PLATONISM AND THE HISTORY OF SCIENCE

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Humanists, when admitted to the fellowship of scientific men, claim that they too are investigators and are trying to discover unknown truth by the exact methods of science.

This is not the occasion for controversy. And I have no wish to disparage that aspect of the so-called Geisteswissenschaften. But I do not think that it is the chief service of humanism. The term science cannot be used here in the sense in which it applies to physics and chemistry, for the simple reason that there is less possibility of verification and less progress. You cannot test in the laboratory the opinions of a scholar about the return of the Heracleidæ or the Platonic philosophy. They may be estimated by fashion, by his general reputation, his skill in self-advertisement, or at best, by the verdict of a dozen or score of possibly jealous experts dispersed through the world. And though we talk of progress in classical studies, and there are of course new discoveries in archæology, the value of a classical text, essay or book, depends much more on the personal scholarship, good sense and literary taste of the writer than on the fact that he writes in the year 1925 and not 1850.

But the chief values of humanism are cultural rather than scientific. And so far as they are scientific, I would stress rather the training of the judgment than the investigation and discovery of fresh truth. Critical judgment of the meaning of books, documents, the written word, is one of the latest, rarest, and most easily lost of human attainments. Lawyers cultivate it with great precision in a narrow field; experts, including men of science, must have something of it in their

own specialty. But the majority of educated men, including lawyers and men of science, do not even know that they lack it in the broader domain of literature and general criticism of life. They do not know that they cannot trust themselves to understand what they read (especially in the literature of the past) or to translate, quote, interpret, or apply it correctly and rationally.

Classical studies will not of themselves impart this discipline to recalcitrant minds. But rightly taught, there is no better educational instrument for training this kind of judgment than the classics, and no field in which it is more needed than in the interpretation of the two great literatures separated from us by the chasm of the Middle Ages and composed in languages we call dead. Misunderstandings of the classics naturally multiply in an age which has so many more pressing things to think about. Trivial errors, which amuse the scholar and delight the gloating pedant, are of no concern. But in the light of the new interest in the evolution of human thought and the history of science, the perpetuation and broadcasting of error about Greek philosophy is a more serious matter. I am not now speaking of doubtful points of metaphysics or the philosophy of history but of the quite definite and demonstrable misapprehensions—"howlers" in fact—which the index of almost any book of recent philosophy, science, or the history of science that mentions Plato, Aristotle and the pre-Socratics at all, will reveal. Writers who expect us to accept on faith their would-be scientific and critical interpretation of special and general relativity, symbolic and mathematical logic, the quantum theory, the constitution of the cell, the structure of the atom, the evidence for the inheritance of acquired qualities, will gravely refer us to a page of Plato or Aristotle for an idea that isn't there, and that intelligent and attentive reading of any good translation even, would have shown them is not there. The limits of my time and the courtesies of the occasion forbid me to mention names. But I have them, and there are astonishingly few exceptions to what may be thought a petulant generalization. The fact

surely indicates some defect in our education, or else the failure of the cautious scientific temper to function in this field. But this is not a paper on education, and in place of further generalization I will confine myself to one widespread and frequently reiterated error about Plato.

Though there are honorable exceptions, it is currently taught that Platonism is the antithesis of the scientific spirit and that Plato is a reactionary in relation to the evolutionary and mechanistic philosophies of the pre-Socratics, and a dreamer, spinning the world out of his inner consciousness, as contrasted with the fact-loving Aristotle.

The association of Platonism with superstition is an historical fact and perhaps a natural tendency. Maeterlinck begins with vague, poetic, Neo-platonic idealism and ends by faith in the performances of the kluger Hans horse. Driesch begins with postulating something he calls entelechy, supplementing mechanism in organic life, and ends with the acceptance of telepathy, telekinesis, and even clairvoyance. William James, who, however, was not a Platonist, begins with assuming an indetectable something that throws its sword into the scales of the will, and ends with faith in the revelations of the medium, Mrs. Piper. And the history of Platonism through the centuries would supply abundant further illustration. The later Neo-platonists practiced levitation. The Cambridge Platonist and poet More, opponent of the materialist and mechanist, Hobbes, is one of the most insistent defenders of the superstition of witchcraft and demoniac possession. The witty Lucian, a great admirer of Plato the literary artist, in his extremely modern dialogue, "The Liar," represents a Platonic philosopher as swallowing all the ghost stories which the Epicurean rejects. No wonder, says Lucian smartly; a man whose eyes are sharp enough to discern the Platonic Ideas can of course see spooks.

The indictment, then, is partly true of historical Platonism. But it does not fairly fit Plato. As an ethical religious teacher he uses the religious language and symbolism of his time precisely as that of their age is used by Schleiermacher, Renan,

Matthew Arnold, Emerson, and the American men of science who protest that their brand of evolution is creative, emergent, or, in the latest phrase, holistic, and not mechanistic. There is no time to prove that here. But it could be proved, and there is no passage in Plato's writings which, correctly understood in its context, is incompatible with this interpretation. Every one of the ten or a dozen passages misused by superstitious Platonism and by too many scholars to-day, is in its context plainly the merely literary, decorative satirical or allegorical employment of imagery and illustration borrowed from the Mysteries, from Orphism, Pythagoreanism, or popular religion.[1] It is not Plato who is unscientific, but the readers who are too uncritical or too impatient to apprehend his clear intentions.

