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BOOK II  
On the Configuration of the Upper Bodies,  
in Fourteen Chapters

CHAPTER ONE  
On the Situation of All the Simple Bodies

[1] Natural Philosophers have proven (*hujjat*) that simple bodies can only have a spherical shape, since other shapes require a difference of parts. However, the practitioners of this science establish the circularity of bodies by sense perception, by observational testing (*i'tibār-i raṣd*), and by proofs (*dalīl-hāyi*) that are based upon observations. Now, when they looked at the stars and the two luminaries, they found them all to be in motion from east to west such that in every nycthemeron they make one complete rotation. They found an apparent point, called the pole, around which the stars move. That which is near [the pole] does not rise or set; the farther the distance from it, the larger the circuit becomes, and all the circuits are parallel until a star is reached that rises and sets. That which is farther from the pole, the period of its invisibility becomes longer proportionally, until a star is reached whose period of invisibility is equal to its period of visibility. That which becomes farther from it in the other direction, its invisibility

becomes greater than its visibility until a star is reached whose visibility in a nycthemeron is not more than momentary.

[2] Furthermore, stars ascend gradually until the line of the meridian is reached, and from there gradually descend until they disappear. A star's size under all circumstances appears equal. It does not at times become smaller and at [other] times larger, since change in size indicates a variation in distance, with the exception of when it is quite close to the horizon, at which time it appears larger because of the density of vapors—just as a grape looks larger in water—because [apparent] size changes due to clarity or turbidity of the air.

[3] In view of these considerations, it became known that the sky is spherical, since these shapes and situations can arise only in a sphere. Upon reflection, they found the Earth as well to be spherical, because as one traverses the distance toward the north the altitude of the stars that are of permanent visibility increases and some of those that had risen and set become permanently visible; toward the south, some of the stars become permanently invisible. If one goes the other way toward the south, the stars that had been permanently invisible begin to be visible and the stars that had been permanently visible begin to have [a period of] invisibility.

[4] If one moves toward the east or west, rising and setting times become earlier or later, since the stars in eastern lands rise earlier than they do in western lands. The truth of this becomes known by the observation of celestial phenomena such as solar and lunar eclipses and shooting stars; for if two persons in two different cities make observations, the one in the city to the east will see things at earlier times than the one in the city to the west.

[5] Therefore, by this and similar evidence, it became known that the Earth is also spherical and that the heavens bounds the Earth on all sides, since if the heavens did not bound it, it would not be possible for

stars to disappear and appear and to return to their points of origin.

[6] Then too, by similar considerations, it became known that the Earth is in the middle of the heavens in a central position, because if it were closer to the upper part of the heavens, the period of visibility of the stars which are on the equator of [the first] motion would be less than their invisibility; and if closer to the lower part, the period of invisibility would be less. But this is not so, since every star that lies at the midpoint between the two poles has equal visibility and invisibility, while those that are closer to the north have a longer visibility and those that are closer to the south have a longer invisibility. When two stars are equidistant in the two directions, the invisibility of one is equal to the visibility of the other. If the Earth were closer to the north or to the south, then when night and day are equal and the Sun is at the midpoint between the two poles, the rising and setting points would not be directly opposite each other and shadows at sunrise and sunset would not coincide on one straight line. [Furthermore,] solar and lunar eclipses would not necessarily be the way they are, as will be explained. If the Earth were closer to the east or west, the length of the first half of the day would not be equal to the second half of the day; indeed, the Sun and stars would stay longer in one half of their periods of visibility and the stars would not appear equal in both directions but would appear smaller at one end. It therefore became known from this evidence that the Earth is placed in the middle of the heavens and does not incline in any direction.

