he has granted existence. He can change it and annihilate it, but (as we have seen) a contingent being cannot give itself existence, nor can it conserve it for a moment by its own force. Thus the reason for continuous existence cannot lie in the creature, who can neither begin nor continue to be but by the will of the Creator, which it needs at all times to sustain itself in the actuality that he has given it.

CHAPTER FOUR

Of hypotheses

THE USEFULNESS OF PROBABILITIES IN PHYSICS.

§.53. The true causes of natural effects and of the phenomena we observe are often so far from the principles on which we can rely and the experiments we can make that one is obliged to be content with probable reasons to explain them. Thus, probabilities are not to be rejected in the sciences, not only because they are often of great practical use, but also because they clear the path that leads to the truth.

USE OF HYPOTHESIS.

§.54. There must be a beginning in all researches, and this beginning must almost always be a very imperfect, often unsuccessful attempt. There are unknown truths just as there are unknown countries to which one can only find the good route after having tried all the others. Thus, some must run the risk of losing their way in order to mark the good path for others; so it would be doing the sciences great injury, infinitely delaying their progress, to banish hypotheses as some modern philosophers have.

MISUSES OF HYPOTHESES BY THE DISCIPLES OF DESCARTES.

§.55. Descartes, who had established much of his philosophy on hypotheses, because it was almost impossible to do otherwise in his time, gave the whole learned world a taste for hypotheses; and it was not long before one fell into a taste for fictions. Thus, the books of philosophy, which should have been collections of truths, were filled with fables and reveries.

THE DISCIPLES OF M. NEWTON HAVE FALLEN INTO THE OPPOSITE EXCESS.

M. Newton, and above all his disciples, have fallen into the opposite excess: disgusted with suppositions and errors that they found filled books of philosophy, they rose up against hypotheses and tried to make them suspect and ridiculous, by calling them *the poison of reason and the plague of Philosophy*.[70] Moreover, he alone, who was able to assign and demonstrate the causes of all that we see, would be entitled to banish hypotheses from physics; but, as for us, who do not seem to be cut out for such knowledge, and who can only arrive at the truth by crawling from probability to probability, it is not for us to pronounce so boldly against hypotheses.

HOW HYPOTHESES ARE MADE.

§.56. When certain things are used to explain what has been observed, and though the truth of what has been supposed is impossible to demonstrate, one is making a hypothesis. Thus, philosophers frame hypotheses to explain the phenomena, the cause of which cannot be discovered either by experiment or by demonstration.[71]

HYPOTHESES ARE THE THREADS THAT LEAD US TO THE MOST SUBLIME DISCOVERIES.

§.57. If we take the trouble to study the way in which the most sublime discoveries were made, we will see that success only came after many unnecessary hypotheses had been made and yet the duration and unprofitableness of this work had not proved discouraging; for hypotheses are often the only available means to discover new truths. It is true that the means is slow and requires labor all the more onerous because for a long time one cannot know if it will be useful or fruitless. Similarly, when one takes an unknown route and finds several paths, it is only after walking a long time that one can be sure if one has taken the good route or if one has been mistaken. But if the uncertainty over which of these routes is the right one were a reason not to take any of them, it is certain that one would never arrive; whereas when one has the courage to set off, there is no doubt that of the three routes, of which two have misled us, the third will infallibly lead us to our goal.

70. In the "General Scholium," which he added to Book III of the *Principia*, Newton said that he refused to "feign" hypotheses in order to explain how gravity and attraction worked. His followers took this to mean that hypotheses in general had no place in science, and that only conclusions deduced from observation and experiment were useful and valid. As Du Châtelet explains, modern science would not have been possible without the use of hypotheses. See I. B. Cohen's "A Guide to Newton's *Principia*," 274–77 and his note to the *Principia*, n.oo, 943.

71. Du Châtelet and her contemporaries distinguished between *experiment*, seeking some new information about phenomena, and *demonstration*, the replication of someone else's experiment. Newton's experiments with prisms told him about the nature of light, but it was some time before others could replicate his results and thus, confirm his discoveries by demonstration.

WITHOUT HYPOTHESIS FEW DISCOVERIES WOULD HAVE BEEN MADE IN ASTRONOMY.

It is in this manner that astronomy has brought us to the point where we admire it today; for, if, to calculate the path of the celestial bodies, astronomers had waited until the true theory of the planets had been found, there would be no astronomy now.

IT IS TO THESE THAT WE OWE THE TRUE SYSTEM OF THE WORLD.

