Émilie Du Châtelet, *Foundations of Physics*, 1740.
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Footnotes are ours except where otherwise indicated.
Du Châtelet's marginal notes are placed in **{bold}** in the closest appropriate place in the text. Please see the French original for the position of each note in the margin alongside the paragraph. Figures are available in the original text, and online via the BNF.

Chapter 15. Of Mr. Newton's Discoveries on Heaviness

339. There are no other Phenomena in Nature whose explanation has puzzled Philosophers more than those of heaviness.

340. In chapter 14 we saw that Aristotle explained them as he did all physical effects, that is, by words devoid of meaning.

341. Descartes -- who by his methodical way of reasoning had disgusted men who were using the unintelligible jargon of the Schools, a jargon that had made Aristotle even more obscure -- seemed to have given a plausible reason for heaviness, and to have explained this Phenomenon that is so ordinary, and so surprising, in a satisfactory manner.

{How Descartes explained the fall of bodies toward the earth.} He had supposed that the earth was surrounded by a great vortex of subtle matter, that circles around the earth from West to East, and that carries it in its daily rotation; and that this subtle matter pushed heavy bodies toward the earth by the superiority of the centrifugal force that it acquired in turning.

342. {This explanation is subject to great difficulties.} It must be admitted that, when one does not calculate with rigor, nothing seems more ingenious and more simple than this explanation that Descartes gave of heaviness. But when one enters into the detail of the Phenomena that accompany the fall of bodies, what seemed at first so simple turns out to be subject to great difficulties.

The two principal difficulties concern the progression in which the fall of bodies takes place, and the direction of their fall. For if the vortex that carries the earth in its daily rotation caused heaviness, bodies ought not to fall in accordance with the progression discovered by Galileo, and instead of being directed toward the center of the earth in their fall, they ought to tend perpendicularly to its axis.

[1] Especially Monica Solomon and Penelope Brading.

343. {The way in which Mr Huygens remedied these two principal difficulties.} Mr. Huygens responded to these two difficulties by supposing that the matter that causes heaviness goes seventeen times faster than the earth, and that the motion of this matter happens in every direction; for by these two suppositions, one can explain why bodies fall according to Galileo's progression, and why they are directed toward the center of the earth, and not perpendicularly to its axis.

344. I will not delay by reporting to you here the other objections that have been made against this explanation of Descartes, nor the way in which great men who followed his view believed they could remedy it; you can see this in their works, many of which are available to you. My aim here is to make known to you the way in which Mr. Newton explains the same Phenomena by attraction, and how the path of the Stars[2] enabled him to discover that all celestial bodies tend toward the center of their revolution by the same cause that makes heaviness on earth.

345. Matter, by its inertia, always tends to conserve its present state; thus, all bodies moved in a circle tend to escape along the tangent, that is to say, along each of the infinitely small right lines that it traverses in each instant; and it is this effort that the body makes of continuing to move along this small right line that we call *centrifugal force.* Therefore no body would be able to move in a circle unless some force made it change its direction at every instant, and forced it to describe a curved line.

Motion in a curved line is therefore always a composite motion. Now, we know that all the Planets orbit around the Sun along curves; therefore there must be two tendencies, one which makes them go in right line and the other which continually draws them back, acting on them and directing them along their paths.

{Celestial bodies would all escape along the tangent, if some force did not draw them back.} We know that the force by which Planets would describe only a straight line is the projectile force, which was impressed upon the Planets in the beginning by the Creator. But which is the force that which pulls them from this right line at each instant, and forces them to describe a curved line, and to revolve around a center; that is what Mr Newton set out to discover.

It is necessary to know Kepler's discoveries concerning the path of the Stars[3] in order to understand how Mr. Newton succeeded in discovering that all celestial bodies tend toward their center, and that it is this principle that keeps them in their orbit, and makes heaviness on the earth.

346. {Explanation of Kepler's two analogies. Plate 6, Fig. 32.} One of the laws discovered by

[2] The “wandering stars”, i.e. the planets and their satellites.
[3] As above, the “wandering stars”.

