Charles Babbage

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Charles Babbage, upon being urged to write his own biography, replied that he had no desire to do it while he had strength and means to do better work. Some men, he said, write their lives to save themselves from *ennui*, careless of the amount they inflict on their readers; others, lest some kind surviving friend in showing off his own talent in writing personal history might show up theirs; and others still from fear that the vampires of literature might make them a prey. He belonged to no one of these classes. What a man had done for others, not what he might say about himself, formed his best life. And so to many who asked him to prepare an autobiography he sent a list of his works, " which," he naively adds, "no one cared to insert." Still, few persons who have made a name while living are insensible to posthumous fame, and Babbage was among the number. While professing to treat these applications lightly, he nevertheless set about placing on record an account of himself, and though he rejects the name of autobiography, he has left behind him, in a work which he entitles "Passages from the Life of a Philosopher," a memoir which in variety of detail and clearness of description, liveliness of style and sententious remark, is almost without its parallel. Without being confined to this witty and erratic narrative, and putting the estimate of the thinking men of the age rather than his own upon what he was and what he did, this notice will aim to do justice to certainly not the least remarkable man of this nineteenth century.

Of the mere personal history of this eminent philosopher and scientific mechanist little need be recorded. He was born of gentle blood and moderate competence on December 26, 1792.[a] From earliest years he showed great desire to inquire into the causes of things that astonish childish minds. He eviscerated toys to ascertain their manner of working; he sought to prove the reality of the devil by drawing with his blood a circle on the floor and repeating the Lord's prayer backward; he dissipated toothaches by reading Don Quixote; he bargained with another boy that whoever died first should appear to the survivor, and spent a night of sleeplessness when the first event of the compact occurred, awaiting in vain his comrade's appearance. In college he was perpetually puzzling his tutors by abstruse questions. When the circulation of the Bible with or without comment became a fierce controversy at Cambridge, he formed, with Herschel, Maule, D'Arblay, and others, an analytical society for the translation of Lacroix's Differential and Integral Calculus, maintaining that the work needed no comment; that the "d's" of Leibnitz were perfect, and consigning to perdition all who supported the heresy of Newton's "dots." It being hinted that the society was infidel, the young student replied, "No! We advocate the principles of pure 'D'-ism in opposition to the 'Dot'-age of the university." He studied the game of chess and beat every expert that was brought against him; formed a ghost club to collect all reliable evidence of the supernatural; joined high players at whist in order to show them that, staking only shillings, he could win at guinea-points; embarked in boating not more from the manual labor than from the intellectual art of sailing; and by making a collection of examples of mathematical problems, in which the notation of Leibnitz was employed, he made it for the interest of tutors of the colleges to abandon the symbols of Newton.

During Babbage's college life the course of his studies led him into a critical examination of the logarithmic tables then in use. The value of these tables had long been recognized in every part of the civilized world. Large sums of money were expended in their preparation, and the greatest care produced only proximate accuracy in the calculations. The young mathematician set himself to consider whether, in the construction of these tables, in place of the perturbable processes of the intellect, it were not possible to substitute the unerring movements of mechanism. The thought was perpetually recurring during the latter portion of his college course. He gave up his leisure time to experiments having this end in view—discussed the subject with Herschel, Ryan, Maule, and others of his class who were interested in philsophical mechanism, and was no sooner graduated than he visited the various centers of machine labor in England and on the continent, that he might become familiar with the combinations in use and study their functions. Returning home, he began to sketch arrangements for a machine by which all mathematical tables might be computed by one uniform process.

The idea of a calculating machine did not originate with young Babbage. Pascal, nearly two hundred years before, had constructed, when in his nineteenth year, an ingenious machine for making arithmetical calculations, which excited admiration. In his Pensées, alluding to this engine, he remarks: "*La machine arithmétique fait des effets qui approchent plus de la pensée que tout ce que font les animaux; mais elle ne fait rien qui puisse faire dire qu'elle a de la volonté comme les animaux*."[b] Subsequently, Leibnitz invented a machine by which arithmetical computations could be made. Polenus, a learned and ingenious Italian, put together wheels by which multiplication was performed; and in the various industrial exhibitions since 1851, contrivances for performing certain arithmetical processes have been exhibited. The principle upon which Babbage's engines have been constructed, however, is entirely new, and intended to do work of a much more important character.

On the 1st of April, 1823, a letter was received from the treasury by the president of the Royal Society, requesting him to ask the council to take into consideration a plan which had been submitted to government by Mr. Babbage for applying machinery to the purposes of calculating and printing mathematical tables, and desiring to be favored with its opinion on the merits and utility of the invention. This is the earliest allusion to the calculating machine in the records of the Royal Society. The invention, however, had been brought before the members in the previous year by a letter from Mr. Babbage to Sir Humphry Davy. In that he had given an account of a small model of his engine for calculating differences, which produced figures at the rate of 44 a minute, and performed with rapidity and precision all those calculations for which it was designed. He had concluded this letter by saying, "that though he had arrived at a point where success was no longer doubtful, it could be attained only at a very considerable expense, which would not probably be replaced by the works it might produce for a long period of time; and which is an undertaking I should feel unwilling to commence, as altogether foreign to my habits and pursuits."

The council of the Royal Society appointed a committee to take Mr. Babbage's plan into consideration. It was composed of the following gentlemen: Sir H. Davy, Mr. Brande, Mr. Combe, Mr, Baily, Mr. Brunel, Mr. Colby, Mr. Davies Gilbert, Sir John Herschel, Captain Kater, Mr. Pond, Dr. Wollaston, and Dr. Young. On the 1st of May, 1823, this committee reported: "That it appears Mr. Babbage has displayed great talents and ingenuity in the construction of his machine for computation, which the committee think fully adequate to the attainment of the objects proposed by the inventor, and that they consider Mr. Babbage as highly deserving of public encouragement in the prosecution of his arduous undertaking." This report was transmitted to the lords of the treasury, by whom it was printed and laid before Parliament. Two months after this a letter was sent from the treasury to the Royal Society, informing them that the issue of £1500 had been directed to Mr. Babbage "to enable him to bring his invention to perfection in the manner recommended."

It is not within the purpose of this memoir to describe the misunderstanding which arose between Mr. Babbage and the British government, during the following twenty years, in consequence of this letter, received by the Royal Society from the lords of the treasury. He regarded the machine he now undertook to build as the property of the government. They understood it to be his. He received the first advance of money as an earnest that all necessary funds would be furnished to complete this difference engine No. 1. They seemed to have regarded it in the light of a temporary assistance, given to a man of genius for the purpose of enabling him to complete an invention which would be of great public benefit. He commenced the work, giving his own labors gratuitously, according to what he considered to be an order. Government looked on, furnished further moneys, consulted the Royal Society once and again as to the progress of the work, but declined committing itself further. Mr. Babbage advanced considerable sums, but was not reimbursed; made great improvements upon his original plans, but was not encouraged; carried with him the convictions of the scientific men of his country and continental Europe, but was left behind by the treasury; and finally, when, in the opinion of such philosophical mechanists as Sir John Herschel, Sir Mark Brunel, Mr. Pond, the astronomer royal, and others, he was on the eve of results far surpassing in importance all that had been contemplated, he was informed that "ultimate success appeared so problematical and the expense so large and so utterly incapable of being calculated, that the government would not be justified in taking upon itself any further liability."

Thus terminated in 1842 the engagement which had existed more than a score of years between Charles Babbage and the British government. During this period of time he had made heavy sacrifices, both pecuniary and personal, had refused highly honorable and profitable situations; had employed in his own house, at his own expense, the most intelligent and skilled workmen to assist him in making experiments necessary for attaining a knowledge of every art which could possibly tend to the perfection of his engine; had repeatedly, at his own expense, visited the manufactories of England and the continent; had invented incidentally, and constructed, mechanical tools and labor-saving machines of great public value, not one of which he protected by letters-patent, and had gratuitously given the results of his energetic mind to the perfect construction of the machines which he regarded as the great purpose of his life. Whether success would have equaled expectation had his government rendered him the required aid, can never be known. He has left behind him no thinker or philosophical mechanic capable of completing his work.

It was to calculate and print tables of figures connected with various sciences; with almost every department of the useful arts; with commerce, astronomy, navigation, surveying, engineering, and everything which depends on mathematical measurements.

To show the immense importance of any method by which these numerical tables, absolutely accurate in every individual copy, could be produced with facility and cheapness, let the reader revert to what European governments have attempted to do in the last hundred years. Dodson's Calculator, published in London in 1747, contained a table of multiplication extending to 10 times 1,000. In 1775 this table was extended to 10 times 10,000. The English board of longitude employed Dr. Hutton, in 1781, to calculate numerical tables up to 100 times 1,000; and to add to these, tables of the squares of numbers as far as 25,400; and also tables of cubes of the first ten powers of numbers reaching to 100. In 1814, Professor Barlow, of Woolwich, published in an octavo volume the squares, cubes, square-roots, cube-roots, and reciprocals of all numbers from 1 to 1,000—a table of the first ten powers from 1 to 100, and a table of the fourth and fifth powers of all numbers from 100 to 1,000.

To a still greater extent were similar tables prepared on the continent. In France, in the year 1785, was published an octavo volume of the tables of squares, cubes, square-roots, and cube-roots of all numbers from 1 to 10,000; and in 1824 from 1,000 times to 100. A larger table of squares than at that time existing was published in Hanover in 1810: a larger still in Leipsic in 1812; a more perfect one at Berlin in 1825; and a similar table at Ghent in 1827.

This class of tables involves only the arithmetical dependence of abstract numbers upon each other. To express peculiar modes of quantity—such as angular, linear, superficial, and solid magnitudes—a larger number of computations are required. Volumes without number of these tables also have been computed and published at infinite labor and expense. Then come tables of a special nature, of importance not inferior, of labor more exacting—tables of interest, discount, and exchange; tables of annuities and life insurance, and tables of rates in general commerce. And then, above all others, tables of astronomy, the multiplicity and complexity of which it is impossible to describe, and the importance of which, in the kindred art of navigation, it would be difficult to over-estimate. The safety of the tens of thousands of ships upon the ocean, the accuracy of coast surveys, the exact position of light-houses, the track of every shore from headland to headland, the latitude and longitude of mid-sea islands, the course and motion of currents, direction and speed of winds, bearing and distance of mountains, and, in short, everything which constitutes the chief element of international commerce in modern times, depends upon the fullness and accuracy of logarithmic tables.

