

ΣΥΝΕΔΡΙΑ ΤΗΣ 9ΗΣ ΑΠΡΙΛΙΟΥ 1992

ΠΡΟΕΔΡΙΑ ΜΙΧΑΗΛ ΣΑΚΕΛΛΑΡΙΟΥ

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ΜΗΧΑΝΙΚΗ.— **‘Ο κόσμος του ‘Αριστοτέλους εις την σφαῖραν τῆς δυναμικῆς**, ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Περικλέους Θεοχάρη\*.

#### 1. ΕΙΣΑΓΩΓΗ

Ἡ ἀντιμετώπισις τῶν φυσικῶν φαινομένων ὑπὸ τοῦ Ἀριστοτέλους ἐπήγαγε καὶ ἐβασίσθη εἰς ἀρχὰς αἱ ὁποῖαι δὲν εἶχον ἄμεσον σχέσιν μὲ τὸν φυσικὸν κόσμον, ἐνῶ ἀντιθέτως εἰς τὰς βιολογικὰς ἐπιστήμας συνεισέφερε σημαντικὴν προσφορὰν. Ἀλλωστε ἡ συμβολὴ τοῦ Ἀριστοτέλους εἰς τὰς ἐπιστήμας αὐτὰς ἦτο ἡ μεγίστη.

Ὁ Ἀριστοτέλης προσεπάθησε νὰ προσαρμόσῃ ὅλα τὰ εὐρήματά του εἰς σταθερὰ πλαίσια καὶ ἐν συνεχείᾳ ἔτεινε νὰ δημιουργήσῃ ἐπ’ αὐτῶν γενικὴν θεωρίαν τὴν ὁποίαν ἀνεκλήρυσεν ὡς ἀπόλυτον. Ὁ δογματικὸς αὐτὸς φορμαλισμὸς, ὁ ὁποῖος δὲν ἐστηρίζετο εἰς ἱκανοποιητικὴν ἐμπειρικὴν τεκμηρίωσιν, εἶναι δυνατόν νὰ καταστῇ ἐπικίνδυνος. Ἐν τούτοις, ἡ βασικὴ συμβολὴ ἐπὶ τῶν ἀρχῶν τῆς ἐπιστήμης ἡ ἀναπτυχθεῖσα ὑπ’ αὐτοῦ ἦτο ἡ πρώτη ἡ ὁποία ἐδημιουργήθη εἰς τὴν ἀνθρωπότητα καὶ δύναται νὰ θεωρηθῇ ὡς ὁ θεμέλιος λίθος τοῦ οἰκοδομήματος τῆς συγχρόνου ἐπιστήμης.

Ἡ βασικὴ ἀρχή, κατὰ τὴν ἄποψιν τοῦ Ἀριστοτέλους, διὰ τὴν ἐπιστήμην ἦτο τελεολογική, βασιζομένη ἐπὶ τοῦ ἀξιώματος ὅτι ὁ,τιδῆποτε συμβαίνει εἰς τὴν φύσιν γίνεται διὰ κάποιον σκοπὸν καὶ ὅτι ὁλόκληρος ὁ κόσμος εἶναι τὸ ἀποτέλεσμα αὐτοῦ τοῦ προγραμματισμοῦ.

Ἡ φιλοσοφία τοῦ Ἀριστοτέλους κυριαρχεῖται ἐπομένως ἀπὸ τὴν ἀρχὴν τῆς τελεολογίας, τῆς ὁποίας θεωρεῖται ὁ ἰδρυτής, ἂν καὶ εἶναι γνωστὸν ὅτι, πρὸ τοῦ

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\* P. S. THEOCARIS, **The Aristotelian cosmos in the sphere of dynamics.**

Ἀριστοτέλους, ὁ Ἐμπεδοκλῆς ἦτο ὁ πρῶτος ὁ ὁποῖος προσέθεσεν εἰς τὴν ἀρχὴν αὐτὴν τὴν ἔννοιαν τῆς δυνάμεως.

Περαιτέρω ὁ Ἀναξαγόρας ἐχρησιμοποίησε μίαν κινήτηριον ἀρχὴν τὴν ὁποίαν ἀπεκάλει «Πνεῦμα» εἰς τὴν διδασκαλίαν του. Ὁ Ἀναξαγόρας ἐθεώρει τὸ «Πνεῦμα» ὡς τὴν αἰτίαν τῆς κινήσεως καὶ δυνάμει, ὡς φυσικὴν οὐσίαν, ἀλλὰ οὐδαμοῦ ἀναφέρει ὅτι τὸ «πνεῦμα» λειτουργεῖ βάσει προδιαγεγραμμένου σχεδίου διαμορφωθέντος ὥστε νὰ δημιουργῇ κάποιαν μορφήν τάξεως. Πράγματι τὸ «πνεῦμα» ἀναφέρεται σαφῶς ὡς τελεολογικὴ δρᾶσις, ἥ ὅποια ὀρίζει ἐκουσίως τὰ πράγματα εἰς τὴν κανονικὴν των τάξιν, καὶ ἡ ἁρμονία τοῦ σύμπαντος προκύπτει διὰ τῆς ἐφαρμογῆς λογικοῦ νόμου σκοπεύοντος εἰς τὴν τελειότητα.

Ἡ ἀνάπτυξις αὐτῇ τῶν σχετικῶν ἰδεῶν ἔφθασεν εἰς τὸ ἀποκορύφωμά της κατὰ τοὺς χρόνους τοῦ Πλάτωνος, ὁ ὁποῖος εἰς τὸν διάλογόν του «Φαῖδων» θέτει εἰς τὸ στόμα τοῦ Σωκράτους ἰσχυρὰς ἐκφράσεις κριτικῆς ἐναντίον τοῦ «πνεύματος» τοῦ Ἀναξαγόρου.

Σήμερον ἀρκεῖ μόνον νὰ παρατηρήσωμεν γύρω μας διὰ νὰ ἴδωμεν ὅτι ἡ ταχεῖα πρόοδος τῶν φυσικῶν ἐπιστημῶν κατὰ τοὺς τελευταίους αἰῶνας ἤρchiσε μόνον ὅταν οἱ ἐπιστήμονες ἔπαυσαν νὰ ἐρευνοῦν διὰ τὰς ἀληθεῖς αἰτίας καὶ περιώρισαν τὴν περιέργειάν των εἰς τὰς ἀναγκαίας συνθήκας τῶν αἰτιῶν αὐτῶν.

Ἡ κλίμαξ τῶν ἀξιῶν ἡ ἐφαρμοσθεῖσα ὑπὸ τοῦ Ἀριστοτέλους κατὰ τὴν ἐρευναν τῆς φύσεως καταλήγουσα εἰς τὴν τελεολογικὴν ἐρμηνείαν τοῦ σύμπαντος ἀπετέλεσε τὸν ἀκρογωνιαίον λίθον τῆς φυσικῆς του. Ὁ Ἀριστοτέλης ἐπῆγε ἀκόμη μακρύτερα καὶ διεμόρφωσε τὴν θεωρίαν του τῆς δυναμικῆς ἐπὶ τῆς ὑποθέσεως τῆς νοήμονος φύσεως, λειτουργούσης διὰ προνοητικοῦ σχεδιασμοῦ. Καθορίζει τὴν ἄποψίν του, κατ' ἀρχὴν, κατὰ τὴν πορείαν ἀνασκευῆς ἐκείνων τῶν Προ-σωκρατικῶν φιλοσόφων, οἱ ὁποῖοι ἐθεωροῦσαν τὰ φυσικὰ φαινόμενα ὡς προϊόντα τῆς «ἀνάγκης» ἢ κατὰ τὴν σύγχρονόν μας ὁρολογίαν, ἐν συμφωνίᾳ μὲ τοὺς νόμους τῆς μηχανικῆς.

Διὰ τὸν Ἀριστοτέλην πᾶσα συμμόρφωσις πρὸς τὸν νόμον εἶναι τελεολογικὴ, καθὼς αὐτὴ ἡ παρουσιαζομένη εἰς τὴν δημιουργίαν τῶν καλλιτεχνῶν. Αὐτὴ εἶναι μία καθαρὰ καὶ ἀναμφίβολου διατύπωσις: «Ἡ μέθοδος τῆς φύσεως εἶναι ὁμοία μὲ τοῦ καλλιτέχνου, καὶ ἀντιστρόφως, ἡ ἀληθινὴ τέχνη ἀπομιμεῖται τὴν φύσιν». Κατὰ συνέπειαν ὁ ἐπιστήμων πρέπει νὰ ἀντιμετωπίζῃ τὸ πρόβλημά του ὅπως ὁ σπουδαστὴς μιᾶς καλλιτεχνικῆς δημιουργίας, ὁ ὁποῖος ἀπὸ τὴς λεπτομέρειες ἐνὸς σπιτιοῦ, σπουδάζει τὴς λειτουργίας τὴς καθορισθεῖσες ἀπὸ τὸν ἀρχιτέκτονα εἰς τὰ διάφορα τμήματά του, ἢ ὁ ὁποῖος ἀντιλαμβάνεται ἀπὸ τὸ σχῆμα ἐνὸς ἀγάλματος τί ὁ καλλιτέχνης ἐπιθυμοῦσε νὰ ἐκφράσῃ διὰ τοῦ ἔργου του.

Ἡ σύλληψις αὐτῇ τῶν φυσικῶν φαινομένων ὡς ἀγῶνος διὰ κάποιον σκοπὸν δύ-

ναται να είναι καρποφόρος και κατάλληλος ως οδηγός αρχή εις τους τομείς της βιολογίας, όπου το θέμα έρευνας είναι ο λειτουργικός ρόλος των οργανικών μορφών και διαδικασιών. Έξ αυτών προκύπτουν αί μεγάλοι έπιτυχίαι του 'Αριστοτέλους εις την ζωολογίαν και ή διατηρουμένη μέχρι σήμερα αξία της συμβολής των βιολογικών του έργων. Αί πραγματεΐαι έπὶ τῆς μορφολογίας των έμβιων όντων όμοιάζουν, ως εάν να παρήχθησαν υπό συγχρόνων έπιστημόνων, ενώ το σύνολον των συμβολών του εις την Φυσικήν διαπνέεται από το πνεύμα ενός κόσμου, ολοκληρωτικώς διαφόρου προς ήμᾶς, ο όποιος ήρχισε να απομακρύνεται από τας συγχρόνους ιδέας μας, από την στιγμήν όπου ή φυσική έπιστήμη έγκατέλειψε την έρώτησιν: *διά ποίον σκοπόν;* και την άντικατέστησε διά τῆς έρωτήσεως: *πώς;*

## 2. ΑΡΧΗ ΤΗΣ ΔΥΝΑΜΙΚΗΣ

‘Η τελεολογική αρχή έπαιξε μεγάλο ρόλον εις την δυναμικήν του 'Αριστοτέλους. ‘Η θεωρία τῆς δυναμικῆς αποτελεῖ ολοκληρωμένο σύνολον τῆς εικόνας του κόσμου. ‘Ο 'Αριστοτέλης παρέλαβε την θεωρίαν των τεσσάρων στοιχείων από τους Προ-σωκρατικούς φιλοσόφους και έπλεξεν όλες αυτές τις θεωρίες εις σύστημα κοσμικών αξιῶν, έπὶ τῇ βάσει τῆς αντίθέσεως μεταξύ τῆς αἰωνίου καλῶς διευθετημένης κινήσεως των ούρανῶν και των άτάκτων έφημέρων κινήσεων έπὶ τῆς γῆς. Συνεπλήρωσε την αντίθεσιν αὐτήν, τονίζοντας την κυρίαν διαφοράν εις την μορφήν μεταξύ των κινήσεων των άστρων και των κινήσεων τῆς κατωτέρας περιοχῆς, εκτεινόμενης μεταξύ τῆς γῆς και τῆς σελήνης.