Kepler is *that the Planets, in revolving around the Sun, describe equal areas in equal times*, such that if one imagines a point B, from which a Planet left, and a point C, where it arrives, and draws two right lines BS, CS, to the Sun S, then the area of the sector SBC of the ellipse formed by these two lines and by the arc of the curve that the Planet has traversed, increases in the same proportion as the time during which it moved.

347. The second law of Kepler is *that the time which a Planet takes to make its revolution around the Sun, is always proportional to the square root of the cube of its mean distance to this Star*. You have seen the explanation of this law in the *Elements of Newton's Philosophy*[4] that we read together, so I will not repeat it here. **{*Elements of Newton*, ch. 20.}**

348. {Demonstrations that Mr. Newton derived from Kepler's laws.} Mr. Newton, in seeking to know the cause of these laws discovered by Kepler, demonstrated, with the help of the most sublime geometry:

1. That if a body that is in motion is drawn toward a mobile or immobile center, it will describe around this center areas proportional to the time, and conversely, that if a body describes around a center areas proportional to the time, then there is a force that carries it toward this center.
2. That if a body that moves around a center that attracts it completes its revolution in a time proportional to the square root of the cube of its mean distance from this center, then the force that attracts it decreases as the square of its distance from the center toward which the body is attracted, and conversely, etc.

349. Thus, Kepler's first law, that is to say, the proportionality of areas and times, enabled Mr. Newton to discover a central force in general, which he called *the centripetal force*; and the second law, which is the relationship between the time of the revolutions of the Planets and their distance from the center, enabled him to know the law that this force follows.

350. {All Planets observe Kepler's laws in their paths.} Not only do the principal Planets observe these laws as they revolve around the Sun, but the secondary Planets also follow them as they revolve around the principal Planet that is the center of their revolution. Thus, the secondary Planets tend toward the principal Planets, around which they revolve, in the same proportion as the principal Planets tend toward the Sun, their center, since both observe the same laws in their paths.

[4] Voltaire's *Éléments de la philosophie de Newton*, 1738. English translation available as: *The elements of Sir Isaac Newton's philosophy*, 1738.

351. This is not the place to show how all celestial bodies confirm this discovery by the regularity of their paths, and how Comets do not seem to come to astonish our Universe, but to bring new testimony to these truths perceived by Mr. Newton: this article belongs to the book in which I will talk to you about our planetary World, and I mention here the discoveries that Mr. Newton made concerning the path of the Stars only because these are the discoveries that led him to the knowledge that the same cause that directs them in their paths also brings about the fall of bodies toward the earth.

352. {How Mr. Newton succeeded in discovering that the Moon, as it revolves around the Earth, observes Kepler's second law.} The Moon tends toward the earth, for as it revolves around the earth it traverses equal areas in equal times. But by only considering the motion of the Moon around the earth, one does not yet know the law that this tendency follows; for, although I have said that the secondary Planets follow the two laws discovered by Kepler in revolving around their principal Planet, it is by comparing the time of the revolution and the distances of the two Planets that revolve around the same center, that one discovers that the time of their revolution is proportional to the square root of the cube of their mean distance from this center, and that one sees consequently that they observe Kepler's second law, and that the force that acts upon them decreases as the square of the distance; for without comparison there is no proportion.

353. Since Jupiter and Saturn each has several Satellites, one easily finds by the rule of three that you know, that these Satellites follow the two laws of Kepler in their revolutions. But since the earth has only the Moon as a Satellite, there is no Planet for comparison, by which to be sure that the Moon in revolving around the earth follows Kepler's second law, and by which to know the proportion according to which the Moon tends toward the earth.

354. **{*Principia Mathematica.*}** By means of shrewdness and calculation, Mr. Newton demonstrated in the first corollary of proposition 45 of his first Book, *that when a Planet moves around a mobile center in an orbit very close to a circle (such as the Orbit that the Moon describes around the earth), one can determine by the motion of its line of apsides*[5] *in what ratio the power that makes it traverse its orbit is acting upon it.* By applying this proposition to the path of the Moon, he determined that the attraction of the earth on this Planet decreases in a ratio a little greater than the ratio of the squares of the distances. But it was the comparison of the fall of bodies with the period of the Moon that fully assured him that the force that keeps the Moon in its orbit decreases in this proportion.

