"The Influence of the Work of Pasteur on Medicine and Surgery."

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by

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It is an extraordinary fact that the man to whose modern medicine and surgery owe more than any other individual, was never a proficient student of the healing art. There are in every generation those whose genius transcends the bounds into which we are ordinarily accustomed to divide human activities and who, in their own career and person illustrate the unity of purpose which inspires those whose quest is truth in whatever sphere. Such a one was Louis Pasteur, trained as a chemist and physicist, whose pursuit of scientific truth led him often into the realm of medicine, always with great profit to the latter and enduring fame to himself. It is still more extraordinary that these excursions were, at least in their beginnings, no part of any deliberately planned campaign of investigation into medical and surgical problems, but merely incidental to the pursuit of other matters. The story of Pasteur's discoveries and their bearing upon medical science is one of surpassing interest, for it brings us into contact both with one (of the
of the greatest scientists the world has known and with the most important and far-reaching problems of medicine and surgery.

The first scene in the story shows us a young chemist picking over a little heap of crystals and patiently separating them into two smaller heaps. To the casual observer all the crystals in the original heap are identical in form; but Pasteur has noticed that there are really two kinds, the one the mirror image of the other. The year is 1848, and any medical man of that period might well be pardoned for wondering what possible bearing the elucidation of an abstruse chemical problem can have upon any department of medicine. The connection, however, is not as remote as one might imagine even in our own day.

Pasteur is about to demonstrate the relation between crystalline structure and the phenomenon known as optical activity, a relationship which has hitherto escaped the notice of the most famous chemists of his day; and this will lead in its turn to the works of Le Bel and van't Hoff and the development of stereochemistry without whose concepts organic chemistry would soon have become chaotic; and how except by the aid of organic chemistry could we today understand the physiology of digestion and metabolism?

But indeed, we need not travel so far if we wish to appreciate some bearing upon the problems of medicine of these early studies of Pasteur.
Pasteur in the molecular dysymmetries of tartaric and paratartaric acids. During the course of his investigations he has discovered that living organisms—the slowly fungi—can discriminate between the optical isomers. These differences had hitherto escaped the notice of the scientists; and long years afterwards the pharmacologists discovered that atropine consists of a racemic mixture of dextro- and laevo- atropine, of which only the latter has potency as a drug, which is simply another way of saying that the human organism too appreciates these fine distinctions of molecular structure.

There was, however, a more immediate application of these observations, and that by Pasteur himself. A beer manufacturer of Silesia asked him to investigate deviations which occurred in the normal process of fermentation. With characteristic thoroughness, Pasteur attacked the problem from every angle. Hitherto the dominant theory, supported by Liebig and Bézier, the two greatest chemists of the day, had been that fermentation was a purely chemical process, notwithstanding the recognition by Koenenholch and Schwann of the vegetable nature of yeast. Pasteur observed that in some fermentations there is produced alone alcohol, an optically active substance, and from this fact he made a very acute deduction. His earlier work had convinced him that optically active substances could only be produced by that selective action of living organisms already described; for in reactions which were
The result merely of physical chemical forces, the optical isomers would be produced in equal proportions, and an inactive racemic mixture would result. Thus the presence of any alcohol among the products of fermentation seemed to them evidence that the fermentation was the result of vital activity. By a series of ingenious experiments, he demonstrated that this actually was the case, and he differentiated between at least two ferments—the ordinary, beer-yeast producing alcoholic fermentation, and lactic-yeast producing a lactic acid fermentation.

Very naturally the next problem was to discover the source from which these ferments came, a problem which involved the question of spontaneous generation, to which up till now science had been inclined to give an affirmative answer. Indeed, it was commonly held that organic fermentable and putrificable substances possessed within themselves a mystery, "vital or vegetative force" which resulted in the spontaneous generation not only of microscopic ferments but even of maggots and worms. Pasteur demolished the whole theory by a series of simple yet convincing experiments. His thesis was that the ferments were contained in the floating dust of the atmosphere. He actually obtained the organisms from cotton wool through which air had been filtered. He showed that fermentable solutions, boiled in flasks which were immediately sealed, kept indefinitely without any change. But on the addition of a
minute piece of the cotton wool through which the air had been filtered, fermentation was at once set up, and yeasts etc. could be recovered from the fermenting solution. This proved that the "vital or vegetative force" of the solution had not been destroyed by the heat, for organisms could still develop within it when once a souring had been introduced from without.

