

ADDRESS ON
 COMMEMORATION DAY AT JOHNS HOPKINS UNIVERSITY*
 22 FEBRUARY, 1877.

Sir! Ladies and Gentlemen!

It is the custom of this country (which will take no denial) that, through the voice of our truly estimable President, calls upon me to appear before you and render an account of my experiences in connection with this great institution, which, so recently inaugurated, is steadily and solidly rising from its foundations, like the stately pile standing almost at its gates—the magnificent bequest of George Peabody to his fellow-citizens—where day by day, quietly but persistently, to the ring of the hammer and the merry click of the chisel, without haste as without pause, we may witness stone after stone lifted into its position, and each pillar set upright and securely on its base. Had I consulted only my own inclinations in the matter, I would have much preferred to remain silent, and let my work in the future tell its own tale.

It is with unaffected feelings of diffidence that I present myself before you, for, save on rare and exceptional occasions, it has not been my wont to make my voice heard in public assemblies. I know, indeed, and can conceive of no pursuit so antagonistic to the cultivation of the oratorical faculty—that faculty so prevalent in this country that the possession of it is not regarded as a gift, but the want of it as a defect—as the study of Mathematics. An eloquent mathematician must, from the nature of things, ever remain as rare a phenomenon as a talking fish, and it is certain that the more anyone gives himself up to the study of oratorical effect the less will he find himself in a fit state of mind to mathematicize. It is the constant

* The address was written on a rather sudden call, within a few hours, and many marks will be apparent to the practised eye of the haste with which it was composed. Two or three paragraphs have been inserted that were not contained in the address as delivered, and the writer is alone responsible for the opinions or sentiments which it expresses. Some copies of it will be forwarded to England, which he hopes to revisit in June next.

I have alluded, as a subject of congratulation, to the absence of all vexatious restraints upon the free action of our students which their conduct justifies. With equal reason may I congratulate myself and the professors and teaching staff with whom I have the happiness to be associated, on the confidence that is reposed in us, and on the free scope that is given to each to carry out in the manner that may seem to him most likely to be conducive to a useful result, the combined objects which this University has been founded to promote, under its two-fold aspect as a teaching body and as a corporation for the advancement and propagation of science and learning.

It has happened to myself, when in a state of despondency and embarrassment as to how I could best divide my energies between the contending claims of the teacher and the investigator, to be released from my difficulty by the cheering words graven lastingly on my memory, "The University desires from you your best and highest work."

And let me take this opportunity of making my profession of faith on a subject much mooted at the present day, as to whether the highest grade of university appointments should be conferred with or without the condition of teaching annexed.

I hesitate not to say that, in my opinion, the two functions of teaching and working in science should never be divorced. I believe that none are so well fitted to impart knowledge (if they will but recognize as existing, and take the necessary pains to acquire, the art of presentation) as those who are engaged in reviewing its methods and extending its boundaries—and I am sure that there is no stimulus so advantageous to the original investigator as that which springs from contact with other minds and the necessity for going afresh to the foundations of his knowledge, which the work of teaching imposes upon him. I look forward to the courses of lectures that I hope to deliver in succession within the walls of this University as marking the inauguration of a new era of productivity in my own scientific existence; nor need I consider any subject too low (as it is sometimes foolishly termed) for me to teach, when I remember to have seen the minutes of the conversation held between the delegates of the Convention, at the time of the French Revolution, and the illustrious Lagrange, the son of the pastry-cook of Turin, possibly the progenitor of the Marquis Lagrange, of turf celebrity (Citoyen Lagrange, as he is styled in the record), who, when asked what subject he would be willing to profess for the benefit of the community, answered meekly, "I will lecture on Arithmetic."

At this moment I happen to be engaged in a research of fascinating interest to myself, and which, if the day only responds to the promise of its dawn, will meet, I believe, a sympathetic response from the Professors of our divine Algebraical art wherever scattered through the world.

they may continue to enjoy the advantages which it affords, it may be for a decade of years to come; when I find classes diligently attending lectures on the most abstruse branches of scholarship and science, remote from all the avenues which lead to fortune or public recognition; when I observe the earnestness with which our younger members address themselves to the studies of the place, and the absence of all manifestations of disorder or levity, without the necessity for the exercise of any external restraint, it seems to me that this establishment, even in its cradle, better responds to what its name should import, more fully embodies the true idea of a university, than if its halls and lecture-rooms swarmed with hundreds of idle and indifferent students, or with students, diligent, indeed, but working not from a pure love of knowledge, not even for the chaplet of olive, or the laurel crown, but for high places in examinations, for marks, as we say in England, the counters or vouchers to enable their fortunate possessor to draw large stakes out of the pool of sinecure fellowships or lucrative civil appointments.

