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Al-Ghazzālī's Natural Philosophy

by

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Introduction

Al-Ghazzālī, Abū Ḥāmid Muḥammad (450/1059 - 505/1111) achieved the synthesis of Muslim mysticism and scholastic theology, which were, prior to his works, widely opposed. By achieving this synthesis, he managed to decrease significantly the influence of Greek philosophy, that is, Aristotelianism, which occupied the dominant position in Muslim philosophy and theology.

While acknowledged as the cornerstone of the classical Muslim thought, Al-Ghazzālī has been frequently accused of the destruction of science as the result of his attacks on Aristotelianism. In the *Preface* to Seyyed Hossein Nasr's *Science and Civilization in Islam*, Giorgio de Santillana states:

> Averroes speaks with the clarity and passionate honesty that we would expect of him, for here was the great Greek tradition at bay, whereas Al-Ghazzālī's famous eloquence, undistinguished intellectually as it is, and to us ethically uninspiring, went to building up the worldwind of intolerance and blind fanaticism which tore down not only science, but the very School system

and the glorious ijtihad, the interpretation of the Qur'an.[1]

Never mind the harshness of the quoted accusation. The important point is that this accusation is based upon a serious contradiction. The contradiction is clear when it is viewed from the perspective of the completed development and achievements of modern science. Aristotelian system of natural philosophy proved itself false in the light of the achievements of the modern science which was developed, though through a long period of time, on the ruins of thereby destroyed Aristotelianism. Now, how can Al-Ghazzālī be accused for playing a destructive role in science when displaying the inconsistencies of the philosophical system which constituted the metaphysical basis of Aristotelian natural science, when the modern science has achieved similar results? That some of Al-Ghazzālī's, thereby achieved, results coincide with some of those of modern science is, moreover, acknowledged by the very accusers. Being aware of the contradiction conveyed by the accusation, de Santillana simply calls it - paradox.

> Al-Ghazzālī's chief argument that physical causes are not true causes, but only 'occasions' for God's direct intervention, shows him to be, paradoxically enough, the counterpoint of men like Malebranche in our world. But the great and candid mind of Malebranche knew how to turn 'occasionalism' to a far different purpose, it provided, in fact, the starting point for Leibniz's profound scientific innovation. Such are strange ways of History.[2]

As if a paradox, that is, a contradiction, is natural state of affairs. After all, it was Leibniz's profound scientific innovation, not Malebranche's. What is then the difference between Al-Ghazzālī's and Malebranche's occasionalism in their respective consequences to the science, when the result is the same? What is the difference between them which

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[1]Nasr, S. H., *Science and Civilization in Islam*, with a *Preface* by Giorgio de Santillana, Cambridge: The Islamic Texts Society, 1987./ 1968., p. xii.
[2]Nasr, *ibid.*, p. xiii.

makes Malebranche great and candid mind in our world (!) while it makes Al-Ghazzālī intolerant and blind fanatic?

The question of whether there is anything paradoxical or not in the work of Al-Ghazzālī, in its relation to the natural science (both Aristotelian and modern) and its metaphysics and epistemology (de Santillana talks about Al-Ghazzālī's closing the *ijtihād*, falsely attributing it to the interpretations of the Qur'an), incited my mind to undertake this research. For Al-Ghazzālī is, as everyone agrees, the cornerstone of the classical Muslim thought.

When dealing with this matter, we are faced by the fact that Al-Ghazzālī was not a scientist who performed experiments in order to prove his concepts with scientific implications. Neither did he transform the concepts into mathematical formulae. He concentrated rather on using logical proof for his metaphysical concepts. The point is that the logical proofs of his metaphysical concepts could have been taken as basis for the formulation of the respective scientific laws, by scientists later.

The subject matter of this research is, therefore, Al-Ghazzālī's contributions to the metaphysics of the natural science and the validity of the logical (in some cases even observational) proof of the respective metaphysical concepts, as well as their epistemological basis.

Methodology

In order to realize the proportion of the whole problem, we will give a short summary of the key breakthroughs of modern science from the perspective of their metaphysical background, that is, of the formulation of the new metaphysical system. We will view the key metaphysical concepts of modern science in their relation to the respective and thereby annulled concepts of Aristotelian science. We will also give a brief summary of those modern concepts which were almost achieved by the scientists of the classical Muslim period, as well as the probable reasons for their failure of achieving a coherent formulation. We will have to touch, therefore, on the problem of the inherent bipolarity of the classical Muslim thought in the fields of philosophy and theology, primarily in their epistemological aspects.

