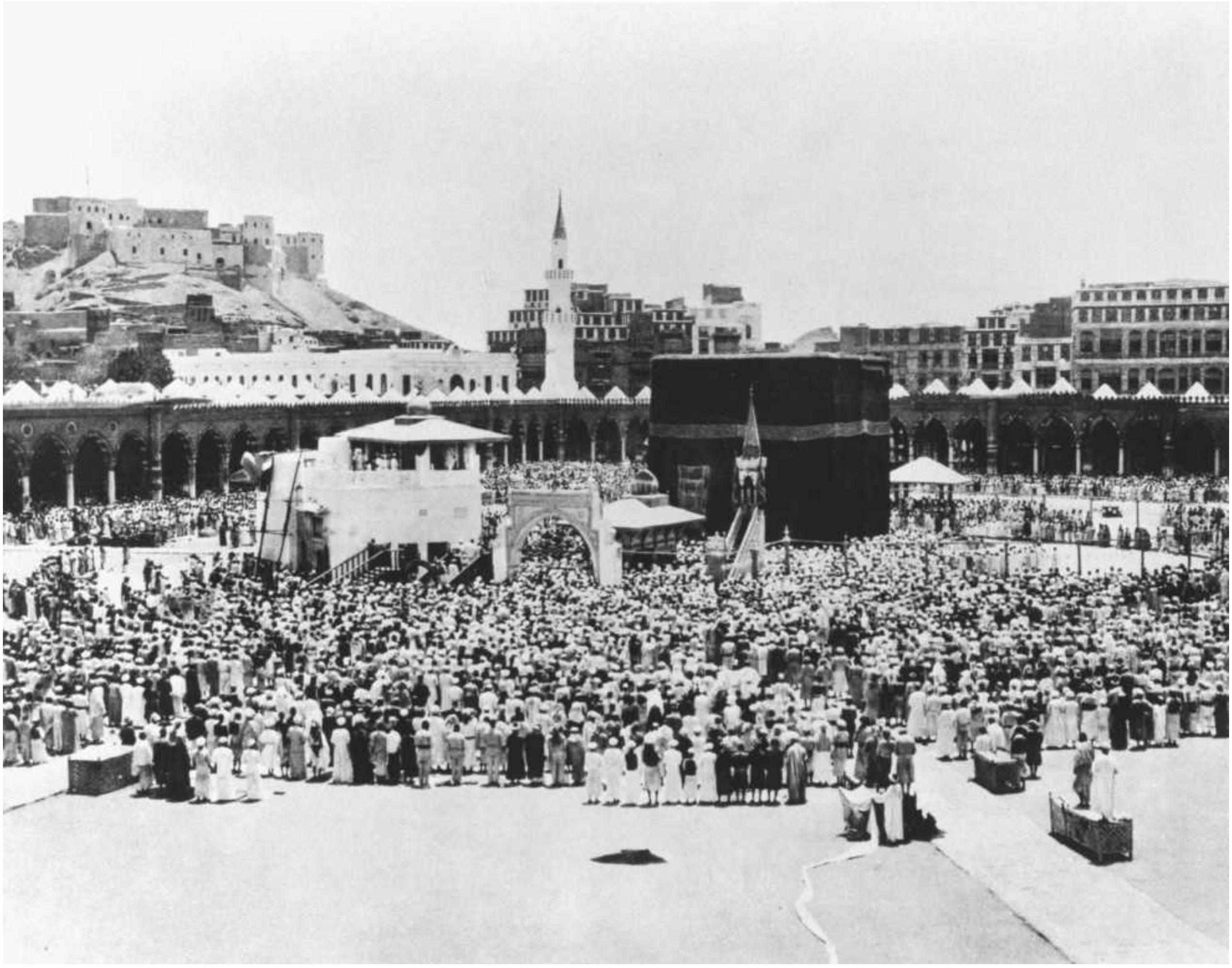

Pilgrimage to Mecca, Saudi Arabia.

Fāṭimids in Egypt (969), the ʻAlids, taking on the title of *sharīf,* became the rulers of Mecca, with varying degrees of dependence upon Egypt. Under the rule of ʼAjlān (1346-75) the Sharīfs gave up the Zaydī creed (*see* SHĪʻTES) to follow the orthodox Shāfiʼī system thereafter. There was again a major political change with Sultan Selîm's conquest of Egypt (1517); the relative dependence of Mecca upon Constantinople and Egypt then varied with the relative strengths of the two. The city was taken by the WAHHĀBIS in 1803 but was freed by Muḥammad ʻAlī in 1813. In 1916 the last of the Sharīfs, Ḥusayn ibn ʻAlī, made himself ruler of the independent kingdom of the Hijaz but was forced to flee when the Wahhābi ʻAbd al-ʻAzīz ibn Saʼūd took the city in October 1924; he was there proclaimed king of Hijaz in 1926. In the following year the sultanate of the Nejd became the Kingdom of SAUDI ARABIA, with the ruler of the combined kingdoms residing at Riyadh.