[7] When, with respect to this state of affairs, observational instruments were constructed and testing was also done with them, it became certain that these circumstances are as described, and no doubt remained. Since the Earth is posited as the center of the World, and heavy bodies are inclined toward the center and light bodies are inclined toward the circumference, therefore: wherever they are, animals have their heads toward the heavens and their feet toward the

Earth; and the direction of the heavens is taken to be “up,” and the direction of the Earth is taken to be “down” such that if we imagine a hole through the Earth and two people standing at either end of the hole, each would think the other was beneath himself. Hence it became known that the distances between the tops of elevated objects is greater than the distances between their bottoms, since the bottoms are closer to the center; therefore every object can be taken to be the endpoint of an Earth diameter. Furthermore, the apparent surface of water and liquids that remain still on the surface of the Earth is convex, like the surface of a sphere. The import of this is evident to sailors, who first see the tops of elevated bodies and later see their bottoms. If the surface of the water were level, they would see them all at once. Since the surface of a sphere is such that the less its distance from the center, the greater the convexity of the surface, it follows necessarily that, for example, if a vessel on top of a mountain is filled with water and the same vessel is filled with water at the bottom of a well, there will be more water at the bottom of the well than at the top of the mountain. This is one of the questions put to this group [of practitioners] by way of examination.

[8] Mountains, elevations, and depressions do not keep the Earth from being circular, because these things have no measure in relation to the Earth. One scholar has said: “I made an investigation by way of measurements, [finding] the largest known mountain to be in relation to the Earth in the proportion of one-fortieth of a millet grain to a sphere that is a cubit (*gaz*) in diameter.”

[9] Turning to the order of the bodies: When the stars were investigated, nine types of motion were found. At first glance, there is one motion that can be seen right away, and it is the diurnal motion that causes the rising and setting of the stars. It is called the **primary motion**, and all the stars share in this motion. The second motion, which became known with much investigation and testing—which some of

the ancients did not recognize—is a motion that takes 36,000 years to complete one revolution according to one group of the ancients. According to modern observations, it takes place in 24,000 years, and it is called the **motion of the fixed stars**. Although other planets share this motion with the fixed stars, nonetheless it has been attributed to the fixed stars because they are distinguished by this motion. The other seven motions are the motions of the seven wandering planets, each of which has a motion in addition to these two. For this reason, nine bodies have been posited, i.e., nine orbs encompassing each other.

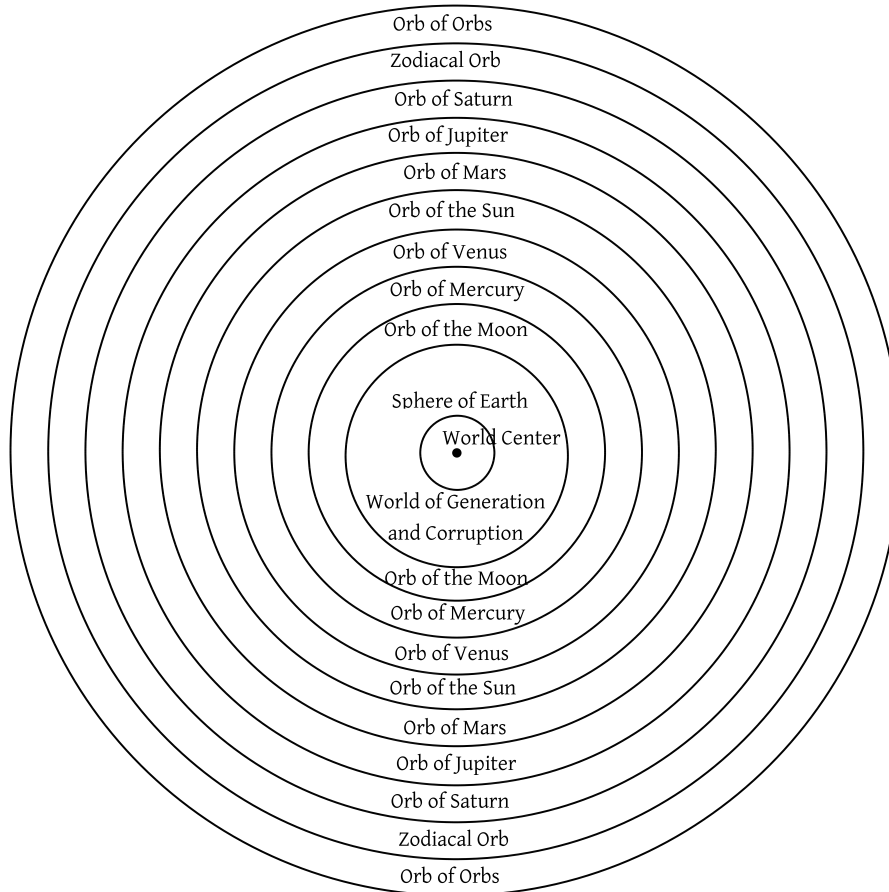
[10] As for the order: the Moon always obscures any stars with which it comes into conjunction, and no star obscures it. Mercury [obscures] Venus, Venus [obscures] Mars, Mars [obscures] Jupiter, Jupiter [obscures] Saturn, and Saturn [obscures] some of the fixed stars. There is never any difference or variation in this order. Thus, for this reason the orbs have been so arranged.

