister of Agriculture with a mission for the study of silkworm disease, which will last at least five months, from February 1 to the end of June. Would you care to join me?"

[1] Le Verrier, a celebrated astronomer, at that time Director of the Paris Observatory. His calculations led him to surmise the existence of the planet Neptune, which was discovered accordingly. Adam, an English astronomer, attained the same result, by the same means, at the same time, each of the two scientists being in absolute ignorance of the work of the other. Le Verrier was the first to publish his discovery. [Trans.]

Raulin excused himself; he was then preparing, with his accustomed slow conscientiousness, his doctor's thesis, a work afterwards considered by competent judges to be a masterpiece.

"I must console myself," wrote Pasteur, expressing his regrets, "by thinking that you will complete your excellent thesis."

One of Raulin's fellow students at the Ecole Normale, M. Gernez, was now a professor at the Collège Louis le Grand. His mind was eminently congenial to Pasteur's. Duruy, then Minister of Public Instruction, was ever anxious to smooth down all difficulties in the path of science: he gave a long leave of absence to M. Gernez, in order that he might take Raulin's place. Another young *Normalien*, Maillot, prepared to join the scientific party, much to his delight. The three men left Paris at the beginning of February. They began by spending a few days in an hotel at Alais, trying to find a suitable house where they would set up their temporary laboratory. After a week or two in a house within the town, too far, to be convenient, from the restaurant where they had their meals, Maillot discovered a lonely house at the foot of the Mount of the Hermitage, a mountain once covered with flourishing mulberry trees, but now abandoned, and growing but a few olive trees.

This house, at Pont Gisquet, not quite a mile from Alais, was large enough to hold Pasteur, his family and his pupils; a laboratory was soon arranged in an empty orangery.

"Then began a period of intense work," writes M. Gernez. "Pasteur undertook a great number of trials, which he himself followed in their minutest details; he only required our help over similar operations by which he tested his own. The result was that above the fatigues of the day, easily borne by us strong young men, he had to bear the additional burden of special researches, importunate visitors, and an equally importunate correspondence, chiefly dealing out criticisms . . ."

Madame Pasteur, who had been detained in Paris for her children's education, set out for Alais with her two daughters. Her mother being then on a visit to the rector of the Chambéry Academy, M. Zevort, she arranged to spend a day or two in that town. But hardly had she arrived when her daughter Cécile, then twelve years old, became ill with typhoid fever.

Madame Pasteur had the courage not to ask her husband to leave his work and come to her; but her letters alarmed him, and the anxious father gave up his studies for a few days and arrived at Chambéry. The danger at that time seemed averted, and he only remained three days at Chambéry. Cécile, apparently convalescent, had recovered her smile, that sweet, indefinable smile which gave so much charm to her serious, almost melancholy face. She smiled thus for the last time at her little sister Marie-Louise, about the middle of May, lying on a sofa by a sunny window.

On May 21, her doctor, Dr. Flesschutt, wrote to Pasteur: "If the interest I take in the child were not sufficient to stimulate my efforts, the mother's courage would keep up my hopes and double my ardent desire for a happy issue." Cécile died on May 23 after a sudden relapse. Pasteur only arrived at Chambéry in time to take to Arbois the remains of the little girl, which were buried near those of his mother, of his two other daughters, Jeanne and Camille, and of his father, Joseph Pasteur. The little cemetery indeed represented a cup of sorrows for Pasteur.

"Your father has returned from his sad journey to Arbois," wrote Madame Pasteur from Chambéry to her son who was at school in Paris. "I did think of going back to you, but I could not leave your poor father to go back to Alais alone after this great sorrow." Accompanied by her who was his greatest comfort, and who gave him some of her own courage, Pasteur came back to the Pont Gisquet and returned to his work. M. Duclaux in his turn joined the hard-working little party.

At the beginning of June, Duruy, with the solicitude of a Minister who found time to be also a friend, wrote affectionately to Pasteur—

"You are leaving me quite in the dark, yet you know the interest I take in your work. Where are you? and what are you doing? Finding out something I feel certain. . . ."

Pasteur answered, "Monsieur le Ministre, I hasten to thank you for your kind reminder. My studies have been associated with sorrow; perhaps your charming little daughter, who used to play sometimes at M. Le Verrier's, will remember Cécile Pasteur among other little girls of her age that she used to meet at the Observatoire. My dear child was coming with her mother to spend the Easter holidays with me at Alais,

when, during a few days' stay at Chambéry, she was seized with an attack of typhoid fever, to which she succumbed after two months of painful suffering. I was only able to be with her for a few days, being kept here by my work, and full of deceiving hopes for a happy issue from that terrible disease.

"I am now wholly wrapped up in my studies, which alone take my thoughts from my deep sorrow.

"Thanks to the facilities which you have put in my way, I have been able to collect a quantity of experimental observations, and I think I understand on many points this disease which has been ruining the South for fifteen or twenty years. I shall be able on my return to propose to the Commission of Sericiculture a practical means of fighting the evil and suppressing it in the course of a few years.

"I am arriving at this result that there is no silkworm disease. There is but an exaggeration of a state of things which has always existed, and it is not difficult, in my view, to return to the former situation, even to improve on it. The evil was sought for in the worm and even in the seed; that was something, but my observations prove that it develops chiefly in the chrysalis, especially in the mature chrysalis, at the moment of the moth's formation, on the eve of the function of reproduction. The microscope then detects its presence with certitude, even when the seed and the worm seem very healthy. The practical result is this: you have a nursery full; it has been successful or it has not; you wish to know whether to smother the cocoons or whether to keep them for reproduction. Nothing is simpler. You hasten the development of about 100 moths through an elevation of temperature, and you examine these moths through the microscope, which will tell you what to do.

"The sickly character is then so easy to detect that a woman or a child can do it. If the cultivator should be a peasant, without the material conditions required for this study, he can do this: instead of throwing away the moths after they have laid their eggs, he can bottle a good many of them in brandy and send them to a testing office or to some experienced person who will determine the value of the seed for the following year."

The Japanese Government sent some cases of seed supposed to be healthy to Napoleon III, who distributed them in the

silkworm growing departments. Pasteur, in the meanwhile, was stating the results he had arrived at, and they were being much criticized. In order to avoid the pébrine, which was indeed the disease caused by the corpuscles so clearly visible through the microscope, he averred that no seed should be used that came from infected moths. In order to demonstrate the infectious character of the pébrine he would give to some worms meals of leaves previously contaminated by means of a brush dipped in water containing corpuscles. The worms absorbed the food, and the disease immediately appeared and could be found in the chrysalides and moths from those worms.

"I hope I am in the right road—close to the goal, perhaps, but I have not yet reached it," wrote Pasteur to his faithful Chappuis; "and as long as the final proof is not acquired complications and errors are to be feared. Next year, the growth of the numerous eggs I have prepared will obviate my scruples, and I shall be sure of the value of the preventive means I have indicated. It is tiresome to have to wait a year before testing observations already made; but I have every hope of success."

While awaiting the renewal of the silkworm season, he was busy editing his book on wine, full of joy at contributing to the national riches through practical application of his observations. It was, in fact, sufficient to heat the wines by the simple process already at that time known in Austria as *pasteurisation*, to free them from all germs of disease and make them suitable for keeping and for exportation. He did not accord much attention to the talk of old gourmets who affirmed that wines thus "mummified" could not mellow with age, being convinced on the contrary that the most delicate wines could only be improved by heating. "The ageing of wines," he said, "is due, not to fermentation, but to a slow oxidation which is favoured by heat."

He alluded in his book to the interest taken by Napoleon III in those researches which might be worth millions to France. He also related how the Imperial solicitude had been awakened, and acknowledged gratitude for this to General Favé, one of the Emperor's aides de camp.

The General, on reading the proofs, declared that his name must disappear. Pasteur regretfully gave in to his scruples, but wrote the following words on the copy presented to General Favé: "General, this book contains a serious omission—that of your name: it would be an unpardonable one had it not been

made at your own request, according to your custom of keeping your good works secret. Without you, these studies on wine would not exist; you have helped and encouraged them. Leave me at least the satisfaction of writing that name on the first page of this copy, of which I beg you to accept the homage, while renewing the expression of my devoted gratitude."

Another incident gives us an instance of Pasteur's kindness of heart. In the year 1866 Claude Bernard suffered from a gastric disease so serious that his doctors, Rayer and Davaine, had to admit their impotence. Bernard was obliged to leave his laboratory and retire to his little house at St. Julien (near Villefranche), his birthplace. But the charm of his recollections of childhood was embittered by present sadness. His mind full of projects, his life threatened in its prime, he had the courage, a difficult thing to unselfish people, of resolutely taking care of himself. But preoccupied solely with his own diet, his own body now a subject for experiments, he became a prey to a deep melancholia. Pasteur, knowing to what extent moral influences react on the physique, had the idea of writing a review of his friend's works, and published it in the *Moniteur Universel* of November 7, 1866, under the following title: *Claude Bernard: the Importance of his Works, Teaching and Method.* He began thus: "Circumstances have recently caused me to re-peruse the principal treatises which have founded the reputation of our great physiologist, Claude Bernard.

"I have derived from them so great a satisfaction, and my admiration for his talent has been confirmed and increased to such an extent that I cannot resist the somewhat rash desire of communicating my impressions. . . ."

Amongst Claude Bernard's discoveries, Pasteur chose that which seemed to him most instructive, and which Claude Bernard himself appreciated most: "When M. Bernard became in 1854 a candidate for the Académie des Sciences, his discovery of the glycogenic functions of the liver was neither the first nor the last among those which had already placed him so high in the estimation of men of science; yet it was by that one that he headed his list of the claims which could recommend him to the suffrages of the illustrious body. That preference on the part of the master decides me in mine."

Claude Bernard had begun by meditating deeply on the

disease known as diabetes and which is characterized, as everybody knows, by a superabundance of sugar in the whole of the organism, the urine often being laden with it. But how is it, wondered Claude Bernard, that the quantity of sugar expelled by a diabetic patient can so far surpass that with which he is provided by the starchy or sugary substances which form part of his food? How is it that the presence of sugary matter in the blood and its expulsion through urine are never completely arrested, even when all sugary or starchy alimentation is suppressed? Are there in the human organism sugar-producing phenomena unknown to chemists and physiologists? All the notions of science were contrary to that mode of thinking; it was affirmed that the vegetable kingdom only could produce sugar, and it seemed an insane hypothesis to suppose that the animal organism could fabricate any. Claude Bernard dwelt upon it however, his principle in experimentation being this: "When you meet with a fact opposed to a prevailing theory, you should adhere to the fact and abandon the theory, even when the latter is supported by great authorities and generally adopted."

This is what he imagined, summed up in a few words by Pasteur—

"Meat is an aliment which cannot develop sugar by the digestive process known to us. Now M. Bernard having fed some carnivorous animals during a certain time exclusively with meat, he assured himself, with his precise knowledge of the most perfect means of investigation offered him by chemistry, that the blood which enters the liver by the portal vein and pours into it the nutritive substances prepared and rendered soluble by digestion is absolutely devoid of sugar; whilst the blood which issues from the liver by the hepatic veins is always abundantly provided with it. . . . M. Claude Bernard has also thrown full light on the close connection which exists between the secretion of sugar in the liver and the influence of the nervous system. He has demonstrated, with a rare sagacity, that by acting on some determined portion of that system it was possible to suppress or exaggerate at will the production of sugar. He has done more still; he has discovered within the liver the existence of an absolutely new substance which is the natural source whence this organ draws the sugar that it produces."

Pasteur, starting from this discovery of Claude Bernard's,

spoke of the growing close connection between medicine and physiology. Then, with his constant anxiety to incite students to enthusiasm, he recommended them to read the lectures delivered by Bernard at the Collège de France. Speaking of the *Introduction to the Study of Experimental Medicine*, Pasteur wrote: "A long commentary would be necessary to present this splendid work to the reader; it is a monument raised to honour the method which has constituted Physical and Chemical Science since Galileo and Newton, and which M. Bernard is trying to introduce into physiology and pathology. Nothing so complete, so profound, so luminous has ever been written on the true principles of the difficult art of experimentation. . . . This book will exert an immense influence on medical science, its teaching, its progress, its language even." Pasteur took pleasure in adding to his own tribute praise from other sources. He quoted, for instance, J. B. Dumas' answer to Duruy, who asked him, "What do you think of this great physiologist?" "He is not a great physiologist; he is Physiology itself." "I have spoken of the man of science," continued Pasteur. "I might have spoken of the man in everyday life, the colleague who has inspired so many with a solid friendship, for I should seek in vain for a weak point in M. Bernard; it is not to be found. His personal distinction, the noble beauty of his physiognomy, his gentle kindliness attract at first sight; he has no pedantry, none of a scientist's usual faults, but an antique simplicity, a perfectly natural and unaffected manner, while his conversation is deep and full of ideas. . . ." Pasteur, after informing the public that the graver symptoms of Bernard's disease had now disappeared, ended thus: "May the publicity now given to these thoughts and feelings cheer the illustrious patient in his enforced idleness, and assure him of the joy with which his return will be welcomed by his friends and colleagues."

The very day after this article reached him (November 19, 1860) Bernard wrote to Pasteur: "My dear friend,—I received yesterday the *Moniteur* containing the superb article you have written about me. Your great praise indeed makes me proud, though I feel I am yet very far from the goal I would reach. If I return to health, as I now hope I may do, I think I shall find it possible to pursue my work in a more methodical order and with more complete means of demonstration, better indicating the general idea towards which my

various efforts converge. In the meanwhile it is a very precious encouragement to me to be approved and praised by a man such as you. Your works have given you a great name, and have placed you in the first rank among experimentalists of our time. The admiration which you profess for me is indeed reciprocated; and we must have been born to understand each other, for true science inspires us both with the same passion and the same sentiments.

"Forgive me for not having answered your first letter; but I was really not equal to writing the notice you wanted. I have deeply felt for you in your family sorrow; I have been through the same trial, and I can well understand the sufferings of a tender and delicate soul such as yours."

Henri Sainte Claire Deville, who was as warm-hearted as he was witty, had, on his side, the ingenious idea of editing an address of collective wishes for Claude Bernard, who answered: "My dear friend,—You are evidently as clever in inventing friendly surprises as in making great scientific discoveries. It was indeed a most charming idea, and one for which I am very grateful to you—that of sending me a collective letter from my friends. I shall carefully preserve that letter: first, because the feelings it expresses are very dear to me; and also because it is a collection of illustrious autographs which should go down to posterity. I beg you will transmit my thanks to our friends and colleagues, E. Renan, A. Maury, F. Ravaisson and Bellaguet. Tell them how much I am touched by their kind wishes and congratulations on my recovery. It is, alas, not yet a cure, but I hope I am on a fair way to it.

"I have received the article Pasteur has written about me in the *Moniteur*; that article paralysed the vasomotor nerves of my sympathetic system, and caused me to blush to the roots of my hair. I was so amazed that I don't know what I wrote to Pasteur; but I did not dare say to him that he had wrongly exaggerated my merits. I know he believes all that he writes, and I am happy and proud of his opinion, because it is that of a scientist and experimentalist of the very first rank. Nevertheless, I cannot help thinking that he has seen me through the prism of his kindly heart, and that I do not deserve such excessive praise. I am more than thankful for all the marks of esteem and friendship which are showered upon me. They make me cling closer to life, and feel that I should be very

foolish not to take care of myself and continue to live amongst those who love me, and who deserve my love for all the happiness they give me. I intend to return to Paris some time this month, and, in spite of your kind advice, I should like to take up my Collège de France classes again this winter. I hope to be allowed not to begin before January. But we shall talk of all this in Paris. I remain your devoted and affectionate friend."

To end this academic episode, we will quote from Joseph Bertrand's letter of thanks to Pasteur, who had sent him the article: ". . . The public will learn, among other things, that the eminent members of the Academy admire and love each other sometimes with no jealousy. This was rare in the last century, and, if all followed your example, we should have over our predecessors one superiority worth many another."

Thus Pasteur showed himself a man of sentiment as well as a man of science; the circle of his affections was enlarging, as was the scope of his researches, but without any detriment to the happy family life of his own intimate circle. That little group of his family and close friends identified itself absolutely with his work, his ideas and his hopes, each member of it willingly subordinating his or her private interests to the success of his investigations. He was at that time violently attacked by his old adversaries as well as his new contradictors. Pouchet announced everywhere that the question of spontaneous generation was being taken up again in England, in Germany, in Italy and in America. Joly, Pouchet's inseparable friend, was about to make some personal studies and to write some general considerations on the new silkworm campaign. Pasteur, who had confidently said, "The year 1867 must be the last to bear the complaints of silkworm cultivators!" went back to Alais in January, 1867. But, before leaving Paris, Pasteur wrote out for himself a list of various improvements and reforms which he desired to effect in the administration of the Ecole Normale, showing that his interest in the great school had by no means abated, in spite of his necessary absence. He brought with him his wife and daughter, and Messrs. Gernez and Maillot; M. Duclaux was to come later. The worms hatched from the eggs of healthy moths and those from diseased ones were growing more interesting every day; they were in every instance exactly what Pasteur had prophesied they would be. But besides studying his own silk-

worms, he liked to see what was going on in neighbouring *magnaneries*. A neighbour in the Pont Gisquet, a cultivator of the name of Cardinal, had raised with great success a brood originating from the famous Japanese seed. He was disappointed, however, in the eggs produced by the moths, and Pasteur's microscope revealed the fact that those moths were all corpuscled, in spite of their healthy origin. Pasteur did not suspect that origin, for the worms had shown health and vigour through all their stages of growth, and seemed to have issued from healthy parents. But Cardinal had raised another brood, the produce of unsound seed, immediately above these healthy worms. The excreta from this second brood could fall on to the frames of those below them, and the healthy worms had become contaminated. Pasteur demonstrated that the pébrine contagion might take place in one or two different ways: either from direct contact between the worms on the same frame, or by the soiling of the food from the very infectious excreta. The remedy for the pébrine seemed now found. "The corpuscle disease," said Pasteur, "is as easily avoided as it is easily contracted." But when he thought he had reached his goal a sudden difficulty rose in his way. Out of sixteen broods of worms which he had raised, and which presented an excellent appearance, the sixteenth perished almost entirely immediately after the first moulting. "In a brood of a hundred worms," wrote Pasteur, "I picked up fifteen or twenty dead ones every day, black and rotting with extraordinary rapidity. . . . They were soft and flaccid like an empty bladder. I looked in vain for corpuscles; there was not a trace of them."

Pasteur was temporarily troubled and discouraged. But he consulted the writings of former students of silkworm diseases, and, when he discovered vibriones in those dead worms, he did not doubt that he had under his eyes a well characterized example of the flachery disease—a disease independent and distinct from the pébrine. He wrote to Duruy, and acquainted him with the results he had obtained and the obstacles he encountered. Duruy wrote back on April 9, 1867—

"Thank you for your letter and the good news it contains.

"Not very far from you, at Avignon, a statue has been erected to the Persian who imported into France the cultivation of madder; what then will not be done for the rescuer of two of our greatest industries! Do not forget to inform me

when you have mastered the one or two lame facts which still stand in the way. As a citizen, as head of the Université, and, if I may say so, as your friend, I wish I could follow your experiments day by day.

"You know that I should like to found a special college at Alais. Please watch for any useful information on that subject. We will talk about it on your return.

"I am obliged to M. Gernez for his assiduous and intelligent collaboration with you."

This letter from the great Minister is all the more interesting that it is dated from the eve of the day when the law on the reorganization of primary teaching was promulgated.

The introduction into the curriculum of historical and geographical notions; the inauguration of 10,000 schools and 30,000 adult classes; the transformation of certain flagging classical colleges into technical training schools; a constant struggle to include the teaching of girls in Université organization; reforms and improvements in general teaching; the building of laboratories, etc., etc.—into the accomplishment of all these projects Duruy carried his bold and methodical activity. No one was more suited than he to the planning out of a complete system of national education. He and Pasteur were indeed fitted to understand each other, for each had in the same degree those three forms of patriotism: love for the land, memories for the past, and hero worship.

In May, 1867, Pasteur received at Alais the news that a grand prize medal of the 1867 exhibition was conferred upon him for his works on wines. He hastened to write to Dumas—

"My dear master, . . . Nothing has surprised me more—or so agreeably,—than the news of this Exhibition prize medal, which I was far from expecting. It is a new proof of your kindness, for I feel sure that I have to thank you for originating such a favour. I shall do all I can to make myself worthy of it by my perseverance in putting all difficulties aside from the subject I am now engaged in, and in which the light is growing brighter every day. If that flachery disease had not come to complicate matters, everything would be well by now. I cannot tell you how absolutely sure I now feel of my conclusions concerning the corpuscle disease. I could say a great deal about the articles of Messrs. Béchamp, Estor and Balbiani, but I will follow your advice and answer nothing . . ."

Dumas had been advising Pasteur not to waste his time by

answering his adversaries and contradictors. Pasteur's system was making way; ten microscopes were set up, here and there, in the town of Alais; most seed merchants were taking up the examination of the dead moths, and the Pont-Gisquet colony had samples brought in daily for inspection. "I have already prevented many failures for next year," he wrote to Dumas (June, 1867), "but I always beg as a favour that a little of the condemned seed may be raised, so as to confirm the exactness of my judgment."

His system was indeed quite simple; at the moment when the moths leave their cocoons and mate with each other, the cultivator separates them and places each female on a little square of linen where it lays its eggs. The moth is afterwards pinned up in a corner of the same square of linen, where it gradually dries up; later on, in autumn or even in winter, the withered moth is moistened in a little water, pounded in a mortar, and the paste examined with a microscope. If the least trace of corpuscles appears the linen is burnt, together with the seed which would have perpetuated the disease.