Inadequate as is the notion of the *importance* of these tables that has been conveyed, still more inadequate must be any notice of their errors. The expedients resorted to for even a limited degree of accuracy have been almost innumerable. The first French Republic, aspiring to lead the nations in science, undertook, through its mathematicians, by a division of labor so admirable that it seemed impossible errors should be committed, or, if committed, remain undetected, to produce a system of logarithmic and trigonometric tables so accurate that it should form a monument of the kind more imposing than had ever been conceived. The attempt failed, for one singular reason among others, that the computers who committed the fewest errors were those who understood nothing beyond the process of addition. Dr. Lardner discovered in forty tables, taken at random, no less than 3,700 *errata*. In the Nautical Almanac Mr. Baily detected more than 500 errors of calculation. The "tables requisite to be used with the Nautical Ephemeris for finding latitude and longitude at sea," computed, revised, and re-revised with the utmost care, under direction of the British board of longitude, and published by the government, was found to contain above a thousand errors.

The tables of the distances of the moon from certain fixed stars, published by the same board, is followed by 1,100 *errata*, and these themselves contained so many errors as to make *errata* upon *errata* necessary. For the special use of the national survey of Ireland, the logarithmic tables, most carefully prepared, were found to contain six errors, and these, by comparison, were found to exist not only in tables published during more than two hundred years in Paris and Gouda, Avignon and Berlin, Florence and London, but also in a set printed in China, in Chinese characters, and purporting to be original calculations. In fact, absolute correctness in logarithmic tables has never been attained. Year after year, through eight generations of mathematicians, one set has followed another to correct its predecessor. Even the last claims but approximate accuracy. Precautions, comparisons, revisions, and alterations from computers to computers, make advances *only toward* an end that is never absolutely reached. And no wonder. We need but to consider the nature of a numerical table, where a thousand pages are covered with figures alone, where neither note nor comment, letters of the alphabet, nor rules of syntax, are permitted to intrude, to understand that the law of chance is on the side of error, and that for one mistake that may happen to be detected a score may escape unnoticed.

Besides the errors incidental to computation, there are those of *transcribing* for the press, and of *composition* into print. Nor does the liability to error stop even here, errors being often produced in the process of printing. A remarkable instance of this occurs in one of the six errors of the Irish Survey Tables, just mentioned. The last five figures of two successive numbers of a logarithmic table were

35875
10436

Both were erroneous. The "8" in the upper line should be "4", and the "4" in the lower line should be "8." It is evident that the types, as first composed, were correct—that two of them, "4" and "8," became loose, adhered to the inking ball, and were drawn out—and that the pressman in replacing transposed them. And this inadvertent error in Vlacq's tables of 1628, traveled over three continents, and, with more or less of mischief, remained undetected for two hundred years.[c]

Numerical correctness in logarithmic tables, is then, and has ever been, the great desideratum. This Mr. Babbage proposed to attain by machinery; to calculate the tables unerringly, as if by a law of nature, and by the same law to reduce them as unerringly to type. Thus was the single purpose of the difference engine No. 1.

The difference engine No. 1 was only partially competed. Confided to the care of King's College, it remained for twenty years in the museum at Somerset house. In 1862 it was exhibited at the Great Industrial Exhibition, since which time it has been stored at the South Kensington Museum. The finished portion of the engine showed itself capable of computing any table whose third difference is constant and less than 1,000; while at the same time it showed the position in the table of each tabular number. In Mr. Babbage's own words:

"1st. The portion of the machine exhibited can calculate any table whose third difference is constant and less than 10.

"2d. It can show how much more rapidly astronomical tables can be calculated in any engine in which there is no constant difference.

"3d. It can be employed to illustrate those singular laws which might continue to be produced through ages, and yet after an enormous interval of time change into other different laws; each again to exist for ages, and then to be superseded by new laws."

It will be borne in mind that all work upon difference engine No. 1 was stopped in the early part of the year 1833. At the general meeting of the Royal Academy at Brussels in May, 1835, a letter received from Mr. Babbage was read announcing that he had been engaged for six months in making drawings of a new calculating machine of far greater power. "I am myself astonished," he wrote, "at the power I have been enabled to give to this machine: a year ago I should not have believed this result possible. The machine is intended to contain a hundred variables, each consisting of twenty-five figures; it will reduce to tables almost all equations of finite differences; it will calculate a thousand values (of e.g. *a b c d* by the formula $p = \sqrt{(a+b)/\mathrm{ca}}$) print them, and reduce them to zero, and will then ring a bell to give notice that a new set of constants must be inserted." "When there exists," he continues, "a relation between any number of successive co-efficients of a series, provided it can be expressed, the machine will calculate them and make their terms known in succession; and it may afterward be disposed so as to find the value of the series for all the values of the variable."

This was the first announcement to the scientific world of a machine, capable of executing not merely arithmetical calculations, but even those of analysis when the laws are known. It was, in fact, the analytical engine, never destined to be completed by its inventor in actual fact, but so perfect in its drawings, so clear in its descriptions, so certain in its sequences, and so logical in all its principles, that, to the minds of men capable of comprehending the details, it became as certainly the realization of a gigantic idea as if it has been doing its work in their presence. If it be asked, how such a machine could of itself, without recourse to thought, assume the successive dispositions necessary, Mr. Babbage answers that Jacquard solved the problem when he invented his loom.

In the manufacture of brocade there are two species of threads, the one longitudinal, which is the *warp*, the other transverse, which is the woof.

Of course the analytical engine could not originate. It would have always been the servant—never the master. It could have done whatever its inventor *knew how to order it to do*. No more. It assisted—marvelously indeed, but it only assisted—in making the *known* available. It could have *followed* analysis, never *anticipated* it. But had it been constructed, it would have achieved three *desiderata* of science—*economy of time*, *economy of intelligence*, *rigid accuracy*. It would have made observations fertile that are now barren for lack of computing powers; it would have saved time for contemplation that is now wasted in arid calculations by men of genius, and it would have made *certain* arithmetical numbers, without the aid of which the veil that envelopes the mysteries of nature can never be raised.

As illustrative of the estimate put upon the operations of the analytical machine, it may not be inappropriate to quote here Mr. Babbage's own remarks: "An excellent friend of mine," he writes, "the late Professor MacCullagh of Dublin, was discussing with me the various powers of the analytical engine. After a long conversation he inquired what the machine could do, if, in the midst of algebraic operations, it was required to perform logarithmic or trigonometric operations. My answer was, that whenever the analytical engine should exist, all the developments of formula would be directed by this condition, that the machine should be able to compute their numerical value in the shortest possible time; I then added that if this answer was not satisfactory, I had provided means by which, with equa1 accuracy, it might compute by logarithmic or other tables.

"I explained that the tables to be used must, of course, be computed and punched on cards by the machine, in which case they would undoubtedly be correct. I then added, that when the machine wanted a tabular number it would ring a bell and then stop itself. On this the attendant would look at a certain part of the machine and find that it wanted the logarithm of a given number, say of 2303; the attendant would then go to the drawer, take the required logarithmic-card, and place it on the machine. Upon this the engine would first ascertain whether the assistant had or had not given it the correct logarithm of the number; if so, it would use it and continue its work. But if the engine found the attendant had given it a wrong logarithm, it would then ring a louder bell and stop itself. On the attendant again examining the engine, he would observe the words, WRONG TABULAR NUMBER, and then discover that he really had given the wrong logarithm, and of course would have to replace it by the right one."

As between the two engines, the difference and the analytical, their powers and principles of construction, the capabilities of the latter would have been immeasurably the more extensive. They hold to each other, in fact, the same relationship that analysis holds to arithmetic. The difference engine was intended to effect but one particular series of operations. It was not the *general* expression even of *one particular* function, much less of any and all possible functions of all degrees of generality. Indeed, it could do nothing but add. It certainly performed the processes of subtraction, multiplication, and division; but then only so far as these could be reduced to a series of additions. The analytical machine, on the contrary, would have been able to add or subtract, multiply or divide—it could have done either and all with equal facility—and it would have performed these operations directly in each case without the aid of any of the other three. This fact implies everything. The one engine merely tabulated but never developed; the other both tabulated and developed.

Mr. Babbage's third invention, which he named " difference engine, No. 2," need not be dwelt upon here. It was never built. Its drawings even were never quite completed. As an entity it had no existence out of his own mind. In laboring to perfect the analytical machine he discovered the means of simplifying and expediting the mechanical processes of difference engine No. 1. The Earl of Rosse, who was greatly interested in the application of mechanism to purposes of calculation, and who was well acquainted with the drawings and notations of the second difference engine so far as made, proposed that Mr. Babbage should perfect and give them to the government, upon condition that they would undertake to construct it. To this, with some reluctance, he consented. It was then proposed to the Earl of Derby, he being prime minister, that the government should apply to the president of the Institution of Civil Engineers to ascertain—

1st. Whether it was possible from Mr. Babbage's drawings and notations to make an estimate of the cost of constructing the machine.
2d. In case this question was answered in the affirmative, then could a mechanical engineer be found who would undertake to construct it, and at what expense.

It was explained to Lord Derby that the cessation of work upon the first difference engine was owing to no fault of Mr. Babbage; that, being new in design and construction, and requiring the utmost mechanical skill for its execution, it had necessarily been costly; that the necessity of constructing and, in many instances, inventing tools and machinery of great complexity for forming with requisite precision parts of the apparatus dissimilar to any used in ordinary mechanical works, had produced unavoidable delays, and that the foremost men of practical science all over Europe who were acquainted with the facts, so far from being surprised at the time and expense that had been required to bring the engine to its then present state, felt much more disposed to wonder that it had been possible to accomplish so much. "If this work," Mr. Babbage wrote to the minister, "upon which I have bestowed so much time and thought were a mere triumph over mechanical difficulties, or simply curious, or if the execution of such engines were of doubtful practicability or utility, some justification might be found for the course which has been taken; but I venture to assert that no mathematician who has a reputation to lose will ever *publicly* express an opinion that such a machine would he useless if made, and that no man distinguished as a civil engineer will venture to declare the construction of such machinery impracticable."