But I look not only to our students, but to the means of instruction at our command, to our chemical and physical and biological laboratories, unsurpassed anywhere in the world for completeness in all essential particulars, furnished and replenished whenever called for without question and without stint, to our libraries and rooms for research and study, where any earnest student can work in comfort and seclusion, with all the materials and aids that he may require to assist him in his investigations, close at hand, and to the multifarious subjects in which (with a necessarily limited staff), even in our inchoate state, all who wish can receive instruction. In the course of time and as opportunities present themselves no doubt our staff of professors and lecturers will receive, as they need, considerable augmentation; but as I have heard it pithily and tellingly expressed, the object of our trustees is to found not chairs but professors.

I have had the pleasure myself of listening to a course of lectures on a very abstruse and important subject, allied to my own, which I am sure could not be surpassed for lucidity of arrangement, strictness of concatenation, aptness, fulness and variety of illustration and application, by lectures given in any university in the world, with which I am acquainted. These were the lectures of our colleague, unfortunately absent on this occasion, owing to ill health, Professor Rowland, on Thermodynamics, in which all the principal conclusions of this wonderful mathematical theory, perhaps the most wonderful since the discovery of universal gravitation, were deduced with geometrical rigor from the two great laws capable of being contained within a few words, the seven last words of the expiring Caloric theory, "*Heat is motion*," "*Temperature seeks its level*."*

* That is to say, temperature in regard to the categories of greater and less. Its measure Professor Rowland identifies with the integrating factor of a partial differential equation.

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There are things called Algebraical Forms. Professor Cayley calls them Quantics. These are not, properly speaking, Geometrical Forms, although capable, to some extent, of being embodied in them, but rather schemes of processes, or of operations for forming, for calling into existence, as it were, Algebraic quantities.

To every such Quantic is associated an infinite variety of other forms that may be regarded as engendered from and floating, like an atmosphere, around it—but infinite in number as are these derived existences, these emanations from the parent form, it is found that they admit of being obtained by composition, by mixture, so to say, of a certain limited number of fundamental forms, standard rays, as they might be termed in the Algebraic Spectrum of the Quantic to which they belong. And, as it is a leading pursuit of the Physicists of the present day to ascertain the fixed lines in the spectrum of every chemical substance, so it is the aim and object of a great school of mathematicians to make out the fundamental derived forms, the Covariants and Invariants, as they are called, of these Quantics.

This is the kind of investigation in which I have for the last month or two been immersed, and which I entertain great hopes of bringing to a successful issue. Why do I mention it here? It is to illustrate my opinion as to the invaluable aid of teaching to the teacher, in throwing him back upon his own thoughts and leading him to evolve new results from ideas that would have otherwise remained passive or dormant in his mind.

But for the persistence of a student of this University in urging upon me his desire to study with me the modern Algebra I should never have been led into this investigation; and the new facts and principles which I have discovered in regard to it (important facts, I believe), would, so far as I am concerned, have remained still hidden in the womb of time*. In vain I represented to this inquisitive student that he would do better to take up some other subject lying less off the beaten track of study, such as the higher parts of the Calculus or Elliptic Functions, or the theory of Substitutions, or I wot not what besides. He stuck with perfect respectfulness, but with invincible pertinacity, to his point. He would have the New Algebra (Heaven knows where he had heard about it, for it is almost unknown in this continent), that or nothing. I was obliged to yield, and what was the consequence? In trying to throw light upon an obscure explanation in our text-book, my brain took fire, I plunged with re-quickened zeal into a subject which I had for years abandoned, and found food for thoughts which have engaged my attention for a considerable time past, and will probably occupy all my powers of contemplation advantageously for several months to come.

I remember, too, how, in like manner, when a very young professor, fresh from the University of Cambridge, in the act of teaching a private pupil the

* See Appendix [p. 85 below].

simpler parts of Algebra, I discovered the principle now generally adopted into the higher text books, which goes by the name of the "Dialytic Method of Elimination." So much for the reaction of the student on the teacher*. May the time never come when the two offices of teaching and researching shall be sundered in this University! So long as man remains a gregarious and sociable being, he cannot cut himself off from the gratification of the instinct of imparting what he is learning, of propagating through others the ideas and impressions seething in his own brain, without stunting and atrophying his moral nature and drying up the surest sources of his future intellectual replenishment.