[5] Du Châtelet's footnote: **{Fig. 33.}** We call the aphelion the point A of the orbit furthest from the Sun S, or from the body that is the centre of the revolution, and the perihelion the point B that is the closest; the line AB that passes through the aphelion A and the perihelion B is called the line of apsides.

355. Bodies that are thrown horizontally fall back toward the earth. Nevertheless, abstracting air resistance, these bodies by their inertia should follow to infinity the right line along which they were thrown, if no other force acted upon them. It is certain that the force that at every moment draws these bodies from the right line along which they were thrown, and that makes them fall back toward the earth in describing a curve, is the same as the force that makes them fall in a perpendicular line when they are left to themselves. Now, experience teaches us that the path of bodies that are thrown is longer before they fall back towards earth, the greater the projectile force impressed upon them. Therefore with a sufficient projectile force, a body could revolve around the earth without falling back down, and the circular motion of this projectile around the earth would be a proof of its gravity as certain as its fall toward the earth in a perpendicular line when it is left to itself.

356. **{The same cause produces the heaviness of bodies on the earth, and directs the Moon in its path.}** By applying this consideration to the Moon, Mr. Newton concluded by analogy that the revolution of the Moon around the earth could very well be the effect of the same force that makes heavy bodies fall toward the earth. Thus, he therefore used these bodies that fall here below[6] toward the earth by their heaviness as a Planet for comparison, and he reasoned thus: if the force that directs the Moon in its orbit decreases as the square of the distance from the center of the earth, and if this same force makes the heaviness of bodies that have weight, this force ought to be 3600 times greater for the bodies that are placed near the surface of the earth than for the Moon; for the spaces traversed by bodies animated by different forces are at the beginning of their fall proportional to these forces. Now, at its mean elongation from the center of the earth, the Moon is about 60 half-diameters away, and all bodies that are near the surface of the earth are regarded as being a half-diameter from its center, owing to the small heights that we can attain. Thus, if this force decreases as the square of the distance, in the first instant of their fall it ought to make the Moon traverse 3600 times less space than it makes heavy bodies fall here on earth.

357. The distance from the Moon to the center of the earth being, as I just said, about 60 half-diameters of the earth at its mean elongation, let BKH **{Fig. 34. Demonstration of this truth by the mean motion of the Moon compared to the fall of bodies.}** be the orbit of the Moon, and BF the arc of this orbit that the Moon traverses in one minute. It is certain that, every circular motion being a composed motion, the Moon in describing this arc BF obeys two forces: the projectile force that on its own would direct it in a right line from East to West, toward BE; and the centripetal force that would make it fall perpendicularly toward the earth along BT if the

[6] i.e. these terrestrial bodies.

Moon obeyed the latter force alone.

Now, by decomposing the composite motion, the quantity of action of each of the composing forces can be known, and consequently the path that each would have made the moving body traverse, if it had been acting alone on it. Thus, by making the arc BF become the diagonal of the parallelogram BDGF, we obtain the lines BG and BD which represent the path that each of these two forces (the forces that make the Moon traverse the arc BF in one minute) would separately have made it traverse during the same time **{Fig. 34.}**.

Without the force that carries it toward the earth, the Moon would traverse in one minute the tangent BG, and consequently the effect of the centripetal force is to draw it from this tangent along the line GF, equal to BD. It is therefore due to the centripetal force that, at the end of a minute, the Moon is found at F instead of at G. GF, or BD that is equal to it, is therefore the space that the force that carries the Moon toward the earth makes the Moon traverse in one minute, independently of the projectile force that pushes it along the tangent BE. It is therefore the value of GF=BD that must be found.

