4. This structure arose from a process in which matter formed into three distinct types as a consequence of the initial circuits of motion that God introduced into the universe
    a. First type: extremely small, high speed slivers that formed in the process of filling interstices -- the sole matter of the sun and stars
    b. Second type: small spherical globules, larger than that of the first type, though small by comparison to matter on earth -- the material of the heavens, varying in size and speed
    c. Third type: larger particles of matter, forming planets and the sensible objects around us, including air
5. At the center of each vortex is a star -- a body made up of matter of the first type in intense agitation, rotating at high speed, and hence pressing against the globular matter surrounding it
    a. Spherical in shape because of the tendency to recede, on the one hand, and the ability of these elements to occupy comparatively ideal spaces because of their small size, on the other
    b. Matter of second type surrounding the spherical star rotates too, but because of larger size, some slippage in speed from resistance effects
6. The various vortices interact with one another, with matter of the first type passing between them, and matter of the second type of adjacent vortices pressing on one another
    a. Matter of the first type circulates, entering a vortex radially at its poles and centrifuging outward at the equator
    b. Basic centrifugal stability of any vortex arises from effects of contiguous vortices pressing on it -- no where for this matter to go in spite of its centrifugal tendency
    c. But this is a dynamic process, with continual variations in the overall shape of a vortex and in patterns within it as a consequence of impact effects from matter of adjacent vortices

B. The Sun, the Planets, and their Satellites
1. Our planetary system one such vortex, with sun at its center and the various planets orbiting in a comparatively small circle near its center [circle HQ in Figure X]
    a. Provides an immediate explanation for why all the (known) planets orbited in more or less the same ecliptic plane: a preferred direction of motion
    b. Total size of vortex huge compared to radius of outermost planet; vortex unable to support planets in equilibrium at more remote reaches
2. The planets themselves are former stars, formed when sunspots enveloped them, interfering with the centrifugal pressure exerted by the star on its surrounding globules and thus allowing neighboring vortices to intrude and destroy the original vortex
    a. Once planet (or comet) formed and vortex around it collapses, engulfed by and moves within adjacent vortex
    b. Planet when it migrates to a point where it reaches an equilibrium of motion with the surrounding globules of the planet

3. Speed of globular particles varies with distance from Sun in a way that accounts for the variation in planetary periods
    a. Primary effect is centrifugal tendency, so that higher speed globules migrate to outside of vortex
    b. Rotation of sun augments motion of globules near it, causing them to move fast; these globules are small, for otherwise they would migrate to a higher radius because of centrifugal effects
    c. Speed thus diminishes until reach a point where globules all of the same size, beyond which speed increases [HQ in Figure X]
4. Moon and other satellites are just planets orbiting the Earth and Jupiter, instead of orbiting the Sun
    a. Satellites have same density as principal, and hence should circulate at same distance from the sun, but owing to their smaller size tend to move faster
    b. Only way to satisfy both conditions: moon orbits the earth, inducing a vortex of globules along with it, resulting in a vortex within the main vortex [Fig XV]
    c. Irregularities of motion of moon from eccentricity of vortex with respect to earth (153)
    d. Two accounts of the earth's rotation: induced by vortex associated with the moon's motion around it, and a residual consequence of its prior rotation as a star
    e. Tides related to Moon: IV, 49-56 [Figure XIX]
5. This is all a dynamic process in which local variations would constantly occur because of interactions with adjacent vortices
    a. Short term changes from vortex variations, and long term changes from gross alterations in the structure of the cosmos
    b. Account thus gives a natural way in which solar system could have formed, exhibit both regularities and continual small fluctuations, and be subject to gross long term changes!

C. The Physics of Curvilinear Motion

1. Descartes struggles in III 56-59 to explain the tendency to recede from the center of motion in curvilinear motion, culminating in the seminal passage quoted above

    "And we experience the same thing with the sling: by means of the greater speed, to be sure, at which the stone in it rotates, the rope is stretched all the more; and indeed this tension, given rise to by the force alone by which the stone endeavors to recede from the center of its motion, displays to us the quantity of force of this kind." (III, 59) [my translation]

    "Idemque etiam experimur in funda: quo celerius enim lapis in as rotatur, eo magis funis intenditur; atque ista tensio, a fola vi qua lapis recedere conatur a centro sui motus exorta, exhibit nobis istius vis quantitatem."

2. Descartes here speaks of "the force by which the stone endeavours to recede from the center of its motion," identifying it as that which issues forth in the tension in the rope of the sling
    a. The word *conatur* and the corresponding *conatus* the Millers translate as "striving," but it can equally be translated as "endeavor," "effort, "or even "tendency" insofar as Descartes himself offers the alternative "*tendere*" in Article 57

b. I tend to prefer to retain the Latin *conatus* to simplify matters

c. But do notice that Descartes speaks of the *force* of this *conatus* as giving rise to the tension

3. Descartes speaks of the need to recognize several tendencies or endeavors in Article 57 (Plate VIII), most notably the tendency to continue motion uniformly in a straight line along a tangent (i.e. from A toward C in the figure) and a tendency to recede radially from the center (from A toward D)

   a. As the Millers and many others have noted, he is here probably initiating some confusion, for the only tendency that the sling is hindering is that toward C; there is no tendency toward D

   b. But that tendency toward C does involve receding from the center (along BC and FG), and hence the phrase "tendency or endeavor to recede from the center" is not improper

   c. That is the tendency or endeavor I am calling the "centrifugal" tendency, using Huygens's term

   d. We shall see later how first Huygens and then Newton (and Hooke) clarify what is going on here

4. The phrase the Millers translate as "we can judge the quantity of this force by this tension" is literally "that tension displays to us the quantity of this kind of force"

   a. The first key notion here is that of this kind of force being or having a quantity, a measure so to speak, as earlier we saw quantity of force given by Descartes as $\Delta(B*speed)$

   b. The second is that this quantity is displayed to us by its effect, namely the tension in the rope

   c. The idea, then, is that the quantity or magnitude of the *conatus* to recede from the center in curvilinear motion can be determined by the magnitude of the tension required to counteract it

5. The idea of measuring the quantity of a tendency toward a particular motion by the tension in a rope required to counteract that tendency, maintaining static equilibrium, was not novel

   a. Consider for example how Galileo invoked a weight hanging from a pulley at the top of an inclined plane to measure the reduced tendency of a given sphere on the plane toward motion

   b. The tension in the string or rope is specified by the weight required to maintain static equilibrium

   c. One can extrapolate from this (Stevin's triangle) to conclude that the tension in the rope can specify the quantity of the *conatus* of a given sphere to descend versus angle of inclination or, in Descartes' case, the *conatus* of a given stone to recede from the center versus its speed

D. The Underlying Physics of Orbital Motion

1. The physics underlying the orbital motion of the planets is just the physics of a sustained fluid vortex

   a. Key question for Descartes is what mechanism offsets the centrifugal *conatus* of the fluid in the vortex, the *conatus* that is characteristic of all curvilinear motion [56-60]

   b. Answer: any one globule is restrained centrifugally "by the other globules beyond it in the same way as the stone is restrained by the sling." [60]

   c. At outer edge globules restrained by action from globules of adjacent vortices

2. End up with complex equilibrium, in which forces [*vires*] from inner globules add to the centrifugal tendencies of outer ones, to be counterbalanced from outside