I should be sorry to suppose that I was to be left for long in sole possession of so vast a field as is occupied by modern mathematics. Mathematics is not a book confined within a cover and bound between brazen clasps, whose contents it needs only patience to ransack; it is not a mine, whose treasures may take long to reduce into possession, but which fill only a limited number of veins and lodes; it is not a soil, whose fertility can be

* Not to speak of professor on professor. Thus it was in order to be able to meet the threatened interrogatories of my valued colleague, the irrepressible Mr Rowland, that I was led, on my return passage to England last summer, to look into Prof. Clerk Maxwell's extremely valuable, but ill-digested and somewhat unduly pretentious treatise on Electricity and Magnetism, which led to my theory of the Bipotential, and to my writing the paper published in the *Philosophical Magazine* for October last, which ought to have the effect of causing the author to rewrite one of his leading chapters on Statical Electricity.

I have at present a class of from eight to ten students attending my lectures on the Modern Higher Algebra. One of them, a young engineer, engaged from eight in the morning to six at night in the duties of his office, with an interval of an hour and a half for his dinner or lectures, has furnished me with the best proof, and the best expressed, I have ever seen of what I call the Law of Concomitant Interchange, applicable to permutation systems, *i.e.* the law which affirms that every complete set of permuted elements may be separated into two parts, or if we like to say so, be presented in the form of a diptych with two precisely similar *Alæ*, such that a single interchange between any two elements is accompanied with a total interchange between the two *Alæ*. This is the theorem which lies at the basis of the great theory of simple equations, which every school-boy is supposed to understand, but which was not really made out until a bevy of great Mathematicians, including Leibnitz, Laplace and Lagrange, had turned their attention to the subject. Jacobi, I have read somewhere, used to say that if he at all excelled other mathematicians, it was chiefly due to his greater facility in manipulating simple equations that he owed it. The same Jacobi, who, I remember, visited our English Cambridge, and so much relished the Trinity audit ale which he drank there, and who once being asked whether he was brother to the eminent physicist, Professor Jacobi, of St Petersburg, replied: "Quite the contrary—he is my brother." And *apropos* of the zeal of the student in question, let me mention for the benefit of my English friends, I have been agreeably surprised to find how widely diffused a spirit there exists in this country of disinterested love of learning. Out of Italy, especially Tuscany, where my friend Enrico Betti, as I had the opportunity of observing, and in his own country too, where no man is supposed to be a prophet, the neighbourhood of Pistoja, as a Professor is more influential, more honored and courted than he could be if he were a rich Marquis, I believe there is no nation in the world where ability with character counts for so much, and the mere possession of wealth (in spite of all that we hear about the Almighty dollar), for so little as in America, with exception it may be of certain of the Trans-Atlantic cities, which are really only colonies and emporiums for the trading classes of Europe.

exhausted by the yield of successive harvests; it is not a continent or an ocean, whose area can be mapped out and its contour defined: it is limitless as that space which it finds too narrow for its aspirations; its possibilities are as infinite as the worlds which are forever crowding in and multiplying upon the astronomer's gaze; it is as incapable of being restricted within assigned boundaries or being reduced to definitions of permanent validity, as the consciousness, the life, which seems to slumber in each monad, in every atom of matter, in each leaf and bud and cell, and is forever ready to burst forth into new forms of vegetable and animal existence.

I think that I am not claiming too much for my own special pursuit when I affirm that every science becomes more perfect, approaches more closely to its own ideal, in proportion as it imitates or imbibes the mathematical form and spirit. It is, therefore, I think, a just cause of congratulation to us that as shown by our official returns and the evidence of those best acquainted with the aims and pursuits of our students, their interest and their proficiency in mathematics is, to say the least, unsurpassed by that which is evinced by them in any other department of instruction carried on within our walls. Many gentlemen who have graduated years ago in other colleges have come up to us with the sole or principal object of continuing and extending their mathematical studies.

I have reason to think that the taste for mathematical science, even in its most abstract form, is much more widely diffused than is generally supposed over this great continent, and that there is really a demand for the higher instruction which we are, or hope to be, prepared to give.

