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Universal natural history and theory of the heavens or essay on the constitution and the mechanical origin of the whole universe according to Newtonian principles

EDITOR'S INTRODUCTION

After publishing two short essays on the Earth (Chapters 2 and 3) in 1754, in March of 1755 Kant, who, it must be remembered, still had no official teaching position at a university nor even a university degree, arranged for the anonymous publication of *Universal Natural History and Theory of the Heavens* with the publisher Johann Friedrich Petersen. It was dedicated to King Frederick II of Prussia (though there is no record showing that the king read it or even held it in his hands). Given its grand scope and its targeted dedication, Kant clearly hoped that it would attract widespread attention from more powerful European figures (as opposed to contributing primarily to the scientific education of the citizens of Königsberg, as the previous essays did) and establish for himself a prominent scholarly reputation (much as winning an academy's prize essay question might do). To understand why Kant would have had such high hopes for this work, it is helpful to see the basic contours of his argument.

In general terms, Kant's aim in the *Universal Natural History and Theory of the Heavens* is to show that the main elements of the entire observable universe – which include the constitution and regular motions not only of the Sun, the Earth, and the other planets, but also that of the moons, comets, and even other solar systems – can all be explained on the basis of three assumptions: (i) a certain initial state – a chaos in which matters endowed with different densities are distributed throughout space in the form of various indeterminate nebula; (ii) Newtonian mechanical principles – primarily attractive and repulsive forces, coupled with the law of universal gravitation; and (iii) the motions that these matters would have initiated and the states that they would eventually come to be in due to these motions and mechanical laws. In this way, Kant intended to lay bare the basic structure that governs the universe. Various limitations attach to his project – he drew on the views of various predecessors

(such as Descartes, Whiston, Buffon, Bentley, Maupertuis, Wright of Durham, Bradley, and of course Newton) such that his position was not completely original; his descriptions and methods of argumentation were not rigorously quantitative (in the way in which Newton's *Principia* was), but rather depended quite extensively on qualitative analogies; he did not even attempt to undertake the kinds of experimental observations that would be required to provide empirical support for his main conclusions (as Herschel would later do); many of his central claims and detailed assertions are, as a result, untenable from a contemporary perspective. Nonetheless, it is clear that Kant's account in the *Universal Natural History and Theory of the Heavens* is an extremely ambitious project, one that clearly made a genuine contribution to natural philosophy. For providing an account of the formation of the entire known physical universe that is at once comprehensive, systematic, and unified while still being based on accepted physical principles, is a significant intellectual accomplishment.

Kant carries out this project in a preparatory section and three parts. In the preface, he is primarily interested in explaining why the view he wants to defend not only represents no threat to religious orthodoxy, but actually provides support for it insofar as the purely mechanical account of the formation of the universe that he recommends does not render God superfluous and thus dispensable, as is sometimes claimed, but instead reveals, on further reflection, that God is positively required as the source of the necessity of the laws of nature and of the consequent order of nature. In the first part, after briefly describing what he takes to be the essential features of Newton's account of the motions of the heavenly bodies, Kant draws an analogy between the structure of our solar system and that of the Milky Way and then between the Milky Way and the fixed stars, which he views, based on the analogy, as an infinite multitude of further systems that were then formed and now move according to the same principles as our own (even if their distance from us makes it impossible for us to perceive these motions); and given this connection, he maintains that the entire universe displays a single systematic constitution. The second, and by far longest, part then presents the core of his account by explaining the formation of the various significant bodies in our solar system and some of their most distinctive features. In the third part, Kant concludes his treatment by engaging in fanciful speculation about the inhabitants of the other planets of our solar system, and by providing a glimpse of the conditions human beings might experience in the next life, he returns to the theological context with which he began.

To appreciate the character and force of Kant's argument, it is worth considering an outline of its basic structure as it is presented in the eight chapters that constitute the second part of the *Universal Natural History and Theory of the Heavens*.[1] In the first chapter, Kant presents his

most basic hypothesis, often referred to today as the nebular hypothesis. According to it, the state of nature that would exist immediately after creation would be one in which the matter that now constitutes the various celestial bodies was originally dispersed, chaotic and unformed (hence like a nebula or cloud), throughout the universe in a state of rest. Because, however, the original materials had different specific densities and different masses, they attracted each other differentially such that the lighter materials start to move towards the heavier materials. Over time, some of the lighter materials that are spread out in a region of space surrounding a heavier body are acted on by its attractive force and fall into it to form a central body, in our case, the Sun, leaving empty the region that they had previously occupied. Others, however, that have somewhat greater densities, are repulsed by this central body and, after they incorporate less dense materials that lie in the regions through which they pass, their motion leads them to adopt a roughly circular orbit, whose magnitude corresponds to the amount of motion that they acquired in their original motion towards the emergent central body. In this way the various planets are formed with their stable orbits around a central body in otherwise empty space.

In the second chapter, Kant explains the varying densities of the planets and the differences of their relative masses and finds confirmation in the agreement of this account with the relative densities of the Earth and its moon. Specifically, Kant argues that although the original distance between a material and its central body is a factor in determining the ultimate density of the planet, the main factor lies in the density of the original material (*pace* Newton, who appealed to the planets' ability to withstand the Sun's heat). And for this reason, there is, in general, an inverse relation between the density of a planet and its distance from the central body. With respect to the relative masses of the planets, Kant considers several factors that derive from his hypothesis in order to determine the agreement of his account with Newton's calculations of the masses of the planets such that, with the exception of Mars, which lost some of the mass that it would otherwise have had to the inordinate strength of Jupiter's attractive force, the mass of a planet stands in direct proportion to its distance from the Sun, though the Sun, as the central body, has a much greater mass.