Introduced in this way, the achievements of Al-Ghazzālī in the field of metaphysics of natural science will be, I believe, clearly comprehended. We will, thereupon, shortly inspect the controversy of the metaphysics of the natural science, as well as its epistemological aspect.

Due to the present controversy of both the metaphysics and history of science, many different views occur, in respect to the formation of the modern science, decline of science in the classical Muslim period and the relation between science and religion. Consequently, the work of Al-Ghazzālī is differently, frequently in opposing manner, interpreted. Therefore, the main method applied in this study of Al-Ghazzālī's contributions to metaphysics of modern science will be that of analyzing his texts. (Please, do excuse unusually extensive and frequent quotations, for Al-Ghazzālī's argumentation, as well as

the subject matter, is too sophisticated and, therefore, potentially subject to misinterpretations.) The texts will be analyzed from the perspective of what they criticize, how (that is, method and its epistemological aspects), on what basis (that is, the metaphysical framework), and what they thereby establish.

Expected Results

We expect to prove that Al-Ghazzālī formulated a coherent metaphysical framework within which some of the major breakthroughs of modern science could have taken place. The metaphysically defined concepts which we find in the work of Al-Ghazzālī are the following:

1. uniformity of the laws which govern all motions in the universe, naturality of circular motion, naturality of state of motion;
2. the possibility of an essentially wider universe, non-circular celestial orbit;
3. nature behaving according to the infinitesimal motion;
4. time/matter relativity, cause/effect relativity.

The scientific concepts which could have been derived (or, in some cases, simply formulated in terms of mathematics) from, or placed into, Al-Ghazzālī's metaphysical concepts are, therefore: inertia (with most of the related concepts); elliptic orbits; infinitesimal calculus and probabilistic logic; time/matter relativity; Quantum physics.

We expect to show the similarities between metaphysics of Al-Ghazzālī and of those philosophers who wrote after him, in terms of their consequences to modern science. Here I do not refer only to those philosophers whose occasionalism resembles that of Al-Ghazzālī, such as Hume and Malebranche, but to those whose metaphysics are not so fatalistic or pantheistic, such as Descartes, Newton, Leibniz and Einstein, as well. Therefore, the metaphysics of Al-Ghazzālī's science, which already conceptualized some of the achievements of modern science, show the achievements of the modern science in a different light. There is nothing anti-religious in the modern science, apart from its *a posteriori* metaphysical interpretations, as well as apart from that which is false. On the contrary, the 'modern' universe proves the nearness and causality of God to be significantly more real than the 'medieval' universe of, 'Islamized' or later 'Christianized', Aristotelianism ever did. This refers primarily to the increased 'role' of God's will, which thereby frees the universe from the Aristotelian intermediaries, as well as from the pantheism attributed to the universe by Neo-Platonists.

Due to misunderstanding of his achievements, Al-Ghazzālī was wrongly both attacked and celebrated. He was attacked by Muslim and Christian historians and philosophers of science for his destruction of 'islamized' and later 'christianized' Aristotelianism (which they consider to be Islamic and Christian science, respectively), as well as by secular and theistic historians and philosophers of science for showing the 'modern' universe being subject to God's will, and for showing that the knowledge does come from God, and not, as they would like him to suggest, from delusive mystical experience. On the other hand, he was celebrated by some mystics because they thought that he considered a mystical experience to be the absolute knowledge of the things as they are in themselves.

In view of the infinite number of the existing post-modern epistemologies and obvious science crisis (primarily in terms of its metaphysics and epistemology), the epistemological principles of Al-Ghazzālī are of great importance for the contemporary science. For they are original, revolutionary, productive, and - not false, as we will show.

Sources of Al-Ghazzālī's Thought

Al-Ghazzālī's range of writings is very wide. He intensively wrote books on various subjects, from law to philosophy. For our purpose we will narrow the range to those writings in which he discussed the problems of natural philosophy, in their physical, metaphysical and epistemological aspects.