Pasteur came back to Paris to receive his medal; perhaps his presence was not absolutely necesary, but he did not question the summons he received. He always attached an absolute meaning to words and to things, not being one of those who accept titles and homage with an inward and ironical smile.

The pageant of that distribution of prizes was well worth seeing, and July 1, 1867, is now remembered by many who were children at that time. Paris afforded a beautiful spectacle; the central avenue of the Tuileries garden, the Place de la Concorde, the Avenue des Champs Elysées, were lined along their full length by regiments of infantry, dragoons, Imperial Guards, etc., etc., standing motionless in the bright sunshine, waiting for the Emperor to pass. The Imperial carriage, drawn by eight horses, escorted by the Cent-Gardes in their pale blue uniform, and by the Lancers of the Household, advanced in triumphant array. Napoleon III sat next to the Empress, the Prince Imperial and Prince Napoleon facing them. From the Palais de l'Elysée, amidst equally magnificent ceremonial, the Sultan Abdul-Aziz and his son arrived; then followed a procession of foreign princes: the Crown Prince of Prussia, the Prince of Wales, Prince Humbert of Italy, the Duke and Duchess of Aosta, the Grand Duchess Marie of Russia, all of whom have since borne a part in

European politics. They entered the Palais de l'Industrie and sat around the throne. From the ground to the first floor an immense stand was raised, affording seats for 17,000 persons. The walls were decorated with eagles bearing olive branches, symbolical of strength and peace. The Emperor in his speech dwelt upon these hopes of peace, whilst the Empress in white satin, wearing a diadem, and surrounded by white-robed princesses, brightly smiled at these happy omens.

On their names being called out, the candidates who had won Grand Prizes, and those about to be promoted in the Legion of Honour, went up one by one to the throne. Marshal Vaillant handed each case to the Emperor, who himself gave it to the recipient. This old Field-Marshal, with his rough bronzed face, who had been a captain in the retreat from Moscow and was now a Minister of Napoleon III, seemed a natural and glorious link between the First and the Second Empires. He was born at Dijon in humble circumstances, of which he was somewhat proud, a very cultured soldier, interested in scientific things, a member of the Institute. The names of certain members of the Legion of Honour promoted to a higher rank, such as Gérôme and Meissonier, that of Ferdinand de Lesseps, rewarded for the achievement of the Suez Canal, excited great applause. Pasteur was called without provoking an equal curiosity : his scientific discoveries, in spite of their industrial applications, being as yet known but to a few. "I was struck," writes an eye-witness, "with his simplicity and gravity ; the seriousness of his life was visible in his stern, almost sad eyes."

At the end of the ceremony, when the Imperial procession left the Palais de l'Industrie, an immense chorus, accompanied by an orchestra, sang *Domine salvum fac imperatorem.*

On his return to his study in the Rue d'Ulm, Pasteur again took up the management of the scientific studies of the Ecole Normale. But an incident put an end to his directorship, while bringing perturbation into the whole of the school. Sainte Beuve was the indirect cause of this small revolution. The Senate, of which he was a member, had had to examine a protest from 102 inhabitants of St. Etienne against the introduction into their popular libraries of the works of Voltaire, J. J. Rousseau, Balzac, E. Renan, and others. The committee had approved this petition in terms which identified the report with the petition itself. Sainte Beuve, too exclusively

literary in his tastes, and too radical in his opinions to be popular in the Senate, rose violently against this absolute and arbitrary judgment, forgetting everything but the jeopardy of free opinions before the excessive and inquisitorial zeal of the Senate. His speech was very unfavourably received, and one of his colleagues, M. Lacaze, aged sixty-eight, challenged him to a duel. Sainte Beuve, himself then sixty-three years old, refused to enter into what he called "the summary jurisprudence which consists in strangling a question and suppressing a man within forty-eight hours."

The students of the Ecole Normale deputed one of their number to congratulate Sainte Beuve on his speech, and wrote the following letter —

"We have already thanked you for defending freedom of thought when misjudged and attacked; now that you have again pleaded for it, we beg you to receive our renewed thanks.

"We should be happy if the expression of our grateful sympathy could console you for this injustice. Courage is indeed required to speak in the Senate in favour of the independence and the rights of thought; but the task is all the more glorious for being more difficult. Addresses are now being sent from everywhere; you will forgive the students of the Ecole Normale for having followed the general lead and having sent their address to M. Sainte Beuve."

This letter was published in a newspaper. Etienne Arago published it without remembering the Université by-laws which forbade every sort of political manifestation to the students. It had given pleasure to Sainte Beuve, the pleasure that elderly men take in the applause of youth; but he soon became uneasy at the results of this noisy publicity.

Nisard, the Director of the school, could not very well tolerate this breach of discipline. In spite of the entreaties of Sainte Beuve, the student who had signed the letter was provisionally sent back to his family. His comrades revolted at this and imperiously demanded his immediate restoration. Pasteur attempted to pacify them by speaking to them, but failed utterly; his influence was very great over his own pupils, the students on the scientific side, but the others, the "*littéraires*," were the most violent on this question, and he was not diplomatic and conciliating enough to bring them round. They rose in a body, marched to the door, and the whole

school was soon parading the streets. "Before such disorder," concluded the *Moniteur*, relating the incident (July 10), "the authorities were obliged to order an immediate closure. The school will be reconstituted and the classes will reopen on October 15."

Both the literary and the political world were temporarily agitated; the Minister was interviewed. M. Thiers wrote to Pasteur on July 10: "My dear M. Pasteur,—I have been talking with some members of the Left, and I am certain or almost certain, that the Ecole Normale affair will be smoothed over in the interest of the students. M. Jules Simon intends to work in that direction; keep this information for yourself, and do the best you can on your side."

At the idea that the Ecole was about to be reconstituted, that is, that the three great chiefs, Nisard, Pasteur and Jacquinet, would be changed, deep regret was manifested by Pasteur's scientific students. One of them, named Didon, expressed it in these terms: "If your departure from the school is not definitely settled, if it is yet possible to prevent it, all the students of the Ecole will be only too happy to do everything in their power. . . . As for me, it is impossible to express my gratitude towards you. No one has ever shown me so much interest, and never in my life shall I forget what you have done for me."

Pasteur's interest in young men, his desire to excite in them scientific curiosity and enthusiasm, were now so well known that Didon and several others who had successfully passed the entrance examinations both for the Ecole Polytechnique and the Ecole Normale, had chosen to enter the latter in order to be under him; by the *Normaliens* of the scientific section, he was not only understood and admired, but beloved, almost worshipped.

Sainte Beuve, who continued to be much troubled at the consequences of his speech, wrote to the Minister of Public Instruction in favour of the rusticated student. Duruy thought so much of Sainte Beuve that the student, instead of being exiled to some insignificant country school, was made professor of *seconde* in the college of Sens. But it was specified that in the future no letter should be written, no public responsibility taken in the name of the Ecole without the authorization of the Director.

Nisard left; Dumas had just been made President of the

Monetary Commission, thus leaving vacant a place as Inspector-General of Higher Education. Duruy, anxious to do Pasteur justice, thought this post most suitable to him as it would allow him to continue his researches. The decree was about to be signed, when Balard, professor of chemistry at the Faculty of Sciences, applied for the post. Pasteur wrote respectfully to the Minister of Public Instruction (July 31): "Your Excellency must know that twenty years ago, when I left the Ecole Normale, I was made a curator, thanks to M. Balard, who was then a professor at the Ecole Normale. A grateful pupil cannot enter into competition with a revered master, especially for a post where considerations of age and experience should have great weight."

When Pasteur spoke of his masters, dead or living, Biot or Senarmont, Dumas or Balard, it might indeed have been thought that to them alone he owed it that he was what he was. He was heard on this occasion, and Balard obtained the appointment.

Nisard was succeeded by M. F. Bouillier, whose place as Inspector-General of Secondary Education devolved on M. Jacquinet. The directorship of scientific studies was given to Pasteur's old and excellent friend, the faithful Bertin. After teaching in Alsace for eighteen years, he had become *maître des conférences* at the Ecole Normale in 1866, and also assistant of Regnault at the Collège de France. It had only been by dint of much persuasion that Pasteur had enticed him to Paris. "What is the good?" said the unambitious Bertin; "beer is not so good in Paris as in Strasburg. . . . Pasteur does not understand life; he is a genius, that is all!" But, under this apparent indolence, Bertin was possessed of the taste for and the art of teaching; Pasteur knew this, and, when Bertin was appointed, Pasteur's fears for the scientific future of his beloved Ecole were abated. Duruy, much regretting the break of Pasteur's connection with the great school, offered him the post of *maître des conférences*, besides the chair of chemistry which Balard's appointment had left vacant at the Sorbonne. But Pasteur declined the tempting offer; he knew the care and trouble that his public lectures cost him, and felt that the two posts would be beyond his strength; if his time were taken up by that double task it would be almost impossible for him to pursue his private researches, which under no circumstances would he abandon.

He carried his scruples so far as to give up his chemistry professorship at the School of Fine Arts, where he had been lecturing since 1863. He had endeavoured in his lessons to draw the attention of his artist pupils, who came from so many distant places, to the actual principles of Science. "Let us always make application our object," he said, "but resting on the stern and solid basis of scientific principles. Without those principles, application is nothing more than a series of recipes and constitutes what is called routine. Progress with routine is possible, but desperately slow."

Another reason prevented him from accepting the post offered him at the Ecole Normale; this was that the tiny pavilion which he had made his laboratory was much too small and too inconvenient to accommodate the pupils he would have to teach. The only suitable laboratory at the Ecole was that of his friend, Henri Sainte Claire Deville, and Pasteur was reluctant to invade it. He had a great affection for his brilliant colleague, who was indeed a particularly charming man, still youthful in spite of his forty-nine summers, active, energetic, witty. "I have no wit," Pasteur would say quite simply. Deville was a great contrast to his two great friends, Pasteur and Claude Bernard, with their grave meditative manner. He enjoyed boarding at the Ecole and having his meals at the students' table, where his gaiety brightened and amused everybody, effacing the distance between masters and pupils and yet never losing by this familiar attitude a particle of the respect he inspired.

Sometimes, however, when preoccupied with the heavy expenses of his laboratory, he would invite himself to lunch with Duruy, from whom—as from the Emperor or any one else—he usually succeeded in coaxing what he wanted. The general state of things connected with higher education was at that time most deplorable. The Sorbonne was as Richelieu had left it—the Museum was sadly inadequate. At the Collège de France, it was indeed impossible to call by the name of laboratory the narrow, damp and unhealthy cellars, which Claude Bernard called "scientists' graves," and where he had contracted the long illness from which he was only just recovering.

Duruy understood and deplored this penury, but his voice was scarcely heard in cabinet councils, the other Ministers being absorbed in politics. Pasteur, whose self-effacing modesty disappeared when the interests of science were in question, pre-

sented to Napoleon, through the medium of his enlightened aide de camp, General Favé, the following letter, a most interesting one, for, in it, possibilities of future discoveries are hinted at, which later became accomplished facts.

"Sire,—My researches on fermentations and on microscopic organisms have opened to physiological chemistry new roads, the benefit of which is beginning to be felt both by agricultural industries and by medical studies. But the field still to be explored is immense. My great desire would be to explore it with a new ardour, unrestrained by the insufficiency of material means.

"I should wish to have a spacious laboratory, with one or two outhouses attached to it, which I could make use of when making experiments possibly injurious to health, such as might be the scientific study of putrid and infectious diseases.

"How can researches be attempted on gangrene, virus or inoculations, without a building suitable for the housing of animals, either dead or alive? Butchers' meat in Europe reaches an exorbitant price, in Buenos Ayres it is given away. How, in a small and incomplete laboratory, can experiments be made, and various processes tested, which would facilitate its transport and preservation? The so-called 'splenic fever' costs the Beauce[1] about 4,000,000 francs annually; it would be indispensable to go and spend some weeks in the neighbourhood of Chartres during several consecutive summers, and make minute observations.

"These researches and a thousand others which correspond in my mind to the great act of transformation after death of organic matter, and the compulsory return to the ground and atmosphere of all which has once been living, are only compatible with the installation of a great laboratory. The time has now come when experimental science should be freed from its bonds . . ."

The Emperor wrote to Duruy the very next day, desiring that Pasteur's wish should be acceded to. Duruy gladly acquiesced and plans began to be drawn out. Pasteur, who scarcely dared believe in these bright hopes, was consulted about the situation, size, etc., of the future building, and

[1] Ancient name of the high flat ground surrounding Chartres and including parts of the Departments of Eure et Loir, Loir et Cher, Loiret and Seine et Oise. These plains are very fertile, the soil being extremely rich, and produce cereals chiefly. [Trans.]

looked forward to obtaining the help of Raulin, his former pupil, when he had room enough to experiment on a larger scale. The proposed site was part of the garden of the Ecole Normale, where the pavilion already existing could be greatly added to.

In the meanwhile Pasteur was interviewed by the Mayor and the President of the Chamber of Commerce of Orleans, who begged him to come to Orleans and give a public lecture on the results of his studies on vinegar. He consented with pleasure, ever willing to attempt awakening the interest of the public in his beloved Science—"Science, which brings man nearer to God."

It was on the Monday, November 11, at 7.30 p.m., that Pasteur entered the lecture room at Orleans. A great many vinegar manufacturers, some doctors, apothecaries, professors, students, even ladies, had come to hear him. An account in a contemporary local paper gives us a description of the youngest member of the Académie des Sciences as he appeared before the Orleans public. He is described as of a medium height, his face pale, his eyes very bright through his glasses, scrupulously neat in his dress, with a tiny Legion of Honour rosette in his button hole.

He began his lecture with the following simple words: "The Mayor and the President of the Chamber of Commerce having heard that I had studied the fermentation which produces vinegar, have asked me to lay before the vinegar makers of this town the results of my work. I have hastened to comply with their request, fully sharing in the desire which instigated it, that of being useful to an industry which is one of the sources of the fortune of your city and of your department."

He tried to make them understand scientifically the well known fact of the transformation of wine into vinegar. He showed that all the work came from a little plant, a microscopic fungus, the *mycoderma aceti*. After exhibiting an enlarged picture of that mycoderma, Pasteur explained that the least trace of that little vinegar-making plant, sown on the surface of any alcoholic and slightly acid liquid, was sufficient to produce a prodigious extension of it; in summer or artificial heat, said Pasteur, a surface of liquid of the same area as the Orleans Lecture room could be covered in forty-eight hours. The mycodermic veil is sometimes smooth and hardly visible, sometimes wrinkled and a little greasy to the touch. The fatty

matter which accompanies the development of the plant keeps it on the surface, air being necessary to the plant; it would otherwise perish and the acetification would be arrested. Thus floating, the mycoderma absorbs oxygen from the air and fixes it on the alcohol, which becomes transformed into acetic acid.

Pasteur explained all the details in his clear powerful voice. Why, in an open bottle, does wine left to itself become vinegar? Because, thanks to the air, and to the mycoderma aceti (which need never be sown, being ever mixed with the invisible dusts in the air), the chemical transformation of wine into vinegar can take place. Why does not a full, closed bottle become acetified? Because the mycoderma cannot multiply in the absence of air. Wine and air heated in the same vessel will not become sour, the high temperature having killed the germs of mycoderma aceti both in the wine itself and in the dusts suspended in the air. But, if a vessel containing wine previously heated is exposed to the free contact of ordinary air, the wine may become sour, for, though the germs in the wine have been killed, other germs may fall into it from the air and develop.

Finally, if pure alcoholized water does not become acetified, though germs can drop into it from the air, it is because it does not offer to those germs the food necessary to the plant —food which is present in wine but not in alcoholized water. But if a suitable aliment for the little plant is added to the water, acetification takes place.

When the acetification is complete, the mycoderma, if not submerged, continues to act, and, when not arrested in time, its oxidating power becomes dangerous; having no more alcohol to act upon, it ends by transforming acetic acid itself into water and carbonic acid gas, and the work of death and destruction is thus achieved.

Speaking of that last phase of the mycoderma aceti, he went on to general laws—laws of the universe by which all that has lived must disappear. "It is an absolute necessity that the matter of which living beings are formed should return after their death to the ground and to the atmosphere in the shape of mineral or gaseous substances, such as steam, carbonic acid gas, ammoniac gas or nitrogen—simple principles easily displaced by movements of the atmosphere and in which life is again enabled to seek the elements of its indefinite perpetuity. It is chiefly through acts of fermentation and slow combustion

that this law of dissolution and return to a gaseous state is accomplished."

Coming back to his special subject, he pointed out to vinegar manufacturers the cause of certain failures and the danger of certain errors.

It was imagined for instance that some microscopic beings, anguillulæ, of which Pasteur projected an enlarged wriggling image on the screen, and which were to be found in the tubs of some Orleans vinegar works, were of some practical utility. Pasteur explained their injurious character : as they require air to live, and as the mycoderma, in order to accomplish its work, is equally dependent on oxygen, a struggle takes place between the anguillulæ and the mycoderma. If acetification is successful, if the mycoderma spreads and invades everything, the vanquished anguillulæ are obliged to take refuge against the sides of the barrel, from which their little living army watches the least accidental break of the veil. Pasteur, armed with a magnifying glass, had many times witnessed the struggle for life which takes place between the little fungi and the tiny animals, each fighting for the surface of the liquid. Sometimes, gathering themselves into masses, the anguillulæ succeed in sinking a fragment of the mycodermic veil and victoriously destroying the action of the drowned plants.

Pasteur related all this in a vivid manner, evidently happy that his long and delicate laboratory researches should now pass into the domain of industry. He had been pleased to find that some Orleans wine merchants heated wine according to his advice in order to preserve it; and he now informed them that the temperature of 55° C. which killed germs and vegetations in wine could be applied with equal success to vinegar after it was produced. The active germs of the mycoderma aceti were thus arrested at the right moment, the anguillulæ were killed and the vinegar remained pure and unaltered. "Nothing," concluded Pasteur, "is more agreeable to a man who has made science his career than to increase the number of discoveries, but his cup of joy is full when the result of his observations is put to immediate practical use."

This year 1867 marks a specially interesting period in Pasteur's life. At Alais he had shown himself an incomparable observer, solely preoccupied with the silkworm disease, thinking, speaking of nothing else. He would rise long before any one else so as to begin earlier the study of the experiments he

had started, and would give his thought and attention to some detail for hours at a time. After this minute observation he would suddenly display a marvellous ingenuity in varying tests, foreseeing and avoiding causes of error, and at last, after so many efforts, a clear and decisive experiment would come, as it had done in the cases of spontaneous generation and of ferments.

The contrasts in his mind had their parallel in his character: this usually thoughtful, almost dreamy man, absorbed in one idea, suddenly revealed himself a man of action if provoked by some erroneous newspaper report or some illogical statement, and especially when he heard of some unscrupulous silkworm seed merchant sowing ruin in poor *magnaneries* for the sake of a paltry gain. When, on his return to Paris, he found himself mixed up with the small revolution in the Ecole Normale, he was seen to efface himself modestly before his masters when honours and titles came in question. Now he had interrupted his researches in order to do a kindness to the people of Orleans, who, practical as they were, and perhaps a little disdainful of laboratory theories, had been surprised to find him as careful of the smallest detail as they themselves were.

He was then in the full maturity of his forty-five years. His great intuition, his imagination, which equalled any poet's, often carried him to a summit whence an immense horizon lay before him; he would then suddenly doubt this imagination, resolutely, with a violent effort, force his mind to start again along the path of experimental method, and, surely and slowly, gathering proofs as he went, he would once more reach his exalted and general ideas. This constant struggle within himself was almost dramatic; the words "Perseverance in Effort," which he often used in the form of advice to others, or as a programme for his own work, seemed to bring something far away, something infinite before his dreamy eyes.

At the end of the year, an obstacle almost arrested the great experiments he contemplated. He heard that the promises made to him were vanishing away, the necessary credit having been refused for the building of the new laboratory. And this, Pasteur sadly reflected, when millions and millions of francs were being spent on the Opera house! Wounded in his feelings, both as a scientist and a patriot, he prepared for the *Moniteur*, then the official paper, an article destined to shake the culpable indifference of public authorities.

". . . The boldest conceptions," he wrote, "the most legitimate speculations can be embodied but from the day when they are consecrated by observation and experiment. Laboratories and discoveries are correlative terms; if you suppress laboratories, Physical Science will become stricken with barrenness and death; it will become mere powerless information instead of a science of progress and futurity; give it back its laboratories, and life, fecundity and power will reappear. Away from their laboratories, physicists and chemists are but disarmed soldiers on a battlefield.

"The deduction from these principles is evident: if the conquests useful to humanity touch your heart—if you remain confounded before the marvels of electric telegraphy, of anæsthesia, of the daguerreotype and many other admirable discoveries—if you are jealous of the share your country may boast in these wonders—then, I implore you, take some interest in those sacred dwellings meaningly described as *laboratories*. Ask that they may be multiplied and completed. They are the temples of the future, of riches and of comfort. There humanity grows greater, better, stronger; there she can learn to read the works of Nature, works of progress and universal harmony, while humanity's own works are too often those of barbarism, of fanaticism and of destruction.

"Some nations have felt the wholesome breath of truth. Rich and large laboratories have been growing in Germany for the last thirty years, and many more are still being built; at Berlin and at Bonn two palaces, worth four million francs each, are being erected for chemical studies. St. Petersburg has spent three and a half million francs on a Physiological Institute; England, America, Austria, Bavaria have made most generous sacrifices. Italy too has made a start.