Kant then turns to explain both the eccentricity of the orbits of planets and the most distinctive features of comets in the third chapter. In line with his account of the formation of planets, Kant first shows that, given the different original densities, masses, and motions of the matter that forms the planets, their orbits will not be perfect circles. He then argues that comets are not different in kind from planets. They simply have more eccentric orbits (due to the lightness of their material) and can thus be explained in the same way. He also addresses several further

features of comets: their atmospheres and tails (which are not, he argues, due to the heat of the Sun, since some comets never approach the Sun); their presence throughout all areas of the zodiac; and their densities and masses.

In the fourth chapter, Kant addresses the formation of moons. He argues that the basic process involved in the formation of the planets around the Sun is also involved in the formation of the various moons around their planets, which lent further support to his basic hypothesis. Moons are thus created whenever there is enough matter left in the space immediately surrounding a planet and the planet also has enough mass to maintain that matter in an orbit. Jupiter, Saturn, and the Earth all have moons, with Jupiter and Saturn, proportional to their mass, having the most moons, and Mars losing out due to its relatively small mass. He also discusses various features of the axial rotation of planets and moons as further astronomical data that must also be accounted for.

The fifth chapter provides an extended account of the nature, origin, and maintenance of a phenomenon thought at that time to be unique in our solar system, namely Saturn's rings. Specifically, Kant argues that since there is no difference in kind between planets and comets, Saturn is composed of the same kinds of materials as comets, which have atmospheres and tails. As a result, Saturn's rings are composed of lighter materials that are at first brought together on the surface of Saturn and then raised from the surface due to the heat generated by the planet and the higher rotational velocity at its equator (which explains the position of the rings around Saturn's equator). Given that the different matters composing Saturn's rings will be moving at different velocities at different distances from the surface, the rings can be maintained, Kant surmises, only if there is not too much interaction between the particles of each ring. For this reason, he asserts that the rings are separated from each other by small gaps. He also attempts to use the ratios of Saturn's rings to determine the rotational velocity of Saturn, which could not be observed with any reliability from the telescopes then in use. He also speculates as to the reasons why no other planet currently has rings like Saturn's. The sixth chapter contains a brief discussion of the Zodiacal Light, and of its (apparent) similarities to and (real) differences from Saturn's rings.

In the remarkable seventh chapter, Kant broadens the scope of his explanatory aims so as to entertain the possibility not only that space and time are infinite, but also that the same structure that obtains for our solar system and those other solar systems with which we are familiar, also obtains throughout the infinity of space and time. Thus, although it does not make sense to speak of a centre point in an infinite space, there must be, he reasons by analogy, a very large mass that serves as the centre point of all of the galaxies that are connected with each other

by their attractive forces, which extend to infinity. And just as our solar system formed over time out of a nebulous expanse of original matters endowed with different specific densities, so too the various galaxies that extend out from this centre point form over time. Furthermore, just as bodies become determinate in ever larger spaces over time, so too what has already formed will return to its original state through a process of decay, at which point it will re-form itself again out of its ashes, just like a "phoenix of nature". Moreover, Kant describes this entire speculative story as one that would be both pleasing and appropriate to the infinitude and perfection of God, displaying a kind of beauty that poets (such as Haller, Addison, and especially Pope) have attempted to express through their verse. Kant concludes his discussion, which consists of speculative metaphysical and aesthetic pronouncements, with a strikingly scientific supplementary chapter that seeks to explain the constitution of suns (as fiery bodies that would eventually be extinguished after having consumed all of the air that is required for their fires to burn).

In the eighth chapter Kant concludes the second part by summarizing the main features of his mechanical account of the formation of the universe. His attention throughout is focused not only on adducing the inherent plausibility of his own account, but also on showing the weaknesses of its main competitor, namely the view that the specific features of the universe on which Kant bases his account are instead the immediate consequence of God's particular intentions (or, as he puts it, the hand of God). Why, for example, would all the planets orbit the Sun in the same direction if it were not due to their common mechanical origin? Why wouldn't they have perfectly circular motions if their orbits were selected by God directly? Why would the masses of the planets correspond to the empty region that surrounds each of their orbits? In all these cases, Kant suggests that his mechanical account provides a superior explanation that involves neither miracles nor improbable coincidences.

Unfortunately, due to circumstances beyond Kant's control, the *Universal Natural History and Theory of the Heavens* had much less of an immediate influence than he had hoped. First, shortly after its publication, his publisher went bankrupt and the warehouse in which a substantial number of copies of Kant's book were held, was impounded. A year later, however, a publisher in Königsberg, Johann Friedrich Driest, sold some copies. Kant's book was also sent out to several appropriate scholarly periodicals and it was reviewed in the *Freyen Urtheilen und Nachrichten* in Hamburg in 1755. Also Kant's *The Only Possible Argument in Support of a Demonstration of the Existence of God* (1763) contains a sketch of the basic argument as well (in the Seventh Reflection of the Second Part, 2:137–151), and he later tried to have the book reissued, without success. J. F. Gensichen, a friend and younger colleague of Kant, did publish a selection from the work along with a German translation of three

essays by Herschel, in *Über den Bau des Himmels* (Königsberg: Nicolovius, 1791). At the same time, these circumstances obviously contributed to the fact that both Johann Lambert and Pierre-Simon Laplace, who published cosmogonies that were similar in their fundamental orientation to Kant's in 1761 and 1799–1825 (respectively), were most likely unaware of his work during the formation of their views.[2] During the course of the nineteenth century, however, Kant's work became more widely known.

