period 4 seconds or quarter period 1 second we have the following values of $\alpha$:—

| | | | |
|---|---|---|---|
| $\alpha$ | = | 1 | 10 / 6 | 2 |
| $\theta / \theta'$ | = | 0.632 | 0.774 | 0.810 |

The middle one of these values corresponds to the ring discussed above when the resistance is one ohm. In these three cases the maximum deflection is reached after 1.54 seconds, 1.45 seconds and 1.40 seconds from the time when the e. m. f. is applied to or removed from the circuit. The conditions here taken may be considered extreme in so far as the period of the needle is concerned, but it is not difficult to find examples of actual measurements in which the period has been equally short.

The examples here given are probably sufficient to direct attention to the care that must be taken in the choice of apparatus and the arrangements of circuits when the ballistic galvanometer is used in magnetic measurements. The method is only applicable when $\alpha$ is so large that $\theta$ and $\theta'$ are practically equal to each other and this condition is approximated to by making R large and L as small as possible. Hence, high e. m. f. s. should be used with high non-inductive resistance in the circuit and magnetic force should be secured with small numbers of turns by using large currents. It is well always when comparing charge with discharge to keep the induction of the circuit the same in both cases by means of an apparatus which cuts out the battery and at the same time keeps the circuit closed through an equal resistance, instead of breaking the circuit when the discharge is measured. A check on the accuracy of the observations in any particular case may be obtained by observing the successive extreme deflection of the needle. If the first deflection has the proper magnitude the mean ordinate of the curves drawn through the extreme deflections to opposite sides of zero should be at all points zero. When the duration of the current is a large fraction of the time of swing of the needle the mean of the deflections to opposite sides will lie for the first few swings on the same side of zero as the initial deflection.

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## *THE SCIENTIFIC METHOD AND MODERN INTELLECTUAL LIFE.*

SCIENCE, as a necessary term, is possibly upon the verge of obsolescence. Within the last half-century it has spread the mantle of its meaning over almost every department of thought until to-day knowledge and science are perceived to be so nearly coextensive that the newer term might rightly yield to the priority of the older. While twenty-five years ago one heard much about science and the languages as rival claimants for place in the college curriculum, one now listens to the message of that useful *science*, classical philology. Then the polemic between science and religion seemed earnest indeed; now theologians and laymen are alike shocked when Mr. Benjamin Kidd suggests that there can not be a science of religion. Antithesis has softened into synonymy. It is not that the lion of science has devoured the lambs of art, literature and philosophy; it is rather that systematists of opinions and beliefs have determined a generic unity where before variety was supposed eternally to exist. Such condition has arisen, it may be presumed, from the prevalence at least among Western nations of what has come to be denominated the scientific method. This prevalence is not yet universality. It does not yet extend in full measure to every individual; nor does it, perhaps, persistently characterize the intellectual life of any man at the present time. The atavism of superstition must somewhere mar the image and superscription of one's intellectual inheritance. Nevertheless, so widespread and so dominant

everywhere is this scientific method that in a broad sense it might be accorded universality. It becomes, then, an important matter to discover, if one can, what effects upon the intellectual life, not only of the individual, but of society in general, are resulting from the method now and will develop in the future.

It is possible to define science as that orderly mass of facts and hypotheses within experience by which we criticise our primitive ideas. Social, not merely individual, experience and the broader implication of criticism are intended. The scientific method is therefore that intellectual process by which facts are recognized, accumulated and arranged, hypotheses framed, tested and exploited and conclusions drawn, verified, accepted and applied where they may seem best to fulfil their function in the enginery of social progress. It would be an error to suppose that any clear demarcation exists between knowledge that is scientific and other knowledge that is not; nor can one, search as he will, discover the birth-place or learn the natal day of the scientific method. As Dr. Osborn has shown, from the Greeks to Darwin there exists a continuity of speculative evolution. Bacon was not the first to make use of induction. Franklin did not discover electricity, nor Lamarck the impermanence of species. Everywhere the older phases of thought merge into the newer, much as one picture seems to follow another in the cunningly presented dissolving views or phantasmagoria of the stage. Yet it will scarcely be gainsaid that while yesterday the scientific method was indeterminate and sporadic, to-day it is definite, characteristic of most that is valuable in thought and in a sense universal.