"And France?

"France has not yet begun. . . ." He mentioned the sepulchre-like cellar where the great physiologist, Claude Bernard, was obliged to live; "and where?" wrote Pasteur. "In the very establishment which bears the name of the mother country, the Collège de France!" The laboratory of the Sorbonne was no better—a damp, dark room, one metre below the level of the street. He went on, demonstrating that the provincial Faculties were as destitute as those of Paris. "Who will believe me when I affirm that the budget of Public Instruction provides not a penny towards the progress of physical

science in laboratories, that it is through a tolerated administrative fiction that some scientists, considered as professors, are permitted to draw from the public treasury towards the expenses of their own work, some of the allowance made to them for teaching purposes."

The manuscript was sent to the *Moniteur* at the beginning of January, 1868. It had lately been publishing mild articles on Mussulman architecture, then on herring fishing in Norway. The official whose business it was to read over the articles sent to the paper literally jumped in his chair when he read this fiery denunciation; he declared those pages must be modified, cut down; the Administration could not be attacked in that way, especially by one of its own functionaries! M. Dalloz, the editor of the paper, knew that Pasteur would never consent to any alterations; he advised him to show the proofs to M. Conti, Napoleon III's secretary.

"The article cannot appear in the *Moniteur*, but why not publish it in booklet form?" wrote M. Conti to Pasteur after having shown these revelations to the Emperor. Napoleon, talking to Duruy the next day, January 9, showed great concern at such a state of things. "Pasteur is right," said Duruy, "to expose such deficiencies; it is the best way to have them remedied. Is it not deplorable, almost scandalous, that the official world should be so indifferent on questions of science?"

Duruy felt his combative instincts awakening. How many times, in spite of his good humour and almost Roman intrepidity, he had asked himself whether he would ever succeed in causing his ideas on higher education to prevail with his colleagues, the other Ministers, who, carried away by their daily discussions, hardly seemed to realize that the true supremacy of a nation does not reside in speeches, but in the silent and tenacious work of a few men of science and of letters. Pasteur's article entitled *Science's Budget* appeared first in the *Revue des cours scientifiques*, then as as pamphlet. Pasteur, not content with this, continued his campaign by impetuous speeches whenever the opportunity offered. On March 10, he saw himself nearing his goal, and wrote to Raulin: "There is now a marked movement in favour of Science; I think I shall succeed."

Six days later, on March 16, whilst the Court was celebrating the birthday of the Prince Imperial, Napoleon III, who, on reading Pasteur's article, had expressed his intention of

consulting not only Pasteur, but also Milne-Edwards, Claude Bernard, and Henri Sainte Claire Deville, asked the four scientists to his study to meet Rouher, Marshal Vaillant and Duruy, perhaps the three men of the Empire who were best qualified to hear them. The Emperor in his slow, detached manner, invited each of his guests to express his opinion on the course to follow. All agreed in regretting that pure science should be given up. When Rouher said that it was not to be wondered at that the reign of applied science should follow that of pure science, "But if the sources of applications are dried up!" interposed the Emperor hastily. Pasteur, asked to express his opinion (he had brought with him notes of what he wished to say), recalled the fact that the Natural History Museum and the Ecole Polytechnique, which had had so great a share in the scientific movement of the early part of the century, were no longer in that heroic period. For the last twenty years the industrial prosperity of France had induced the cleverest Polytechnicians to desert higher studies and theoretical science, though the source of all applications was to be found in theory. The Ecole Polytechnique was obliged now to recruit its teaching staff outside, chiefly among Normaliens. What was to be done to train future scientists? This: to maintain in Paris, during two or three years, five or six graduates chosen from the best students of the large schools as curators or preparation masters, doing at the Ecole Polytechnique and other establishments what was done at the Ecole Normale. Thanks to that special institution, science and higher teaching would have a reserve of men who would become an honour to their country. Next, and this was the second point, no less important than the first, scientists should be given resources better appropriated to the pursuit of their work; as in Germany, for instance, where a scientist would leave one university for another on the express condition that a laboratory should be built for him, "a laboratory," said Pasteur, "usually magnificent, not in its architecture (though sometimes that is the case, a proof of the national pride in scientific glory), but in the number and perfection of its appliances. Besides," he added, "foreign scientists have their private homes adjoining their laboratories and collections," indeed a most pressing inducement to work.

Pasteur did not suggest that a scientist should give up teaching; he recognized, on the contrary, that public teaching forces

him to embrace in succession every branch of the science he teaches. "But let him not give too frequent or too varied lectures! they paralyze the faculties," he said, being well aware of the cost of preparing classes. He wished that towns should be interested in the working and success of their scientific establishments. The Universities of Paris, of Lyons, of Strasburg, of Montpellier, of Lille, of Bordeaux, and of Toulouse, forming as a whole the University of France, should be connected to the neighbourhood which they honour in the same way that German universities are connected with their surroundings.

Pasteur had the greatest admiration for the German system: popular instruction liberally provided, and, above it, an intellectually independent higher teaching. Therefore, when the University of Bonn resolved in that year, 1868, to offer him as a great homage the degree of M.D. on acount of his works on micro-organisms, he was proud to see his researches rated at their proper value by a neighbouring nation. He did not then suspect the other side of German nature, the military side, then very differently preoccupied. Those preoccupations were pointed out to the French Government in a spirit of prophecy, and with some patriotic anguish, by two French officers, General Ducrot, commanding since 1865 the 6th Military Division, whose headquarters were at Strasburg, and Colonel Baron Stoffel, military attaché in Prussia since 1866. Their warnings were so little heeded that some Court intrigues were even then on foot to transfer General Ducrot from Strasburg to Bourges, so that he might no longer worry people with his monomania of Prussian ambition.

On March 10, the evening of the day when the Emperor decided upon making improvements, and when Duruy felt assured, thanks to the promised allowances, that he could soon offer to French professors "the necessary appliances with which to compete with their rivals beyond the Rhine," Pasteur started for Alais, where his arrival was impatiently awaited, both by partisans and adversaries of his experiments on silkworm disease. He would much have liked to give the results of his work in his inaugural lecture at the Sorbonne. "But," he wrote to Duruy, "these are but selfishly sentimental reasons, which must be outweighed by the interest of my researches."

On his arrival he found to his joy that those who had prac-

tised seeding according to his rigorous prescriptions had met with complete success. Other silkworm cultivators, less well advised, duped by the decoying appearances of certain broods, had not taken the trouble to examine whether the moths were corpuscled; they were witnesses and victims of the failure Pasteur had prophesied. He now looked upon pébrine as conquered; but flachery remained, more difficult to prevent, being greatly dependent upon the accidents which traverse the life of a silkworm. Some of those accidents happen in spite of all precautions, such as a sudden change of temperature or a stormy day; but at least the leaves of the mulberry tree could be carefully kept from fermentation, or from contamination by dusts in the nurseries. Either of those two causes was sufficient to provoke a fatal disorder in silkworms, the feeding of which is so important that they increase to fifteen thousand times their own weight during the first month of their life. Accidental flachery could therefore be avoided by hygienic precautions. In order to prevent it from becoming hereditary, Pasteur—who had pointed out that the micro-organism which causes it develops at first in the intestinal canal of the worm and then becomes localized in the digestive cavity of the chrysalis—advised the following means of producing a healthy strain of silkworms: "This means," writes M. Gernez, Pasteur's assiduous collaborator in these studies, "does not greatly complicate operations, and infallibly ensures healthy seed. It consists in abstracting with the point of a scalpel a small portion of the digestive cavity of a moth, then mixing it with a little water and examining it with a microscope. If the moths do not contain the characteristic micro-organism, the strain they come from may unhesitatingly be considered as suitable for seeding. The flachery micro-organism is as easily recognized as the pébrine corpuscle."

The seed merchants, made uneasy by these discoveries which so gravely jeopardized their industry, spread the most slanderous reports about them and made themselves the willing echo of every imposture, however incredible. M. Laurent wrote to his daughter, Madame Pasteur, in a letter dated from Lyons (June 6): "It is being reported here that the failure of Pasteur's process has excited the population of your neighbourhood so much that he has had to flee from Alais, pursued by infuriated inhabitants throwing stones after him." Some of these legends lingered in the minds of ignorant people.

Important news came from Paris to Pasteur in July, and on the 27th he was able to write to Raulin : " The building of my laboratory is going to be begun ! the orders are given, and the money found. I heard this two days ago from the Minister." 30,000 francs had been allowed for the work by the Minister of Public Instruction, and an equal sum was promised by the Minister of the Emperor's household. Duruy was preparing at the same time a report on two projected decrees concerning laboratories for teaching purposes and for research. " The laboratory for research," wrote Duruy, " will not be useful to the master alone, but more so even to the students, thus ensuring the future progress of science. Students already provided with extensive theoretical knowledge will be initiated in the *teaching laboratories* into the handling of instruments, elementary manipulations, and what I may call classical practice ; this will gather them around eminent masters, from whom they will learn the art of observation and methods of experiment. . . . It is with similar institutions that Germany has succeeded in obtaining the great development of experimental science which we are now watching with an anxious sympathy."

Pasteur returned to Paris with his enthusiastic mind overflowing with plans of all kinds of research. He wanted to be there when the builders began their work on the narrow space in the Rue d'Ulm. He wrote to Raulin on August 10, asking his opinion as he would that of an architect ; then went on to say, planning out his busy holidays : " I shall leave Paris on the 16th with my wife and children to spend three weeks at the seaside, at St. George's, near Bordeaux. If you were free at the end of the month, or at the beginning of September, I wish you could accompany me to Toulon, where experiments on the heating of wines will be made by the Minister of the Navy. Great quantities of heated and of non-heated wine are to be sent to Gabon so as to test the process ; at present our colonial crews have to drink mere vinegar. A commission of very enlightened men is formed and has begun studies with which it seems satisfied. . . . See if you can join me at Bordeaux, where I shall await a notice from the chairman of the Commission, M. de Lapparent, director of naval construction at the Ministry of Marine."

The Commission mentioned by Pasteur had been considering for the last two years the expediency of applying the heating

process to wines destined for the fleet and to the colonies. A first trial was made at Brest on the contents of a barrel of 500 litres, half of which was heated. Then the two wines were sealed in different barrels and placed in the ship *Jean Bart*, which remained away from the harbour for ten months. When the vessel returned, the Commission noted the limpidity and mellowness of the heated wine, adding in the official report that the wine had acquired the attractive colour peculiar to mature wines. The non-heated wine was equally limpid, but it had an astringent, almost acid flavour. It was still fit to drink, said the report, but it were better to consume it rapidly, as it would soon be entirely spoilt. Identical results were observed in some bottles of heated and non-heated wines at Rochefort and Orleans.

M. de Lapparent now organized a decisive experiment, to take place under Pasteur's superintendence. The frigate *la Sibylle* started for a tour round the world with a complete cargo of heated wine. Pasteur, who returned to Arbois for a short rest before going back to Paris, wrote from there to his early confidant, Chappuis (September 21, 1868) : "I am quite satisfied with my experiments at Toulon and with the success of the Navy tests. We heated 650 hectolitres in two days; the rapidity of this operation lends itself to quick and considerable commissariat arrangements. Those 650 hectolitres will be taken to the West Coast of Africa, together with 50 hectolitres of the same wine non-heated. If the trial succeeds, that is to say if the 650 hectolitres arrive and can be kept without alteration, and if the 50 hectolitres become spoilt (I feel confident after the experiments I have made that such will be the result), the question will be settled, and, in the future, all the wine for the Navy will be ensured against disease by a preliminary heating. The expense will not be more than five centimes per hectolitre. The result of these experiments will have a great influence on the trade, ever cautious and afraid of innovations. Yet we have seen, at Narbonne in particular, some heating practised on a large scale by several merchants who have spoken to me very favourably about it. The exportation of our French wines will increase enormously, for at present our ordinary table wines lend themselves to trade with England and other countries beyond seas, but only by means of a strong addition of alcohol, which raises their price and tampers with their hygienic qualities."

The experiments were successful. Pasteur's life was now over full. He returned to Paris at the beginning of October, and threw himself into his work, his classes at the Sorbonne, the organization of his laboratory, some further polemics on the subject of silkworm disease, and projected experiments for the following year. This accumulation of mental work brought about extreme cerebral tension.

As soon as he saw M. Gernez, he spoke to him of the coming campaign of sericiculture, of his desire to reduce his adversaries to silence by heaping proof upon proof. Nothing could relieve him from that absorbing preoccupation, not even the gaiety of Bertin, who, living on the same floor at the Ecole Normale, often used to come in after dinner and try to amuse him.

On Monday, October 19, Pasteur, though suffering from a strange tingling sensation of the left side, had a great desire to go and read to the Académie des Sciences a treatise by Salimbeni, an Italian, who, having studied and verified Pasteur's results, declared that the best means of regenerating the culture of silkworms was due to the French scientist. This treatise, the diploma of the Bonn University, the Rumford medal offered by the English, all those testimonials from neighbouring nations were infinitely agreeable to Pasteur, who was proud to lay such homage before the shrine of France. On that day, October 19, 1868, a date which became a bitter memory to his family and friends—in spite of an alarming shivering fit which had caused him to lie down immediately after lunch instead of working as usual—he insisted on going to the Academy sitting at half past two.

Mme. Pasteur, vaguely uneasy, made a pretext of some shopping beyond the Quai Conti and accompanied him as far as the vestibule of the Institute. As she was turning back, she met Balard, who was coming up with the quick step of a young man, stopped him and asked him to walk back with Pasteur, and not to leave him before reaching his own door, though indeed it seemed a curious exchange of parts to ask Balard at sixty years of age to watch over Pasteur still so young. Pasteur read Salimbeni's paper in his usual steady voice, remained until the end of the sitting and walked back with Balard and Sainte Claire Deville. He dined very lightly and went to bed at nine o'clock; he had hardly got into bed when he felt himself attacked by the strange symptoms of the afternoon. He

tried to speak, but in vain; after a few moments he was able to call for assistance. Mme. Pasteur sent at once for Dr. Godélier, an intimate friend of the family, an army surgeon, Clinical Professor at the Ecole du Val-de-Grâce [1]; and Pasteur, paralysed one moment and free again the next, explained his own symptoms during the intervals of the dark struggle which endangered his life.

The cerebral hæmorrhage gradually brought about absence of movement along the entire left side. When the next morning Dr. Noël Gueneau de Mussy, going his regulation round of the Ecole Normale students, came into his room and said, so as not to alarm him, "I heard you were unwell, and thought I would come to see you," Pasteur smiled the sad smile of a patient with no illusions. Drs. Godélier and Gueneau de Mussy decided to call Dr. Andral in consultation, and went to fetch him at three o'clock at the Académie de Médecine. Somewhat disconcerted by the singular character of this attack of hemiplegia, Andral prescribed the application of sixteen leeches behind the ears; blood flowed abundantly, and Dr. Godélier wrote in the evening bulletin (Tuesday): "Speech clearer, some movements of the paralysed limbs; intelligence perfect." Later, at ten o'clock: "Complains of his paralysed arm." "It is like lead; if it could only be cut off!" groaned Pasteur. About 2 a.m. Mme Pasteur thought all hope was gone. The hastily written bulletin reads thus: "Intense cold, anxious agitation, features depressed, eyes languid." The sleep which followed was as the sleep of death.

At dawn Pasteur awoke from this drowsiness. "Mental faculties still absolutely intact," wrote M. Godélier at 12.30 on Wednesday, October 21. "The cerebral lesion, whatever it may be, is not worse; there is an evident pause." Two hours later the words, "Mind active," were followed by the startling statement, "Would willingly talk science."

While these periods of calm, agitation, renewed hopes, and despair were succeeding each other in the course of those thirty-six hours, Pasteur's friends hastened to his bedside. He said to Henri Sainte Claire Deville, one of the first to come: "I am sorry to die; I wanted to do much more for my country." Sainte Claire Deville, trying to hide his grief under

[1] *Val-de-Grâce.* A handsome monument of the seventeenth century, now a military hospital. [Trans.]

apparent confidence, answered, "Never fear; you will recover, you will make many more marvellous discoveries, you will live happy days; I am your senior, you will survive me. Promise me that you will pronounce my funeral oration. . . . I wish you would; you would say nice things of me," he added between tears and smiles.

Bertin, Gernez, Duclaux, Raulin, Didon, then a curator at the Ecole Normale, Professor Auguste Lamy, the geologist Marcou (the two latter being Franche-comté friends), all claimed the privilege of helping Mme. Pasteur and M. Godélier in nursing one who inspired them all, not merely with an admiring and devoted affection, but with a feeling of tenderness amounting almost to a cult.

A private letter from a cousin, Mme. Cribier, gives an idea of those dark days (October 26, 1868): "The news is rather good this morning; the patient was able to sleep for a few hours last night, which he had not yet done. He had been so restless all day that M. Godélier felt uneasy about him and ordered complete silence in the whole flat; it was only in the study which is farthest away from the bedroom, and which has padded doors, that one was allowed to talk. That room is full from morning till night. All scientific Paris comes to inquire anxiously after the patient; intimate friends take it in turns to watch by him. Dumas, the great chemist, was affectionately insisting on taking his turn yesterday. Every morning the Emperor and Empress send a footman for news, which M. Godélier gives him in a sealed envelope. In fact, every mark of sympathy is given to poor Marie, and I hope that the worst may be spared her in spite of the alarming beginning. His mind seems so absolutely untouched, and he is still so young, that with rest and care he might yet be able to do some work. His stroke is accompanied by symptoms which are now occupying the attention of the whole Academy of Medicine. Paralysis always comes abruptly, whilst for M. Pasteur, it came in little successive fits, twenty or thirty perhaps, and was only complete at the end of twenty-four hours, which completely disconcerted the doctors who watched him, and delayed their having recourse to an active treatment. It seems that this fact is observed for the first time, and is puzzling the whole Faculty."

M. Pasteur's mind remained clear, luminous, dominating his prostrate body; he was evidently afraid that he should die

before having thoroughly settled the question of silkworm diseases. "One night that I was alone with him," relates M. Gernez, who hardly left his bedside during that terrible week, "after endeavouring in vain to distract his thoughts, I despairingly gave up the attempt and allowed him to express the ideas which were on his mind; finding, to my surprise, that they had his accustomed clearness and conciseness, I wrote what he dictated without altering a word, and the next day I brought to his illustrious colleague, Dumas—who hardly credited his senses—the memorandum which appeared in the report of the Académie on October 26, 1868, a week after the stroke which nearly killed him! It was a note on a very ingenious process for discovering in the earlier tests those eggs which are predisposed to flachery.

The members of the Academy were much cheered by the reading of this note, which seemed to bring Pasteur back into their midst.

The building of the laboratory had been begun, and hoardings erected around the site. Pasteur, from his bed, asked day by day, "How are they getting on?" But his wife and daughter, going to the window of the dining-room which overlooked the Ecole Normale garden, only brought him back vague answers, for, as a matter of fact, the workmen had disappeared from the very first day of Pasteur's illness. All that could be seen was a solitary labourer wheeling a barrow aimlesly about, probably under the orders of some official who feared to alarm the patient.

As Pasteur was not expected to recover, the trouble and expense were deemed unnecessary. Pasteur soon became aware of this, and one day that General Favé had come to see him he gave vent to some bitter feelings as to this cautious interruption of the building works, saying that it would have been simpler and more straightforward to state from the beginning that the work was suspended in the expectation of a probable demise.

Napoleon was informed of this excess of zeal, not only by General Favé, but by Sainte Claire Deville, who was a guest at Compiègne at the beginning of November, 1868. He wrote to the Minister of Public Instruction—

"My dear M. Duruy,—I have heard that—unknown to you probably—the men who were working at M. Pasteur's laboratory were kept away from the very day he became ill; he has

been much affected by this circumstance, which seemed to point to his non-recovery. I beg you will issue orders that the work begun should be continued. Believe in my sincere friendship.—Napoleon."

Duruy immediately sent on this note to M. du Mesnil, whose somewhat long title was that of "Chief of the Division of Academic Administration of Scientific Establishments and of Higher Education." M. du Mesnil evidently repudiated the charge for himself or for his Minister, for he wrote in a large hand, on the very margin of the Imperial autograph—

"M. Duruy gave no orders and had to give none. It is at his solicitation that the works were undertaken, but it is the *Direction of Civic Buildings* alone which *can* have interrupted them; the fact should be verified."

M. de Cardaillac, head of the Direction of Civic Buildings, made an inquiry and the building was resumed.

It was only on November 30 that Pasteur left his bed for the first time and spent an hour in his armchair. He clearly analyzed to himself his melancholy condition, stricken down as he was by hemiplegia in his forty-sixth year; but having noticed that his remarks saddened his wife and daughter, he spoke no more about his illness, and only expressed his anxiety not to be a trouble, a burden, he said, to his wife, his son and daughter, and the devoted friends who helped to watch him at night.

In the daytime each offered to read to him. General Favé, whose active and inquiring mind was ever on the alert, brought him on one of his almost daily visits an ideal sick man's book, easy to read and offering food for meditation. It was the translation of an English book called *Self-Help*,[1] and it consisted in a series of biographies, histories of lives illustrating the power of courage, devotion or intelligence. The author, glad to expound a discovery, to describe a masterpiece, to relate noble enterprises, to dwell upon the prodigies which energy can achieve, had succeeded in making a homogeneous whole of these unconnected narratives, a sort of homage to Will-power.