Plato's fluid, literary, and edifying use of religious language has been taken literally, and developed into rigid theological and mystical systems by superstitious Platonists throughout the ages. And the distaste which hard-headed mechanistic positivists and behaviorists feel for such writers has been transferred to Plato. It is allowable only to those who are willing to condemn as superstition anything less than dogmatic mechanistic materialism, and to include in the condemnation not only Plato and the Platonists but all the liberal theologians and men of science to whom I have referred. Plato himself never opposes specific scientific enquiry,[2] or substitutes the final for the mechanistic cause. He merely, like our creative evolutionists, expresses his broad faith that the final cause, if we knew all, might well be superposed on, and found compatible with, the mechanistic secondary cause.

[1] This is what Diès, *Autour de Platon*, calls somewhat cryptically "la transposition platonicienne."

[2] There is one apparent exception, exploited by Goethe and Schopenhauer in the controversy on the theory of color. In Timaeus 68D after stating the apparent results of the mixture or blending of colors, he adds: "But if anyone should try to test all this by experience (in fact) he would have misconceived the difference between human nature and the divine. God alone both knows how and is able to combine the many into one and break up the one into the many. But no man is now capable of doing either of these things, or ever will be." This language bears a certain resemblance to modern denials of the possibility of the chemical synthesis of organic products. But however that may be, it has nothing to do with our present point, the alleged misuse of the final cause by Plato.

The only truth in the commonplace contrast between the facts of Aristotle and the dreams of Plato is, first, that Plato was a mathematician and Aristotle a biologist, and a biologist naturally collects more little facts than a mathematician. And, secondly, that Plato was an artist and Aristotle an encyclopædist—and an artist digests his facts while an encyclopædist catalogues them. The eighth book of the "Republic," so greatly admired by Macaulay, if compared with the catalogues and classifications of Aristotle's "Politics," will illustrate this contrast. One of its opening sentences reads almost like an ironical forecast of Aristotle's work and Herbert Spencer's sociological tables. (544*c*) "Can you name any other form of government—I mean any that presents a clear distinctive type? For principalities and purchased sovereignties and other such constitutions intermediate between those named can be found in even greater numbers among the barbarians than among the Greeks. Many indeed and outlandish are the kinds that are reported."

None the less, Plato's writings as a whole are quite as concrete, as rich in experience, as free from *a priori* logic chopping and unverifiable deduction as Aristotle's. Both inevitably fell into many errors; but Plato as a whole is far nearer the point of view of recent science than Aristotle. The contrary opinion is due to a few sentences excerpted from Aristotle's biological works, the philosophic generalizations of which are in fact mostly derived from Plato.

After clearing away these misconceptions it remains to review some specific passages of Plato that have been thought to be anti-scientific in temper, and lastly to indicate his specific service to, and place in, the history of Greek science.

The chief and first exhibit for the prosecution is the so-called "Timæus," which stands quite apart from the logical, ethical, and social questions that are the main substance of the Platonic dialogues. It is a philosophic prose poem. It is what one ancient critic called it, a hymn of the universe. It belongs, broadly speaking, to the type of literature represented by the fragments of the pre-Socratics, Lucretius' poem

"On the Nature of Things," Cicero's "Dream of Scipio," Poe's "Eureka"—which is however on a much lower plane though by no means as absurd as it is usually represented to be—and Bergson's "Creative Evolution." It is an attempt to set forth in pregnant, generalized and impressive language the picture and conception of the universe that results from the science of a given age and the personal philosophy, the religion and the cosmic emotion of the writer. Historically, the "Timæus" is by the range of its influence in antiquity, on the Christian Fathers, in the Middle Ages, the Renaissance, and even as late as Goethe and Emerson, who admired it greatly, the most important of all books of this class. With that we are not concerned.

Obviously such a book cannot be critically or fairly estimated by the simple method of extracting some of its errors about scientific fact and cataloguing and displaying them apart from their context, and the purport and tone of the whole. It is intelligible only when critically interpreted in its relation to the pre-Socratics and the science of Plato's time—not to speak of the Platonic philosophy. Yet it is by disconnected extracts taken usually not from the original, but from Grote's arid summary, that the orators of anti-Platonism and too many men of science pass a hasty judgment not only on the "Timæus" but on Plato and Platonism.

They do not even pause to ask which of the errors were common to the age and believed by Aristotle, which are only jest and irony, which are fancies that the writer himself says lack verification, which are allegories and symbols, either of moral and religious principles, or of scientific ideas that, despite their mistaken illustrations, are valid to-day even as some of Plato's philosophy of language is sound, despite the false etymologies that accompany it.

I of course cannot present a critical interpretation of the "Timæus" here. I can only indicate the lines of a juster appreciation. It is, as I have said, Plato's "De Rerum Natura," his attempt to rewrite from his own point of view the pre-Socratic cosmogonies, his unconscious anticipation of Lucretius' great poem.

The often uncritical scholars, philosopher and poets of the Renaissance were right in feeling this essential identity of poetical tone and sentiment about nature and the universe in spite of the deep underlying philosophic dissidence. More literal-minded critics think first of the difference, which is that the pre-Socratics were all tending toward that materialism and elimination of design which were so dogmatically and eloquently expounded, by Lucretius,[1] while Plato's purpose is to write his cosmogony in terms of design as far as the scientific knowledge of his day would allow. In so doing, he works partly as a literary artist, and partly as a philosophic student of contemporary science. As an artist he introduces the suggestion, the symbolism, the implication of design in ways which do not affect his treatment of specific scientific principles and particular scientific facts, but which are as irritating to dogmatic mechanists as they are pleasing to convinced teleologists. That is something that can be understood and allowed for only by critics who are able and willing to distinguish a writer's explicit affirmations from the suggestion by tricks of style of his personal preferences.

