VOL. III. OCTOBER, 1896. No. 1.

The University of Toronto Quarterly.

CONTENTS.

Conducted by Undergraduate Societies of the University of Toronto.

$1.00 Per Annum. **Single Copies 25 Cents**

TORONTO:
C. BLACKETT ROBINSON, PRINTER.
1896.

THE

University of Toronto Quarterly

Vol. III. TORONTO, OCTOBER, 1896. No. 1.

SOME ASPECTS OF GREEK ETHICS.

By Maurice Hutton, M.A.

[An Address delivered before the Philosophical Society, March, 1896.]

In the few words which I have to say here to-day in response to the invitation and courtesy of the Philosophical Society and its President, I shall call your attention first and foremost to one or two of the questions connected with the evolution of the virtues in Greek civilization. The doctrine of such an evolution is of course now a commonplace, but it is curious and interesting, I think, to note what a meagre part such speculations play even in the Ethical works of Plato and Aristotle themselves. The "relativity" of moral standards is conspicuous rather by its absence; the "absoluteness" of moral standards seems rather to be maintained in the absolute sense of the term.

And first with Plato in the "Republic." Socrates asks for a definition of justice, and is referred, as is natural, to the Greek Bible, Catechism and Confession, to the writings of the poets, in particular to Homer and Simonides; but it appears from these writings, as ordinarily understood at any rate, that conduct ambiguous or worse will be included under the title of "just"; for Homer has praised not Odysseus only, but his grandfather Autolycus, whose record was unsurpassed in perjury and stealing; while Simonides is generally understood to have defined justice as "helping friends and injuring enemies," whereas it is evident, says Socrates, that the just man will injure no one.

The inference to be drawn from all this, we might suppose, is that Homer and Simonides have been left behind by the advance of the Greek conscience since their time; that it was all very well in Homer's time to lie or steal, especially from your enemies, possibly even from your countrymen so long as they were not your near kinsmen; that it was all very well even in Simonides' much more enlightened days to love your friends and hate your enemies, to exact an eye for an eye and a tooth for a tooth, to shout "my country right or wrong"; in other words the inference we might have expected Socrates to draw is that expressed in the luminous summary of the author of Physics and Politics. "Civilization is strewn with creeds and institutions, each of which has been in its time and term a step forward and a gain to man, but has often survived to be a curse and a clog upon further progress." Such an inference would at once have saved the credit of the Greek Bible, the poetry of Homer and Simonides, without making of that poetry a hindrance to the use of new and better lamps; and Plato, at once rationalist and pietist, conservative and reformer, if ever man was, would have been the first, one would have thought, to so solve the difficulty. Yet this was not Plato's solution: rather he appears to surrender Homer as indefensible and as immoral, and to save Simonides only by an amazing *tour de force*. Socrates boldly expurgates the offending text from the gospel of Simonides as an interpolation. The suggestion of course is wholly without probability, historical or *a priori*, and yet it looks as if it were seriously made, as the best means of combining what Plato always sought to combine—reverence for orthodoxy with reverence for the truth.

The same dilemma appears again in the second and third books of the "Republic" in a slightly altered form; certain legends, offensive to the morality of Socrates and his friends, are handed down by the same authority, the poets, touching the deeds of certain heroes of old, understood to have been men after God's own heart; the dilemma as put by Socrates is, as before, incisive, uncompromising and wholly unnecessary; namely, either these men did not do these deeds *or* they were not heroes beloved of the gods. To the former solution, as the more conservative of the two, as involving the lesser breach with honoured authorities and household names, Plato characteristically inclines; but no breach is necessary if the heroes of old be judged in the light of the morality of their own days, and not in the light of subsequent morality, and still less in the light of counsels of perfection. Just in the same way, as Mr. Ruskin says, tenderhearted people a generation ago found a stumbling block in the bloodshed of the Jews or Romans, and could not understand how an elect people could be elect if their humanitarianism was not up to date. Precisely the converse scruple is just now uppermost in men's minds, and the late Mr. Pearson in his book on "National Life and Character," instead of blaming the Jews for not being as soft-hearted and scrupulous as Nineteenth Century Englishmen, appears to regret that our conscience will not permit us to be as drastic as the Jews or Oliver Cromwell, and to think that our civilization is threatened by our humanitarianism. May it not turn out that our consciences and instincts are as true and safe a guide to salvation here and hereafter under modern conditions of living, as the very different conscience and instincts of the Romans and Jews under a life of ancient conditions? I do not mean that all the immoralities of the Greek Bible could have been solved and explained away by Plato from this point of view, only that this point of view would have solved several, and that he has ignored it. It is the more curious that the slow growth of morals is not present to Plato's mind, inasmuch as Thucydides in his introduction and his references to Homeric immoral moralities, such as piracy, has opened a way for a defence of Autolycus and his peers, which would have secured for their memories a rational acquittal. "Not guilty, but don't do it again," must necessarily often be the verdict of the comparative moralist.

Another form of absoluteness in moral standards is found in the "Republic." I mean it's standards are not only absolute rather than relative to the age, they are also absolute rather than relative to the individual. Virtue in the "Republic". is not to do one's best, and therefore this to me and that to you, according to what is our best and the number of our talents; rather virtue is an absolute objective series of acts, or rather of omissions.

"I am not unjust, an extortioner, an adulterer like this publican," is the Greek virtuous man's plea. Justice is the omission of overt offences and whosoever omits them is virtuous *ipso facto* ;

and so money becomes all-powerful as an agent in morality, for it delivers the possessor from vulgar temptations to thieving and extortion; it brings a good conscience and a cheerful anticipation of safety from the pains of Hell. "How hardly shall the poor man enter the Kingdom" is Cephalus' thought ("Republic," I); the Christian thought that the temptations and engrossment of wealth exceed its safeguards is only just presented incidentally by Socrates in a later book (VI) in the form "How hardly shall the clever man enter the Kingdom." The idea that of him to whom much has been given much shall be required, and he shall be beaten with many stripes, has not occurred to Cephalus. Compare the same mechanical and absolute standard in the younger Pliny: "Illness is a boon because it makes a man virtuous," *i.e.*, inactive, out of mischief; and contrast the vigorous Christianity of Dr. Johnson: "Every man is a rascal when he is sick," because sickness stimulates self-engrossment and selfishness. The same absoluteness of standard appears in "Republic," X, in a curious form. The respectable rich saved by an absolute standard go to Heaven as a reward, but coming again to a second life on earth, they at length pay for the shallowness and unreality of their virtue. They make a bad choice of this second life; they choose a fatal life of power unregulated and unscrupulous, and ending here or hereafter in misery; and this just because their virtue is unintelligent and superficial. On the other hand the unfortunate paupers, who have been betrayed into offences in their past life by their poverty and have atoned for those offences by a thousand years in Hell, now reap the benefit of their suffering. They choose their new life wisely, and so there is in this second life on earth a general fall of the saints from Heaven and a rise of the sinners who are come from Hell, and the second period of a thousand years will be spent by the quondam saints in Hell, by the quondam sinners in Heaven. The rich man and Lazarus have changed places; in his first lifetime he received his good things, and likewise Lazarus evil things; now Lazarus is comforted and he is tormented.

When we come to Aristotle we find the same absoluteness and finality of moral standards on the whole: there is nothing in the Ethics, *e.g.*, of the rise and growth of virtues, each is treated as it is, not as it was, or rather there is no suggestion that what each now is, it has only come to be, and once was not; rather one would gather that Aristotle regards each virtue as the same, yesterday, to-day and forever. This is the more surprising because Aristotle continually admits not only the evolution of society, but the very different aspects which the same institution or the same habit may wear in different stages of progress. It is one of his favorite speculations that habits and institutions have been introduced into the world by Nature, through appeals to some low motive and for some common place object, which yet have ultimately subserved, and have all the time been primarily intended to subserve a much higher end. When Nature desired to educate the human race to virtue and civilization, she treated her pupils as schoolboys, who do not know what is good for them, and in whose case the "argumentum ad baculum" is the truest argument, because the truest to them. She forced mankind into the State that is, by an appeal to commercial motives, and for a commercial purpose, in order that by the subdivision of labor thereby introduced they might be better fed and clothed. But, to use the more familiar words of the New Testament uttered in a like context, it was only for the hardness of their hearts that Nature thus condescended: at the times of their ignorance she winked. But it was not so, perhaps, in the beginning; at any rate it was not to be so in the end. The thin end of the wedge thus introduced by the witchery of Nature, primitive man was persuaded for his stomach's sake, as he fondly imagined, to found and organize states through the stages of the family and the village; but the state once founded and organized commended itself to wise men for far deeper ends; it became the means of organizing education in the practical and political virtues; it became the means of a universal paternal government, as benevolent as the government of the best individual parents, and with the universality and the irresistibility and the impartiality which the individual parent lacks. And so man gradually recognized that he had been cheated by Nature for his own good, that he had been the victim of a pious fraud, that he thought he was founding commerce only, when in reality he was founding virtue. It is obvious that speculations such as these pave the way for a treatment of Ethics generally as an evolution, but Aristotle does not follow up any further this promising vein of thought. He is content with the conclusion that the commercial instinct in man is but the first stirring in him of the implicit moral instinct, *is* the moral instinct in germ: that as the man grows to manhood by way of boyhood and youth, so he grows to morality and civilization by way of commerce, food and clothing, but that the latter only subsist for the former and have no independent existence. So strenuously does he insist on this that he denies, somewhat unnecessarily, perhaps, the existence of any State or organized body of men limited to the commercial instinct, concerned only with the organization of industry and the satisfaction of the primary physical wants. This instinct, this organization and satisfaction, he argues, is nascent morality, and cannot stop short of morality: there is no merely self-regarding and prudential intelligence, capable of commerce, but incapable of the loftier virtues and the higher civilization. One might have supposed that in some races or individuals Reason would stop short at the lower stage, development being there arrested for want of suitable conditions. But Aristotle seems to think that to concede this would weaken his argument (that Nature's real end and object is civilization, not commerce), and he therefore denies that any severance is possible between that lower intelligence necessary to the foundation of a state and the organization of industry, and the higher intelligence necessary to the higher civilization and the virtues: Reason in all its forms is absolutely one. I dwell on this because a well-known book, "Social Evolution," which has had a great vogue lately, pushes into prominence the opposite idea, the idea that intelligence is merely self-regarding, is merely enlightened selfishness: the commercial instinct and so forth has not only not conduced directly to the most characteristic features of our civilization, but has withstood, consciously or unconsciously, the advance of that civilization; not only are we not indebted to intelligence, but we have had to defy and disregard it: Reason itself, in the language of "Social Evolution," is set at naught in our characteristic virtues [as Mr. Pearson also asserts]. There is no use in quarrelling about words; the point I wish to notice is that civilization is wholly traceable, according to Aristotle, to the Reason, and that intellectual and moral qualities are not only not divorced but are inseparable parts of one and the same Reason. I presume the cause why Aristotle has not dwelt upon the evolution of the virtues, as his theory of the evolution of the state qualified him to do, is the same cause which made him chary of dwelling upon the evolution of laws and constitutions. Ethics is a branch of Politics, and Politics, though it presents many analogies to the arts and sciences, is not itself an art or science. It depends not on demonstration but on the force of habit to teach and convince. We are satisfied with our politics (or our ethics) because they are ours and we are used to them. Once upset this wholesome faith and there is nothing to put in its place for the ordinary man or woman, nothing to do but to shoot Niagara. To dwell, therefore, on the relativity and evolution of morals is only to unsettle everything without proving anything of present importance. If morals did change in the past, they may change in the future; perhaps they ought to be changing to-day. Where shall we begin? If habits and institutions in the past have been at first beneficial but then mischievous, our own habits and institutions may have outlived their usefulness and may be ripe for dissolution. What shall we discard first? Speculations such as these would have been infinitely repugnant to the sober common sense and cautious conservatism of Aristotle, and it is therefore, I suppose, that he touches with so gingerly a touch the evolution of virtue.

But there is one virtue in particular which would not only have admitted of treatment from the standpoint of development or evolution, but would have lent itself readily to the very same doctrine of development which Aristotle gives us in his theory of the State, and that is the virtue of love to the State, of patriotism. It is regrettable and strange that patriotism is nowhere directly discussed by Plato and Aristotle. Greek patriotism is discussed, however, in the late Professor Green's "Prolegomena," where he argues that the real difference between Christian and Pagan social feeling lies only in the area and range of the feelings, in the number and nature of the persons covered by it, not in any difference in the social instinct itself, in its basis or *raison d'être*. The ancient world, he thinks, included in the sphere of duty and affection the family, then the village, then the state. There it stopped. Christianity then supervened and extended ancient patriotism, until a similar obligation, similar in kind if not in degree, extends to and covers the whole human race.