Pasteur agreed with the English writer in thinking that the supremacy of a nation resides in "the sum total of private virtues, activities and energy." His thoughts rose higher still; men of science could wish for a greater glory than that of con-

[1] By Dr. Smiles. [Trans.]

tributing to the fame and fortune of their country, they might aspire to originating vast benefits to the whole of humanity.

It was indeed a sad and a sublime spectacle, that of the contrast between that ardent, soaring soul and that patient helpless body. It was probably when thinking of those biographies—some of them too succinct, to his mind, Jenner's for instance—that Pasteur wrote: "From the life of men whose passage is marked by a trace of durable light, let us piously gather up every word, every incident likely to make known the incentives of their great soul, for the education of posterity." He looked upon the cult of great men as a great principle of national education, and believed that children, as soon as they could read, should be made acquainted with the heroic or benevolent souls of great men. In his pious patriotism he saw a secret of strength and of hope for a nation in its reverence for the memories of the great, a sacred and intimate bond between the visible and the invisible worlds. His soul was deeply religious. During his illness—a time when the things of this world assume their real proportions—his mind rose far beyond this earth. The Infinite appeared to him as it did to Pascal, and with the same rapture; he was less attracted by Pascal, when, proud and disdainful, he exposes man's weakness for humiliation's sake, than when he declares that "Man is produced but for Infinity," and "he finds constant instruction in progress." Pasteur believed in material progress as well as in moral improvement; he invariably marked in the books he was reading—Pascal, Nicole and others—those passages which were both consoling and exalting.

In one of his favourite books, *Of the Knowledge of God and of Self*, he much appreciated the passage where Bossuet ascribes to human nature "the idea of an infinite wisdom, of an absolute power, of an infallible rectitude, in one word, the idea of perfection." Another phrase in the same book seemed to him applicable to experimental method as well as to the conduct of life: "The greatest aberration of the mind consists in believing a thing because it is desirable."

With December, joy began to return to the Ecole Normale: the laboratory was progressing and seemed an embodiment of renewed hopes of further work. M. Godélier's little bulletins now ran: "General condition most satisfactory. Excellent morale; the progress evidenced daily by the return of action in the paralysed muscles inspires the patient with great confidence.

He is planning out his future sericiculture campaign, receives many callers without too much fatigue, converses brightly and often dictates letters."

One visit was a great pleasure to Pasteur—that of the Minister, his cordial friend, Duruy, who brought him good news of the future of Higher Education. The augmented credit which was granted in the 1869 budget would make it possible to rebuild other laboratories besides that of the Ecole Normale, and also to create in other places new centres of study and research. After so many efforts and struggles, it was at last possible to foresee the day when chemistry, physics, physiology, natural history and mathematics would each have an independent department in a great province, which should be called the Practical School of Higher Studies. There would be no constraint, no hard and fast rules, no curriculum but that of free study : young men who were attracted to pure science, and others who preferred practical application, would find a congenial career before them as well as those who desired to give themselves up to teaching. It can well be imagined with what delight Pasteur heard these good tidings.

The bulletins continued to be favourable : " (December 15) : Progress slow but sure : he has walked from his bed to his armchair with some assistance. (December 22) : he has gone into the dining-room for dinner, leaning on a chair. (29th) : he has walked a few steps without support."

Pasteur saw in his convalescence but the returning means of working, and declared himself ready to start again for the neighbourhood of Alais at once, intead of taking the few months' rest he was advised to have.

He urged that, after certain moths and chrysalides, had been examined through a microscope, complete certainty would be acquired as to the condition of their seed, and that perfect seed would therefore become accessible to all tradesmen both great and small; would it not be absurd and culpable to let reasons of personal health interfere with saving so many poor people from ruin?

His family had to give way, and on January 18, exactly three months after his paralytic stroke, he was taken to the *Gare de Lyon* by his wife and daughter and M. Gernez. He then travelled, lying on the cushions of a *coupé* carriage, as far as Alais, and drove from Alais to St. Hippolyte le Fort, where

tests were being made on forced silkworms by the agricultural society of Le Vigan.

The house he came into was cold and badly arranged. M. Gernez improvised a laboratory, with the assistance of Maillot and Raulin, who had followed their master down. From his sofa or from his bed, Pasteur directed certain experiments on the forced specimens. M. Gernez writes: "The operations, of which we watched the phases through the microscope, fully justified his anticipations; and he rejoiced that he had not given up the game." In the world of the Institute his departure was blamed by some and praised by others; but Pasteur merely considered that one man's life is worthless if not useful to others.

Dumas wrote to him early in February: "My dear friend and colleague,—I have been thinking of you so much! I dread fatigue for you, and wish I could spare it you, whilst hoping that you may successfully achieve your great and patriotic undertaking. I have hesitated to write to you for fear you should feel obliged to answer. However, I should like to have direct news of you, as detailed as possible, and, besides that, I should be much obliged if you could send me a line to enlighten me on the two following points—

"1. When are you going back to Alais? And when will your Alais broods be near enough to their time to be most interesting to visit?

"2. What should I say to people who beg for healthy seed as if my pockets were full of it? I tell them it is too late; but if you could tell me a means of satisfying them, I should be pleased, particularly in the case of General Randon and M. Husson. The Marshal (Vaillant) is full of solicitude for you, and we never meet but our whole conversation turns upon you. With me, it is natural. With him less so, perhaps, but anyhow, he thinks of you as much as is possible, and this gives me a great deal of pleasure. . . . Please present to Madame Pasteur our united compliments and wishes. We wish the South could have the virtues of Achilles' lance—of healing the wounds it has caused.—Yours affectionately."

Pasteur was reduced to complete helplessness through having slipped and fallen on the stone floor of his uncomfortable house, and was obliged to dictate the following letter—

"My dear master,—I thank you for thinking of the poor invalid. I am very much in the same condition as when I

left Paris, my progress having been retarded by a fall on my left side. Fortunately, I sustained no fracture, but only bruises, which were naturally painful and very slow to disappear.

"There are now no remaining traces of that accident, and I am as I was three weeks ago. The improvement in the movements of the leg and arm appears to have begun again, but with excessive slowness. I am about to have recourse to electricity, under the advice and instructions of Dr. Godélier, by means of a small Ruhmkorff apparatus which he has kindly sent me. My brain is still very weak.

"This is how my days are spent: in the morning my three young friends come to see me, and I arrange the day's work. I get up at twelve, after having my breakfast in bed, and having had the newspaper read to me. If fine, I then spend an hour or two in the little garden of this house. Usually, if I am feeling pretty well, I dictate to my dear wife a page, or more frequently half a page, of a little book I am preparing, and in which I intend to give a short account of the whole of my observations. Before dinner, which I have alone with my wife and my little girl in order to avoid the fatigue of conversation, my young collaborators bring me a report of their work. About seven or half past, I always feel terribly tired and inclined to sleep twelve consecutive hours; but I invariably wake at midnight, not to sleep again until towards morning, when I doze again for an hour or two. What makes me hope for an ultimate cure is the fact that my appetite keeps good, and that those short hours of sleep appear to be sufficient. You see that on the whole I am doing nothing rash, being moreover rigorously watched by my wife and little daughter. The latter pitilessly takes books, pens, papers and pencils away from me with a perseverance which causes me joy and despair.

"It is because I know your affection for your pupils that I venture to give you so many details. I will now answer the other questions in your letter.

"I shall be at Alais from April 1; that will be the time when they will begin hatching seed for the industrial campaign, which will consequently be concluded about May 20 at the latest. Seeding will take place during June, more or less early according to departments. It is indeed very late to obtain seed, especially indigenous seed prepared according to my process. I had foreseen that I should receive demands at

the last moment, and that I should do well to put by a few ounces; but, about three weeks ago, our energetic Minister wrote to ask me for some seed to distribute to schoolmasters, and I promised him what I had. However I will take some from his share and send you several lots of five grammes. The director of a most interesting Austrian establishment has also ordered two ounces, saying he is convinced of the excellence of my method. His establishment is a most interesting experimental *magnanerie*, founded in a handsome Illyrian property. Lastly, I have also promised two ounces to M. le Comte de Casabianca. One of my young men is going out to his place in Corsica to do the seeding.

"I was much touched by what you tell me of Marshal Vaillant's kind interest in my health, and also by his kind thought in informing me of the encouragement given to my studies by the Society of Agriculture. I wish the cultivators of your South had a little of his scientific and methodical spirit.

"Madame Pasteur joins with me in sending you and your family, dear master, the expression of my gratitude and affectionate devotion."

The normal season for the culture of silkworms was now aproaching, and Pasteur was impatient to accumulate the proofs which would vouch for the safety of his method; this had been somewhat doubted by the members of the Lyons Silks Commission, who possessed an experimental nursery. Most of those gentlemen averred that too much confidence should not be placed in the micrographs. "Our Commission," thus ran their report of the preceding year, "considers the examination of corpuscles as a useful indication which should be consulted, but of which the results cannot be presented as a fact from which absolute consequences can be deducted."

"They *are* absolute," answered Pasteur, who did not admit reservations on a point which he considered as invulnerable.

On March 22, 1869, the Commission asked Pasteur for a little guaranteed healthy seed. Pasteur not only sent them this, but also sample lots, of which he thus predicted the future fate:—

1. One lot of healthy seed, which would succeed;

2. One lot of seed, which would perish exclusively from the corpuscle disease known as pébrine or gattine;

3. One lot of seed, which would perish exclusively from the flachery disease;

4. One lot of seeds, which would perish partly from corpuscle disease and partly from flachery.

"It seems to me," added Pasteur, "that the comparison between the results of those different lots will do more to enlighten the Commission on the certainty of the principles I have established than could a mere sample of healthy seed.

"I desire that this letter should be sent to the Commission at its next meeting, and put down in the minutes."

The Commission accepted with pleasure these unexpected surprise boxes.

About the same time one of his assistants, Maillot, started for Corsica at M. de Casabianca's request. He took with him six lots of healthy seed to Vescovato, a few miles from Bastia.

The rest of the colony returned to the Pont Gisquet, near Alais, that mulberry-planted retreat, where, according to Pasteur, everything was conducive to work. Pasteur now looked forward to his definitive victory, and, full of confidence, organized his pupils' missions. M. Duclaux, who was coming to the Pont Gisquet to watch the normal broods, would afterwards go into the Cévennes to verify the seedings made on the selection system. M. Gernez was to note the results of some seedings made by Pasteur himself the preceding year at M. Raibaud-Lange's, at Paillerols, near Digne (Basses Alpes). Raulin alone would remain at the Pont Gisquet to study some points of detail concerning the flachery disease. So many results ought surely to reduce contradictors to silence!

"My dear friend and colleague," wrote Dumas to Pasteur, "I need not tell you with what anxiety we are watching the progress of your precious health and of your silkworm campaign. I shall certainly be at Alais at the end of the week, and I shall see, under your kind direction, all that may furnish me with the means of guiding public opinion. You have quacks to fight and envy to conquer, probably a hopeless task; the best is to march right through them, Truth leading the way. It is not likely that they will be converted or reduced to silence."

Whilst these expeditions were being planned, a letter from M. Gressier, the Minister of Agriculture, arrived very inopportunely. M. Gressier was better versed in *sub rosâ* ministerial combinations than in seeding processes, and he asked Pasteur

to examine three lots of seeds sent to him by a Mademoiselle Amat, of Brives-la-Gaillarde, who was celebrated in the department of the Corrèze for her good management of silkworms. This *magnanarelle*, having had some successful results, was begging his Excellency to accord to those humble seeds his particular consideration, and to have them developed with every possible care.

At the same time she was sending samples of the same seeds to various places in the Gard, the Bouches du Rhône, etc., etc.

M. Gressier (April 20) asked Pasteur to examine them and to give him a detailed report. Pasteur answered four days afterwards in terms which were certainly not softened by the usual administrative precautions—

"Monsieur le Ministre, . . . these three sorts of seed are worthless. If they are developed, even in very small nurseries, they will in every instance succumb to corpuscle disease. If my seeding process had been employed, it would not have required ten minutes to discover that Mademoiselle Amat's cocoons, though excellent for spinning purposes, were absolutely unfit for reproduction. My seeding process gives the means of recognizing those broods which are suitable for seed, whilst opposing the production of the infected eggs which year by year flood the silkworm cultivating departments.

"I shall be much obliged, Monsieur le Ministre, if you will kindly inform the Prefect of the Corrèze of the forecasts which I now impart to you, and if you will ask *him* to report to you the results of Mademoiselle Amat's three lots.

"For my part, I feel so sure of what I now affirm, that I shall not even trouble to test, by hatching them, the samples which you have sent me. I have thrown them into the river. . . ."

J. B. Dumas had come to Alais, Messrs. Gernez and Duclaux now returned from their expeditions. In two hundred broods, each of one or two ounces of seed, coming from three different sources and hatched in various localities, not one failure was recorded. The Lyons Commission, which had made a note of Pasteur's bold prognosis, found it absolutely correct; the excellence of the method was acknowledged by all who had conscientiously tried it. Now that the scourge was really conquered, Pasteur imagined that all he had to do was to set up a table of the results sent to him. But, from the south of France and from Corsica, jealousies were beginning

their work of undermining; pseudo-scientists in their vanity proclaimed that everything was illusory that was outside their own affirmations, and the seed merchants, willing to ruin everybody rather than jeopardize their miserable interests, "did not hesitate (we are quoting M. Gernez) to perpetrate the most odious falsehoods."

Instead of being annoyed, saddened, often indignant as he was, Pasteur would have done more wisely to look back upon the history of most great discoveries and of the initial difficulties which beset them. But he could not look upon such things philosophically; stupidity astonished him and he could not easily bring himself to believe in bad faith. His friends in Alais society, M. de Lachadenède, M. Despeyroux, professor of chemistry, might have reminded him, in their evening conversations, of the difficulties ever encountered in the service of mankind. The prejudice against potatoes, for instance, had lasted three hundred years. When they were brought over from Peru in the fifteenth century, it was asserted that they caused leprosy; in the seventeenth century, that accusation was recognized to be absurd, but it was said that they caused fever. One century later, in 1771, the Besançon Academy of Medicine having opened a competition for the answer to the following question of general interest: "What plants can be used to supplement other foods in times of famine?" a military apothecary, named Parmentier, competed and proved victoriously that the potato was quite harmless. After that, he began a propagandist campaign in favour of potatoes. But prejudice still subsisted in spite of his experimental fields and of the dinners in the menu of which potatoes held a large place. Louis XVI had then an inspiration worthy of Henry IV; he appeared in public, wearing in his buttonhole Parmentier's little mauve flower, and thus glorified it in the eyes of the Court and of the crowd.

But such comparisons had no weight with Pasteur; he was henceforth sure of his method and longed to see it adopted, unable to understand why there should be further discussions now that the silkworm industry was saved and the bread of so many poor families assured. He was learning to know all the bitterness of sterile polemics, and the obstacles placed one by one in the way of those who attempt to give humanity anything new and useful. Fortunately he had what so many men of research have lacked, the active and zealous collabora-

tion of pupils imbued with his principles, and the rarer and priceless blessing of a home life mingling with his laboratory life. His wife and his daughter, a mere child, shared his sericiculture labours; they had become *magnanarelles* equal to the most capable in Alais. Another privilege was the advocacy of some champions quite unknown to him. Those who loved science and who understood that it would now become, thanks to Pasteur, an important factor in agricultural and sericicultural matters hailed his achievements with joy. For instance, a letter was published on July 8, 1869, in the *Journal of Practical Agriculture* by a cultivator who had obtained excellent results by applying Pasteur's method; the letter concluded as follows: "We should be obliged, if, through the columns of your paper, you would express to M. Pasteur our feelings of gratitude for his laborious and valuable researches. We firmly hope that he will one day reap the fruit of his arduous labours, and be amply compensated for the passionate attacks of which he is now the object."

"Monsieur Pasteur," once said the Mayor of Alais, Dr. Pagès, "if what you are showing me becomes verified in current practice, nothing can repay you for your work, but the town of Alais will raise a golden statue to you."

Marshal Vaillant began to take more and more interest in this question, which was not darkened, in his eyes at least, by the dust of polemics. The old soldier, always scrupulously punctual at the meetings of the Institute and of the Imperial and Central Society of Agriculture, had amused himself by organizing a little silkworm nursery on the Pasteur system, in his own study, in the very centre of Paris. These experiments, in the Imperial palace might have reminded an erudite reader of Olivier de Serres' *Théâtre d'Agriculture* of the time when the said Olivier de Serres planted mulberry trees in the Tuileries gardens at Henry IV's request, and when, according to the old agricultural writer, a house was arranged at the end of the gardens "accommodated with all things necessary as well for the feeding of the worms as for the preparation of silk."

The Marshal, though calling himself the most modest of sericicultors, had been able to appreciate the safety of a method which produced the same results in Paris as at the Pont Gisquet; the octogenarian veteran dwelt with complacency on the splendid condition of his silkworms in all their phases from

the minute worm hatched from the seed-like egg to the splendid cocoon of white or yellow silk.

It occurred to Vaillant to suggest a decisive experiment in favour of Pasteur and of the silkworm industry. The Prince Imperial owned in Illyria, about six leagues from Trieste, a property called Villa Vicentina. One of Napoleon's sisters, Elisa Bonaparte, had lived peacefully there after the fall of the first Empire, and had left it to her daughter, Princess Baciocchi, who bequeathed it to the Prince Imperial, with the rest of her fortune. Vines and mulberry trees grew plentifully on that vast domain, but the produce of cocoons was nil, pébrine and flachery having devastated the place. Marshal Vaillant, Minister of the Emperor's Household, desired to render the princely property once again productive and, at the same time, to give his colleague of the Institute an opportunity of "definitely silencing the opposition created by ignorance and jealousy." In a letter dated October 9, he requested Pasteur to send out 900 ounces of seed to Villa Vicentina, a large quantity, for one ounce produced, on an average, thirty kilogrammes of cocoons. Six days later the Marshal wrote to M. Tisserand, the director of the Crown agricultural establishments, who knew Villa Vicentina: "I have suggested to the Emperor that M. Pasteur should be offered a lodging at Villa Vicentina; the Emperor acquiesces in the most gracious manner. Tell me whether that is possible."

M. Tisserand, heartily applauding the Marshal's excellent idea, described the domain and the dwelling house, Villa Elisa, a white Italian two-storied house, situated amongst lawns and trees in a park of sixty hectares. "It would indeed be well," continued M. Tisserand, "that M. Pasteur should find peace, rest, and a return of the health he has so valiantly compromised in his devotion to his country, in the midst of the lands which will be the first to profit by the fruit of his splendid discoveries and where his name will be blessed before long."

Pasteur started three weeks later with his family; the long journey had to be taken in short stages, the state of his health still being very precarious. He stopped at Alais on the way, in order to fetch the selected seed, and on November 25, at 9 p.m., he reached Villa Vicentina. The fifty tenants of the domain did not suspect that the new arrival would bring back with him the prosperity of former years. Raulin, the "temporizer," joined his master a few weeks later.

This was a period not of rest, but of a great calm, with regular work under a pure sky. Whilst waiting for hatching time, Pasteur continued to dictate to his wife the book he had mentioned to J. B. Dumas in a letter from St. Hippolyte le Fort. But the projected little book was changing its shape and growing into a two-volume work full of facts and documents. It was ready to publish by April, 1870.

When the moment for hatching the seed had arrived, Pasteur distributed twenty-five ounces among the tenants and kept twenty-five ounces for himself. An incident disturbed these days of work: a steward, who had by him an old box of Japanese seed, sold this suspicious seed with the rest. The idea that confiding peasants had thus been swindled sent Pasteur beside himself; in his violent anger he sent for this steward, overwhelmed him with reproaches and forbade him ever to show his face before him again.

"The Marshal," wrote Dumas to Pasteur, "has told me of the swindles you have come across and which have upset you so much. Do not worry unreasonably; if I were you I would merely insert a line in a local paper: 'M. Pasteur is only answerable for the seeds he himself sells to cultivators.'" Those cultivators soon were duly edified. The results of the seeding process were represented by a harvest of cocoons which brought in, after all expenses were paid, a profit of 22,000 francs, the first profit earned by the property for ten years. This was indeed an Imperial present from Pasteur; the Emperor was amazed and delighted.

The Government then desired to do for Pasteur what had been done for Dumas and Claude Bernard, that is, give him a seat in the Senate. His most decided partisan was the competitor that several political personages suggested against him: Henri Sainte Claire Deville. Deville wrote to Mme. Pasteur in June: "You must know that if Pasteur becomes a Senator, and Pasteur alone, you understand—for they cannot elect two chemists at once!—it will be a triumph for your friend—a triumph and an unmixed pleasure."

The projected decree was one of eighteen then in preparation. The final list—the last under the Emipre—where Emile Augier was to represent French literature was postponed from day to day.

Pasteur left Villa Vicentina on July 6, taking with him the gratitude of the people whose good genius he had been for

nearly eight months. In northern Italy, as well as in Austria, his process of cellular seeding was now applied with success.

Before returning to France he went to Vienna and then to Munich : he desired to talk with the German chemist, Liebig, the most determined of his adversaries. He thought it impossible that Liebig's ideas on fermentation should not have been shaken and altered in the last thirteen years. Liebig could not still be affirming that the presence of decomposing animal or vegetable matter should be necessary to fermentation ! That theory had been destroyed by a simple and decisive experiment of Pasteur's : he had sown a trace of yeast in water containing but sugar and mineral crystallized salts, and had seen this yeast multiply itself and produce a regular alcoholic fermentation.