[R. M. FRANK/EDS.]

MECHANISM

Mechanism attempts to explain the physical world by the movement of inert bodies that are pushed or pulled through direct or indirect physical contact with other bodies. Its proponents often hold that local motion is the only real motion, and that a body is maintained in such motion by its own inertia or impetus. Again, they frequently reduce physical bodies to purely quantitative principles, thereby giving mathematics primacy in physical science. Mechanists likewise deny purposes as explanatory principles, and sometimes deny the existence of inherent natural goals in bodies undergoing motion. Mechanism is often, but not necessarily, associated with the view that physical bodies are composed of atoms moving in a void (*see* ATOMISM). It also generally entails a denial of chance or contingency in nature; thus an apparent chance event is explained by the inability of man's finite mind to grasp all the relevant physical causes.

Mechanism is sometimes completely materialistic in orientation, though it need not be so (*see* MATERIALISM).

Since the meaning of the term mechanism has varied in the course of time, the details of its characteristics can best be noted in a survey of its historical development.

Greek and Medieval Origins. In ancient Greek philosophy, Democritus' theory of atoms moving in a void represents one form of mechanism. These atoms exert influence on each other only by physical contact and have no natural purposes. The Epicureans also espoused this rudimentary atomism of DEMOCRITUS, which reached the zenith of its development in the *De rerum natura* of the Roman poet, LUCRETIUS (*see* EPICUREANISM).

At the end of the 13th century, the Franciscan PETER JOHN OLIVI stressed an additional characteristic of mechanism. He defended a proposal made in the 6th century by JOHN PHILOPONUS, who maintained that a hurled projectile is given an IMPETUS that enables it to continue moving after it has lost contact with the original mover. This is an anticipation of the concept of inertia that plays an important role in later mechanism. Likewise Francis of Marchia and JOHN BURIDAN, in the 14th century, developed theories of impetus.

Other 14th-century philosophers, while not denying final causality in nature, nevertheless concentrated on approaches to nature which ignored finality. At Merton College in Oxford, THOMAS BRADWARDINE, who later became archbishop of Canterbury, studied relationships between distance, time, speed, and acceleration and expressed these in mathematical formulas that were basically algebraic. At Paris, NICHOLAS ORESME did similar work using graphing techniques that anticipated the development of modern analytic geometry. These kinematic studies, though not mechanistic in themselves, fostered mathematical, rational, and nonexperimental analyses of motion that were quite compatible with the mechanistic viewpoint.

Medieval mechanicians also considered forces acting on bodies and thus made beginnings in the science of dynamics that matched their work in kinematics. In his analysis of motive and resistive forces, Aristotle had stated that when a force was sufficient to put a body in motion, the velocity of the body was directly proportional to the force acting on it and indirectly proportional to the resistance of the medium through which it moved. In order to give intelligent meaning to Aristotle's proportionality, and also to explain why a small force cannot initiate motion, Bradwardine developed a logarithmic law of motion. This was not as accurate as later laws, but it did represent an improvement over earlier Aristotelian analyses.

In the 15th century NICHOLAS OF CUSA, although not a complete mechanist, invoked an impetus theory to explain the movements of the heavenly bodies. For him, God initiates all movement, but bodies afterward maintain themselves in motion. Cusanus was likewise sympathetic to atomism and the principle of the conservation of matter. The notion of impetus as a sustaining cause for local motion was accepted also by Leonardo da Vinci. In general, these late medieval philosophers advocated goals or purposes for moving bodies but did not concentrate upon them in their physics.

Scientific Revolution. In the early 17th century, Galileo GALILEI adopted and greatly promoted several ideas characteristic of mechanism. In his controversial work *Dialogue on the Two Chief Systems of the World* Galileo discussed sympathetically the Aristotelian doctrine of natural place as the normal goal of local motion. But in a later work, *Discourse on Two New Sciences,* he avoided discussions of purposes and concentrated on describing in mathematical terms how motions occur. His mechanism here consisted in denying the fruitfulness of studying purposes in physics rather than in denying that finality exists. Galileo also accepted the atomism of Democritus. He made colors, sounds, and other qualities subjective and stressed mathematics as the proper instrument for discovering physical natures.