There have been three previous English translations of this work: one by William Hastie in 1900;[3] another by Stanley L. Jaki in 1981;[4] and a third by Ian Johnston in 1998.[5] Hastie's translation was incomplete, leaving out everything after the supplement to the seventh chapter of the second part, corresponding to thirty-five pages of Academy edition text. Jaki's very literal translation, which obscures Kant's thought on occasion, contains valuable information in a long introductory essay and in its footnotes, though his highly critical and often polemical perspective on Kant's achievements can make it difficult to separate the wheat from the chaff. Johnston's recently completed translation strives for readability (for undergraduate students) by breaking up Kant's at times long German sentences into more manageable English ones, but at the cost of not always providing an exact sense of what Kant intended. Though the present translation was completed in draft form prior to any close study of these other translations, it proved useful to consult them in later stages regarding certain passages that had presented special difficulties for their translation.

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Universal *Natural History and Theory of the Heavens*

Or

Essay

on the Constitution and the Mechanical Origin

of the Whole Universe

according to

Newtonian Principles.[6]

To the

Most Noble, Most Mighty King and Lord

Lord

Frederick,

King of Prussia,

Markgrave of Brandenburg,

Lord Chamberlain and Elector of the Holy Roman Empire

Sovereign and Chief Duke of Silesia etc. etc. etc.,

To My Most Gracious King and Lord.

Most Noble, 1:219
Most Mighty King,
Most Gracious King and Lord!

The awareness of my own unworthiness and the brilliance of the throne cannot cause my bashfulness to be as timid as the mercy which the most gracious Monarch spreads over all his subjects with equal magnanimity, gives me the hope that the boldness I am undertaking will not be regarded with ungracious eyes. With the most humble respect, I hereby place one of the least examples of that zeal at the feet of Your Royal Majesty with which Your Most Noble Academies have been exhorted by the encouragement and the protection of their Sovereign to emulate other nations in the sciences. How happy would I be if the present efforts with which the most humble and respectful subject is ceaselessly striving to make himself useful to his fatherland, were to be successful in acquiring the very highest pleasure of his Monarch. I die in the most profound devotion,

Your Royal Majesty's
Most humble servant,

Königsberg
14th March 1755.

The Author

PREFACE

I have chosen a project[a] which, from the aspect both of its inherent difficulty and in relation to religion, is capable of influencing the reader to adopt an unfavourable prejudice from the very beginning. To discover the system that connects the great parts of creation in the whole extent of infinity, to derive the formation of the celestial bodies themselves and the origin of their motion out of the first state of nature through mechanical laws: insights such as these would appear to go well beyond the powers of human reason. From the other side, religion threatens us with a solemn accusation for the audacity with which one might make so bold as to ascribe to nature, which is left to itself, such consequences in which one can rightly become aware of the immediate hand of the highest being, and is concerned to find protection for the atheist in the forwardness of such observations. I see all these difficulties clearly, and yet am not faint of heart. I feel all the power of the obstacles in my way and do not despair. I have dared to undertake a dangerous journey on the basis of a slight supposition and already see the foothills of new lands. Those who have the courage to pursue the exploration, will step onto those lands and have the pleasure of bestowing their own name upon them.

I did not set out upon this enterprise until I saw myself secure in relation to the duties of religion. My eagerness was redoubled when I
1:222 saw that with every step the mists dispersed whose darkness seemed to hide monsters; and after they parted, the glory of the highest being shone forth with the most vivid brilliance. Since I know these efforts to be free of all reproach, I will sincerely adduce anything that well-intentioned, but also weak minds might find offensive in my plan, and am prepared to submit it to the severity of the orthodox Areopagus[7] with the frankness that is characteristic of an honest disposition. The champion of faith may nonetheless make his reasons heard first.

If the universe[b] with all its order and beauty is merely an effect of matter left to its general laws of motion, if the blind mechanism of the powers of nature knows how to develop so magnificently and to such perfection all of its own accord: then the proof of the divine Author, which one derives from the sight of the beauty of the universe, is entirely stripped of its power, nature is sufficient in itself, divine government is superfluous, Epicure lives again in the middle of Christendom, and an unholy philosophy tramples faith under foot, which hands that philosophy a bright light to illuminate it.

[a] *Vorwurf*

[b] *Weltbau*

If I had found this objection well-founded, the conviction I have regarding the infallibility of divine truths is so powerful[c] in me that I would consider everything that contradicts them to be sufficiently disproved and would reject it. It is, however, precisely the agreement between my system and religion that raises my confidence to a fearless serenity in the face of all difficulties.

I am aware of the entire value of those proofs that are adduced from the beauty and perfect arrangement of the universe to confirm a most wise Author. If one is not arbitrarily opposed to all convincing arguments, one must hand the victory to such incontrovertible reasons. I, however, maintain that the defenders of religion, by using these reasons in a bad way, will perpetuate the argument with the naturalists,[8] offering a weak flank without any need to do so.

People are accustomed to note and emphasize the harmony, the beauty, the purposes, and a perfect correspondence of the means to 1:223
them in nature. But, by elevating nature from this perspective, one also seeks to lower it from another perspective. This harmony, people say, is foreign to it; left to its own universal laws, nature would bring about nothing but disorder. These harmonies point to a foreign hand that has been able to force a wise plan onto matter devoid of all regularity. But I answer: If the universal laws of causation of matter are also a result of the highest plan, then they can presumably have no purpose other than that which strives to fulfil of their own accord that plan which the highest wisdom has set itself; or, if this is not the case, one ought not to fall into the temptation of believing that at least matter and its universal laws are independent and that the wisest power, which has been able to use the laws in so laudable a fashion, is great yet not infinite, powerful yet not entirely self-sufficient.