Αί ούράνιαι κινήσεις είναι κυκλικαί, ενώ αί κινήσεις τῆς περιοχῆς μας είναι πεπλεγμένοι, λαμβάνουσαι πολλές φορές την μορφήν εὐθειῶν γραμμῶν. ‘Η κλίμαξ αὐτῆς των κοσμικών αξιῶν έπιτάσσει την προτεραιότητα των ούρανίων έπὶ των γήινων κινήσεων και το πρωτεῖον τῆς κυκλικῆς κινήσεως. «‘Η περιστροφική κίνησις είναι άπλῇ και δύναται να είναι αἰωνία, διότι όλαί αί κινήσεις αὐταί καταλήγουν εις την ήρεμίαν, όπου ή κίνησις χάνεται».

‘Η έννοια τῆς φυσικῆς μορφῆς τῆς κινήσεως συνδέεται με την σύλληψιν τῆς έννοίας τῆς *φυσικῆς θέσεως*, ή όποία είναι ή γῆ και το ὕδωρ. ‘Αμφότερα τὰ στοιχεῖα, έπομένως, εύρίσκονται εις το κέντρον του σύμπαντος. Είναι έξ ἴσου φανερόν ότι ή φυσική θέσις των δύο άλλων στοιχείων των Προ-σωκρατικῶν, κατά τον 'Αριστοτέλην, του αέρος και του πυρός, είναι εις τας ανωτέρας περιοχάς. ‘Ως αποτέλεσμα τῆς φυσικῆς αὐτῆς κινήσεως είναι ή τάσις των διαφορών ειδῶν τῆς ὕλης τὰ όποῖα δέν είναι εις την φυσικήν των θέσιν, να μεταβαίνουν εις αὐτήν, λόγω τῆς έπιθυμίας των να καταλαμβάνουν την κανονικήν των θέσιν εις τόν κόσμον, επαναφέροντα οὕτως



οιανδήποτε απόκλισιν εἰς τὴν τελείαν τάξιν. Τοιουτοτρόπως, αἱ φυσικαὶ κινήσεις καθίστανται ἡ δυναμικὴ ἐκδήλωσις λειτουργίας τῆς τελεολογίας εἰς τὸ φυσικὸν σύμπαν.

Ἐφόσον ἀπλᾶ σώματα πρέπει νὰ ἔχουν ἀπλᾶς κινήσεις, συνάγομεν ἐπομένως ὅτι αἱ μόναι ἀπλᾶ κινήσεις εἶναι ἡ κυκλικὴ καὶ ἡ εὐθύγραμμος, ἡ τελευταία δύο εἰδῶν, ἀπομακρυνομένη ἀπὸ τὸ κέντρον καὶ βαίνουσα πρὸς τὸ κέντρον. Ἐπομένως, ἰσχύει ἡ γενικὴ ἀρχὴ ὅτι τὸ κάθε τι καθορίζεται ἀπολύτως εἰς μίαν θέσιν καὶ δὲν εἶναι δυνατόν ἓνα ἄλλο σῶμα νὰ καταλάβῃ τὴν θέσιν αὐτήν.

Εἶναι δυνατόν νὰ θεωρήσωμεν ὅτι καὶ ἡ μοντέρνα φυσικὴ ἐπίσης προχωρεῖ κατὰ τὸν αὐτὸν τρόπον καὶ ὅτι ἡ μετάβασις εἰς τὴν μηχανικὴν τῆς σχετικότητος περιέχει πλήρη νοητικὴν ἐπανάστασιν, διότι ἀκριβῶς οἱ νόμοι τῆς Φυσικῆς τοῦ Νεύτωνος ἀπέβησαν ἓνα θεωρητικὸν δόγμα. Ἐν πάσῃ περιπτώσει, ὑπάρχει μιὰ βασικὴ διαφορὰ μεταξύ τοῦ Νεύτωνος καὶ τοῦ Ἀριστοτέλους.

Τὸ πείραμα παίζει ἓνα πολὺ μεγαλύτερον ρόλον εἰς τὴν σύγχρονον φυσικὴν, δεδομένου ὅτι εἶναι ὁ μοναδικὸς κριτὴς περὶ τῆς ἀληθείας οἰασθήποτε θεωρίας. Ἐπομένως ἡ σύγχρονος ἐπιστήμη προϋποθέτει ἓνα περισσότερον εὐκαμπτον χαρακτηρὰ, καὶ ἡ συνεχὴς πρόοδός της καθίσταται δυνατὴ διὰ τῆς συνεχοῦς ἐπανεκτιμήσεως τῶν βασικῶν της ἀρχῶν. Ἡ προσέγγισις τοῦ Ἀριστοτέλους, ἐξ ἄλλου, μὴ στηριζομένη εἰς τὸ πείραμα, ἀδυνατεῖ νὰ παρατηρήσῃ τὴν σωστὴν ἰσορροπίαν μεταξύ ἐπαγωγῆς καὶ ἀναγωγῆς καὶ φθάνει νὰ κυριαρχῇται εὐρέως ἀπὸ τὴν τελευταίαν.

Ἐξετάζοντας τώρα τίς δύο εἰδικές φυσικὲς κινήσεις, τὴν πρὸς τὰ ἄνω καὶ τὴν πρὸς τὰ κάτω κίνησιν, αἱ κινήσεις αὗται ἐθεωρήθησαν ὑπὸ τοῦ Ἀριστοτέλους ὡς ἀπολύτως ἀντίθετοι. Κατ' αὐτὸν τὸν τρόπον ὁ Ἀριστοτέλης δὲν συμφωνεῖ μὲ τὸν Πλάτωνα καὶ τοὺς ἄλλους φιλοσόφους, οἱ ὅποιοι ἐθεώρουν ὅτι τὸ Σύμπαν ἀποτελεῖται ἀπὸ ἓν κέντρον καὶ ἀπὸ σφαιρικὴν περίμετρον καὶ ὅπου αἱ ἰδέαι αὐτὲς ὀφείλουν νὰ εἶναι σχετικαί. Κατὰ τὸν αὐτὸν τρόπον ὁ Ἀριστοτέλης ἐθεώρησε τὸ βαρὺ καὶ τὸ ἐλαφρὸν ὡς ἀπόλυτα. Αὐτὴ ἡ πρότασις ἀπετέλεσε τὴν ἀρχὴν τῆς ἀντιθέσεως, ἡ ὁποία ἐμπόδισε τὴν ἀνάπτυξιν τῆς βασικῆς ιδέας τοῦ εἰδικοῦ βάρους.

Παρομοίως, ὁ Ἀριστοτέλης προβλέπει τὸ βάρος καὶ τὴν ἐλαφρότητα κατὰ δύο τρόπους, κατὰ τὸν ἀπόλυτον καὶ τὸν σχετικόν. Ἀναφέρει εἰς τὸ βιβλίον του περὶ οὐρανοῦ (307 B) ὅτι: Οἱ πρόγονοί μας ἀνέπτυξαν τὴν ἔννοιαν τοῦ σχετικοῦ ἀλλὰ οὐχὶ τοῦ ἀπολύτου: Οὐδὲν ἀνέφερον περὶ τῆς σημασίας τοῦ βάρους καὶ τῆς ἐλαφρότητας, ἀλλὰ ἐξήτασαν τί εἶναι βαρύτερον καὶ τί εἶναι ἐλαφρύτερον μεταξύ τῶν πραγμάτων ποὺ ἔχουν βάρος. Ἐξηγώντας τὰ παραπάνω δύναται νὰ συμπεράνῃ κανεὶς ὅτι ὑπάρχουν ὠρισμένα πράγματα, τῶν ὁποίων ἡ φύσις εἶναι νὰ κινοῦνται πάντοτε ἀπομακρυνόμενα ἀπὸ τὸ κέντρον καὶ ἄλλα νὰ κινοῦνται πρὸς τὸ κέντρον. Τὰ πρῶτα



καλοῦνται κινούμενα πρὸς τὰ ἄνω, τὰ δὲ δεύτερα πρὸς τὰ κάτω.

Θεωρώντας τώρα τὸ πρόβλημα τῆς δυναμικῆς τοῦ Ἀριστοτέλους δυνάμεθα νὰ διατυπώσωμεν ὅτι ἡ μελέτη αὐτῆς τῆς ἐρωτήσεως ἀποτελεῖ ἀφ' ἑαυτῆς τὴν κυρίαν αἰτίαν τῆς φήμης τοῦ Ἀριστοτέλους, διότι οὗτος ἀπετέλεσε τὸν *μόνον ἀρχαῖον ἐπιστήμονα*, ὁ ὁποῖος ἡσχολήθη μὲ τὴν ἀνάπτυξιν ποσοτικῆς θεωρίας εἰς τὸ βασικὸν αὐτὸ πεδίον. Αὐτὸ ἀπετέλεσεν ἓνα *μεγάλον ἐπίτευγμα*. Ἡ μηχανικὴ τοῦ Γαλιλαίου καὶ τοῦ Νεύτωνος μᾶς ἔδειξαν ὅτι τὰ φαινόμενα τῆς δυναμικῆς, τὰ ὁποῖα φαίνονται εἰς τοὺς ἀκατατόπιστους ὡς στοιχειώδη, εἶναι εἰς τὴν πραγματικότητά λίαν πολυπλοκά.

Γνωρίζομεν τώρα ὅτι ἡ μελέτη τῶν νόμων τῆς κινήσεως περιπλέκεται ἀπὸ δύο παράγοντας, ἥτοι τὴν τριβὴν καὶ τὴν ἀντίστασιν τοῦ περιβάλλοντος, ποὺ δὲν δύνανται εὐκόλως νὰ ἐξουδετερωθοῦν. Ἡ ταχύτης τοῦ κινουμένου σώματος σταθερῶς ἐλαττοῦται ἐξαιτίας τῶν δύο αὐτῶν παραγόντων. Τὸ γεγονός αὐτὸ ἔδωσεν ἀφορμὴν εἰς τὴν παρεξήγησιν, πρὸ τοῦ Γαλιλαίου, ὅτι τὸ κινούμενον σῶμα ὀφείλει νὰ ὑποβάλλεται εἰς τὴν ἐπίδρασιν σταθερᾶς δυνάμεως διὰ νὰ διατηρῇ σταθερὰν ταχύτητα. Πράγματι, μία τοιαύτη δύναμις χρειάζεται ἀπλῶς νὰ ἀντιδρᾷ εἰς τὰς δυνάμεις τῆς τριβῆς καὶ τῆς ἀντιστάσεως τοῦ μέσου. Τὸ πρόβλημα καθίσταται περαιτέρω πολυπλοκὸν ἐκ τοῦ γεγονότος ὅτι τὸ κινούμενον σῶμα εὐρίσκεται συνήθως ὑπὸ τὴν ἐπίδρασιν τοῦ πεδίου βαρύτητος τῆς γῆς.

