

is more famous. Pascal wrote that “the arithmetical machine produces effects which appear nearer to thought than all the actions of animals.” Gottfried Wilhelm Leibniz (1646–1716) built a mechanical device intended to carry out operations on concepts rather than numbers, but its scope was rather limited. Leibniz did surpass Pascal by building a calculator that could add, subtract, multiply, and take roots, whereas the Pascaline could only add and subtract. Some speculated that machines might not just do calculations but actually be able to think and act on their own. In his 1651 book *Leviathan*, Thomas Hobbes suggested the idea of an “artificial animal,” arguing “For what is the heart but a spring; and the nerves, but so many strings; and the joints, but so many wheels.”

It’s one thing to say that the mind operates, at least in part, according to logical rules, and to build physical systems that emulate some of those rules; it’s another to say that the mind itself *is* such a physical system. René Descartes (1596–1650) gave the first clear discussion of the distinction between mind and matter and of the problems that arise. One problem with a purely physical conception of the mind is that it seems to leave little room for free will: if the mind is governed entirely by physical laws, then it has no more free will than a rock “deciding” to fall toward the center of the earth. Descartes was a strong advocate of the power of reasoning in understanding the world, a philosophy now called **rationalism**, and one that counts Aristotle and Leibniz as members. But Descartes was also a proponent of **dualism**. He held that there is a part of the human mind (or soul or spirit) that is outside of nature, exempt from physical laws. Animals, on the other hand, did not possess this dual quality; they could be treated as machines. An alternative to dualism is **materialism**, which holds that the brain’s operation according to the laws of physics *constitutes* the mind. Free will is simply the way that the perception of available choices appears to the choosing entity.

Given a physical mind that manipulates knowledge, the next problem is to establish the source of knowledge. The **empiricism** movement, starting with Francis Bacon’s (1561–1626) *Novum Organum*,² is characterized by a dictum of John Locke (1632–1704): “Nothing is in the understanding, which was not first in the senses.” David Hume’s (1711–1776) *A Treatise of Human Nature* (Hume, 1739) proposed what is now known as the principle of **induction**: that general rules are acquired by exposure to repeated associations between their elements. Building on the work of Ludwig Wittgenstein (1889–1951) and Bertrand Russell (1872–1970), the famous Vienna Circle, led by Rudolf Carnap (1891–1970), developed the doctrine of **logical positivism**. This doctrine holds that all knowledge can be characterized by logical theories connected, ultimately, to **observation sentences** that correspond to sensory inputs; thus logical positivism combines rationalism and empiricism.³ The **confirmation theory** of Carnap and Carl Hempel (1905–1997) attempted to analyze the acquisition of knowledge from experience. Carnap’s book *The Logical Structure of the World* (1928) defined an explicit computational procedure for extracting knowledge from elementary experiences. It was probably the first theory of mind as a computational process.

² The *Novum Organum* is an update of Aristotle’s *Organon*, or instrument of thought. Thus Aristotle can be seen as both an empiricist and a rationalist.

³ In this picture, all meaningful statements can be verified or falsified either by experimentation or by analysis of the meaning of the words. Because this rules out most of metaphysics, as was the intention, logical positivism was unpopular in some circles.

RATIONALISM

DUALISM

MATERIALISM

EMPIRICISM

INDUCTION

LOGICAL POSITIVISM

OBSERVATION
SENTENCESCONFIRMATION
THEORY