The defender of religion is concerned that those harmonies that can be explained by a natural tendency of matter can be said to prove the independence of nature from divine providence. He admits it quite clearly: that if natural causes can be discovered for all the order in the universe that can be brought about by the most general and most essential properties of matter, then it is not necessary to invoke a highest governing power. The naturalist finds his satisfaction by not disputing this premise. But he unearths examples that prove the fruitfulness of the universal laws of nature by means of perfectly beautiful consequences, and with such grounds, which could become invincible weapons in his hands, he puts the orthodox believer into danger. I will quote some examples. It has frequently been cited as one of the clearest proofs of a beneficent providence watching over human beings that in the hottest regions of the

[c] *vermögend*

earth, sea breezes waft across the heated land and refresh it at just the time when it is most in need of them, almost as though they had been ordered. For example, on the island of Jamaica, as soon as the sun has risen to the point where it throws its greatest heat onto the land, soon after 9 o'clock in the morning, a wind begins to rise from the sea which blows across the land from all sides; its strength increases in relation to
1:224 the height of the sun. At one o'clock in the afternoon, when it is naturally hottest, the wind is strongest and gradually decreases with the setting of the sun so that in the evening the same stillness prevails as at sunrise. Without this desirable arrangement, this island would be uninhabitable. This same relief is enjoyed by all the coasts of countries in hot zones. They are also the ones that need it most, because, as they are the lowest lying regions of the dry land, they are subject to the greatest heat; for the regions that are situated higher up, where this sea breeze does not reach, do not need it as much, since their more elevated situation places them in a cooler region. Is all this not beautiful, are these not visible purposes achieved by cleverly applied means? But in opposition, the naturalist must find the natural causes of this in the most universal properties of the air without being able to presume special arrangements for this reason. He observes correctly that these sea breezes must make such periodic motions even if there were no human beings living on the island, that is, as a result of no property of the air other than what is inevitably necessary for the growth of plants, even without any intention in relation to this, namely a result of its elasticity and mass. The heat of the sun cancels out the balancing effect of the air by making that which is over land thinner and thus causes the cooler sea air to raise it from its position and occupy its place.

In any case, what benefits do the winds not have for the good of the globe, and what uses does the astuteness of man not make of them! There are, however, no arrangements necessary to bring them about other than that same universal character of the air and of heat which must have been present on the Earth irrespective of these purposes.

At this point, the free thinker says: admit that if useful constitutions directed at particular purposes can be derived from the most universal and simple laws of nature without any necessity for any special government by a highest wisdom, then see now the proofs which will catch you by your own admission. All nature, especially unorganized nature, is full of such proofs which show that matter, which determines itself through the mechanism of its forces, has a certain rightness in its con-
1:225 sequences and satisfies the rules of propriety without being forced to. If a well-intentioned person were to try to dispute this capacity of the universal laws of nature in order to save the good cause of religion, then he will place himself into an embarrassing situation and give the unbeliever cause to triumph through a bad defence.

But let us see how these reasons, which are feared as being harmful in the hands of one's enemies, are instead powerful weapons to dispute them. Matter, which determines itself through its most universal laws, by its natural behaviour or, if one wishes to call it so, by a blind mechanism, creates good consequences that appear to be the plan of a highest wisdom. Air, water, and heat, if one observes them left to their own devices, cause winds and clouds, rain, rivers that bring moisture to the lands, and all those useful consequences without which nature would necessarily remain sad, empty, and barren. However, they do not bring those consequences by some mere chance or accident that might just as easily have turned out to be detrimental, but rather, we see that they are limited by their natural laws to have this and no other effect. What are we to think of this harmony? How could it be possible that things of different natures in connection with one another should aim to bring about such excellent harmonies and beauty, even for the purposes of such things which are located, as it were, outside the range of dead matter, that is, to the benefit of human beings and animals, if they did not have a common origin, that is, an infinite reason, in which the essential natures of all things were conceived in relation to each other? If their natures were necessary for themselves and independently of each other, what amazing chance, or rather, what an impossibility it would be, that their natural endeavours should fit them together in such a way as a deliberate clever choice could have united them.

Now I will confidently apply this to my current purpose. I assume the matter of the whole world to be universally dispersed and I make complete chaos out of it. I see matter form in accordance with the established laws of attraction and modify its motion through repulsion. Without the assistance of any arbitrary inventions, I enjoy the pleasure of seeing the 1:226
creation of a well-ordered whole by reason of established laws of motion which looks so much like the system of the world we have before our eyes that I cannot help but regard it as the same. This unexpected development of the order of nature on a large scale initially seems suspicious to me because it bases such a composite rightness on such a poor and simple foundation. Finally, I instruct myself from the aforementioned observation that such a development of nature is not something unheard of, but that its essential endeavour necessarily brings with it such a development, and that this is the most magnificent evidence of its dependence on that original being which contains within itself even the origins of beings themselves and their first laws of causation.[d] This insight redoubles my trust in the proposal I have made. My confidence increases with every step I take forward and my timidity ceases completely.

[d] *Wirkungsgesetze*

But the defence of your system, people will say, is also the defence of Epicure's opinions, which have the greatest similarity with them. I do not reject all agreement with him. Many have become atheists through the semblance[e] of such reasons, which, on closer consideration, could have convinced them most powerfully of the certainty of the highest being. The consequences a confused understanding draws from the most faultless principles are often very faulty, and this was the case with Epicure's conclusions, even though his conception was in accord with the keenness of a great mind.