The book in which Al-Ghazzālī discussed the problems related to natural philosophy in the most detailed manner is *The Incoherence of the Philosophers* (*Tahāfut al-Falāsifa*)[3]. We find a great number of his hypotheses on natural philosophy in this book. Another book where we find his arguments closely related to natural philosophy is *The Ninety-Nine Beautiful Names of God* (*Al-Maqṣid al-Asnā fī Sharḥ Ma'ānā Asmā' Allah al-Ḥusna*)[4]. Al-Ghazzālī, in this book, was oriented more towards system-building, than he was in the case of writing *The Incoherence of the Philosophers*. Consequently,

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[3]Al-Ghazzālī, A. Ḥ., *The Incoherence of the Philosophers*, translated by Kamali, S. A., Lahore: Pakistan Philosophical Society, 1958., being the translation of Al-Ghazzālī's *Tahāfut al-Fālasifa*, Bayrūt: Dār al-Mashriq Shamm, 1990.

[4]Al-Ghazzālī, A. Ḥ, *The Ninety-Nine Beautiful Names of God*, translated with *Notes* by D. B. Burell and N. Daher, Cambridge: The Islamic Texts Society, 1992., being the translation of Al-Ghazzālī's *Al-Maqṣid al-Asnā fī Sharḥ Ma'ānā Asmā' Allah al-Ḥusna*, Limassol: Al-Jaffan & Al-Jabi, 1987.

greater number of metaphysical hypotheses are found in *The Ninety-Nine Beautiful Names of God.*

In these two books Al-Ghazzālī elaborates on his views about natural philosophy in their totality. Generally, no systematic arguments related to the problems of natural philosophy can be found in his other writings. Only few such arguments are elaborated in the *Deliverance from Error* (*Al-Munqidh min al-Ḍalāl*)[5], which will also be discussed in this study.

Deliverance from Error is Al-Ghazzālī's late autobiographical writing. It will help us to understand the differences which appear between some concepts elaborated in *The Incoherence of the Philosophers* and the respective concepts elaborated in *The Ninety-Nine Beautiful Names of God.* The former book was written prior to his spiritual crisis, whereas the latter book was written posterior to it. We will be, therefore, able to determine which standpoints Al-Ghazzālī changed by the outcome of the spiritual crisis, as well as those which he did not change. This will also shed some more light on the nature of the spiritual crisis that he experienced.

Since the nature of the crisis was, as we will see, primarily epistemological, we will discuss his epistemological principles. We will mainly rely on his short writing, *Al-Risāla al-Ladunīya*[6], which he wrote after the crisis. His epistemological principles and the concept of the human soul are presented therein in a systematic manner. *Deliverance from Error* will enhance our understanding of his epistemological principles in respect to their experiential aspect. Majority of the concepts elaborated in *Al-Risāla al-Ladunīya* are also

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[5]Al-Ghazzālī, A. Ḥ., *Deliverance from Error*, translated in *The Faith and Practice of Al-Ghazzālī* by Montgomerry Watt, Lahore: SH. Muhammad Ashraf, 1963./ 1953., being the translation of Al-Ghazzālī's *Al-Munqidh min al-Ḍalāl*, İstanbul: İhlas Vakfı, 1984.

[6]Al-Ghazzālī, A. Ḥ., *Al-Risālat Al-Laduniyya*, Part II and Part III, translated by Margaret Smith in the *Journal of the Royal Asiatic Society*, April and July 1938., being the translation of Al-Ghazzālī's *Al-Risāla al-Ladunīya*, Dimashq: Dār al-Ḥikma, 1986.

presented in numerous writings of *The Revival of the Religious Sciences (Iḥyā' 'Ulūm al-Dīn)*[7]. These epistemological concepts are elaborated therein in a very detailed manner, as a consequence to Al-Ghazzālī's intention of writing *The Revival of the Religious Sciences*. Consequently, these principles are elaborated in a significantly more dogmatic manner than it is the case in his other books, which were not written for public[8]. Therefore, we did not find it necessary to rely on *The Revival of the Religious Sciences* when treating the epistemological principles of Al-Ghazzālī. As for the problems related to natural philosophy, which are the primary subject matter of this study, they are not discussed in *The Revival of the Religious Sciences*.