In England at about the same time Francis BACON developed a system employing mechanistic features. He rejected the notion of Aristotle and of most medieval scholars that bodies have nonmathematical substantial forms and are the subjects of real qualities. While the Democritan idea of atoms moving in a void appealed to him, he regarded this as a hypothesis, and anything that was merely postulated and not immediately evident he looked upon with suspicion. Thus he differed from Galileo, who accepted atomism uncritically and favored a postulational approach in his science. Bacon believed in final causes or purposes in nature, but eliminated them from scientific considerations because he did not consider them useful for technological applications.

The writings of Johann KEPLER on the nature of the physical world were an unusual combination of science and mysticism. Pythagorean and Neoplatonic in his leanings, he nevertheless held some doctrines that are compatible with a mechanistic cosmology. Thus for him the real world is quantitative, and real qualities outside of man are reduced to the quantitative relations studied in mathematics.

Hobbes, Gassendi, and Descartes. Thomas HOBBES, a 17th-century Englishman, was clearly mechanistic in his views of the nature of the physical world. In his analysis of bodies he reduced all phenomena to matter in local motion. Hobbes was also much impressed with the power of quantitative analysis, and eliminated Aristotelian final causes or purposes for his science. While he did not deny that spiritual substances exist, he denied that philosophy could come to a knowledge of such substances. Therefore, for him, philosophy must be materialistic as well as mechanistic.

Furthermore, in Hobbes one sees mechanism linked to a general SKEPTICISM about man's ability to know the natures of things. The Greek atomists, Galileo, and Descartes, to the extent that they exhibited mechanistic elements in their work, believed that they were making statements about the natures of physical things. But Hobbes' skepticism caused him to associate mechanical conceptions with the appearances of things alone, and not with their true natures.

The impact of mechanistic thought in France in the early 17th century is reflected in the works of Pierre GASSENDI and René DESCARTES. Gassendi, a philosopher and mathematician, was an atomist. In fact he identified the Aristotelian notion of prime matter with the atoms of Democritus and Epicurus. He also accepted the ancient Greek notion that these atoms move in a void.

Descartes's view of the physical world is a classical statement of mechanism. For him final causality does not pertain to the study of cosmology. Descartes is also a good example of a mechanist who is not an atomist. Since he holds that extension is the essence of matter, wherever there is space there must be matter; therefore there is no void in which atoms can move. The entire cosmos is thus filled with rigid matter or with vortices of a very subtle matter. Causal influence is produced by the direct contact of bodies or by their indirect contact through some material medium.

Again, if extension is the essence of bodies, it follows that mathematics will be the science best suited to study their natures. In the thought of THOMAS AQUINAS and other scholastics, the substantial form is a principle of unity which makes the whole somehow greater than the aggregate of the parts. In the mechanistic world of Descartes, on the other hand, the universe resembles a mathematical whole which is merely the summation of its parts.

Boyle and Newton. In late 17th-century England, Robert Boyle continued the mechanist tradition. He affirmed that the qualities of bodies are derived from the size, shape, and local motion of their parts. Like other mechanists, he rejected the substantial forms of Aristotle and was hostile toward using the notion of natural end in physics. Yet his mechanistic views in cosmology never led him to doubt the reality or importance of spiritual entities.

At the same period, Sir Isaac Newton produced his great synthesis, which is usually associated with mechanistic philosophy. It does exhibit some key characteristics of mechanism, such as its aversion for final causality and its brilliant mathematical approach. But other aspects of Newton's thought, as expressed in *The Mathematical Principles of Natural Philosophy, The Opticks,* and his correspondence, reveal the presence of nonmechanical elements. While he accepts atomism and the notion of absolute space, for example, he also speaks of electric spirits. His famous three laws of motion are mechanistic in the sense that they invoke inertia, make no reference to finality, regard all motions as extrinsically determined, and explain causal interaction by making action mathematically equivalent to reaction. Yet Newton's universal law of gravitation, subsuming, as it does, celestial and terrestial phenomena under one law, is not mechanical in such a clear sense. It posits a mysterious force between bodies. These influence each others' motions even though they are not, and have never been, in contact. Though action through a void is not proposed, no physical substantial medium is posited. Cartesian mechanism is thus not in complete accord with the Newtonian variety (*see* MOTION).