This insistence on teleology deepens the suspicion aroused by the mystics who take Plato's name in vain, and heightens the unfavorable contrast with Epicurus and Lucretius. The more thoughtful men of science would, I think, admit that their objection is not so much to the teleological idea in itself, as to the absurdities of its detailed application, or the misuse of it to discountenance experimental endeavours to ascertain the mechanism. From both of these faults Plato (though not always historical Platonism), is free. Except in obvious jest he does not use the Bridgewater treatise and Xenophontic type of argument from design; he does not oppose a mechanistic explanation of particular phenomena or substitute for it a vague teleological affirmation. His teleology, such as it is, is superadded to mechanism, and does not displace it.

[1] Cf. my article on Greek Philosophy in Hasting's "Encyclopædia of Religion and Ethics." Professor Dewey's generalization that Greek philosophy was from the beginning the hand-maid or apologist of theology is apparently a transfer to the pre-Socratics of the modern positivist's feeling about historical Platonism. Heiberg (geschichte der Mathematik und Naturwissenschaften, p. 1) states the matter correctly.

The censure of the mechanistic philosophy of Anaxagoras, in the Phædo [97c ff.], has been misunderstood. It is often bitterly denounced as fanatical, anti-scientific obscurantism.[1] The full meaning of the "Phædo" and its many secondary intentions are not to be apprehended by a hasty reader. Plato says in effect, that he would prefer a teleological evolution but that he cannot discover it himself, and that he was disappointed in not finding it in a philosopher who proclaimed that Nous or Intelligence was the first principle. Aristotle, whom the denouncers of Plato contrast favorably with this passage of the "Phædo," says much the same. Plato goes on in the "Phædo" to explain a non-committal logic of causation which is in fact the origin of the Aristotelian syllogism.[2] The first half of the "Timæus" is a poetical, symbolic exposition of the teleological philosophy of nature which the "Phædo" despaired of as strict science.

With these allowances the concrete science of the "Timæus" is quite on a level with the best thought of Plato's time. The unavoidable scientific errors are less vital than those of the Aristotelian Astronomy and physics, and are half redeemed by Plato's insistence throughout that he is only telling a probable tale that admits of no proof.

It is only the main conception, and not the insignificant and irrelevant details, that concern us here. The world has been drawing up outlines and making superficial paraphrases and summaries of the "Timæus" for the past two thousand years. More than a dozen have been published by eminent scholars or men of science or philosophers in the last twenty years, not to speak of mere popularisers. I need not add to their number. Any one of them will serve for a general introductory notion. Few, if any, can be trusted to be critical throughout.[3] Passing over the poetry, the symbolism and the

[1] Lange, "History of Materialism," 1, 9; H. G. Wells', "History (1920)," 1, 358.

[2] Cf. my paper on "The Origin of the Syllogism," *Classical Philology*, Jan., 1924.

[3] That valuable work, "Le système du monde," of Pierre Duhem (not to name living scholars) draws far-reaching conclusions from simple mistranslations.

I., p. 59, douées d'une puissance antagoniste qui les tire vers lui; p. 37, l'être universel, understanding therby the universe as a whole. The meaning is simply: everything that is—anything that really is, and on p. 82 the misapprehension of *enarges*

artistic framework, I turn at once to one of the central scientific conceptions. The peculiar form of the atomic theory associating the molecules, so to speak, of the four traditional elements with four of the five regular solids, and atoms with certain types of triangles, is like the teleology of the first half a deliberate, arbitrary and consciously artistic choice. But it is nevertheless, as Professor Whitehead said, nearer the point of view of the atomic theories of to-day than anything in either Aristotle or Democritus. The same may be said of Plato's discussion of space, time and change.

These analogies have been approached in recent years from two directions: in German dissertations on Plato and Democritus or Plato and Mathematics [1] and in modern books, on the philosophy of the sciences, of which Professor Emile Meyerson's "De l'explication dans les sciences," (Paris, 1921), and his "La déduction relativiste" (Paris, 1925) are the most convenient types.[2] It is pointed out, for example, that Kekule, Vant Hoff and Werner have tried to explain otherwise inexplicable chemical isomeries by the properties of the hexagon, the tetrahedron and the octahedron.[3] I cannot here undertake to distinguish the fanciful from the solid in those German dissertations,[4] or to examine all the analogies between the "Timæus" and the "Republic" and the most recent physics in M. Meyerson's thoughtful book. But I may be permitted to point out that the general notion that Plato's theory of matter is a more philosophical type of atomism is to be found already in old Cudworth and that my own paper on "The Interpretation of the Timæus" in *A. J. P.*, 1888, Vol. IX, anticipates most significant points in these recent discussions and protests in advance against some of their errors. I will illustrate this by an extract [p. 416–17] in which some of the anticipations are italicized for brevity, and which will at

[1] Engeborg Hammer Jensen, Demokrit and Plato, *Archiv für geschichte der Philosophie*, Bd. XVI. Eva Sachs, "De Theaeteto . . . mathematico," Berlin, 1914. Cf. *infra*, p. 77, n. 3.

[2] Cf., also P. W. Bridgman, "The Logic of Modern Physics" (Macmillan, 1927), who, however, says nothing of Plato or history.

[3] Meyerson, "De l'explication, etc.," p. 298–300.