I will therefore not deny that Lucretius' theory or that of his predecessors, Epicure, Leucippus, and Democritus, has much in common with mine. Like those philosophers, I posit a first state of nature as a universal dispersion of the original material of all world-bodies, or atoms as they call them. Epicure posited a heaviness that caused these elementary particles to fall and this does not seem to be very different to Newtonian attraction, which I accept; he also accorded them a certain deviation from the straight linear motion of their fall, even though he had absurd notions of their causes and effects: This deviation to some extent corresponds
1:227 to the change in the straight fall that we attribute to the repulsive force of the particles; finally, the whirlpools that arose out of the perturbed[f] motion of the atoms were a centrepiece of the theories of Leucippus and Democritus, and they will also be found in ours. The close relationship with a doctrine that was the proper theory of the denial of the divine in antiquity, will not, however, drag mine into association with their errors. Even in the most senseless opinions that have succeeded in gaining the applause of men, we will always find some truth. One false principle or a few ill-considered connecting principles will lead men from the path of truth via imperceptible errors right into the abyss. Despite the similarity I have just mentioned, there does nonetheless remain one basic difference between ancient cosmogony and the current one, which allows us to draw quite opposite conclusions from the latter.

The aforementioned teachers of the mechanical origins of the universe[g] derived all the order that could be perceived in it from the accidental chance that made the atoms come together so fortuitously that they constituted a well-ordered whole. Epicure was even so impudent that he insisted that the atoms deviated from their straight motion without any reason in order to be able to encounter one another. All of them together took this nonsense to the point that they made this blind coincidence the origin of all living creatures and really derived reason from the lack of reason.[9] In my theory, however, I find that matter is

[e] *Schein*
[f] *verwirrten*
[g] *Weltbaues*

tied to certain necessary laws. In their complete dissolution and dispersion, I see a beautiful and orderly whole develop quite naturally. This does not happen through accident and by chance, but rather one can see that natural properties bring it about in a necessary fashion. Does not this move one to ask: Why did matter have to have precisely such laws as have order and propriety as their purpose? Was it really possible that many things, each of which has a nature independent of the others, should determine each other by themselves in precisely such a way that a well-ordered whole emerges from it, and if they do this, does this not provide an undeniable proof of their common first origin, which must be an all-sufficient highest mind in which the natures of things were designed in accordance with unified purposes? 1:228

Matter, which is the original material[b] of all things, is thus bound by certain laws, and if it is left freely to these laws, it must necessarily bring forth beautiful combinations. It is not at liberty to deviate from this plan of perfection. Since, therefore, it is subject to a most wise purpose, it must necessarily have been placed into such harmonious connections by a first cause that ruled over it, and *a God exists precisely because nature cannot behave in any way other than in a regular and orderly manner, even in chaos*.

I have such a good opinion of the honest attitude of those who do my proposal the honour of examining it that I consider myself assured that the reasons mentioned will at least put the purity of my intention beyond doubt, even if they do not yet remove all concerns about the harmful consequences of my system. If, notwithstanding this, there are spiteful zealots who regard it as a worthy duty of their holy calling to attach harmful interpretations to the most innocent opinions, then I am sure that their judgement will have an effect on all reasonable people that is exactly the opposite of their intention. Furthermore, I will not be deprived of the right that Descartes always enjoyed from fair judges when he dared to explain the formation of the heavenly bodies from purely mechanical laws. I will therefore quote the authors of the universal history of the world:* "We, however, cannot but believe that the attempt by this philosopher, who attempts to explain the formation of the world over a certain period of time from chaotic matter by the simple continuation of a motion once impressed on it and has reduced this to a few simple and universal laws of motion, just as little as others *who have since then and with much applause tried to do the same thing from the original and created properties of matter*, is punishable or demeaning of God

* Part I, §88.

[b] *Urstoff*

as many have imagined, because *instead, a higher conception of his infinite wisdom is brought about by this means*."[10]

1:229 I have attempted to remove the difficulties that appeared to threaten my propositions from the point of view of religion. There are several that are no less significant in relation to the matter itself. If it is true, people will say, that God has placed into the forces of nature a secret ability to form itself out of chaos into a perfect world constitution,[i] then will the mind of man, which is so weak in relation to the lowest things, be capable of investigating the hidden properties in so great a subject matter[j]? Such an endeavour[k] is the same as if one were to say: *just give me matter and I will build you a world out of it*. Cannot the weakness of your insights, which is made as nought by the slightest things that occur near you every day, teach you that it is futile to try to discover the immeasurable and what took place in nature even before the world existed? I shall destroy this difficulty by demonstrating clearly that of all the investigations that could be raised in the study of nature, this is the one in which one can most easily and most surely reach back as far as its beginning. Just as of all the tasks facing research into nature, none has been resolved with greater accuracy and certainty than the true constitution of the universe[l] on the large scale, the laws of motion, and the internal mechanism of the orbits of all the planets into which Newtonian philosophy can give such insights as can be found in no other part of philosophy: just so, I maintain, that of all the things in nature whose first cause we can investigate, the origin of the world system[m] and the generation of the heavenly bodies together with the causes of their motions is the one which we might first hope to understand thoroughly and reliably. The reason for this is simple to see. The heavenly bodies are spherical masses, that is, of the simplest form that any body can have whose origin one seeks. Their motion is similarly unmixed. It is nothing other than a free continuation of a tangential force[11] once impressed,[n] which, combined with the attraction of the body in the centre, becomes circular. Furthermore, the space in which they move is empty, the distances separating them are quite uncommonly great and thus all are placed most clearly separate from one another both in unimpeded[o] motion and for the clear
1:230 observation of it. It seems to me that in a certain sense one could say here without being presumptuous: *Give me matter and I will build a world out of it*, that is, give me matter and I will show you how a world is to come into being out of it. Because if matter endowed with an essential