I know that in response to a circular letter inviting opinions as to the expediency of founding a mathematical journal of a high character under the auspices of the authorities of this University, we have received some scores of replies expressing deep interest in the proposed undertaking, with hopes for its speedy realization, coupled with distinct pledges of support and co-operation.

Such a journal, I venture to vaticinate, would not fail to receive contributions from mathematicians of the highest eminence in Europe, and would form a new chain of connection, of which this University would hold the leading link in its hand, between America and the other nations of the world which lead the van of science.

In contributing my share to the matter and superintendence of this journal I should feel that I was discharging one important duty of my office. Another branch of my duty will consist, as now, in being open to communication, at a stated hour of the day, with all who wish to confer with me in relation to their studies.

A third branch of my duty will be to deliver a succession of lectures on subjects either of special interest in themselves, or in which I may happen to

possess what may seem to me to be new views, or in which I may have succeeded in making discoveries of any general interest.

I ought not to omit to mention here the invaluable aid which I derive from the concurrence of the gentlemen associated with me in the work of mathematical instruction carried on under my general direction.

My associate, Dr Story, has had the advantage of studying for a long course of years in more than one German university, and I can speak, from personal attendance on one of his courses of lectures, from which I have derived both pleasure and instruction, of his thorough mastery over many of the most important and difficult branches of mathematical science.

Our students have thus the advantage of being put in direct communication with, and made participants of, all that has been done and is doing in that classical land of learning, in the way of mathematical research. In thoroughness of exposition, whatever may be the case as regards lucidity of presentation or spontaneity of initiative, I need hardly add my testimony to the general verdict of the world that our Teutonic brethren occupy the foremost rank. Many important *lacunæ*, which I should find otherwise a difficulty in filling up out of my own intellectual resources, are thus completely and efficiently supplied. Added to this, one of the most promising of our Fellows has lent his co-operation in bringing up to the standard of our University instruction such of our junior members as have come here insufficiently prepared, either from a too-short course of study or the lack of competent instruction in the schools or colleges in which they have received their preliminary education, and I am happy to be able to state that our trustees, with wise liberality, have recognized his services by raising him at once to the rank of a stipendiary lecturer.

Any one who will look through the syllabus of the lectures, not merely announced, but *bona fide* delivered and followed by attentive audiences within our walls, will see how respectable a range our courses of mathematical instruction comprehend: Analytical Geometry, Determinants, the Theory of Equations, the Differential and Integral Calculus, Definite Integrals, Rational Mechanics, Thermodynamics, the Theory of Elasticity and Modern Higher Algebra, are the subjects which have been actually taught here to smaller or larger classes of diligent students within the last few months.

Various other courses have been announced and will form part of our programme of instruction in this or future years.

The mention of Germany brings to my mind the importance of universities to the maintenance or development of a national spirit in the countries in which they are fostered and carried on with an animus free from local or sectarian prejudices.

I think that there can be little doubt that the greatest fact in modern history, the resuscitation of the German Empire, the resurrection of the

German people, is mainly to be attributed to the feeling of brotherhood and the spirit of nationality kept alive in those ganglions of thought, those centres of intellectual activity, the German universities.

It is the university professors who have made German unity a possibility, and I cannot but deplore the unpatriotic short-sightedness of those in my own country who, until so late a period, have struggled, and still covertly struggle, to make our universities in England not the representatives of the universal English mind, but the monopoly of a party and the appanage of a sect.

Their work it is that a separation deeper and a chasm more difficult to fill up has been created between the two most free and powerful nations in the world, England and America, than any due to political causes present or past.

Not the strained prerogative of a well-meaning but obstinate and narrow-minded monarch, nor the subservience of his ministers, nor the echoing voice of a misguided people it is, which has set up a permanent wall of separation between these two countries, a separation not founded on any opposition of material interests, but striking to the very groundwork of our mental constitution. Why is it that the flower of American youth resort not where the ties of a common language and of a common kindred would naturally have attracted them, to our English universities, to receive their mental impulse and their higher education, not to Oxford or Cambridge, but to Berlin, Leipzig, Göttingen, Jena or Heidelberg?

It is because there they were welcomed to whatever religious communion they were attached or unattached, without question and without distinction. It is because there they could rest on the bosom of a common mother, who shows kindness to all and favor to none.