Al-Ghazzālī is famous for another book, namely, *The Niche of Lights* (*Mishkāa al-Anwār*)[9], where he systematized the levels of mystical experience. Though the systematization of the levels of mystical experience is epistemologically significant, we failed to perceive any relationship between mystical epistemology, as systematized in *The Niche of Lights*, and natural philosophy. This is, however, not the case in the other writings of Al-Ghazzālī, such as *The Ninety-Nine Beautiful Names of God*, where mysticism is defined in relation to natural philosophy. Therefore, the content of *The Niche of Lights* is not significant for our purpose. Moreover, exclusively metaphorical interpretation of the Qur'anic Light verse (*Aya al-Nūr*) seems to be in a serious contradiction with the entire work of Al-Ghazzālī, primarily in respect to his criticism of the metaphorical interpretations of the Qur'an. This point rises a doubt about the authenticity of Al-Ghazzālī's authorship of *The Niche of Lights*.

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[7]Al-Ghazzālī, A. Ḥ., *Iḥyā' 'Ulūm al-Dīn*, Vol. 1-5, Cairo: Dār al-Ḥadīth, 1994.

[8]Elitist tendencies of Al-Ghazzālī we find in his several writings. See Al-Ghazzālī, A. Ḥ., *The Book of Knowledge of the Revival of the Religious Sciences*, translated with *Notes* by Nabih Amin Faris, Lahore: SH. Muhammad Ashraf, 1987., p. 152., being the translation of Al-Ghazzālī's *Kitāb al-'Ilm min Iḥyā' 'Ulūm al-Dīn*, Vol. 1. See also Al-Ghazzālī, *The Ninety-Nine Beautiful Names of God*, p. 47., where he, in order to keep the secrets from abuse of putting them in the book, gives up discussing the problem of the intricate seeming contradiction of the Qur'anic verse (18:17) which has direct implications to the problem of projectiled motion.

[9]Al-Ghazzālī, A. Ḥ., *Mishkāa al-Anwār*, Cairo: Abū al-'Alā 'Affīfī, 1983./ 1964.

I Developments of Natural Philosophy

In the terms of the medieval philosophical tradition, philosophy is inseparable from natural philosophy, which primarily refers to physics, whereas philosophy would thereby refer to metaphysics. Al-Ghazzālī dealt in detail with natural philosophy, that is physics, as consequential to metaphysics, which, in the case of Islam, primarily refers to theology (*kalām*). His immense interest in the evaluation of propositions of then valid natural philosophy is consequential to his intention of establishing concepts which would be in harmony with the metaphysics, which, he believed, were not to be conceptualized, but were, in its essence, constituted by Islam.[10]

We will, therefore, give a short summary of the major developments of natural philosophy from the stage of the medieval philosophy which Al-Ghazzālī was confronted with until the completion of the formation of the modern science, with a few later developments. Since the formation of the modern science has been achieved through a long

[10]This refers to his conflict with theologians for their arbitrary and metaphorical speculation on the essence of God. See the *Deliverance from Error*.

period of time, and by the interaction of the achievements in different disciplines, primarily in astronomy and physics, we will classify the developments according to their respective disciplines. We are aware of the fact that this approach tends to partly confuse the study of natural philosophy, which is not naturally divided into separate disciplines. However, we will, when relevant, point out the relation of a concept treated to the respective philosophical system.

Astronomy

For our purpose, this is the best point to start from. Problems of medieval astronomy were included in two different systems. Ptolemaic system was mathematical and developed in an attempt to be in harmony with the astronomical observational data. Due to some fictional geometrical models, such as epicycle over deferent, which was introduced in order to explain irregularities of celestial motions, it was irreconcilable with the other then existent system, namely, Aristotelian. Aristotelian system was based on physical propositions derived from Aristotle's cosmology. It presupposed, therefore, the existence of the crystalline spheres of the celestial bodies, which made the concept of Ptolemaic epicycles physically unintelligible. However, Aristotelian system, due to its presupposed existence of the crystalline spheres, could not explain variations of brightness of the celestial objects.

On the other hand, the two systems were in agreement on the following points:

1. geocentricity - the earth is stable while planets move around the earth;
2. circular orbits of the celestial objects;
3. distinction between terrestrial and celestial physical regions;
4. finite universe.

The third point was based on the Aristotelian physics. Aristotle's concept of motion made the distinction necessary. The physical laws governing motions in the terrestrial region were different in their nature from those governing motions in the celestial region. Motions of the objects in the terrestrial region were natural or violent, and imperfect, whereas those of the celestial objects were volitional and perfect. That is, the motion of the celestial objects could not have been explained in the terms of physics which was valid for the motions of objects in the terrestrial region.