This is Prof. Green's theory. But I am not sure that we must not borrow from the Darwinian school of moralists, who argue that all *unselfish* qualities (such as patriotism) are the slow outcome of purely *selfish* qualities by association of ideas, confusion of thought and heredity, and combine something of their view with Mr. Green's theory, if we want to explain the evolution of Greek patriotism. Not that any unselfish feeling can, properly speaking, be developed out of selfishness, but it may be developed by way of selfishness, and through selfishness διὰ though not ὑπὸ φιλαυτίας. And this is the element of truth, I take it, in the Darwinian explanation, which Mr. Green's account of Greek social virtue overlooks. Several considerations appear to me to point to the conclusion that Greek social feeling was distinct from Christian social feeling, not merely because it was straitened within the narrow limits of patriotism, but also because this very patriotism itself justified itself to the average Greek only as a form of self interest, because patriotism itself, therefore, was, consciously at least, and theoretically, based on self-love and not unselfishness. As I understand the evolution of Greek patriotism, Nature—to throw the argument into an Aristotelian form—Nature made the Greeks patriotic, truly patriotic, slowly and by a ruse; by deluding them for their own good. She tempted them into patriotism by appeals to selfishness, by the argument (and it was the only argument they would listen to) that patriotism was necessary to their own safety. Afterwards, but afterwards only, having thus induced them to co-operate, to sacrifice self, to live for the State, she left this wholesome discipline of co-operation and sacrifice to work its inevitable and beneficent result, to leaven the selfishness upon which it had been superimposed, to foster the germs of unselfishness lying unknown and unsuspected (except to herself) beneath the seething mass of egotism which constituted the earliest and the normal type of Greek patriotism. And so those who became patriots for selfish ends remained so for unselfish; those who at first were patriots only because they were egotists, grew to be patriots in the true sense.

The evidences which point to this evolution of Greek patriotism *viâ* pure egotism are such as the following: (1) This virtue is always based in Greek literature, both in poets and historians, on self-interest directly and entirely. There is almost a horror of appearing even to appeal to anything but self. Alcibiades expresses the egotistic basis of patriotism most crudely and brutally, but he is not contradicting, only emphasizing, the arguments used by every speaker. (2) The facts of history point to the same conclusion: The existence side by side in Greek states of intense patriotism and intense treachery and selfishness. The Spartans were the most patriotic and the most selfish of all Greeks. Patriotism was in Sparta—what cynics call it still—sheer egotism. "The tyranny of the state the egotism of the individual" sums up their system. (3) Again, the schools of thought which caught up and echoed Greek individualism and egotism passed easily and naturally from Greek patriotism—itself a form of individualism if I am right—to an individualistic and egotistic cosmopolitanism; the Cynics and the Cyrenaics. Their cosmopolitanism was not based on the love of man, but on indifference to all external ties. It was not because they loved man more, but because they loved their neighbor less, that they parted company with Greek patriotism and ostentatiously disavowed it; for this attitude the type of patriotism prevalent in their day had directly paved the way; they did but develop Greek patriotism. (4) The other schools of thought which did rebel against the individualism and egotism of the Greek mind, and which did seek to establish the solidarity of the Greek race, and to draw the Ishmaels together to peace and mutual help and love, the followers of Plato and of Isocrates, these show no zeal for patriotism, these acknowledge no debt to it. Pan-Hellenism, not patriotism, is their end, and just for this reason that patriotism had not helped their cause, that patriotism had not been at bottom in most men a spirit of love and neighborliness and a social force, but on the contrary merely a spirit of national egotism directly based upon, and always (overtly and consciously at least) justified as, a form of personal egotism. Of course, men are better as well as worse than their creeds, and no doubt hundreds of Athenians learnt true patriotism in the discipline of suffering and sacrifice which even this egotistic patriotism forced upon them; but the point is that in theory and in consciousness the social virtues of Greece, from patriotism downwards, were understood by the Greeks themselves to rest merely on egotism; they would have endorsed Hobbes' account of social virtue. So that with Christianity not only has social virtue widened its area, it has also changed its base.

THE DAWN OF ROMANTICISM IN FRENCH LITERATURE.

By Malcolm W. Wallace, '96.

[Read before the Modern Language Club, February 10th, 1896.]

Before entering on the discussion of my subject I must confess that the title, "The Dawn of Romanticism," is to a considerable extent a misnomer. I have attempted to portray the chief characteristics of the classic school in French Literature, to trace the gradual development of the romantic tendency in writers who were not pronouncedly adherents of either school, and to indicate the tentative efforts of the early Romantics. The difficulty of finding a comprehensive name for such a subject, may in some measure excuse the title I have chosen.

Classicism is so dominated by certain strongly defined and almost universal characteristics, that its peculiarly distinguishing features may be considered *per se* without necessary reference to individual authors. The characteristics of Romanticism, on the other hand, are of so complex and varied a nature, and its manifestations are so intimately connected with the personality of the author, that a study, however superficial, of this phase of literature, involves the consideration of the authors themselves. Accordingly we shall investigate the chief features of classicism in a general way, and then proceed to an acquaintance with the founders of the Romantic school, in connection with our study of the movement itself.

Speaking in round numbers, classicism may be said to have been the dominant tendency in French Literature, from the middle of the sixteenth century till the beginning of the nineteenth—from the Renaissance till the French Revolution. During this period literature is governed by certain clearly defined principles, against which there is almost no opposition. In Maraud we see the first indications of a spirit at variance with that of the Middle Ages, and the *Pléiade* may be said to have fairly ushered in the new movement. As in the case of most great historical movements, the essential characteristics of the new literature were by no means universally recognized by contemporary authors. *L'Art Poétique* of Boileau is in reality a glowing tribute to the author of *La Défense et Illustration de la Langue Française;* nevertheless, Boileau savagely attacks the *Pléiade* and their doctrines. The later works of Malherbe, with their chastened, strictly regulated style, show the change very clearly.

The literature of the seventeenth century is plainly stamped with the change. It was an age of absolutism and unquestioning submission. *L'Art Poétique* was a no less omnipotent code in the literary world, than were the fiats of *le Grand Monarque* in the state. Bossuet governed the church absolutely; Descartes was supreme in the realm of philosophy. Louis XIV. had made himself an absolute ruler, and after the days of the *Ligue*, and later on of the *Fronde*, we no longer hear any question raised concerning the legitimacy of the existing form of government. All men were satisfied and contented under this absolute rule, to which they gave a ready and joyful obedience. They were perfectly convinced, not only of its legitimacy, but of its infinite superiority over any other form of government, and the writers of the period vied with each other in extolling its magnificence. And, as we have already said, not only in the political world did this absolutism reign supreme; literature, philosophy, religion—every branch of human knowledge was in subjection to this same spirit of unquestioning submission. Each department had its dictator, who exercised a peaceable and generally recognized authority. If we seek for a reason of this almost phenomenal state of things, there is but one answer: their authority was founded on principles in harmony with the temperament of their age. It was not a critical age; men paid an almost abject devotion to authority. The apparent contradictions and seeming lack of moral harmony in the universe disturb them no more than the difficulty of solving the mystery of its wonderful complexity. A superior intelligence reigns high above all; is that not a sufficient explanation? A perfect equilibrium between thought and expression, a strictly-regulated forcefulness, harmonious proportions and pure clear language characterize the seventeenth century style.

The Renaissance had been brought about in the name of the ancients, and their influence during the seventeenth century was even greater than in the preceding one. This allegiance to the classics was in large measure a blind devotion. They did not thoroughly appreciate those whose virtues they extolled, and very often that which they admired, is that which we condemn. This blind devotion to authority generated that self-satisfaction and self-sufficiency which permeate every page of the literature of the period. Dignity, conciseness, simplicity in grandeur, are everywhere in evidence. Criticism there was also, but criticism ceased dumbfounded, at the name of an authority. Boileau announced his *Art Poétique* as the final tribunal of appeal in literary matters, for, were its principles not based on Horace? Racine's continual question in criticising his own works, was: "What would Homer, Euripides or Sophocles say, if he were reading this scene?" They only wished to approximate the perfection of their masters; to equal them on their own lines, or to rival them on new ones, never entered their mind. A haughty contempt for the national past of France was a natural result of this worship of antiquity. The splendid productions of the Middle Ages in Gothic architecture, as well as in literature, were characterized by this society, enchanted with its own perfections, as gross, rude and barbarous. The *chansons héroiques* and the *romans d'aventure* excited only their disgust, and inspired no interest regarding their uncouth forefathers.

One of the most striking characteristics of this whole age is the effacement of the author's personality in his work. The *moi* was almost a prescribed expression. People were not interested in the hopes and fears, joys and sorrows of the individual; it was in the sovereign, the representative of the whole state, or else in characters who were types of a large class, that their interest was fixed. Molière has repeatedly been charged with effacing the individual in order to produce the type, and the titles of his plays would seem to justify the charge: Corneille and Racine indeed write plays entitled *Le Cid, Horace, Athalie, Andromaque,* but these are characters all drawn from the highest class of society, and may fairly be considered as representative of the life of the state. To speak or act at variance with the universal laws which governed human existence, was an exhibition of low-breeding and bad taste. Frequently authors do not scruple to ridicule the virtue which is not sufficiently flexible to conform to the tyrannies of conventionality. Molière's *Alceste* furnishes us with an example of this. The stiff, unnatural ceremoniousness existing between members of the same family, is to us almost incredible, and quite ludicrous, for all natural affection was considered a *bourgeois* sentiment. The whole composition of society was the complete triumph of the community over the individual.

We can only indicate a few more manifestations of this spirit. Nature presented no charms to this society so proud of its artificial splendor. It is Molière who fixes the scene of a pastoral in "*un lieu champêtre mais agréable.*" In the one word "*mais*" is wrapped up a wonderful store of information regarding this period. Of the intimate personal relations, which existed between Jean Jacques and his beloved nature, they would have had no conception; and they covered with ridicule La Fontaine's very moderate admiration of country places and peasants, good-naturedly regarding him as a little childish.

It will easily be inferred that at a time when enthusiasm and mysticism in every form were sternly frowned upon, religion had developed into a dead mechanical ceremonialism. God was recognized as an intellectual necessity—a majestic, awful Being, supreme over, but certainly not immanent in things. The idea of a God entering into daily, vital, personal relations with the individual, was directly opposed to the suppression of the individual, his enthusiasm and feeling, and the elevation of abstract reason, by means of which alone, absolute truth might be approached. The thinking principle in man should be developed, while the feelings and imagination—those blind, misleading guides—should be dwarfed. One concluding example of the suppression of the individual may be seen in the style of literary criticism. A single absolute standard, against which there was no appeal, was set up, and an author's excellence was determined by his degree of conformity to this standard. The conditions under which a work was produced were considered no more than was the peculiar genius of the author. There was no attempt at local coloring; all their characters acted, spoke and, to a great extent, dressed like Frenchmen of the seventeenth century. As Racine once remarked, good sense and human nature were the same at all epochs and in all lands. The eternally fixed principles—immutable as the laws of the Medes and Persians—of *L'Art Poétique*, they believed to be the result of the march of centuries toward perfection, no less than Louis XIV was the consummation of that noble political development which had found its beginnings in the time of the Merovingian Kings. If we wished to characterize briefly the literature of the seventeenth century, it might be summed up in the words, absolutism, rationalism, the suppression of the individual, devotion to authority and self-sufficiency.

Classicism reached its most brilliant period during the reign of Louis XIV, though its influence was supreme for at least half a century subsequent to his death. During this half century Voltaire was the great literary dictator, and on the whole he is a consistent follower of the prevailing school. In criticism, he follows the literary canons of the preceding century as strictly as even Boileau could have wished; in the drama he observes the time-honored "unities," and clothes his thought in the stately, somewhat monotonous Alexandrine. His characterization of Shakespeare as *un sauvage ivre*, clearly shows his hostility to anything which was even vaguely suggestive of the "romantic." And yet, in Voltaire, as in nearly every other author of the century, we can detect the germs of a mighty change. The self-satisfaction and complacency of the preceding century is gone; an almost universal murmur of discontent is heard, a curiosity concerning natural phenomena, and a consequent enthusiasm in the study of the natural sciences is everywhere evident. True, men did not as yet question the origin or foundation, and legitimacy of the existing conditions of society; that only came about toward the close of the century. But men are awakening from the lethargy in which they have so long slept, and the "why" is becoming the all-important subject in every department of knowledge. In the essentially destructive, sceptical genius of Voltaire, we see constant indications of this unrest.