If German professors have made Germany what it is, England may thank the narrow-minded class, or section of a class, of its university professors and chiefs (for there are numerous and noble-minded examples of English university leaders who combine the highest genius with the most liberal views; think of the Herschels, the Peacocks, the Sedgwicks, the De la Prymes, the Babbages, the Henslows and Lubbocks of the past, the Sidgwicks, the Stanleys, the Jowetts, the Liddells, the Brodies, the Mark Pattisons, the Pries, the Henry Smiths, His Grace of York, and many other illustrious men, leaders of thought, children of light, of the present generation,)—England, I say, may thank the obscurantist class of her university professors and heads, if the right arm of her spiritual power is shortened—if she is now, and it is to be feared will long remain, so much inferior in intellectual weight and influence in the world to what she ought to, and but for them would have been. They it is who, surrendering to party what was meant for

mankind, and laboring to cut out an English university upon the pattern of the University of Salamanca, have made a rent in the garment that should have been without seam, and alienated from us the intellectual sympathy of a mighty and kindred race. Driven to bay, like Rizzio at Holyrood, cowering behind *their* chairs and covered with *their* academic gowns, Intolerance found its last refuge and received, or is destined to receive, its last stab. Yet we shall probably live to see, as we have seen on former occasions, on the principle of "setting the cat to watch the cream," those very same men entrusted with the task of carrying out and shaping the promised university reforms who have passed their lives in endeavoring to frustrate or avert all substantial reforms up to this time.

I have been struck, almost from the first hour of my landing on these shores, by the manifestations I have everywhere witnessed of the close scholarly alliance which has sprung up between America and Germany. It is German books that are read, German professors who are quoted, German opinion on all matters of science and learning that is appealed to; and as regards community of work and intellectual ties, I do not think it at all extravagant to assert that Germany and America belong to one hemisphere, and we in England to another. If the English and American minds are ever again to be brought into contact, it will have to be on neutral and German soil.

I am old enough to remember when the great universities of England affixed their corporate seals to petitions to Parliament praying that the Crown would refuse to grant a charter to the University of London, then in the course of being founded, to enable it to give degrees, and that, too, at a time when, within their own walls, in many or most of the colleges, a religious test applied even to the admission of students*, and when no student, not a member of the Anglican communion, could be admitted to take a degree, so that not only would the universities not confer their own degrees, but they labored to prevent all Englishmen unwilling to sign the Thirty-nine Articles, from obtaining degrees elsewhere.

Then followed a struggle against Mr James Heywood's bill to open the degrees of the old universities to members of every faith; and in the third stage of this protracted contest, after the awakened intelligence and conscience of the magnanimous English people had overruled the monkish objections of the professorial and other chiefs of the retrograde party, the official head of

* The tutor on "one of the sides" at Trinity College, Cambridge, acting under the express directions of Dr Whewell, the then Master of the College, made strict inquisition of a gentleman, now occupying a Professor's chair in the University of Oxford, whether he professed the faith in which the founder of Christianity was educated, as in that case he must refuse to admit him as a student of the College. If I am not mistaken, the tutor in question was the present highly estimable and learned Master of the College. This incident was reported to me by the gentleman to whom and at the time when it occurred.

Physical Science in my own Alma Mater (for as such and not as an Injusta Noverca, or as a neglectful nurse who leaves her helpless charge whilst she perambulates with others more dear to her, will I ever continue to regard and cherish her) not merely signed, but was, (as I have been credibly informed, the projector and originator, and to my certain knowledge,) the active and leading canvasser for signatures to a petition* to the two Houses of Parliament to estop all others but members of the Church of England from holding any office of instruction in the university! This happened only a very few years ago.

Such is the blinding and blighting effect of early sectarian influences, one-sided culture, and narrow partisan connections, even on minds of a superior intellectual order, and on dispositions amiable by nature. There is a black drop of gall, a taint of congenital rancour and animosity, which infects all it comes in contact with, more indelible, more difficult to wring out or efface, than that dread smear on Lady Macbeth's hand, which could "the multitudinous sea incarnadine."† I doubt not that those who have taken this part, so prejudicial to their country's welfare, believe themselves to have been actuated by honest motives, just as I should not hesitate to admit that Torquemada was actuated by such and believed that he was doing a work acceptable to God when torturing heretics or presiding at the celebration of one of those *Auto da fé's* more horrid but scarcely more brutalizing than the bull-fights which I have seen supply their place.