[i] *Weltverfassung*
[j] *Vorwurfe*
[k] *Unterfangen*
[l] *Verfassung des Weltbaues*
[m] *Weltsystems*
[n] *eines einmal eingedrückten Schwunges*
[o] *unverwirrten*

attractive force is present, then it is not difficult to determine those causes that can have contributed to the arrangement of the world system,[p] viewed on the large scale. We know what is necessary for a body to achieve a spherical shape, we understand what is required for free-floating spheres to adopt a circular motion around the centre point to which they are attracted. The position of the orbits in relation to each other, the coincidence of the direction, the eccentricity, all this can be reduced to the simplest mechanical causes, and we can confidently hope to discover them because they can be posited on the simplest and clearest grounds. But can we claim such advantages about the most insignificant plant or insect? Are we in a position to say: *Give me matter and I will show you how a caterpillar can be created*? Do we not get stuck at the first step due to ignorance about the true inner nature of the object and the complexity of the diversity contained in it? It should therefore not be thought strange if I dare to say that we will understand the formation of all the heavenly bodies, the cause of their motion, in short, the origin of the whole present constitution of the universe[q] sooner than the creation of a single plant or caterpillar becomes clearly and completely known on mechanical grounds.

These are the reasons upon which I base my confidence that the physical part of cosmology[r] may in future hope for that completeness to which Newton raised its mathematical half. Next to the laws governing the universe[s] in its current constitution, there are perhaps no others in the whole of research on nature capable of being so determined mathematically as those according to which it came about, and without doubt the hand of a practised mathematician would cultivate fruitful fields here.

After I have made the effort to commend a favourable reception for the subject[t] of my observations, I may be allowed briefly to explain the 1:231
way in which I have treated it. The first part is concerned with a new system of the structure of the universe[u] on the large scale. Herr **Wright of Durham**,[12] with whose treatise I became acquainted through the *Hamburg Freie Urteile* of the year 1751,[13] first gave me cause to regard the fixed stars not as a scattered milling mass without any visible order, but rather as a system with the greatest similarity to a planetary one, so that, just as in the latter the planets are very close to a common plane, so also the fixed stars in their position relate as closely as possible to a certain plane, which has to be thought of as extending through the entire heavens, and where they are most densely massed, they form the

[p] *Weltsystems*
[q] *Weltbau*
[r] *Weltwissenschaft*
[s] *Weltbau*
[t] *Vorwurf*
[u] *Weltgebäude*

bright band that is called the Milky Way. I have become convinced that, because this zone, illuminated by countless suns, has very exactly the direction of a very large circle, our sun must also be very close to this large plane of reference. While pursuing the causes of this feature, I have found the following to be very probable: that the fixed stars could actually be slowly moving planets of a higher order. As confirmation of what will be found about this thought in its proper place, I will quote here just one section of **Herr Bradley**'s treatise on the motion of fixed stars.[14] "If a judgement may be formed, <with regard to this matter,> from the result of the comparison of our best modern observations, with such as were formerly made with any tolerable degree of exactness; there appears to have been a real change in the position of some of the fixed stars with respect to each other; and such, as seems independent of any motion in our own system, and can only be referred to some motion in the stars themselves. Arcturus affords a strong proof of this. For if its present declination be compared with its place, as determined either by **Tycho** or **Flamsteed**, the difference will be found to be much greater than what can be suspected to arise from the uncertainty of their observations. It is reasonable to expect that other instances of the like kind must also occur among the great number of visible stars; because their
1:232 relative positions may be altered by various means. For if our own solar system be conceived to change its place with respect to absolute space, this might, in process of time, occasion an apparent change in the angular distances of the fixed stars; and in such a case, the places of the nearest stars being more affected, than of those that are very remote; their relative positions might seem to alter; tho' the stars themselves were really immoveable. And on the other hand, if our own system be at rest and any of the stars really in motion, this might likewise vary their apparent positions; and the more so, the nearer they are to us, <or the swifter their motions are,> or the more proper the direction of the motion is, to be rendered visible by us. Since then the <relative> places of the stars may be changed from such a variety of causes, considering the amazing distances at which it is certain that some of them are placed, it may require the observation of many ages, to determine the laws of the apparent changes, even of a single star; much more difficult therefore must it be, to settle the laws relating to all the most remarkable stars."[v,15]

I cannot determine exactly the borders between the system of Herr **Wright** and my own and in what ways I have merely imitated his model or have explained it further. But acceptable reasons presented themselves to me afterwards to extend it considerably in one direction. I observed

[v] Texts enclosed within <> are in the original, but not in Kant's text.

the kind of nebulous stars that **Herr von Maupertius** considers in his *Treatise on the Figure of the Stars**,[16] and which have the figure of more 1:233
or less open ellipses, and readily assured myself that they could be nothing other than an accumulation of many fixed stars. The roundness of these figures that is measured at all times taught me that an inconceivably numerous mass of stars must be arranged here around a common centre point, because otherwise their free positions in relation to one another would present irregular shapes but not measured figures. I also realized that in the system in which they are united, they must be mainly limited to one plane, because they do not present circular but elliptical figures and that, because of their pale light, they must be incomprehensibly distant from us. The treatise itself will present to the investigation of the unprejudiced reader what I have concluded from these 1:234
analogies.