Before dealing with the founders of the Romantic school, it may be instructive to glance for a moment at those whom we may consider as transition writers, or precursors of Romanticism. And while this category would doubtless include the names of Buffon, Montesquieu, D'Alembert, Chénier and many others, we shall confine our remarks to one author, who may be considered as representative of the tendency, Jean Jacques Rousseau. In Rousseau we behold the incarnation of all the unrest, all the discontent, all the subjectivity, so to speak, which had hitherto been only vaguely felt. Every line in his numerous works, every act of his aimless, erratic life, shows him to us as thoroughly antagonistic to the opinions, social usages, and conventionalities of his age. He is a most incomprehensible compound of timidity and rudeness, of misanthropy and cordiality, of tenderness and effrontery. No age had been prouder of its brilliant civilization, but Rousseau does not hesitate to advocate to his contemporaries the adoption of the savage life. A sort of conventional honor had superseded genuine morality, and on this "honor" Rousseau empties the vials of his wrath, and declares "virtue," "conscience," "duty" to be the only foundation of true morality. He is entirely at variance with all the dogmas of the *philosophes*. They had worshipped reason and cast out feeling; Rousseau declares the conscience to be the only genuine criterion of the moral value of an act; he who takes conscience for a guide cannot stray. Unassisted reason, especially as manifested in the niceties of logic, is deceptive in the highest degree. With rationalistic philosophy and social conventionalities he breaks entirely. And now we see come into prominence that which was to prove one of the distinctive features of Romanticism, the personal element. To Rousseau the type, as such, possessed no attraction, for he hated to deal in abstractions; his essentially concrete mind occupied itself more willingly with individuals, with personalities often unaccountably inconsistent with themselves. The *moi*, which had so long been under the ban, now enters a period in which it reigns supreme. Rousseau's whole philosophy was subjective, and here may be found the key to understanding his strangely contradictory life, the source at once of his weakness and strength. From childhood he had lived in an imaginary world, and this had entirely unfitted him for any acquiescence in the dead externalism of the self-seeking world in which he found himself. His love of Nature was of the most highly idealized, romantic kind. Never was he happier than when alone in the depths of the forest, relieved of the necessity of thinking—only hearing, seeing, feeling, drinking in the odors and giving free rein to his imagination. His descriptions of Nature consist of a few simple, suggestive details, and the impression of the scene on himself—no lifeless unsympathetic enumeration of these details. He loves Nature's wild majestic beauties no less than her gentler calmer ones; she consoles and inspires him. To hear Nature spoken of as a personality—a sympathetic, loving personality, must have been strange indeed to Jean Jacques' contemporaries. Intensity of feeling once more characterizes love—"that elegant commerce of minds that was dying of inanition." In his *Héloïse d'Abailard*, Rousseau succeeded in giving back to love its passionate mystical element, and made it at once the most sacred, as well as the most profound of all human relationships. Deep, passionate gravity characterizes his lovers, who, it may be remarked, do not love in the drawing-room, but in the midst of hills and rocks and pine trees, as far removed as possible from the unrealities of polite society. All this has an air about it, wonderfully suggestive of *Atala and Réné*. Even Voltaire's ridicule could not neutralize the effects of Rousseau's ideas concerning love nor yet his position in regard to religion. To the fashionable rationalistic Theism of the time—Voltaire's "intellectual necessity,"—he replied not by a learned and logical treatise, but by a declaration of profound belief in a beneficent, all-wise Father, and in the deep spirituality of the Christian religion. His impassioned enthusiasm could not but affect, and affect deeply, even the *blasé* society of his time. Parents felt once more their deep responsibilities toward their children, though, strange to say, that sense of duty had been impressed upon them by a man whose own children had to be cared for by strangers. The purity and sacredness of the home were forcibly impressed on his generation by a man whose own domestic relations were far from ideal.

All Rousseau's proposals for the reorganization of society were highly idealized, imaginary, and took no cognizance of historic continuity; indeed, he had no accurate knowledge of history. In large measure he is a thorough Romanticist, his literary style alone uniting him to the earlier part of the century.

The different phases in the development of the tendencies we have indicated are seen only in individual authors. To trace the influence of the work of Sainte-Beuve in literary criticism, of Chénier in poetry, and of many others in their distinctive fields of work would be very interesting in this connection. To study the practical scientific spirit of Diderot, to examine his work in the drama, where, to the time-honored decree forbidding an author to *confondre les genres,* he replied by announcing, "*la nécessité d'accorder le théâtre avec la nature,*" to consider the optimistic, as well as the didactic character of his whole work,—all this and much in the same line would be instructive and highly interesting, but we must hasten on, to a brief consideration of those two master spirits who are generally recognized as the founders of Romanticism.

For many years looked upon as the leaders of two diametrically opposed schools of thought, and always at personal enmity, the one to the other, Chateaubriand and Madame de Staël were unconsciously working together, to the inauguration of a new era in French literature. Chateaubriand is the more radical, the more visionary; Madame de Staël is more bound to the 18th Century, though directly under the influence of many of the doctrines promulgated by Jean Jacques. If we look for Madame de Staël's "fixed idea"—I mean that idea which seems to come out in variously modified forms in all her works—we shall find it in her doctrine of human perfectibility. "*Les progrès futurs de notre espèce,*" this is her constant theme. We have said that Madame de Staël was, in many points, in harmony with the eighteenth century. This optimistic faith in the destiny of mankind is the supreme expresssion of eighteenth century rationalism. So deep-rooted is Mme. de Staël's conviction on this point, that in the very midst of the Reign of Terror she could maintain "*que la raison et la philosophie acquièrent toujours de nouvelles forces à travers les malheurs sans nombre de l'espèce humaine.*" With her clever, far-seeing penetration, she strove to gaze into the future, and from that unbiased position interpret the hidden meaning of all the apparently mad, meaningless tumult. Then in religion also she was largely influenced by the "*philosophes.*" But her deeply spiritualistic temperament came under Jean Jacques' all-powerful sway, and inclined her more and more toward Christianity if not Catholicism. Her ideal, in regard to the relations existing between God and man, tended toward an intimate communion, unattended by ceremonialism or symbols. She was not attracted however by Chateaubriand's highly imaginative conception of religion; feeling, not imagination, shaped her beliefs. Rousseau's deep fervor and enthusiasm in things spiritual call forth her warmest praise, which she pours out unstintingly in her *Lettres sur Jean Jacques*! For all that was optimistic in his teaching, and for the deep tenderness and enthusiasm of his nature, her admiration is unbounded; on the other hand she repudiates utterly his attacks on civilization, and his will-o'-the-wisp schemes regarding a return to the savage state.

If we seek to determine the service which Mme. de Staël rendered to French literature we shall find it to have been largely the outcome of her cosmopolitanism. Her education and the constant vicissitudes of a wandering life, had trained her æsthetic, as well as her intellectual, faculties in a quite unique manner. She had come under the influence of what she calls *Le Génie du Nord*, which, with her, is almost synonymous with Romanticism, and whose great characteristics, she believed, were seriousness and profundity. She introduced into France a broader, more tolerant, more cosmopolitan spirit, which, while it admired and did full justice to, protested against regarding, *le siècle de Louis Quatorze comme un modèle de perfection ou delà du quel aucun écrivain éloquent ni penseur ne pourra jamais s'élever*. For the sterilizing and pedantic criticism of Boileau she has only contempt. Slavish adhesion to the unities in the drama, she considers the subjection of thought to form, and demands more *réalité*, more *actualité* and less artificiality. She introduced comparative criticism, and thereby laid the foundation for every critical work which the nineteenth century has produced. For the puppet-like precision and exactness of the type, she would substitute the more distinctive, more erratic individual. The impression made on us by a poem, she considers a truer criterion of its merit than any artificial standard.

An ever-present sense of the Infinite and a deep, genuine morality pervade her every work. She directs her pitiless all-destroying sarcasm against abuses of every kind. To poets she says: *Soyez vertueux, croyants, libres ; respectez ce que vous aimez ; cherchez l'immortalité dans l'amour, et la Divinité dans la Nature. Sanctifiez votre âme comme un temple.*"

Her work in literature has all been in the line of emancipation from narrow standards, and the substitution in their place of a broad, sympathetic, comprehensive criticism. To her, external artificial unity was not nearly so desirable as that condition of things which aided the development of the many and complex phases of human thought. And if to-day Mme. de Staël is but little read, we may find the cause in her literary style. To again quote her own words she was an "*esprit penseur*," not a literary artist. The volume of thought often seems too great for adequate, much less artistic, expression. She established the victory of Romanticism, and ushered in an era of broader, more charitable views.

While Mme. de Staël, with the true perception of historic continuity, and as a result of the eclectic nature of her own ethical system, sought to ally herself to the eighteenth century, and by a process of selection of the good and rejection of the worthless, unite it to the nineteenth, Chateaubriand viewed all commerce between the new and the old as treason to the cause to which he was sworn. He would ignore the past entirely, and proposed to reform the world by starting anew, neither benefited nor hindered by experience. His antagonism to Mme. de Staël was due to the fact that he considered her as the champion of the eighteenth century, largely owing to her doctrines of human progress and perfectibility. As a matter of fact, their work was largely complementary. Mme. de Staël we have said was an "*esprit penseur*"; Chateaubriand was, before all, a literary artist. Not a page of his works is to be found that is not embellished with the most extravagant imagery and most striking metaphors. He loved Nature, and yet in a different way from Jean Jacques: the latter loved natural scenery as it really exists; Chateaubriand loved a highly idealized and largely imaginary nature. In describing a scene he selected the striking or pleasing elements from many scenes, and united them into an imaginary whole. Let me quote a most striking illustration of this, selected from Atala: "*Souvent égarées d'arbre en arbre les lianes traversent des bras de rivières, sur lesquelles elles jettent des ponts de fleurs.*"

And again:

"*Une multitude d'animaux placés dans ces retraites par la main du Créateur y repandent l'enchantement et la vie. De l'extrémité on aperçoit des ours enivrés de raisin, qui chancellent sur les branches des ormeaux; des cariboux se baignent dans un lac; des écureuils noirs se jouent dans l'épaisseur des feuillages; des oiseaux-moqueurs, des colombes de Virginie de la grosseur d'un passereau descendent sur les gazons rougis par les fraises; des perroquets verts à tête jaune, des piverts empourprés, des cardinaux de feu, grimpent en circulant au haut des cyprès; des colibris étincellent sur le jasmin des Florides, et des serpents-oiseleurs sifflent suspendus aux dômes des bois en s'y balançant comme des lianes.*"

One may smile when reading this, and yet if we simply accept it as it is, how delightful! What a charm all this unreal dreaming possesses, what a beautiful world to live in, in a word how romantic! Cease to remember that this picture has no counterpart in the world about us, accept the extravagances, the absurdities if you will, and then nothing is more delightfully charming than one of Chateaubriand's stories, where even pain and suffering are idealized to such a degree that they are beautiful in themselves, and we would not have them otherwise. Réné has to undergo extreme suffering, and yet we love his very sorrow no less than we sympathize with him.

Like Bossuet, Chateaubriand was the great Catholic apologist of his age, but how different is his method of procedure. He does not attempt to prove the truth of Christianity by any learned disquisition; on the contrary through two immense volumes in his *Génie du Christianisme* he presents picture after picture to demonstrate the magnificence, glory and poetical nature of Christianity. In his life as in his works is seen that love of the grandiose and pompous even in small matters. He himself is always *en scène*, and the contradictions and weaknesses of his heroes are largely his own. His religion is really æstheticism, and sentimental bursts of enthusiasm form his demonstrations. He does not pierce to the heart of things, but satisfies himself with an examination of externals. He first called attention to the beauties of Gothic architecture, which later became such a favorite theme with the Romantics, as he was also the first to introduce lyricism into prose. In the matter of his works, his manner of dealing with his subject, and his literary style, Chateaubriand is thoroughly Romantic and richly deserves the title "The Father of Romanticism."

In the necessarily brief time allotted to this paper, it has been impossible to do more than merely indicate the general direction of these two great currents in French literature. Indeed, it may be urged that we have not considered Romanticism in an abstract manner at all. This is true, but such a study must necessarily follow that of the individual authors whom we have been studying; nor can we now stop to consider what, in its essence Romanticism means, nor whether it still holds all-powerful sway in French literature. But we may say that it was a thorough regeneration of literature, and a raising of the soul of man from a narrow to a broad cosmopolitan position, and while men continue to love liberty, and to believe that every man should be sympathetically aided to realize the highest and best in his nature, so long will the French emancipation of letters—Romanticism—be a vital progressive force in French literature.

THE POLLINATION OF FLOWERS.

BY H. M. E. EVANS, '97.

[A paper read before the Natural Science Association, December, 1895.]

TOWARDS the close of the last century a treatise appeared entitled, "*Das entdeckte Geheimniss der Natur im Baue und in der Befruchtung der Blumen.*" The author, Christian Conrad Sprengel, in revealing the secret of nature in the form and fertilization of flowers, was the first to recognize their true significance. Premising the adaptation of all created things to some useful end, he proceeds to point out the purpose of flowers. Sprengel introduces the subject by noting the stages in his discovery. In 1787, his attention was called to the protection of the nectar in flowers from rain, by means of hairs, which, however, allowed free access to insects. In the following summer he observed that the coloring of the corolla was brightest, or that there was a spot of some other color, at the point where the nectar was stored, and that often there were rays of markings leading to it; all of which he considered as "path-finders" or "honey guides." Then the bright color of the whole flower and its perfume appeared as means of attracting insects. In 1789, experiment showed that some species of Iris could only be fertilized by insects; and many similar cases were afterwards found. Hence Sprengel concluded that the secretion of nectar by the flower, its protection against the rain, the bright color of the corolla and its peculiar markings, are contrivances of use to the flower itself by bringing about its fertilization by insects. Many of the views he expressed were ignored at the time, but modern scientists are willing to accord him more credit.