It is difficult to estimate the lengths to which human self-delusion can be carried. No one questions that a great English statesman believes that he is prompted by the purest motives of philanthropy and patriotism when

* I ought to have said "to two petitions," one to shut out non-Anglicans from offices of emolument in the Colleges, the other to shut them out from Professors' Chairs in the University. I can understand upon what grounds (mistaken as they may appear to me) it may have been thought right to retain the management and endowments of the Colleges in the hands of a single denomination, but am really at a loss to conceive what reasonable plea can be offered for petitioning Parliament to exclude any one from teaching Anatomy, Latin and Greek or Mathematics in the University, who should happen not to say his prayers out of the same prayer-book as the signatories to the petition—a petition more worthy, it seems to me, to have proceeded from the members of some red-hot Irish Orange Lodge than from sober-minded Professors in a great National English University.

† A young gentleman, born in County Antrim, near the Giant's Causeway, was one night returning home from a dinner party with three-cornered hat and frilled shirt, "flushed," as we may suppose, not "with the juice of the Tuscan grape," but with run claret or *crooked* potheen, when, in passing over a narrow plank bridge that spanned a mountain torrent, he espied coming towards him an aged priest with lantern in hand, probably on his way to perform some silent deed of charity and mercy. He did *not* throw him over the bridge, but for two years afterwards felt much troubled in mind at the thought of having let slip so favorable an opportunity of doing a good deed. He subsequently emigrated to America, where he often recounted the story, and lived to shudder at the temptation to which he had so nearly succumbed. I have taken this account from the lips of his grandson, one of the most respected and enterprising citizens of Baltimore.

agitating to paralyze a government and overthrow a rival odious to him, and to cast his country at the feet or into the arms of an insidious suitor and foe, or that one who treads in his footsteps believes that he is acting with a single eye to the interests of education when he cries up the University of London, and, like Ham, mocking the nakedness of his parent, with sublime self-abnegation or *matchless* cynicism, derides the venerable university where he was nurtured, where he taught, and which gave him his start in life.*

I think that you in this favored land are so far educated out of such pseudo-religious and antisocial views (survivals of a bygone age), that you will feel almost prompted to doubt the veracity of my statements, or the faithfulness of my recollections on the subject, and I am certain that not a score of signatures could be gathered to any document of such a nature in this country, were the continent canvassed from Maine to Florida, or from Chesapeake Bay to the shores of the Pacific. If I speak with some warmth on this subject, it is because it is one that comes home to me—because I feel what irreparable loss of facilities for domestic and foreign study, for full mental development and the growth of productive power, I have suffered, what opportunities for usefulness been cut off from, under the effect of this oppressive monopoly, this baneful system of protection of such old standing and inveterate tenacity of existence. I cannot easily express myself at any length in cold blood, but require to be warmed by a sense of personal interest in my subject, when I venture to address a public audience; with me *facit indignatio versus*, nor can I sit down to compose except in conformity with the dictates of the Muse to the impassioned Sidney, "Fool! look in thy heart," she said—"there learn to write."

Happy the young men gathered under our wing, who, unfettered and untrammelled by any other test than that of diligence and attainments, have here afforded to them an opportunity of filling up a complete scheme of education, such as a Milton or a Locke would have deemed adequate to their ideal.

How rejoiced should I be, were I of less ripe years and under less preeminent obligations as to the disposal of my time, branching out from mathematics as my natural mental centre of gravity, to diverge into the physical and chemical studies which lie so near to it, and which there are here such ample means accorded of studying under the most competent instructors, and with all the aids that modern ingenuity and the improvements in mechanical science can devise for putting direct questions to

*"Viewed her own feather on the fatal dart,
 "And winged the shaft that quivered in her heart;
 "Keen were her pangs, but keener far to feel
 "She nursed the pinion that impelled the steel."

—Byron's lines on the death of Henry Kirke White.

Nature, and complementing and substantiating theory by visible and palpable Experience. For Experimental Physics, like the Practice of Gunnery, thanks in a great measure to the close alliance which the go-between Telegraphy has brought about between Science and Commerce, has in these days almost become a refined branch of Mechanical Engineering, very changed from those when a James Watt worked at his bench, when Priestley may have used a washhand basin for a Pneumatic Trough, or when a Woollaston could point to his cupboard as his Laboratory, and to a saucer holding a watch-glass, a lens and a blowpipe as his Philosophical Apparatus.