Since all nitrogenized organic matter (constituting the ferment, according to Liebig) was absent, Pasteur considered that he thus proved the life of the ferment and the absence of any action from albuminoid matter in a stage of decomposition. The death phenomenon now appeared as a life phenomenon. How could Liebig deny the independent existence of ferments in their infinite littleness and their power of destroying and transforming everything? What did he think of all these new ideas? would he still write, as in 1845 : " As to the opinion which explains putrefaction of animal substances by the presence of microscopic animalculæ, it may be compared to that of a child who would explain the rapidity of the Rhine current by attributing it to the violent movement of the numerous mill wheels of Mayence? "

Since that ingeniously fallacious paragraph, many results had come to light. Perhaps Liebig, who in 1851 hailed J. B. Dumas as a master, had now come to Dumas' point of view respecting the fruitfulness of the Pastorian theory. That theory was extended to diseases ; the infinitely small appeared as disorganizers of living tissues. The part played by the corpuscles in the contagious and hereditary pébrine led to many reflections on the contagious and hereditary element of human diseases. Even the long-postponed transmission of certain diseases was becoming clearer now that, within the vibrio of flachery, other corpuscles were found, germs of the flachery disease, ready to break out from one year to another.

To convince Liebig, to bring him to acknowledge the triumph of those ideas with the pleasure of a true *savant*, such

was Pasteur's desire when he entered Liebig's laboratory. The tall old man, in a long frock coat, received him with kindly courtesy; but when Pasteur, who was eager to come to the object of his visit, tried to approach the delicate subject, Liebig, without losing his amenity, refused all discussion, alleging indisposition. Pasteur did not insist, but promised himself that he would return to the charge.

CHAPTER VII

1870—1872

PASTEUR, on his return, spent forty-eight hours in Strasburg, which was for him full of memories of his laborious days at the Faculty of that town, between 1848 and 1854, at a time when rivalry already existed between France and Germany, a generous rivalry of moral and intellectual effort. He then heard for the first time of the threatening war; all his hopes of progress founded on peace, through scientific discoveries, began to crumble away, and his disappointment was embittered by the recollection of many illusions.

Never was more cruel rebuff given to the generous efforts of a policy of sentiment: after having laid the foundation of the independence and unity of Italy, France had sympathized with Germany's desire for unity, and few of the counsellors, or even the adversaries of the Empire, would not have defended this idea, which was supposed to lead to civilization. During that period of anxious waiting (beginning of July, 1870), when the most alarming news was daily published in Strasburg, it did not occur to any one to look back upon quotations from papers only a few years old, though in that very town a pamphlet might have been found, written by Edmond About in 1860, and containing the following words—

"Let Germany become united! France has no dearer or more ardent desire, for she loves the German nation with a disinterested friendship. France is not alarmed at seeing the formation of an Italian nation of 26,000,000 men in the South: she need not fear to see 32,000,000 Germans found a great people on the Eastern frontier."

Proud to be first to proclaim the rights of nations; influenced by mingled feelings of kindliness, trustfulness, optimism and a certain vanity of disinterestedness, France, who loves to be loved, imagined that the world would be grateful for her

international sociability, and that her smiles were sufficient to maintain peace and joy in Europe.

Far from being alarmed by certain symptoms in her neighbours, she voluntarily closed her eyes to the manœuvres of the Prussian troops, her ears to the roar of the artillery practice constantly heard across her eastern frontier; in 1863 patrols of German cavalry had come as far as Wissemburg. But people thought that Germany was "playing soldiers." Duruy, who shared at that time the general delusion, wrote in some traveller's notes published in 1864: "We have had your German Rhine, and though you have garnished it with bristling fortresses and cannon turning France-wards, we do not wish to have it again, . . . for the time for conquests is past. Conquests shall only now be made with the free consent of nations. Too much blood has been poured into the Rhine! What an immense people would arise if they who were struck down by the sword along its banks could be restored to life!"

After the thunderclap of Sadowa, the French Government, believing, in its infatuation, that it was entitled to a share of gratitude and security, asked for the land along the Rhine as far as Mayence; this territorial aggrandizement might have compensated for Prussia's redoubtable conquests. The refusal was not long in coming. The Rhenish provinces immediately swarmed with Prussian troops. The Emperor, awaking from his dream, hesitating to make war, sent another proposition to Prussia: that the Rhenish provinces should become a buffer State. The same haughty answer was returned. France then hoped for the cession of Luxemburg, a hope all the more natural in that the populations of Luxemburg were willing to vote for annexation to France, and such a policy would have been in accordance with the rights of nations. But this request, apparently entertained at first by Prussia, was presently hampered by intrigues which caused its rejection. Duped, not even treated as an arbiter, but merely as a contemptible witness, France dazzled herself for a moment with the brilliant Exhibition of 1867. But it was a last and splendid flash; the word which is the bane of nations and of sovereigns, "to-morrow," was on the lips of the ageing Emperor. The reform in the French army, which should have been bold and immediate, was postponed and afterwards begun jerkily and unmethodically. Prussia however affected to be alarmed. Then irritation at having been duped, the evidence

of a growing peril, a lingering hope in the military fortune of France—everything conspired to give an incident, provoked by Prussia, the proportions of a *casus belli*. But, in spite of so many grievances, people did not yet believe in this sudden return to barbarism. The Imperial policy had indeed been blindly inconsistent; after opening a wide prospect of unity before the German people it had been thought possible to say "No further than the Main," as if the impetuous force of a popular movement could be arrested after once being started. France suddenly opened her eyes to her danger and to the failure of her policy. But if a noble sentiment of generosity had been mingled with the desire to increase her territory without shedding a drop of blood, she had had the honour of being in the vanguard of progress. Were great ideas of peace and human brotherhood about to be engulfed in a war which would throw Europe into an era of violence and brutality?

Pasteur, profoundly saddened, could not bear to realize that his ideal of the peaceful and beneficent destiny of France was about to vanish; he left Strasburg—never to return to it—a prey to the most sombre thoughts.

When he returned to Paris, he met Sainte Claire Deville, who had come back from a scientific mission in Germany, and who had for the first time lost his brightness and optimism. The war appeared to him absolutely disastrous. He had seen the Prussian army, redoubtable in its skilful organization, closing along the frontier; the invasion was certain, and there was nothing to stay it. Everything was lacking in France, even in arsenals like Strasburg. At Toul, on the second line of fortifications, so little attention was paid to defence that the Government had thought that the place could be used as a dépôt for the infantry and cavalry reserves, who could await there the order for crossing the Rhine.

"Ah! my lads, my poor lads!" said Sainte Claire Deville to his Ecole Normale students, "it is all up with us!" And he was seen, between two experiments, wiping his eyes with the corner of his laboratory apron.

The students, with the ordinary confidence of youth, could not believe that an invasion should be so imminent. However, in spite of the privilege which frees *Normaliens* from any military service in exchange for a ten years' engagement at the University, they put patriotic duty above any future University appointments, and entered the ranks as private

soldiers. Those who had been favoured by being immediately incorporated in a battalion of *chasseurs à pied* the dépôt of which was at Vincennes, spent their last evening—their vigil as they called it—in the drawing-room of the sub-director of the Ecole, Bertin. Sainte Claire Deville and Pasteur were there, also Duruy, whose three sons had enlisted. Pasteur's son, aged eighteen, was also on the eve of his departure.

Every one of the students at the Ecole Normale enlisted, some as *chasseurs à pied*, some in a line regiment, others with the marines, in the artillery, even with the *franc tireurs*. Pasteur wished to be enrolled in the *garde nationale* with Duruy and Bertin, but he had to be reminded that a half-paralysed man was unfit for service. After the departure of all the students, the Ecole Normale fell into the silence of deserted houses. M. Bouillier, the director, and Bertin decided to turn it into an ambulance, a sort of home for the *Normaliens* who were stationed in various quarters of Paris.

Pasteur, unable to serve his country except by his scientific researches, had the firm intention of continuing his work; but he was overwhelmed by the reverses which fell upon France, the idea of the bloodshed and of his invaded country oppressed him like a monomania.

"Do not stay in Paris," Bertin said to him, echoed by Dr. Godélier. "You have no right to stay; you would be a useless mouth during the siege," he added, almost cheerfully, earnestly desiring to see his friend out of harm's way. Pasteur allowed himself to be persuaded, and started for Arbois on September 5, his heart aching for the sorrows of France.

Some notes and letters enable us to follow him there, in the daily detail of his life, amongst his books, his plans of future work, and now and then his outbursts of passionate grief. He tried to return to the books he loved, to feel over again the attraction of "all that is great and beautiful" to quote a favourite phrase. He read at that time Laplace's *Exposition du Système du Monde*, and even copied out some fragments, general ideas, concurring with his own. The vision of a Galileo or a Newton rising through a series of inductions from "particular phenomena to others more far-reaching, and from those to the general laws of Nature," on this earth, "itself so small a part of the solar system, and disappearing entirely in the immensity of the heavens, of which that system is but an unimportant corner,"—that vision enveloped Pasteur

with the twofold feeling with which every man must be imbued: humility before the Great Mystery, and admiration for those who, raising a corner of the veil, prove that genius is divinely inspired. Such reading helped Pasteur through the sad time of anxious waiting, and he would repeat as in brighter days, "*Laboremus.*"

But sometimes, when he was sitting quietly with his wife and daughter, the trumpet call would sound, with which the Arbois crier preceded the proclaiming of news. Then everything was forgotten, the universal order of things of no account, and Pasteur's anguished soul would concentrate itself on that imperceptible corner of the universe, France, his suffering country. He would go downstairs, mix with groups standing on the little bridge across the Cuisance, listen breathlessly to the official communication, and sadly go back to the room where the memories of his father only emphasized the painful contrast with the present time. In the most prominent place hung a large medallion of General Bonaparte, by the Franc-Comtois Huguenin, the habit of authority visible in the thin energetic face; then a larger effigy in bronzed plaster of Napoleon in profile, in a very simple uniform; by the mantelpiece a lithograph of the little King of Rome with his curly head; on the bookshelves, well within reach, books on the Great Epoch, read over and over again by the old soldier who had died in the humble room which still reflected some of the Imperial glory.

That glory, that legend had enveloped the childhood and youth of Pasteur, who, as he advanced in life, still preserved the same enthusiasm. His imagination pictured the Emperor, calm in the midst of battles, or reviewing his troops surrounded by an escort of field marshals, entering as a sovereign a capital not his own, then overwhelmed by numbers at Waterloo, and finally condemned to exile and inactivity, and dying in a long drawn agony. Glorious or lugubrious, those visions came back to him with poignant insistency in those days of September, 1870. What was Waterloo compared to Sedan! The departure for St. Helena had the grandeur of the end of an epic; it seemed almost enviable by the side of that last episode of the Second Empire, when Napoleon III, vanquished, spared by the death which he wooed, left Sedan by the Donchery road to enter the cottage where Bismarck was to inform him of the rendezvous given by the King of Prussia.

The Emperor had now but a shadow of power, having made

the Empress Regent before he left Paris; it was therefore not the sword of France, but his own, that he was about to surrender. But he thought he might hope that the King of Prussia would show clemency to the French army and people, having many times declared that he made war on the Emperor and not on France.

"Can it be credited," said Bismarck, speaking afterwards of that interview, "that he actually believed in our generosity!" The chancellor added, speaking of that somewhat protracted *tête-à-tête*, "I felt as I used to in my youth, when my partner in a cotillon was a girl to whom I did not quite know what to say, and whom nobody would fetch away for a turn!"

Napoleon III and the King of Prussia met in the Château of Bellevue, in the neighbourhood of Sedan, opposite a peninsula henceforth known by the sad name of "Camp of Misery." The Emperor looked for the last time upon his 83,000 soldiers, disarmed, starving, waiting in the mud for the Prussian escort which was to convey them as prisoners far beyond the Rhine. Wilhelm did not even pronounce the word peace.

Jules Favre, taking possession on September 6 of the department of Foreign Affairs, recalled to the diplomatic agents the fall of the Empire and the words of the King of Prussia; then in an unaccustomed outburst of eloquence exclaimed: "Does the King of Prussia wish to continue an impious struggle which will be as fatal to him as to us? Does he wish to give to the world in the nineteenth century the cruel spectacle of two nations destroying each other and forgetful of human feelings, of reason and of science, heaping up ruin and death? Let him then assume the responsibility before the world and before posterity!" And then followed the celebrated phrase with which he has been violently and iniquitously reproached, and which expressed the unanimous sentiment of France: "We will not concede one inch of our territory nor a stone of our fortifications."

Bismarck refused the interview Jules Favre asked of him (September 10), under the pretext that the new Government was irregular. The enemy was coming nearer and nearer to Paris. The French city was resolved to resist; thousands upon thousands of oxen were being corralled in the Bois de Boulogne; poor people from the suburbs were coming to take refuge in the city. On the Place de la Concorde, the statue which repre-

sents the city of Strasburg was covered with flowers and flags, and seemed to incarnate the idea of the *Patrie* itself.

Articles and letters came to Arbois in that early September, bringing an echo of the sorrows of Paris. Pasteur was then reading the works of General Foy, wherein he found thoughts in accordance with his own, occasionally copying out such passages as the following: "Right and Might struggle for the world; Right, which constitutes and preserves Society; Might, which overcomes nations and bleeds them to death."

General Foy fought for France during twenty-five years, and, writing in 1820, recalled with a patriotic shudder the horrors of foreign invasions. Long after peace was signed, by a chance meeting in a street in Paris, General Foy found himself face to face with Wellington. The sight was so odious to him that he spoke of this meeting in the *Chambre* with an accent of sorrowful humiliation which breathed the sadness of Waterloo over the whole assembly. Pasteur could well understand the long continued vibration of that suffering chord, he, who never afterwards could speak without a thrill of sorrow of that war which Germany, in defiance of humanity, was inexcusably pursuing.

It was the fourth time in less than a hundred years that a Prussian invasion overflowed into France. But instead of 42,000 Prussians, scattered in 1792 over the sacred soil of the *Patrie*—Pasteur pronounced the word with the faith and tenderness of a true son of France—there were now 518,000 men to fight 285,000 French.

The thought that they had been armed in secret for the conquest of neighbouring lands, the memory of France's optimism until that diplomatic incident, invented so that France might stumble over it, and the inaction of Europe, inspired Pasteur with reflections which he confided to his pupil Raulin. "What folly, what blindness," he wrote (September 17), "there are in the inertia of Austria, Russia, England! What ignorance in our army leaders of the respective forces of the two nations! We *savants* were indeed right when we deplored the poverty of the department of Public Instruction! The real cause of our misfortunes lies there. It is not with impunity—as it will one day be recognized, too late—that a great nation is allowed to lose its intellectual standard. But, as you say, if we rise again from those disasters, we shall again see our statesmen lose themselves in endless

discussions on forms of government and abstract political questions instead of going to the root of the matter. We are paying the penalty of fifty years' forgetfulness of science, of its conditions of development, of its immense influence on the destiny 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!'"

There is a passage in the Psalms where the captives of Israel, led to Babylonian rivers, weep at the memory of Jerusalem. After swearing never to forget their country, they wish their enemies every misfortune, and hurl this last imprecation at Babylon: "Blessed shall he be that taketh thy children and throweth them against the stones."[1] One of the most Christlike souls of our time, Henri Perreyve, speaking of Poland, of vanquished and oppressed nations, quoted this Psalm and exclaimed: "O Anger, man's Anger, how difficult it is to drive thee out of man's heart! and how irresistible are the flames kindled by the insolence of injustice!" Those flames were kindled in the soul of Pasteur, full as it was of human tenderness, and they burst out in that sobbing cry of despair.

On that 17th of September, the day before Paris was invested, Jules Favre made another attempt to obtain peace. He published an account of that interview which took place at the Château of Ferrières, near Meaux; this printed account reached every town in France, and was read with grief and anger.

Jules Favre had deluded himself into thinking that victorious Prussia would limit its demands to a war indemnity, probably a formidable one. But Bismarck, besides the indemnity, intended to take a portion of French soil, and claimed Strasburg first of all. "It is the key of the house; I must have it." And with Strasburg he wanted the whole Department of the *Haut-Rhin*, that of the *Bas-Rhin*, Metz, and a part of the Department of *Moselle*. Jules Favre, character-

[1] Ps. cxxxvii. 9.

istically French, exhausted his eloquence in putting sentiment into politics, spoke of European rights, of the right of the people to dispose of themselves, tried to bring out the fact that a brutal annexation was in direct opposition to the progress of civilization. "I know very well," said Bismarck, "that they (meaning the Alsatians and Lorrainers) do not want us; they will give us a deal of trouble, but we must annex them." In the event of a future war Prussia was to have the advantage. All this was said with an authoritative courtesy, an insolent tranquillity, through which contempt for men was visible, evidently the best means of governing them in Bismarck's eyes. As Jules Favre was pleading the cause of heroic Strasburg, whose long resistance was the admiration of Paris, "Strasburg will now fall into our hands," said Bismarck coldly; "it is but a question for engineers; therefore I request that the garrison should surrender as prisoners of war."

Jules Favre "leapt in his grief"—the words are his—but King Wilhelm exacted this condition. Jules Favre, almost breaking down, turning away to hide the tears that welled into his eyes, ended the interview with these words: "It is an indefinite struggle between two nations who should go hand in hand."

Traces of this patriotic anguish are to be found in one of Pasteur's notebooks, as well as a circular addressed by Jules Favre to the diplomatic representatives in answer to certain points disputed by Bismarck. Pasteur admiringly took note of the following passage: "I know not what destinies Fate has in store for us. But I do feel most deeply that if I had to choose between the present situation of France and that of Prussia, I should decide for the former. Better far our sufferings, our perils, our sacrifices, than the cruel and inflexible ambition of our foe."

"We must preserve hope until the end," wrote Pasteur after reading the above, "say nothing to discourage each other, and wish ardently for a prolonged struggle. Let us think of hopeful things; Bazaine may save us." . . . How many French hearts were sharing that hope at the very time when Bazaine was preparing to betray Metz, his troops and his flag!

"Should we not cry: 'Happy are the dead!'" wrote Pasteur a few days after the news burst upon France of that army lost without being allowed to fight, of that city of Metz, the strongest in France, surrendered without a struggle!

Through all Pasteur's anxieties about the war, certain obser-

vations, certain projected experiments resounded in his mind like the hours that a clock strikes, unheeded but not unheard, in a house visited by death. He could not put them away from him, they were part of his very life.

Any sort of laboratory work was difficult for him in the tanner's house, which had remained the joint property of himself and his sister. His brother-in-law had continued Joseph Pasteur's trade. Pasteur applied his spirit of observation to everything around him, and took the opportunity of studying the fermentation of tan. He would ask endless questions, trying to discover the scientific reason of every process and every routine. Whilst his sister was making bread he would study the raising of the crust, the influence of air in the kneading of the dough, and his imagination rising as usual from a minor point to the greatest problems, he began to seek for a means of increasing the nutritive powers of bread, and consequently of lowering its price.

The *Salut Public* of December 20 contained a notice on that very subject, which Pasteur transcribed. The Central Commission of Hygiene which included among its members Sainte Claire Deville, Wurtz, Bouchardat and Trélat, had tried, when dealing with this question of bread (a vital one during the siege), to prove to the Parisians that bread is the more wholesome for containing a little bran. "With what emotion," wrote Pasteur, "I have just read all those names dear to science, greater now before their fellow-citizens and before posterity. Why could I not share their sufferings and their dangers!" He would have added "and their work" if some of the Académie des Sciences reports had reached him.

The history of the Academy during the war is worthy of brief mention. Moreover it was too deeply interesting to Pasteur, too constantly in his thoughts, not to be considered as forming part of his biography.

During the first period, the Academy, imagining, like the rest of France, that there was no doubt of a favourable issue of the war, continued its purely scientific task. When the first defeats were announced, the habitual communications ceased, and the Academy, unable to think of anything but the war, held sittings of three-quarters of an hour or even less.

One of the correspondents of the Institute, the surgeon Sédillot, who was in Alsace at the head of an ambulance corps, and who himself performed as many as fifteen amputations in

one day, addressed two noteworthy letters to the President of the Academy. Those letters mark a date in the history of surgery, and show how restricted was then in France the share of some of Pasteur's ideas at the very time when in other countries they were adopted and followed. Lister, the celebrated English surgeon, having, he said, meditated on Pasteur's theory of germs, and proclaimed himself his follower, convinced that complications and infection of wounds were caused by their giving access to living organisms and infectious germs, elements of trouble, often of death, had already in 1867 inaugurated a method of treatment. He attempted the destruction of germs floating in air by means of a vaporizer filled with a carbolic solution, then isolated and preserved the wound from the contact of the air. Sponges, drainage tubes, etc., were subjected to minute precautions; in one word, he created antisepsis. Four months before the war he had propounded the principles which should guide surgeons, but it occurred to no one in France, in the first battles, to apply the new method. "The horrible mortality amongst the wounded in battle," writes Sédillot, "calls for the attention of all the friends of science and humanity. The surgeon's art, hesitating and disconcerted, pursues a doctrine whose rules seem to flee before research. . . . Places where there are wounded are recognizable by the fetor of suppuration and gangrene."

Hundreds and thousands of wounded, their faces pale, but full of hope and desire to live, succumbed between the eighth and tenth day to gangrene and erysipelas. Those failures of the surgery of the past are plain to us now that the doctrine of germs has explained everything; but, at that time, such an avowal of impotence before the mysterious *contagium sui generis*, which, the doctors averred, eluded all research, and such awful statistics of mortality embittered the anguish of defeat.