Rise of Dynamism. G. LEIBNIZ strongly attacked Descartes's conception of the physical world. He claimed that both inorganic and organic bodies have within themselves unextended (and hence immaterial) substantial realities which he called monads (*see* MONAD). These simple unextended dynamic entities were centers of force and were inherently active in nature. Although Leibniz's cosmological system is sometimes referred to as DYNAMISM, it still incorporates some characteristics of mechanism. Whereas Descartes believed that the total quantity of motion in the universe was constant, Leibniz asserted the total amount of physical energy in the universe to be constant. Even God could not change this, and all motions of bodies were thus preestablished harmoniously by God. Leibniz also characterized the universe as a perfect clock that, once started, needs no adjusting. That Leibniz held this mechanical view of the universe is clear from his criticism of Newton's affirmation that God intermittently changes the courses of planets and comets, and thereby compensates for celestial irregularities.

Immanuel Kant was an 18th-century physicist turned philosopher. In his early writings, he was influenced not only by Leibniz's RATIONALISM, but also by the latter's proposal that force, as found in the monad, was more fundamental than space and time. Kant was influenced also by Ruggiero Boscovich, who, like Leibniz, rejected atoms and made points of force his fundamental cosmological entities. In his early work Kant had sought a compromise between the position of Leibniz, which made force more fundamental, and that of Descartes, which made extension and space more fundamental. Nevertheless, in his writings before the *Critique of Pure Reason,* the view of Leibniz seems to have predominated; for Kant, force, which may be both attractive and repulsive, leads to the notion of space by way of the notions of connection and order. Then, in his post-critical period, under the influence of David HUME, with his EMPIRICISM and skepticism, he denied the ability of the mind to know natures in the physical world. In this period, Kant reversed himself and attempted to work from a priori forms of space and time to the notions of order, connection, and force.

Undoubtedly, the views of Boscovich, Kant, and Leibniz conflict with the strict mechanism of Descartes. Yet they do not conflict with some tenets of mechanism such as those which would exclude final causality. Again, Kant never confused the study of pure mathematics with the study of the physical world. Even in his critical period, he saw mathematics as a set of deductions from clear definitions. Since philosophy of nature, as exemplified in Newtonian physics, derives its basic concepts from sense experience and these concepts are somewhat indistinct, definitions come at the end of the reasoning process in the philosophy of nature. For Kant, philosophy as a whole should follow the same procedure as physics.

Decline of Mechanism. Despite the sophisticated analyses of Leibniz, Boscovich, and Kant, atomistic versions of mechanism did not die in the 18th century. Several new attempts were made to explain gravitation atomistically. A vortex theory involving small particles was proposed by J. Bernoulli; according to this, bodies were pushed to earth by tiny pellets of a mysterious nature, in turn driven down by whirling motions in the heavens. It should be pointed out, however, that in the late 18th and early 19th centuries strong antimechanistic currents already existed in the form of philosophical ROMANTICISM and IDEALISM.

Within physics itself the central position of mechanics in physics was concurrently being challenged. New work in heat, light, electricity, and magnetism, as well as in the foundations of mathematics, challenged the ideas of strict mechanism. Hermann von Helmholtz maintained that the sum total of all forms of energy remains constant. This was in accord with mechanism in some ways, for it posited a closed nonevolutionary universe. Nevertheless, heat, light, and electrical energy now enjoyed equal status with mechanical energy. The second law of thermodynamics, formulated by Carnot and Kelvin, again departs from mechanism. In relating this law to mechanism it should be noted that it involves no presuppositions regarding the existence of atoms or of the void, and utilizes the concept of ''unavailable energy,'' which itself suggests a return to the occult qualities of the scholastics.

Field Concepts. In the areas of light and electricity, Young's diffraction experiments favored the wave theory of light over the more mechanistic corpuscular theory. This trend continued with the work of Michael Faraday. It culminated in the contribution of James Clerk Maxwell, who synthesized optical, electrical, and magnetic phenomena in his famous field theory, a theory that posited an ether and avoided the notions of atom and void. This theory also postulated the mysterious ability of bodies to influence each other when not in direct physical contact and when not connected by any obvious physical medium.

Additional difficulties for mechanistic philosophy developed from new studies on the foundations of mathematics. The work of Lobachevskiĭ, Riemann, and others introduced the concepts of non-Euclidean or curved geometries, and thereby questioned the objectivity of Euclidean straight-line geometry. This, in turn, affected the acceptance of Newtonian mechanics, since the law of inertia affirmed that the motion of a body tended to be in a straight line, just as the law of gravity affirmed that two bodies tend to approach each other in straight lines.

Positivism and Conventionalism. Scientists and philosophers toward the beginning of the 20th century undertook to draw philosophical implications from these new developments in science. Their thought led to a gradual acceptance of what is called positivist philosophy. Auguste COMTE, who earlier had introduced POSITIVISM, affirmed that our minds can only grasp phenomena or positive data. His basic idea was developed by three leading scientific minds, Ernst Mach, Pierre Duhem, and Henri Poincaré, all of whom reacted against classical mechanism. Mach criticized Newtonian mechanics on the grounds that its definitions of concepts such as force, mass, and acceleration were in fact circular, and that its laws were not objective representations of the physical world. Duhem and Poincaré thought along similar lines, although they concentrated more on the analysis of scientific methodology.