Of earlier investigators, Kölrenter is deserving of mention. In 1799, Andrew Knight stated, as a law, that in no plant does self-fertilization occur for an unlimited number of generations. No important advances were made until the time of Darwin. In his *Origin of Species* he confirmed Knight's law and extended it to all organic beings. The results of Darwin's extended researches in this subject, which were made with his accustomed marvellous care and thoroughness, are to be found in his *Variation of Plants and Animals under Domestication*, *The Fertilization of Orchids by Insects*, *The Different Forms of Flowers on Plants of the Same Species*, etc., etc. Detailed investigations have been made by F. Hildebrand; and he has published a very large number of works. The best book for general reference is *The Fertilization of Flowers by Insects*, by Hermann Müller. The weakness in Sprengel's work is pointed out in this book. He failed to consider the all-important question: "What advantage can it be to the plant that its pollen should be conveyed by insects to the stigma?" The direct contact of the reproductive organs in the flower would be a much more certain method. From whatever standpoint we regard nature, we can admit nothing that seems unnecessary and capricious. In the language of modern science, those modifications that are of advantage to their possessor can alone be preserved by natural selection.

The essential point in the process of fertilization is the fusion of a nucleus from the pollen grain with the nucleus of the egg cell. The origin of these two components has, of necessity, the greatest possible influence on the product of fertilization. In general, *only sexual cells belonging to one and the same species give a product capable of development*. Nevertheless, many cases are known of union between two different species of the same genus, *e.g.*, in the willow family (Salicaceæ); of the thirty-two European species, seventy hybrids are known growing wild. The same occurs in the Scrophulariaceæ, especially in *Verbascum*; in the Solanaceæ; in the Caryophyllaceæ, in the genera *Dianthus*, *Lychnis*, and *Silene*; in the Rosaceæ, in *Rosa*, and *Rubus*; in the Onagraceæ, in *Epilobium*; in the Compositæ, especially in *Cirsium* and *Cnicus*. The flowers of such hybrids are often more numerous, larger, and more beautifully colored; indeed, much of the success of the florist depends on his skill in contriving new combinations by crossing. But the reproductive power of hybrids is weakened. Seeds, if produced at all, are fewer in number, and the fruitfulness decreases with successive generations: and the weakening of the power of reproduction of the hybrid is more marked according as the parent plants are more distantly related.

On the other hand, it is a general law that *the union of sexual cells too closely allied is unfavorable for propagation.* Accordingly, we find the most various contrivances for precluding self-fertilization and for effecting fertilization by a stranger or *xenogamy.* That is, in the majority of cases, the pollen from the anthers of a flower does not fall on the stigma of the same flower, but is transferred to the stigma of another flower of the same species. The following are the more important means to this end:

1. In the various grades of uni-sexual flowers, monœcious, gyno-diœcious, diœcious, etc., cross-fertilization must of necessity take place, since self-fertilization is a meaningless term.

2. In many hermaphrodite flowers, the reproductive organs reach maturity at different times—a phenomenon known as *dichogamy.* The anthers may discharge their pollen before the stigma is completely formed and in a condition to receive it. Such a flower is *proterandrous.* In this case an older flower must be fertilized by a younger. Proterandrous flowers occur in the Geraniaceæ, Malvaceæ, Umbelliferæ, Compositæ, Campanulaceæ, etc. Or, conversely, the stigma is first developed and has received the pollen of another flower before the pollen of the same flower is ripened and discharged. Then the flower is *proterogynous.* Such flowers occur in the Juncaceæ, many Gramineæ, *Potamogeton, Aristolochia* and *Plantago.*

3. Where the organs mature at the same time, the desired result is often brought about by a difference in the form of the flowers. One mode is by a difference in the length of the styles in the flowers of different plants of the same species—a condition known as *heterostyly.* One flower has long filaments and a short style, another has short filaments and a long style. Where there are two modifications, the flowers are *dimorphic*; where three, *trimorphic.* Since, in these flowers, the anthers of one form always stand at the same height as the stigma of the other form, there is the best possible arrangement for cross-fertilization by visiting insects, which are, in each case, reaching to the bottom of the flower for nectar. Darwin found in the case of *Primula veris*; that the fertility of *legitimate* and *illegitimate* unions was in the ratio of 100:65. In the dimorphic flowers of *Linum grandiflorum,* he found complete sterility

from self-fertilization. Other dimorphic plants are *Polygonum*, *Mitchella*, *Houstonia*, etc. Trimorphic heterostyled flowers are found in *Lythrum salicaria*, *Nesæa*, *Oxalis*, *Pontederia*. In *Lythrum salicaria*, *e.g.*, the pistils and the stamens are of three lengths; each flower contains a pistil, and two sets of stamens corresponding in length to the two lengths of styles found in the other two members of the series. Hence, each stigma may receive pollen from two sets of stamens, one set of each of the other flowers. This is a most complex arrangement. Two of the three hermaphrodites must exist; and when all three coexist the scheme is perfect; there is no waste of pollen and no false adaptation. There are eighteen distinct unions possible. Of these, the legitimate unions were by far the most fertile. Darwin, in investigating, made 223 experiments; and his results show almost complete sterility for many of the illegitimate unions.

4. Many hermaphrodite flowers are self-sterile. When the pollen falls on the stigma of the same flower, it either produces no pollen tube, or no fertilization takes place. This is the case, according to Hildebrand, in *Corydalis cava*. Fritz Müller states that the pollinia and stigmas of the orchid genus *Oncidium*, are even deadly poisonous to one another. But, although crossing is better than self-fertilization, the latter is infinitely better than no fertilization at all. So it is found that self-fertilization can, in most cases, take place, and does take place if the agents for crossing fail.

One great exception to the law of xenogamy is found in the occurence of *cleistogamous* flowers, in some plants, in addition to the ordinary open flowers. Cleistogamous flowers never open, and so resemble buds; their petals are rudimentary or quite aborted; their stamens are often reduced in number, with the anthers of very small size, containing few pollen grains, which have remarkably thin transparent coats and generally emit their tubes while still enclosed within the anther cells; and, lastly, the pistil is much reduced in size with the stigma, in some cases hardly at all developed. These flowers do not secrete nectar nor emit any odor, and are singularly inconspicious. Consequently insects do not visit them, and could not effect an entrance if they did. They are, therefore, invariably self-fertilized and yet produce an abundance of seed. They seem to serve the purpose of the production of a large supply of seed with little consumption of nutrient matter or expenditure of vital force. The open flowers, generally produced on the same plants, afford an opportunity for the invigoration of the race by cross-fertilization. According to Darwin, cleistogamous flowers occur in forty-five genera of the Dicotyledous and ten genera of the Monocotyledous, for which see Darwin's *Different Forms of Flowers on Plants of the Same Species.*

A similar modification occurs in certain plants (*Lysimachia vulgaris, Euphrasia officinalis, Rhinanthus crista-galli* and *Viola tricolor*). Some individuals bear conspicuous flowers adapted for cross-fertilization; others have much smaller and less conspicuous flowers, which have often been slightly modified to ensure self-fertilization. Although they differ in not being completely closed, and in occurring on different individuals, they approach the cleistogamous flowers in the purpose they serve, viz., the assured propagation of the species. In several Acanthaceous genera the flowers towards the outside of the inflorescence are large, conspicuous and sterile, evidently serving to attract insects; the next in order are smaller, open, capable of cross-fertilization, and moderately fertile; while the central ones are cleistogamous, being still smaller, closed and highly fertile.

Then according to the means by which pollination is effected, we may divide the Angiosperms into three classes.

1. *Hydrophilous*—where the agent is water. They comprise only those few water plants whose flowers bloom submerged, in which case the pollen is conveyed by currents or simply by sinking. The pollen of such plants has very thin smooth walls, and, in *Zostera,* instead of the usual rounded form, has that of long thin cylinders, lying parellel in the anthers. Such plants are some of the Najadaceæ and *Ceratophyllum.*

2. *Anemophilous*—the pollen is borne by currents of the air. Here the pollen grains are smooth, light, dry and dust-like, and hence are easily scattered. The number of male flowers and of anthers is very large, and the pollen is produced in great quantities. This is obviously necessary on account of the enormous waste. The stigmas project freely from the flowers and are often provided with long hairs for catching the pollen. Many of these plants blossom before the opening of the leaves, which would be a

hindrance to the free access of the pollen to the flowers. This is the case in the oak family (Cupuliferæ). In *Typha*—the cattail—the female inflorescence stands directly beneath the male, so that the pollen falls by its own weight.

There are means for aiding the delivery of the pollen to the air. Most often it is shaken out by the wind. In many Gramineæ—the grasses—the anthers hang on extremely thin filaments and are swayed by the least current of air. In *Rumex acetosa* and *Rumex acetosella*—the common sheep sorrel—it is the pedicel of the flower which supplies the necessary flexibility. In *Briza* the whole panicle vibrates. The lax condition of the male catkins of the Cupuliferæ and the poplars serve the same purpose. In *Parietaria*, *Urtica* (common nettle), *Celtis*, etc., the pollen is hurled out of the anther with explosive violence. The mechanism is this. In the bud the stamens are bent inward, and the anthers are pressed against the ovary. The tension caused by the pressure on the inner side of the filament becomes greater and greater with further growth, until, at the complete expansion of the flower, the anthers are suddenly freed, and the filament flies back with sufficient force to project the pollen into the air. Anemophilous plants are characterized by possessing small inconspicuous flowers, since large showy flowers are clearly superfluous. The Gymnosperms are, for the most part, anemophilous; but recent investigations by Strasburger have shown that to some extent they belong to the following class.

3. *Zoidiophilous*. The flowers of most Angiosperms are fertilized by certain animals which visit them. The pollen adheres to some part of the body of the visitor, and thence is detached on the surface of the stigma of another flower. The pollen grain of all such flowers is possessed of a thick extine coat, the outer surface of which is made adhesive by its various processes and sculptures, and by the copious supply of yellow or other colored oil. On the other hand the stigma is adapted for holding the pollen by its especial stickiness at the time of fertilization.

The means by which the flower attracts the animals which are so necessary for its proper pollination, and, above all, the peculiarities of structure which force just those actions, on the part of the visitor, that must accomplish with certainty a transfer of the pollen of one flower to the stigma of another of the same species, form a very beautiful study. To attempt to completely outline this part of the subject would be quite impossible. The bright colors and the perfumes which characterize all these flowers are the means by which they are rendered conspicuous and so easily to be found by their guests. The attraction they offer is principally the nectar. The nectaries are, in most cases, at the very bottom of the flower, beneath all the other organs; the reason for which is obvious. Some softer parts of the flower may be used for food, and many insects feed on the pollen itself. In a few trophical species birds are the agents; *e.g.*, in *Marcgravia nepenthoides*, the hanging umbel of flowers resembles an inverted chandelier, beneath which in the centre are a group of flask-shaped nectaries. These attract insects, which in turn attract insectivorous birds, and these while feeding on the insects touch and cross-fertilize the flowers above. But the great majority of the flowers of this class are pollenized by insects, *i.e.*, are *entomophilous*.

In the dimorphic and trimorphic flowers previously referred to, the fact that those stamens and stigmas which are designed for one another stand at the same height secures the proper pollination by an insect that is, in each case, reaching to the bottom for nectar. In the ordinary monomorphic flowers it is necessary that the pollen should be on that part of the insect's body which will come in contact with the stigma of another flower. This is secured in various ways. The anthers may originally have a position directly above the stigma. In *Geranium*, which is proteranderous, the stamens are spread, but when the pollen is just about to be discharged they, by a movement of nutation, swing in towards the pistil, so that the anthers are directly above the stigma, which is not yet matured. Accordingly, an insect, visiting such a flower and then an older flower, deposits the pollen on the stigma of the latter. In *Salvia pratensis*—the sage—the stigma projects forward, beyond and above the two stamens. When the proboscis of a bee touches the base of the corolla tube, the anthers are thrust forward against the back of the visitor, and so the pollen is placed in such a position that it will be brushed off by the stigma of the next flower visited.

In *Aristolochia* the tubular calyx is inflated at the base, and in the chamber thus formed are situated the reproductive organs, of which the stigma ripens first. An insect which is bringing some pollen from an older flower enters the tube of the calyx, reaches the chamber, and there deposits the pollen on the stigma. But it is prevented from retreating from the flower by long, backward-set hairs which line the tube of the calyx, and which only wither after the flower has been fertilized and after the anthers have ripened. Then the insect with a fresh load of pollen is permitted to depart to go through the same experience in another younger flower. Grant Allen adds to the picturesqueness of these proceedings by stating that the very useful activities of the prisoner are increased by an intoxicating fluid secreted by the flower—a difficult point to prove.

In *Phaseolus coccineus*—the scarlet runner—the stamens and style are enclosed in a part of the corolla known as the carina, the apex of which is full of pollen. The stigma is surrounded by its own pollen, but until the papillæ have been forcibly rubbed the surface of the stigma is not sticky. When a bee alights on the flower, its weight depresses the carina and forces out the style; the stigma receives the pollen adhering to the base of the proboscis; then, on further depression, the pollen carried out by the hairy brush on the style becomes attached to the bee and is carried to the next flower. A similar extrusion of pollen, brought about by various mechanical contrivances, takes place in many other flowers.