It seemed now (1852) as if there were a probability that government would order a resumption of the work. The Earl of Derby was a man of large gifts and extended views, and his chancellor of the exchequer, himself the son of a philosopher, was known as widely almost by his philosophic sentiments as by his great powers of debate. The country was at peace. The first exhibition of the whole world's industry had by its marvelous success the previous year given a new impulse to the arts. Politics, indeed, ran high, but in every other aspect there was encouragement. The Royal Society; the Society of Civil Engineers; the Royal Academy of Sciences, at Brussels; the principal philosophical mechanists of the three kingdoms, led by the Earl of Rosse and Sir Benjamin Hawes; the astronomical observers following in the bold path opened by Sir John Herschel; and Prince Albert, the most accomplished, as he was the most judicious, of thinking men; together with Plana, Menabria, MacCullagh, Mosotti, Plantamour, Dr. Lardner, and Lady Lovelace—this last an example, almost equal to that of Mrs. Somerville, of the power sometimes possessed by the female mind in dealing with abstract truths—all gave the weight of their opinion in favor of the difference engine, when completed, as fully adequate to the attainment of the objects proposed by the inventor. "No enterprise," said the president of the Royal Society, when reciting the history of the engine at their anniversary in 1854—"no enterprise could have had its beginning under more auspicious circumstances. The government had taken the initiative; they had called for advice, and the adviser was the highest scientific authority in this country—your council guided by such men as Derby, Wollaston, and Herschel. By your council the undertaking was inaugurated; by your council it was watched over in its progress. That the first great effort to employ the powers of calculating mechanism, in aid of the human intellect should have been suffered in this great country to expire fruitless because there was no tangible evidence of immediate profit, as a British subject I deeply regret, and as fellow my regret is accompanied with feelings of bitter disappointment. Where a question has once been disposed of, succeeding governments rarely re-open it; still, I thought I should not be doing my duty if I did not take some opportunity of bringing the facts once more before government."

This was accordingly done. It was shown that mechanical engineering, tools, trained workmen, the founder's art, and screw-cutting machines, had made such progress during the years the difference-engine had been laid aside that it was probable persons could be found willing to complete it for a specific sum. Never had a ministry a nobler opportunity to illustrate its history by the encouragement of science. It was, however, all in vain. Art was weighed against gold, and the former, touched the beam. The chancellor of the exchequer, to whom Lord Derby referred the question, pronounced the project as—

"1. Indefinitely expensive.
"2. The ultimate success problematical.
"3. The expenditure utterly incapable of being calculated."

"This Herostratus of science," Mr. Babbage characteristically remarks, "if he escape oblivion, will be linked with the destroyer of the Ephesian Temple."

It would be unjust to the memory of the great philosophical mechanist were no reference made to the incidental invention of a mechanical notation which Mr. Babbage explained in a paper read before the Royal Society in 1826. Dr. Lardner entitled it a discovery of "the utmost practical value," and it has long been adopted as a topic of lectures in institutions all over Europe for the instruction of civil engineers. It came up in this wise: Memory has its limit. There cannot be borne in mind a great variety of motions propagated simultaneously through complicated trains of mechanism. Incompatible motions will encounter each other. The memory can neither guard against nor correct them. Some expedient which at a glance could exhibit what every moving piece in the machinery was doing at each instant was needed. Necessity, the mother of invention, suggested to Mr. Babbage a system of signs, by which the mechanist, simply moving his finger along a certain line, could follow out the motion of every piece from effect to cause until he arrived at the prime mover. The same sign which indicated the *source* of motion indicated also its *species*. It also divided time into parts, showing what was being done by a machine at any moment. By this means the contriver understood the situation *instanter*, saw as if by intuition the fault, and discovered the *niche* in which to place the movement required. It also enabled the inventor to dismiss from his mind the arrangement of the mechanism. Like algebraic signs it reduced wheels and valves rods and levers, to an equation. In fact, what algebra is to arithmetic Mr. Babbage's notation was to mechanism.

During the construction of some parts of the calculating machinery a question arose as to the best method of producing and arranging a certain series of motions necessary to calculate and print a number. Mr. Babbage, with his assistant, an eminent practical engineer, had so arranged these motions that they might be performed by twelve revolutions of the principal axis. It was desirable there should be less. To this end each put himself to work, the engineer to a study of the complicated working machinery, the inventor to a consideration of his notation symbols. After a short time, by some transposition of these, the latter succeeded in producing the series by *eight* turns of the axis. Pushing his inquiries still further, he proceeded to ascertain whether his scheme of symbols did not admit of a still more compact arrangement, and whether eight revolutions were not needless waste of power. The question was exceedingly abstruse. Finding every effort to keep in mind the order and arrangement of wheels and pulleys, levers and shafts, claws and bolts, so as to suggest any improved arrangement, the engineer completely broke down. Mr. Babbage, however, with scarcely any mental exertion, and merely by sliding a bit of ruled pasteboard up and down his plan in search of vacant places, contrived at length to reduce the eight motions to six, to five, and to three. This application of an almost metaphysical system of abstract signs, by which the motion of the hand alternately performs the office of the mind and practical mechanics, to the construction of a complicated engine, is regarded by many eminent engineers as the most wonderful and useful discovery the great inventor ever made.

Although no one of the principal inventions of the philosophic mechanist has ever been completed, and though his marvelously comprehensive thoughts of what machinery, working on the border land of intellect, might be made to accomplish would seem to have passed from the world without good, yet his work was not in vain. Hundreds of mechanical appliances in the factories and workshops of Europe and America, scores of ingenious expedients in mining and architecture, the construction of bridges and boring of tunnels, and a world of tools by which labor is benefited and the arts improved—all the overflowings of a mind so rich that its very waste became valuable to utilize—came from Charles Babbage. He more, perhaps, than any man who ever lived, narrowed the chasm that from earliest ages has separated science and practical mechanics.

This memoir has thus far treated its subject as a mathematician and philosophical mechanist. He was both, in a degree that made his name famous. But he was more than this. As a scientific man, keeping himself abreast with the progress of modern discovery; as a man of intellect, accepting, analyzing, and suggesting thought that is emancipating mind from old traditions; and as a man of his time, the associate for more than half a century of statesmen and poets, chemists, and geographers, engineers, and philologists, he is worthy of notice. Upon whatever he spoke or wrote he was always perspicuous. Language was to him preeminently the embodiment of ideas. Logical sequence was the one essential element of his train of thinking. His estimate of men was formed less from what they were than from what they did. He was neither tuft-hunter nor cynic. Faults his character possessed, grievous and ridiculous, perchance, when viewed in certain lights, but they were never inconsistent with his independent manliness, nor derogatory to his elevated philosophy. He knew his own worth; asserted his rightful claims; kept an unquailing aspect in his long single-hand fight in behalf of his inventions with purblind rulers; victorious never, but never vanquished; heroic in most that he said and all that he did; above ordinary stature; and, saving perhaps the acceptance of certain rules of obedience to law, without which no one can wisely govern himself, played a part in the drama of life that will not be soon forgotten.

It is proposed now to speak of Charles Babbage in the two characters of an *observer of his time* and as a *contributor to knowledge*. In each, as the most certain way to reach the end in view, we shall quote without restriction or further acknowledgment from his own writings:

"My engine," he said to some scientific friends after a friendly breakfast, "will count the natural numbers as far as the millionth term. It will then commence a new series, following a different law. This it suddenly abandons and calculates another series by another law. This again is followed by another, and still another. It may go on throughout all time. An observer, seeing a new law coming at certain periods, and going out at others, might find in the mechanism a parallel to the laws of life. That all men die is the result of a vast induction of instances. That one or more men at given times shall be restored to life, may be as much a consequence of the law of existence appointed for man at his creation, as the appearance and re-appearance of the isolated cases of apparent exception in the arithmetical machine. Miracles, therefore, may not be the breach of established laws, but the very circumstances that indicate the existence of higher laws, which, at appointed times produce the preintended results.

"For example, the analytical engine might be so set that at definite periods, known only to its maker, a certain lever might become movable during the calculations then making. The consequence of moving it might be to cause the then existing law to be violated for one or more times, after which the original law would resume its reign. Of course, the maker of the calculating engine might confide this fact to the person using it, who would thus be gifted with the power of prophecy if he foretold the event, or of working a miracle at the proper time if he withheld his knowledge from those around until the moment of its taking place. Such is the analogy between the construction of machinery to calculate and the occurrence of miracles. A further illustration may be taken from geometry; curves are represented by equations. In certain curves there are portions, such as ovals, disconnected from the rest of the curve. By properly assigning the values of the constants, these ovals may be reduced to single points. These singular points may exist upon a branch of a curve, or may be entirely isolated from it; yet these points fulfill by their position the law of the curve as perfectly as any of those which, by their juxtaposition and continuity, form any of its branches."

"Miracles," Mr. Babbage adds, "are not therefore the breach of established laws, but the very circumstances that indicate the existence of far higher laws which, at the appointed times, produce their preintended results."

Now whatever may be thought of the conclusiveness of this reasoning, its originality is, and its ingenuity undeniable. That it was satisfactory to a mind whose reach was as wide and whose logic as consecutive as that of Charles Babbage, is sufficient to demand for it fair consideration. He evidently believed it; urged it upon other minds upon the same level with his own, and received no answers that detected in it a fallacy or showed it to be a sophism.

There is surpassing interest in watching the workings of a great mind in *honest* search after truth. There are no volumes of the fathers; no sermons of Laurin or Bossuet; no essays of' Fénelon or Pascal; no personal narrative of Arnauld, Françoise de Sales, de Rancé, or of the saints of Port Royal; no memoirs of the pietists of France, or martyrs of England; no lives of foreign missionaries, Protestant or Catholic, who gave their all, even to death, to propagate what to them was Divine that in our apprehension can confine the attention or challenge the judgment of a sincere, intelligent inquirer after truth, like the thirtieth chapter in the "Passages from the Life of a Philosopher." One sees in it no favorite opinion to be defended; no peculiar error to be denounced; no class, no creed, no caste to be built up; no prejudice to be favored nor tradition exempted from trial; nothing, in fact, but the record of the thoughts of a great mind in honest pursuit of truth. It would be marred by quotations, and its life deadened by condensation; though it does not traverse the ground of more modern skepticism, and deals only with the old positions of the encyclopedists and Hume, it assumes a position in regard to Divine revelation which, if not impregnable, has never yet been overturned.