Carrying farther the definitions which are so useful if one desires to make one's meaning plain, it will appear that the intellectual life is a concept that has enlarged, imperceptibly at first, but surely during these later days. When one sees the phrase in type one does not stop with Hamerton. Insensibly the meaning of the word *life* has expanded in the minds of thoughtful men until the limits of individualism are instinctively transcended and the instant idea is of the greater social, not of the lesser individual organism. No more impressive evidence of an onward movement in thought could be offered, no more conclusive demonstration of some welding, humanizing force unconsciously at work generalizing and extending the point of view. The intellectual life is seen to be not merely an efflorescence of culture; it is not the knowing of the best that has been said and written in the history of the world; it is not the peace of introspective calm, nor serenity in a delightful oasis amid the desert sands of a crass and insentient materialism; it is a strenuous, an austere exertion of those high human powers that command the world of things for the world of thought. Culture, essentially individualistic, is not the concretely social and dynamic intellectual life. It is true one must not altogether forget the traditional meaning of the phrase, but that traditional meaning is after all suggestive principally as a vestigial character. Its peculiar interest lies in the fact that it has been outgrown.

Having indicated the content of such phrases as *intellectual life* and *scientific method*, it remains to show briefly how the latter in its slow but massive development has influenced the former, or rather how the two have unfolded themselves in unison. In the course of the examination, it will perhaps become apparent that the larger modern implication of such a phrase as *intellectual life* is due, above all, to precisely such influences as have been brought to bear upon the texture of society by the progressively larger, though in great part unconscious, activity of what has been termed the scientific method.

Noting first the evident contact points,

especially in pedagogics, between the scientific method and the intellectual life of the individual, one cannot but reaffirm in the light of experience what has long been maintained by those who advocate the fundamental position of science in every educational system. In the domain of reason, breadth, grasp and clarity are developed as under no other discipline. Sanity in emotion is secured, and vigor, together with modesty and a reasonable deliberation, tends to distinguish the active life of the man who has brought himself into what may be styled a scientific frame of mind. The accumulation of any mass of facts, if the search be tireless, must stimulate the growth of a certain cosmopolitanism. The Scarabean doubtless found more foreign letters in his mail than did the Autocrat. When one goes farther and attempts an induction or an hypothesis he must hold firmly the facts he has, his eye must be unclouded, his step steady, or he will fail. Still more certainly will his office remain an humble one if, when he ventures to make known to others his discoveries or conclusions, he want in transparency and precision. Nor will the man whose life is truly illuminated by the sun of science lack somewhat of self-control; under less favorable conditions this equipoise may take the guise of unenthusiasm, but at its best it is activity —sympathic, tolerant, enlightened. Such being their recognized educational productivity, the so-called sciences have taken masterful positions in the schools of Europe and America. It will not be necessary here to point out in detail the precise pedagogic adaptability and the importance of the various sciences in a general educational scheme; it will suffice to inquire whether it be not true that whatever branch of learning popularly classed outside of the sciences maintains itself in school curricula, it does so by virtue of the scientific method being possible in its presentation.

Although clearly not so fundamental in their effect upon the individual character as must be these simple reactions where the scientific method is brought into an alembic with nascent intellect, there are some relatively subtle yet far-reaching influences that should not be overlooked. From a number that might be chosen I will bring forward three. A just appreciation and personal application of the scientific method tends to discourage introspective and metaphysical habits of thought, to counteract the insidious pessimism with which so much of modern life is tinged, and to impel one unmistakably toward a rational and sober altruism. I would not be understood to regard metaphysics as altogether pernicious. At its worst it may be as Walter Pater thought it, 'the art of methodically muddling one's self,' but it has its place and its mission. Yet there is an individualistic and almost a selfish tendency in much of what passes for philosophy. One need not pursue the thorny path of dialectics to the end that one denies the existence of all but himself. Whatever intellectual attitude demands, an attentive scrutiny of one's own mental, moral or physical mechanism can not but be self-centered. For this reason, if for no other, the failure of deductive philosophy to carry its influence beyond the lecture room or seminarium might easily have been predicated in advance. The student of the history of philosophy is scarcely more impressed by the cumulative intricacy of philosophic speculation than by its progressive futility as a guide in the every-day affairs of life. Employment of the scientific method discourages on the whole that naive self-inspection which was the badge of the older intellectual *cultus*, just as on the other hand it lends encouragement to the open-eyed, outward searchings of the modern investigator. This objectivity, whether or not it be an indication of intellectual maturity in a nation, is distinctly charac-

teristic of modern Occidental civilization in no less degree than the reverse condition is supposed to mould the thought and life of the Orient. Such objectivity—not without the stigma of materialism—seems to result from the general prevalence of the scientific methods in contemporaneous thought.