358. Now, there are several ways to find the value of this line BD=GF.

The shortest and simplest depends upon a proposition demonstrated by Messrs Huygens and Newton: *that a body that makes its revolution in a circle would fall in a given time toward the center of its revolution, by centripetal force alone, from a height equal to the square of the arc that it describes in the same time, divided by the diameter of the circle.* **{*Princip. Mathem*., book 1, corol. 9, prop. 4 and 36, and Huygens, *De Vi Centrif*., prop. 6.}**

This proposition being accepted by all Geometers, it is easy to find by this means the value of the line GF, and consequently that of the line BD that is equal to it.

We know from the measurements of Mr. Picard that the circumference of the earth is 123,249,600 Paris feet; consequently we know that the orbit of the Moon, which is 60 times greater, is 7,394,976,000 feet, and that the diameter of this orbit is 2353893840 feet.

The revolution of the Moon around the earth takes 27 days 7 hours 43 sideral minutes, or 39,343 minutes. Thus, by dividing the orbit of 7,394,976,000 feet by 39,343, we find that the arc BF, that the Moon traverses in one minute, is 187,961 feet. Therefore, following the proposition of Messrs Huygens and Newton, the square of this arc BF^2, that is 35,329,337,521 feet, being divided by the diameter of the orbit of the Moon, that is, by line BG, that is 235893840 feet, one has GF or $BD=BF^2/BG$, that is to say, {35,329,337,521}/{235,893,840}=15 Paris feet approximately.[7]

[7] Du Châtelet's footnote: **{Fig. 35.}** There are two comments to be made about this estimate of the arc BF and of the small line BD. In order for it to be correct, one must consider only a part of the orbit of the Moon traversed during a very short time, as I did in the cited example, so that this arc can be taken as the Diagonal of the parallelogram BDGF. For one knows that in a very short

359. The force which brings the Moon toward the earth therefore makes the Moon traverse a little over 15 Paris feet in one minute. Therefore if the same force that directs the Moon in its orbit also makes bodies fall toward the earth, and if this force decreases as the square of the distance to the center of the earth, then bodies ought to traverse here, near the surface of earth, 54,000 feet in the first minute, or 15 feet in the first second, that is to say, 3600 times more space than they would traverse in the same time if they were transported to the height where the Moon is. This is because 36,000 is the square of 60, the distance of the Moon from the earth in half-diameters of the earth. **{The force that keeps the Moon in its orbit, and that makes bodies fall, decreases as the square of the distance from the center of the earth.}** Now you have seen in the previous chapter that bodies here on earth fall 15 Paris feet in the first second; this force therefore acts 3600 times less on the Moon than on heavy bodies that fall here on earth. Therefore, it is the same force that keeps the Moon in its orbit and that makes bodies fall here on earth, and this force decreases as the square of the distance from the center.

360. Everyone knows, but it cannot be repeated too often, that Mr Newton had abandoned the idea that he had conceived (that the same force that keeps the Planets in their orbit brings about down here on earth the heaviness of bodies and the fall of bodies) because, having false measurements of the earth, and having no knowledge, when living in solitude, of those that Mr. Picard took in 1669 nor of that of his compatriot Mr Norwood in 1636, he did not find the relationship between the mean motion of the Moon and the fall of bodies on the earth that ought

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time the line traversed by a body in its circular motion can be considered without perceptible error as a small right line that is the diagonal of the two directions which the body actually has. Without this condition of the small size of the arc BF in relation to large size of the circle BFE, it would not be permissible to consider GF as the space traversed during the fall toward the center; this would be HF, but when the arc BF is very small, the difference between GF and HF is imperceptible.

The second observation is that the demonstration of Messrs. Huygens and Newton is for a circle, and that the Planets make their revolutions in ellipses, of which some are not even regular ellipses, like the one described by the Moon, for example.

