Aristotle's Physics

for Prof. Smoot's class

http://aether.lbl.gov/www/classes/p10/aristotle-physics.html

ARISTOTLE: Aristotle held that the universe was divided into two parts, the terrestrial region and the celestial region. In the realm of Earth, all bodies were made out of combinations of four substances, *earth, fire, air,* and *water,** whereas in the region of the universe beyond the Moon the heavenly bodies such as the Sun, the stars, and the planets were made of a fifth substance, called *quintessence*.

*Here the elements are denoted by italics. Thus, *earth* is a pure element, whereas Earth is a planet made mostly of *earth* but also containing some of the other elements; *air* is a pure element, whereas the air we breathe is mostly *air*, but with some other elements mixed in.

Heavy material bodies like rocks and iron consisted mostly of *earth* with small parts of the other elements. Less dense objects were thought to contain a larger admixture of the other elements along with *earth*. For instance, humans consisted of a complex mixture of all the elements: *earth*, which gave material strength and weight; *fire*, which provided warmth; *water*, which accounted for blood and other bodily fluids; and *air*, which filled the lungs and provided the breath of life. Of course, some people were more earthly, fiery, airy, or watery than others. The Sun, planets, and stars were made of *quintessence*, a pure, perfect substance, quite unlike the elements found on Earth. The Moon, marking the boundary between the sublunary earthly region and the supralunary heavenly region, was mostly *quintessence*, but because of its proximity to Earth it was contaminated with a small admixture of earthly elements, which accounted for the visible imperfections on its surface.

The fundamental assumption in Aristotelian physics was that the natural state of sublunary matter is rest. *Earth*, *air*, and *water* must seek their natural place at rest in the center of Earth unless stopped by an impenetrable surface like the ground or a table. The natural place of rest of the element *fire* is somewhere above us (but well below the Moon). The air we see around us is a mixture of the elements *air* and *fire* (after all, air, at least in Greece, has warmth), so its behavior is complicated by the competition between the tendency for *fire* to rise and *air* to fall. Except in very complicated situations such as when *air* and *fire* were mixed together, motion was not a natural state of affairs.

Aristotle's model provided a simple, compelling explanation for falling rocks, rising flames, and the circulation of the air. However, it was less successful in explaining "violent motion" such as when an object is hurled from a catapult. To see why this would be a problem for the Aristotelian worldview, imagine the following experiment: Find a cat, and putt it from a siege machine. You would observe that the cat continues to travel through the air (before landing safely on its feet) even after it was no longer being pushed by the arm of the machine. If the natural state of motion of the cat is rest on Earth, why didn't the cat drop to the ground immediately on leaving the pult?

Here, Aristotelian physics had to say that this kind of motion is different because it is "violent," and had to invent some mechanism to keep the cat in the air during violent motion. All of the mechanisms fall under the technical description "hand waving." One of the most popular explanations was that the air in front of the cat became disturbed by the movement of the cat, and swirled behind the cat and pushed it along. Thus, in Aristotelian dynamics, there was a distinction between "natural" downward motion (for example, a rock falling to the ground when dropped) and unnatural violent motion not directed toward the center of Earth (such as that resulting from a catapult).

In contrast to earthly motions, in the supralunary regions of the heavens the natural state of motion was circular, because circles were considered to be the perfect geometric figure. Thus the planets would travel forever in circular orbits without the intervention of any force or impetus, because, well, it's the natural thing for planets to do.

Although there was some degree of experience and observation in the physics of Aristotle, at its heart was a philosophical approach to science where the laws of nature are constructed to conform to a particular philosophical outlook. This basis for the investigation of nature led to some strange statements by Aristotle - for instance, that women have fewer teeth than men. Either Aristotle was not a very accurate observer, he couldn't count, or he had odd taste in women.

Actually, it is often fashionable to make such critisms of Aristotle as a residual of the long fight between the new view and the classical Greek view. And there are a number of areas where it is easy to ridicule; however, in general the classical Greek scholars and in particular Aristotle were quite good in their work and their descriptions of the world. Their contribution to science was major.

Although Aristotle had been the first and last word on dynamics for two millennia, after the work of Galileo, Descartes, and others it had become clear to the leading natural philosophers that a new system was needed. Although in the intellectual vanguard of physicists the feeling was that the physics of Aristotle was dead, in the curriculum of many universities in the mid-seventeenth century Aristotelian physics was not yet buried. Now we think of universities as the petri dishes of society where all sorts of new ideas and philosophies are grown (and, thankfully, most are discarded). But in the sixteenth and seventeenth centuries the universities were reactionary institutions dominated by Aristotelians, and they were not about to relinquish their authority without a struggle.