Ὅλαι αὗται αἱ προτάσεις τῆς συγχρόνου φυσικῆς εἶναι τὸ ἀποτέλεσμα πειραματικῆς καὶ θεωρητικῆς ἀναλύσεως τῶν διαφόρων παραγόντων τῶν ἐπενεργούντων κατὰ τὸν χρόνον τῆς κινήσεως. Δεδομένου ὅτι ὁ Ἀριστοτέλης δὲν ἀνέλυε τὴν κίνησιν εἰς τοὺς συνιστῶντας ὅρους τῆς, δὲν εἶναι καθόλου παράξενον ὅτι οἱ νόμοι τοῦ τῆς κινήσεως δὲν ἀντιστοιχοῦν μὲ τὰ γεγονότα. Πράγματι ὁ Ἀριστοτέλης ἐπιμένει ὅτι ἡ ἀπόστασις ἢ διανυομένη ἀπὸ ἓνα σῶμα εἶναι εἰς εὐθεῖαν ἀναλογίαν μὲ τὴν δύναμιν ἢ ὁποῖα ἐπενεργεῖ σταθερῶς ἐπ' αὐτοῦ καὶ μὲ τὸν ἀπαιτούμενον χρόνον καὶ εἰς ἀντίστροφον ἀναλογίαν μὲ τὴν μᾶζαν τοῦ σώματος.

Ἀλλὰ ἡ ἐμπειρία τοῦ ἀπέδειξεν ὅτι ὁ Νόμος αὐτὸς δὲν ἦτο παρὰ μία χονδροειδὴς προσέγγισις καὶ ἀποτυγχάνει ὁλοσχερῶς ὅταν ἡ δυσαναλογία μεταξὺ τῆς δυνάμεως καὶ τῆς μᾶζης εἶναι πολὺ μεγάλη. Ἐπομένως, ἐθεώρησεν ἀναγκαῖον νὰ ἀποδείξῃ εἰδικῶς τὸν νόμον τοῦτον, καὶ νὰ δώσῃ σειρὰν ἐμπειρικῶν παραδειγμάτων πρὸς ὑποστήριξιν του. Εἰς ἐνδιαφέρουσαν ἀναφορὰν εἰς τὸ βιβλίον τοῦ τῶν *Φυσικῶν* (249B) παρακολουθοῦμεν ἓναν ἐντελῶς διάφορον Ἀριστοτέλην, ἓναν Ἀριστοτέλην ὁ ὁποῖος εἶναι πολὺ κοντύτερα πρὸς ἡμᾶς, ἐν συγκρίσει μὲ τὸν ἄνθρωπον ὁ ὁποῖος δογματίζει διὰ τὴν δομὴν τοῦ κόσμου χωρὶς νὰ ἀμφιβάλλῃ οὐδ' ἐπὶ στιγμὴν διὰ τὴν ἀναλυτικὴν δύναμιν τῆς καθαρᾶς του σκέψεως.

Ἄν καὶ ὁ προαναφερθεὶς προηγούμενος νόμος του δὲν εἶναι ὀρθός, ἐν τούτοις ἡ διαμόρφωσίς του εἶναι ὀρθή ὡς πρὸς δύο ἀπόψεις ἐν συσχετισμῷ μὲ τὸ πνεῦμα τῶν συγχρόνων καιρῶν μας: εἶναι μαθηματικὴ κατὰ τὴν μορφήν, καὶ ἡ ἰσχὺς της ἀποδεικνύεται δι' ἀναφορᾶς εἰς τὸ πείραμα.

Ἡ ἀναφορὰ αὐτὴ λέγει τὰ ἑξῆς:

«Ἐὰν ἡ δύναμις  $E$  κινή τὸ σῶμα  $A$  εἰς ἀπόστασιν  $B$  κατὰ τὸν χρόνον  $\Gamma$ , δὲν συμπεραίνεται ἀπαραιτήτως ὅτι ἡ αὐτὴ δύναμις  $E$  δύναται νὰ κινήσῃ διπλάσιον σῶμα  $A$  εἰς τὸ ἥμισυ τῆς ἀποστάσεως  $\Gamma$  κατὰ τὸν αὐτὸν χρόνον...». Πράγματι, εἶναι δυνατὸν νὰ ἰσχύῃ ὅτι μπορεῖ καὶ νὰ μὴ δημιουργήσῃ καθόλου κίνησιν διότι δὲν προκύπτει ὅτι δεδομένη κινήτηριος δύναμις θὰ δημιουργήσῃ κίνησιν, εἴτε ὡς πρὸς ὠρισμένον μέγεθος, εἴτε δι' ὠρισμένον διάστημα χρόνου: ἄλλως πῶς; ἕνας ἄνθρωπος δύναται νὰ κινήσῃ ἕνα πλοῖον ἐφόσον ἀμφότερες καὶ ἡ κινήτηριος δύναμις τῶν μεταφορέων τοῦ πλοίου καὶ ἡ ἀπόστασις, πού ἀναγκάζουν τὸ πλοῖον νὰ διατρέξῃ, εἶναι διαιρετέες σὲ τόσα μέρη ὅσα εἶναι καὶ οἱ ἄνθρωποι (Φυσικὰ 249β).

Αἱ διάφοροι διατυπώσεις αἱ προταθεῖσαι ὑπὸ τοῦ Ἀριστοτέλους διὰ τὸν Νόμον τοῦτον ἀποδεικνύουν ὅτι ἦτο προσεκτικὸς εἰς τὴν μὴ διαταραχὴν τῶν ἀρχῶν τοῦ γενικοῦ αὐτοῦ Νόμου ὅτι: ὅσον μεγαλύτερον εἶναι τὸ σῶμα τόσον εὐκολώτερον ἀναπτύσσει τὴν κανονικὴν του κίνησιν (Φυσικὰ 290Α). «Ὅσον μεγαλύτεραι εἶναι αἱ ποσότητες τοῦ πυρός ἢ τῆς ὕλης, πάντοτε μετακινουῦνται ταχύτερον ἀπὸ τὴν μικροτέραν εἰς τὴν τελικὴν φυσικὴν των θέσιν (Φυσικὰ 277Β). «Ὅσον μεγαλύτερα εἶναι ἡ ποσότης τοῦ πυρός, τόσον περισσότερον ταχέως κινεῖται τοῦτο πρὸς τὰ ἄνω, ἐν συγκρίσει πρὸς τὴν μικροτέραν. Ὅμοιως μεγαλύτερα ποσότης χρυσοῦ ἢ μολύβδου κινεῖται πρὸς τὰ κάτω ταχύτερον, παρὰ μικροτέρα ποσότης, καὶ αὐτὸ συμβαίνει μὲ ὅλα τὰ βαρέα σώματα (Φυσικὰ 309Β).

Περαιτέρω, ἡ ποσοτικὴ διατύπωσις τοῦ Νόμου καθορίζεται ὡς ἀκολούθως: ἐὰν ὠρισμένον βάρος κινῆται εἰς ὠρισμένην ἀπόστασιν κατὰ ὠρισμένον χρόνον, μεγαλύτερον βάρος κινεῖται εἰς τὴν αὐτὴν ἀπόστασιν εἰς βραχύτερον χρόνον καὶ αἱ σχέσεις μεταξὺ τῶν βαρῶν καθὼς ἐπίσης καὶ τῶν χρόνων εὐρίσκονται ἐν ἀναλογίᾳ, δηλαδή ἐὰν τὸ ἥμισυ τοῦ βάρους καλύπτῃ μίαν ἀπόστασιν εἰς χρόνον  $x$ , ὁλόκληρον τὸ βάρος θὰ καλύπτῃ τὴν αὐτὴν ἀπόστασιν εἰς χρόνον  $x/2$  (Περὶ οὐρανοῦ 273Β).

Ἐπομένως ὁ νόμος τοῦ Ἀριστοτέλους γιὰ τὰ πίπτοντα σώματα λέγει ὅτι ἡ ταχύτης τοῦ πίπτοντος σώματος εἶναι ἀνάλογος τοῦ βάρους του. Ὁ νόμος αὐτὸς ἐγένετο εὐρέως γνωστὸς ἀπὸ τὴν κριτικὴν τὴν ὁποίαν ἀνέπτυξεν ὁ Γαλιλαῖος εἰς τὸ βιβλίον του: «Θεωρήματα καὶ μαθηματικαὶ ἀποδείξεις» (1638). Ἡ κριτικὴ αὐτὴ τοῦ Γαλιλαίου τοῦ νόμου τοῦ Ἀριστοτέλους καθορίζει τὸ σημεῖον στροφῆς ἀπὸ τὴν Φυσικὴν τῶν ἀρχαίων εἰς τὴν σύγχρονον Φυσικὴν.



Ἐξετάζοντας τὸ πρόβλημα τοῦ νόμου τούτου ἐν λεπτομερείᾳ δυνάμεθα νὰ θέσωμεν ὅτι ὅλον τὸ θέμα τῶν νόμων τῶν πιπτόντων σωμάτων ἔχει σημασίαν ἐκτὸς τῶν στενῶν ὁρίων τοῦ νόμου τῆς εἰδικῆς κινήσεως, διὰ τοῦ συνδέσμου του μὲ τὴν ἀπόλυτον ἄρνησιν ὑπὸ τοῦ Ἀριστοτέλους τοῦ κενοῦ καὶ μὲ τὴν ἀποψίν του, σχετικῶς μὲ τὴν ἐπίδρασιν τοῦ περιβάλλοντος εἰς τὴν κίνησιν. Ἐπομένως, ἀφορᾷ τὰς κυρίας ἀρχὰς συλλήψεως τοῦ φυσικοῦ κόσμου.

Οἱ ἰδρυταὶ τῆς ἀτομικῆς σχολῆς τῆς ἀρχαίας Ἑλλάδος ἦσαν οἱ πρῶτοι οἱ ὁποῖοι ἐθεώρουν τὴν ὑπαρξίν τοῦ κενοῦ ὡς ἀναγκαίαν συνθήκην τῆς κινήσεως. Ἡ σύλληψις των αὐτῇ ἦτο ριζοσπαστικὴ εἰς τὸ μέγιστον: Τὰ βασικά στοιχεῖα τῆς ὕλης πρέπει νὰ διαχωρίζονται τὸ ἐν ἀπὸ τὸ ἄλλον διὰ τῆς ἀπουσίας τῆς ὕλης. Ἐκαστον ἄτομον κινεῖται εἰς τὸ κενὸν μέχρις ὅτου συγκρουσθῇ μὲ ἓνα ἄλλο ἄτομον. Τοιουτοτρόπως, εἰς τὸν κόσμον τῶν ἀτόμων κάθε δραστηριότης γεννᾶται ἀπὸ κινήσεις εἰς τὸ ἀπόλυτον κενὸν καὶ συγκρούσεις ὕλης μὲ ὕλην.

Ἡ ἀρχὴ αὐτῇ ἦτο μία ἀπὸ τὰς βαθυτέρας συλλήψεις τῆς ἀρχαίας Ἑλλάδος, ἐνῶ ἡ ἀπόρριψις τῆς ἀπὸ τὸν Ἀριστοτέλην ἦτο μία ἀντίθεσις, κατ' ἀρχήν, πρὸς τὴν θεωρίαν. Μεταξὺ τῶν πολλῶν λόγων τῶν προβληθέντων ὑπὸ τοῦ Ἀριστοτέλους κατὰ τῆς ὑπάρξεως τοῦ κενοῦ εἰς τὸ τέταρτον τμήμα τῶν Φυσικῶν του (Φυσικὰ 214B), ἡ πλέον χαρακτηριστικὴ ἔκφρασις τοῦ τρόπου σκέψεώς του δίδεται ἀπὸ τὴν παρακάτω πρότασιν: «Τὸ κενόν, ὅσο τοῦτο εἶναι κενόν, δὲν δέχεται καμμίαν διαφοράν». Δι' αὐτοῦ ἐννοεῖ ὅτι τὸ κενὸν δὲν ἔχει ξεχωριστὰ γεωμετρικὰ χαρακτηριστικά, οὔτε ἔχει καμμίαν ἀπὸ τὰς ιδιότητας τὰς βασικὰς διὰ τὸν καθορισμὸν τῆς διευθύνσεως καὶ τῆς κινήσεως. Εἰς τὸ κενὸν κατὰ συνέπειαν δὲν ὑπάρχει δυνατότης προσανατολισμοῦ εἰς τὸν χῶρον.