The revolution of modern astronomy has been completed after a series of revolutionary achievements, from Copernicus until Newton, which changed the very four propositions shared both by Ptolemaic and Aristotelian systems. The new basic four propositions of modern astronomy thereby became established:

1. heliocentricity - the sun is stable in the Copernican system while the planets move around the sun;
2. elliptic orbits of the planets' motions;
3. physical laws governing motions are universal;
4. infinite universe.

The first two propositions were achieved as mathematical changes which destroyed Aristotelian physics. The third and fourth propositions, which signify the grand synthesis

of modern astronomy, have been reinforced by the revolution of physics, as a consequence of the mathematical revolution of astronomy. Aristotelian system has been thus replaced. This has been achieved through mathematization and idealization of physics.

Before we elaborate, in a little wider manner, on the aforesaid achievements of modern astronomy, and, later, physics, let us see the achievements of Muslim scientists of the classical period, in the field of astronomy.

Muslim scientists of the classical period revolutionized mathematics by introducing decimal system, algebra and trigonometry. These achievements made the astronomical calculations significantly simpler. When they applied the new calculations to the Ptolemaic system, they found the inconsistencies of the Ptolemaic system, which they thereupon criticized. Al-Bīrūnī even considered the idea of heliocentricity and elliptical orbit, but he never tried to construct a consistent system based on such propositions. Al-Bīrūnī, like the other scientists of the classical Muslim period, failed to relate problems of astronomy to those of physics. That is, in spite of criticizing it, they remained attached to Aristotelian notion of motions and to its consequential distinction between terrestrial and celestial regions.

In terms of metaphysical foundation, the first proposition, that is, geocentricity, is commonsensical, rather than philosophical. Due to its conformity with common sense it was in agreement with different metaphysical systems, such as various Greek philosophical systems apart from that of Pythagoreans, as well as systems based on monotheism of Christianity and Islam. However, because of philosophical expression of the commonsensical Aristotelian notion of motions as applied to the universe, that is, the first and the third propositions, Aristotelian cosmology was in the state of conflict with the new system, and, later, with the astronomical observational data, as expounded by Tycho

Brahe. This fact marked the beginning of the great epistemological crisis, which ended in the modern concept of reason (not common sense) as the primary source of knowledge, whose concepts have to be proven by observations and experiments. Experimentalists' and positivists' concepts of epistemology, which tried to reestablish observations as the only source of knowledge, however, proved themselves illusive. As for the second proposition of the classical astronomy, that is, the dogma of circular orbit, it originated in Plato's belief in the reality of mathematical and ideal universals, that is, the belief in geometrical atomism. The proposition was, again, in agreement with common sense.

Copernicus, knowing the inconsistencies of the Ptolemaic system, as well as its critiques, applied the only existing non-commonsensical proposition, namely, the Pythagorean concept of the motion of the earth around fire, and substituted the latter by the sun under the metaphysical inspiration of the Platonic mathematization, idealization and simplicity. He thus managed to explain the irregularities of motions of the celestial objects without inconsistencies and imperfections of thereby annulled Ptolemaic system. At the same time, he made the mathematical astronomy absolutely irreconcilable with Aristotelian physics, since the third proposition, that is, the distinction between terrestrial and celestial regions based on Aristotelian concept of motion, as well as the first one, were not in agreement with the new system.

It was Kepler who managed to change the second proposition by showing that the observational data can perfectly fit in only with the elliptical orbit. By improved new astronomical data, Brahe showed the existence of comets. The motion of comets was very different from the uniform circular motion of planets. By this he showed the state of conflict between observations and the Aristotelian concept of physically real crystalline spheres. He also managed to show other imperfections of the objects of the celestial region, making them thus more earth-like.

Now, how was all this physically possible? Galileo, knowing the critiques of Aristotelian concept of motions and consequent developments, as well as the results of Merton College's kinematical revolution achieved through mathematization and idealization of motions and based on the distinction between two properties of a quality (total quantity and its intensity), came up with the great breakthrough. In the process of solving the problem of the motion of projectiles he distinguished between uniform and uniformly accelerated motion, and thus arrived at the concept of inertia. In terms of metaphysics, it meant that the natural state of body is not only rest, but the state of uniform motion, as well. He managed to explain circular motions of celestial objects in terms of physics, thereby nullifying the Aristotelian distinction between terrestrial and celestial regions and establishing the universality of laws of physics. Descartes later proposed rectilinear inertia, which was finally synthesized with Newton's theory of gravity, whereby the new astronomical system, in its both mathematical and physical aspects has been firmly established.