The views held by some, that the gases of the atmosphere, even the oxygen, were in some way responsible for fermentation and putrefaction was met in very simple yet convincing fashion. Blood, milk, wine and other putrescible substances were after boiling kept indefinitely in flasks which were not sealed but had long necks drawn out into several curves. By this device, the gases of the air had free access to the fluids, but the solid constituents, including the fermentative organisms were mechanically excluded. No fermentation ever took place in any of the solutions.

These experiments of Pasteur are classical in the realm of pure science, for in spite of opposition and contradictions which he was fully able to meet, they dealt the death-blow to the doctrine of spontaneous generation and established the truth of the celebrated dictum of Harvey: "Omne vivum ex vivo" — a dictum which the author of it, according to some of his writings, did not himself fully believe.

The facts which Pasteur thus established are today part of the ordinary knowledge of every educated...
educated man, and not even the most junior medical student can fail to appreciate their bearing upon problems of practical medicine. Yet several years elapsed between their discovery and their successful application to the problems especially of surgery. It is not likely that many medical men were aware of these experiments; or if they did, it would be difficult for them to realize that, interesting and important as they were from the standpoint of pure science, they could have any practical bearing upon problems in their own profession. Indeed, it would seem that in this, as in the case of some of his later discoveries, Pasteur himself was quicker to perceive the bearing of his work upon medicine and surgery. There were, indeed, two medical men who distinguished The keenness of his work and in some measure appreciated its significance. One was a companion, Feins hermine, who accepted Pasteur’s germ theory of fermentation and, recognizing that protosporin in wounds is a species of fermentation, applied carboxylic acid to such wounds in order to prevent the growth of these of the fermentative organisms; — for Pasteur had demonstrated the germicidal power of “antisepsis,” a class of substances already recognized.

The other was a distinguished English surgeon, Spencer Wells, who in a paper published in the British Medical Journal of 1864 described Pasteur’s work, indicated its bearing upon practical surgery, and deduced therefrom the need for ...
sanguine cleanliness in the performance of the operation at which he was a master, over-estimating, but did not suggest any active antiseptic measures.

But it needed a bolder spirit properly to appreciate the significance of Pasteur's work for surgery, and to elaborate the details which were necessary for its successful application to the problems which confronted the surgeon of that period.

How dreadful those problems were it is difficult for us today to realize. The surgeon was dogged in his work by a number of diseases collectively known as 'hospital diseases,' whose origin was a mystery, but which wrought a havoc all too sadly evident. Wounds, either accidental or operative, rarely healed by first intention; within a few days an angry blackness appeared around the margin, accompanied with fever and with pain. Purulent scabs formed, and if the drainage originally provided were not adequate, dead-seated pockets were formed requiring multiple incisions for their evacuation and leaving a series of unsightly scars. Definite complications — the true hospital diseases: septicemia, pyaemia, dysenteric, sometimes tetanus, and hospital gangrene — frequently appeared and often caused a fatal termination. Recovery, if it took place at all, was a matter of weeks and even months, marked by suffering and frustration for the patient and perpetual anxiety for the surgeon.

The mortality rate for most operations, including even trivial ones, varied from 25 per cent to almost 100 per cent; so that operations of every (expedience...
Experience were commonly regarded as quite unjustifiable; and some hospitals, especially on the Continent, were so riddled with these septic diseases that for months on end the surgeons literally dare not operate, knowing that their cases would inevitably end fatally. The most distressing feature of this sad state of affairs was the terrible uncertainty which attended the result of any operation. Disasters occurred in the practice of the most careful surgeons, and none had any true idea as to why they ever occurred at all. There were of course all sorts of theories and all sorts of remedies, proving by their very multiplicity that none of them was really adequate. As to the cause, the fact that subsequent septic injuries healed sceptically seemed to show that the harmful agent resided in the atmosphere, and vague theories were developed as to local microbes which haunted the hospital wards, while others less imaginative said simply that it was the oxygen that was to blame. As to remedies, their numbers was legion. Some had a rational basis, but unfortunately the premises were always wrong. Others were merely empiric, being justified only by more or less successful use, and these included not a few antiseptic substances. It is rather curious that some should have claimed by mere hazard upon substances so efficacious. Whereas others who were at least attempting to work upon a rational basis fell far short of success.
substances, it was to the effect that in some way they 'stimulated' the tissues to heal without trouble-some complications.