Ἐνταῦθα ἀναφέρεται ἀνάλογόν τι μὲ τὴν ἄρνησιν τῆς ἀπολύτου κινήσεως εἰς τὸν Νευτώνιον χῶρον. Ἐὰν ὑπῆρχε μόνον ἐν σῶμα εἰς ὁλόκληρον τὸ κενὸν τοῦ ἀπείρου χώρου, δὲν θὰ ἦτο δυνατόν νὰ προσδιορίσωμεν εἰς αὐτὸ μίαν θέσιν ἢ μίαν κατάστασιν κινήσεως, διότι διὰ τὸν σκοπὸν αὐτὸν τουλάχιστον δύο σώματα ἀπαιτοῦνται, ὥστε νὰ καθορίσουν τὴν σχετικὴν κίνησιν εἰς δοθὲν πλαίσιον ἀναφορᾶς. Ὁ Ἀριστοτέλης δὲν βλέπει τρόπον δημιουργίας τοιούτου πλαισίου ἂν τὰ σώματα διαχωρίζονται τὸ ἐν ἀπὸ τὸ ἄλλον διὰ τοῦ κενοῦ.

Δεδομένου ὅτι οὐδεὶς γεωμετρικὸς σύνδεσμος συνδέει ἐν σῶμα περιβαλλόμενον ἀπὸ τὸ κενὸν μὲ ἕτερον σῶμα, δὲν ὑπάρχει λόγος νὰ ἀπεικονίζωμεν τὴν κατάστασιν του εἴτε ὡς πρὸς τὴν θέσιν του εἴτε ὡς πρὸς τὴν κίνησιν. Ἀπὸ τὴν ἐποχὴν τοῦ Νεύτωνος καὶ ἐντεῦθεν οἱ φυσικοὶ συνήθισαν νὰ θεωροῦν τὸν χῶρον ὡς ἓνα γεωμετρικὸν πλαίσιον ἐκτεινόμενον ἐπὶ τοῦ κενοῦ καὶ συνδέον μετὰ τὸς τὰ φυσικὰ σημεῖα. Ὁ Ἀριστοτέλης ἀπέρριψε μίαν φυσικὴν περιγραφὴν διὰ μιᾶς ἀφηρημένης γεω-



μετρίας έκτεινομένης πέραν τῶν ὁρίων τῆς ὕλης. Ἐν ἀντιθέσει πρὸς τοὺς συγχρόνους ἐταύτισε τὸν χῶρον μὲ τὸν ὄγκον, πληρωμένον ἀπὸ ὕλην, ταυτότης ἣ ὁποία ὑποχρεώνει τὴν συνέχειαν τῆς ὕλης. Εἶναι χαρακτηριστικὸν ὅτι ὁ Ἀριστοτέλης δὲν χρησιμοποιεῖ τὴν λέξιν *χῶρος*, ἀλλὰ τὴν λέξιν *θέσις* διὰ νὰ ἐκφράσῃ τὴν τοποθεσίαν δεδομένου σώματος. Ἡ *θέσις* εἶναι συγκεκριμένος ὅρος, διάφορος ἀπὸ τὸν χῶρον, δεδομένου ὅτι δίδει γεωμετρικὸν ὅρισμὸν ἐνὸς εἰδικοῦ σημείου ἐν σχέσει πρὸς τὰ σύνορά του.

Ὁ συνδυασμὸς ὑπὸ τοῦ Ἀριστοτέλους τῆς γεωμετρίας καὶ τῆς ὕλης διὰ τὸν σχηματισμὸν τῆς ἐννοίας τῆς θέσεως δὲν διαφέρει καθόλου μὲ τὴν σύλληψιν τοῦ χώρου ἀπὸ τὴν γενικὴν θεωρίαν τῆς σχετικότητος. Ἡ θεωρία αὕτη ἐπίσης ἀπορρίπτει τὴν Νευτώνιον ἀπεικόνισιν τοῦ χώρου, ὡς εἶδους ἀπείρου κυτίου ἐντὸς τοῦ ὁποίου τὰ φυσικὰ σώματα κινοῦνται. Ἀντ' αὐτοῦ ἀπεικονίζει τὸν χῶρον ὡς ἐν εἶδος ἐπικοινωνίας τοῦ σώματος μὲ τὸ περιβάλλον του. Εἶναι τὸ σῶμα, τὸ ὁποῖον καθορίζει τὴν γεωμετρίαν τοῦ περιβάλλοντός του, καὶ ἡ γεωμετρία αὕτη δὲν δύναται τεχνητῶς νὰ διαχωρισθῇ ἀπὸ αὐτὸ τοῦτο τὸ σῶμα. Κατὰ συνέπειαν ἐν φυσικὸν σημεῖον εἶναι ἀπλῶς μία ἰδιομορφία εἰς τὸ μετρικὸν πεδίον ποὺ τὸ περιβάλλει καὶ τὸ πεδίον αὐτὸ δὲν εἶναι καθόλου ἕνας κενὸς χῶρος.

Αὐτὸς ὁ συλλογισμὸς, ὅπως ἐπίσης καὶ ὁ τοῦ Ἀριστοτέλους, ὁδηγεῖ εἰς τὴν ἄρνησιν τοῦ κενοῦ. Ὁ κόσμος ὅπως ἀντιμετωπίζεται ἀπὸ ἡμᾶς σήμερον εἶναι πολὺ διάφορος ἀπὸ τὸ κενὸν δοχεῖον τοῦ Νεύτωνος ἢ τῶν Ἑλλήνων ἀτομιστῶν. Ὁ διαστρικὸς χῶρος εἶναι πλήρης ἀπὸ ἠλεκτρομαγνητικὴν ἀκτινοβολίαν. Αἱ ἐπεκτάσεις του περιλαμβάνουν ἐπίσης πεδία βαρύτητος καὶ διαπερῶνται ἀπὸ βαρυτικὰ κύματα. Παρομοίως, ὑπάρχουν πεδία δυνάμεων περὶ τὰ ἄτομα, ἀπὸ τὰ ὁποῖα τὰ φυσικὰ σώματα συντίθενται, καὶ εἰς τοὺς χώρους τοῦ ατόμου ἢ τοῦ πυρῆνος ὑπάρχει ἀλληλεπίδρασις παρομοίων δυνάμεων μεταξὺ τῶν πρωτογενῶν σωματιδίων. Ἡ ὁμοιότης μεταξὺ τῆς ἀντιμετωπίσεως ὑπὸ τοῦ Ἀριστοτέλους τοῦ προβλήματος τοῦ συνεχοῦς χώρου καὶ ἐκείνου τοῦ θεωρουμένου εἰς τὴν γενικὴν θεωρίαν τῆς σχετικότητος εἶναι πολὺ ἐνδιαφέρονσα, ἀλλὰ χρειάζεται προσοχὴν εἰς τὴν εὐρύτεραν ἐπέκτασιν τῶν συμπερασμάτων αὐτῶν.

Ἡ ἄρνησις τοῦ κενοῦ ἔχει τοιοῦτον ἐνδιαφέρον εἰς τὸν Ἀριστοτέλην ὥστε νὰ τὴν ἐξετάζῃ κατ' ἐπανάληψιν καὶ ὑπὸ διαφόρους ἀπόψεις. Ἐν πάσῃ περιπτώσει, συνοψίζοντας τοὺς συλλογισμοὺς του, ὁ Ἀριστοτέλης ἀναφέρει, μόνον διὰ νὰ ἀπορρίψῃ, ἕνα συμπέρασμα τὸ ὁποῖον πράγματι ἀποτελεῖ σαφῆ διατύπωσιν τοῦ Νόμου τῆς Ἀδρανείας τοῦ Γαλιλαίου. Ἡ ἄρνησις τοῦ κενοῦ συνάγεται ἐπομένως ἀπὸ τὸ λανθασμένον συμπέρασμα τὸ ὁποῖον ἀποκλείει τὴν δυνατότητα μεταβάσεως εἰς τὸ ὅριον, ἀπὸ ἕνα μέσον πεπερασμένης πυκνότητος εἰς ἕτερον τοῦ ὁποίου ἡ πυκνότης

νά εἶναι μηδενική, καὶ ἐπομένως ὁ Ἀριστοτέλης συμπεραίνει ὅτι ἂν ὁ κόσμος εἶναι ἐν τέλειον συνεχές, θὰ πρέπει νὰ εἶναι μία ἀπλῇ ὁλότης, ἐν ἐνιαῖον σῶμα, καὶ τὸ σῶμα αὐτὸ πρέπει νὰ εἶναι πεπερασμένον.

Ἐπομένως, ἐνῶ παραδέχεται τὴν δυνατότητα ἀπειρισμοῦ εἰς τὴν διαίρεσιν, τὴν ἀπορρίπτει εἰς τὴν ἔκτασιν. Ὁ κόσμος ἐπομένως εἶναι πεπερασμένος. Περαιτέρω, ἐπειδὴ ἡ ἀνάγκη διὰ τελειότητα ἀπαιτεῖ, καὶ τὰ ἀστρονομικὰ φαινόμενα ἀποδεικνύουν, τὴν σφαιρικότητα τοῦ κόσμου, ὁ κόσμος εἶναι μιὰ πεπερασμένη σφαῖρα, μὲ τὴν γῆν εἰς τὸ κέντρον της, καὶ τὰ σταθερὰ ἄστρα εἰς τὰ ὅριά της. Τὸ πεπερασμένον τοῦ κόσμου συνάγεται ἐπίσης κατὰ τὸν Ἀριστοτέλην ἀπὸ τὴν κυκλικὴν κίνησιν. Ἄλλως θὰ ἔπρεπε νὰ παραδεχθῶμεν μίαν ἄπειρον ταχύτητα.

Ἡ ἰδέα ὅτι ὁ κόσμος εἶναι πεπερασμένος ἀποτελεῖ πόρισμα τῆς δυναμικῆς τοῦ Ἀριστοτέλους καὶ τῆς ἰδέας του τῆς φυσικῆς θέσεως. Ἐν ἀντιθέσει πρὸς τοὺς Προσωκρατικούς φιλοσόφους, ὁ Ἀριστοτέλης ἀπορρίπτει τὴν ἰδέαν τῆς δημιουργίας, διότι ὅ,τιδήποτε δημιουργεῖται πρέπει καὶ νὰ καταστρέφεται. Κατὰ συνέπειαν ἡ αἰωνιότης τοῦ κόσμου ἐπεκτείνεται καὶ πρὸς τὰς δύο χρονικὰς κατευθύνσεις, τὸ παρελθὸν καὶ τὸ μέλλον. Δὲν χρειάζεται νὰ ἀναφερθῇ ὅτι ὁ Ἀριστοτέλης κρίνει δυσμενῶς τὸν Πλάτωνα, ὅτι ἐβάσισε τὴν κοσμολογίαν του εἰς τὴν δημιουργίαν τοῦ κόσμου καὶ ταυτοχρόνως ἰσχυρίζετο ὅτι ὁ κόσμος θὰ διαρκέσῃ ἐπ' ἄπειρον.