[4] The hypothesis that Plato discovered Democritus when he had written as far as 47E in the "Timæus" and then suddenly changed his plan is of course an absurdity.

the same time serve as a résumé of some of the most significant scientific ideas of the "Timaeus."[1] "In the explanation of material things we accept the four elements from contemporary science, though they are obviously not elementary in any proper sense. The *only real elements involved in objects of sense are space and the mathematical relations. So far we accept the results of Democritus.* But the atomists cannot really claim to have proved their specific doctrines with regard to the shapes and sizes of their atoms. *The atomic chemistry has nothing to go upon but the obvious analogies between a smooth body and a soft sensation, or between a rough, jagged body and a harsh sensation.*[2] In order, then, to maintain against the theory of flux and vortex, our principle that God geometrizes [3] and introduces proportion and harmony wherever possible, we shall arbitrarily base our atoms on an *a priori* geometrical construction (53DE). But we shall willingly yield the palm to the surer science that shall demonstrate a better method (54A). Furthermore, the atoms of Democritus are particles of unqualified matter in space, and suffice in themselves for the production of all qualities. *We recognize no abstract matter apart from space. Our atoms are purely mathematical relations. They explain only the connections and changes of things. The essential qualities that make each thing what it is are derived from the absolute eternal idea. We were forced to assume such fixed eternal unities in logic, and we cannot dispense with them here* (51B). In neither case are we able to state clearly now their virtue is infused into transient things. Assuming these atoms and the cosmic agency of the Demiurgus, a few general forces will enable us to give a plausible analogical explanation of the chief phenomena brought before us.

Among these are the attraction of similar bodies (63E, 53A), the constant revolution of the heavens (58A), which maintains a plenum (58A, 79B, 80C), sets up a περίωσις (80C,

[1] Cf. Bridgman, *op. cit.*, p. 43–4, 93, etc.

[2] Cf. Meyerson, "De l'explication," Vol. I, p. 281 ff., especially: la chaleur du feu est de même, expliquée par les angles aigus de ses particules. Mais les atomistes font appel" a la même ressource.

[3] I of course was and am aware that Plato himself never said this in terms.

79C), and makes impossible a positive *actio in distans* (80C, ὁλκὴ μὲν οὐκ ἔστιν οὐδενί ποτε);[1] the far-reaching distinction between mobile and stable bodies (64AB), and the principle of the stability of the homogeneous and the instability of the heterogeneous (57A, 58C). In human physiology and anatomy the prime fact is the distinction between the intellectual, emotional, and appetitive or vegetable soul, and our study should be directed to tracing the designs of our makers in providing instruments for the first, discipline for the second, and the necessary conditions for the harmonious working and due subordination of the third. Diseases are explicable on purely physical grounds; they are of the nature of living organisms, and are to be treated as far as possible by flexible regimen. Moral defect is in the main due to removable physical conditions (87B). There is a certain continuity throughout the animal kingdom indicated by rudimentary organs (76DE). The Democriteans evolve the higher from the lower by the operation of chance. Proof there is none, and we will therefore substitute for the guess of transmorphism the assertion of a metaschematism intentionally devised for ethical ends by the moral ruler of the world."

There is space for only a few further illustrations of recent discussions of the analogies which I brought out in the page reprinted above. Professor Meyerson, *e.g.*, shows that Plato, like Descartes and our newest physics tends to reduce matter to configuration in space.[2] He admits that this is the drift of recent physics, but thinks that there and in Plato this tendency ignores the irreducible element of irrationality, that is of impenetrability by the deductive reason, in our experience. And so he approves Aristotle's criticism of what he calls the pan-mathematism of Plato. That, however, is to forget what I had already shown, that Plato does not actually construct reality out of configured space. Space is the recipient, Plato says, in some marvellous and unexplained way, of forces, powers, potentialities, that enter into it from the world of Platonic Ideas, and the mathematical construction is solidified

[1] Cf. Bridgman, *op. cit.*, p. 46.
[2] Cf., *e.g.*, "De l'explication," I., p. 179.

before it becomes an elemental atom or molecule.[1] Now as Professor Meyerson himself quotes with approval leaders of science to the effect that our scientific laws like Plato's Ideas are more truly real things than are the so-called real objects of sense,[2] he could not consistently object to the Platonic solution of the mystery or recognition of the irrationality which I pointed out but which he seems to overlook.

Professor Robin, on the other hand, seems to forget that the physicist of to-day stands helpless before the same problem and the same antinomies.[3] And so he cannot refrain from constructing out of the dubious testimony of Aristotle and his own interpretation of the "Philebus" and "Timæus" a final metaphysics for Plato which will solve them. He apparently would repeat of Plato what Meyerson, p. 161, naïvely says of Einstein: "l'appareil entier de la déduction einsteinienne a besoin de l'interpretation pour produire du réel." This recalls Zeller's lament that he could find in Plato "keine Ableitung des Sinnlichen," to which as far back as my doctor's dissertation I replied by asking him to name some satisfactory modern deduction of the world of sense from abstract metaphysical or mathematical principles. And similarly when writers to-day complain that Plato's atomic theory does not make it perfectly clear how he extracts quality from quantity I ask: what modern physicist does make it clear? Professor Robin writes ("La physique dans la philosophie de Platon," p. 50, italics mine): "Ainsi, quand le Timée explique le feu sensible à la fois par la configuration géométrique du feu élémentaire et par l'Idée du feu, il se place tour à tour au point de vue de la *réduction de la qualité à la quantité et à celui du rapport des qualités particulières à leur essence absolue.* Mais, en nous rappelant qui'l existe une science divine des principes d'où dérivent les relations mathématiques auxquelles se réduit la qualité sensible, *Platon, interprété à l'aide des témoignages d'Aristote*, semble nous indiquer en même temps que ces

[1] Tim., 56B: *stereon gegonos eidos.*

[2] Cf. Bridgman, p. 35.

[3] Cf., *e.g.*, Lucien Poincaré, apud Meyerson, "De l'explication," p. 23, and Meyerson, "La déduction relativiste," p. 12 ff., and Bridgman, *op. cit., passim.*

principes doivent aussi servir à expliquer la qualité intelligible, c'est-à-dire l'Idée."