We cannot easily resist the temptation to quote a few of his clear and vigorous remarks from the chapter in question. Speaking of an examination of the Creator's works as one of' the sources of our knowledge of His existence, Babbage says:

"Unlike transmitted testimony, which is weakened at every stage, its evidence derives confirmation from the progress of the individual as well as from the advancement of the knowledge of the race.

"Almost all thinking men who have studied the laws which govern the animate and inanimate world around us, agree that the belief in the existence of one Supreme Creator, possessed of infinite wisdom and power, is open to far less difficulties than the supposition of the absence of any cause, or the existence of a plurality of causes.

"In the works of the Creator, ever open to our examination, we possess a firm basis on which to raise the superstructure of an enlightened creed. The more man inquires into the laws which regulate the material universe, the more he is convinced that all its varied forms arise from the action of a few simple principles. These principles themselves converge, with accelerating force, toward some still more comprehensive law to which all matter seems to be submitted. Simple as that law may possibly be, it must be remembered that it is only one among an infinite number of simple laws; that each of these laws had consequences at least as extensive as the existing one, and, therefore, that the Creator who selected the present law must have foreseen the consequences of all other laws.

"The works of the Creator, ever present to our senses, give a living and perpetual testimony of his wisdom and goodness far surpassing any evidence transmitted through human testimony. The testimony of men becomes fainter at every stage of transmission, while each new inquiry into the works of the Almighty gives to us more exalted views of his wisdom, his goodness, and his power."

The true value of the Christian religion in Babbage's estimation rested not upon speculative views of the Creator, which must necessarily be different in each individual, according to the extent of the finite being who employs his own feeble powers in contemplating the infinite, but rather upon those doctrines of kindness and benevolence which that religion claims and enforces, not merely in favor of man himself but of every creature susceptible of pain or of happiness.

There is something exceedingly refreshing in the original views Mr. Babbage takes of every subject that comes within the scope of his vision. His autobiography—for such in spite of his disclaimer it really is—has the interest of a romance. He is never dull, never tiresome, never cloudy. His style is clear as limpid water and natural as a running brook. He possesses a rich fund of humor, which flecks and dapples even his mathematical descriptions like sunshine falling through foliage.

"A curious reflection" he says in the chapter we do not willingly leave, "presents itself, when we meditate upon a state of rewards and punishments in a future life. We must possess the memory of what we did during our existence upon this earth in order to give them those characteristics. In fact, memory seems to be the only faculty which must, of necessity, be preserved in order to render a future state possible.

"If memory be absolutely destroyed, our personal identity is lost.

"Further reflection suggests that in a future state we may, as it were, awake to the recollection that, previously to this our present life, we existed in some former state, possibly in many former ones, and that the then state of existence may have been the consequences of our conduct in those former stages.

"It would be a very interesting research if naturalists could devise any means of showing that the dragon fly, in its three stages of a grub beneath the soil, an animal living in the water, and that of a flying insect, had in the last stage any memory of its existence in its first.

"Another question connected with this subject offers still greater difficulty. Man possesses five sources of knowledge through his senses: He proudly thinks himself the highest work of the Almighty Architect, but it is quite *possible* that he may be the very lowest. If other animals possess senses of a different nature from ours, it can scarcely be possible that we could ever be aware of the fact. Yet those animals, having other sources of information and of pleasure, might, though despised by us, yet enjoy a corporeal as well as intellectual existence far higher than our own."

Mr. Babbage's autobiography, relating isolated facts, which, with a sort of indifference to the estimate history might put upon his character—strongly in contrast with even the best class of journals and diaries, say, Sir Walter Scott's, or Dr. Chalmer's, or Edward Payson's, or Missionary Judson's, as if while it was necessary that *they* should take care of their *post-mortem* fame *his* possessed the vitality to care for itself—are arranged without order of time or similarity of subject, after all divides itself very naturally into the two branches of personal recollections and personal experiences. He remembers Wollaston, Rogers, and Sir Humphrey Davy, and gives pen-outlines of their characters as vivid and living as the portraits of Duow. He has discussed mathematics with Laplace, compared analysis with Fourier, exhibited and explained his inventions to Biot, and lived on terms of intimacy with Humboldt. He was the frequent companion of the Duke of Wellington; was the associate of various branches of the Bonaparte family; was the friend of Mosotti, Menabria, and Prince Albert, and throughout life, from collegiate competitions to the mutual respect of mature years, held firmly as his friend the younger Herschel. Of all these his notes are pictures, unequalled even by the descriptions which Boswell gives of the associates of the great lexicographer.

It is the same with his experiences. He risks drowning by water and baking by fire, loss of life by railway speed and loss of reputation by picking locks, character in exploring the secrets of theatrical displays, and purse in traversing the haunts of St. Giles. His thirst for knowledge knew no bounds. Into an electioneering contest he entered with the same indomitable energy that he pursued a mathematical calculus. The same keen avidity that detected a logarithmic error was applied to suppressing a street nuisance. He vitalized whatever he touched. If life gives beauty it might be more truly said of Charles Babbage than of most men of mark, *Nihil tetigit quod non ornavit*.[d] In fact there was no secret of nature he hesitated to explore, no enigma of the sphynx which he was afraid to question. Impulsiveness, want of patience, and hatred of shams have indeed left many of his investigations partial and fragmentary, but about every one of them there is rich compensation in striking aphorisms, profound observations, wisdom applicable to human need, and wit available for its enjoyment. He says of himself:

"I have always carefully watched the exercise of my own faculties, and I have always endeavored to collect from the light reflected by other minds some explanation of the question.

"I think one of my most important guiding principles has been this: That every moment of my waking hours has always been occupied by *some train of inquiry*. In far the largest number of instances the subject might be trivial, but still work of inquiry was always going on.

"The difficulty consisted in adapting the work to the state of the body. The necessary training was difficult. Whenever at night I found myself sleepless and wished to sleep, I took a subject for examination that required little mental effort, and, which also had little dependence on worldly affairs by its success or failure.

"On the other hand, when I wanted to concentrate my whole mind upon an important subject, I studied during the day all the minor accessories and after 2 o'clock in the morning I found that repose which the nuisances of the London streets only allow from that hour until 6 in the morning.

"At first I had many a sleepless night before I could thus train myself.

"I believe my early perception of the immense power of signs in aiding the reasoning faculty contributed much to whatever success I may have had. Probably a still more important element was the intimate conviction I possessed that the highest object a reasonable being could pursue was to endeavor to discover those laws of mind by which man's intellect passes from the known to the discovery of the unknown."

In perusing the writings of Mr. Babbage, one is constantly struck with the philosophical nature of his mind. His style is not only pregnant with thought, but, like Montaigne's, is perpetually shaping itself into apothegms. "Men," he writes, when managing an election contest, "will always give themselves tenfold more trouble to crush a man obnoxious to their hatred, than they will take to serve their most favored ally."

Again, speaking of Dr. Lardner, who had candidly admitted that some of those doctrines he had once supported further information had shown him were erroneous, our author says, "Nothing is more injurious to the progress of truth than to reproach any man who honestly admits he has been in error."

In order to put down street organ-grinders, with whom he had lifelong quarrels, he proposes to himself to act upon this principle: "*to make it more unprofitable to the offender to do the wrong than the right*."

"It requires considerable training to become an accurate witness of facts. No two persons, however well trained, ever express in the same form of words the series of facts they have both observed."

"Once, at a large dinner party, Mr. Rogers, author of 'Italy' and other poems, was speaking of an inconvenience arising from the custom, then commencing, of having windows formed of one large sheet of glass. He said that a short time ago he sat at dinner with his back to one of these single panes of plate-glass; *it appeared to him that the window was wide open, and such was the force of the imagination that he actually caught cold*.

"It so happened that I was sitting just opposite to the post. Hearing this remark, I immediately said, Dear me, how odd it is, Mr. Rogers, that you and I should make such a very different use of the faculty of imagination. When I go to the house of a friend in the country and unexpectedly remain for the night, having no night-cap I should naturally catch cold. *But by tying a piece of pack-thread tightly round my head, I go to sleep imagining that I have a night cap on; consequently I catch no cold at all*."

"I was once asked by an astute and sarcastic magistrate, whether I seriously believed that a man's brain would be injured by listening to an organ. My reply was, *Certainly not, for the obvious reason that no man having brains ever listened to street musicians*."

These fragmentary quotations, however, scarcely do Mr. Babbage justice. Let us allow him to tell one of the many experiences of his life in his own way.

Under the head of " Hints for travelers," in his " Passages from the life of a philosopher, " Mr. Babbage says:

"A man may, without being a proficient in any science, often make himself useful to those who are most instructed. However limited the path he may himself pursue, he will insensibly acquire other information in return for that which he can communicate. I will illustrate this by one of my own pursuits. I possess the smallest possible acquaintance with the vast fields of animal life, but at an early period I was struck by the numerical regularity of the pulsations and the breathings. It appeared to me that there must exist some relation between these two functions. Accordingly I took every opportunity of counting the numbers of the pulsations and the breathings of various animals. The pig fair at Pavia and the book fair at Leipsic equally placed before me menageries in which I could collect such facts. Every zoological collection of animals which I visited thus became to me a source of facts relating to that subject. This led me at another period to generalize the subject of inquiry, and to print a skeleton form for the constants of the class mammalia. It was reprinted by the British Association at Cambridge in 1833, and also at Brussels in the *Travaux du Congrés du Général de Statistique in 1853*.[e]

"One of the most useful accomplishments for a philosophical traveler I learned from a workman who taught me how to punch a hole in a plate of glass. The process is simple. Two center-punches, a hammer, an ordinary bench-vise, and an old file, are all the tools required. Having decided upon the part of the glass, scratch a cross (x) resting upon the spot with the point of an old file, turn the glass over and scratch the same on the other side corresponding. Fix one of the small center-punches with its point upward in the vise. Let an assistant hold the glass with its scratched point (x) resting upon the point of the punch. Take the other punch, place its point in the center of the upper scratch, hit it very slightly twice or thrice, turn the glass two or three times, repeating the slight blows, and the hole is formed.