But Mr. Huygens demonstrated that each curve in any one of its parts has the same curvature as a certain circle, called the *osculating circle*, because in this region there is a part common to the curve and the circle. By considering this circle, for which Mr. Huygens discovered how to find the radius for each point on the curve, one can find the expression for the centripetal force in all curves, and compare this force, not only for each point on the same curve, but also from curve to curve. This proposition served Mr.Newton very well. Thus, it is Mr. Huygens whom one can say has been the precursor of Newton, much more than Descartes, from whom Newton took almost nothing.

to have been found if these two Phenomena had been brought about by the same cause; a relationship that I have just shown you, that the true measurements gave him.

361. If the motions of the celestial bodies and the laws of Kepler revealed to Mr. Newton one of these laws, according to which heaviness and the path of the Planets are brought about, that which takes place here on earth in the fall of bodies revealed to him another law **{This force is proportional to the masses.}**: the force that brings about these Phenomena follows equally inviolably the law of being proportional to the masses.

362. We have seen in chapter 14 (§322) that Pendulums of equal weight make their vibrations[8] in equal times when the wire from which they are suspended is equal, no matter what kind of bodies compose them; and consequently the force that makes them fall here on earth pertains to all the proper matter of bodies, and resides in every part of them, such that in different bodies this force is always directly proportional to the quantity of proper matter that they contain. Therefore since we have just seen in previous sessions that the same force that makes bodies fall toward the earth keeps the Moon in its orbit, this force resides in the whole body of the Moon, in direct proportion to the proper matter of this Planet, just as it resides here on earth in the different bodies in direct proportion to their quantity of proper matter. Now, the principal Planets, in revolving around the Sun, and the secondary Planets, in revolving around their principal Planet, follow the same laws as the Moon in its revolution around the earth. Therefore the force that keeps them in their orbits acts on each of them in direction proportion to the quantity of proper matter that they contain.

363. Moreover, since the time that the Planets take to make their revolution around the Sun is proportional to the square root of the cube of their mean distance from this Star, the force that carries them toward the Sun decreases as the square of their distance from the Sun. Therefore at equal distances from the Sun the force that carries them toward it acts upon them equally. Therefore they would traverse equal spaces in equal times toward the Sun, and if they lost all their projectile force, they would arrive in the same time at this Star, just as all bodies that fall here on earth from the same height reach the surface of the earth in the same time, when air resistance is removed. Now, the force that acts equally upon unequal bodies must necessarily be proportional to the mass of these bodies. Therefore the force that makes bodies fall toward the earth, and that makes the Planets revolve around their center, is proportional to their different masses; and consequently the weight of each Planet toward the Sun is in direct proportion to the quantity of proper matter that each of them contains.

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[8] We track Du Châtelet's use of "vibrations and" "oscillations" with the corresponding English words.

364. We will prove the same thing about the satellites of Jupiter and about the Moons of Saturn, in relation to their principal planet; for the time of their revolution around the Planet which serves as their center is proportional to the square root of the cube of their mean distance from this Planet.

365. You can see by all I have just told you the very long path that human reason had to make before succeeding in discovering which laws the cause that brings about heaviness follow, since the celestial bodies that are placed so far from us needed, so to speak, to teach us.

366. {False opinion about the weight of bodies.} Some people believed that the weight of the same quantity of proper matter was variable in the same place on the earth, due to false experiments that had thrown them into this error, and this is a pitfall against which we must guard ourselves all the more, because self-love always speaks to us in favor of those experiments that we ourselves carried out. In truth, the weight of the same bodies can vary in the same place on the earth, but this is only by the increase or decrease of the proper matter of these bodies, and this is what happens to Planets that fade and to any body that evaporates. But the weight of bodies at the same distance from the center of the earth is always as the quantity of proper matter that they contain.

367. But when this distance increases, then the weight of bodies decreases; I mean, their absolute weight, for their relative weight remains always the same. Thus, a man who carries 100t[9] near the surface of the earth, for example, would carry 900t if he was three times further from its center, but the weight of 100t would there be the ninth part of a weight of 900t, as here below.