The Academy then attempted to take a share in the national co-operation by making a special study of any subject which interested the public health and defence. A sitting on methods of steering balloons was succeeded by another on various means of preserving meat during the siege. Then came an anxious inquiry into modes of alimentation of infants. At the end of October there were but 20,000 litres of milk per day to be procured in the whole of Paris, and the healthy were implored to abstain from it. It was a question of life and death for young

children, and already many little coffins were daily to be seen on the road to the cemetery.

Thus visions of death amongst soldiers in their prime and children in their infancy hung over the Academy meeting hall. It was at one of those mournful sittings, on a dark autumn afternoon, that Chevreul, an octogenarian member of the Institute, who, like Pasteur, had believed in civilization and in the binding together of nations through science, art and letters, looking at the sacks of earth piled outside the windows to save the library from the bursting shells, exclaimed in loud desolate tones—

"And yet we are in the nineteenth century, and a few months ago the French did not even think of a war which has put their capital into a state of siege and traced around its walls a desert zone where he who sowed does not reap! And there are public universities where they teach the Beautiful, the True, and the Right."

"Might goes before Right," Bismarck said. A German journalist invented another phrase which went the round of Europe: "the psychological moment for bombardment." On January 5, one of the first Prussian shells sank into the garden of the Ecole Normale; another burst in the very ambulance of the Ecole. Bertin, the sub-director, rushed through the suffocating smoke and ascertained that none of the patients was hurt; he found the breech between two beds. The miserable patients dragged themselves downstairs to the lecture rooms on the ground floor, not a much safer refuge.

From the heights of Châtillon the enemy's batteries were bombarding all the left bank of the Seine, the Prussians, regardless of the white flags bearing the red cross of Geneva, were aiming at the Val-de-Grâce and the Panthéon. "Where is the Germany of our dreams?" wrote Paul de St. Victor on January 9, "the Germany of the poets? Between her and France an abyss of hatred has opened, a Rhine of blood and tears that no peace can ever bridge over."

On that same date, Chevreul read the following declaration to the Academy of Science—

The Garden of Medicinal Plants, founded in Paris
by an edict of King Louis XIII,
dated January, 1826,
Converted into the Museum of Natural History

by a decree of the Convention on June 10, 1793,
was Bombarded,
under the reign of Wilhelm I King of
Prussia, Count von Bismarck, Chancellor,
by the Prussian army, during the night
of January 8–9, 1871.
It had until then been respected by all parties
and all powers, national or
foreign.

Pasteur, on reading this protest, regretted more than ever that he had not been there to sign it. It then occurred to him that he too might give vent to the proud plaint of the vanquished from his little house at Arbois. He remembered with a sudden bitterness the diploma he had received from the University of Bonn. Many years had passed since the time in the First Empire when one of the 110 French Departments had been that of Rhine and Moselle, with Coblentz as its *préfecture* and Bonn and Zimmern as *sous-préfectures*. When, in 1815, Prussia's iron hand seized again those Rhenish provinces which had become so French at heart, the Prussian king and his ministers hit upon the highly politic idea of founding a University on the picturesque banks of the Rhine, thus morally conquering the people after reducing them by force. That University had been a great success and had become most prosperous. The Strasburg Faculty under the Second Empire, with its few professors and its general penury, seemed very poor compared to the Bonn University, with its fifty-three professors and its vast laboratories of chemistry, physics and medicine, and even a museum of antiquities. Pasteur and Duruy had often exchanged remarks on that subject. But that rivalry between the two Faculties was of a noble nature, animated as it was by the great feeling that science is superior to national distinctions. King Wilhelm had once said, "Prussia's conquests must be of the moral kind," and Pasteur had not thought of any other conquests.

When in 1868 the University of Bonn conferred upon him the diploma of Doctor of Medicine, saying that "by his very penetrating experiments, he had much contributed to the knowledge of the history of the generation of micro-organisms, and had happily advanced the progress of the science of fermentations," he had been much pleased at this acknowledgment of

the future opened to medical studies by his work, and he was proud to show the Degree he had received.

"Now," he wrote (January 18, 1871), to the Head of the Faculty of Medicine, after recalling his former sentiments, "now the sight of that parchment is odious to me, and I feel offended at seeing my name, with the qualification of *Virum clarissimum* that you have given it, placed under a name which is henceforth an object of execration to my country, that of *Rex Gulielmus*.

"While highly asseverating my profound respect for you, Sir, and for the celebrated professors who have affixed their signatures to the decision of the members of your Order, I am called upon by my conscience to ask you to efface my name from the archives of your Faculty, and to take back that diploma, as a sign of the indignation inspired in a French scientist by the barbarity and hypocrisy of him who, in order to satisfy his criminal pride, persists in the massacre of two great nations." Pasteur's protest ended with these words—

"Written at Arbois (Jura) on January 18, 1871, after reading the mark of infamy inscribed on the forehead of your King by the illustrious director of the Museum of Natural History M. Chevreul."

"This letter will not have much weight with a people whose principles differ so totally from those that inspire us," said Pasteur, "but it will at least echo the indignation of French scientists."

He made a collection of stories, of episodes, and letters, which fell in his way; amongst other things we find an open letter from General Chanzy to the commandant of the Prussian troops at Vendôme, denouncing the insults, outrages, and inexcusable violence of the Prussians towards the inhabitants of St. Calais, who had shown great kindness to the enemy's sick and wounded.

"You respond by insolence, destruction and pillage to the generosity with which we treat your prisoners and wounded. I indignantly protest, in the name of humanity and of the rights of men, which you trample under foot."

Pasteur also gathered up tales of bravery, of heroism, and of resignation—that form of heroism so often illustrated by women—during the terrible siege of Paris. And, from all those things, arose the psychology of war in its two aspects: in the invading army a spirit of conquest carried to oppression, and even apart

from the thrilling moments of battle, giving to hatred and cruelty a cold-blooded sanction of discipline; in the vanquished nation, an irrepressible revolt, an intoxication of sacrifice. Those who have not seen war do not know what love of the mother country means.

France was the more loved that she was more oppressed; she inspired her true sons with an infinite tenderness. Sully-Prudhomme, the poet of pensive youth, renouncing his love for Humanity in general, promised himself that he would henceforth devote his life to the exclusive love of France. A greater poet than he, Victor Hugo, wrote at that time the first part of his *Année Terrible*, with its mingled devotion and despair.

The death of Henri Regnault was one of the sad episodes of the war. This brilliant young painter—he was only twenty-seven years of age—enlisted as a *garde nationale*, though exempt by law from any military service through being a laureate of the *prix de Rome*.[1] He did his duty valiantly, and on January 19, at the last sortie attempted by the Parisians, at Buzenval, the last Prussian shot struck him in the forehead. The Académie des Sciences, at its sitting of January 23, rendered homage to him whose coffin enclosed such dazzling prospects and some of the glory of France. The very heart of Paris was touched, and a great sadness was felt at the funeral procession of the great artist who seemed an ideal type of all the youth and talent so heroically sacrificed—and all in vain—for the surrender of Paris had just been officially announced.

Regnault's father, the celebrated physicist, a member of the Institute, was at Geneva when he received this terrible blow. Another grief—not however comparable to the despair of a bereaved parent—befell him—an instance of the odious side of war, not in its horrors, its pools of blood and burnt dwellings, but in its premeditated cruelty. Regnault had left his laboratory utensils in his rooms at the Sèvres porcelain manufactory, of which he was the manager. Everything was apparently left in the same place, not a window was broken, no locks forced; but a Prussian, evidently an expert, had been there. "Nothing seemed changed," writes J. B. Dumas, "in that abode of science, and yet everything was destroyed; the glass tubes of barometers, thermometers, etc., were broken; scales

[1] *Prix de Rome.* A competition takes place every year amongst the students of the *Ecole des Beaux Arts* for this prize; the successful competitor is sent to Rome for a year at the expense of the Ecole. [Trans.]

and other similar instruments had been carefully knocked out of shape with a hammer." In a corner was a heap of ashes; they were the registers, notes, manuscripts, all Regnault's work of the last ten years. "Such cruelty," exclaimed J. B. Dumas, "is unexampled in history. The Roman soldier who butchered Archimedes in the heat of the onslaught may be excused—he did not know him; but with what sacrilegious meanness could such a work of destruction as this be accomplished!!!"

On the very day when the Académie des Sciences was condoling with Henri Regnault's sorrowing father, Pasteur, anxious at having had no news of his son, who had been fighting before Héricourt, determined to go and look for him in the ranks of the Eastern Army Corps. By Poligny and Lons-le-Saulnier, the roads were full of stragglers from the various regiments left several days behind, their route completely lost, who begged for bread as they marched, barely covered by the tattered remnants of their uniforms. The main body of the army was on the way to Besançon, a sad procession of French soldiers, hanging their heads under the cold grey sky and tramping painfully in the snow.

Bourbaki, the general-in-chief, a hero of African battlefields, was becoming more and more unnerved by the combinations of this war. Whilst the Minister, in a dispatch from Bordeaux, had ordered him to move back towards Dôle, to prevent the taking of Dijon, then to hurry to Nevers or Joigny, where 20,000 men would be ready to be incorporated, Bourbaki, overwhelmed by the lamentable spectacle under his eyes, could see no resource for his corps but a last line of retreat, Pontarlier.

It was among that stream of soldiers that Pasteur attempted to find his son. His old friend and neighbour, Jules Vercel, saw him start, accompanied by his wife and daughter, on Tuesday, January 24, in a half broken down old carriage, the last that was left in the town. After journeying for some hours in the snow, the sad travellers spent the night in a little wayside inn near Montrond; the old carriage with its freight of travelling boxes stood on the roadside like a gipsy's caravan. The next morning they went on through a pine forest where the deep silence was unbroken save by the falling masses of snow from the spreading branches. They slept at Censeau, the next day at Chaffois, and it was only on the Friday that they reached Pontarlier, by roads made almost impracticable by the snow, the carriage now a mere wreck.

The town was full of soldiers, some crouching round fires in the street, others stepping across their dead horses and begging for a little straw to lie on. Many had taken refuge in the church and were lying on the steps of the altar; a few were attempting to bandage their frozen feet, threatened with gangrene.

Suddenly the news spread that the general-in-chief, Bourbaki, had shot himself through the brain. This did not excite much surprise. He had telegraphed two days before to the Minister of War: "You cannot have an idea of the sufferings that the army has endured since the beginning of December. It is martyrdom to be in command at such a time," he added despairingly.

"The retreat from Moscow cannot have been worse than this," said Pasteur to a staff officer, Commandant Bourboulon, a nephew of Sainte Claire Deville, whom he met in the midst of those horrors and who could give him no information as to his son's battalion of *Chasseurs*. "All that I can tell you," said a soldier anxiously questioned by Mme. Pasteur, "is that out of the 1,200 men of that battalion there are but 300 left." As she was questioning another, a soldier who was passing stopped: "Sergeant Pasteur? Yes, he is alive; I slept by him last night at Chaffois. He has remained behind; he is ill. You might meet him on the road towards Chaffois."

The Pasteurs started again on the road followed the day before. They had barely passed the Pontarlier gate when a rough cart came by. A soldier muffled in his great coat, his hands resting on the edge of the cart, started with surprise. He hurried down, and the family embraced without a word, so great was their emotion.

The capitulation of starving Paris and the proposed armistice are historical events still present in the memory of men who were then beginning to learn the meaning of defeat. The armistice, which Jules Favre thought would be applied without restriction to all the army corps, was interpreted by Bismarck in a peculiar way. He and Jules Favre between them had drawn up a protocol in general terms; it had been understood in those preliminary confabulations that, before drawing up the limits of the neutral zone applicable to the Eastern Army Corps, some missing information would be awaited, the respective positions of the belligerents being unknown. The information did not come, and Jules Favre in his imprudent

trustfulness supposed that the delimitation would be done on the spot by the officers in command. When he heard that the Prussian troops were continuing their march eastwards, he complained to Bismarck, who answered that "the incident cannot have compromised the Eastern Army Corps, as it already was completely routed when the armistice was signed." This calculated reserve on Bismarck's part was eminently characteristic of his moral physiognomy, and this encounter between the two Ministers proved once again the inferiority—when great interests are at stake—of emotional men to hard-hearted business men; however it must be acknowledged that Bismarck's statement was founded on fact. The Eastern Corps could have fought no more; its way was blocked. Without food, without clothes, in many cases without arms, nothing remained to the unfortunate soldiers but the refuge offered by Switzerland.

Pasteur went to Geneva with his son, who, after recovering from the illness caused by fatigue and privation, succeeded in getting back to France to rejoin his regiment in the early days of February. Pasteur then went on to Lyons and stayed there with his brother-in-law, M. Loir, Dean of the Lyons Faculty of Science. He intended to go back to Paris, but a letter from Bertin dated February 18 advised him to wait. "This is the present state of the Ecole: south wing: pulled down; will be built up again; workmen expected. Third year dormitory: ambulance occupied by eight students. Science dormitory and drawing classroom: ambulance again, forty patients. Ground floor classroom: 120 artillery-men. Pasteur laboratory: 210 *gardes nationaux*, refugees from Issy. You had better wait." Bertin added, with his indomitable good humour, speaking of the bombardment: "The first day I did not go out, but I took my bearings and found the formula: in leaving the school, walk close along the houses on my left; on coming back, keep close to them on my right; with that I went out as usual. The population of Paris has shown magnificent resignation and patience. . . . In order to have our revenge, everything will have to be rebuilt from the top to the bottom, the top especially."

Pasteur also thought that reforms should begin from the top. He prepared a paper dated from Lyons, and entitled "Why France found no superior men in the hours of peril." Amongst the mistakes committed, one in particular had been before his mind for twenty years, ever since he left the Ecole Normale:

"The forgetfulness, disdain even, that France had had for great intellectual men, especially in the realm of exact science." This seemed the more sad to him that things had been very different at the end of the eighteenth century. Pasteur enumerated the services rendered by science to his threatened country. If in 1792 France was able to face danger on all sides, it was because Lavoisier, Fourcroy, Guyton de Morveau, Chaptal, Berthollet, etc., discovered new means of extracting saltpetre and manufacturing gunpowder; because Monge found a method of founding cannon with great rapidity; and because the chemist Clouet invented a quick system of manufacturing steel. Science, in the service of patriotism, made a victorious army of a perturbed nation. If Marat, with his slanderous and injurious insinuations, had not turned from their course the feelings of the mob, Lavoisier never would have perished on the scaffold. The day after his execution, Lagrange said: "One moment was enough for his head to fall, and 200 years may not suffice to produce such another." Monge and Berthollet, also denounced by Marat, nearly shared the same fate: "In a week's time we shall be arrested, tried, condemned and executed," said Berthollet placidly to Monge, who answered with equal composure, thinking only of the country's defence, "All I know is that my gun factories are working admirably."

Bonaparte, from the first, made of science what he would have made of everything—a means of reigning. When he started for Egypt, he desired to have with him a staff of scientists, and Monge and Berthollet undertook to organize that distinguished company. Later, when Bonaparte became Napoleon I, he showed, in the intervals between his wars, so much respect for the place due to science as to proclaim the effacement of national rivalry when scientific discoveries were in question. Pasteur, when studying this side of the Imperial character, found in some pages by Arago on Monge that, after Waterloo, Napoleon, in a conversation he had with Monge at the Elysée, said, "Condemned now to command armies no longer, I can see but Science with which to occupy my mind and my soul . . ."

Alluding to the scientific supremacy of France during the early part of the nineteenth century, Pasteur wrote: "All the other nations acknowledged our superiority, though each could take pride in some great men: Berzelius in Sweden, Davy in England, Volta in Italy, other eminent men in Ger-

many and Switzerland; but in no country were they as numerous as in France . . ." He added these regretful lines: "A victim of her political instability, France has done nothing to keep up, to propagate and to develop the progress of science in our country; she has merely obeyed a given impulse; she has lived on her past, thinking herself great by the scientific discoveries to which she owed her material prosperity, but not perceiving that she was imprudently allowing the sources of those discoveries to become dry, whilst neighbouring nations, stimulated by her past example, were diverting for their own benefit the course of those springs, rendering them fruitful by their works, their efforts and their sacrifices.

"Whilst Germany was multiplying her universities, establishing between them the most salutary emulation, bestowing honours and consideration on the masters and doctors, creating vast laboratories amply supplied with the most perfect instruments, France, enervated by revolutions, ever vainly seeking for the best form of government, was giving but careless 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 manifestations of thought in Art, in Science and in Letters, in a word the disinterested exercise of the mind in every direction and the centres 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."

At the very time when Pasteur was preoccupied with the desire of directing the public mind towards the principles of truth, justice and sovereign harmony, Sainte Claire Deville, speaking of the Academy, expressed similar ideas, proclaiming that France had been vanquished by science and that it was now time to free scientific bodies from the tyranny of red tape. Why should not the Academy become the centre of all measures relating to science, independently of government offices or officials?

J. B. Dumas took part in the discussion opened by Sainte Claire Deville, and agreed with his suggestions. He might

have said more, however, on a subject which he often took up in private : the utility of pure science in daily experience. With his own special gift of generalization, he could have expounded the progress of all kinds due to the workers who, by their perseverance in resolving difficult problems, have brought about so many precious and unexpected results. Few men in France realized at that time that laboratories could be the vestibule of farms, factories, etc. ; it was indeed a noble task, that of proving that science was intended to lighten the burden of humanity, not merely to be applied to devastation, carnage, and hatred.

Pasteur was in the midst of these philosophical reflections when he received the following answer from the principal of the Faculty of Medicine of Bonn :

"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.*"—Dr. Maurice Naumann.

"P.S.—Desiring to keep its papers *free from taint*, the Faculty herewith returns your screed."

Pasteur's reply contained the following : "I have the honour of informing you, Mr. Principal, that there are times when the expression of contempt in a Prussian mouth is equivalent for a true Frenchman to that of *Virum clarissimum* which you once publicly conferred upon me."

After invoking in favour of Alsace-Lorraine, Truth, of Justice, and the laws of humanity, Pasteur added in a postscript—

"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, founded on my part on such actions. 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, taint will rest, you may be assured, 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."

Whilst Pasteur thus felt those simple and strong impressions as a soldier or the man in the street might do, the creative power of his nature was urging him to great and useful achievements. He wrote from Lyons in March to M. Duclaux—

"My head is full of splendid projects; the war sent my brain to grass, but I now feel ready for further work. Perhaps I am deluding myself; anyhow I will try. . . . Oh! why am I not rich, a millionaire? I would say to you, to Raulin, to Gernez, to Van Tieghem, etc., come, we will transform the world by our discoveries. How fortunate you are to be young and strong! Why can I not begin a new life of study and work! Unhappy France, beloved country, if I could only assist in raising thee from thy disasters!"

A few days later, in a letter to Raulin, this desire for devoted work was again expressed almost feverishly. He could foresee, in the dim distance, secret affinities between apparently dissimilar things. He had at that time returned to the researches which had absorbed his youth (because those studies were less materially difficult to organize), and he could perceive laws and connections between the facts he had observed and those of the existence of which he felt assured.

"I have begun here some experiments in crystallization which will open a great prospect if they should lead to positive results. You know that I believe that there is a cosmic dissymmetric influence which presides constantly and naturally over the molecular organization of principles immediately essential to life; and that, in consequence of this, the species of the three kingdoms, by their structure, by their form, by the disposition of their tissues, have a definite relation to the movements of the universe. For many of those species, if not for all, the sun is the *primum movens* of nutrition; but I believe in another influence which would affect the whole organization, for it would be the cause of the molecular dissymmetry proper to the chemical components of life. I want to be able by experiment to grasp a few indications as to the nature of this great cosmic dissymmetrical influence. It must, it may be electricity, magnetism. . . . And, as one should always proceed from the simple to the complex, I am now trying to crystallize double racemate of soda and ammonia under the influence of a spiral solenoid.

"I have various other forms of experiment to attempt. If one of them should succeed, we shall have work for the rest of

our lives, and in one of the greatest subjects man could approach, for I should not despair of arriving by this means at a very deep, unexpected and extraordinary modification of the animal and vegetable species.

"Good-bye, my dear Raulin. Let us endeavour to distract our thoughts from human turpitudes by the disinterested search after truth."

In a little notebook where he jotted down some intended experiments we find evidence of those glimpses of divination in a few summary lines: "Show that life is in the germ, that it has been but in a state of transmission since the origin of creation. That the germ possesses possibilities of development, either of intelligence and will, or—and in the same way—of physical organs. Compare these possibilities with those possessed by the germ of chemical species which is in the chemical molecule. The possibilities of development in the germ of the chemical molecule consist in crystallization, in its form, in its physical and chemical properties. Those properties are in power in the germ of the molecule in the same way as the organs and tissues of animals and plants are in their respective germs. Add: nothing is more curious than to carry the comparison of living species with mineral species into the study of the wounds of either, and of their healing by means of nutrition—a nutrition coming from within in living beings, and from without through the medium of crystallization in the others. Here detail facts. . . ."

In that same notebook, Pasteur, after writing down the following heading, "Letter to prepare on the species in connection with molecular dissymmetry," added, "I could write that letter to Bernard. I should say that being deprived of a laboratory by the present state of France, I am going to give him the preconceived ideas that I shall try to experiment upon when better times come. There is no peril in expressing ideas *a priori*, when they are taken as such, and can be gradually modified, perhaps even completely transformed, according to the result of the observation of facts."

He once compared those preconceived ideas with searchlights guiding the experimentalist, saying that they only became dangerous when they became fixed ideas.