If it be protested that the scientific method is blighting in its tendency to suppress metaphysics, not so certain objections will be made to its efficiency as a counterfoil against philosophic pessimism. Whether one professes with Schopenhauer to believe that this is the worst possible world, or joins von Hartmann in that more dismal suggestion that this is the best possible world, but not worth living in; whether one sigh with De Musset, weep with LeConte de Lisle, or rave with Baudelaire, one must give the sanction in so doing to existence, and if to existence then to evolution, by which such existence became possible, and if to evolution then to progress. Therefore, if we have the scientific spirit two escapes are possible from the darkness of pessimism—superficially by occupying one's self with some scientific protocol, or more profoundly by turning one's despairing thoughts aside in the recognition of an indwelling power in the social organism which makes, if not for righteousness, at least for social evolution. If under the leadership of the scientific method one can actually grasp the form of truth there is in positivism; if one can really feel the existence of a social organism and listen to his ideals as did Comte, believing them to be the sealed orders of humanity; if one can learn with Weismann to know the profound sense in which all men are brothers, *for all men are one*, it will make little odds to him whether he be shown with most convincing logic that the constitution of the nervous system makes pain the positive and pleasure the negative and that death is merely an acquired physiological trait useful to insure the permanence of the species at the zenith of its youth and power. But after all, perhaps the most fatal blow that the scientific method strikes to pessimism is, as argued above, in its settled antagonism to introspection. For pessimism as an ethical and metaphysical system is based peculiarly upon self-observation. A man does not despair of the world from what he sees around him, but from what he sees in the secret places of his own heart. By its discouragement of morbid subjectivity the scientific method cuts the very foundation from under the philosophic pessimist.

We are led then to the third postulate—that the scientific method impels us unmistakably toward a rational and sober altruism. This indeed links itself inseparably with the others. If defective this type of altruism is defective in fire and in enthusiasm. Domination by the calm reasonableness of the inductive philosophy does not stimulate one to take up the tambourines and drums of the Salvation Army. He who has ordered his mental processes in accordance with a scientific method is inclined to prefer the charity organization to personal alms-giving; he shrinks a little from the zeal of the social reformer; he is unlikely to be a poet in literature, a rhapsodist in music or a revivalist in religion. He is rather to be sought among the rank and file of the great, silent army which is behind every reform as 'public sentiment' or as the 'moral sense of the community.' But as has been pointed out elsewhere this quiet acquiescence is a necessary factor in social reform, just as underneath every successful revolution there has been a subtile and tacit confession of faultiness in the established order by the very party that storms barricades in the struggle for its maintenance. To sum it up in a word, under the scientific method men may not be so ready to conquer rights and privileges for others, but they are prepared unflinchingly to con-

cede such rights when the request has come with authority.

From this point the transition is easy to the consideration of what influence the scientific method may exert in a general way upon society as a whole. There is not space in the compass of a review article to discuss adequately a matter of so many complications, but it is possible to offer a syllabus for reflection. It must first of all be kept in mind that *world-wideness* is in the fabric of all sceince. Since induction is objective, the scientific method is cosmopolitan. The humble describer of a new species of butterfly must have passed, in orderly fashion, all the butterflies of the earth before his mind ere he ventures to set his own over against the rest as new. The question of the German University laboratory—'Was haben Sie neues gefunden?'—presupposes a knowledge of what the world has done before. This characteristic of the scientific method cannot be too strongly emphasized. What then must be the natural reflex of the method upon social institutions?

Science has bound the world together by its spirit no less than by its discoveries. Interest in others would make communication easy even if the telegraph did not exist. Sympathy is a stronger cable than those that lie along the bottom of the Atlantic. Hence in every region of human intellectual activity one traces the broadening influence of the scientific method. In politics, democracy; in warfare, humanity; in commerce, freedom; in art and in literature, realism; in all the social relations of life, kindliness and charity; in religion, tolerance and dynamic helpfulness—these are the children of this scientific method. Perhaps nowhere better than in the field of religion has the change to the new order made itself felt. Religion is to-day recognized as social rather than as individual. Faith is blended in works, and in place of a pitiful solicitude for the welfare of one's own immortal soul there has been developed a missionary spirit, boundless in its self-sacrifice, a magnificient phenomenon of altruism. It is very remarkable when comparing theological literature of say the Oxford Tractarian movement with that of the present decade, such as the discourses of Washington Gladden or the Unitarian writings of Martineau, to note that the essential difference between the two groups is that in the former everything is discrete and individualistic in tone, while in the latter everything is concrete and social. Under the stress of the scientific method, sanctity has seemed second to helpfulness, just as individual culture has seemed a less noble end than social progress.