"The principles of this are, that glass is a material breaking in every direction with a conchoidal fracture, and that the vibrations which would have caused cracking are checked by the support of the fixed center-punch.

"In the year 1825, during a visit to Devonport, I had apartments in the house of a glazier, of whom I inquired one day if he knew this secret. He answered that he did not, and expressed great curiosity to see it done. Finding that at a short distance there was a blacksmith, we went to his shop, and selecting from his rough tools the center-punches and the hammer, I executed the whole process.

"On the eve of my departure I asked for my landlord's account, which was sent up correct except the omission of charge for apartments. I added the eight guineas for my lodgings; and the next morning, having placed the total amount upon the bill, I sent for my host in order to pay him, remarking that he had omitted the principal article of his account, which I had inserted.

"He replied that he had intentionally omitted the lodgings, as he could not think of taking payment for them from a gentleman who had done him so great service. Quite unconscious of having rendered him any service, I asked him to explain. He replied that he had the contract for the supply and repair of the lamps of Devonport, and that the art in which I had instructed him would save him more than twenty pounds a year. I found some difficulty in prevailing on my grateful landlord to accept what was justly his due."

Scarcely at the risk of being tedious—which no passages in the life of this extraordinary man can ever be—but at the greater risk of space which must be devoted to his contributions to knowledge, we cannot forbear a single quotation further, which, like a dash from the brush of Rubens, depicts the multifariousness of his character:

"While I was preparing materials for the 'Economy of manufactures,' he writes, "I had occasion frequently to travel through our mining and manufacturing districts. On these occasions I found the travelers' inn or travelers' room was usually the best adapted to my purpose, both in regard to economy and to information. As my inquiries had a wide range, I found ample assistance in carrying them on. Nobody doubted that I was one of the craft; but opinions were widely different as to the department in which I practiced my vocation.

"In one of my tours I passed a very agreeable week at the Commercial Hotel in Sheffield. One evening we sat up after supper much later than is usual, discussing a variety of commercial subjects.

"When I came down rather late to breakfast I found only one of my acquaintances of the previous evening remaining. He remarked that we had had a very agreeable party last night, to which I assented. He referred to the intelligent remarks of some of our party, and then added that when I left them they began to talk about me. I merely added that I felt quite safe in their hands, but should be glad to profit by their remarks. It appeared, when I retired for the night, that they debated about what trade I traveled for. 'The tall gentleman in the corner,' said my informant, 'maintained that you were in the hardware line, while the fat gentleman, who sat next you at supper, was quite sure that you were in the spirit trade. Another of the party declared that they were both mistaken; he said he had met you before, and that you were traveling for a great iron-master.' 'Well,' said I, 'you, I presume, knew my vocation better than our friends.' 'Yes,' said my informant, 'I knew perfectly well that you were in the Nottingham lace trade!'"

In the year 1828 Mr. Babbage was nominated to the Lucasian professorship of mathematics in his old university, occupying in that capacity a chair which had once been held by no less a man than Sir Isaac Newton. This chair he held during eleven years. It was while holding this professorship, at the general election of November, 1832, which followed on the passage of the first reform bill, that he was put forward as a candidate for the representation of Finsbury in Parliament. He stood in the advanced liberal interest as a supporter not only of parliamentary, financial, and fiscal reform, but of the ballot, triennial parliaments, and the abolition of all sinecure posts and offices. But the electors did not care to choose a philosopher; so he was unsuccessful, and never again wooed the suffrages of any constituency.

Mr. Babbage was the author of published works to the extent of some eighty papers. A full list of these, however, would not interest or edify the reader. Perhaps the best known of them all is what he styled the *Ninth Bridgewater Treatise*, (which it was not,) a work designed at once to refute the doctrine, supposed to be implied in the first volume of that learned series, that an ardent devotion to mathematical studies is unfavorable to a real religious faith; and also to adduce specimens of the defensive aid which the science of numbers may give to the evidences of Christianity, if that science be studied in a proper spirit. As compared with the eight treatises written by Chalmers, Whewell, Sir Charles Bell, Dr. Buckland, and others, so far from discrediting its supposititious name, it has probably been more generally read than any work of the series.

Mr. Babbage's contributions to political economy were both incidental and direct. The tendency of his mind, upon whatever it was engaged, was toward the practical. There is scarcely one of his works—nay, there is hardly one of the various employments in which he engaged himself with his whole soul during his long life—that in its ultimate reach does not lay hold of the industrial condition of mankind. Keen in investigation, acute in analysis, subtle in detection of error, and pre-eminently logical in conclusions, no matter how purely intellectual may be the laboratory of his workings, the experiments he makes and the outlooks in which he indulges have for their end invariably the material benefit of the working classes. Whether it be the solution of "problems relating to the calculus of functions" or relating to the "knight's move in chess;" whether the "determination of the general term of a new class of infinite series" or the "application of machinery to the computation of mathematical tables," the "measurement of heights" or the "improvements of diving-bells," "proportion of letters occurring in various languages" or "observations on the Temple of Serapis," "thoughts on the principles of taxation" or "statistics of light-houses," his purpose in every essay is practical good. He enlivens the dry subject of political economy by the most interesting and pertinent anecdotes; draws the attention of engine-drivers and stokers to his abstruse discussions of curves and gauges on railways by maxims and rules that are of constant use; discusses the subject of Greenwich time-signals with a variety of illustrations that makes it attractive to every ship-master; mingles his philosophical theories on occulting lights with narratives of observations and experiences that amuse and instruct the most ordinary minds; and treats the vexed question of glaciers with a liveliness and perspicuity which interest if they do not convince.

The reader will judge whether we have overestimated or misunderstood the real characteristics of Mr. Babbage's mind from the examples we now propose to give from some of his contributions to knowledge.

Mr. Babbage was one of the oldest members of the Royal Society at the time of his death in October of last year. He was also, more than half a century ago, one of the founders of the Astronomical Society, and he and Sir John Herschel were the last survivors of those founders. He was also an active and zealous member of many of the leading learned societies of London and Edinburg, and, in former years at least, an extensive contributor to their published transactions. His last important publication was the amusing and only too characteristic autobiographical work from which we have freely quoted—"Passages from the Life of a Philosopher."

There were methods of action—qualities they might perhaps be more properly called—in the mind of Charles Babbage that recall to the philosophical peruser of his works in the exact sciences traits not dissimilar in kind, however distinct in degree, to those possessed by that most original of all thinkers, Sir Isaac Newton. He possessed in common with Newton extraordinary powers of intellectual introversion. What he desired to accomplish he *thought out*. His mind, like a photographic plate, was cleansed by a continued force of will to think rightly, and when cleansed received its impressions from the light of truth. Not only his contributions to knowledge and his complex and intricate calculating-machines, but the scores of lesser inventions which he produced from time to time, are illustrative of this. Like Newton, he first pondered his facts, illuminated them by persistent thought, and then proceeded to the principles on which these facts depend.

Pestalozzi, the Italian philanthropist, after a long life spent in works of benevolence, came at last to the conclusion that no man could be much helped or hindered by any one but himself. The remark is applicable to Charles Babbage more than to most persons. He both made and marred his own fortune. There was not a place which he ever sought (the Lucasian chair he did not seek) that he gained. He aspired to the professorship of mathematics at the East India College at Harleyburgh; to Playfair's chair at Edinburg; to a seat at the Board of Longitude; to the mastership of the mint; and to the office of registrar-general of births and deaths—and failed in all. On the other hand, there was not all invention connected with his name—and in mathematical mechanics he ranks among the foremost the world ever produced—which, in the opinion of the best-disciplined minds of his day, he could not have perfected had sufficient pecuniary means been at his command. Unfortunately, he measured everything by his own unaided impressions, and judged himself by others instead of judging others by himself. To rest all claim to greatness on self-assertion rather than self-denial, though it may have made the heroes of the classic ages, cannot but be a grave fault in the conduct of any modern life. Still, he bore his disappointments bravely, possessed his intellect undimmed up to the verge of his fourth-score year, made his old age a lesson—not unwisely at any time enforced—of the philosophy with which the rest of death may be awaited, and was to the last ready to contemplate calmly in his own case what arose to the thought of Antony—

> I have been sitting longer at life's feast
> Than does me good. I will arise and go.

Extracts from a notice of Charles Babbage, by A. Quetelet, of Brussels, translated from the "Annuaire de l'Observatoire royal de Bruxelles" for 1873.

Babbage says, in his passage from the Life of a Philosopher, " From my earliest years I had a great desire to inquire into the causes of all things and events which astonish the childish mind.[f] At a later period I commenced the still more important inquiry into those laws of thought and those aids which assist the human mind in passing from received knowledge to that other knowledge then unknown to our race." These few lines express sufficiently well the character of the distinguished *savant* whose career we shall endeavor rapidly to sketch. Notwithstanding his own ardent desire to inquire into everything which could interest himself, our author never seems to have dreamed of informing others as to his exact age. According to his friends, he was born in 1792, and was consequently about 80 at the time of his death.

He did not begin seriously the study of mathematics until after the age of 22, when he was with his friend Herschel at Trinity College, Cambridge. They soon after published a joint work on mathematics, which did much toward introducing the continental methods and notation of this science into England. Fourteen years after this, while Mr. Babbage was in Rome, he accidentally read in an English newspaper the following paragraph: "Yesterday the bells of St. Mary rang out a peal to celebrate the election of Charles Babbage, Lucasian professor of mathematics at Cambridge;" or, in other words, his appointment to the chair formerly occupied by Newton.