Such was the unsettled and unsatisfactory condition of surgery when Lister first entered upon its practice. He saw that it was comparatively useless to work at new operative procedures until a safe and certain method of wound treatment had been evolved. Following certain ideas of John and working himself at questions of inflammation and of coagulation of the blood, he developed the view that the essential cause of suppuration in wounds is the putrefaction of the discharge or of dead pieces of tissue. He knew that scrupulous cleanliness in the ordinary sense diminished, but did not with certainty preclude, the chances of such putrefaction occurring. Why it should even occur at all was a complete mystery to him as it was to his contemporaries.

It was at this stage, when he was Professor of Surgery in Glasgow, that in 1865 his attention was directed by his colleague in Chemistry to the writings of Louis Pasteur. These shed a flood of light upon the very problem that was so perplexing to him, revealing not only the true cause of putrefaction in wounds but also indicating how it might be prevented. All the world was now aware of Pasteur's discoveries in the field of microbe. The "Antiseptic System" which Lister devised was indeed the direct outcome of Pasteur's work.
It was initially based upon the principle that micro-organisms in a living state were excluded from a wound; supraperitoneal and therefore septic complications would not occur. Those who objected that the organisms might originate spontaneously within the wound, were pointed to the experiments of Pasteur, confirmed by Lister himself, which proved that the formation of organic substances occurred only on the introduction into them of living organisms from without. Pasteur's work having focused attention on the air as the source of these organisms, it was natural that elaborate precautions should be taken to kill all atmospheric germs before they could reach the wound, though both Pasteur and Lister realised that the germs present in the floating dust were a forerunner also on instruments, clothing, and the persons of operator and patient. Thus in addition to washing instruments, clothes and his own hands as well as the skin of the patient with carbolic solutions, Lister also introduced the apparatus known as the Spray, which was in common use for the next fifteen years or more. This produced during an operation a continuous cloud of carbolic vapour which was supposed to kill all the germs present in the atmosphere. Probably they were less inconvenient than everyone else present, and Lister later realised that the machine was not only unnecessary, but probably also ineffective even for its supposed purpose; it is interesting, however, (to note...
to note that Pasteur was an early proponent of the antiseptic system. His work, which was deeply influenced by the prevailing belief in the purity of the atmosphere, was based on the observation that many microorganisms were pathogenic, particularly those found in the atmosphere. Pasteur's work helped to develop the doctrine of specificity, which stated that not all organisms were pathogenic, particularly those found in the atmosphere. This, in turn, justified his decision to use the spray method with some safety, because it could be abandoned.

Another point in the history of the antiseptic system was the introduction of the principle of specific infection, which Pasteur did so much to further. Soon, it was clear that Pasteur's criterion was flawed, and he led to the abandonment of the concept of infection. This was further reinforced by the essential pathological factor of infection.

It is pleasing to record that Pasteur constantly acknowledged his indebtedness to Pasteur, with whom he formed a friendship that was inspired by a common love for truth and desire to serve humanity. Nothing could have been more fitting than that Pasteur should have been chosen to convey the tribute of medicine and surgery to Pasteur on his seventieth birthday, and his address was not the least eloquent of the many that were made on that occasion.
occasion in the Sorbonne. "Grâce à vous," said
latter, "la chirurgie a subi une révolution
complète qui l’a dépossédée de ses terveurs
et a érigé presque sans limite son pouvoir
officier." There is indeed scarcely any
department of medicine and surgery that has not
benefited from the applications of the Germ Theory
to disease. The great advances which have been
made in operative surgery are obvious, including
for example practically the whole of abdominal
and intracranial surgery. The physiologist, armed
with the new knowledge, has been able to
bring to a successful conclusion experiments
which have greatly increased our knowledge of the
functions of every part of the body, thus enabling
a more rational system of medicine to be built
up.