It is more truly philosophical, as well as more critical, I think, to take Plato as we find him, with less expense of ingenuity in the interpretation, to read the Timæus as a philosophical poem shot through with suggestions and intuitions of science, and not to demand of Plato a metaphysical completeness, a symmetry, an ultimate dogmatic consistency, which are to be found not in the serious scientific thought but only in the system-mongering of to-day.[1]

The other chief stumbling-block to the modern scientific reader is the discussion of mathematical astronomy and physics in the programme of the higher education in the "Republic" (VII., 523 ff.). The fact that Plato bases the higher education of his guardians on a severe course in science is of itself a sufficient refutation of the notion that he is an enemy of science. But into that we need not enter. Plato had not and could not have our utilitarian reasons for making science the staple of the higher education. It would be possible to answer those who condemn Plato for this by quotations from many leaders of modern science who teach that disinterested intellectual curiosity is the highest motive of science, and that, even when utility results in the end, it is fatal to the scientific spirit to keep this end slavishly in view. They point to the error of Comte, who said that astronomy outside our solar system could never be of any use, and that we ought not to speculate about the physical constitution of the stars. Science too is a kind of idealism and must hitch its wagon, the chariot of progress, to a star. However that may be, there was and could be in Plato's age no clear premonition of the Baconian mastery over nature which is the miracle of our day.[2] Plato values science as mental discipline, and more specifically as developing the power of pure abstract thought.

[1] On the earlier attempt of Mr. Henry Jackson to find parallel metaphysical systems in the "Philebus" and "Timæus," cf. my paper on "Recent Platonism in England," *A. J. P.*, 1888, Vol. IX., p. 274. Its arguments are applicable to all such endeavors, and until they are answered it is unnecessary to amplify them.

[2] Yet cf. Plato's anticipation of the chief Baconian formula in my paper on "The Origin of the Syllogism," *Classical Philology*, January, 1924, p. 17.

Mathematics, to begin with, compels the child to think not of ten apples or a score of beans, as our schools of education would have him do, but of the numbers themselves.[1]

When Socrates in the "Republic" turns next to astronomy, the other speaker, taking Platonic metaphors literally, as sentimental Platonists still do, says, "Astronomy certainly turns the eye of the mind upward." But Socrates ridicules that star-gazing conception of astronomy and says that the upward gaze of the soul means the study and contemplation of abstract ideal mathematical relations and principles in their application to solids in motion. It is easy for a hasty modern reader to mistake that for a rejection of observation and fact and a proposal to deduce the phenomena of astronomy *a priori*. But Plato is not thinking of that. He is in some sort predicting the mathematical astronomy of to-day. That is of course not the whole of our modern astronomy. But it exists and is a fulfillment of Plato's prophecy.

Plato expresses this idea by saying in anticipatory correction of the Aristotelian error which dominated the Middle Ages, that the actual movements of the heavenly bodies, however wonderful, fall in precision far short of the true movements of real swiftness and real slowness in true number and in all true geometrical figures moving in relation to one another and bearing along in their movements their content. The meaning of this is sound science. But the language of Platonic idealism seems to us upside down. The movements and the mathematical relations are spoken of as the real things and the sun, moon, planets and stars are things put into these movements and carried along by them. And as if that were not enough, he adds: We must study astronomy as we do geometry, in generalized problems abstracted from particular matter, and let the things in the heavens alone. The meaning is quite harmless. It is an unconscious prophecy of modern mathematical astronomy. But the exaggerated Emersonian emphasis of the phrase "let the things in the heavens alone" [2]

[1] Cf. my paper on "Ideas and Numbers," *Class. Phil.*, April, 1927.

[2] For a modern utterance nearly as drastic, cf. Bouasse, apud Meyerson, "De l'explication," I., 125–6. "Il semble que je rabaisse étrangement le rôle de l'expérience, le principe découvert, elle n'interviendrait plus que pour vérifier les déductions de la géométrie. Dans l'espèce son rôle était par conséquent inutile, etc."

will continue to convince matter-of-fact readers careless of the context that Plato is the prototype of those Aristotelian professors of Italy and France who refused to look through Galileo's telescope at the phases of Venus and pronounced the spots of the sun specks in the glass, because they are not mentioned in Aristotle. Duhem, pp. 96 ff., interprets more reasonably and is essentially right in saying that Plato would substitute the *true* astronomy for the astronomy of observation.

It may be thought that these analogies are merely the uncritical enthusiasm of a teacher of Greek for his favorite author. And if you turn to the best scientific work on ancient astronomy, T. L. Heath's "Aristarchus of Samos," that suspicion will be confirmed: "Plato (he writes, p. 139) was a master of Method and it is an attractive hypothesis to picture him as having at all events foreshadowed the methods of modern astronomy." But in rejection of this hypothesis he quotes Plato himself as saying that "the person who thought that the heavenly bodies should always move precisely in the same way and show no aberration whatever would properly be thought absurd, and that it would be absurd to exhaust one's self in efforts to make out the truth about them." Besides, Heath adds, observation is excluded by the words "we shall let the heavens alone."

The first of these statements is true, and as we have seen is a remarkable anticipatory protest against the superstitious belief of Aristotle and the Middle Ages in an unchangeable heaven.