It was in Paris, in 1826, at a dinner given by Bouvard, the astronomer, that I had an opportunity to become acquainted with Babbage. There were at the same time present Poisson and several other of the scientists who then made Paris illustrious, with all of whom he was a center of interest. He, with truly fraternal kindness, offered me his assistance in procuring from the English mechanicians, among whom was the celebrated Troughton, the instruments for the Belgian observatory. He also proposed my co-operation in a work which he had projected which was to contain a register of everything capable of being measured, such as the specific gravity of bodies; the linear expansion of metals; their weight; the size of animals; the quantity of air they breathe; the nourishment they need, &c. "The extent of this work," I said, "is too vast to be carried out unless by the cooperation of many minds. The outline of what may be necessary for man alone is so great that with the help of many friends I could not hope to complete more than a skeleton of the whole." The reply was that time is an element of solution which overcomes the greatest difficulties of investigation; and if our efforts are properly directed our descendents will finish what we have properly begun.

Nothwithstanding his immense labor connected with the calculating-machine, Babbage, in April, 1835, turned his attention to assist his friend Herschel, then at the Cape of Good Hope, in carrying out over the whole world, on certain days, a system of meteorological observations. These days, which were called term-days, were the 21st of December, 21st of March, 21st of June, and 21st of September. At these times continued observations were to be made at every hour, commencing at noon on the days above mentioned and terminating the next day at the same hour. These observations, in the introduction of which Mr. Babbage took an active part, were continued in Europe, America, India, and Africa, and led finally to the establishment of the various systems of simultaneous weather-reports of the present day.

While I was in London, in 1851, at the great exhibition of industrial products, Babbage made me acquainted with Lord Lovelace, a gentleman of great ability and high reputation, who had married the cherished daughter of Lord Byron. This charming lady, remarkable for her beauty and personal accomplishments, and noted for her intellectual powers, had published a translation of an Italian account of the calculating-machine. She received me very graciously, and urged Mr. Babbage and myself to visit her frequently for conversation on literary and scientific subjects, with which she was familiar. She was especially interested in the calculus of probabilities, and so far did we carry our discussions on this point that it was agreed that we should compose and publish a joint work on this subject. Unfortunately, the plan was prevented from being carried out by the premature death of this interesting lady.

I owe it to the friendship which long united me with Mr. Babbage to having seen in London, on several occasions and in the greatest detail, all the parts of the calculating-machine, and to having been able to form for myself a just conception of a labor of which I had often heard but of which very few people knew the particulars. The machine is certainly very complicated, and extreme attention is needed to follow the action of its different parts; hence, I shall not attempt to give a description of it, which would unquestionably fill quite a considerable volume if we paid respect to the ideas of the inventor, to the extreme perfection of the mechanical workmanship, and to all the mathematical calculations which the machine can perform.

Researches into statistics also claimed the attention of Babbage, and he was personally instrumental in adding to the committees of the British Association one on this subject. The attention of the committee on statistics was first turned to the need of exact documents in regard to population, a want much felt in England, especially as to everything relative to births, deaths, &c. Meetings were afterward held in London of persons interested in the subject of statistics, in which Mr. Babbage took an active part, and to which I was admitted. They examined, among other questions, that of the labor imposed upon children in manufactories. The following questions were propounded to me in regard to Belgium, which I transmitted to the minister of the interior who promised to have collected the necessary data for a satisfac-

Number of times different letters are doubled in ten thousand words

Letters	English	French	Italian	German	Latin
A				1.5	
B			10.8		
C	9.4	7.2	23.7		8.2
D	1.9		1.1		4.4
E	18.9	7.2		19.4	
F	14.6	8.1	12.0	8.2	9.4
G	1.5		20.4		1.4
H					
I				0.4	8.9
J				0.8	
K				38.7	
L	16.1	55.5	70.6	21.2	36.5
M	6.4	25.7	12.0	19.7	5.9
N	8.3	17.7	20.4	0.4	4.4
O	12.7			0.4	
P	12.4	5.7	12.0		4.4
Q					11.2
R	12.7	32.2	10.8	7.8	41.7
S	13.9	44.2	53.7	53.5	5.9
T	13.1	12.0	64.5	9.3	5.2
U				1.9	
V			2.2		
W					
X					
Y					
Z			7.6		
Total	**141.8**	**215.5**	**230.8**	**166.5**	**147.7**

tory reply. The honorable *savants* asked—

> "The number of births produced by each marriage during its entire length;
> "The proportional number of children who reach the period of marriage;
> "The number of children living by each marriage;
> "The salaries paid in manufactures and agriculture in different provinces, especially the price of an average day's labor in agriculture;
> "The quantity of wheat which such a day's pay can procure in ordinary times;
> "The mean price of different kinds of grain;
> "The habitual food of the day-laborer;
> "The proportional number of sterile marriages;
> "The proportional number of marriages having five or six children living."

As an instance of our friend's singular disposition to enter upon investigations of the most out-of the-way character, I may mention that for a time he lost sight of the profound speculations of political economy, and busied himself with the question as to how many times any letter in different languages doubles itself in 10,000 words. The following table gives the result which he obtained:

[In regard to the question of what use is this, we would remark that this question is never asked by the student of nature; since every item of knowledge is connected in some way with all other knowledge. Nothing can be said to be useless which tends to exhibit new relations, and indeed it is impossible to say *a priori* that a given fact may not find an application even in practice, however remote it may seem from anything of this kind. The results given in the foregoing investigation may be of importance in determining the casting of double types. The number of occurrences of a given letter in 10,000 words of any language determines the number of types of that letter in a font.—J. H.]

Our physicist always took care, in traveling, to carry with him those instruments which would enable him to carry on some investigations. He was essentially a man of experiment. He held that the eye and the ear were great aids to the judgement, and a demonstration never seemed to him complete until he knew how to render it evident to the sense and the reason. Toward the end of his life his vivacity was considerably moderated, and the mortification which he felt on account of not being able to complete his calculating-machine, and the loss of friends, cast a shadow over his latter days.

[I had myself the pleasure to make the acquaintance of Mr. Babbage in 1837, while he was in the zenith of his mental power, and to witness the operation of his first calculating-machine. I again visited him in 1870, after an interval of just one-third of a century. I found him in the same house, still interested in the calculating-machine, with apparently but little diminution of mental activity. He informed me that he felt himself gradually declining; that he endeavored to note the change in himself; that he found it difficult to enter upon new subjects of thought, but that he could reason and mentally act on materials already in his mind in the way of new computations and new deductions. He regretted the loss of memory, since with it was the loss of personal identity.—J. H.]

[Extract from writings of Charles Babbage.]

OF OBSERVATIONS.

There are several reflections connected with the art of making, observations and experiments, which may be conveniently arranged in this chapter.

Of Minute Precision.

No person will deny that the highest degree of attainable accuracy is an object to be desired, and it is generally found that the last advances toward precision require a greater devotion of time, labor, and expense than those which precede them. The first steps in the path of discovery and the first approximate measures are those which add most to the existing knowledge of mankind.

The extreme accuracy required in some of our modern inquiries has, in some respects, had an unfortunate influence by favoring the opinion that no experiments are valuable unless the measures are most minute and the accordance among them most perfect. It may, perhaps, be of some use to show that even with large instruments and most practiced observers this is but rarely the case. The following extract is taken from a representation made by the present astronomer-royal to the council of the Royal Society, on the advantages to be derived from the employment of two mural circles:

"That by observing, with two instruments, the same objects at the same time, and in the same manner, we should be able to estimate how much of that *occasional discordance from the mean, which attends even the most careful observations*, ought to be attributed to irregularity of refraction, and how much to the *imperfections of instruments*."

In confirmation of this may be adduced the opinion of the late M. Delambre, which is the more important, from the statement it contains relative to the necessity of publishing all the observations which have been made:

> "Main quelque soit le parti que l'on préfère, il me semble qu'on doit tout publier. Ces irregularités mêmes sont des faits qu'il importe de connoitre. *Les soins les plus attentifs n'en sauroient préserver les observateurs les plus exercés*, et celui qui ne produiroit que des angles toujours parfaitement d'accord auroit été singulièrement bien servi par les circonstances ou ne seroit pas bien sincère."
>
> —*Base de Système métrique, discours préliminaire*, p. 158.[g]

This desire for extreme accuracy has called away the attention of experimenters from points of far greater importance, and it seems to have been too much overlooked in the present day that genius marks its track, not by the observation of quantities inappreciable to any but the acutest senses, but by placing Nature in such circumstances that she is forced to record her minutest variations on so magnified a scale that an observer, possessing ordinary faculties, shall find them legibly written. He who can see portions of matter beyond the ken of the rest of his species confers an obligation on them by recording what he sees; but their knowledge depends both on his testimony and on his judgment. He who contrives a method of rendering such atoms visible to ordinary observers communicates to mankind an instrument of discovery, and stamps his own observations with a character alike independent of testimony or of judgment.

0n the Art of Observing.

The remarks in this section are not proposed for the assistance of those who are already observers, but are intended to show to persons not familiar with the subject that, in observations demanding no unrivaled accuracy, the principles of common sense may be safely trusted, and that any gentleman of liberal education may, by perseverance and attention, ascertain the limits within which he may trust both his instrument and himself.

If the instrument is a divided one, the first thing is to learn to read the verniers. If the divisions are so fine that the coincidence is frequently doubtful, the best plan will be for the learner to get some acquaintance who is skilled in the use of instruments, and, having set the instrument at hazard, to write down the readings of the verniers, and then request his friend to do the same. Whenever there is any difference, he should carefully examine the doubtful one, and ask his friend to point out the minute peculiarities on which he founds his decision. This should be repeated frequently, and, after some practice, he should note how many times in a hundred his reading differs from his friend's, and also how many divisions they usually differ.

The next point is, to ascertain the precision with which the learner can bisect an object with the wires of the telescope. This can be done without assistance, It is not necessary even to adjust the instrument, but merely to point it at a distant object. When it bisects any remarkable point, read off the verniers, and write down the result; then displace the telescope a little and adjust it again. A series of such observations will show the confidence which is due to the observer's eye in bisecting an object, and also in reading the verniers; and as the first direction gave him some measure of the latter, he may, in a great measure, appreciate his skill in the former. He should also, when he finds a deviation in the reading, return to the telescope and satisfy himself if he has made the bisection as complete as he can. In general, the student should practice each adjustment separately, and write down the results wherever he can measure its deviations.