The obstetricians, who produced in
Semmelweis the father of modern obstetrics, who
might indeed have anticipated him that Pasteur’s
discovery, some twenty years earlier, — have
likewise been tremendously aided in their work
by the new ideas and methods brought forward
by Pasteur and hister. It is fitting that in
the year which celebrates the centenary of
hister’s birth, one should pause to observe the
happy results that have followed from his
ready application of the discoveries of Pasteur.
The amount of human suffering which the work
of these two great men has relieved, and will
continue to relieve for all time, is beyond all
computation. By the use he made of hister’s
laws added to the glory of Pasteur’s discoveries,
and detected nothing from the meagre of his own achievement. For, as Pasteur gratefully acknowledged, only a surgeon could have made the successful application of his work to the conditions of surgery.

Having determined the true nature of fermentation, and having won the battle against the doctrine of spontaneous generation, Pasteur next began a series of studies on subjects of great industrial importance, though at first, thought to have little bearing on medicine and surgery. Yet these investigations, from about 1863 to 1871, into the diseases of wine, of silkworms, and again of beer, resulted in important bacteriological discoveries and deductions for general pathology and epidemiology—all with a very definite contribution to make to the contemporaneous developments in medical science.

Bacteriology, which is the foundation of so large a part of modern medicine, was born with these researches of Pasteur. In the course of these he discovered, for example, the process of lactic fermentation which still bears his name—"Pasteurisation." He began to recognise that there are many distinct species of ferment which are not transmissible, and thus paved the way for the fuller development, under Koch, of the doctrine of specificity. In his studies of fermentation, the silkworm disease, he gave expression to the concept of "the seed" and "the soil" which dominate modern thinking.
about infection, noting that the result of infections varied with such factors as the dosage and virulence of the infecting organism, the path of entry, the intrinsic susceptibility and environmental conditions of the host. All these were conclusions which required no modification in applying them to human pathology, as Pasteur himself recognized, for in 1879 we find him in an address before the Academy recommending young doctors to read his Studies on silkworms. In his experiments with the grape vineyards, he showed that there were certain diseases due to organisms of universal occurrence, and others due to organisms confined to local areas; and again he recognized that this could be applied to human diseases, some of which are of universal occurrence, while others are localized, being spread by contact from one person to another. Only in the latter case, he argued, is quarantine effective, but if properly applied it should be entirely successful in its purpose.

It was Pasteur who discovered anaerobic bacteria. The first, the butyric ferment, was discovered during the course of his early studies in fermentation, and led him to speculate that it was the role of such bacteria in the cycle of natural decay. Some years later, in 1877, he discovered an anaerobic pathogen to cause the Vibriosis septicum. This led to other discoveries of similar organisms causing the wound-septicemia of wounds, and Pasteur at this time indicated that the best method of treatment for wounds thus infected is free exposure to the oxygen of the air.
The air—a method that was successfully used in the Great War.

By 1878 Pasteur and his associates had made so many bacteriological discoveries of importance to medicine that he thought it well worth while to present to the Academy a joint paper with Joubert and Chamberland, bearing for its title "The Germs Theory and its Application to Medicine and Surgery." In this he emphasized particularly the importance of his discoveries to practical surgery, and gracefully referred to the work of his teacher.

It is interesting to note that by this time, largely owing to his teaching, the principles of antisepsis in surgery were firmly established in most countries, except France. Pasteur in this paper indicated that the germs in the atmosphere were far less numerous and far less to be feared than those in the dust scattered about the anteroom of an operation. He recommended the sterilization of sheet and clothes by dry heat at 110°-120°C.

For his controversy with Bastian two years before had shown him that there were some (spore-forming) organisms which were not destroyed at 100°C,—and in this he foreshadowed one of the methods of the "antiseptic surgery" which was soon to take its rise under von Behrens in Germany.

In the same year that this communication was made to the Academy here appeared Koid's classical memoir on the etiology of traumatic infective diseases; and now commenced a period fruitful for a succession...
of bacteriological discoveries of first-rate importance. Pasteur and Koch, with their immediate disciples, headed the advance. Pasteur himself began to visit the hospitals, much as he distrusted the spectacle of suffering in any form. In 1879 he discovered in the purulent discharge from cases of puerperal fever, "un microbe en chaîne de grains" — *Staphylococcus pyogenes*. At about the same time he discovered in the locustal discharge from cases of pyemia fever, "un microbe en chaîne de grains" — *Staphylococcus pyogenes*. and had no hesitation in declaring it to be the commonest cause of the long-feared obstetric. Interrupting a discussion at a learned society one day he said: "It is the doctor ... who carries microbes from a sick woman to a healthy one!" When the speaker replied that he doubted whether this microbe would ever be discovered, Pasteur rushed up to the blackboard and drew the organism in chains, exclaiming "Look! that is what it is like!" He would look to forecast, from an examination of the locustia alone, who would have a rise of temperature, and to demonstrate in a severe case of puerperal fever the microbe in blood from the finger; both of which he did successfully.