The first idea of those who applied themselves to this science, just like the first idea of all other men, must have been that the Sun and all the celestial bodies turned around the Earth in twenty-four hours. Thus, they began to explain and to predict phenomena by this hypothesis, called *Ptolemy's hypothesis*, until the insurmountable difficulties of the consequences that derived from it when compared with observations, and the impossibility of constructing tables according to this hypothesis which were in accord with the phenomena of the sky, brought Copernicus to abandon it entirely and to test the opposite hypothesis, which is so much in agreement with the phenomena, that its certitude is at present not far from demonstration; and that no astronomer dares adopt that of Ptolemy.[72]

THEY OFTEN GIVE THE IDEA OF HOW TO DO NEW, VERY USEFUL EXPERIMENTS.

§.58. Hypotheses must then find a place in the sciences, since they promote the discovery of truth and offer new perspectives; for when a hypothesis is once posed, experiments are often done to ascertain if it is a good one, experiments which would never have been thought of without it. If it is found that these experiments confirm it, and that it not only explains the phenomenon that one had proposed to explain with it, but also that all the consequences drawn from it agree with the observations, its probability grows to such a point that we cannot refuse our assent to it, and that is almost equivalent to a demonstration.

The example of astronomers can further serve marvelously well to clarify this matter; for the true orbits of the planets were ascertained by first supposing they made their revolutions in circles, of which the Sun occupied the center; but the variation in their speed and their apparent diameters being

72. Nicolaus Copernicus (1473–1543), the Polish astronomer, by his observations and new hypotheses about the universe began the shift in Europe from an Earth-centered to a Sun-centered solar system.

contradictory to this hypothesis, it was supposed they moved in eccentric circles, that is to say, in circles of which the Sun did not occupy the center. This supposition, which corresponded to the movements of the Earth well enough, deviated greatly from what is observed about the planet Mars; and to remedy this, attempts were made to make a new correction to the curve the planets describe in their annual revolution. This procedure succeeded so well that finally Kepler, going from supposition to supposition, found their true orbit, which admirably corresponded to all the appearances of the planets, and this orbit is an ellipse, of which the Sun occupies one of the foci.

By means of this hypothesis of the elliptic nature of orbits Kepler came to discover the proportionality of the areas and the times, and that of the times and the distances. And these two famous theorems, called the *Analogies of Kepler*, put M. Newton in reach of demonstrating that the supposition of the elliptic nature of the planets' orbits agrees with the laws of mechanics, and of assigning the proportion of forces that direct the movements of celestial bodies.[73]

Thus, it is evident that it is to hypotheses first made and then corrected that we are indebted for the beautiful and sublime knowledge of which astronomy and its subsidiary sciences are filled at present. It is impossible to see how men could have arrived there by other means.

IT IS BY MEANS OF HYPOTHESES THAT M. HUYGENS DISCOVERED THAT SATURN WAS SURROUNDED BY A RING.

By the same means we know today that Saturn is surrounded by a ring that reflects light, and is separated from the body of the planet, and inclined to the ecliptic. For M. Huygens, who discovered it first, did not observe what astronomers now describe; but he observed several phases of it, which sometimes resembled nothing less than a ring. Next, comparing the successive changes of these phases and all the observations that he had made of it, he sought a hypothesis that fit them, and explained these different appearances. That of a ring succeeds very well; it not only explains the appearances but also predicts the phases of this ring very accurately.

This correspondence between hypothesis and observation has finally converted this supposition of M. Huygens into a certainty; and no one doubts now that this ring is very real; thus, hypotheses brought us this beautiful discovery of the ring of Saturn.

73. Du Châtelet uses the term *analogies* in the Newtonian sense of laws based on mathematical models and experiment, though by her day Kepler's suppositions had been long accepted as proved by observations of the celestial bodies.

The same can be said of the ingenious explanation the same M. Huygens gave for halos, that is to say, of these sorts of colored crowns that sometimes appear around stars. No one before him had conceived of what might be the cause of these phenomena; but M. Huygens, after several fruitless suppositions, finally found that, by supposing the air to be filled with frozen grains of hail with a kernel of snow in their center, all the circumstances that accompany these phenomena could be explained, and no one has ventured to call into question M. Huygens's explanation.

DIVISION IS FOUNDED ON HYPOTHESES ONLY.

§.59. It is the same with numbers. Division, for example, is founded on hypotheses only. Without hypotheses you could not divide, for when you begin division, you suppose that the divisor is contained in the dividend as many times as the first number of the divisor is contained in the first number, or in the first two numbers of the dividend; and then you verify this supposition by multiplying the divisor by the quotient, and by subtracting from the dividend the product of this multiplication. If you find that this subtraction cannot be done, you conclude that the quotient is too big, and then you correct it. This whole operation is done by means of hypotheses.

HYPOTHESES ARE NOT ONLY VERY USEFUL, BUT EVEN SOMETIMES VERY NECESSARY.