How delightful it were to be brought into contact with the treasures of antiquity and the music of the most perfect instrument of language, interpreted with Hellenic taste and wit and subtlest intellectual sympathy by my gifted colleague, whom you have just had the pleasure of listening to*, on whose lips all the bees of Hymettus seem to have settled and left their sweetest honey there; or, under the guidance of our enthusiastic and accomplished junior associate, penetrate to the foundations of our Indo-Germanic tongue; or, if that were not a dream too bright to be realized, to be led to the pure well of English undefiled, by one whose stay among us is, alas! only too short and transitory, who has effected among us what the rewards offered by an Eastern potentate were incompetent to bring forth—the Invention of a New pleasure—the eminent Chaucerian scholar, to whom I shall ever feel I owe a heavy debt of gratitude in supplying an unfailing source of delight, a pillow of repose for my declining years, in bringing to my knowledge and teaching me how to read and enter into the charm of another, a fresher and earlier Shakspeare!

* Ἄλλ' οὐ γὰρ ὡς τὸς πάντ' ἐπιστάσθαι βροτῶν
Πέφυκεν.

Even as the case stands, could our trustees but see their way to the institution of a certain number—I must not say of new mathematical chairs, but of additional mathematical professors, through whom I might supplement my deficiencies, and with them interchange ideas and carry on joint studies—I know not where in the wide world, out of my own country, I could feel more content to abide, or where I could find more conveniently within my reach all the materials for a complete mental equipment than within these walls, in this Temple of the Muses, in this free and law-abiding and

* Mr Gildersleeve, late Professor of Greek in the University of Virginia, who, like all of my other American colleagues, has drunk deep out of and been baptized in the perennial springs, in which whoever has been dipped comes out twice the man he was before he went in, which bubble up in those sacred precincts of science, the German Universities, and whose grammatical and other works are familiar to all scholars. I am informed that he is at present engaged in completing a Magnum Opus on Greek Syntax, which is likely to give him constant occupation for the next four or five years to come.

hospitable land—a land, to borrow the words of a fantastic but, to me, sympathetic rhymester,

Where tost bark a haven may find,
And new earth its roots to bind,
Drawing sap with instinct blind,
Willow stooping to each wind,
Oak, the monarch of its kind.

I thank you, ladies and gentlemen, for the kindness with which you have listened to my feeble utterances and, bird of night, given up to moping and brooding on my solitary perch, gladly make way for the lark, the herald of the morn, the star conspicuous amidst the effulgence of those Northern Lights*, which, "shooting madly from their spheres" for the last month past, have wandered into *our* latitudes and glowed in *our* sky, the poet whose name is honored wherever the English language is spoken or read, the author of the "Biglow Papers" and the "Ode to Washington."

APPENDIX.

There are three methods of treating the question of the Scale of Fundamental Invariants and Covariants—the *realistic*, the *symbolic* and the *fatalistic* or *peprotic*. In the first of these methods (the explicit or realistic) the derived Quantics, set out in full or abridged, through the intervention of canonical forms, are dealt with. It was thus that I established the scale for Ternary Cubics and for Binary Quartics and Quintics, in my early papers in the *Philosophical Magazine*, the *Cambridge and Dublin Mathematical Journal*, and in my Trilogy, published in the *Philosophical Transactions*. In the second, (the symbolic, schematic or embryonic method,) the derivations are not regarded as actually deduced, but are studied through the medium of the symbolic processes which gave the key to their existence (this is the method

* During the last month, Professors Childs and James Russell Lowell, both of Harvard University, have been giving lectures on Chaucer and Dante at Johns Hopkins University, and Mr Norton, Professor of the Fine Arts, and Mr Fiske, Assistant Librarian at Harvard, on English Cathedrals and the Aryan language and myths at the Peabody Institute. Professor Whitney is at present holding under the spell of his eloquence an audience of some hundreds of people, of both sexes, at the University, with lectures on the History of the Inflectional Structure of the Indo-European languages. There are many ladies in Baltimore who know Greek, and some who are about to enter upon a course of Sanskrit; others whose skill in singing and playing would command attention in any European concert room; and I have heard Professor Childs say that he never was in any city in the world where there was so pronounced a dramatic instinct as in Baltimore. Not to speak or read French and German is rather the exception than the rule. I mention these facts in order that my friends in Europe may well understand that my lot has not been cast among a barbarous or uncultivated race, and that the University has been planted in a congenial soil. Professor Lowell's recitation of his poem on Washington, at the Johns Hopkins Commemoration, "moved many of the audience, men as well as women, even to tears."