We now come to what is perhaps the most interesting and remarkable chapter in the life of Pasteur. We have already noted his recognition that these were in nature ranging strains of virulence among pathogenic microbes.
What he was now to discover was how artificially to weaken the virulence of organisms and how to use these modified strains in order to produce immunity against the attacks of other, more violent organisms. It was in almost accidental fashion that he was led to these discoveries, although as he himself once said, "In the field of observation, chance favours only the trained mind.

He had been working at the virus of chicken-cholera, and on his return from vacation in 1879, he found that the cultures left behind would now no longer grow when sub-cultured. Further, when inoculated into fowls, they produced little or no effect. Only a Pasteur would have thought of the next step. He inoculated the same fowls with fresh cultures, and to his astonishment the birds did not develop cholera. This at once suggested comparison with Jennerian vaccination, a method of proven value which had however never been explained. There was, however, a difference. It was generally held that vaccination, as the name implied, produced an attack of the wild disease cowpox or Vaccinia, and that this conferred an immunity against the disease smallpox or Variola. Pasteur's new discovery was akin rather to the old method of " Variolisation" — inoculation from a "wild" case of genuine smallpox: a risky method, for it sometimes had fatal issues. It should be added that, in the view of some modern authorities, Vaccinia itself is in reality a true form of Variola, modified by its passage through another species of animal
of animals. However, it was clear to Pasteur that he had discovered a method of vaccination against chicken cholera which was certain and safe, and which might be used in other diseases as well.

The method by which attenuation of virulence might be achieved was claimed by Pasteur. He discovered that in the case of chicken cholera it was due to the presence of oxygen, and was only perceptible after the lapse of two months. Cultures brought to a certain state of attenuation could be kept at this state by continued culture away from oxygen. A similar investigation into anthrax, a disease in which he had previously made important studies, led to the discovery that cultures of B. anthracis were less attenuated by keeping them at a temperature of 120—145°C instead of the usual 37°C, and that the culture could then be fixed in a spore form. The spores on germination would reproduce the same degree of attenuation as that of the culture in which they had been formed.

Aided by Roux, in 1881 Pasteur gave a brilliantly successful demonstration of this method of protecting sheep against anthrax by vaccination with attenuated viruses.

Pasteur also showed that, by successive passage through a series of animals, attenuated viruses rapidly regain their normal strength and indeed go far beyond it—the "exaltation" or "refinement" of viruses. This phenomenon provides the speculative with interesting hypotheses.
hypotheses in epidemiology.

The importance of the part of Pasteur's work can hardly be overestimated. It has formed the starting point for the whole of the modern science of immunology. The problems presented by it have proved complex and difficult, and from the point of view of therapists results have often been disappointing; but the last word is still far from being said in this fascinating subject, and there is reason to hope that discoveries will continue to be made that will be of practical benefit to mankind.

The chief modifications since Pasteur's time have been the use of filtered or dead cultures (containing exotoxins and endotoxins) instead of living attenuated cultures, and the process of passive as opposed to active immunisation.

Examples of the former are the antibilharziasis and antipLAGUE vaccines introduced by Haasfink; the antityphoid vaccine introduced by Wright and Trager; while under the guidance chiefly of Sir Almroth Wright vaccines have been devised, with varying degrees of success, against most of the common infections. Passive immunisation has achieved two brilliant successes in the diphtheritic antitoxin brought forward by Pasteur's successor Roux, and in the antitetanic serum.