368. Since the force that makes bodies fall and have weight on the earth acts all the less on them as they are further away from the center of the earth, they will fall toward the earth all the less quickly as they are further away from this center. But at equal distance they will all fall equally fast, such that a ball made of paper, transported to the region of the Moon and at this distance[10] weighing toward the earth only a 3600th part of that which it weighs here below, will fall toward the earth in the same time as the Moon (if the Moon were to have lost all its projectile motion). This ball and the Moon would traverse equal spaces during all time that they would take to fall (abstracting all resistance of the medium in which they fall); for the fall is as if we suppose the Moon to be divided into parts each with the mass of the paper ball.

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[9] "t" here may perhaps be the old French unit of a "talent"; see https://en.wikipedia.org/wiki/Units_of_measurement_in_France_before_the_French_Revolution#Mass.

[10] Correction from the second edition (1742) used in this translation, for sense.

369. We have seen in chapter 13 that Galileo demonstrated before Mr. Newton that the force, whatever it may be, that animates bodies to fall toward the earth, being supposed to act equally at each indivisible instant, should make them traverse spaces as the squares of the times and the speeds. His demonstration sufficed for knowing the action of gravity on bodies that fall here on earth, because the heights that we can reach are too small to produce any perceptible differences in the initial fall.

But Galileo's theory would have been far from sufficient if we had been able to do experiments at heights great enough to perceive the decrease in heaviness; for this theory assumed a uniform force, and Mr. Newton demonstrated, as we have just seen, that the energy of this force decreases as the square of the distance.

370. {Mr. Richer's experiment with the Pendulum.} Mr. Richer was the first to notice, during a voyage that he made to the Cayenne Island[11] in 1672, that the Pendulum Clock that he had brought from Paris was running considerably behind the mean motion of the Sun, and that consequently it must be that the oscillations of the Pendulum of this Clock had slowed down on approaching the equator. Now the duration of the oscillations of a Pendulum that describes arcs of a cycloid or very small arcs of a circle depends either on the resistance that air brings to these oscillations, or on the length of the Pendulum, or finally on the force with which bodies tend to fall toward the earth.

371. {Consequences that arise from this experiment.} The first of these three causes, that is to say, air resistance, is so small that it can be discounted without perceptible error, more especially as Mr. Richer's Pendulum encountered the same resistance in Paris as it did in Cayenne. The second cause, the length of the Pendulum, had not changed at all, since it was the same Clock. Therefore it must have been that the force that makes bodies fall was less in Cayenne than in Paris, that is to say, at about 5 degrees, which is the latitude of the Cayenne Island, than at about 49 degrees, which is that of Paris, since the oscillations of the same Pendulum were slower on this island than in Paris.

372. This experiment of Mr. Richer was rejected for a long time. Some people claimed that we must attribute it to the warmth of the climate that had lengthened the metal rod on which the Pendulum was suspended, but apart from the fact that experiment has proved that the lengthening caused by the heat even of boiling water is less than that in Mr. Richer's experiment, one has always been always obliged to shorten the Pendulum when approaching the equator, although it is often less warm at the equator than at 15 or 20 degrees of latitude; and finally, the members of the Académie des Sciences who went to Peru were obliged to shorten their

[11] Perhaps an island near French Guiana, such as Devil's Island.

Pendulum in Quito while it was freezing hard: the shortening of the Pendulum in the Cayenne Island was therefore caused solely by the decrease of heaviness toward the equator.

373. {What the causes of the decrease of heaviness are.} Assuming the diurnal motion of the earth, which I believe no one doubts at present, although it has not been rigorously demonstrated, two reasons could decrease the heaviness of bodies: the centrifugal force that the parts of the earth acquire by its rotation (for centrifugal force, by tending to distance bodies from the center[12] of the earth, opposes heaviness which makes them tend toward it); and the variations that can be found in different places on the earth in the force that makes bodies fall toward the earth, that is to say, in heaviness itself,.

374. {Digression on the shape of the earth.} The centrifugal force of equal bodies that describe in the same time unequal circles, is proportional to the circles they describe. Thus, the centrifugal force of the parts of the earth must increase proportionally as we approach the equator, since the equator is the great circle of the earth. It is therefore at the equator where the centrifugal force decreases heaviness the most.

