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Addressing the Ancient Greeks' Concerns on the Spherical Nature of the Earth

In his book *On the Heavens*, Aristotle claimed of the existence of five cosmic elements, air, water, earth, fire, and aether, which together made up all of the universe and heavenly bodies. Each of these elements had natural positions which could be observed by natural phenomena. Namely, earth is the heaviest element of all and is attracted to the center of the universe, and so the center of the universe has attained a massive ball of Earth, with the core at the exact middle. A piece of earth, by definition, moves to the closest remaining point to the center of the universe. In other words, if the region above the center of the universe is covered by earth, the next piece would travel to the region directly below the center, instead of resting on top and being far away. With an abundance of earth and time, Aristotle argued, by symmetry, a conglomerate of earth would form near the center of the universe, assuming a spherical shape, which in fact happens to be the very planet we reside on.

For the ancient Greeks, however, no images nor satellites nor even everyday experiences confirmed Aristotle's claim that the Earth was spherical. In fact, as far as the eye could see, or as far as an individual walked and sailed, the Earth remained consistently flat. However, Aristotle's belief in the five fundamental elements with their natural positions was equally convincing. For instance, the natural positions of the second, third, and fourth heaviest elements, which were water, air, and fire, respectively, were towards the center of the universe as well, but each was lighter than the elements before it, and therefore floated above the elements heavier than it on the ball of the center of universe. For this reason, water in the oceans lay on the surface of the Earth, and the Earth's atmosphere with all of its air lay above the water. Any disturbance to any of the elements would be subsequently followed by an action returning it to its natural position. For instance, a rock thrown upwards would settle back on the ground, water falling to the sky would make its way to rivers, helium balloons, when let go, would return to the air, flames in fires naturally point up, and even volcanoes shoot molten lava, which is fire, up as high as possible. Aristotle and most of the ancient Greeks were quite pleased with the above description of motion, for it could accurately predict and explain the events that would unfold in any situation. However, in order to reconcile one of its chief consequences with the observations of skeptics, Aristotle would provide several more arguments, explaining why the sense, while still being allowed to be trusted, could not detect the curvature of the Earth.

Firstly, Aristotle offered the example of a ship returning to a port from far off shore. As an individual watches the horizon, they would notice the upper parts of the ship, such as the sail and mast appear first, only after which would the hull and remainder be visible. This, Aristotle, noted, was due to the spherical surface of the Earth. If the Earth was not spherical, there would be no explanation for why structures far away need to grow taller and taller for the uppermost tip to just be visible. When critics questioned why the last part of the ship that is visible over the horizon, or the edge of the rising Sun against the ocean would appear entirely flat however, Aristotle responded by saying the curvature of the Earth was too little to be observed by the naked eye over such distances. With many not satisfied with this response, Aristotle provided a second argument, one based on his travels from Egypt to Cyprus, barely one thousand kilometers apart. Here, Aristotle noted, the position and presence of the stars in the night sky changed significantly. For instance, a star angled thirty degrees away from the zenith of the night sky at one point appears to move closer when travelling in that direction. Moreover, certain stars close to the horizon would disappear behind the curvature of the Earth when moving away from the equator However, certain constructions of a flat Earth model, such as one with a fixed set of stars above a flat circle representing Earth, could manage to demonstrate nearly identical phenomena, given that the observer moves sufficiently vertically on the level surface. Furthermore, even with a change of distance of one thousand kilometers, critics noted that the relative movement of the stars was minimal and not at all as drastic as commonly mentioned. With the equipment available at the time, it could have simply been confirmation bias at play.

Therefore, it took a third and fourth argument from Aristotle to finally convince the doubters of his claim, each of which involved much more solid pieces of evidence. Aristotle noted that the Sun and the Moon and even the speckish stars in the heavens, had to be quite large and quite distant, but still retained a spherical shape when viewed from a distance. Aristotle reasoned that the Earth, even with its tremendous size, would appear similar from a distance, despite what a tiny individual's sense would indicate up close, and that it would be quite odd for the Earth to be any different from any other celestial body, as a flat disk in a world of roundness. Finally, Aristotle pointed to the most objective of his pieces of evidence, the fact that the Earth's shadow on the Moon is circular, and that it was mathematically impossible to achieve such a shadow with any other shaped object. With all five of these arguments on his side, and by addressing the one argument and concerns of his opponents quite well with a rebuttal that, while unable to be physically measured with just the human eyes, existed clearly in the field of mathematics, Aristotle convinced, not only the ancient Greeks, but nearly every society after him, of the spherical nature of the Earth, for the two thousand years that would follow.

In this paper, I have considered the arguments for and against the curvature of the Earth in ancient Greece, addressing the issues on both sides with the tools widely available to the most prominent philosopher, Aristotle, at the time. In particular, I explicitly questioned Aristotle's explanation of how the senses could not detect the flatness of the Earth, and provided an Aristotelian refutation to topics glossed over or implicitly covered in his works. Since the time of Aristotle's works, further refinements were provided by the advent of the telescope in confirming that the specks of celestial bodies were in fact quite spherical, and in satellite imaging and other direct proof showing the Earth's curvature. To this day, the arguments provided by Aristotle are still utilized in convincing proponents of the flat Earth theory, for unlike most of his other works, they have withstood scientific tests over time.