But it is in the orchids that we find the most marvellous adaptations. Darwin's *Fertilization of Orchids by Insects* is an intensely interesting book. Despite the fact that each fertilized orchid produces an enormous number of seeds, amounting to more than a million in some tropical species, the number of plants is not increasing. Why this is so is not exactly known, but it indicates that they are holding the position they occupy in the vegetable kingdom only by a very hard struggle. Accordingly we find that they are highly specialized for producing the enormous number of seeds with a minimum of possible loss of energy in waste of pollen, etc. Perhaps it will be as well if we refresh our minds a little as to the structure of an orchid flower. One of the petals is modified more or less forming the *lip* or *labellum.* This is really the one nearest the stem, but by a twist of the ovary it comes to be directed forward and away from the stem. Of the six stamens only one or in some cases two are functional and bear anthers. The three pistils are fused together with the functional stamens and the rudiments of the remaining stamens to form the *column.* Two of the stigmas are functional; the upper one is modified into an extraordinary organ called the *rostellum.* It is this which furnishes the viscid disk attached by a stalk to the *pollinia*—the club-shaped masses into which the pollen of most orchids is congregated.

In *Orchis* an insect alights on the lip and pushes its head into the chamber, at the back of which lies the stigma, in order to reach with its proboscis the end of the nectary. It touches the rostellum, the exterior membrane of which ruptures, exposing the two viscid balls attached to the pollinia. When the insect withdraws its head one or both pollinia will also be withdrawn, firmly cemented to it and projecting up like horns. The viscid substance sets hard like a cement in a few minutes' time. It is evident that when the insect visits another flower, the pollinium thus firmly attached would simply be pushed back against the face of the anther. But there is a minute disk of membrane, by which the pedicel of the pollinium is attached to the viscid disk, and this contracts within thirty seconds of the time of exposure, causing the pollinium to sweep through an angle of about 90° always in the same direction, viz., towards the apex of the proboscis. In this position the thick end exactly hits the stigmatic surface and deposits pollen on it. The elastic threads which hold the pollen grains together in the pollinia break much more easily than the attachment of the whole to the proboscis. Hence the very viscid stigma removes only a part of the pollinium, the remainder serving for another flower. In *Orchis pyramidalis* the two pollinia are attached to a saddle-shaped disk which clasps around the thin proboscis of an insect, thus causing the originally parallel pollinia to diverge Then by the same contraction as in the former case they are directed forwards. These movements of the pollinia are most accurately adapted to the particular circumstances, as the following considerations show. In most species of *Orchis* the stigma lies directly beneath the anther cells; and the pollinia simply move vertically downward. In *Orchis pyramidalis* there are two lateral and inferior stigmas; and the pollinia move outward and downward diverging to just the proper angle. In *Habenaria* the stigmatic surface lies beneath and between the two widely separated anther cells; and the pollinia converge and move downward.

In an Australian orchid—*Pterostylis*—the lip, when touched by an insect, springs up rapidly, carrying with it the insect, and thus temporarily imprisoning it in the flower, which is, but for the lip, almost completely closed. The lip remains shut from half an hour to an hour and a half. Meanwhile the imprisoned insect can only escape by a narrow passage. In thus escaping it first deposits on the stigma whatever pollen it may be carrying; then it is coated with viscid matter by the rostellum; after which it comes in contact with the pollen which it can hardly fail to remove. Lastly, in *Catasetum* the flower is provided with processes which can only be likened to antennæ. When one of these is touched, the pollinium is shot out with the viscid disk forward and with sufficient force to make it stick to a window pane three feet away. I have not space to dwell on the intricate mechanism of this form. It is visited for the most part by large insects, and the force is necessary to ensure the adhesion of the pollinium to the hairy thorax of its guest.

Even this outline will serve to indicate the marvellous adaptations which exist for the purpose of securing proper pollination. Had it been supplemented by all the amazing complexity of detailed structure which a minute study reveals, we would be lost in wonder and admiration.

THE FOURTH DIMENSION.

By A. Kirschmann, Ph.D.

[Read before the Philosophical Society.]

It is needless to say that it is not my intention to give within the limited space of this paper an exhaustive treatment of a subject so frequently discussed, and yet so hazy and enigmatic as that of the fourth dimension, a subject which has baffled for so long a time so many scientific thinkers, mathematicians and philosophers, and perhaps still more unscientific mystics. I shall confine myself to the discussion of a few significant points which may be brought under the head of two paragraphs. In the first I shall sketch what seems to me the most justifiable, although the least acknowledged of the motives, which lead to the assumption of higher dimensions; and in the second I shall attempt to examine and to criticise the foundation, on which the construction of this at least problematic and transcendent conception is based.

I.

The space in which we live, it is said, is three-dimensional, but we know, so it is claimed, things of fewer dimensions, as surfaces, lines, points. Now it is true, in every system, known to us, of 1, 2 or 3 dimensions, there are space-relations possible or occurring, which irresistibly suggest the introduction of the next higher dimension.

If we have a one-dimensional system, a line, there are two kinds of movements possible; say to the right and to the left. But as long as we remain within the one-dimensional system, there is no possibility to transform a movement of the one kind into one of the other. The transformation can easily be performed with the help of the second dimension, if we only move the negative stretch (or the line which represents a movement to the left) out of the one-dimensional system, and turn it within the plane round an angle of 180°, and bring it then in its former place again. Let us now proceed to the second dimension. If you have in a plane two geometrically equal (size and shape) but symmetrical figures, *e.g.*, two congruent triangles, the one of which has at the right side what the other has at the left, then it will be impossible to bring them into perfect coincidence by shifting the one of them without leaving the plane. But it is easy to make the one cover the other by turning it over "through the third dimension." In other words: the transformation cannot be performed by simple displacement within the two-dimensional system; but it may be easily accomplished by circumversion through the next higher, *i.e.*, the third dimension.

Now, let us go one storey higher. There are in our three-dimensional space imaginable geometrical constructions or real objects, which are in size and shape perfectly equal, and still different in their relation as a whole to space, so that it is by no means possible to make the one fill the space occupied by the other. Examples of this kind of structure are the right and left hand or glove, an object and its image in a plane mirror, screws of equal size and shape, but of contrary winding, etc. Now, it is claimed, the transformation of the spatial structure of a solid body into that of its mirror-image, which cannot be attained by simple displacement, that is by application of the principle of the relativity of space-magnitudes, could be easily accomplished, if there was something like a circumversion through a fourth dimension.

But from the mere possibility of such space-constructions, or from the mere existence of objects whose shape involves the above described peculiar space-relations, does by no means follow the necessity of their transformation. The world can quite well go on without having the possibility of making right gloves and screws out of left ones. But the affair presents suddenly a different aspect, as soon as we have to deal with objects which show the mentioned space-relations, not only in their outside form, but throughout their whole inner structure. This is the case with the so-called enantiomorph crystals. Minerals or crystallized chemicals of this kind (*e.g.*, the crystals of quartz and those of grape sugar), do not only show in their exterior shape the phenomenon of enantiomorph hemihedry, according to which they occur as two classes of individuals, which have to each other the space-relations of the above described untransformable three-dimensional structures, but also their inner nature must be totally different down to their smallest particles. For, under the polarisation microscope they show a different succession of the interference colors; *i.e.*, in order to make the succession of the colors equal for both kinds, the one has to be turned to the right, the other to the left. And though you may place the two crystals under your instrument in any way you please, you can never make the right one turn the colors to the left and *vice versa*. We have to assume here, that even to the form and order of their molecules inhere those enantiomorph qualities. The molecular movements in them must be of such a nature that the curves which a particle of a right-turning crystal describes can by simple displacement in three-dimensional space never be transformed into those of its left-turning brother. And still, the two crystals may be genuine twin-brothers, they may have crystallized out of the same solution; they may even form different layers of the same crystal, as sometimes in the case of the amethyst. Thus their development has to be traced back to the same or a common cause. But we know that the cause of a movement can only be another movement from which the former can be derived by simple displacement and application of the principle of relativity of space magnitudes. But how is it possible then that the same cause produces movements which cannot be transformed the one into the other? Here we have to face the embarrassing alternative, either to assume that the crystallization of the two twin-individuals out of the same liquid, and under precisely the same conditions, has not had the same cause throughout, *i.e.*, that their different spatial features stand in no causal connexion to each other; or adopt the view that the three-dimensional properties are not essential to the ultimate nature of the crystals concerned, and that their spatial qualities would no longer appear irreconcilable if seen from the standpoint of a space of higher dimensions.

If you prefer the former, you have to give up causality as a uniform principle for the explanation of natural phenomena; for, if the enantiomorph space-properties of the two crystals, developed out of the same solution of silicic acid, or those of the different layers of one and the same amethyst-individual, do not stand in any causal connection whatsoever, they must be independent of each other. In order to account for their different demeanor you have to attribute to their molecules or atoms certain non-mechanical qualities, no matter what name you give them—psychophysical forces, voluntary action or molecule-souls. And these crystal-souls are in a certain way superior to those of higher organisms and human beings; for, they can do what men and animals never can; they perform movements, which are not linked into the great continuous chain of mechanical causality. Thus, facing the fact of enantiomorph hemihedry, which is in more than one respect a puzzle to the scientist, we stand before what we cannot help calling a plain "miracle;" and the hypercritical smile with which so many in our enlightened nineteenth century meet this expression, when mentioned outside of the church, finds a stern rebuff in this state of affairs, which at least should suggest a closer examination of the terms "miracle, nature, reality, belief, knowledge," etc. All these difficulties we escape if we adopt the theory, that the space of "Reality" possesses a fourth dimension, which differs from the three space-dimensions of our phenomenal world only in this, that it is not given to us. This four-dimensional space remains of course, so it is said, for us just as inconceivable as our three-dimensional space would be to the inhabitants of a world of only two dimensions. They would only perceive linear and angular magnitudes, all arranged in a single plane, and if one of us three-dimensional beings would take one of their objects out of the plane in which they live, the object would disappear to their senses and they would regard that as a miracle, although the fact would be so simple and natural for us. Just in the same relations we stand to the beings of a four-dimensional world. If we make a knot in a string, and fasten the ends afterwards by seals, then it is utterly impossible for us to untie the knot, without breaking the seals. For the four-dimensional spirits this is a very easy matter, just as easy as it is for us to open a simple loop in a string.* Many similarly wonderful deeds

* The experiment has only been once performed under the auspices of a scientific person, namely, by Mr. Slade, a highly spirited medium in the service of Prof. Zoellner. But, if I am right, there were some doubts afterwards, either about the order in which the knot and the seals had been put on the string, or about the nature of the knot.

can be accomplished by means of the fourth-dimension, and from the standpoint of this principle all difficulties concerning the molecular movements in enantiomorph crystals vanish. The real essence of the crystals is, like that of all matter, four-dimensional, and what is inconceivable for us three-dimensional beings, the transformation of one of the two contrary forms into the other, or the derivation of the two enantiomorph movements from one common cause, can be simply performed by "Circumversion in the fourth dimension."

Theories of this nature are adopted and advocated by modern spiritualists, and they find believers enough, who do not pay attention to the fact, that these spirits need for their performances always something in addition to the fourth dimension, namely, a three-dimensional "medium," who mostly combines with his spirit-attractive powers the qualities of a skilled sleight-of-hand man. Further, these spirits at the disposal of the medium never accomplish any deed of practical or ethical value; they content themselves by performing tricks which a fair-magician at a variety-show may even surpass. They write their messages from the four-dimensional world in the same style and in the same incorrect orthography as their mediumistic master uses, and—last, not least—they "strike" as soon as the latter is not supported with good three-dimensional money.*

Not only professional spiritualists, but also learned mathematicians of highest reputation and authority, have found the theory of a fourth and higher dimensions, acceptable at least as a theoretical means for gaining higher or more general truths. From this standpoint our three-dimensional space appears as a special case of a manifoldness of n dimensions; and in the same sense, as we represent plane figures as shadows, projections or sections of solid bodies, the latter are regarded as the three-dimensional sections, projections or boundings of four-dimensional structures. Thus, if we regard x^0 as the expression for a space of 0 dimensions, *i.e.* a point; x^1 as that of a space of one dimension, *i.e.* a line, and so on, then x^2 will represent a square, x^3 a cube, and x^4 the corresponding four-dimensional solid; and as the square is bounded by four straight lines, the cube by six squares, so the four-dimensional body x^4 would be bounded by

* Compare Wundt, Essays, page 342.

8 cubes; and it would have 16 four-dimensional corners. The limited space of this paper does not allow us to enter into a discussion of all the mathematical problems in which the theory of the fourth dimension has been applied with more or less apparent success. But we may mention, that not all the scientists, who have been interested in this matter, have treated the fourth dimension as a mere theoretical speculation. Some have practically combined the view of the mathematician with that of the spiritualist, so *e.g.* the celebrated astrophysicist Zœllner, who brings forward in favor of the theory an argument which deserves special attention.

Zœllner holds that we have the less right to reject the theory of higher dimensions, since our visual as well as our tactual space is, corresponding to the spatial arrangement of the sensitive organs (skin, retina) in surfaces, two-dimensional only, whilst we obtain the third dimension, the presentation of distances, only by inference. Thus he claims: The space of experience has really only two dimensions. The third dimension is already the product of a construction. There is no reason why we should not be allowed to push our construction a little further and establish a fourth dimension, a fifth, etc.