The statement that it would be absurd to exhaust one's self in efforts to make out the truth *about* them is in tone, at least, unfair to Plato's meaning. What Plato really intended to say, is, I think, that the true philosopher or scientific astronomer will in every way try to ascertain the truth or reality *of* these things, meaning loosely the more exact mathematical principles to which the apparent movements are only an approximation.[1] The whole means only that he will study

[1] Cf., *e.g.*, "Phædo," 74, and "Republic," 510, cf. Bridgman, *op. cit.*, pp. 17, 34, 61 and *passim*.

mathematically those abstract or ideal motions to which the same word "true" is applied in the preceding two or three paragraphs. He is not saying colloquially that it is foolish to try to make out the truth, that is the apparent facts, *about* the sensible movements of the heavenly bodies. I personally believe that an irregularity of construction, of which there are other examples in the Republic, determines this meaning.[1] But the usual construction, that given in Adam's edition, for example, will suffice for my purpose in Duhem's fairer interpretation (p. 95), "Il regardera comme un insensé . . . celui qui s'efforce de toutes manières de *saisir la vérité en* ces choses accessibles aux sens," the tone of which is quite different from that of Heath's "make out the truth *about* them." With no intention of disparaging Mr. Heath's admirable and indispensable book, I will use another paragraph of it to illustrate the caution that these studies require, and at the same time to develop a little further the topic of Plato's knowledge of astronomy. Speaking of alleged contradictions in Plato, he says on p. 171, "the description [in the Timæus, 39] of the 'wanderings' of the planets as 'incalculable' in multitude and marvellously intricate, is an admission in sharp contrast to the assumption of the spirals described on spheres of which the independent orbits are great circles,[2] and still more so to the assertion in the "Laws" [821–2] that it is wrong and even impious to speak of the planets as wandering at all since each of them traverses the same path, not many paths, but always one circular path." "For the moment," he adds, "Plato condescends to use the language of apparent astronomy, the astronomy of observation; and this may remind us that Plato's astronomy even in its latest form is consciously and intentionally ideal in accordance with his conception of the true astronomy, which lets the heavens alone." Even when this is literally correct, its tone is again, I think, misleading. "Incalculable," which is Archer-Hind's translation, conveys

[1] Briefly, I think the subject of the infinitive *zetein* seek (530 B.) is the true astronomer, and that it does not depend on *atopon* absurd, so in 492 C. *φήσειν*, if that is the text, refers to the youth. Cf. also the use of *kalein* in 581 E.

[2] The "spirals" of the "Timæus," 39 A, are clearly explained by Duhem, p. 55–7.

to us an idea of the negation of science not in the original. *Amechanon* hardly means incalculable except in the sense incredible or wonderful. The alleged contradiction with the "Laws" is of no significance for Plato's development. For Heath himself admits that the supposed contradiction is almost as sharp with the immediately preceding paragraph of the "Timæus" itself. The phrase "Plato condescends to use" is an unwarranted sneer, and the remark that the astronomy of the "Timæus" and Laws is ideal in the sense of the "Republic," which lets the heavens alone, is an equivocation which hardly rises above the dignity of a pun; the astronomy of the "Republic" passage is ideal in the sense that it is to be abstract and mathematical. If the word ideal is applied to the popular sketches given in the "Timæus" and "Laws," it can only mean that so much astronomy as Plato deems essential for general culture and philosophy is there stated in simplified form with omission of technical details and problems that are as yet not solved or that the readers he has in mind could not understand. There is no real contradiction between the statement in the "Laws" that the planets are not really errant or wandering bodies, and the remark in the "Timæus" that the full explanation of their wanderings (their apparent wanderings, that is) would be too complicated and time-consuming for the present work. Duhem, p. 97, 101–102, explains this well, but is misleading when he brings in the doubtfully genuine Epinomis to justify a third stage in Platonic astronomy, the theological. Plato undoubtedly in his theodicy [1] holds that the heavens declare the glory of God and that an undevout astronomer is mad. He wishes his rulers to know enough astronomy to feel and teach this, and everybody to learn enough not to blaspheme—which is his way of saying, not to misrepresent grossly the movements of the planets. But to call this a "theological astronomy" is to give the impression of superstition, from which Plato is free.

To return to the "Republic." The application of similar principles to a postulated mathematical study of acoustics [531] is too complicated for this brief summary. After

[1] "Laws," Book X.

studying as much as I could understand of Henry J. Watt's "Psychology of Sound," I am inclined to think that Plato has here overshot himself, and has been led into error by the assumed analogy with celestial mechanics, which is in a certain sense and to a certain degree an *a priori* science. But there is, I suppose, no such *a priori* Kantian intuition of intrinsically harmonious musical vibrations. It is a matter of observation and experiment. But I shall be glad to hear from some expert on this point.

In thus defending Plato against the charge that, because he emphatically demanded mathematics, he would have rejected observation and experiment, I might invoke the dangerous alliance of modern mathematical mysticism, which is only too ready to exalt Plato and Pythagoras before him for anticipating the proposed reduction of all philosophy and all science to mathematics.[1] I need not quote illustrations of a view which you meet everywhere in philosophical literature to-day. When it is not bluff, mysticism, or the mathematician's magnifying of his office, it can only be a prophecy of the final triumph of materialism. Philosophy and science can be swallowed up in mathematics only in so far as all qualities can be definitely correlated with measurable quantities. We may leave that consummation to the unknown future. There is no prediction of it in Plato; and the passages in which he praises mathematics and opposes measurement to guessing do not justify attributing it to him.

As for Pythagoras, of whom we know nothing, the wise reader turns the page when he sees that name, as Tyndall (or was it Huxley?) did when he saw the word 'polarity.'

But in these passages Plato has some notable anticipations of recent dicta of leaders of modern science on this subject, which are worth quoting. In "Republic" 602D, he says that measuring, counting and weighing are most gracious aids against the illusions of sense and the subjectivities of opinion; in "Philebus" 55E he says still more notably that if one

[1] Cf. Bridgman, p. 62, "There is no longer any basis for the idealization of mathematics"; and p. 63, "mathematics reminds one of the loquacious—orator who was said to be able to set his mouth going and go off and leave it."

divorces arithmetic, measurement and weighing, from the arts and sciences, that which remains is of little value—there is left only conjecture and guess-work and the exercise of the senses by empiricism and habit.