Pasteur crowned his lifework with the discovery which has always appealed most strongly to the popular imagination and has contributed most to his fame outside the realms of science and medicine.
medicine. For this was nothing less than the
discovery of a cure for rabies, dreaded for the
inhabitability of its fatal terminations and for the frequently
horrible nature of that end. The problem before
Pasteur was no easy one. The virus of rabies had
never been isolated. But for his characteristic skill
and caution, he might have been led to suppose
that an organism — afterward known as Frankel's
Pneumococcus — constantly found in the saliva of
people dying of rabies, and capable of causing the
death of rabbits inoculated with it, was the cause of
rabies. But Pasteur noted that the incubation
period was far too short, and continued his search
in other directions. Finally the virus was located
in the central nervous system of animals afflicted with
rabies. Pasteur discovered that the successive
passage of the virus through animals of the same species
gives a state of virulence fixed with regard to that
species, but varying for different species. He then
obtained a very strong "standard" virus by passing
it through a series of ninety rabbits. This virus was
capable of producing rabies on the seventh day after
inoculation. The spinal cords of rabbits thus
inoculated were aseptically removed and dried up
in dry air, whereupon the action of the oxygen upon
them resulted in a progressive loss of virulence.
Using these cords, Pasteur immunized dogs against
rabies by periodic inoculations with extracts of
cords of decreasing age, i.e., of increasing
virulence. The method proved entirely successful,
and when Pasteur awaited a suitable human case
on which to test his method. On July 6, 1885,
(Here
There arrived a little Asiatic boy who had been bitten in fourteen places by a dog undoubtedly rabid; he was treated by Pasteur on the lines indicated above, and to the joy of the great scientist the child not only escaped rabies but proved immune to a virus more virulent than that of an ordinary rabid dog. Within the next six months nearly three hundred people were successfully treated with the preventive inoculations. All the world was stirred. From all over Europe patients came to Pasteur. The English Government sent a special commission, of which Sir James Paget was chairman, to Paris to investigate. Its finding was as follows: "Mr. Pasteur has discovered a method of preventing rabies comparable to that of vaccination for smallpox. It would be difficult to exaggerate the importance of this discovery, both as regards its practical applications and its effect on general pathology."

The necessity for the founding of an establishment for anti-rabic inoculation led to the erection of the Pasteur Institute, opened on November 14, 1886, in the presence of the President of the Republic. Here, although he was not destined long to work in it himself, Pasteur's pupils, notably Roux, continued the investigations in bacteriology and allied subjects. Such is Pasteur's genius had begun. The Institute, too, became a model for similar institutions in other countries; so that the spirit of Pasteur continues to work in many lands.
Pasteur will ever be remembered as one of the greatest figures of the nineteenth century. His influence on the evolution of medical science, and indeed on biology in the broadest sense, has been profound and far-reaching.

The Germ Theory which dominates the modern practice of medicine and surgery was established and developed by his genius. Antiseptic surgery, including its later development as aseptic surgery, the elucidation of the true nature of infectious diseases, vaccine therapy, the specific cure for rabies—all these are the direct outcome of the discoveries that he made.

Yet greater than any of his discoveries was the man himself. He was the perfect scientific investigator, so faithful in the pursuit of truth that one has called him the Galileo of Science. He hated obscurity, and felt always a desire to understand and see clearly. He was never guilty of superficial thinking, but weighed the significance of every fact, particularly any which contradicted some previously formulated hypothesis. He had a genius for experimentation, devising always the experiment which gave a decisive answer to the question he put to nature. He never published anything incomplete, or that did not rest on a secure basis of proven facts. He received the reward of the genius that took such infinite pains in always seeing further into a subject than anyone before him. The joy of discovery was thus frequently his, and his joy was
multiplied by the knowledge that his discoveries did so much to alleviate human suffering. In his speech at the opening of the Institute which bears his name and perpetuates his memory, he gave utterance to some wise precepts which his own career nobly exemplified:

"Always accompany enthusiasm with rigid restraint. Put forward nothing which cannot be proved simply and decisively. Cultivate the critical faculty. By itself it is neither an originator of ideas nor a stimulus to great things, but without it nothing is sound. It always has the last word. What I ask of you, and what you should ask of the disciples that you will make in the future, is the most difficult thing there is for the discoverer.

To believe that one has made an important scientific discovery; to be at a fever to announce it; and to restrain oneself; for days, weeks, and sometimes years to fight against oneself; to force oneself to compute one's own experiments; and only to proclaim a discovery when all contradictory hypotheses have been disproved; — yes, this is an onerous task.

But when, after many, many attempts, one has at last arrived at certainty, one experiences one of the greatest joys the human mind can feel, and the thought that one will add to one's country's glory, makes this joy greater still."

— THE END —