One of the latest writers on this subject, Hermann Schubert,* thinks he has refuted this argument by the statement that all material processes are three-dimensional and that the photochemical process in the retina is no exception. Therefore, the retina image has, like every picture, a certain thickness, and is by no means two-dimensional. It is only by an abstractive process that we give it in our mind a "vanishingly small thickness." I think that this materialistic argument of Schubert is more faulty than the original proposition of Zœllner. For, we have no direct knowledge of retina images; what we know about them is the product of inference and construction. A man could have the most perfect and accurate visual perceptions without knowing anything about eye and retina. What is directly given to us are extended sensations of light and color, and they are without doubt arranged in surfaces, that is two-dimensional. But Zœllner's proposition that our visual space is two-dimensional, because it consists of differently illuminated

* Hermann Schubert, the Fourth Dimension in *The Monist*, vol. iii., p. 433 fol.

and colored surfaces, is still wrong; not on account of Schubert's erroneous objection that we form our visual presentations according to our retina-images, and these are three-dimensional, but on account of the fact that the perception of surfaces implies already the third dimension. *For a surface can only be perceived as such from a point without it.* We cannot even imagine a surface without representing it as at a distance. The distance may be indefinite, as in the early visual perceptions of the child, but it is not equal to zero. If this was not so, if our visual space was really a plane (a curved surface would involve third dimension), we would require to think ourselves as *within this plane*, and then we would of course no longer be able to see parts of this plane as surfaces. What is acquired, gained by inference, in the course of experience, is not the third dimension, but the definite localization in it; and therein is the third dimension not different from the others. I think the very subject of the dispute between the nativistic and the genetic theory is not "space," but the "localization in space." For all attempts to derive space from something else than space have hitherto failed: either the problem was misunderstood or space was derived from something, which already implied space-relations. And I believe that all attempts of this kind will fail in future; for all our perceptions, presentations and conceptions, in short all states of consciousness, contain spatial relations, and deducing space from any of them is, therefore, arguing in a circle. Hence we have to say: Space, as a common property of all experience, is *a priori*; but all localization and quantitative relation in space is acquired in the course of experience. Whether or not it is justifiable to call the space, as it is given to us, three-dimensional, is a question of entirely different bearing; this question may occupy us in the next paragraph, in which we deal with the foundation of the conception of a fourth dimension.

II.

The scientific edifice of the fourth and higher dimensions rests entirely on the apparently evident proposition "that space, as it is given to us, has really three dimensions," and therewith on the definition of dimension. We shall within the limits of this paper not attempt to climb up to all attics and turrets of this scientific edifice, and to describe and measure its boldly curved arcs and enigmatic ornamental appendages, but we shall try to examine carefully and without prejudice the firmness of the ground on which it stands, *i.e.*, the alleged three-dimensionality of space, and the solidity of its corner stone, the definition of dimension.

There are two principal ways of speaking of dimensions: That of common sense, and that of the mathematicians. In common experience you will seldom hear the term dimension defined, and if it occurs we have to do with nothing but a mere verbal definition, as: "Dimension is a common expression for the three measurements, length, breadth and thickness"; or, "Dimensions are called the three extensions of space," or something of this nature. We do not need to dwell on these propositions, for it is obvious, as soon as we treat them as real definitions, we are arguing in a circle.

The mathematicians on the other hand seem to find it necessary to define dimension by terms which do not imply any reference to spatial quantities at all. But it could be disputed that we are ever able to think of any quantity without referring implicitly to space. Even purely numerical quantities imply spatial relations, for we cannot even think of two things, two points, without representing them as separated in space or time; and time itself, regarded as a quantity, cannot otherwise be represented or measured, than by expressing it in terms of space.

But besides this, even if we admit a definition which deduces dimension from time or from numerical quantities, we will find, that such a definition will either not differ essentially from that of a "variable," or it will prove itself untrue when applied to any spatial affair. The definition of the mathematicians who have dealt with this subject, although not always explicitly stated, amounts more or less to this: A system is one-dimensional, if the relations of any one of its elements to all the others can be expressed by a single number. Or, as Hermann Schubert expresses it:* "We call every totality or system of infinitely numerous things one-dimensional, in which one number is all that is requisite to determine and distinguish any particular one of these things amidst the entire totality." Correspondingly, a

* The above stated article, page 404.

system whose elements need for their determination two numbers will be a two-dimensional one, and so on, until an n-dimensional system which requires n numbers to express the determination of one of its elements. Now, I believe, that this kind of "Dimensions" has either nothing to do with space, or if applied to spatial affairs it will show itself to be wrong.

If the former is agreed upon, *i.e.*, if the mathematicians admit, that the term dimension in this connection does not mean anything spatial, we must ask why they introduced it, why they did not content themselves with the application of a term which has been for a long time in use, and which would suit the purpose just as well: I mean the term "Variable." Their one-dimensional system is then nothing but a totality, which can be represented by an expression with one variable; and an n-dimensional system would be that, which needs an expression with n variables for its representation. I do not wish to be misunderstood on this point. I am far from disputing the value of the wonderful works of so excellent and acute men as Gauss, Riemann and Helmholtz, but I claim that their results, in so far as it concerns expressions with more than three variables, do not bear any actual or verifiable relation to space. They could, on the other hand, have got just as far as they really did, if they had not introduced the term dimension, and if they had not thought of representing in terms of space anything that has more than three variables.

In the second case, *i.e.*, when it is not admitted that "higher dimensions" have no other relation to space than "higher variables" would have, I must show that the definition mentioned is actually wrong as soon as it is applied to spatial affairs. According to the above-mentioned article, a totality, the determination of whose elements requires two "numbers" is two-dimensional. Now imagine a celestial body, *e.g.*, a meteorite, moving in a straight line towards the earth, whilst the sun stands in the same line with the other two bodies (sun and earth may either be thought as standing still or as performing any movement in the same line as the meteorite's motion). Any position of the meteorite needs for its determination two numbers, one to measure the influence of the attraction of the sun, the other that of the earth. According to Schubert, the totality of its positions, *i.e.*, the straight line, is a two-dimensional magnitude. It is quite clear that the term dimension can here not mean the same thing which we ordinarily understand by it, or else the proposition is wrong. A movement in a straight line is always, from a spatial point of view, one-dimensional, no matter whether it has a uniform velocity or a constant or inconstant acceleration, and be analytically represented by a formula with one, several or n variables. On the other hand, there are geometrical forms which require for the determination of their elements but one number, and which could not well be called one-dimensional. When Schubert, *e.g.*, calls a circle or any curve which returns to itself, one-dimensional, it is obvious that this term can here not mean what we ordinarily understand by it, for geometrically these figures are certainly two-dimensional. He obviously does not mean here the curves as such, but the lengths in it without regard to their curvature. Any curvature whatever requires at least two dimensions. I think these examples may suffice in order to show that the attempt to deduce dimension from numerical quantities has proved a failure.

In order to approach a correct comprehension of the nature of "dimension," let us ask, first: Is it really true that space has three dimensions? In other words: Have we first the conception of a dimension, and then see that space contains three of them? I think we have from the very first the full space, which, although its quantitative determination or the definite localization in it developes in the course of experience, has those qualities which we are accustomed to call three-dimensional, from the very outset. In space, as it is given to us as the condition and common property for all experience, there are from every point an infinite number of directions, or straight lines possible. In all bodies or things, or parts of space, which we meet in reality or which we are able to construct in imagination, we can from any point of the interior, draw in an absolutely infinite number of directions straight lines which meet the limits of the body, *i.e.*, the surface. It is therefore not true to say things have a three-fold extension. Things are simply "extended," *i.e.*, they have a spatial magnitude in any direction which we may choose. If we speak of a line as representing only one (or a pair) of these directions, we abstract from the quantitative properties and interrelations of all the others, but not altogether from their relations to the one concerned. For a line is never an isolated one-dimensional magnitude, but always a *certain* direction *in the fully extended space.*

But for the sake of simplicity in our representations of experienced spatial quantities and our construction of any which are imagined as possible, we find it necessary to reduce the infinite number of possible directions to a confined number of them which have special properties and to which all others can be referred. We are fully at liberty concerning number and relations of the directions which we select as the skeleton for all our space-constructions. We could, *e.g.*, select the directions of the four diagonals of a cube, which would divide the whole space around a point in six perfectly equal four-sided pyramids. Or if we draw straight lines from the centre of a tetrahedron through its angular points, these lines, four in number, will stand in perfectly equal angular relations to one another (the angle between each pair of them being about 109° 30′). They divide the entire space into four parts, each of which has a solid angle of the value π. There are other sets of fundamental directions possible. The most important of them is that one in which the lines intersect at an angle of 90° and which divides the space around a point into eight equal parts with an angular value of $\frac{\pi}{2}$. This selection of fundamental directions possesses properties which make it especially convenient to serve as the scaffold for all our space-constructions, *i.e.*, as a system of coordinates. Consequently since the time of Descartes it has been generally preferred to all others, and a great many people, even mathematicians, have forgotten that it is, although the simplest and most convenient, not the only possible system of regular coordinates. In analytic geometry you find, concerning linear coordinates, besides the rectangular system, that of oblique coordinates treated. But scarcely any mention is made of the possibility of other regular coordinates. Consequently most people are inclined to think of the rectangular coordinates as *the* coordinate system, as if it was not only an artificially established means of reducing the manifold and complicated space-relations to modifications of a few simple relations, but as if it were the only possible means, directly founded in the very nature of things, and could not well be avoided. It is for the very same reason that uneducated people think that the decimal system of notation is the only possible one, although it owes its preference chiefly to the circumstance that we are provided with 2×5 fingers, and although it could very well be replaced by a system with the base 12, which would even leave greater play to the exact division by 2, 3, 4, and 6. It is for the very same reason, too, that even some of the most celebrated scientists do not see that the *possibility* of representing the whole manifoldness of color qualities by an expression with three variables does not involve the *necessity* to believe in the *existence* of *three fundamental colors.*

If we would agree to make the above-mentioned four lines in the tetrahedron our coordinates, we would have to speak of four dimensions. This system of coordinates would certainly be less practicable and less convenient than that which is now in use; but, nevertheless, it would do. And the disadvantage which it would carry with it in cases where we have to change the zero-point, would, to some extent, be counterbalanced by the advantage that it would allow us to escape from making the arbitrary determination of positive and negative directions. This leads me to another point which is not alogether insignificant. It is said, space is three-dimensional, because three known quantities (distances) determine the place of any point. This is not true, for, we need besides the three distances from the respective coordinate-planes a determination of the directions in which we count the coordinates positive and negative. As soon as we give up this arbitrary arrangement we need always at least *four* quantities to determine the place of a point. The position of a point in space is determined when its distance from four given points, not lying in the same plane, is known. Why do we then say space is three-dimensional? Should we not say in order to be correct: "Space is three-dimensional after the arbitrary decision about negative and positive directions, which have no corresponding equivalent in reality, is made?"

The circumversion through the second and third dimension assumes another aspect regarded from our standpoint. By circumversion of a line through the second dimension we really mean that the line is turned *in the shortest way through all the other directions* which are possible from that point of the line round which we turn. Similarly the circumversion of a plane figure through the third dimension is the rotation of the plane of which the figure is a part in the shortest way through all other possible planes. After having thus corrected the definition of circumversion, it may easily be seen that the application of this term to a fourth or higher dimensions is altogether impossible, or else we must introduce the expression "through other possible spaces" (*i.e.*, spaces different from our space), to which evidently no meaning whatever can be attached.

Further, when we define a plane as having two dimensions only and interpret this proposition in such a way that we assume that a plane could ever exist or be imagined without reference to the fully extended or three-dimensional space, we are wrong. If we see a plane or a surface we see it always in some (though perhaps indefinite) distance. And if we imagine a plane or a surface we do not really abstract entirely from the third dimension; we only neglect its quantity. A surface or a plane is therefore, speaking exactly, a part of three-dimensional space, with special reference to the limits (or boundaries) of the same, while neglecting all other quantities. Similarly we have to define "line" and "point." The latter definition will be rather complicated if we wish to escape the fallacy of which even so great a mathematician and philosopher as Descartes could become a victim, when he argued that the soul, being not extended, could not act upon the body as an extended part of the latter, and that therefore the inter-action between soul and body must take place at a "point."

After having shown in the foregoing that space and extension are only different names for the same thing, and that the three-dimensionality, *i.e.*, the reduction of all possible directions in space to the confined number of three directions with special qualities, is not so much a characteristic property of space as it is a particular means of simplifying our methods of viewing the complicated manifoldness of space relations, we believe the only justifiable definition of the term "Dimension" in its present meaning reads as follows: "*By dimensions we understand the three directions* (or straight lines) *which can be conceived as issuing from any point in space and intersecting each other at right angles.*" A fourth dimension would then be "*the fourth of the three directions* which intersect at right angles." But such a notion belongs to the same category as "the fourth angle of a triangle or the fifth side of a quadrilateral figure."