Having thus practiced the adjustments, the next step is to make an observation. But in order to try both himself and the instrument, let him take the altitude of some fixed object, a terrestrial one, and having registered the result, let him derange the adjustment, and repeat the process fifty or a hundred times. This will not merely afford him excellent practice, but enable him to judge of his own skill.

The first step in the use of every instrument is to find the limits in which its employer can measure the *same object under the same circumstances*, and, after that, of *different objects under different circumstances*.

The principles are applicable to almost all instruments. If a person is desirous of ascertaining heights by a mountain-barometer, let him begin by adjusting the instrument in his own study, and, having made the upper contact, let him write down the reading of the vernier, and then let him derange the *upper* adjustment *only*, re-adjust, and repeat the reading. When he is satisfied about the limits within which he can make that adjustment, let him do the same repeatedly with the lower, but let him not, until he knows his own errors in reading and adjusting, pronounce upon those of the instrument. In the case of a barometer, he must also be assured that the temperature of the mercury does not change during the interval.

A friend once brought me a beautifully-constructed piece of mechanism for marking minute portions of time; the three hundredth part of a second was indicated by it. It was a kind of watch, with a pin for stopping one of the hands. I proposed that we should each endeavor to stop it twenty times in succession at the same point. We were both equally unpracticed, and our first endeavors showed that we could not be confident of the twentieth part of a second. In fact, both the time occupied in causing the extremities of the fingers to obey the volition, as well as the time employed in compressing the flesh before the fingers acted on the stop, appeared to influence the accuracy of our observations. From some few experiments I made I thought I perceived that the rapidity of the transmission of the effects of the will depended on the state of fatigue or health of the body. If any one were to make experiments on this subject, it might be interesting to compare the rapidity of the transmission of volition in different persons with the time occupied in obliterating an impression made on one of the senses of the same persons. For example, by having a mechanism to make a piece of ignited charcoal revolve with different degrees of velocity, some persons will perceive a continuous circle of light before others, whose retina does not retain so long impressions that are made upon it.

On the Frauds of Observers

Scientific inquiries are more exposed than most others to the inroads of pretenders; and I feel that I shall deserve the thanks of all who really value truth, by stating some of the methods of deceiving practiced by unworthy claimants for its honors, while the mere circumstance of their arts being known may deter future offenders.

There are several species of impositions that have been practiced in science, which are but little known, except to the initiated, and which it may, perhaps, be possible to render quite intelligible to ordinary understandings. These may be classed under the heads of hoaxing, forging, trimming, and cooking.

Of Hoaxing.—This, perhaps, will be better explained by an example. In the year 1788, M. Gioeni, a knight of Malta, published at Naples an account of a new family of *Testacea*, of which he described with great minuteness one species, the specific name of which has been taken from its *habitat*, and the generic he took from his own family, calling it *Gioenia sicula*. It consisted of two round triangular valves, united by the body of the animal to a smaller valve in front. He gave figures of the animal, and of its parts; described its structure, its mode of advancing along the sand, the figure of the track it left, and estimated the velocity of its course at about two-thirds of an inch per minute. He then described the structure of the shell, which he treated with nitric acid and found it approached nearer to the nature of bone than any other shell.

The editors of the *Encyclopédie méthodique* have copied this description and have given figures of the *Gioenia sicula*. The fact, however, is, that no such animal exists, but that the knight of Malta, finding on the Sicilian shores the three internal bones of one of the species of *Bulla*, of which some are found on the south-western coast of England,[1] described and figured these bones most accurately, and drew the whole of the rest of the description from the stores of his own imagination.

Such frauds are far from justifiable; the only excuse which has been made for them is, when they have been practiced on scientific academics which had reached the period of dotage.

It should, however, be remembered that the productions of nature are so various that mere strangeness[2] is very far from sufficient to render doubtful the existence of any creature for which there is evidence; and that, unless the memoir itself involves principles so contradictory[3] as to outweigh the evidence of a single witness, it can only be regarded as a deception without the accompaniment of wit.

Forging differs from hoaxing, inasmuch as in the latter the deceit is intended to last for a time, and then be discovered to the ridicule of those who have credited it; whereas the forger is one who, wishing to acquire a reputation for science, records observations which he has never made. This is sometimes accomplished in astronomical observations by calculating the time and circumstances of the phenomenon from tables. The observations of the second comet of 1784, which was only seen by the Chevalier d'Angos, were long suspected to be a forgery, and were at length proved to be so by the calculations and reasoning of Encke. The pretended observations did not accord among each other in giving any possible orbit. But M. Encke detected an orbit, belonging to some of the observations, from which he found that all the rest might be almost precisely deduced, provided a mistake of a unit in the index of the logarithm of the radius vector were supposed to have been made in all the rest of the calculations. (*Zach. Corr. Astron.*, tom. iv, p. 456.)

Fortunately, instances of the occurrence of forging are rare.

Trimming consists in clipping off little bits here and there from those observations which differ most in excess from the mean, and in sticking them on to those which are too small; a species of "equitable adjustment," as a radical would term it, which cannot be admitted in science.

This fraud is not, perhaps, so injurious (except to the character of the trimmer) as cooking, which the next paragraph will teach. The reason of this is, that the *average* given by the observations of the trimmer is the same, whether they are trimmed or untrimmed. His object is to gain a reputation for extreme accuracy in making observations; but from respect for truth, or from a prudent foresight, he does not distort the position of the fact he gets from nature, and it is usually difficult to detect him. He has more sense or less adventure than the cook.

Of Cooking.—This is all art of various forms, the object of which is to give to ordinary observations the appearance and character of those of the highest degree of accuracy.

One of its numerous processes is to make multitudes of observations, and out of these to select those only which agree or very nearly agree. If a hundred observations are made, the cook must be very unlucky if he cannot pick out fifteen or twenty which will do for serving up.

Another approved receipt, when the observations to be used will not come within the limit of accuracy which it has been resolved they shall possess, is to calculate them by two different formulas. The difference in the constants employed in those formulas has sometimes a most happy effect in promoting unanimity among discordant measures. If still greater accuracy is required, three or more formulas can be used.

It must be admitted that this receipt is in some instances most hazardous; but in the cases where the positions of stars, as given in different catalogues, occur, or different tables of specific gravities, specific heats, &c., it may safely be employed. As no catalogue contains all stars, the computer must have recourse to several; and if he is obliged to use his judgment in the selection, it would be cruel to deny him any little advantage which might result from it. It may, however, be necessary to guard against one mistake into which persons might fall.

If an observer calculate particular stars from a catalogue which makes them accord precisely with the rest of his results, whereas had they been computed from other catalogues the difference would have been considerable, it is very unfair to accuse him of *cooking*; for those catalogues may have been notoriously inaccurate, or they may have been superseded by others more recent, or made with better instruments; or the observer may have been totally ignorant of their existence.

It sometimes happens that constant quantities in formulas given by the highest authorities, although they differ among themselves, yet they will not suit the materials. This is precisely the point in which the skill of the artist is shown; and an accomplished cook will carry himself triumphantly through it, provided, happily, some mean value of such constants will fit his observations. He will discuss the relative merits of formulas he has just knowledge enough to use; and, with admirable candor, assigning their proper share of applause to Bessel, to Gauss, and to Laplace, he will take *that* mean value of the constant used by three such philosophers which will make his own observations accord to a miracle.

There are some few reflections I would venture to suggest to those who cook, although they may not receive the attention which, in my opinion, they deserve, from not coming from the pen of an adept.

In the first place, it must require much time to try different formulas. In the next place, it may happen that, in the progress of human knowledge, more correct formulas may be discovered, and constants may be determined with far greater precision. Or it may be found that some physical circumstance influences the results, (although unsuspected at the time,) the measure of which circumstance may perhaps be recovered from other contemporary registers of facts.[4] Or, if the selection of observations has been made that with the view of its agreeing precisely with the latest determination, there is some little danger that the average of the whole may differ from that of the chosen ones, owing to some law of nature dependent on the interval between the two sets, which law some future philosopher may discover; and thus the very best observations may have been thrown aside.

In all these, and in numerous other cases, it would most probably happen that the cook would procure a temporary reputation for unrivaled accuracy at the expense of his permanent fame. It might also have the effect of rendering even all his crude observations of no value; for that part of the scientific world whose opinion is of most weight is generally so unreasonable as to neglect altogether the observations of those in whom they have, on any occasion, discovered traces of the artist. In fact, the character of an observer, as of a woman, if doubted, is destroyed.

The manner in which facts apparently lost are restored to light, even after considerable intervals of time, is sometimes very unexpected, and a few examples may not be without their use. The thermometers employed by the philosophers who composed the Accademia del Cimento have been lost; and as they did not use the two fixed points of freezing and boiling water, the results of a great mass of observations have remained useless from our ignorance of the value of a degree on their instruments. M. Libri, of Florence, proposed to regain this knowledge by comparing their registers of the temperature of the human body and of that of some warm springs in Tuscany which have preserved their heat uniform during a century, as well as of other things similarly circumstanced.

Another illustration was pointed out to me by M. Gazzeri, the professor of chemistry at Florence. A few years ago an important suit in one of the legal courts of Tuscany depended on ascertaining whether a certain word had been erased by some chemical process from a deed then before the court. The party who insisted that an erasure had been made availed themselves of the knowledge of M. Gazzeri, who, concluding that those who committed the fraud would be satisfied by the disappearance of the coloring matter of the ink, suspected (either from some colorless matter remaining in the letters, or perhaps from the agency of the solvent having weakened the fabric of the paper itself beneath the supposed letters) that the effect of the slow application of heat would be to render some difference of texture or of applied substance evident by some variety in the shade of color which heat in such circumstances might be expected to produce. Permission having been given to try the experiment, on the application of heat the important word re-appeared, to the great satisfaction of the court.

[One of the most noted deceptions of this kind was that called the moon hoax, published in New York about thirty years ago, which purported to be a series of discoveries made in the moon by Sir John Herschel during his residence at the Cape of Good Hope. These discoveries were said to be the result of a great improvement in the telescope. It is well known that, with a given-sized object-glass, the power of this instrument is limited by the degree to which the image in the focus of the glass can be magnified; the light remaining the same, the more the size of the image is increased the darker it becomes. The alleged improvement consisted in the illumination of this image by artificial light. By the application of this idea, the telescope employed by the astronomer at the Cape of Good Hope admitted of an eye-glass of such magnifying power that moving objects on the surface of the moon were observable, and men and animals of remarkable forms were actually discovered.