Αἱ δύο μεγάλαι φιλοσοφικαὶ σχολαί, ἐμφανισθεῖσαι μετὰ τὴν ἐποχὴν τοῦ Ἀριστοτέλους, δὲν παρεδέχθησαν τοὺς νόμους αὐτοὺς. Πράγματι καὶ οἱ Στωϊκοὶ καὶ οἱ Ἐπικούριοι ἐπανῆλθον εἰς τὴν δημιουργίαν τῆς κοσμικῆς ἐξελίξεως. Ἡ θεωρία τοῦ Ἀριστοτέλους διὰ τὴν αἰωνιότητα τοῦ κόσμου παρέμεινε μία καὶ μοναδικὴ ἀτομικὴ ἰδέα καθ' ὅλην τὴν ἀρχαιότητα.

Αἱ δύο βασικαὶ ἀρχαὶ τῆς Ἀριστοτελικῆς φυσικῆς φιλοσοφίας ἐξελίχθησαν καὶ ἐτροποποιήθησαν εἰς τὴν φυσικὴν τῶν Στωϊκῶν. Ἡ τελεολογικὴ ἰδέα ἐνεφανίσθη εἰς τὴν διδασκαλίαν των εἰς τὴν πλέον ἐξελιγμένην ὁρησκειτικὴν μορφήν της, τὴν μορφήν τῆς Προνοίας. Ἡ ἄποψις τοῦ συνεχοῦς τοῦ κόσμου ἔλαβεν ἀκροτάτην δυναμικὴν μορφήν εἰς τὴν σχολὴν τῶν Στωϊκῶν. Ἀνεδύθη ὡς τὸ δόγμα ὅτι ὅλα τὰ μέλη τοῦ κόσμου εἶναι ἀλληλοεξαρτημένα καὶ εἶναι αὐτὴ ἡ ἀλληλοεξάρτησις πὺν μετατρέπει τὸν κόσμον εἰς πεδῖον φυσικῆς δραστηριότητος, ἡ ὁποία διαχέεται εἰς αὐτὸν καὶ τὸν συνενώνει εἰς ἐν δυναμικὸν σύνολον.

Αἱ ὑποθέσεις τοῦ Ἀριστοτέλους διὰ τὸ πεπερασμένον τοῦ κόσμου καὶ διὰ τὴν ἀπόλυτον ἄρνησιν τοῦ κενοῦ δὲν ἔγιναν παραδεκταὶ ἐν τῷ συνόλῳ των μέχρι τοῦ μεσαίωνος. Οἱ Στωϊκοὶ διετύπωσαν τὴν ὑπαρξιν ἐνὸς ἀπείρου κενοῦ, περιβάλλοντος τὸ πεπερασμένον συνεχές τοῦ κόσμου. Οἱ Ἐπικούριοι ἀνέπτυξαν τὴν θεωρίαν τοῦ Λευκίππου καὶ τοῦ Δημοκρίτου διὰ τὴν ἀτομικὴν δομὴν τῆς ὕλης καὶ τῆς ἀπείρου



ἐκτάσεως τοῦ κενοῦ εἰς τὸν χώρον μεταξύ καὶ ἐκτὸς τῶν ἀτόμων. Ὁ Ἰωάννης ὁ Φιλόπονος, ὁ ὁποῖος ἔζησεν εἰς τὰς ἀρχὰς τοῦ 6ου αἰῶνος μ.Χ., διαφωνεῖ μὲ τὴν σκέψιν ὅτι, ἐν ἀπουσίᾳ ἐνὸς μέσου καθυστερήσεως, ἡ ταχύτης τῆς πτώσεως δύναται νὰ φθάσῃ εἰς τὸ ἄπειρον. Ἡ διαφωνοῦσα διάθεσις τοῦ Φιλόπονου διὰ τὴν δυναμικὴν τοῦ Ἀριστοτέλους ἦτο ἡ τελευταία λέξις κριτικῆς, εἰς βάρος του, κατὰ τὰ χίλια ἔτη τὰ ὁποῖα προηγήθησαν τοῦ Γαλιλαίου.

Ὑπάρχουν ἐπίσης ἐνδείξεις κριτικῆς διαθέσεως πολλῶν ἀπὸ τὰς βασικὰς ἰδέας τοῦ Ἀριστοτέλους, αἱ ὁποῖαι ἐγένοντο κατὰ τὴν ἑλληνιστικὴν περίοδον καὶ ἀναφέρονται εἰς τὰ ἔργα τοῦ Πλουτάρχου. Ὁ Φίλων ὁ Βυζάντιος, ὁ Ἡρων ὁ Ἀλεξανδρεὺς καὶ ὁ Ρωμαῖος Βιτρούβιος, βασιζόμενοι εἰς τὴν πειραματικὴν ἐργασίαν ἡ ὁποία ἀνεπτύχθη ἐν τῷ μεταξύ ἀπὸ τῆς βαλλιστικῆς μηχανῆς δι' ἐμπειρικῶν μεθόδων, εἰσήγαγον μερικοὺς βασικοὺς νόμους τῆς κινήσεως, ὅπως π.χ. τὸν νόμον τοῦ παραλληλογράμμου τῶν ταχυτήτων. Ὡς συνέπεια τῶν ἐπιτευγμάτων αὐτῶν ἡ δυναμικὴ τοῦ Ἀριστοτέλους ἐτοποθετήθη εἰς τὴν πραγματικὴν τῆς ἱστορικῆς προοπτικῆς, ὡς ἡ θεωρία ἡ ὁποία ἦτο κυρίως βασικὴ καὶ ἐνδιαφέρουσα διὰ τὴν ἑναρξιν τῆς μακρᾶς ἀναπτύξεως τῆς ἐπιστήμης.

Ἡ τελεολογία τοῦ Πλάτωνος καὶ τοῦ Ἀριστοτέλους εὐρῆκεν ἀντιπάλους ἀκόμη καὶ κατὰ τὴν ἀρχαιότητα. Ἡ ἀτομικὴ θεωρία τοῦ Δημοκρίτου ἐβασίσθη ἐπὶ πλήρως μὴ τελεολογικῆς ἀντιμετωπίσεως. Ἐτερος ὁξὺς κριτικὸς τῆς τελεολογίας ἦτο ὁ μεγάλος μαθητὴς τοῦ Ἀριστοτέλους, ὁ ἰδρυτὴς τῆς συστηματικῆς βοτανολογίας, ὁ Θεόφραστος. Εἰς τὰ Μεταφυσικά του, ὁ Θεόφραστος ἀμφιβάλλει διὰ τὴν ἄποψιν ὅτι αἱ οὐράνιαι κινήσεις ἀποτελοῦν εἰδικὸν φαινόμενον, οὐσιαστικῶς διάφορον ἀπὸ τὰ ἀντίστοιχα γήινα, συμπεριλαμβανομένων καὶ ἐκείνων τῶν ἐμβίων ὄντων. Οὕτως, ὁ Θεόφραστος συμπίπτει μὲ τὰς ἀπόψεις τῶν ἀτομιστῶν, οἱ ὁποῖοι ἐθεώρουν τὴν κίνησιν αὐτὴν, ὡς ἐν ἐκ τῶν βασικῶν στοιχείων τοῦ σύμπαντος, ὅπως εἶναι καὶ ἡ ὕλη, τὴν αἰτίαν τῆς ὁποίας εἶναι ἀσήμαντον νὰ ἐπιζητῇ τις.

Ὅλη αὕτη ἡ κριτικὴ, ὅσον καὶ καταστροφικὴ καὶ ἂν εἶναι διὰ τὴν ἀπόρριψιν τῆς τελεολογικῆς ἀπόψεως τοῦ Ἀριστοτέλους, δὲν κατῴρθωσεν οὔτε καὶ νὰ τὴν ἐνοχλήσῃ αἰσθητῶς. Ἐν τέλει ὁ κόσμος τοῦ Ἀριστοτέλους ἐξηκολούθησε νὰ κυριαρχῇ εἰς τὴν ἀνθρωπίνην σκέψιν καθ' ὅλην τὴν ἀρχαίαν καὶ τὴν σχολαστικὴν περίοδον μέχρι τοῦ 16ου αἰῶνος. Οὔτε εἶναι ἐκπληκτικὸν τὸ γεγονός αὐτὸ ὅτι κατῴρθωσε νὰ θεωρηθῇ ἰδιαιτέρως κατάλληλος καὶ νὰ διατηρήσῃ τὴν θέσιν αὐτὴν, τόσον εἰς τὸν ἀρχαῖον κόσμον, ὅσον καὶ μετὰ τὴν ἐμφάνισιν τοῦ Χριστιανισμοῦ.

Κατὰ τὴν φιλοσοφίαν τοῦ Ἀριστοτέλους, ὁ κόσμος ἀποτελεῖ τὴν ὑπερτάτην ἐκδήλωσιν τοῦ κανόνος τῆς τάξεως εἰς τὸ Σύμπαν. Ἡ ἰδέα αὕτη ἦτο κατάλληλος τόσον μὲ τὴν νοοτροπίαν τὴν ἑλληνικὴν, κατὰ τὴν ὁποίαν ἡ ἀρχὴ τῆς τάξεως συν-



πιπτε με τὰς ἀρχὰς τῆς ὠραιότητος καὶ τῆς τελειότητος, ὅπως αὐται ἐξεφράζοντο εἰς τὴν καλλιτεχνικὴν δημιουργίαν, ὅσον ἐπίσης καὶ μετὰ τὴν βασικὴν πίστιν τῶν μονοθεϊστικῶν θρησκειῶν τοῦ Χριστιανισμοῦ, τοῦ Ἰουδαϊσμοῦ, καὶ τοῦ Μωαμεθανισμοῦ, αἱ ὁποῖαι θεωροῦν τὴν παγκόσμιον τάξιν ὡς τὸ ἔργον τοῦ Δημιουργοῦ καὶ τὴν ἔκφρασιν τῆς Θελήσεώς του.

Κατὰ συνέπειαν, ἡ τελεολογικὴ ἰδέα διετηρήθη ὡς ὁδηγὸς διὰ τὴν ἐρμηνείαν τῆς φύσεως ζυμωθεῖσα μετὰ τὴν ἀποψιν τῆς μεσαιωνικῆς θρησκευτικῆς σκέψεως. Μακρὰ ζωὴ ἐπίσης ἐξησφαλίσθη εἰς τὴν Ἀριστοτελικὴν ἀντίθεσιν μεταξὺ οὐρανοῦ καὶ γῆς, ριζωμένη ὅπως ἦτο εἰς τὴν λατρείαν τῶν ἀστέρων, τῆς ὁποίας ἔχνη ἀνευρίσκονται καθ' ὅλην τὴν διάρκειαν τῆς ἑλληνικῆς περιόδου. Εἰς τὴν θεολογίαν τῶν μονοθεϊστικῶν πίστεων, ἡ ἀντίθεσις αὐτὴ ἐπανεμφανίσθη ἐκ νέου, διὰ τῆς τοποθετήσεως τοῦ Θεοῦ καὶ τῶν ἀγγέλων του εἰς τοὺς οὐρανούς, εἰς τὴν καθαρὰν περιοχὴν τῶν Ἀριστοτελείων αἰωνίων κινήσεων.