[11] The fact that the Master Abū ʿAlī [Sīnā]—may God have mercy upon him—is reported to have said, “I saw Venus as a mole on the face of the Sun,” also attests to this order. Testing conjunctions with the Sun is difficult, since no star appears in its rays, except the Moon, which obscures it during solar eclipses. It has therefore been recognized that the Sun is beyond the Moon. It then became clear, based on parallax—the meaning of which will come to be known later—that the Sun is beyond Venus and below Mars, since no star has parallax less than the Sun, and Mars has no perceptible parallax. From [geometrical] demonstration, the closer anything is to the Earth the greater its parallax. It then became known that the Sun is between Mars and Venus. And this arrangement is connected with the natural order, for whatever is farther from the Earth has a larger circuit and a slower motion. Secondly, since the other wandering planets are linked with the Sun—as will become known later—and the link of the three upper planets is of one sort, the link of the two lower planets is of another,

and the link of the Moon is of yet another, then the position of the Sun in the middle of these six is closer to the natural order. The order of these eight orbs being known, the body that was posited for the purpose of moving them all with the primary motion must encompass them all, since moving an external by an internal, the thickness of the former being many, many times that of the latter, would be considered quite objectionable; and since the motion of this body is closer to simplicity than the other bodies, which are moved by its motion and have additional motions, and furthermore the sphere of the fixed stars is more simple as it has no motion other than the two [aforementioned], then placing it in a way that encompasses all [other orbs] seemed better for this reason as well. For these reasons the universal mover is called the **first orb**.

[12] Then, based on these considerations, nine orbs have been arranged in this order, starting from the top: first, the **Orb of Orbs**, which is also called the **starless orb** and the **Atlas orb**; second, the orb of the fixed stars, which is also called the **zodiacal orb**; third, the orb of Saturn; fourth, the orb of Jupiter; fifth, the orb of Mars; sixth, the orb of the Sun; seventh; the orb of Venus; eighth, the orb of Mercury; and ninth, the orb of the Moon. If, however, one starts from [our] direction, they will be in reverse, i.e., first the orb of the Moon, and ninth the Orb of Orbs.

[13] The world of generation and corruption is inside the orb of the Moon. Its order, as has become known to natural philosophers, is thus: first, the sphere of fire; second, the sphere of air; third, the sphere of water; and fourth, the sphere of earth. Earth and water are mixed together, since water's encompassment of earth is incomplete, as will be explained later. The Earth is the center of the World and in the middle of the bodies; an illustration of these bodies in their encompassment is as set forth [in the following]—God is all-knowing:



[Figure 1]

## CHAPTER TWO

### An Exposition of the Primary and Secondary Motions, and the Names of the Great Circles

[1] In the introduction we said that when a sphere has rotational motion, there results an equator, two poles and an axis, and that the equator is one of the great circles. Now we say that two different rotational motions in one sphere cannot be perceived, unless they are around either different poles or different centers; so that, for example: [1] the two poles of one motion are different from the two poles of the other