It is astonishing the effect which the annunciation of these discoveries produced. Instead of detecting at once the scientific absurdity of illuminating a shadow in order that it might be more highly magnified, many persons, even professors in colleges, gave the announcement credence, and thus added to the popularity of the hoax. This fraud owed its success, in a great measure, to a want, at the time, of precise scientific knowledge in this country, and after the absurdity was pointed out the invention was cried up as a most extraordinary production, since those who had been hoaxed by it attributed their credulity to the ingenuity of the deception rather than to their own want of knowledge.

The success of this hoax has had an exceedingly bad influence on the character of our country for veracity. It was followed immediately after, and has been even down to the present time, by a series of contemptible imitations; and, indeed, to such an extent was this imitation carried on a few years ago, that scarcely any announcement of phenomena of unusual occurrence could be accepted as truth. Among these imitations within a few years, the most successful, and one which evinced considerable reading as well as ingenuity, was that of the pretended discovery of a series of Runic inscriptions on the face of a rock in the Potomac River near Washington. This was the invention of a young student of law in this city, and excited quite a sensation among the archaeologists of this and other countries. It was copied in various ethnological journals as a truth, and was hailed by the Scandinavians as a new evidence of the early explorations of the Northmen in the United States.

Such inventions must be classed with those practical jokes which have been happily termed "gymnastic wit," of which a notable example was given in England, where a "society" was founded for "insulting women and frightening children." The chronicler naively remarks that the members were never discovered, and, what is just as remarkable, the wit was equally a mystery. "Truth," says Dr. Johnson, "is a matter of too much importance to be tampered with, even in trifles."—J. H.]

On the Permanent Impression of our Words and Actions on the Globe we inhabit.

The principle of the equality of action and reaction, when traced through all its consequences, opens views which will appear to many persons most unexpected. The pulsations of the air, once set in motion by the human voice, cease not to exist with the sounds to which they gave rise. Strong and audible as they may be in the immediate neighborhood of the speaker, and at the immediate moment of utterance, their quickly-attenuated force soon becomes inaudible to the human ears. The motions they have impressed on the particles of one portion of our atmosphere are communicated to constantly-increasing numbers, but the total quantity of motion measured in the same direction receives no addition. Each atom loses as much as it gives, and regains again from other atoms a portion of those motions which they in turn give up.

The waves of air thus raised perambulate the earth and the ocean's surface and in less than twenty hours every atom of its atmosphere takes up the altered movement due to that infinitesimal portion of the primitive motion which has been conveyed to it through countless channels, and which must continue to influence its path throughout its future existence.[5]

But these aerial pulses, unseen by the keenest eye, unheard by the acutest ear, unperceived by human senses, are yet demonstrated to exist by human reason; and, in some few and limited instances, by calling to our aid the most refined and comprehensive instrument of human thought, their courses are traced and their intensities are measured. If man enjoyed a larger command over mathematical analysis, his knowledge of these motions would be more extensive; but a being possessed of unbounded knowledge of that science could trace even the minutest consequence of that primary impulse. Such a being, however far exalted above our race, would still be immeasurably below even our conception of infinite intelligence.

But supposing the original conditions of each atom of the earth's atmosphere, as well as all the extraneous causes acting on it, to be given, and supposing also the interference of no new causes, such a being would be able clearly to trace its future but inevitable path, and he would distinctly foresee and might absolutely predict for any, even the remotest period of time the circumstances and future history of every particle of that atmosphere.

Let us imagine a being, invested with such knowledge, to examine at a distant epoch the coincidence of the facts with those which his profound analysis had enabled him to predict. If the slightest deviation existed, he would immediately read in its existence the action of a new cause; and, through the aid of the same analysis, tracing this discordance back to its source, he would become aware of the time of its commencement and the point of space at which it originated.

Thus considered, what a strange chaos is this wide atmosphere we breathe! Every atom, impressed with good and with ill, retains at once the motions which philosophers and sages have imparted to it, mixed and combined in ten thousand ways with all that is worthless and base. The air itself is one vast library, on whose pages are forever written all that man has ever said or woman whispered. There, in their mutable but unerring characters, mixed with the earliest as well as with the latest sighs of mortality, stand forever recorded, vows unredeemed, promises unfulfilled, perpetuating in the united movements of each particle, the testimony of man's changeful will.

But if the air we breathe is the never-failing historian of the sentiments we have uttered, earth, air and ocean are the eternal witnesses of the acts we have done. The same principle of the equality of action and re-action applies to them; whatever movement is communicated to any of their particles is transmitted to all around it, the share of each being diminished by their number, and depending jointly on the number and position of those acted upon by the original sources of disturbance. The waves of air, although in many instances perceptible to the organs of hearing, are only rendered visible to the eye by peculiar contrivances; but those of water offer to the sense of sight the most beautiful illustration of transmitted motion. Every one who has thrown a pebble into the still waters of a sheltered pool has seen the circles it has raised, gradually expanding in size, and as uniformly diminishing in distinctness. He may have observed the reflection of those waves from the edges of the pool. He may have noticed also the perfect distinctness with which two, three, or more series of waves each pursues its own unimpeded course, when diverging from two, three, or more centers of disturbance. He may have seen, in such cases, the particles of water where the waves intersect each other partake of the movements due to each series.

No motion impressed by natural causes or by human agency is ever obliterated. The ripple on the ocean's surface, caused by a gentle breeze, or the still water which marks the more immediate track of a ponderous vessel gliding with scarcely expanded sails over its bosom, are equally indelible. The momentary waves raised by the passing breeze, apparently born but to die on the spot which saw their birth, leave behind them an endless progeny, which, reviving with diminished energy in other seas, resisting a thousand shores, reflected from each, and perhaps again partially concentrated, will pursue their ceaseless course till ocean be itself annihilated.

The track of every canoe, of every vessel which has yet disturbed the surface of the ocean, whether impelled by manual force or elemental power, remains forever registered in the future movement of all succeeding particles which may occupy its place. The furrow which it left is, indeed, instantly filled up by the closing waters; but they draw after them other and larger portions of the surrounding element, and these again once moved communicate motion to others in endless succession.

The solid substance of the globe itself, whether we regard the minutest movement of the soft clay which receives its impression from the foot of animals, or the concussion arising from the fall of mountains rent by earthquakes, equally communicates and retains, through all its countless atoms, their apportioned shares of the motions so impressed.

While the atmosphere we breathe is the ever-living witness of the sentiments we have uttered, the waters, and the more solid materials of the globe, bear equally enduring testimony of the acts we have committed.

If the Almighty stamped on the brow of the earliest murderer the indelible and visible mark of his guilt, he has also established laws by which every succeeding criminal is not less irrevocably chained to the testimony of his crime; for every atom of his mortal frame, through whatever changes its several particles may migrate, will still retain, adhering to it through every combination, some movement derived from that very muscular effort by which the crime itself was perpetrated.

The soul of the negro whose fettered body, surviving the living charnel-house of his infected prison, was thrown into the sea to lighten the ship, that his Christian captor might escape the limited justice at length assigned by civilized man to crimes whose profit had long gilded their atrocity, will need, at the last great day of human account, no living witness of his earthly agony. When man and all his race shall have disappeared from the face of our planet, ask every particle of air still floating over the unpeopled earth, and it will record the cruel mandate of the tyrant.

Original footnotes

1. Bulla lignaria.
2. The number of vertebrae in the neck of the Plesiosaurus is a strange but ascertained fact.
3. The kind of contradiction which is here alluded to is that which arises from well ascertained final causes; for instance, the ruminating stomach of the hoofed animals is in no case combined with the claw-shaped form of the extremities, frequent in many of the carnivorous animals, and necessary to some of them for the purpose of seizing their prey.
4. Imagine, by way of example, the state of the barometer or thermometer.
5. "La courbe décrit par une simple molécule d'air ou vapeurs est réglée d'une manière aussi certain que les orbites planétaires; il n'y a de différence entre elles que celle qu'y met notre ignorance."—La Place, Théorie Analytique des probabilitiés, introduction, p.iv.[h]

Editorial notes

a. Babbage was born on Boxing day, 1791, not 1792. Babbage may himself have been the source of this error. According to Maboth Mosley's biography of Babbage, *Irascible Genius* (Hutchinson, London, 1964, p. 29): "In extreme old age he wrote to the Statistical Society: 'You may inform the French gentleman who made the enquiry that the place of my birth was London and the year was 1792.'"

b. Translation: The adding machine produces effects closer to thought than anything done by the animals, but it does nothing to justify the assertion that it has a will like the animals.—A.J. Krailsheimer, trans., *Pascal Pensées*, (Penguin Books, Harmondsworth, 1966, p. 256).

c. Dodge erroneously spelled Vlacq's name as Blacq in the original.

d. Perhaps a misquote for "Nullum quod tetigit non ornavit"—He touched nothing that he did not adorn (*Johnson's Epitaph on Goldsmith)*.

e. Reprinted as "Tables of the Constants of Nature and Art," *Smithsonian Annual Report 1856*, pp. 289-302.

f. See Charles Babbage, *Passages from the Life of a Philosopher*, with a new introduction by Martin Campbell-Kelly, ed., Rutgers Univ. Press/IEEE Press, 1994.

g. Translation: But whichever result is preferred, it seems to me that all should be published. These irregularities are themselves facts which it is important to know. The most careful precautions cannot protect even the most trained observers, and he who produces only angles which always agree completely is either particularly well-served by circumstances, or is not altogether truthful.—M. Campbell-Kelly, ed., *Works of Babbage* (American University Press, New York, 1989, Vol. 6, p. 86).

h. Translation: The curve described by a simple molecule of air or vapor is regulated in a manner just as certain as the planetary orbits; the only difference between them is that which comes from our ignorance.—Pierre Simon Laplace, *A Philosophical Essay on Probabilities*, trans. F.W. Truscott and F.L Emery (John Wiley, New York, 1951, p. 6).

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