Ἐπομένως τὸ φυσικὸν δόγμα τοῦ Ἀριστοτέλους παρέμεινεν ὡς δόγμα διὰ ἐξήκοντα γενεάς. Καμμία ἄλλη προσωπικότης εἰς τὴν ἱστορίαν τῶν ἐπιστημῶν καὶ μικρὸς ἀριθμὸς σοφῶν, καθ' ὅλην τὴν διάρκειαν τοῦ ἀνθρωπίνου πολιτισμοῦ, εἶχαν τόσον βαθεῖαν καὶ μακροχρόνιον τὴν ἐπίδρασιν εἰς τὰς σκέψεις τῆς ἀνθρωπότητος.

Ἦδη κατὰ τὴν ἀρχαίαν ἐποχὴν αἱ ἀπόψεις τοῦ Ἀριστοτέλους ἔφερον τὴν σφραγίδα τῆς ἀνωτάτης ἐξουσίας, τὴν ὁποίαν μόνον ὀλίγα τολμηρὰ πνεύματα ἐτόλμησαν νὰ ἀπορρίψουν. Ἡ ἐξουσία αὐτὴ κατ' οὐδένα τρόπον ἀδυνατίσεν ἀπὸ τὰς ἀντιπάλους προτάσεις, τὰς διατυπωθεῖσας διὰ τὴν φιλοσοφίαν τοῦ Πλάτωνος, αἱ ὁποῖαι ἐγένοντο κατὰ τὸ τέλος τῆς κλασσικῆς περιόδου καὶ τῆς ἐνάρξεως τοῦ μεσαίωonos. Ἐν πάσῃ περιπτώσει εἰς τὴν σφαῖραν τῶν φυσικῶν ἐπιστημῶν δὲν ὑπῆρξεν οὐσιαστικὴ διαφορὰ σκέψεων μεταξὺ τῶν δύο φιλοσοφιῶν.

Οἱ βασικοὶ ἐρμηνευταὶ τῶν τριῶν μεγάλων μονοθεϊστικῶν θρησκειῶν, τοῦ Χριστιανισμοῦ, τοῦ Ἰουδαϊσμοῦ καὶ τοῦ Μωαμεθανισμοῦ, ἀνέμειζαν τελικῶς τὰς βασικὰς ἀρχὰς τῆς φιλοσοφίας τοῦ Ἀριστοτέλους μετὰ τὴν θρησκευτικὴν τῶν σύλληψιν τοῦ σύμπαντος καὶ κατ' αὐτὸν τὸν τρόπον μετέτρεψαν τὸ σύνολον τῆς φιλοσοφίας αὐτῆς, συμπεριλαμβανομένων καὶ τῶν φυσικῶν τῆς καὶ τῶν κοσμικῶν τῆς ἀπόψεων, εἰς ἀναντίρρητον δόγμα. Κατ' αὐτὸν τὸν τρόπον, τὸ ἔθνος τὸ ὅποion ἐδημιούργησε τὰς Φυσικὰς Ἐπιστήμας καὶ τὴν μεθοδολογικὴν ἐπιστημονικὴν σκέψιν, ἐμποδίσθη, ἀπὸ τὸν δογματισμὸν αὐτόν, νὰ προαγάγῃ τὴν ἀνάπτυξίν των, πέραν τῶν ἀρχικῶν των σταδίων.

Ἐν τῇ ἀπουσίᾳ τῶν πειραματισμῶν καὶ τῶν σημαντικῶν καὶ καθοδηγητικῶν ἐπινοήσεων, ἡ διαδικασία τῆς ἐπιστημονικῆς δημιουργίας ἤρχισε νὰ ὑποφέρῃ μετὰ τὴν λαμπράν τῆς ἀρχικῆς ἀνάπτυξιν. Τὰ πρῶτα σημεῖα αὐτῆς τῆς καταπτώσεως

ἐμφανίζονται κατὰ τὸν 2ον αἰῶνα π.Χ. Αἱ σοβαραὶ συνέπειαι τῆς καταστάσεως αὐτῆς ἐπεδεινώθησαν ἀκόμη περισσότερο διὰ τῆς εἰσόδου τῶν προκαταλήψεων εἰς τὴν περιοχὴν τῆς ἐπιστήμης, καὶ μὲ τὴν ἀνάπτυξιν τῶν ἀποκρύφων τάσεων, ποὺ ἠκολούθησαν τὴν ἀνάμειξιν τῆς Ἀνατολῆς καὶ τῆς Δύσεως κατὰ τὴν Ἑλληνιστικὴν ἐποχὴν.

Ἡ παρακμὴ αὐτῆς τῆς δημιουργικῆς ἐπιστήμης ἀπετέλεσε μέρος τῆς γενικῆς ἐκλείψεως τοῦ ἀρχαίου κόσμου, ἡ ὁποία ἠκολούθησε τὴν παρακμὴν καὶ τὴν διάλυσιν τῆς Ρωμαϊκῆς Αὐτοκρατορίας. Μὲ τὴν διάδοσιν τοῦ Χριστιανισμοῦ τὰ φυσικὰ προβλήματα κατέλαβον μόνον τὴν δευτέραν θέσιν, ὅσον ἀφορᾷ τὸ βασικὸν ἐνδιαφέρον τῆς ἀνθρωπότητος, τὸ ὁποῖον ἦτο ἡ σχέσις τῆς μὲ τὸν Δημιουργόν. Ἐκ τῆς διαζεύξεως τοῦ ἀνθρώπου μὲ τὰ ζωτικὰ του ἐνδιαφέροντα διὰ τὰ φυσικὰ φαινόμενα, ἡ ἐκκλησία ἐβοηθήθη εἰς τὴν δημιουργίαν τῆς πίστεως ὅτι ὁ κόσμος ἦτο κάτι τι ξένον καὶ ἀπόμακρον ἀπὸ τὸν ἄνθρωπον.

Ἐν συσχετισμῷ μὲ τὰ ἀνωτέρω, εἶναι ἐνδιαφέρον νὰ θεωρήσωμεν τὴν μεγάλην ὑπηρεσίαν τὴν προσφερθεῖσαν ἐκ τῆς ἀναπτύξεως τῶν ἐπιστημονικῶν ὀργάνων καὶ ἐπιστημονικῶν μηχανῶν, αἱ ὁποῖαι ἤρχισαν νὰ δημιουργοῦνται κατὰ τὴν κλασσικὴν περίοδον τῆς ἀρχαιότητος καὶ ἔτυχον μεγάλης ἐξελίξεως, ἐν συνεχείᾳ, κατὰ τὴν ἑλληνιστικὴν ἐποχὴν. Ἡ πρόοδος αὐτὴ ἐπεξέτεινε τὴν γνῶσιν τῆς φύσεως ἀπὸ τὸν ἄνθρωπον πέραν τῶν ὁρίων τῶν πέντε αἰσθήσεων καὶ τὸν κατέστησεν ἱκανὸν νὰ ὑπερκεράσῃ τὴν ἀδυναμίαν τῶν αἰσθήσεων, τὴν ὁποίαν ὁ Ἀναξαγόρας ἐθεώρει ὡς τὸ κύριον ἐμπόδιον εὐρέσεως τῆς ἀληθείας.

Ἄν ἡ γνωσιολογικὴ περιπέτεια τῆς συγχρόνου ἐπιστήμης εἶναι ἴσως ἡ μεγαλύτερα ἀπὸ ὅλας τὰς περιπετείας, αἱ ὁποῖαι ἐνεκαινιάσθησαν κατὰ τὴν σύγχρονον ἐποχὴν, τοῦτο ὀφείλεται κυρίως εἰς τὴν ἀνάπτυξιν τῶν μαθηματικῶν ποὺ ἀπετέλεσαν τὸ κλειδὶ διὰ τὸν καθορισμὸν τῶν νόμων τῆς φύσεως. Εἶναι ἀληθὲς ὅτι ὁ κόσμος μας ἔχει ἀποστραγγισθῇ ἀπὸ ὅλον τὸ ἀνθρώπινον περιεχόμενόν του, ποὺ διέθετε κατὰ τὴν ἑλληνικὴν περίοδον. Εἶναι ἀληθὲς ὅτι ὁ ἀπλοῦς κόσμος τῶν αἰσθήσεων ἔχει διαχωρισθῇ ἀπὸ τὸν κόσμον τῆς ἐπιστήμης, διὰ χάσματος τὸ ὁποῖον ὅλον καὶ περισσότερο διαπλατύνεται· εἶναι ἀληθὲς ὅτι τὸ νὰ ἀντιληφθῇ κανεὶς τὸν κόσμον τῆς ἐπιστήμης ἀπαιτεῖ τρομακτικὰς δυνάμεις ἀφαιρέσεως καὶ ἐπαγγελματικῆς καὶ πνευματικῆς ἐκπαιδεύσεως, ποὺ καθίσταται προοδευτικῶς ὅλον καὶ περισσότερο αὐστηρά. Ἀλλὰ, ἀπὸ τὴν ἄλλην πλευράν, ὁ κόσμος αὐτὸς εὐρίσκεται εἰς συνεχῆ ἐξέλιξιν, καὶ νέα καὶ θαυμάσια περιεχόμενα δημιουργοῦνται, τὰ ὁποῖα καθιστοῦν τὴν ἐμπειρίαν τῶν μεμυμένων ἀνθρώπων, ὅχι ὀλιγότερον πλούσιαν, ἀπὸ τὴν κοσμικὴν ἐμπειρίαν τῶν πρώτων σχεπτομένων ἀνθρώπων τῆς ἀρχαίας Ἑλλάδος.

Ἐπομένως εἶναι δυνατόν νὰ γίνῃ παραδεκτὸν ὅτι αὐτοὶ οἱ ἴδιοι οἱ φιλόσοφοι

τῆς ἀρχαιότητος ἦσαν μεταξύ τῶν πνευματικῶν μας προγόνων τῆς συγχρόνου ἐποχῆς μας, καὶ δὲν ὑπάρχει καμμία ἀμφιβολία διὰ τὸ συμπέρασμα αὐτὸ εἰς οἷονδῆποτε συγκρίνει τὴν κληρονομίαν τῆς ἐλληνικῆς ἐπιστήμης, καὶ εἰδικῶς τὴν μεθοδικὴν τῆς ἀντιμετώπισιν, τὴν αὐστηρότητα τῆς φαντασίας τῆς, τὴν ἔμπνευσιν καὶ τὴν συσχετισμένην δύναμιν καὶ ἔντασιν τῆς ἐπιδράσεώς τῆς μετὰ τὴν ἐπιστήμην τῶν καιρῶν μας.

Ἐὰν πρέπει νὰ κρίνωμεν τὴν συμβολὴν τοῦ Ἀριστοτέλους καὶ τῶν ἄλλων φιλοσόφων τῆς ἀρχαιότητος μετὰ σύγχρονα κριτήρια, δυνάμεθα εὐκόλως νὰ καταγράψωμεν ἀποτυχίας, ἀνικανότητας καὶ λάθη, τὰ ὅποια παρεισέφευσαν εἰς τὴν σύλληψιν τοῦ κόσμου, συγκρινόμενα μετὰ τὰς δοξασίας τῆς συγχρόνου ἐπιστήμης. Ἄλλ' αὐτὸ θὰ σημαίνει ἀκριβῶς ὅτι ἔχομεν παρανοήσει καὶ ἐκτιμήσει κακῶς τὰς συμβολὰς των, ἂν τοὺς κρίνωμεν μετὰ ἀρχάς, αἱ ὅποια ἐνεφανίσθησαν πολλοὺς αἰῶνας ἀργότερον, ἀρχάς αἱ ὅποια ἀνεπτύχθησαν ἐξαιτίας τῶν ἰδεῶν ποὺ ἄνθισαν διὰ πρώτην φοράν κατὰ τοὺς χρόνους τῶν ἀρχαίων.