375. {The present form of the earth depends on a combination of its original heaviness and centrifugal force.} We easily see that the present shape of the earth must result from its original heaviness and from centrifugal force; and that whether the form of the earth (assumed to be at rest when it left the hands of the Creator) was that of a perfect sphere, or of some spheroid, centrifugal force must have changed this form. For since the force unequally diminishes the heaviness of the columns of matter (assumed to be homogeneous and fluid) that compose the earth, according to whether they are further from or nearer to the equator, the columns whose heaviness is more diminished must become longer in order for them to be in equilibrium with those whose heaviness is less diminished. Thus, centrifugal force must necessarily have altered the original shape of the earth.

376. {But its original form depended upon heaviness alone.} But what was this first form of the earth? This we can know only by knowing the original heaviness, for it is certain that the form of the earth, assumed to be at rest, must have been the effect of heaviness alone. It is therefore certain that, if its original heaviness (that is to say, the heaviness not diminished by centrifugal force) was well known, the experiments with Pendulums in different regions of the earth would determine its shape with certainty; for these experiments would give us the diminution that centrifugal force brings to the original heaviness, at different latitudes. And it

[12] Du Châtelet's footnote: It is only at the equator that the centrifugal force destroys a part of the heaviness equal to itself; but in all other places on the earth, it decreases heaviness unequally, and as much the less the further one moves from the equator.

would be easy to deduce from this the alteration that it must have been brought to the original shape of the earth, whose matter is assumed to have been fluid and homogeneous at the time of the creation.

377. Also, Messrs Huygens and Newton thought that knowing the different degrees of heaviness in the different regions of the earth could suffice to determine its shape; Mr. Newton even believed that this was the most certain way of determining it: *Et certius per experimenta pendulorum, deprehendi possit, quam per arcus geographice mensuratos in meridiano.* **{*Principia*, Book 3, p. 83.}**

378. Since the original gravity can hardly be known except from the Phenomena, which determine it only *a posteriori*, Mr. Richer's experiment seems exceedingly surprising, even though it followed from the theory of centrifugal forces. But we do not find it sufficient for determining the shape of the earth; for the earth could originally have had a form such that its heaviness would have been stronger at the poles than at the equator, even though centrifugal force diminishes it at the equator and does not diminish it at the poles.

379. {Messrs Huygens and Newton believed the earth to be a flattened spheroid.} Messrs Huygens and Newton, both starting from this experiment of Mr. Richer (that had been confirmed by several subsequent experiments) and from the theory of centrifugal forces (invented by Mr Huygens), concluded that the earth must be a spheroid flattened toward the poles. These two Philosophers reached this conclusion even though they had used different laws of heaviness, Mr. Huygens believing it to be everywhere the same, and Mr. Newton supposing it to be different at different places on the earth, and dependent upon the mutual attraction of the parts of matter. The only difference to be found in the shape that these two Philosophers attributed to the earth was that from Mr. Newton's theory there resulted a greater flattening than from that of Mr. Huygens.

380. {Messrs Cassini's measurements gave an elongated spheroid for the form of the earth.}

But Mr. Cassini in completing the meridian of France begun by M Picard -- having found that the Meridional[13] degrees were larger than the Septentrional[14], and the elongated spheroid toward the poles being the necessary consequence of these measurements -- the name of Mr. Cassini and the fame of his results, which always gave him the elongated spheroid, provided a new reason for doubt about the shape of the earth, and counterbalanced the authority of Messrs Huygens and Newton and the consequences that they had drawn from Richer's experiment, all the more because the arguments of these two great Geometers, although based on the laws of statics,

[13] Southern.
[14] Northern.

nevertheless always depend on some hypotheses, and although these hypotheses were, as Mr. Maupertuis said **{*Preface, La Figure de la Terre.*}** , of the kind that one can hardly avoid admitting, nevertheless in making other hypotheses on heaviness (highly constrained, but nonetheless possible), we can [a toute force] reconcile the incontestable experiment of Mr. Richer and the diminution of the Septentrional degrees that resulted from the measurements of Messrs. Cassini. Thus, the question of the shape of the earth, a decision on which is so important for Geography, for navigation, and for Astronomy, remained undecided.