Civil war had now come, showing, as Renan said, "a sore under the sore, an abyss below the abyss." What were the hopes and projects of Pasteur and of Sainte Claire Deville now

that the very existence of the divided country was jeopardized under the eyes of the Prussians? The world of letters and of science, helpless amidst such disorders, had dispersed; Saint Claire Deville was at Gex, Dumas at Geneva. Some were wondering whether lectures could not be organized in Switzerland and in Belgium as they had been under the Empire, thus spreading abroad the influence of French thought. Examples might be quoted of men who had served the glory of their country in other lands, such as Descartes, who took refuge in Holland in order to continue his philosophic meditations. Pasteur might have been tempted to do likewise. Already, before the end of the war, an Italian professor of chemistry, Signor Chiozza, who had applied Pasteur's methods to silkworms in the neighbourhood of Villa Vicentina, got the Italian Government to offer him a laboratory and the direction of a silkworm establishment. Pasteur refused, and a deputy of Pisa, Signor Toscanelli, hearing of this, obtained for Pasteur the offer of what was better still—a professor's chair of Chemistry applied to Agriculture at Pisa; this would give every facility for work and all laboratory resources. "Pisa," Signor Chiozza said, "is a quiet town, a sort of Latin quarter in the middle of the country, where professors and students form the greater part of the population. I think you would be received with the greatest cordiality and quite exceptional consideration . . . I fear that black days of prolonged agitation are in store for France."

Pasteur's health and work were indeed valuable to the whole world, and Signor Chiozza's proposition seemed simple and rational. Pasteur was much divided in his mind: his first impulse was to renew his refusal. He thought but of his vanquished country, and did not wish to forsake it. But was it to his country's real interests that he should remain a helpless spectator of so many disasters? Was it not better to carry French teaching abroad, to try and provoke in young Italian students enthusiasm for French scientists, French achievements? He might still serve his beloved country in that quiet retreat, amidst all those facilities for continuous work. He thought of writing to Raulin, who had relations in Italy, and who might follow his master. Finally, he was offered very great personal advantages, a high salary—and this determined his refusal, for, as he wrote to Signor Chiozza, "I should feel that I deserved a deserter's penalty if I sought, away from my

country in distress, a material situation better than it can offer me."

"Nevertheless allow me to tell you, Sir (he wrote to Signor Toscanelli, refusing his offer), in all sincerity, that the memory of your offer will remain in the annals of my family as a title of nobility, as a proof of Italy's sympathy for France, as a token of the esteem accorded to my work. And as far as you, M. le Député, are concerned it will remain in my eyes a brilliant proof of the way in which public men in Italy regard science and its grandeur."

And now what was Pasteur to do—he who could not live away from a laboratory? In April, 1871, he could neither go back to Paris and the Commune nor to Arbois, now transformed into a Prussian dépôt. It seemed, indeed, from the letters he received that his fellow citizens were now destined but to feed and serve a victorious foe, whose exactions were all the more rigorous that the invasion of the town on January 25 had been preceded by an attempt at resistance on the part of the inhabitants. On that morning, a few French soldiers who were seeking their regiments and a handful of *franc tireurs* had posted themselves among the vines. About ten o'clock a first shot sounded in the distance; in a turn of the sinuous Besançon road, when the Prussian vanguard had appeared, a Zouave—who the day before was begging from door to door, shaking with ague, and who had taken refuge in the village of Montigny, two kilometres from Arbois—had in despair fired his last cartridge. A squad of Prussians left the road and rushed towards the smoke of the gun. The soldier was seized, shot down on the spot, and mutilated with bayonets. Whilst the main column continued their advance towards the town, detachments explored the vines on either side of the road, shooting here and there. An old man who, with a courageous indifference, was working in his vineyard was shot down at his work. A little pastrycook's boy, nicknamed Biscuit by the Arboisians, who, led by curiosity, had come down from the upper town to the big poplar trees at the entrance of Arbois, suddenly staggered, struck by a Prussian bullet. He was just able to creep back to the first house, his eyes already dimmed by death.

Those were but the chances of war, but other crueller episodes thrilled Pasteur to the very depths of his soul. Such things are lost in history, just as a little blood spilt disappears

in a river, but, for the witnesses and contemporaries of the facts, the trace of blood remains. An incident will help the reader to understand the lasting indignation the war excited in Pasteur.

One of the Prussian sergeants, who, after the shot fired at Montigny, were leading small detachments of soldiers, thought that a house on the outskirts of Arbois, in the faubourg of Verreux, looked as if it might shelter *franc tireurs*. He directed his men towards it and the house was soon reached.

It was now twelve o'clock, all fighting had ceased, and the first Prussians who had arrived were masters of the town. Others were arriving from various directions; a heavy silence reigned over the town. The mayor, M. Lefort, led by a Prussian officer who covered him with a revolver whenever he addressed him, was treated as a hostage responsible for absolute submission. Every door in the small Town Hall was opened in succession in order to see that there were no arms hidden. The mayor was each time made to pass first, so that he should receive the shot in case of a surprise. In the library, three flags, which General Delort had brought back from the Rhine campaign when he was a captain in the cavalry and given to his native town, were torn down and the general's bust overturned.

The sergeant, violently entering the suspected house with his men, found a whole family peacefully sitting down to their dinner—the husband, wife, a son of nineteen, and two young daughters. The invaders made no search nor asked any questions of those poor people, who had probably done nothing worse than to offer a few glasses of wine to French soldiers as they passed. The sergeant did not even ask the name of the master of the house (Antoine Ducret, aged fifty-nine), but seized him by his coat and ordered his men to seize the son too. The woman, who rushed to the door in her endeavour to prevent her husband and her son from being thus taken from her, was violently flung to the end of the room, her trembling daughters crouching around her as they listened to the heavy Prussian boots going down the wooden stairs. There is a public drinking fountain not far from the house; Ducret was taken there and placed against a wall. He understood, and cried out, "Spare my son!!" "What do you say?" said the sergeant to the boy. "I will stay with my father," he answered simply. The father, struck by two bullets at close range, fell at the feet of

his son, who was shot down immediately afterwards. The two corpses, afterwards mutilated with bayonets, remained lying by the water side; the neighbours succeeded in preventing the mother and her two daughters from leaving their house until the bodies had been placed in a coffin. On the tombs of Antoine and Charles Ducret the equivocal inscription was placed "Fell at Arbois, January 25, 1871, under Prussian fire." For the honour of humanity, a German officer, having heard these details, offered the life of the sergeant to Ducret's widow; but she entertained no thoughts of revenge. "His death would not give them back to me," she said.

Pasteur could not become resigned to the humiliation of France, and, tearing his thoughts from the nightmare of the war and the Commune, he dwelt continually on the efforts that would be necessary to carry out the great task of raising the country once again to its proper rank. In his mind it was the duty of every one to say, "In what way can I be useful?" Each man should strive not so much to play a great part as to give the best of his ability. He had no patience with those who doubt everything in order to have an excuse for doing nothing.

He had indeed known dark moments of doubt and misgivings, as even the greatest minds must do, but notwithstanding these periods of discouragement he was convinced that science and peace will ultimately triumph over ignorance and war. In spite of recent events, the bitter conditions of peace which tore unwilling Alsace and part of Lorraine away from France, the heavy tax of gold and of blood weighing down future generations, the sad visions of young men in their prime cut down on the battlefield or breathing their last in hospitals all to no apparent purpose; in spite of all these sad memories he was persuaded that thinkers would gradually awaken in the nations ideas of justice and of concord.

He had now for nine years been following with a passionate interest some work begun in his own laboratory by Raulin, his first curator. Some of the letters he wrote to Raulin during those nine years give us a faint idea of the master that Pasteur was. It had been with great regret that Raulin had left the laboratory in obedience to the then laws of the University in order to take up active work at the Brest college, and Pasteur's letters (December, 1862) brought him joy and encouragement: "Keep up your courage, do not allow the idleness of pro-

vincial life to disturb you. Teach your pupils to the very best of your ability and give up your leisure to experiments; this was M. Biot's advice to myself." When in July, 1863, he began to fear that Raulin might allow imagination to lead him astray in his work, he repeatedly advised him to state nothing that could not be proved: "Be very strict in your deductions"; then, apparently, loth to damp the young man's ardour: "I have the greatest confidence in your judgment; do not take too much heed of my observations."

In 1863 Pasteur asked Raulin to come with him, Gernez and Duclaux, to Arbois for some studies on wines, etc., but Raulin, absorbed in the investigations he had undertaken, refused; in 1865 he refused to come to Alais, still being completely wrapt up in the same work. Pasteur sympathized heartily with his pupil's perseverance, and, when Raulin was at last able to announce to his master the results so long sought after, Pasteur hurried to Caen, where Raulin was now professor of Physics, and returned full of enthusiasm. His modesty in all that concerned himself now giving way to delighted pride, he spoke of Raulin's discoveries to every one. Yet they concerned an apparently unimportant subject—a microscopical fungus, a simple mucor, whose spores, mingled with atmospheric germs, develop on bread moistened with vinegar or on a slice of lemon; yet no precious plant ever inspired more care or solicitude than that *aspergillus niger*, as it is called. Raulin, inspired by Pasteur's studies on cultures in an artificial medium, that is, a medium exclusively composed of defined chemical substances, resolved to find for this plant a typical medium capable of giving its maximum development to the aspergillus niger. Some of his comrades looked upon this as upon a sort of laboratory amusement; but Raulin, ever a man of one idea, looked upon the culture of microscopic vegetation as a step towards a greater knowledge of vegetable physiology, leading to the development of artificial manure production, and from that to the rational nutrition of the human organisms. He started from the conditions indicated by Pasteur for the development of mucedinæ in general and in particular for a mucor which has some points of resemblance with the aspergillus niger, the *penicillium glaucum*, which spreads a bluish tint over mouldy bread, jam, and soft cheeses. Raulin began by placing pure spores of aspergillus niger on the surface of a saucer containing everything

that seemed necessary to their perfect growth, in a stove heated to a temperature of 20° C.; but in spite of every care, after forty days had passed, the tiny fungus was languishing and unhealthy. A temperature of 30° did not seem more successful; and when the stove was heated to above 38° the result was the same. At 35°, with a moist and changing atmosphere, the result was favourable—very fortunately for Raulin, for the principal of the college, an economically minded man, did not approve of burning so much gas for such a tiny fungus and with such poor results. This want of sympathy excited Raulin's solemn wrath and caused him to meditate dark projects of revenge, such as ignoring his enemy in the street on some future occasion. In the meanwhile he continued his slow and careful experiments. He succeeded at last in composing a liquid, technically called Raulin's liquid, in which the aspergillus niger grew and flourished within six or even three days. Eleven substances were necessary: water, candied sugar, tartaric acid, nitrate of ammonia, phosphate of ammonia, carbonate of potash, carbonate of magnesia, sulphate of ammonia, sulphate of zinc, sulphate of iron, and silicate of potash. He now studied the part played by each of those elements, varying his quantities, taking away one substance and adding another, and obtained some very curious results. For instance, the aspergillus was extraordinarily sensitive to the action of zinc; if the quantity of zinc was reduced by a few milligrams the vegetation decreased by one-tenth. Other elements were pernicious; if Raulin added to his liquid $\frac{1}{1600000}$ of nitrate of silver, the growth of the fungus ceased. Moreover, if he placed the liquid in a silver goblet instead of a china saucer, the vegetation did not even begin, "though," writes M. Duclaux, analysing this fine work of his fellow student, "it is almost impossible to chemically detect any dissolution of the silver into the liquid. But the fungus proves it by dying."

In this thesis, now a classic, which only appeared in 1870, Raulin enumerated with joyful gratitude all that he owed to his illustrious master—general views, principles and methods, suggestive ideas, advice and encouragement—saying that Pasteur had shown him the road on which he had travelled so far. Pasteur, touched by his pupil's affection, wrote to thank him, saying: "You credit me with too much; it is enough for me that your work should be known as having been begun in my

laboratory, and in a direction the fruitfulness of which I was perhaps the first to point out. I had only conceived hopes, and you bring us solid realities."

In April, 1871, Pasteur, preoccupied with the future, and ambitious for those who might come after him, wrote to Claude Bernard: "Allow me to submit to you an idea which has occurred to me, that of conferring on my dear pupil and friend Raulin the Experimental Physiology prize, for his splendid work on the nutriment of mucors, or rather of a mucor, the excellence of which work has not escaped you. I doubt if you can find anything better. I must tell you that this idea occurred to me whilst reading your admirable report on the progress of General Physiology in France. If therefore my suggestion seems to you acceptable, you will have sown the germ of it in my mind; if you disapprove of it I shall make you partly responsible."

Claude Bernard hastened to reply: "You may depend upon my support for your pupil M. Raulin. It will be for me both a pleasure and a duty to support such excellent work and to glorify the method of the master who inspired it."

In his letter to Claude Bernard, Pasteur had added these words: "I have made up my mind to go and spend a few months at Royat with my family, so as to be near my dear Duclaux. We shall raise a few grammes of silkworm seed."

M. Duclaux was then professor of chemistry at the Faculty of Clermont Ferrand, a short distance from Royat, and Pasteur intended to walk every day to the laboratory of his former pupil. But M. Duclaux did not countenance this plan; he meant to entertain his master and his master's family in his own house, 25, Rue Montlosier, where he could even have one room arranged as a silkworm nursery. He succeeded in persuading Pasteur, and they organized a delightful home life which recalled the days at Pont Gisquet before the war.

Pasteur was seeking the means of making his seed-selecting process applicable to small private nurseries as well as to large industrial establishments. The only difficulty was the cost of the indispensable microscope; but Pasteur thought that each village might possess its microscope, and that the village schoolmaster might be entrusted with the examination of the moths.

In a letter written in April, 1871, to M. Bellotti, of the Milan Civic Museum, Pasteur, after describing in a few lines the simple process he had taken five years to study, added—

"If I dared to quote myself, I would recall those words from my book—

"'If I were a silkworm cultivator I never would raise seed from worms I had not observed during the last days of their life, so as to satisfy myself as to their vigour and agility just before spinning. The seed chosen should be that which comes from worms who climbed the twigs with agility, who showed no mortality from flachery between the fourth moulting and climbing time, and whose freedom from corpuscles will have been demonstrated by the microscope. If that is done, any one with the slightest knowledge of silkworm culture will succeed in every case.'"

Italy and Austria vied with each other in adopting the seed selected by the Pasteur system. But it was only when Pasteur was on the eve of receiving from the Austrian Government the great prize offered in 1868 to "whoever should discover a preventive and curative remedy against pébrine" that French sericicultors began to be convinced. The French character offers this strange contrast, that France is often willing to risk her fortune and her blood for causes which may be unworthy, whilst at another moment, in everyday life, she shrinks at the least innovation before accepting a benefit originated on her own soil. The French often wait until other nations have adopted and approved a French discovery before venturing to adopt it in their turn.

Pasteur did not stop to look back and delight in his success, but hastened to turn his mind to another kind of study. His choice of a subject was influenced by patriotic motives. Germany was incontestably superior to France in the manufacture of beer, and he conceived the thought of making France a successful rival in that respect; in order to enable himself to do so, he undertook to study the scientific mechanism of beer manufacture.

There was a brewery at Chamalières, between Clermont and Royat. Pasteur began by visiting it with eager curiosity, inquiring into the minutest details, endeavouring to find out the why and the wherefore of every process, and receiving vague answers with much astonishment. M. Kuhn, the Chamalières brewer, did not know much more about beer than did his fellow brewers in general. Very little was known at that time about the way it was produced; when brewers received complaints from their customers, they procured yeast

from a fresh source. In a book of reference which was then much in use, entitled *Alimentary Substances: the Means of Improving and Preserving them, and of Recognizing their Alterations*, six pages were given up to beer by the author, M. Payen, a member of the Institute. He merely showed that germinated barley, called malt, was diluted, then heated and mixed with hops, thus forming beer-wort, which was submitted, when cold, to alcoholic fermentation through the yeast added to the above liquid. M. Payen conceded to beer some nutritive properties, but added, a little disdainfully, "Beer, perhaps on account of the pungent smell of hops, does not seem endowed with stimulating properties as agreeable, or as likely to inspire such bright and cheerful ideas, as the sweet and varied aroma of the good wines of France."

In a paragraph on the alterations of beer—"*spontaneous* alterations"—M. Payen said that it was chiefly during the summer that beer became altered. "It becomes acid, and even noticeably putrid, and ceases to be fit to drink."

Pasteur's hopes of making French beer capable of competing with German beer were much strengthened by faith in his own method. He had, by experimental proof, destroyed the theory of spontaneous generation; he had shown that chance has no share in fermentations; the animated nature and the specific characteristics of those ferments, the methods of culture in appropriate media, were so many scientific points gained. The difficulties which remained to be solved were the question of pure yeast and the search for the causes of alteration which make beer thick, acid, sour, slimy or putrid. Pasteur thought that these alterations were probably due to the development of germs in the air, in the water, or on the surface of the numerous utensils used in a brewery.

As he advanced further and further into that domain of the infinitely small which he had discovered, whether the subject was wine, vinegar, or silkworms—this last study already opening before him glimpses of light on human pathology—new and unexpected visions rose before his sight.

Pasteur had formerly demonstrated that if a putrescible liquid, such as beef broth for instance, after being previously boiled, is kept in a vessel with a long curved neck, the air only reaching it after having deposited its germs in the curves of the neck, does not alter it in any way. He now desired to invent an apparatus which would protect the wort against external

dusts, against the microscopic germs ever ready to interfere with the course of proper fermentation by the introduction of other noxious ferments. It was necessary to prove that beer remains unalterable whenever it does not contain the organisms which cause its diseases. Many technical difficulties were in the way, but the brewers of Chamalières tried in the most obliging manner to facilitate things for him.

This exchange of services between science and industry was in accordance with Pasteur's plan; though he had been prophesying for fourteen years the great progress which would result from an alliance between laboratories and factories, the idea was hardly understood at that time. Yet the manufacturers of Lille and Orleans, the wine merchants and the silkworm cultivators of the South of France, and of Austria and Italy, might well have been called as enthusiastic witnesses to the advantages of such a collaboration.

Pasteur, happy to make the fortune of others, intended to organize, against the danger of alterations in beer, some experiments which would give to that industry solid notions resting on a scientific basis. "Dear master," wrote he to J. B. Dumas on August 4, 1871, from Clermont, "I have asked the brewer to send you twelve bottles of my beer. . . . I hope you will find it compares favourably even with the excellent beer of Paris cafés." There was a postscript to this letter, proving once more Pasteur's solicitude for his pupils. "A thousand thanks for your kind welcome of Raulin's work; Bernard's support has also been promised him. The Academy could not find a better recipient for the prize. It is quite exceptional work."

Pasteur, ever full of praises for his pupil, also found excuses for him. In spite of M. Duclaux's pressing request, Raulin had again found reasons to refuse an invitation to come to Auvergne for a few days. "I regret very much that you did not come to see us," wrote Pasteur to Raulin, "especially on account of the beer. . . . Tell me what you think of doing. When are you coming to Paris for good? I shall want you to help me to arrange my laboratory, where everything, as you know, has still to be done; it must be put into working order as soon as possible."

Pasteur would have liked Raulin to come with him to London in September, 1871, before settling down in Paris.

The Chamalières brewery was no longer sufficient for Pasteur; he wished to see one of those great English breweries

which produce in one year more than 100,000 hectolitres of beer. The great French *savant* was most courteously received by the managers of one of the most important breweries in London, who offered to show him round the works where 250 men were employed. But Pasteur asked for a little of the barm of the porter which was flowing into a trough from the cask. He examined that yeast with a microscope, and soon recognized a noxious ferment which he drew on a piece of paper and showed to the bystanders, saying, "This porter must leave much to be desired," to the astonished managers, who had not expected this sudden criticism. Pasteur added that surely the defect must have been betrayed by a bad taste, perhaps already complained of by some customers. Thereupon the managers owned that that very morning some fresh yeast had had to be procured from another brewery. Pasteur asked to see the new yeast, and found it incomparably purer, but such was not the case with the barm of the other products then in fermentation—*ale* and *pale ale*.

By degrees, samples of every kind of beer on the premises were brought to Pasteur and put under the microscope. He detected marked beginnings of disease in some, in others merely a trace, but a threatening one. The various foremen were sent for; this scientific visit seemed like a police inquiry. The owner of the brewery, who had been fetched, was obliged to register, one after another, these experimental demonstrations. It was only human to show a little surprise, perhaps a little impatience of wounded feeling. But it was impossible to mistake the authority of the French scientist's words: "Every marked alteration in the quality of the beer coincides with the development of micro-organisms foreign to the nature of true beer yeast." It would have been interesting to a psychologist to study in the expression of Pasteur's hearers those shades of curiosity, doubt, and approbation, which ended in the thoroughly English conclusion that there was profit to be made out of this object lesson.

Pasteur afterwards remembered with a smile the answers he received, rather vague at first, then clearer, and, finally—interest and confidence now obtained—the confession that there was in a corner of the brewery a quantity of spoilt beer which had gone wrong only a fortnight after it was made, and was not drinkable. "I examined it with a microscope," said Pasteur, "and could not at first detect any ferments of

disease; but guessing that it might have become clear through a long rest, the ferments now inert having dropped to the bottom of the reservoirs, I examined the deposit at the bottom of the reservoirs. It was entirely composed of filaments of disease unmixed with the least globule of alcoholic yeast. The complementary fermentation of that beer had therefore been exclusively a morbid fermentation."

When he visited the same brewery again, a week later, he found that not only had a microscope been procured immediately, but the yeast of all the beer then being brewed had been changed.