Ἐντὸς τῶν ὁρίων τῶν ὀρισθέντων διὰ τὸν κόσμον των, ἀπὸ τὴν ἱστορίαν, οἱ Ἕλληνες, διὰ τῶν πνευματικῶν των ἱκανοτήτων, ἐπέτυχον νὰ πλέξουν ἓνα θαυμασίως πλούσιον πλέγμα σκέψεων, ποὺ μᾶς ξαφνιάζει ἐκ τῆς μεγάλης ὁμοιότητός του μετὰ τὸν σύγχρονον πνευματικὸν μας κόσμον. Ἐντὸς τῶν ὁρίων τῆς ἐπιστημονικῆς των γλώσσης, καθώρισαν ὅλα τὰ βασικὰ στοιχεῖα, τὰ ὅποια δύνανται νὰ ὀρισθοῦν ἐν συμφωνίᾳ μετὰ τὸν νόμον τῶν φαινομένων, ὅσον ἀφορᾷ τὸν ἀριθμὸν των, καὶ τὴν διαδοχὴν των, καθὼς καὶ τὸν συσχετισμὸν τῶν διαφόρων στοιχείων τῆς φυσικῆς πραγματικότητος. Ὅποιοσδῆποτε ἐπιχειρήσει μίαν μελέτην τοῦ ἐπιστημονικοῦ κόσμου τῆς ἀρχαίας Ἑλλάδος, δὲν δύναται παρὰ νὰ πληρωθῇ ἀπὸ θαυμασμὸν διαπιστώνοντας ὅτι, πέραν ὅλων τῶν διαφορῶν καὶ ἀλλαγῶν ποὺ ἔλαβον ἐν τῷ μεταξύ χώρῳ, ὁ κόσμος τῶν Ἑλλήνων ἀποτελεῖ καὶ σήμερον τὴν βάσιν τοῦ συγχρόνου κόσμου μας.



### The Aristotelian cosmos in the sphere of dynamics

The approach to physical phenomena by Aristotle was sprang from a conception which held no key to the physical world, although it did something to offer for biological sciences, where Aristotle's achievements were the greatest. Moreover, Aristotle tried to fit all his findings into fixed patterns and then tended to construct on them a general theory which he declared as absolute. This dogmatic formulation, which was not supported by sufficient empirical evidence may become dangerous. However, the basic contributions on the principles of science developed by him were the first developed by humanity and may be considered as the founding stone on the building of modern science.

The leading principle in Aristotle's view of nature was *teleology* based on the axiom that everything happening is done for a certain end and that the whole cosmos is the result of a planning. Aristotle's philosophy is so dominated by the principle of teleology that he used to be regarded as its inventor, although it was well known that before him Empedocles was the first to add to this principle the notion of force.

Moreover, Anaxagoras used a motive principle, which he called «Mind» in his doctrine. Anaxagoras regarded mainly «mind» as the cause of motion and virtually as a physical substance, but nowhere he mentions that the «mind» functions on a preconceived plan designed to produce some kind of order. Indeed, «mind» was explicitly mentioned as a teleological operation, which sets intentionally things in the proper order, and the harmony of the universe comes about through the force of an intelligent law aiming at perfection.

This development reached its climax in the time of Plato, who, in his dialogue *Phaedo*, puts into the mouth of Socrates strong words of criticism against the «mind» of Anaxagoras.

Today we need only to look around us to see that the rapid advance of the natural sciences in recent centuries began only when scientists stopped searching for the true causes and confined their curiosity to the necessary conditions of these causes.

The perspectives of our modern cosmos were widened to us the day when the scientists of the seventeenth century gave up asking «Why», or «for what purpose» and limited themselves to the question «how»?

The scale of values imposed by Aristotle on the investigation of nature, culminating in the teleological explanation of the universe, became the corner-stone of his physics. Aristotle went still further and formed his theory of dynamics on the supposition of an «*intelligent nature*», functioning by deliberate design. He defines his own stand in principle in the course of a refutation of those pre-Socratic philosophers, who regarded natural phenomena as the product of «necessity», or, in modern terminology, of conformity to mechanical law.

For Aristotle all conformity to law is teleological, like that displayed in the creation of artists. This is a clear and unambiguous statement: «Nature's method is that of the artist, and conversely, true art is the imitation of nature». Accordingly, the scientist should approach his problem like the student of an artistic creation who, from the details of the house, learns the functions assigned by the builder to its various parts, or who understands from the shape of a statue what the artist wanted to express in it.

This conception of natural phenomena as the striving for an end may be fruitful and valuable as a guiding principle in those sectors of biology, where the subject of investigation is the functional role of organic forms and processes. Hence Aristotle's great achievements in zoology and the enduring value of no small part of his biological works. His treatises on the morphology of living creatures read as if they had been written by a contemporary of ours, whereas his whole *Physics* is permeated by the spirit of a world entirely alien to us, which begun to pass away from the moment that physical science abandoned the teleological approach and replaced the question: «*for what purpose*», by «*how*».

The teleological principle played a great part in the dynamics of Aristotle. The theory of dynamics is an integral part of his picture of the cosmos. Aristotle took over the theory of four elements from the pre-Socratic philosophers and wove all these theories into a system of cosmic values on the basis of the antithesis between eternal well-ordered motion of the heavens and the irregular ephemeral movements on the earth. He completed this antithesis by stressing the essential difference in form between the move-

ments of the stars and the movements of a lower region extending between the earth and the moon.

The heavenly movements are circular, whereas those in our region are complex, taking sometimes the form of straight lines. This scale of cosmic values postulates the priority of heavenly over terrestrial movements and the primacy of circular motion. The rotatory motion is a simple one and can be eternal, whereas no other motion can be so, since in all of them rest must occur, and with the occurrence of rest the motion is perished.

The notion of the natural form of motion is connected with the concept of natural place, which is the earth and the water. Both elements are, therefore, at the center of the universe. It is likewise clear that the natural place of the two other elements of the pre-Socratics, the air and the fire, is in the upper regions. As a result of this natural motion is the tendency of the various kinds of matter, which are not in their natural place, to get to it from their desire to occupy their proper place in the cosmos, thus connecting any deviation from its perfect order. In this way the natural movements become the dynamic manifestation of the working of teleology in the physical universe.

Since simple bodies must have simple motions, we hold therefore that the only single motions are the circular and the rectilinear, the latter of two sorts, away from the center and towards the center. Then, a general formula has been decided on that everything is definitely fixed and there is no place for another simple body in our cosmos.

It may be argued that modern physics, too, proceed in the same way and that the transition to relativistic mechanics involved a complete mental revolution, just because the formulae of Newtonian physics had become a theoretical dogma. However, there is an essential difference between Newton and Aristotle. Experiment plays a far greater part in modern physics, so much so that it plays now the arbitrer of every theory. Hence modern science assumes a much more flexible character, its continuous progress being made possible by a constant re-evaluation of its fundamentals. Aristotle's approach, on the other hand, not supported by any experimental evidence, failed to observe the right balance between *induction* and *deduction* and came to be dominated largely by the latter.

Considering now the two particular natural movements, the upward and downward movement, they have been made by Aristotle absolute opposites, thus disagreeing with Plato and others who understood that in a universe,



having a center and a spherical perimeter, such concepts should be relative. In the same way, Aristotle also turned «heavy» and «light» into absolutes. This was the origin of an antithesis which hampered the formation of the fundamental notion of *specific weight*.

In the same context Aristotle predicates weight and lightness in both an absolute and a relative mode. He mentions in his book: *de Caelo* (307B) that: «Our predecessors have treated of the relative sense, but not of the absolute: They say nothing of the meaning of weight and lightness, but discuss which is heavier and which is lighter among things possessing weight. Let me make my meaning clearer. There are certain things, whose nature is always to move away from the center, and others always towards the center. The first I speak of as moving upwards, the second downwards».

Considering now the problem of Aristotle's dynamics we may state that the study of this question is in itself Aristotle's chief claim to fame, for he was the only ancient scientist, who worked on the development of a quantitative theory in this fundamental field. This was a great achievement. The mechanics of Galileo and Newton have shown us that the phenomena of dynamics, which may seem to the layman as elementary, are in reality very complicated.

We know now that the study of the laws of motion is entangled by two factors, that is friction and resistance of the environment, which cannot easily be neutralized. The velocity of a moving body constantly decreases because of these two factors. This fact gave rise to the pre-Galilean misconception that the moving body has to be subjected to a constant force in order to maintain a constant velocity. Actually such force merely serves to overcome the opposing forces of friction and of the resistance of the medium. The problem is further complicated by the fact that the moving body usually is within the gravitational field of the earth.

All these findings of modern Physics are the result of experimental and theoretical analysis of the various factors operative at the time of movement. Since Aristotle did not break down motion into its component factors, it is not surprising that his laws of motion do not correspond to the facts. Indeed, Aristotle maintains that the distance traversed by a body is in direct proportion with the force acting upon it constantly, and the time taken, and in inverse proportion to the mass of the body.

But experience showed him that this law was only a very rough approxi-

mation and that it fails completely when the disproportion between force and mass is very great. He therefore found it necessary to qualify his law and to give empirical examples in support of this qualification. In an interesting passage in his physics 249B we hear an entirely different Aristotle, an Aristotle who is far closer to us, than the one who dogmatizes about the structure of the cosmos, never for one moment doubting the analytical power of pure intellect.

Although his law quoted in the passage is not correct, its formulation is, in two respects, akin to the spirit of our own times: it is mathematical in form, and its validity is qualified by reference to experience. This passage states that:

«...If (force ?) E moves F a distance C in a time D, it does not necessarily follow that E can move twice F half the distance C in the same time... In fact it might well be that it will cause no motion at all; for it does not follow that, if a given motive power will cause motion either of any particular amount or in any length of time: Otherwise one man might move a ship, since both the motive powers of the ship-haulers and the distance that they all cause the ship to traverse are divisible into as many parts as they are men» (Physics, 249B).

The various formulations discussed by Aristotle for his law show that he was careful not to infringe the principles of his general law: «The larger a body the more swiftly it performs its proper motion» (Physics 290A). «The larger quantity of fire or earth, always moves more quickly than a smaller to its natural place» (Physics, 277B). «The larger the quantity (of fire) moves upwards more quickly than the smaller. Similarly, a larger quantity of gold or lead moves downwards faster than a smaller, and so with all heavy bodies» (Physics, 309B).

Furthermore, the quantitative formulation of the law was defined as follows: If a certain weight moves a certain distance in a certain time, a greater weight will move the same distance in a shorter time, and the proportion which the weights bear to one another, the times too will bear to one another, i.e. if the half weight covers a distance in  $x$ , the whole weight will cover it in  $x/2$ . (de Caelo, 273B).