§.60. So making hypotheses is allowed, and it is even very useful in all cases when we cannot discover the true reason for a phenomenon and the attendant circumstances, neither a priori, by means of truths that we already know; nor a posteriori, with the help of experiments.

HOW ONE MUST PROCEED WHEN MAKING A HYPOTHESIS.

§.61. Without doubt there are rules to follow and pitfalls to avoid in hypotheses. The first is, that it not be in contradiction with the principle of sufficient reason, nor with any principles that are the foundations of our knowledge. The second rule is to have certain knowledge of the facts that are within our reach, and to know all the circumstances attendant upon the phenomena we want to explain. This care must precede any hypothesis invented to explain it; for he who would hazard a hypothesis without this precaution would run the risk of seeing his explanation overthrown by new facts that he had neglected to find out about. This is what happened to him who wanted to explain electricity after having only seen how Spanish wax, rubbed vigorously, attracts bits of paper. For it would have been easy to make other bodies do what happens with Spanish wax; rubbed in the same way, they would also have been electrified. Thus, the explanation of electricity by Spanish wax alone had been insufficient and precipitous.

When one can hope to know the greatest number of circumstances attendant upon a phenomenon, then one can seek the reason for it by means of hypotheses, taking the risk of having to correct it or having to be corrected; but the efforts made to find the truth are always glorious, even though they might be fruitless.

PITFALL TO AVOID IN HYPOTHESES.

§.62. Since hypotheses are only made in order to discover the truth, they must not be passed off as the truth itself, before one is able to give irrefutable proofs. So it is very important for the progress of the sciences not to delude oneself and others with the hypotheses one has invented, but one should estimate the degree of probability in a hypothesis, and never impose it on others by detours and a semblance of demonstration, which has much too often led people with a thirst for knowledge into error.

With this precaution one does not run the danger of taking for certain that which is not; and one inspires those who follow us to correct the faults in our hypotheses and to provide what they lack to make them certain.

§.63. Most of those who, since Descartes, have filled their writings with hypotheses to explain facts, which very often they only knew imperfectly, have sinned against this rule and have tried to pass off their suppositions as truths; this is partly the source of the disgust for hypotheses in this century. But the excessive resort to a useful thing does not detract from its utility and must not prevent us from making use of it when this can bear fruit.

A SINGLE CONTRARY EXPERIMENT SUFFICES TO REJECT A HYPOTHESIS.

§.64. One experiment is not enough for a hypothesis to be accepted, but a single one suffices to reject it when it is contrary to it. It follows, for example, from the hypothesis in which one supposes that the Sun moves around the Earth, which serves as the center of its orbit, that the diameters of the Sun must be equal at all times of the year; but experience shows that they appear unequal. From this observation, one can therefore conclude with certainty that the hypothesis, of which this equality is a consequence is false, and that the Earth does not at all occupy the center of the Sun's orbit.

A HYPOTHESIS CAN BE TRUE IN ONE OF ITS PARTS AND FALSE IN ANOTHER.

§.65. A hypothesis may be true in one of its parts and false in another; then the part that is found to be in contradiction with experiment must be corrected.

But great care must be taken to put in the conclusion only what must be there, and not to attribute to the entire hypothesis a fault which only applies to one of its parts. For example, M. Descartes attributed the fall of bodies toward the center of the Earth to a vortex of fluid matter impelling bodies to move toward the center by its rapid swirling around the Earth; but M. Huygens demonstrated by an irrefutable experiment that, according to this supposition, bodies should be directed in a fall perpendicular to the axis of the Earth and not toward its center. It can be concluded from that, that a vortex of fluid matter, such as M. Descartes conceived, would not cause bodies to fall toward the center of the Earth; but it would be too precipitous to conclude that no fluid material caused the phenomenon of the fall of bodies. It is the same with the other vortices, which, according to M. Descartes, carry the planets around the Sun; for M. Newton demonstrated that this supposition did not agree with the laws of Kepler. So it must be inferred that the movements of the planets are not the effect of the vortices of fluid material that M. Descartes supposed explained them. But it cannot be legitimately concluded that a vortex, or several vortices, conceived of in a different way, cannot be the cause of these movements.[74]

§.66. Thus, in making a hypothesis one must deduce all the consequences that can legitimately be deduced, and next compare them with experiment; for should all these consequences be confirmed by experiments, the probability would be greatest. But if there is a single one contrary to them, either the entire hypothesis must be rejected, if this consequence follows from the entire hypothesis, or that part of the hypothesis from which it necessarily follows.