* Because I do not have the quoted treatise to hand, I will add here the relevant pieces from the explanation in the *Ouvrages diverses de Msr de Maupertius* in the *Actis Erud.* (1745). The first phenomenon are those **bright spots** in the sky that are called nebulous stars and are thought to be an accumulation of small fixed stars. With the aid of excellent telescopes, however, astronomers have found them to be merely large oblong spots that are somewhat brighter than the rest of the sky. **Huygen** was the first to find something of this sort in Orion; **Halley** discusses six such spots in the *Anglical Trans*: 1. In the sword of Orion, 2. In Sagittarius, 3. In the Centaur, 4. In front of the right foot of Antinous, 5. In Hercules, 6. In the belt of Andromeda. If these are viewed through a reflective telescope of 8 feet, one can see that only a quarter of them can be considered as a mass of stars; the 1:233
remainder have only presented whitish spots without any significant difference, except that one is more in the nature of a round circle, another is more oblong. It also appears that in the case of the former, the small stars visible through the telescope cannot be the cause of their whitish shimmer. **Halley** believes that these phenomena can explain what is found in the beginning of the creation story in Genesis, namely that light was created before the Sun. **Derham** compares them with openings through which a further immeasurable region and perhaps the fire sky shines through. He thinks he has been able to observe that those stars that have been seen near these spots are much closer to us than lighter places. To these observations the author appends a list of nebulous stars from **Hevelius**. He regards these phenomena as great light masses that have been flattened by a mighty change. If the matter of which they consist had the same power of light as the other stars, they would have to be of immense size so that, viewed from a far greater distance than the other stars, they are still able to appear in the telescope as having remarkable shape and size. If, however, they were approximately similar to the other fixed stars in size, they would not only have to be much closer to us but also give off a much weaker light, since they have such a pale shimmer despite such proximity and apparent size. It would therefore be worth the effort to discover their parallax if they have one. For those who say they have none are perhaps extrapolating their conclusion from some cases to all. The small stars encountered in the middle of these spots, as in Orion (or even better in the one in front of the right foot of Antinous, which looks no different to a fixed star surrounded by a nebula), would, if they were closer to us, be seen either in the manner of a projection onto it, or would shine through those masses, as though through the tails of comets.

In the **second part**, which contains the most essential object[w] of this treatise, I seek to develop the constitution of the universe[x] from the simplest state of nature through mechanical laws alone. If I may dare to suggest to those who are outraged at the boldness of this undertaking that they adopt a certain order in their examination with which they honour my thoughts, then I would request that they read the **eighth chapter** first, which I hope may prepare their judgement towards a correct insight. If, however, I invite the gentle reader to examine my opinions, then I am rightly concerned that, since hypotheses of this type are usually not held in higher esteem than philosophical dreams, it will be a sour favour for a reader to decide to undertake a careful examination of the histories of nature that I have thought up for myself and patiently to follow the author through the twists and turns by which he avoids the difficulties he encounters, in order finally perhaps to laugh at his own gullibility, like the audience of the London market crier.*,17 I can, however, confidently promise that if the reader is hopefully persuaded by the suggested preparatory section to dare to undertake such a physical adventure on the basis of such probable conjectures, he will not encounter as many dead ends and impassable obstacles on his way as he might have originally feared.

It is with the greatest care that I have indeed relinquished all arbitrary inventions. I have, after I placed the world in the simplest chaos, made use of no forces other than those of attraction and repulsion to develop the great order of nature, two forces which are equally certain, equally simple, and equally original and universal. They have both been borrowed from Newtonian philosophy. The former is now a law of nature that is beyond doubt. The second, which Newtonian science is unable to provide with as much clarity as it has for the first, I will assume here
1:235 only in the sense that no one rejects it, namely in relation to the smallest dispersion of matter as, for instance, in vapours. It is for these so simple reasons that I have derived the following system, without any artifice or consideration of other consequences than those upon which the attention of the reader would have arrived by itself.

Finally, I ask to be permitted a short explanation relating to the validity and the presumed value of those propositions which will appear in the following theory and according to which I would wish to be examined by fair judges. The author is properly judged according to the stamp he puts on his wares; I therefore hope that one will not require any more strict responsibility of my opinions in the different parts of this treatise than the value I give to them myself. In fact, the greatest geometrical acuity

* Cf. *Gellert*'s fable: *Hans Nord*

[w] *Vorwurf*

[x] *Weltbau*

and mathematical infallibility can never be demanded of a treatise of this kind. If the system is based on analogies and harmonies in accordance with the rules of credibility and a correct way of thinking, it has satisfied all the requirements of its object. I believe that I have attained this level of competence in some parts of this treatise, such as in the theory of the system of fixed stars, in the hypothesis of the nature of the nebulous stars, in the general plan of the mechanical creation of the universe,[y] in the theory of the ring of Saturn and several others. Certain other parts of my explanation will be less satisfying, for instance the determination of the relations of eccentricity, the comparison of the masses of the planets, the varied deviations of the comets, and some others.

If, therefore, in the seventh chapter, enticed by the fruitfulness of the system and the attractiveness of the greatest and most admirable thing we are capable of imagining, and while adhering to the thread of analogy and a reasonable credibility, I extend the results of our doctrine[z] as far as possible; if I represent the infinite nature of all creation, the formation of new worlds and the decline of the old ones and the unlimited realm of the chaos of the imagination: I hope the reader will grant the charming attractiveness of the object and the pleasure one experiences in seeing the agreement of a theory in its greatest extension, sufficient consideration so 1:236
as not to judge it according to the greatest geometrical strictness, which does not in any case have any relevance in this type of consideration. It is precisely this fairness I expect in the third part. Nonetheless, the reader will find somewhat more than mere arbitrariness but somewhat less than undoubtedness in it.

[y] *des Weltbaues*

[z] *des Lehrgebäudes*

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[c] *Dünnigkeit*

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[d] *Centralkörper*
[e] *Inbegriffe*
[f] *Weltbau*
[g] *Weltbau*
[h] *Weltbau*
[i] *Weltbau*

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Natural History and Theory of the Heavens

Part One.