These utterances surely differ little from Lord Kelvin's statements that he understood a thing only when he could construct a working model of it, and that if you can measure a thing and express it by number, you have some knowledge of it, otherwise not; from Kant's declaration that the only part of any theory of nature that is scientific in the strict sense of the word is the quantity of mathematics which it contains; from Clerk Maxwell's statement that progress is symbolized in the clock, the balance and the foot-rule.

The histories of science, and especially of mathematics and astronomy, will give a fair general—though by no means always critical—notion of Plato's actual attainments. It would serve no purpose, and I have not space, to summarize the often doubtful details again here.[1]

Plato not only advocated education in science, but practiced it. Various steps in the progress of mathematics and astronomy are attributed to Plato as head of the Academy and director of research. He himself uses language that implies this conception of his function.[2] One legend assigns to him the solution of the Delian Problem of the duplication of the cube. His friend Theætetus, whose name is attached to one of the profoundest dialogues, apparently discovered and constructed some or all of the five regular solids.[3] The astronomer Eudoxus, whose theory of the celestial spheres prepares that of Aristotle and the Middle Ages, was a friend of Plato and attended his lectures. There is and can be, perhaps, no complete and critical account of the theory of the spheres, but Duhem [1.102 ff.], Heath, J. L. E. Dreyer,

[1] Cf., Heiberg, *op. cit.*, pp. 7–12 and 51–52 (slight). Heiberg, p. 51, accepts the notion that "Laws," VII, 821b–822c, is a late conversion to belief in the revolution of the earth on its axis. Plato's text does not justify the interpretation. Duhem, p. 88, rejects it. England's notes *ad. loc. discuss* the evidence and the probabilities.

[2] "Republic," VII., 528 B C, "Euthydemus," 290 C.

[3] Cf. "Die fünf platonischen Körper," Eva Sachs, in the Kiessling and Wilamowitz "Philologische Untersuchungen," Berlin, 1917.

"History of the Planetary Systems from Thales to Kepler," and the notes of Ross on Aristotle's "Metaphysics," Lambda 8, after the chief authority, Schiaparelli ("I precursori di Copernice nell' Antichità") will suffice for all practical purposes. The too common attribution of real physical spheres, crystal or otherwise, to Plato himself, is unwarranted, either by "Phædrus," 246–7, or by "Laws," Bk. V., to which, *e.g.*, Duhem (Vol. I., p. 39), refers. It belongs to the uncritical science of Chalcidius' commentary on the "Timæus." The Greek historian of astronomy, Eudemus, reported a tradition that Plato proposed to his students the problem: what hypothesis of regular and homogeneous movements will save the phenomena of the apparently irregular movements of the planets? The history of the phrase "save the phenomena," Milton's ignorantly contemptuous "to save appearances" has been sketched by an English [1] and written by a French scholar.[2] It proves conclusively that the more intelligent ancients [3] anticipated that most modern distinction between the working hypotheses of any science and ultimate material facts, a distinction which those, who tell us that Einstein has proved that space is bent and curved, forget [Cf. Bridgman, p. 176]. It would be superfluous to repeat that there is a school of philosophy which in reaction against nineteenth-century positivism is again trying to abolish that distinction, and insist that true physical relations must be relations of something. Many puzzled physicists feel in this way; they do not know how to answer their students' question: "If atoms are only charges of positive and negative electricity, what is it that is charged?" [cf. Bridgeman, p. 41 and *passim*] Meyerson quotes Sir Oliver Lodge as saying plaintively, quite in the logic of Plato's "Parmenides," [4] "Waves must be waves of something." Meyerson himself says ("De l'explication," I., 7): "La science est essentiellement ontologique—elle ne peut se passer d'une réalité posée en dehors du moi."

[1] J. B. Mayor, *Journal of Philology*, 1876, VI., 12, p. 171.
[2] Pierre Duhem.
[3] Duhem would even attribute the idea to Pythagoras himself.
[4] 132 B is each of their thoughts (*i.e.*, ideas) a thought of nothing?

As Herbert Spencer, refuting Berkeley, pathetically cries, "Should the idealist be right, the doctrine of Evolution is a dream." [1]

Further mathematical and astronomical detail would contribute nothing to the purpose of this paper, and can be readily found in the books to which I have referred.[2] They must be read with caution, with the precautions which this paper is intended to suggest.

The actual scientific knowledge of no ancient thinker, except perhaps some of the methods of the later mathematicians and some clinical observations of physicians, is of any concern to any working investigator to-day. The interest of the history of ancient science is either that of any evolutionary study of origins, or it depends on the significance that we attach to the anticipation by ancient thinkers of those large, general conceptions, which it is commonly said modern science first introduced into the world. That may be partly true, if we take for our starting point and standard of comparison the darkest period of the Middle Ages, as a too often quoted purple patch of rhetoric about *un homme d'autrefois* on the first page of Anatole France's "Jardin d'Épicure" does, and as Professor Dewey and the *Scientific American* did when they told us that nobody knew that the earth was round. It may be true in a sense, if we are thinking of the democratic masses of mankind whom modern means of communication make accessible to the popularization and propaganda of science for the first time. It is not true, if the comparison is with Graeco-Roman philosophy and the cultured few who have always had access to it. There are few, perhaps no, general conceptions

[1] But cf. Bridgman, p. 58: "I do not believe that the additional implication of physical reality has justified itself by bringing to light a single positive result.