Astronomers give us another example of this rule; indeed, a plethora of discoveries would not have come about in astronomy if no attempt had been made to verify by experiment what was deduced from hypotheses. It follows, for example, from Copernicus's hypothesis that if the distance of a star to the Earth has a relationship comparable to the diameter of its orbit, the height of the pole and the fixed stars must vary at different times of the year. The desire to verify this consequence led several astronomers to make observations on this annual parallax or height of the fixed stars; among others, M. Bradley, in whose hands this consequence was not only confirmed

74. Du Châtelet believes that attraction explains these phenomena but continues to give credence to Descartes' explanation to prove her point about the correct use of hypotheses. Leonhard Euler and Johann Bernoulli would fit this latter description, for they accepted attraction but continued to seek a material explanation for it. Note that Newton never successfully explained the cause of attraction, only its observed effects in the universe.

but then gave birth to this beautiful theory of the aberration of the fixed stars, which would never have been thought of before.[75]

DEFINITION OF HYPOTHESES. WHAT MAKES THEM PROBABLE.

§.67. Hypotheses, then, are only probable propositions that have a greater or lesser degree of certainty, depending on whether they satisfy a more or less great number of circumstances attendant upon the phenomenon that one wants to explain by their means. And, as a very great degree of probability gains our assent, and has on us almost the same effect as certainty, hypotheses finally become truths when their probability increases to such a point that one can morally present them as a certainty; this is what happened with Copernicus's system of the world, and with M. Huygens's on the ring of Saturn.

WHAT MAKES THEM INVALID.

By contrast, a hypothesis becomes all the more improbable as it fails to explain more of its attendant circumstances, as in Ptolemy's hypothesis.

§.68. When a hypothesis is made, one must have reasons for preferring the supposition on which it is founded to all other suppositions; otherwise one spews forth chimeras, and precarious principles that have no foundation.

§.69. So it is necessary not only that all one supposes be possible, but also that it be possible in the manner one uses it; and that the phenomena result necessarily, and without the obligation to make new suppositions. Otherwise, the supposition does not deserve the name of hypothesis; for a hypothesis is a supposition that explains a phenomenon. When the necessary consequences do not follow from it, and to explain the phenomenon, a new hypothesis must be created in order to use the first, this hypothesis is only a fiction unworthy of a philosopher.

§.70. If those who wanted to explain so many surprising effects by means of hooked, branchlike, and serrated particles had paid attention to what is required to make a truly philosophical hypothesis, they would not have slowed, as they did, the progress of the sciences by creating monsters that subsequently had to be fought against as realities.[76]

75. James Bradley (1693–1762) was professor of astronomy at Oxford, the successor to Edmund Halley (1656–1742) as astronomer royal. Both were known for their astronomical observations.

76. Nicolas Lémery (1645–1715), French chemist and public lecturer, developed a corpuscular theory of pointed particles that could unite with others that were serrated.

HYPOTHESES ARE ONE OF THE GREAT MEANS OF THE ART OF INVENTION. GOOD HYPOTHESES HAVE ALWAYS BEEN MADE BY THE GREATEST MEN.

§.71. By distinguishing between the good and the bad use of hypotheses, both extremes are avoided, and without giving oneself up to fictions, a method very necessary to the art of invention is not denied to the sciences, a method that is the only means that can be used in difficult researches requiring correction over several centuries and the work of several men before attaining a certain perfection. And it must not be feared that by this method philosophy might become a heap of fables; for we have seen that a good hypothesis can only be made when a great number of facts and circumstances attendant upon the phenomenon one wants to explain have been observed (§.61), and that the hypothesis is only true and only deserves to be adopted when it explains all the circumstances (§.66). Therefore, the good hypotheses will always be the work of the greatest men. Copernicus, Kepler, Huygens, Descartes, Leibniz, M. Newton himself, have all imagined useful hypotheses to explain complicated and difficult phenomena; and the examples of these great men and their success must show how much those who want to banish hypotheses from philosophy misunderstand the interests of the sciences.

CHAPTER SIX

Of time

ANALOGY BETWEEN TIME AND SPACE.

§.94. The notions of time and space are very similar. In space, one simply considers the order of the coexistents insofar as they coexist; and in time, the order of successive things, insofar as they succeed each other, discounting any other internal quality than simple succession.

THE ORDINARY IDEA OF TIME IS FALSE. IT LEADS TO THE SAME DIFFICULTIES AS THAT OF PURE SPACE.

§.95. Ordinarily our image of time, as of space, is produced by confused ideas: thus, one imagines it as a being composed of continuous, successive parts, which flow uniformly, which subsists independently of things existing in time, which has been in a continual flux from all eternity, and which will continue in the same way. But it is obvious that this notion of time as a being composed of continuous and successive parts that flows uniformly, being once accepted, leads to the same difficulties as those of absolute space; that is to say that, according to this notion time would be a necessary being,