On the whole the influence of the scientific method upon society is two-fold. Statically it has added organizability to the social character, and by virtue of this it has dynamically contributed to the advance in social progress. The influence mentioned upon character could scarcely strike more profoundly, for the capacity to take part in organization is possibly the most important trait of all in social character. Precisely as organization becomes most perfect will progress be most rapid. And here one perceives that a veritable intellectual sanction for progress is to be sought. The author of *Social Evolution* has denied that such sanction exists, but apparently without taking into account the very method by which he arrived at this conclusion. There is quite as strong an instinctive quality in science as in religion. Each takes progress for granted, each in its own field contributes to the advance, and in so doing each gives its sanction to the movement. Since progress lies principally within the realm of the social organism, its sanctions are social rather than individual. And the error has been in failing to perceive the strong social nature of a certain type of intellection

and in assuming the metaphysical or introspective type to be the only one worthy of consideration. In the phrase 'devotees of science' there is a gleam of true meaning, for in its social quality, its instinctiveness, science is akin to religion. One might term science an intellectual religion and not go wide of the mark. While it may be argued that philosophy in the traditional sense does not sanction progress, it cannot be argued that science withholds either sanction or its encouragement. Science is social thought reflected back into the mind of individuals; metaphysics is individual thought radiated outward upon society. The sanction for social progress is therefore derived rather from society as a whole than from individual introspection. For this reason the intellectual sanction is all the more forceful and takes its place beside the moral sanction offered by religion. There need then be no fear that progress is intrinsically irrational, and there may be a science of religion, as there is a religion of science. It is the function of the scientific method to organize for victorious contest the battalions of the intellect, while religion may bring on the moral forces. Therefore it appears that progress is an open-minded movement onward, of which we are all a part, and to which reason, under the sway of the scientific method, gives sanction no less than does emotion.

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*THE LIQUEFACTION OF GASES.—A CONTROVERSY.*

The scientific world has been treated during the last few weeks to one of those happily to-day rather infrequent controversies which are always unseemly, the more so when the parties are men of eminent scientific reputation. Polemics in science may sometimes be entertaining, but are always unprofitable and tend to bring discredit upon the participants, if not on their work. The recent discussion* on the subject of liquefaction of gases is no exception to the rule.

Prof. Dewar, in defending his failure to give Prof. Olszewski due credit, has made what might have been looked on as a pardonable omission appear almost as intentional deceit. In taking up the cudgels in Prof. Olszewski's defense, Professor Muir has seemed to make an unjust and almost spiteful attack upon Professor Dewar; while Professor Olszewski, whose work was already too well and favorably known to need any defense, has added nothing to his reputation; indeed, he has rather laid himself open to the charge he prefers against Professor Dewar, inasmuch as in his article in the Engineering and Mining Journal he makes but slighting reference to the work of Pictet and Cailletet, and the name of Wróblewski is but once, and that incidentally, mentioned. The following is a summary of the more important work of these investigators in this field:

In 1877 two independent experimenters almost simultaneously succeeded in condensing to liquids the so-called permanent gases. Cailletet, the French ironmaster at Chantillon-sur-Seine, used a hydraulic press, and obtained the necessary lowering of temperature by suddenly diminishing the pressure on the compressed gas. A mist appears in the glass tube containing the gas, and, except in the case of hydrogen, condenses to small drops. Pictet, at Geneva, used the pressure occasioned by the generation of the gas in wrought iron cylinders, and cooled his steel condensing tube with liquid carbon dioxid. In experimenting with hydrogen, Pictet obtained an opaque steel blue liquid, which appeared to solidify

*On the Liquefaction of Gases. Charles Olszewski, James Dewar, M. M. Pattison Muir, *Nature*, Jan. 10, 1895, and following numbers. Letters to the Editor. Also in *The Philosophical Magazine.*