Relativity and Quantum Theory. The failure of the Michelson-Morley experiment (1887) to detect the notion of light relative to an ether or absolute space led Albert EINSTEIN to propose the thesis that the Newtonian concepts of absolute space, absolute rest, and absolute motion were meaningless in physics. In conformity with this view, in the theory of special relativity formulated in 1905, he postulated that the measured velocity of light would be constant and that the laws of physics would be the same in all systems of coordinates moving at constant velocity with respect to each other. Applying this to the laws of conservation of momentum and conservation of energy for collision problems, he deduced that the mass of a body varies with its velocity and that matter can be converted into energy. These notions have served to undermine the conception of matter in Newtonian mechanics and in philosophical mechanism. Again, while the notion of inherent finality or purpose in nature does not appear in the theory of special relativity, the concept of space-time geodesic associated with general relativity seems compatible with this type of teleology.

A second major reason for the downfall of strict mechanistic physics in the 20th century is found in quantum theory. Significant contributions to this microcosmic theory were made by Planck, Bohr, De Broglie, and Heisenberg in the first quarter of the century. Quantum theory, like relativity theory, discarded the idea of the void. De Broglie's work blurred the distinction between energy waves and corpuscles, and rejected the notion that subatomic particles have definite boundaries like billiard balls. Heisenberg's uncertainty principle, formulated in 1927, left room for chance and contingency in nature, as opposed to the determinism associated with the mechanism of Pierre Simon de Laplace. Again, there are intimations in recent theories that a whole atom is somehow more than the mechanical summation of its parts. Yet quantum theory seems to take no explicit account of purpose or finality in the processes of nature.

Out of relativity and quantum theory came a variation of positivism called OPERATIONALISM, which stresses that meaningful physical concepts can be derived only from measured activities of bodies. This fosters skepticism regarding the ability of the mind to reach the natures of things, and to this degree resembles the thought of Hobbes. Other streams of early 20th-century philosophy broke with mechanism in varying degrees— WHITEHEAD, BERGSON, the pragmatists, and the existentialists all stressed different points of departure (*see* EXISTENTIALISM).

Mechanism and Thomism. The most fundamental difference between mechanism and THOMISM is the former's denial of, and the latter's affirmation of, the existence of intrinsic purposes or goals for motions occurring in nature. Thomists and other scholastics assert the presence of finality in nature and use the manifestation of NATURAL LAW at the inorganic level as a foundation for its broader extension to the realms of organic and of human activity (*see* FINAL CAUSALITY). A mechanist philosophy does not encourage this type of reasoning.

Another basic difference is the attitude toward quantity and the notion of absolute space. Scholastic philosophers, following Aristotle, maintain that quantity is an accident of a physical body, and not its essence, as would be maintained by Cartesians. Therefore, while admitting the importance of mathematics and mathematical physics, they do not concede to these sciences complete autonomy from natural philosophy when using quantitative techniques to investigate the nature of the physical world (*see* PHILOSOPHY AND SCIENCE). Again, scholastics, such as Aquinas, deny the existence of a void or of absolute space, like that espoused by Newton, and in place of these notions apply the Aristotelian notion of natural PLACE to the analysis of local MOTION.

Scholastics likewise reject the atomistic concepts usually associated with mechanism. While affirming the existence of elementary particles, they do not regard these as indivisible subsisting entities, and maintain that a natural body is more than a mechanical aggregate of its parts. Thus they explain the organization and functioning of all bodies, including the inorganic, through an internal principle called the substantial form (*see* MATTER AND FORM; HYLOSYSTEMISM).

Finally, with regard to the strict determinism affirmed by classical mechanists, scholastic philosophers allow for a basic indeterminism in nature which permits the existence not only of CHANCE, but also of FREE WILL and miracles. Notwithstanding this, they still assert confidence in the ability of the human mind to attain truth and certitude through the habit of SCIENCE, and thus reject skepticism in favor of epistemological REALISM.

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MECHANISM, BIOLOGICAL

Any application of the general principles of MECHANISM to the explanation of life and vital processes. The several varieties of biological mechanism that have appeared in the history of thought are first explained in this article and then subjected to philosophical analysis and critique.

Early Forms. Histories of biological mechanism commonly begin with the examination of Cartesian DUALISM. Both Aristotle and THOMAS AQUINAS, however, found themselves in opposition to a doctrine, similar to