pursued with so large a measure of success by Prof. Gordan). The third, (the Deontological or Peptotic,) which precedes the one last named in the order of time, is the method indicated by Professor Cayley, in his memorable Second Memoir on Quantics, published in the *Philosophical Transactions*, which, owing to an error in its application, committed by its illustrious author, has fallen into neglect, and even the validity of whose substratum has been called into question. In this method the qualities of the derived forms, and the modes in which they can be brought into existence, are equally ignored: they are treated as mere Arithmetical existences, and, through the medium of that subtlest of all instruments for putting Nature and Reason to the question—a Partial Differential Equation—the numerical laws to which they are subject are made to depend on a problem in the Partition of Numbers.

This is the method followed in my researches, the validity of which I have established on an irrefragable basis, and which I have extended and modified so as to recover, by its aid alone, all the results obtained by Professors Clebsch and Gordan, and to go beyond them in showing how, with very great probability, (for at present I have not completed a strict apodictic proof of my Cardinal Principle,) an Algebraical Limit may be set to the degree and order of the Fundamental Derivations.

In order that I may not be supposed to be making a gratuitous assertion, I subjoin the Complete Generating Function, by means of which I can obtain the fundamental Invariants and Covariants given in Clebsch's Binären Formen for the Binary Sextic, demonstrate (with the aid of my Cardinal Principle) that there are none others, and establish all the fundamental Syzygants by which they are connected; for it ought to be noticed that alongside of the problem of determining the fundamental scale of Invariants or Covariants, there is the correlative problem, equally deserving of a solution, of determining the fundamental Syzygants, *i.e.* those rational integral functions of the Invariants or Covariants which, expressed in the terms of the coefficients of the Primary Quantic, are identically zero. I find that the total number of Covariants of the order m in the coefficients, and of n in the facients, (of course when n is zero the Covariants become Invariants,) is the coefficient of $t^m \cdot v^n$ in the fraction whose Denominator is

$$(1 - t^2)(1 - t^4)(1 - t^6)(1 - t^{10})(1 - t^2 v^4)(1 - t^2 v^8)(1 - t v^6)$$

and whose Numerator is

$$\begin{aligned} & (1 + t^{15}) + (t^3 + t^5 + t^7 + t^8 + t^{10} + t^{12}) v^2 \\ & + (t^4 + t^5 + t^6 + t^7 + t^8 + t^9 + t^{10} + t^{11} + t^{13} - t^{17}) v^4 \\ & + (t^3 + t^4 + 2t^6 + t^8 + t^9 + t^{11} - t^{16}) v^6 \\ & + (t^3 + t^5 + t^7 - t^{13} - t^{15} - t^{17}) v^8 \\ & + (t^4 - t^9 - t^{11} - t^{12} - 2t^{14} - t^{16} - t^{17}) v^{10} \\ & + (t^3 - t^7 - t^9 - t^{10} - t^{11} - t^{12} - t^{13} - t^{14} - t^{15} - t^{16}) v^{12} \\ & - (t^5 + t^{20}) v^{16} - (t^8 + t^{10} + t^{12} + t^{13} + t^{15} + t^{17}) v^{14}. \end{aligned}$$

I am thus enabled to show that the fundamental Covariants and Invariants are composed of two classes—Primaries, which are got from the Denominator, and Secondaries, from the Numerator—a distinction of the utmost importance, but which does not disclose itself in Professor Gordan's method. And it ought to be noticed that besides the problem of forming the fundamental scale, there is the not less important one in all cases of determining the *total* number of Invariants and Covariants of any given degree and order to which Gordan's method gives no general clue, but which is absolutely and completely resolved by my extension of the Peprotic method, above indicated. I repeat emphatically that no table of fundamental Invariants and Covariants will serve to calculate the *total number* of a given order and degree in the absence of a correlative table of the fundamental syzygies.

So completely had the Peprotic or partial-differential-equation method fallen into discredit, that I believe no allusion is made to it in Clebsch's work; only a slight reference is made to it in a note in Dr Salmon's new edition of his Modern Higher Algebra, and a condemnation is passed upon it by Professor Faà de Bruno, in his Treatise on Binary Forms, in so far as regards its application to Covariants of Quantics exceeding the fourth degree.