Thus the conception of a "fourth dimension," as well as that of "higher dimensions," as long as they are intended to designate anything with reference to spatial relations, are pseudo-conceptions, or illegitimately chosen terms which carry their contradiction in themselves.

The results of the foregoing discussion may be summarized in the following propositions:

1. The notion of a fourth dimension bears its contradiction in itself, for the term dimension in its present meaning implies tacitly that there are but *three*.

2. The terms "higher dimensions," and "multiply-extended magnitudes," as used by mathematicians, have no other relations to space than the terms "higher variables," and "multiply-variable magnitudes" would have. By the introduction of the term "*n* dimensions," nothing can be accomplished which could not be accomplished by the use of the expression "*n* variables."

3. Space is a constant property of consciousness; it is the form through which we are bound to view our world. We have no *knowledge* of an independently existing objective space. Exact science and philosophy can never deny the *possibility* of beings who are not bound to space. But, from the standpoint of exact science and philosophy, it must be emphasized that such higher, non-spatial beings *cannot stand to our spatial world in those relations*, which the spiritualistic adherents of the Fourth-Dimension Theory advocate.

HISTORY AND GROWTH OF THE DIFFERENTIAL CALCULUS.

By Miss A. Lick, '99

[Read before the Mathematical and Physical Society.]

In observing the growth of the Differential Calculus, the first trace recorded is in the "Method of Exhaustion," used by Archimedes, who lived during the third century, B.C. His writings show a most thorough acquaintance with all the work previously done in mathematics. Consequently, whatever may have been known of the Infinitesimal Calculus before this time, without doubt he had knowledge of it.

Reading the works of Archimedes, we notice that quadrature and cubature of curvilinear areas and solids bounded by curved surfaces, were his chief hobbies and the process which he most affects is exhaustion. This he handles with consummate mastery, and with it he obtains results for which we now look to the Infinitesimal Calculus. In his book on Spirals he points out the chief results of the treatise on Spirals, and concludes with a note that he has used the ordinary lemma of Euclid on which the method of exhaustion is founded.

His treatise on the Sphere and the Cylinder contains seven propositions bearing on the theory of exhaustion; for example, the sixth is, "a circle being given and also two unequal magnitudes, it is possible to describe about and within the circle two polygons, such that the circumscribed polygon shall have to the inscribed a less ratio than the greater given magnitude to the less."

The works of Archimedes and Apollonius, we are told, marked the most brilliant epoch of ancient Geometry. They may be regarded, moreover, as the origin and foundation of two questions which have occupied geometers at all periods. The greater part of their works are connected with these. The first of these two great questions is the quadrature of curvilinear figures, which gave rise to the Calculus of the infinite conceived and brought to perfection by Kepler, Cavalieri, Fermat, Leibnitz and Newton.

Of these Johann Kepler, whose career is said to have been accompanied with bad luck, lived from 1571-1630. He has been of much service in the "History" of the Infinitesimal Calculus. In his Stereometry, which was published in 1615, he determines the volumes of certain vessels and the areas of certain surfaces by means of Infinitesimals, instead of by the long and tedious method of exhaustions. These investigations, as well as those of 1604, arose from a dispute with a wine merchant as to the proper way of gauging the contents of a cask. This use of infinitesimals was objected to by Guldinus and other writers as inaccurate, but though the methods of Kepler are not altogether free from objection, he was substantially correct, and by applying the law of Continuity to infinitesimals he prepared the way for Cavalieri's method of indivisibles and the infinitesimal Calculus of Newton and Leibnitz. Cavalieri, who lived from 1598-1647, asserted in his early enunciation of the principles of indivisibles, that a line was made up of an infinite number of points (each without magnitude), a surface of an infinite number of lines (each without breadth), and a volume of an infinite number of surfaces (each without thickness). To meet the objection of Guldinus and others the statement was recast, and in its final form, as used by the mathematicians of the seventeenth century, it was published in 1647. The method of indivisibles is simply that any magnitude may be divided into an infinite number of small quantities which can be made to bear any required ratios one to the other. The analysis given by Cavalieri is very involved, chiefly in consequence of his limited power of summation.

Fermat who lived from 1601-1665, is said to have lived a life unruffled by any event which calls for special notice save a somewhat acrimonions dispute with Descartes on the validity of his analysis, which was chiefly due to the obscurity of Descartes, but the tact and courtesy of Fermat brought it to a friendly conclusion. His extant papers on infinitesimals deal however only with the application of infinitesimals to geometry; it seems probable that these papers are a revision of his original manuscripts (which he destroyed), and were written about 1663, but he was certainly in possession of the general idea of his method for finding maxima and minima as early as 1628 or 1629. Kepler had already remarked that the values of a function immediately adjacent to and on either side of a maximum (or minimum) value must be equal. Fermat applied this to a few examples. Thus to find the maximum value of x, namely $x-e$ where e is very small, he put $x\ (a-x)=(x-e)\ (a-x+e)$. Simplifying and ultimately putting $e=0$ he got $x=\frac{1}{2}a$. This value of x makes the given expression a maximum. The above is the principle of Fermat's method, but his analysis is more involved. He obtained the subtangent to the ellipse, cycloid, cissoid, conchoid and quadratrix by making the ordinates of the curve and a straight line the same for two points whose abscissæ were x and $x-e$; but there is nothing to indicate that he was aware that the process was general; and though in the course of his work he used the principle, it is probable that he never separated it, so to speak, from the symbols of the particular problem he was considering.

In his earliest papers the method of fluxions and fluents as devised by Newton, who lived from 1642-1727, is interesting, as being the form that the infinitesimal Calculus first took, and Newton's treatment of it is very similar to that which is now usual. A great deal of confusion has been caused by the English writers in the eighteenth century, who tried to alter the nomenclature, calling the infinitesimal increment a fluxion and denoting it by $\dot{x}$. Most of Newton's problems do not differ in principle from the examples which are to be found in our modern text-books. The fluxional or infinitesimal Calculus was invented by Newton in or before the year 1666, and circulated in manuscript amongst his friends in and after the year 1669, though no account of the method was printed till 1693.

The question as to whether the general idea of the Calculus was obtained by Leibnitz from Newton, or whether it was invented independently gave rise to a long and bitter controversy. There is no question that Newton used the method of fluxions as early as 1666, and that an account of it was communicated in manuscript to friends and pupils from and after 1669, but no description of it (other than what might be gathered from the Principia) was printed till 1693, some nine years after Leibnitz's account of his differential Calculus had been published.

Unless, therefore, a charge of bad faith can be established against Leibnitz, he is certainly entitled to the credit of having independently invented it, and in such a matter the presumption must be in favor of his good faith. Unfortunately, Leibnitz's good faith in the matter is open to question.

The facts are very briefly these. In 1705, Leibnitz wrote an anonymous review of Newton's tract on Quadrature, in which he made some remarks on Newton's method, for which it is admitted there was no authority or justification ; and amongst other statements implied that Newton had borrowed the idea of fluxional Calculus from him. This review, which was correctly attributed to Leibnitz, excited considerable indignation and led to an examination of the whole question. Till this time the statement of Leibnitz that he had discovered the Calculus later than Newton, but independently, had been generally accepted without examination. On now looking into the matter more closely this was doubted, and in 1708 John Keill, the Savilian Professor at Oxford, publicly accused Leibnitz of having derived the fundamental ideas of his Calculus from papers by Newton which had been communicated to him through Collins and Oldenburg, and having only changed the notation and the name. After an acrimonious controversy, Leibnitz appealed to the Royal Society to compel Keill to withdraw the accusation. Newton now investigated the matter himself. There is no doubt that he was convinced that the charge was true ; and in April he made a speech to the Society giving a complete history of the affair. A letter from Keill dated May, written to Leibnitz by order of the Society, is an abstract of it. Leibnitz in his reply in December asked the Society to adjudicate the matter ; and a committee was accordingly appointed to look into it. They reported four months later, and decided that Keill's charge was substantiated. Leibnitz was not represented before the committee, and they had no opportunity of hearing any explanation he could have offered.

Writers agree in saying that it shows a marked bias in favor of Newton, but it hardly needs so much labor to prove that the report of a committee which only heard one side is not impartial. Leibnitz now sought for some other way of vindicating himself, and he appealed to John Bernoulli. Bernoulli, who disliked Newton and detested his philosophy, eargerly seized the opportunity; and in his reply stated that Newton had not so much as thought of fluxions before the differential Calculus was invented, and was ignorant of how to take a fluxion of a fluxion when he wrote the Principia. However, the matter occupies a place in the history of the subject which is quite disproportionate to its true importance.

If we must confine ourselves to one system of notation then there can be no doubt that that which was invented by Leibnitz is better fitted for most of the purposes to which the infinitesimal Calculus is applied than that of fluxions, and for some it is indeed almost essential. It should, however, be remembered that at the beginning of the eighteenth century the methods of the infinitesimal Calculus had not been systematized, and either notation was equally good. The development of that Calculus was the main work of the mathematicians of the first half of the eighteenth century. The application of it by Euler, Lagrange and Laplace to the principles of mechanics laid down in the Principia was the great achievement of the last half of that century, and finally demonstrated the superiority of the differential to the fluxional Calculus. The translation of the Principia into the language of modern analysis and the filling in of these details of the Newtonian theory by the aid of that analysis was effected by Laplace.

Leibnitz lived from 1646-1716. His early life was marked with difficulties, but his industry overcame all his difficulties. He was called to Paris to explain the details of a scheme to offer German co-operation. While here he met a gentleman from whom he learned the pleasure of the study of mathematics, which he described as opening a new world to him. The only papers of first rate importance which he produced are those on the differential Calculus. The earliest of these was one published in October, 1684, in which he enunciated a general method for finding maxima and minima. One inverse problem, namely to find the curve whose subtangent is constant, was also discussed. The notation is the same as that with which we are familiar, and the differential coefficients x^n and of products and quotients are determined. In 1686, he wrote a paper on the principles of the New Calculus. In both of these papers the principle of continuity is explicitly assumed, while his treatment of the subject is based on the use of infinitesimals and not on that of the limiting value of ratios. In answer to some objections which were raised, in 1694, by those who asserted that $\frac{dy}{dx}$ stood for an unmeaning quantity like $\frac{0}{0}$, Leibnitz explained that the value of $\frac{dy}{dx}$ in Geometry could be expressed as the ratio of two finite quantities. Leibnitz's statement of the objects and methods of the Infinitesimal Calculus, as contained in these papers, which are the three most important memoirs on it that he produced, are not as able as those given by Newton, and his attempt to place the subject on a metaphysical basis did not tend to clearness; but the notation he introduced is superior to that of Newton, and the fact that all the results of modern time are expressed in the language invented by Leibnitz has proved the best monument to his work.

Leibnitz was only one amongst several continental writers whose papers in the *Acta Eruditorium* familiarized mathematicians with the use of the differential Calculus. James Bernoulli was one of the earliest to realize how powerful as an instrument of analysis was the differential Calculus, and he applied it to several problems, but he did not himself invent any new processes. In 1698, he published an essay on the differential Calculus which contains numerous applications to Geometry. On the continent, under John Bernoulli, the Calculus had become an instrument of great analytical power expressed in an admirable notation—and for practical application it is impossible to overestimate the value of the good notation—but the continental school had confined themselves almost entirely to obtaining a thorough knowledge of the differential Calculus without considering the uses to which it could be put.

The first text-book on the differential Calculus which has any claim to be both complete and accurate, and on which it may be said all modern treatises on the subject are based, was published in 1755. Of the more modern composers, Cauchy and De Morgan have written treatises. The latter, published in 1842, is a work of the highest ability.

The controversy with Leibnitz was regarded in England as an attempt by foreigners to defraud Newton of the credit of his invention, and the question was complicated on both sides by national jealousies. It was, therefore, natural, though it was unfortunate, that the geometrical and fluxional methods as used by Newton, were alone studied and employed at Cambridge. The consequence was that, in spite of the brilliant band of scholars formed by Newton, the improvement of the method of analysis was almost wholly effected on the continent; and it was not until about 1820 that, under the influence of Babbage, Peacock and Herschel, the value of the differential Calculus was recognized at Cambridge. The introduction of the notation of the differential Calculus into England was due to these three undergraduates at Cambridge—two of whom died in 1871, and the other in 1888. These three men founded the "Analytical Society," which Babbage explained was to advocate "the principles of pure deism as opposed to the dotage of the University." In 1816, the society published a translation of La Croix's differential Calculus, which was followed in 1820 by two volumes of examples. All elementary works on this subject since published have abandoned the exclusive use of the fluxional notation.

Special note, in concluding, of Herschel, the elder of the trio at Cambridge. It was while an undergraduate there that he made the acquaintance of Babbage and Peacock. With youthful enthusiasm he proposed that they should enter into a compact to "do their best to leave the world wiser than they found it," and the introduction of the differential Calculus into the University Curriculum was proposed by his two friends as the first test of their sincerity.

ELECTRICAL RESISTANCE.

By W. Reuben Carr, '96.

[Read before the Mathematical and Physical Society.]

In view of the many interested in this subject, who have had no opportunity either in the lecture room or the laboratories of as close an acquaintance with this part of the Department of Physics as may enable them at once to understand the force of the term, I beg to be allowed to make a very brief, and I fear inadequate, explanation of the meaning of the word Resistance as applied to electricity.