Aristotle's law of falling bodies says, therefore, that the velocity of a falling body is proportional to its weight. This law became widely known through the criticism levelled against it by Galileo in his book: «Discourses



and *Mathematical Proofs*» (1638). Galileo's criticism of this law marked a turning-point in the transition from ancient to modern physics.

By examining the problem of this law in more detail we can state that the whole subject of the laws of falling bodies is of significance outside the narrow limits of the law of a specific movement, through its connection with Aristotle's absolute negation of a vacuum and with his view about the influence of the environment on motion. It, thus, concerns the main principles of the conception of the physical world.

The founders of the atomic school in ancient Greece were the first who regarded the existence of a vacuum as a necessary condition of movement. Their conception was radical in the extreme: The ultimate elements of matter must be separated from each other by the absence of matter. Every atom moves in a vacuum until it collides with another atom. Thus, in the world of atoms all activity is made up of movements in an absolute vacuum and impacts of matter on matter. This was one of the profoundest conceptions of ancient Greece, whereas Aristotle's rejection of it was also an objection in theory and in principle. Among the many reasons advanced by Aristotle against the existence of the vacuum in the fourth part of his *Physics* (*Physics*, 214B) the most characteristic of his way of thinking is expressed by the sentence: «The void, in so far as it is void, admits no difference». By this he means that the vacuum has no distinguishing geometrical features, nor any of the qualities essential for the fixing of direction and motion; in a vacuum, therefore, there is no means of spatial orientation.

There is an analogy here with the negation of absolute motion in the Newtonian space. If there were only one single body in the whole emptiness of infinite space, there would be no sense in assigning to it a place or a state of motion, since for that at least two bodies are required, thus defining relative motion in a given reference frame. Aristotle sees no way of constructing such a framework, if bodies are separated from each other by a vacuum.

Since no geometric link connects a body surrounded by the void to another body, there is no point in depicting its state, either in terms of place, or movement. Since Newton, physicists have grown accustomed to regard space as a geometric network spread over the vacuum and joining together the physical points. Aristotle rejected a physical description by an abstract geometry extending beyond the bounds of matter. Instead, he identified space with volume filled by matter, an identification which neces-

sitates the continuity of matter. It is characteristic that Aristotle does not use the word «space», but «place», to express the location of a given body. Place is far more concrete term than space, since it gives a geometrical definition of a particular point in terms of its boundaries.

Aristotle's combination of geometry and matter to form his concept of place is not unlike the conception of space in the General Theory of Relativity. This theory also rejects the Newtonian portrayal of space, as a sort of infinite box, in which physical bodies move. Instead, it pictures a space as a kind of communion of the body and its surroundings. It is the body that determines the geometry of its environment, and this geometry cannot artificially be separated from the body itself. Hence a physical point is simply a singularity in the metric field surrounding it, and this field is not at all an empty space.

This reasoning, like Aristotle's, also leads to the negation of a vacuum. The cosmos, as envisaged by us today, is very different from the «*empty box*» of Newton, or the Greek atomists. Interstellar space is full of electromagnetic radiation. Its expanses gravitational fields and are traversed by gravitational waves. Similarly, there are fields of forces round the atoms, of which physical bodies are composed, and in the spaces within the atom or nucleus, there is likewise interplay of forces at work between the primary particles.

This resemblance between Aristotle's approach to the space-continuum problem and that embodied in the General Theory of Relativity is very interesting, but we should beware of drawing sweeping conclusions from it.

The negation of a vacuum is so important to Aristotle that he discusses the question again and again from various angles. However, in summing up his arguments, Aristotle mentions, only to reject, a conclusion which is in fact an explicit formulation of Galileo's law of inertia. The negation of a vacuum results therefore from the absurd conclusion rejecting the transition to the limit from a medium of finite density to one whose density is nil. Then, he results that if the cosmos is a perfect continuum, it must be a single entity, a uniform body, and this body should be finite.

Then, while he assumes the possibility of infinity in division, he denies it in extension. The cosmos is thus finite. Furthermore, since the demand for perfection requires, and astronomical phenomena prove, its sphericity, the cosmos is a finite sphere, with the earth as its center and the sphere of



the fixed stars as its limits. The finiteness of the cosmos also follows from the circular motion; otherwise we should have to admit an infinite velocity.

The idea that the cosmos is finite is a corollary of Aristotle's dynamics and his conception of natural place. Unlike the pre-Socratic philosophers, Aristotle rejects the idea of creation, since what is created must eventually decay. Therefore, the eternity of the cosmos extends in the two temporal directions past and future. It goes without saying that Aristotle criticizes Plato for basing his cosmology on the creation of the world and at the same time holding that the world will last for ever.

The two great philosophical schools appeared after Aristotle's era did not take up also these views. Instead, the Stoics and the Epicureans returned to the idea of the cosmic development. Aristotle's theory about the eternity of the cosmos remained a unique individual opinion throughout ancient times.

The two fundamentals of the Aristotelian natural philosophy were developed and modified in the physics of the Stoics. The teleological idea appeared in their teaching in its most downright religious form as *Providence*. The continuum view of the cosmos took on an extreme dynamic form in the Stoic school. It emerged as the doctrine that all the parts of the cosmos are interdependent — and it is this interdependence that makes the cosmos a field of physical activity which pervades it and unites it into a dynamic whole.

Aristotle's assumptions about the finiteness of the cosmos and his absolute negation of a vacuum were not accepted in their entirety until the Middle Ages.

The Stoics postulated the existence of an infinite vacuum surrounding the finite continuum of the cosmos. The Epicureans developed the theory of Leucippus and Democritus about the atomic structure of matter and the infinite extensions of the vacuum in the space between and outside the atoms.

John Philoponus, who lived at the beginning of the sixth century A.D., disagrees with his argument that, in the absence of a retarding medium, the velocity of fall would reach infinity. The disagreeing attitude of Philoponus to Aristotle's dynamics was the last word of such criticism for the thousand years which preceded Galileo.

There are also many indications of critical attitude to several Aristotle's fundamental ideas made in the Hellenistic period, mentioned in Plutarch's works. Philo of Byzantium, Hero of Alexandria and the Roman Vitruvius, based on the experimental work developed meanwhile in ballistics and ap-



plied mechanics, during the improvement of ballistic machines by empirical methods, they established some fundamental laws of motion, such as the law of the parallelogram of velocities. In consequence of these achievements Aristotle's dynamics were placed in their true historical perspective, as a theory which was important as the beginning of a long development.

The teleology of Plato and Aristotle did not go unchallenged even in the Ancient World. The atomic theory of Democritus was based on an entirely non-teleological approach. Another keen critic of teleology was Aristotle's great pupil, the founder of systematic botany, Theophrastus. In his metaphysics Theophrastus disputes the view that the celestial movements are a special phenomenon, essentially different from terrestrial ones including those of living creatures. Thus, Theophrastus joins forces with the atomists who regarded this motion as one of the fundamental data of the universe, like matter, the reason for which it is pointless to seek.

All these criticisms devastating as they were from sweeping the teleological viewpoint out of existence, did not even succeed in noticeably disturbing it. In the end, Aristotle's cosmos continued to dominate human thought throughout the ancient and scholastic periods, right up to the sixteenth century. Nor is this surprising, seeing that it was eminently qualified to maintain this position both in the Ancient World and after the rise of Christianity.

In Aristotle's philosophy the cosmos is a sublime manifestation of the rule of order in the universe. This idea was as well suited to the greek mentality, in which the concept of order was blended with those of beauty and perfection, as expressed in artistic creation, as to the basic creed of the monotheistic religions of Christianity, Judaism and Mohamedanism, which regard the cosmic order as the work of Creator and the expression of His Will.

The teleological idea, therefore, endured as a guiding principle in the explanation of nature, being woven into the pattern of mediaeval religious thought. Long life was likewise assured to the Aristotelian antithesis between heaven and earth, rooted as it was in star-worship, of which spiritual traces are to be found throughout the greek period. In the theology of the monotheistic creeds this antithesis reappeared a new in the location of God and His angels in the Heavens, in the pure region of Aristotle's eternal movements.

Then, Aristotle's physical doctrine was accepted as dogma for sixty generations. No other personality in the history of science, and very few in

the whole course of human culture, had so deep and long-lasting an influence on subsequent thought.

Already in the Ancient World Aristotle's views bore the stamp of a supreme authority which only a few bold spirits dared to reject. This authority was in no way weakened by the rival claims made for Plato's philosophy at the end of the classical period and the beginning of the middle ages. However, in the sphere of natural sciences there was no essential difference of opinion between the two philosophies.

The chief interpreters of the three great monotheistic religions, Christianity, Judaism and Mohamedanism, finally blended the main principles of Aristotle's philosophy with their religious conception of the universe thus turning the whole of that philosophy, including its physical and cosmic aspects, into unquestionable dogma. Then the nation which created the natural sciences and the methodical scientific thought was obstructed by this dogmatism to advance their development beyond the first stages.

In the absence of experimentation and significant and leading technical invention the process of scientific creation began to suffer after its brilliant initial development. The first signs of this appeared in the second century B.C. Its serious consequences were made still worse by the penetration of superstitions into the domain of science and the growth of occult tendencies consequent upon the merging of East and West during the Hellenistic era.

This decline of creative science became part of the general eclipse of the ancient World, followed the decline and the disintegration of the Roman Empire. With the spread of Christianity, nature problems only took second place to the main concern of humanity, which was its relations with the Creator. By divorcing man and his vital interests from natural phenomena the Church helped to create the feeling that the cosmos was something alien and remote from man.

In this connection it is interesting to mention the tremendous service rendered by the development of scientific instruments and scientific machines which started at the classical period and formed a great evolution during the hellenistic era and afterwards. This development extended man's knowledge of nature beyond the limits of the five senses, thus enabling him to overcome the *«weakness of the senses»* which Anaxagoras regarded as the chief obstacle to ascertaining the Truth.

If the intellectual adventure of modern science is perhaps the greatest

of all adventures inaugurated in the modern era, this is due to the development of mathematics as the key to the laws of nature. It is true that our cosmos has been drained of all the *human* content which it contained in the Greek period; it is true that the naive world of senses is separated from the world of science by an ever-widening chasm; it is true that understanding this world of science calls for enormous powers of abstraction and a professional and intellectual training which is becoming ever more rigorous. But on the other hand this cosmos is continuously developing new and marvellous contents which make the experience of initiated people not less rich than the cosmic experience of the first thinkers of ancient Greece.

Then, it may be accepted that these same philosophers were among the spiritual ancestors of our own era and they will not be doubted by anyone who compares the heritage of greek science and especially its methodical approach the vigour of its imagination and inspiration, its associative strength and power of inference with the science of our own time.

If we should judge the contribution of Aristotle and the other philosophers of antiquity by modern criteria we could at ease register failings, insufficiencies and errors committed to their conception of the cosmos as compared with our beliefs of modern science. But, this would be exactly to misunderstand and misvalue their contributions if we judge them with principles appeared many centuries afterwards, principles which have been developed because of their ideas flourished for the first time during their time.

Within the limits set to their cosmos by history the Greeks through their spiritual resources succeeded in weaving a marvelously rich canvas of thought, which surprises us by its close resemblance to our own mental world. Within the limits of their scientific language, they stated all the essential things that can be stated about the conformity to law of phenomena, as regards their number and sequence, and about the interrelationship of the various elements of physical reality. Whoever makes a close study of the scientific world of ancient Greece cannot but be filled with veneration as he can realize that, beyond all differences and changes, the cosmos of the Greeks is still the basis of our own cosmos.