[2] Cf. *supra*, pp. 167 and 177. I. L. Heiberg, "Geschichte der Mathematik und Naturwissenschaften im Altertum," in the Iwan Müller Handbuch, München 1925, is a résumé of 118 pages close-packed with facts and bibliography, which supersedes his similar contribution to the Gercke and Norden Handbuch, 1912, and makes further bibliography superfluous here. I may mention, however, E. Hoppe, "Mathematik und Astronomie im classischen Alterthum," Heidelberg, 1911, and the brief but clear outline of L. Laurand, "Manuel des Etudes grecques et latines," Paris, 1923. The Encyclopædia Britannica articles on mathematics and astronomy are good; the article on Plato is misleading.

of modern science applicable to religion, ethics, philosophy, education, or psychology, that were not familiar, often in more precise or more eloquent formulation, to readers of the pre-Socratics, Plato, Aristotle, the Stoics, Epicurus, Cicero, Plutarch, and so on down to the worthy Bishop Nemesius's treatise "On the Nature of Man" about 400 A.D. That is the thesis of a long-delayed book which I hope to complete in two or three years. Meanwhile, I shall be grateful for any friendly letter of challenge to match some significant large idea which the writer regards as the peculiar appanage of modern science. Plato alone rightly understood will usually suffice. But where Plato fails, some one of his successors will almost always guide us to any by-path of our latest speculations.

Once more, from the point of view of working science and material progress, and flying the Atlantic in a night, all this is of no significance. All depends on whether we are as much interested in the ascertainable history of the civilized human mind, as we seem to be in that of the hypothetic psychology of the cave-man. If we are, it is worth while to get it right.

Educated ancients, men like Cicero and Plutarch, understood the facts which I have related and knew that the real scientific men of antiquity were Platonists and Aristotelians, not Epicureans. The mere dogmatic assertion of atomic materialism, and the denunciation of every form of the idea of design could not in their eyes make a true scientific thinker out of a poet who supposed the moon and sun to be about their apparent size and who denied the possibility of the antipodes. Many also of the great scientific men of the Renaissance and the following centuries understood the matter and spoke respectfully of Plato's scientific attainments and conceptions. It is enough to mention Galileo and Leibniz.

The chief source of the opposite tradition is the Italian predecessors of Bacon and Bacon himself, who, in spite of his own immense debt to Plato, chose to prefer Democritus.[1]

[1] Heiberg, p. 12, accepts a similar view of Plato and Democritus from the German dissertations mentioned above, p. 167.

We need not here trace the recent fashion of exalting Lucretius and depreciating Plato as a reactionary further back than Macaulay's essay on Bacon and Lange's "History of Materialism." I have read Macaulay's essay on Bacon some dozen times because it is the source of more plausible errors in contemporary opinion than any other writing known to me except Spencer on Education and Wells' "History." But like most readers I never took time to test its quotations. Glancing at it again for this paper I re-read the page of declamatory denunciation of Plato for scorning all practical applications of mathematics; I looked up the references to Plutarch and found that Macaulay had missed the main point: Plato's chief objection was not to the practical use of mathematics in mechanics, about which Plutarch indulges in some idealistic rhetoric, but to the attempt to solve the problem of the duplication of the cube or of the finding of two means between given extremes [1] by the construction of a mechanical model instead of by pure mathematical reasoning. It is thus that the history of philosophy and science is written.[2] From Bacon, Macaulay, and Lange, this conception of Platonism as anti-scientific passed into the popular writings of Huxley and Tyndall, and so became a commonplace. On the other hand, Huxley says that Lucretius had drunk more deeply of the scientific spirit than any other poet, and Tyndall echoes him. Lucretius' materialism and his hostility to design account in part for this judgment. But the chief reason is the praise of science and the scientific man in Lucretius' poem, and the magnificent rhetoric of cosmic emotion outsoaring even Bacon, the modern orator of science. There could be no more striking proof of the ineluctable dominion of rhetoric even over the scientific mind.

Past the wall unsurmounted that bars out our vision with iron and fire
He has sent forth his soul for the stars to comply with and suns to conspire.

[1] Cf. Duhem, pp. 29–30.
[2] Cf., however, Heiberg, *op. cit.*, p. 8.

There are few sentiments which the man of science to-day is moved to utter in his exalted moods that he cannot find better expressed in Lucretius than in any modern poet, orator, or philosopher. Perhaps that ought not to be so, but it is. The modern poet of science may know more and versify an unimpeachable history of science:

> How many problems geometric
> Are easy now, thanks to the metric
> Trick of Descartes, who found a way
> To think them out by algebra.

That—I am translating, not inventing—I presume, is sound science. But when the man of science wishes to be thrilled and stirred, he goes back to his Lucretius and repeats of Newton, Darwin and Einstein what Lucretius says of Epicurus: "Nam si ut ipsa petit maiestas cognita rerum dicendum est, deus ille fuit, deus, inclyte Memmi." Hence, even the widely-read and cultured Doctor Osler, addressing the British Classical Association on "The Old Humanities and the New Science," while fairly appreciative of Plato's moral eloquence, overstresses the scientific importance of Lucretius, and complains that classical education in neglecting the "De Rerum Natura" disregards the scientific side of ancient thought. The classicists are not really negligent of Lucretius the poet. But having studied rhetoric more than their scientific colleagues, they are more nearly immune to it, less likely to be swept from their moorings by a blast of eloquence. And they know that Lucretius, like Bacon, is not the representative, but the orator, of science. The founder of ancient science was Plato, and it is from him that the world has received both the idea of science and the conception of a scientific education and the public encouragement of research.[1]

[1] "Republic," 528C.