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The Abraham Pais Prize Lecture: The historical Development of the Physical Concept of Time

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The Irish physicist and mathematician John Lighton Synge once (1959) proclaimed that of all physical measurements that of time is the most fundamental and its theory "the most basic theory of all." Twenty years later the Belgian physicist and chemist Ilya Prigogine declared that "the concept of time is much more complex than we thought." Indeed, having studied the basic notions in physics like space, mass, force, simultaneity and written on each of them a detailed monograph, I always postponed a similar treatment of the concept of time because I realized that just by being the "most basic" it is also the most "complex" of all notions in physics and therefore a rather complicated subject of research. In fact, time, as perceived by us, is both "flowing" and "enduring" and its "passing" always "lasts." If I venture nevertheless to offer herewith a survey of the conceptual development of the notion of time, I do so because I delimit myself to the role of time only in physics and ignore as far as possible general metaphysical, psychological or biological issues. The presentation thus ignores the history of the notion of time as conceived in the myths and religions of ancient civilizations and begins, after some brief remarks about the Pythagoreans, with the theories of time as proposed by the Pre-Socratics, Plato and Aristotle. After a critical discourse on the early proponents of an idealistic interpretation of the notion of time, like that of St. Augustine, medieval theories of time, like those which proposed the atomicity of time, are discussed. After a presentation of sixteenth century discussions of time, like that by Bruno or Gassendi, Isaac Barrow's and Isaac Newton's theories of physical time are critically analyzed. This is followed by a brief study of the conceptions of time by Locke and Berkeley and subsequently by Leibniz, who is often regarded as the first proponent of a relational or causal theory of time. Following some brief remarks about Hume's conception of time Kant's critical investigation of the notion of time is analyzed and followed by the theories of an "arrow if time" as a result of the existence of irreversible thermodynamic processes. After a brief discussion of Poincaré's thesis of the conventional status of temporal metric, Einstein's interpretation of distant simultaneity and consequently his definition of time via simultaneity, as presented in his famous 1905 paper on relativity, are discussed. This is followed by some remarks on the concept of time in the general theory of relativity. A brief outline of the role of the concept of time in modern cosmology and, in particular, Hawking's notion of "imaginary time" conclude this essay.