When water is drained from a tank by a tube 1 inch in diameter, a known volume passes out in a known time. If this tube be replaced by a larger one (say 2 inches in diam.) in exactly the same position, the quantity of water carried off in the same time is increased in the ratio of the areas of the cross-sections of the tubes, and we say the *resistance* of the smaller is greater than that of the larger tube.

If now an apparatus could be contrived by means of which the current of water would do work (as in the case of an ideal water-wheel, where every drop of water would be utilized), the amount of work done would depend on the volume of water, and would vary therefore as the cross-section of the stream. But the amount of work done must vary inversely as the resistance offered to the accomplishment of that work, and from this we can conclude that the resistance offered varies inversely as the cross-section of the conducting tube.

With an electric current, the tube being replaced by a conducting wire, experiment has shown, as in the case of the water current, the resistance offered by the wire to the passage of a current along it, to vary inversely as the area of the cross-section of that wire.

Experiment also shows that the resistance varies *directly* as the *length* of the conductor, thus giving us two immutable laws under like conditions of temperature. These, we may call for convenience the Relative Laws of Resistance, to distinguish them from the more general laws which I purpose dealing with at greater length, and which can probably be no more lucidly expressed than in the words of the famous Clerk Maxwell.

(1) The Electrical Resistance of a conductor is independent of the strength of the current passing through it.

(2) Resistance is independent of the Elec. Potential at which the current is maintained, and of the density of distribution of electricity on the surface of the conductor.

(3) *It depends entirely on the nature of the material of which the conductor is composed, on the state of aggregation of its parts, and on its temperature.*

To the last law alone I am going now to draw your special attention, and quoting from the most recent experiments will show that in the case of pure metals, a marked, almost incredible, change in resistance accompanies the raising or lowering of the temperature. With alloys we shall see that the difference is not so great; while with non-metals, the experiments being incomplete, only a supposition is made as to the real issue of the investigations.

It is only within recent years that the subject seems to have received sufficient attention to produce satisfactory results. In 1885, MM. Caillelet and Bouty made observations on the resistance and resistance changes of various metals at $-100°$ C., by the employment of liquid ethlene as the cooling agent, and in the same year Wroblewski measured the resistance of wires of electrolytic copper at temperatures varying from 100° C., to $-100°$ C.

More recent experiments have been performed by Prof. Dewar of the Chemical Department in the Royal Institute and Prof. Fleming of University College, London; and many of the statements in these pages have been copied from their investigated results published in the *Phil. Magazine* of 1892-3.

Their method of working was somewhat as follows: A number of small resistance coils were prepared by taking strips of mica about 5 c.m. long and 1 or 2 c.m. wide, around which wires were coiled, being held in place by notches in the edges of the metal strip. The ends of these wires were connected with two others of larger cross-section, formed of high-conductivity copper, well insulated with india-rubber, and having their extremities curved downwards so as to bury themselves in a cup of mercury. The small resistance coil so formed could then be lowered into a test-tube filled with liquid gas or other fluid, by means of which the temperature of the wire was determined.

The majority of the wires used had a length of from 50 to 100 cms. and diameter of .003 in. The resistance was measured by means of a Wheatstone bridge. The wires used were as pure as they could be obtained, the gold being 999.9 degrees fine. In the following results, I have purposely picked out the metals which showed the greatest difference in resistance, though in almost every case a very large change was observed. The results are expressed in electro magnetic units (Ohms).

Platinum	Temp.		100°	0°	−219°	6 :1
	Res.		14814	10950	2439	
Nickel	Temp.		192°	1°.35−	−197	16 :1
	Res.		29730	12402	1908	
Gold	Temp.	194°	90°	1°.05−	−197°	6 :1
	Res.	3992	2941	2200	681	
Commercial Aluminium	Temp.		190°	1°	−219°	15 :1
	Res.		4898	2683	324	

If these specific resistances be graphically represented by a series of curves, taking the absolute temperature as the zero point, we find that all the lines of resistance are more or less curved, tending in their downward course in such a direction as to show that if extended below −200° C., they would probably pass through the origin or very near it. These curves of resistance can be divided into three classes : (1) Those representing metals such as iron, nickel, tin, and perhaps copper, which are concave upwards ; (2) those representing metals such as gold, platinum and pallădium, which are concave downwards ; (3) those representing metals such as aluminium, which are apparently straight lines.

In the case of metals of the first class, the resistance changes with the temperature in such a way that the *rate* of change of resistance with temperature *in*creases as the temperature *in*creases ; in other words the second differential of resistance with respect to temperatare is positive. In the case of a metal of the second class, the second differential with respect to temperature, is negative; that is, as the temperature *in*creases, the *rate* of change of resistance with respect to temperature *de*creases.

The most interesting fact which these experiments have brought to light, is the enormous decrease in specific resistance offered by the perfectly pure metals when cooled to very low temperatures. For instance, the resistance of a given pure iron wire at $-197°$ C. is only $\frac{1}{23}$ of its resistance at $100°$ C. For pure copper the resistance is about as 1 to 11 between the same limits of temperature. Strangely enough the very smallest impurity greatly checks the decrease. Some nickel wire *supposed* to be pure changed only from 13387 at 0° to 6739 at $-182°$ C., or from 2 to 1; but when a piece *absolutely* pure was obtained, the change was from 12000 at 0° to 1900 at $-162°$, or rather more than 6 to 1, showing the decrease with the pure metal to be three times as great as in the case where it was *almost* pure.

A fact, which may be worthy of your notice, is that generally the best conductors among metals are those which are most sonorous. Silver, aluminium, gold and copper would make good bells; while lead, thālium, tin and pallădium, which are poor conductors, would be quite unsuitable for that purpose.

An examination was also made of a large number of alloys of known composition, and the curves are shown as in the case of pure metals.

Platinum Silver..........	Temp.	93°.25	1°.85	−197°.1
	Res.	32296	31573	30173
Gold Silver.................	Temp.	91°.65	0°.9	−197°.1
	Res	6997	6293	4817
Manganese Steel..........	Temp.	89°.9	1°.0	−1970°.1
	Res.	75294	67222	55414

The figure shows the resistance lines in this case to be nearly straight and almost vertical, indicating a very small change in resistance with changes in temperature. It was found, however, that when the constituent parts of the alloy are chemically similar the resistance lines are much steeper; still they never incline in such a manner as to lead one to suppose that if continued downwards they would come near the absolute zero, but tend rather to correspond to the resistance lines of impure metals.

In two cases at least irregularities were noted. The resistance of the alloy manganese steel, like the other alloys, was represented by an approximately straight line from the higher temperature down to about $-40°$ C. At this point the resistance line takes a decided turn downwards and again follows a straight course to the lowest temperature.

But the most unexpected was the variation in the resistance of manganin, what was proven to be a maximum at about 16° C., gradually decreasing as the temperature was either lowered or raised. Thus the curve representing manganin has both its extremities tending towards the abscissa.

It is very interesting too to notice the effects of the various constituent elements in the alloys. An admixture of 6% silver with aluminium has a much greater effect in changing the resistance than the same percentage of copper; whilst 3% of aluminium has a greater effect still in changing the resistance of copper.

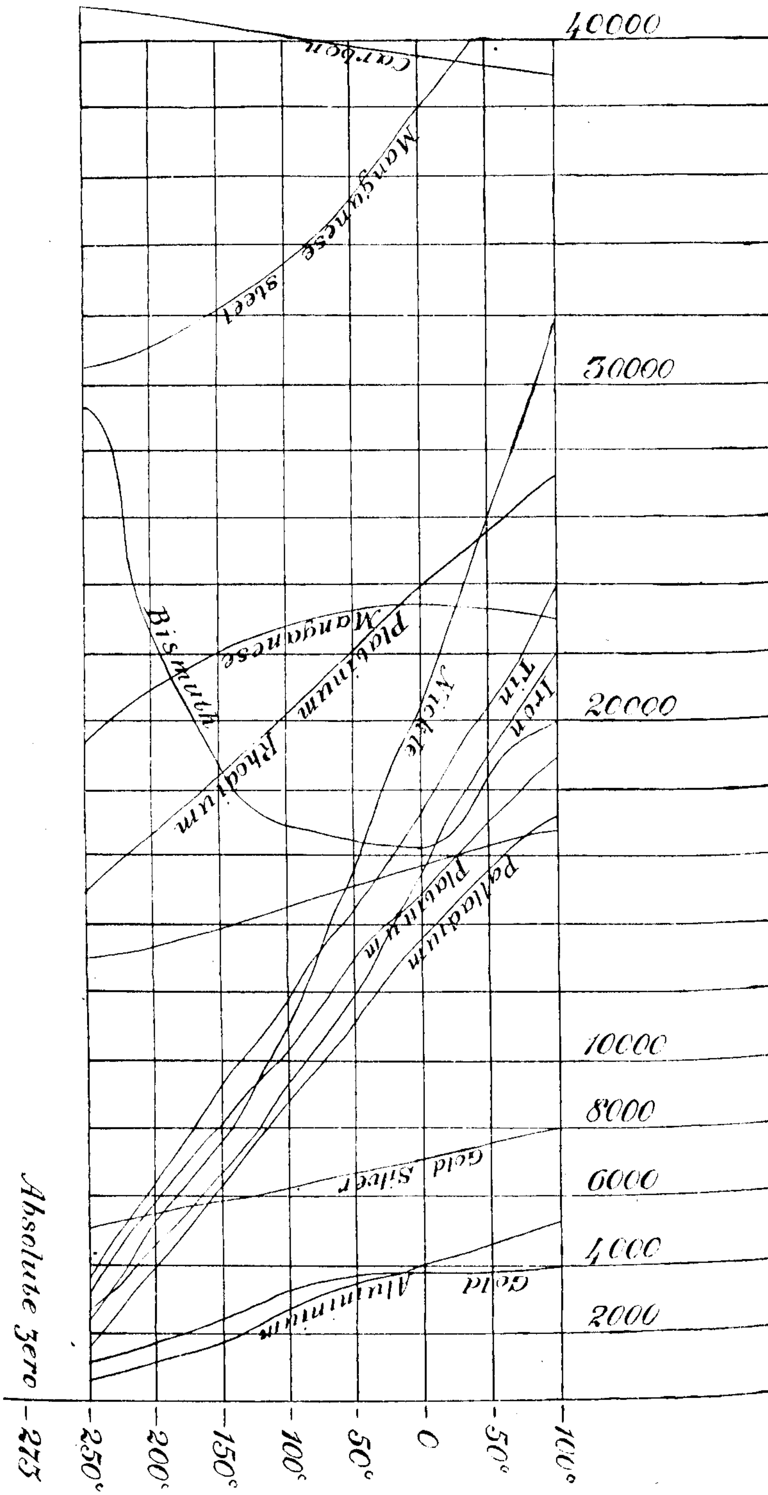
The examination at similarly low temperatures of the change in resistance of non-metals has not yet been completed. It is certainly known, however, that contrary to the action of pure metals and even alloys, the resistance constantly decreases with a rise in temperature; and Professors Dewar and Fleming in their closing paragraph give it as their opinion that for such bodies we may ultimately find a maximum elec. resistance, and that it may prove that non-metals approach a maximum and metals a minimum as the absolute zero is reached.

In a later paper (Sept., 1895), these same gentlemen give the result of their experiment with the metal bismuth. The curve of resistance has not been plotted by them, and I have taken the liberty of hurriedly adding to their diagram what I have deemed a fair representation of the resistance line.

In this metal the resistance was found to waver, sometimes increasing sometimes diminishing. At 96° R=202550, at 50° R=164750, at 234° R=294300, where it either remains or more probably tends again toward the abscissa.

I shall only keep you longer to mention the puzzling results which were the outcome of the investigations in the case of carbon, which substance above all others, perhaps, during these exhaustive experiments edged the already keen interest of these distinguished investigators. It was found that, though generally supposed to be an *element*, and as such destined to follow the laws governing metals, the resistance of carbon continually decreased with a rise in temperature through the whole range of experiments, thus following the law of a *compound* and adding weight to the long-entertained suspicion that when the combined knowledge of centuries has done its utmost, when the master minds among chemists fail to elicit anything like satisfactory results, when defeats and discouragements meet every advance, the baffled and disheartened investigator *must* turn to the Physicist for an explanation of his difficulties.

It remains, to some extent, with us, as a Mathematical and Physical Society, to see that the call for assistance is not made in vain. We may not win immortality, but each of us can do something in this glorious department of study towards pushing a little deeper into the depths of undiscovered treasure. Let each of us labor, not in fear of the approaching examinations, but from pure love of his work; and who can say that the efforts of our Alma Mater may not in the near future be rewarded by the production of men as great as Newton or as fortunate as Roentgen.


40000
30000
20000
10000
8000
6000
4000
2000
Carbon
Manganese steel
Bismuth
Manganese
Platinum Rhodium
Nickle
Tin
Iron
Platinum
Palladium
Gold Silver
Aluminium
Gold
Absolute zero
-275
-250°
-200°
-150°
-100°
-50°
0
50°
100°