The metaphysical aspects of the triumphant mechanical philosophy we will treat in a more detailed manner in the following subchapter, when summarizing the developments of physics.

Physics

In the previous subchapter, while summarizing the formation of the modern astronomy, we have touched on astronomy-related problems of the medieval physics. The essential problem was the disagreement of Aristotelian concept of motion with the astronomical observational data. However, the problem of motion was the central problem of both medieval and modern physicists, even when it was not related to the problems of astronomy.

Within his cosmology, based on the four elements and the respective qualities, Aristotle defined motion as the tendency of a body to reach its natural state of rest. Heavy bodies fall down tending to reach the center of the earth, which is, therefore, the center of the universe, whereas light things, such as fire and air, move upwards in order to reach their natural place of rest. In the case of fire, the place of rest is the outermost sphere of the terrestrial region, while in the case of air, it is the atmosphere. Every motion has its cause continually acting on the body which is in the state of motion. Consequently, there are two types of motions, namely, natural, which is in the case of heavy bodies caused by their weight, and violent, which is caused by external force preventing body to reach its natural place. In order to explain the motions of celestial objects, Aristotle had to attribute different characteristics to the celestial region, by introducing two concepts. Firstly, he introduced the concept of the fifth element named ether which was supposed to constitute the crystalline spheres and the celestial bodies, because the applications of the laws of physics which he attributed to the terrestrial region to the motions of the celestial objects would make them fall down to the earth. Secondly, he characterized the motions of celestial objects as volitional in order to explain their constant state of motion.

This exclusively qualitative physical system has been later formulated in terms of mathematics, and, in that form, was subject to criticism by Philoponus. Philoponus particularly criticized Aristotle's explanation of projectile motion. According to Aristotle, a projectile moves after it leaves the hand of its thrower due to projectiled air which surrounds the projectile. But Philoponus claimed that a projectile moves after it leaves the hand of its thrower due to an internal force imparted by the thrower into the projectile. Ibn Sīnā claimed that the internal force is permanent and is exhausted only when resisted. However, this was still not the concept of inertia, since it presupposes the imparted force. That is, the state of constant motion is not natural. Yet, this was quite a significant breakaway from Aristotle's essential proposition of rest as the only natural state. Note the aspect of the idealization of the problem introduced by Ibn Sīnā.

Bradwardine managed to mathematically describe the puzzle of the speed-force-resistance relationship by showing that the relation is logarithmic, and Buridan applied Ibn Sīnā's concept of imparted force to the motions of celestial objects, that is, the crystalline spheres. The motion of crystalline spheres, he considered as the example of permanent motion caused by the imparted force, in a void. Had Muslim physicists managed to treat the problems of physics in relation to those of astronomy, they would have hardly missed the scientific revolution. However, they also failed to reach another aspect of the revolution, namely, the quantitative aspect of the idealization of physics.

The scientists of Merton College achieved the kinematical revolution. They managed to define motions while ignoring their causes, that is, force. They quantitatively described motions in relation to time and distance, achieving the definition of velocity and acceleration. They achieved this by showing that each quality has two properties. Firstly,

each quality has a total quantity of quality, which is, in the case of motion, distance. The second property of each quality is its intensity, which is, in the case of motion, velocity.

Galileo arrived at the concept of inertia in the process of describing and experimentally proving that the projectile motion is parabolic due to its two simultaneous motions, namely, inertial, which is continuous, and the one caused by weight, which is uniformly accelerated. However, he defined inertia as the tendency for circular motion in order to explain celestial motions.

The rectilinear inertia was proposed by Descartes. To the circularly moving objects he consequently attributed the tendency of moving away from the center. Newton achieved a synthesis by the theory of gravity which successfully explained rectilinear inertia and the circular motion of celestial objects in terms of the universal law of gravity. It is important to note here that this revolution would have not been formulated, were there not the mathematical revolution parallelly achieved by Newton and Leibniz, namely, the formation of the infinitesimal calculus.

By Newton's achievement, Aristotelian physics was finally overthrown, the basis of which can be summarized in the form of the following propositions:

1. Natural state of physical object is the state of rest;
2. Motion is caused by a force constantly acting on the object which moves;
3. Motions of objects in the terrestrial region are natural or violent, imperfect, and only qualitatively describable;
4. Motions of objects in the celestial region are constant, since they are volitional and take place in a perfect medium, and in the perfect way.