381. Finally, in 1736, the Academy of Sciences decided, in order to settle the question, to measure at one and the same time a degree of Meridian at the equator and at the polar circle; thus, we can say that these two voyages are a type of homage rendered to the name Cassini.

382. We know the result of the voyage to the Pole, and Mr. Maupertuis showed us, by the account he gave us of it, how this enterprise, so glorious to the Nation, almost led him to regret it, since we cannot read without fear the dangers that he, Messrs Clairaut, le Monier, and the other learned men who undertook this voyage came through, and they have taught us by their example that the love of truth can make us face dangers just as great as the desire for what men more commonly call glory.

383. {The measurements of the Academicians who were at the Pole give to the earth the shape of a spheroid flattened toward the Poles.} It follows from their measurements **{*Figure de la Terre,* p. 125.}**, the most accurate that have perhaps ever been made, that the degree of Meridian that intersects the polar circle is greater than the degree measured by Mr. Picard between Paris and Amiens by 437 toises when not counting the aberration, and by 377 toises when including it. From this it follows that the earth is a spheroid flattened toward the Poles. You see that this conclusion is entirely the opposite to that which followed from the measurements of Messrs Cassini; it is for the Academicians who are still in Peru to settle this big question, about which the greatest Philosophers are still divided, and on which we await the decision as a time equally glorious to the Sciences, and to the Nation which will have obtained it for them.

384. {It is the work of the French that gave rise to the discoveries of Mr. Newton.} One can say that it is to the measurements and observations of the French that Mr. Newton owed his admirable discoveries, and will owe the confirmation of them should the measurements taken in Peru decide for the flattening of the earth. For we have seen in this chapter that it was the measurements of Mr. Picard that enabled him to discover that the same laws that govern the Celestial Bodies in their paths cause heaviness on the earth.

I have presented to you this digression on the shape of the earth because of the important relationship that there is between this shape and heaviness.[15]

[15] In a later printing of the 1740 edition (containing errata), Du Châtelet updated the end of this chapter making the following changes to §§383&4:

383. {The measurements of the Academicians who were at the Pole give to the earth the shape of a spheroid flattened toward the Poles.} It follows from their measurements **{*Figure de la Terre,* p. 125.}**, the most accurate that have perhaps ever been made, that the degree of Meridian that intersects the polar circle is greater than the degree measured by Mr. Picard between Paris and Amiens by 437 toises when not counting the aberration, and by 377 toises when including it. From this it follows that the earth is a spheroid flattened toward the Poles. ~~You see that this conclusion is entirely the opposite to that which followed from the measurements of Messrs Cassini; it is for the Academicians who are still in Peru to settle this big question, about which the greatest Philosophers are still divided, and on which we await the decision as a time equally glorious to the Sciences, and to the Nation which will have obtained it for them.~~ Thus, this famous question is settled, and one can say that it is a discovery as useful to the Sciences as it is glorious to the Nation, to which the Sciences are indebted.

384. {It is the work of the French that gave rise to the discoveries of Mr. Newton.} ~~One can say that it is to the measurements and observations of the French that Mr. Newton owed his admirable discoveries, and will owe the confirmation of them should the measurements taken in Peru decide for the flattening of the earth. For we have seen in this chapter that it was the measurements of Mr. Picard that enabled him to discover that the same laws that govern the Celestial Bodies in their paths cause heaviness on the earth.~~ We await the return of the Academicians who are still in Peru, to determine the quantity of flattening. The one that comes from the measurements taken at the Pole is approximately such as Mr. Newton had determined with his theory. Thus, it is true to say that it is to the measurements and observations of the French that Mr. Newton owed his admirable discoveries (§360) and to which he will most likely owe their confirmation.

I have presented to you this digression on the shape of the earth because of the important relationship that there is between this shape and heaviness.