Pasteur was happy to offer to the English, who like to call themselves practical men, a proof of the usefulness of disinterested science, persuaded as he was that the moral debt incurred to a French scientist would in some measure revert to France herself. "We must make some friends for our beloved France," he would say. And if in the course of conversation an Englishman gave expression to any doubt concerning the future of the country, Pasteur, his grave and powerful face full of energy, would answer that every Frenchman, after the horrible storm which had raged for so many months, was valiantly returning to his daily task, whether great or humble, each one thinking of retrieving the national fall.

Every morning, as he left his hotel to go to the various breweries which he was now privileged to visit in their smallest details, he observed this English people, knowing the value of time, seeing its own interests in all things, consistent in its ideas and in its efforts, respectful of established institutions and hierarchy; and he thought with regret how his own countrymen lacked these qualities. But if the French are rightly taxed with a feverish love of change, should not justice be rendered to that generous side of the French character, so gifted, capable of so much, and which finds in self-sacrifice the secret of energy, for whom hatred is a real suffering? "Let us work!" Pasteur's favourite phrase ever ended those philosophical discussions.

He wanted to do two years' work in one, regardless of health and strength. Beyond the diseases of beer, avoidable since they come from outside, he foresaw the application of the doctrine of exterior germs to other diseases. But he did not allow his imagination to run away with him, and resolutely

fixed his mind on his present object, which was the application of science to the brewing industry.

"The interest of those visits to English breweries," wrote Pasteur to Raulin, "and of the information I am able to collect (I hear that I ought to consider this as a great favour) causes me to regret very much that you should be in want of rest, for I am sure you would have been charmed to acquire so much instruction *de visu*. Why should you not come for a day or two if your health permits? Do as you like about that, but in any case prepare for immediate work on my return. We need not wait for the new laboratory; we can settle down in the old one and in a Paris brewery."

When Pasteur returned to Paris, Bertin, who had not seen him since the recent historic events, welcomed him with a radiant delight. School friendships are like those favourite books which always open at the page we prefer; time has no hold on certain affections; ever new, ever young, they never show signs of age. Bertin's love was very precious to Pasteur, though the two friends were as different from each other as possible. Pasteur, ever preoccupied, seemed to justify the Englishman who said that genius consists in an infinite capacity for taking pains; whilst Bertin, with his merry eyes, was the very image of a smiling philosopher. In spite of his position as sub-director, which he most conscientiously filled, he was not afraid to whistle or to sing popular songs as he went along the passages of the Ecole Normale. He came round to Pasteur's rooms almost every evening, bringing with him joy, lightness of heart, and a rest and relaxation for the mind, brightening up his friend by his amusing way of looking at things in general, and—at that time—beer in particular.

Whilst Pasteur saw but pure yeast, and thought but of spores of disease, ferments, and parasitic invasions, Bertin would dilate on certain cafés in the Latin quarter, where, without regard to great scientific principles, experts could be asked to pronounce between the beer on the premises and laboratory beer, harmless and almost agreeable, but lacking in the refinement of taste of which Bertin, who had spent many years in Strasburg, was a competent judge. Pasteur, accustomed to an absolutely infallible method, like that which he had invented for the seeding of silkworms, heard Bertin say to him, "First of all, give me a good *bock*, you can talk learnedly afterwards." Pasteur acknowledged, however, the improve-

ments obtained by certain brewers, who, thanks to the experience of years, knew how to choose yeast which gave a particular taste, and also how to employ preventive measures against accidental and pernicious ferments (such as the use of ice, or of hops in a larger quantity). But, though laughing at Bertin's jokes, Pasteur was convinced that great progress in the brewer's art would date from his studies.

He was now going through a series of experiments, buying at Bertin's much praised cafés samples of various famous beers —Strasburg, Nancy, Vienna, Burton's, etc. After letting the samples rest for twenty-four hours he decanted them and sowed one drop of the deposit in vessels full of pure wort, which he placed in a temperature of 20° C. After fifteen or eighteen days he studied and tasted the yeasts formed in the wort, and found them all to contain ferments of diseases. He sowed some pure yeast in some other vessels, with the same precautions, and all the beers of this series remained pure from strange ferments and free from bad taste; they had merely become *flat*.

He was eagerly seeking the means of judging how his laboratory tests would work in practice. He spent some time at Tantonville, in Lorraine, visiting an immense brewery, of which the owners were the brothers Tourtel. Though very carefully kept, the brewery was yet not quite clean enough to satisfy him. It is true that he was more than difficult to please in that respect; a small detail of his everyday life revealed this constant preoccupation. He never used a plate or a glass without examining them minutely and wiping them carefully; no microscopic speck of dust escaped his short-sighted eyes. Whether at home or with strangers he invariably went through this preliminary exercise, in spite of the anxious astonishment of his hostess, who usually feared that some negligence had occurred, until Pasteur, noticing her slight dismay, assured her that this was but an inveterate scientist's habit. If he carried such minute care into daily life, we can imagine how strict was his examination of scientific things and of brewery tanks.

After those studies at Tantonville with his curator, M. Grenet, Pasteur laid down three great principles—

1. Every alteration either of the wort or of the beer itself depends on the development of micro-organisms which are ferments of diseases.

2. These germs of ferments are brought by the air, by the ingredients, or by the apparatus used in breweries.

3. Whenever beer contains no living germs it is unalterable.

When once those principles were formulated and proved they were to triumph over all professional uncertainties. And in the same way that wines could be preserved from various causes of alteration by heating, bottled beer could escape the development of disease ferments by being brought to a temperature of 50° to 55°. The application of this process gave rise to the new word "*pasteurized*" beer, a neologism which soon became current in technical language.

Pasteur foresaw the distant consequences of these studies, and wrote in his book on beer—

"When we see beer and wine subjected to deep alterations because they have given refuge to micro-organisms invisibly introduced and now swarming within them, it is impossible not to be pursued by the thought that similar facts may, *must*, take place in animals and in man. But if we are inclined to believe that it is so because we think it likely and possible, let us endeavour to remember, before we affirm it, that the greatest disorder of the mind is to allow the will to direct the belief."

This shows us once more the strange duality of this inspired man, who associated in his person the faith of an apostle with the inquiring patience of a scientist.

He was often disturbed by tiresome discussions from the researches to which he would gladly have given his whole time. The heterogenists had not surrendered; they would not admit that alterable organic liquids could be indefinitely preserved from putrefaction and fermentation when in contact with air freed from dusts.

Pouchet, the most celebrated of them, who considered that part of a scientist's duty consists in vulgarizing his discoveries, was preparing for the New Year, 1872, a book called *The Universe: the Infinitely Great and the Infinitely Small.* He enthusiastically recalled the spectacle revealed at the end of the seventeenth century by the microscope, which he compared to a sixth sense. He praised the discoveries made in 1838 by Ehrenberg on the prodigious activity of infusories, but he never mentioned Pasteur's name, leaving entirely on one side the immense work accomplished by the infinitely small and ever active agents of putrefaction and fermentation.

He owned that "a few microzoa did fly about here and there," but he called the theory of germs a "ridiculous fiction."

At the same time Liebig, who, since the interview in July, 1870, had had time to recover his health, published a long treatise disputing certain facts put forward by Pasteur.

Pasteur had declared that, in the process of vinegar-making known as the German process, the chips of beech-wood placed in the barrels were but supports for the *mycoderma aceti*. Liebig, after having, he said, consulted at Munich the chief of one of the largest vinegar factories, who did not believe in the presence of the mycoderma, affirmed that he himself had not seen a trace of the fungus on chips which had been used in that factory for twenty-five years.

In order to bring this debate to a conclusion Pasteur suggested a very simple experiment, which was to dry some of those chips rapidly in a stove and to send them to Paris, where a commission, selected from the members of the Académie des Sciences, would decide on this conflict. Pasteur undertook to demonstrate to the Commission the presence of the mycoderma on the surface of the chips. Or another means might be used: the Munich vinegar maker would be asked to scald one of his barrels with boiling water and then to make use of it again. "According to Liebig's theory," said Pasteur, "that barrel should work as before, but I affirm that no vinegar will form in it for a long time, not until new mycoderma have grown on the surface of the chips." In effect, the boiling water would destroy the little fungus. With the usual clear directness which increased the interest of the public in this scientific discussion, Pasteur formulated once more his complete theory of acetification: "The principle is very simple: whenever wine is transformed into vinegar, it is by the action of the layer of *mycoderma aceti* developed on its surface." Liebig, however, refused the suggested test.

Immediately after that episode a fresh adversary, M. Frémy, a member of the Académie des Sciences, began with Pasteur a discussion, which was destined to be a long one, on the question of the origin of ferments. M. Frémy alluded to the fact that he had given many years to that subject, having published a notice on lactic fermentation as far back as 1841, "at a time," he said, "when our learned colleague—M. Pasteur—was barely entering into science." . . . "In the production of wine," said M. Frémy, "it is the juice of the fruit

itself, which, put in contact with air, gives birth to grains of yeast by the transformation of albuminous matter, whilst M. Pasteur declares that the grains of yeast are produced by germs." According to M. Frémy, ferments did not come from atmospheric dusts, but were created by organic bodies. And, inventing for his own use the new word *hemiorganism*, M. Frémy explained the word and the action by saying that there are some *hemiorganized* bodies which, by reason of the vital force with which they are endowed, go through successive decompositions and give birth to new derivatives; thus are ferments engendered.

Another colleague, M. Trécul, a botanist and a genuine truth-seeking *savant*, arose in his turn. He said he had witnessed a whole transformation of microscopic species each into the other, and in support of this theory he invoked the names of the three inseparables—Pouchet, Musset and Joly. Himself a heterogenist, he had in 1867 given a definition to which he willingly alluded: "Heterogenesis is a natural operation by which life, on the point of abandoning an organized body, concentrates its action on some particles of that body and forms thereof beings quite different from that of the substance which has been borrowed."

Old arguments and renewed negations were brought forward, and Pasteur knew well that this was but a reappearance of the old quarrel; he therefore answered by going straight to the point. At the Académie des Sciences, on December 26, 1871, he addressed M. Trécul in these words: "I can assure our learned colleague that he might have found in the treatises I have published decisive answers to most of the questions he has raised. I am really surprised to see him tackle the question of so-called spontaneous generation, without having more at his disposal than doubtful facts and incomplete observations. My astonishment was not less than at our last sitting, when M. Frémy entered upon the same debate with nothing to produce but superannuated opinions and not one new positive fact."

In his passion for truth and his desire to be convincing Pasteur threw out this challenge: "Would M. Frémy confess his error if I were to demonstrate to him that the natural juice of the grape, exposed to the contact of air, deprived of its germs, can neither ferment nor give birth to organized yeasts?" This interpellation was perhaps more violent than

was usual in the meetings of the solemn Academy, but scientific truth was in question. And Pasteur, recognizing the old arguments under M. Frémy's hemiorganism and M. Trécul's transformations, referred his two contradictors to the experiments by which he had proved that alterable liquids, such as blood or urine, could be exposed to the contact of air deprived of its germs without undergoing the least fermentation or putrefaction. Had not this fact been the basis on which Lister had founded "his marvellous surgical method"? And in the bitterness given to his speech by his irritation against error, the epithet "marvellous" burst out with a visible delight in rendering homage to Lister.

Pasteur, then in full possession of all the qualities of his genius, was feeling the sort of fever known to great scientists, great artists, great writers: the ardent desire of finding, of discovering something he could leave to posterity. Interrupted by these belated contradictors when he wanted to be going forward, he only restrained his impatience with difficulty.

His old master, Balard, appealed to him in the Académie itself (January 22, 1872), in the name of their old friendship, to disregard the attacks of his adversaries, instead of wasting his time and his strength in trying to convince them. He reminded him of all he had achieved, of the benefits he had brought to the industries of wine, beer, vinegar, silkworms, etc., and alluded to the possibility foreseen by Pasteur himself of preserving mankind from some of the mysterious diseases which were perhaps due to germs in atmospheric air. He ended by urging him to continue his studies peacefully in the laboratory built for him, and to continue the scientific education of young pupils who might one day become worthy successors of Van Tieghem, Duclaux, Gernez, Raulin, etc. . . . thus forming a whole generation of young scientists instructed in Pasteur's school.

M. Duclaux wrote to him in the same sense: "I see very well what you may lose in that fruitless struggle—your rest, your time and your health; I try in vain to see any possible advantage."

But nothing stopped him; neither Balard's public advice, his pupils' letters, even J. B. Dumas' imploring looks. He could not keep himself from replying. Sometimes he regretted his somewhat sharp language, though—in his own words—he never associated it with feelings of hostility towards his

contradictors as long as he believed in their good faith; what he wanted was that truth should have the last word. "What *you* lack, M. Frémy, is familiarity with a microscope, and you, M. Trécul, are not accustomed to laboratories!" "M. Frémy is always trying to displace the question," said Pasteur, ten months after M. Balard's appeal.

Whilst M. Frémy disputed, discussed, and filled the Académie with his objections, M. Trécul, whose life was somewhat misanthropical and whose usually sad and distrustful face was seen nowhere but at the Institute, insisted slowly, in a mournful voice, on certain transformations of divers cells or spores from one into the other. Pasteur declared that those ideas of transformation were erroneous; but—and there lay the interest of the debate—there was one of those transformations that Pasteur himself had once believed possible: that of the *mycoderma vini*, or wine flower, into an alcoholic ferment under certain conditions of existence.

A modification in the life of the mycoderma when submerged had led him to believe in a transformation of the mycoderma cells into yeast cells. It was on this question, which had been left in suspense, that the debate with Trécul came to an end, leaving to the witnesses of it a most vivid memory of Pasteur's personality—inflexible when he held his proofs, full of scruples and reserve when seeking those proofs, and accepting no personal praise if scientific truth was not recognized and honoured before everything else.

On November 11 Pasteur said: "Four months ago doubts suddenly appeared in my mind as to the truth of the fact in question, and which M. Trécul still looks upon as indisputable. . . . In order to disperse those doubts I have instituted the most numerous and varied experiments and I have not succeeded through those four months in satisfying myself by irrefragable proofs; I still have my doubts. Let this example show to M. Trécul how difficult it is to conclude definitely in such delicate studies."

Pasteur studied the scientific point for a long time, for he never abandoned a subject, but was ever ready to begin again after a failure. He modified the disposition of his first tests, and by the use of special vessels and slightly complicated apparatus succeeded in eliminating the only imaginable cause of error—the possible fall, during the manipulations, of exterior germs, that is, the fortuitous sowing of yeast cells. After that

he saw no more yeast and no more active alcoholic fermentation; he had therefore formerly been the dupe of a delusion. In his *Studies on Beer* Pasteur tells of his error and its rectification: "At a time when ideas on the transformations of species are so readily adopted, perhaps because they dispense with rigorous experimentation, it is somewhat interesting to consider that in the course of my researches on microscopic plants in a state of purity I once had occasion to believe in the transformation of one organism into another, the transformation of the *mycoderma vini* or *cerevisiae* into yeast, and that this time I was in error; I had not avoided the cause of illusion which my confirmed confidence in the theory of germs had so often led me to discover in the observations of others."

"The notion of species," writes M. Duclaux, who was narrowly associated with those experiments, "was saved for the present from the attacks directed against it, and it has not been seriously contested since, at least not on that ground."

Some failures are blessings in disguise. When discovering his mistake, Pasteur directed his attention to a strange phenomenon. We find in his book on beer—a sort of laboratory diary—the following details on his observation of the growth of some mycoderma seed which he had just scattered over some sweetened wine or beer-wort in small china saucers.

"When the cells or articles of the mycoderma vini are in full germinating and propagating activity in contact with air on a sweetened substratum, they live at the expense of that sugar and other subjacent materials absolutely like the animals who also utilize the oxygen in the air while freeing carbonic acid gas, consuming this and that, and correlatively increasing, regenerating themselves and creating new materials.

"Under those conditions not only does the mycoderma vini form no alcohol appreciable by analysis, but if alcohol exists in the subjacent liquid the mycoderma reduces it to water and carbonic acid gas by the fixation of the oxygen in the air." Pasteur, having submerged the mycoderma and studied it to see how it would accommodate itself to the new conditions offered to it, and whether it would die like an animal asphyxiated by the sudden deprivation of oxygen, saw that life was continued in the submerged cells, slow, difficult, of a short duration, but undoubtedly life, and that this life was accompanied by alcoholic fermentation. This time fermentation was due to the fungus itself. The mycoderma, originally an

aërobia—that is, a being to the life and development of which air was necessary—became, after being submerged, an anaërobia, that is, a creature living without air in the depths of the liquid, and behaving after the manner of ferments.

This extended the notions on aërobiæ and anaërobiæ which Pasteur had formerly discovered whilst making researches concerning the vibrio which is the butyric ferment, and those vibriones which are entrusted with the special fermentation known as putrefaction. Between the aërobiæ who require air to live and the anaërobiæ which perish when exposed to air, there was a class of organisms capable of living for a time outside the influence of air. No one had thought of studying the mouldiness which develops so easily when in contact with air; Pasteur was curious to see what became of it when submitted like the mycoderma to that unexpected *régime*. He saw the penicillium, the aspergillus, the mucor-mucedo take the character of ferments when living without air, or with a quantity of air too small to surround their organs as completely as was necessary to their aërobia-plant life. The mucor, when submerged and thus forced to become an anaërobia, offers budding cells, and there again it seemed as if they were yeast globules. "But," said Pasteur, "this change of form merely corresponds to a change of function, it is but a self-adaptation to the new life of an anaërobia." And then, generalizing again and seeking for laws under the accumulation of isolated facts, he thought it probable that ferments had, "but in a higher degree, a character common to most mucors if not to all, and probably possessed more or less by all living cells, viz., to be alternately aërobic or anaërobic, according to conditions of environment."

Fermentation, therefore, no longer appeared as an isolated and mysterious act; it was a general phenomenon, subordinate however to the small number of substances capable of a decomposition accompanied by a production of heat and of being used for the alimentation of inferior beings outside the presence and action of air. Pasteur put the whole theory into this concise formula, "Fermentation is life without air."

"It will be seen," wrote M. Duclaux, "to what heights he had raised the debate; by changing the mode of interpretation of known facts he brought out a new theory."

But this new theory raised a chorus of controversy. Pasteur held to his proofs; he recalled what he had published concern-

ing the typical ferment, the yeast of beer, an article inserted in the reports of the Académie des Sciences for 1861, and entitled, *The Influence of Oxygen on the Development of Yeast and on Alcoholic Fermentation.* In this article Pasteur, à propos of the chemical action connected with vegetable life, explained in the most interesting manner the two modes of life of the yeast of beer.

1. The yeast, placed in some sweet liquid in contact with air, assimilates oxygen gas and develops abundantly; under those conditions, it practically works for itself only, the production of alcohol is insignificant, and the proportion between the weight of sugar absorbed and that of the yeast is infinitesimal. 2. But, in its second mode of life, if yeast is made to act upon sugar without the action of atmospheric air, it can no longer freely assimilate oxygen gas, and is reduced to abstracting oxygen from the fermentescible matter.

"It seems therefore natural," wrote Pasteur, "to admit that when yeast is a ferment, acting out of the reach of atmospheric air, it takes oxygen from sugar, that being the origin of its fermentative character." It is possible to put the fermentative power of yeast through divers degrees of intensity by introducing free oxygen in variable quantities.

After comparing the yeast of beer to an ordinary plant, Pasteur added that "the analogy would be complete if ordinary plants had an affinity for oxygen so strong as to breathe, by withdrawing that element from unstable components, in which case they would act as ferments on those substances." He suggested that it might be possible to meet with conditions which would allow certain inferior plants to live away from atmospheric air in the presence of sugar, and to provoke fermentation of that substance after the manner of beer yeast.

He was already at that time scattering germs of ideas, with the intention of taking them up later on and experimenting on them, or, if time should fail him, willingly offering them to any attentive scientist. These studies on beer had brought him back to his former studies, to his great delight.

"What a sacrifice I made for you," he could not help saying to Dumas, with a mixture of affection and deference, and some modesty, for he apparently forgot the immense service rendered to sericiculture, "when I gave up my studies on ferments for five whole years in order to study silkworms ! ! ! "

No doubt a great deal of time was also wasted by the endless

discussions entered into by his scientific adversaries; but those discussions certainly brought out and evidenced many guiding facts which are now undisputed, as for instance the following—1. Ferments are living beings. 2. There is a special ferment corresponding to each kind of fermentation. 3. Ferments are not born spontaneously.

Liebig and his partisans had looked upon fermentation as a phenomenon of death; they had thought that beer yeast, and in general all animal and vegetable matter in a state of putrefaction, extended to other bodies its own state of decomposition.

Pasteur, on the contrary, had seen in fermentation a phenomenon correlative with life; he had provoked the complete fermentation of a sweet liquid which contained mineral substances only, by introducing into it a trace of yeast, which, instead of dying, lived, flourished and developed.

To those who, believing in spontaneous generation, saw in fermentations but a question of chance, Pasteur by a series of experimental proofs had shown the origin of their delusion by indicating the door open to germs coming from outside. He had moreover taught the method of pure cultures. Finally, in those recent renewals of old quarrels on the transformations into each other of microscopic species, Pasteur, obliged by the mycoderma vini to study closely its alleged transformation, which he had himself believed possible, had thrown ample light on the only dark spot of his luminous domain.

"It is enough to think," writes M. Duclaux concerning that long discussion, "we have but to remember that those who denied the specific nature of the germ would now deny the specific nature of disease, in order to understand the darkness in which such opinions would have confined microbian pathology; it was therefore important that they should be uprooted from every mind."

END OF VOL. I.

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