Summary of a systematic constitution among the fixed stars

and also

of the vast number of such systems of fixed stars

Is the great chain that draws all to agree,
And drawn supports, upheld by God or thee?
Pope.[18]

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Short summary of the most essential basic concepts of Newtonian science, which are necessary for understanding what follows.*

Six planets, three of which have satellites, Mercury, Venus, Earth with its Moon, Mars, Jupiter with four and Saturn with five satellites, which describe orbits with the Sun at the centre, as well as the comets which do likewise, coming from all sides in very extensive orbits, constitute a system which we call the solar system[k] or the planetary universe.[l],19 Because it is circular and is on a closed orbit, the motion of all these bodies presupposes two forces that are both equally necessary in every type of doctrine, that is, a **shooting force**,[m] which would cause them to continue in a direction straight ahead at every point of their curved path and move into an infinity if there were not also **a second force**, whatever it may be, which constantly forced them to leave that path and to proceed in a curved path with the Sun at its centrepoint. This second force, as is indubitably determined by geometry itself, aims at the Sun from all points and is thus called the sinking, the centripetal force or also gravity.

1:244 If the orbits of the heavenly bodies were exact circles, then the simplest analysis of the composition of curved motions would show that a continuous push towards the centre point is required for this; however, although these motions of all planets and comets are ellipses with the Sun as a common focus, higher geometry, with the assistance of Kepler's Analogy[20] (according to which the *radius vector*, or the line drawn from the planets to the Sun, always sweeps out such spaces from the elliptical orbit that are proportional to the times), demonstrates with infallible certainty that a force would have to continuously drive the

* I wanted to provide this brief introduction, which may perhaps be superfluous in the view of most readers, for those who are not sufficiently knowledgeable about Newtonian principles, as a preparation for understanding the theory that follows.

[k] *System der Sonne*
[l] *Weltbau*
[m] *schießende Kraft*

planet throughout its entire orbit to the centre point of the Sun. This lowering force[n] then, which applies throughout the entire planetary system and is directed towards the Sun, is an established phenomenon of nature, and the law by which this force extends from the centre to the far reaches of space has been equally reliably proved. It always decreases in inverse proportion to the square of the increase in distance from the centre. This rule flows in just as infallible a manner from the time required by the planets for their orbits at varying distances. These times are always the square roots of the cube of the mean distances from the Sun, from which we can deduce that the force attracting these heavenly bodies to the centre point of their revolutions must decrease in inverse proportion to the square of the distance.[21]

Precisely the same law that applies among the planets in so far as they orbit around the Sun, is also found in small systems, namely those constituted by moons orbiting around their main planets. The durations of their orbits are proportional to the distances in precisely the same way and establish precisely the same ratio of the lowering force in relation to the planet as that to which the planet is subject in relation to the Sun. All this is forever beyond any contradiction as a result of the most infallible geometry based on indisputable observations. In addition there is the idea that this lowering force[o] is the same impetus as what is called gravity on the surface of the planet and which decreases gradually with distance in accordance with the above law. This may be observed by comparing the quantum of gravity on the surface of the Earth with the 1:245
force that drives the Moon to the centre point of its orbit, which stands to it exactly as does the attraction in the entire universe, that is, in inverse proportion to the square of the distances. This is the reason why the often mentioned central force is also called gravity.

Furthermore, because it is probable in the highest degree that if an effect occurs only in the presence of and in proportion to the attraction to a particular body, its direction is also related precisely to that body, we may believe that this body is the cause, in whatever manner, of that effect; so it has been thought that there was sufficient reason on account of this to ascribe this general sinking of the planets towards the Sun to an attracting force of the latter and to attribute this capacity of attraction to all heavenly bodies in general.

If, therefore, a body is left freely to this drive, which causes it to sink towards the Sun or some planet, then it will fall down towards it at a constantly accelerated motion and unite with that mass in a short time. If, however, it has received a blow to one side, then, provided the blow is not so strong as to be exactly equivalent to the force of the sinking, it will

[n] *Senkungskraft*

[o] *Senkungskraft*

sink towards the central body in a curved motion and if the tangential force[p] impressed upon it was at least as powerful as to remove it before it touches its surface from the vertical line by half the thickness of the body at the centre, then it will not touch its surface but, after it has swung closely around it, it will rise as high again as it has fallen by means of the velocity it has reached in falling, so that it will continue its path around it in a constant orbital motion.

The difference between the orbits of the comets and the planets therefore consists in the deviation[q] of the sideways motion against the pressure that drives them to fall; which two forces, the more they approach equality, the more the orbit is similar to the shape of a circle and the less similar they are, the weaker the shooting force[r] is in relation to the central force, the more elongated the circle, or as it is called, the more eccentric it is because the heavenly body approaches the Sun very much more closely in one part of its orbit than in another part.

1:246 Because nothing in all of nature is balanced with complete precision, no planet has a completely circular motion, but comets deviate from it most because the tangential force[s] that has been impressed upon them from the side was least proportional to the central force of its original distance.

In the treatise, I shall frequently use the expression of a **systematic constitution of the universe**.[t] So that there will be no difficulty in understanding what is meant by this, I shall explain it briefly. Actually, all the planets and comets that belong to our universe[u] constitute a system simply because they orbit around a common central body. But I take this term in a narrower meaning in that I consider the more precise relationships that have made their connection to one another regular and uniform. The orbits of the planets relate as closely as possible to a common plane, namely to the extended equatorial plane of the Sun; the deviation from this rule occurs only at the outermost border of the system, where all motions gradually cease. If, therefore, a certain number of heavenly bodies that are arranged around a common central point and move around this, are simultaneously restricted to a certain plane in such a way that they have the freedom to deviate from it to either side only as little as possible; if such deviation occurs gradually only in those that are most remote from the centre point and thus participate less in the relationships than the others: then, I say, that these bodies are related to each other in a **systematic constitution**.

[p] *Schwung*
[q] *Abwiegung*
[r] *schießende Kraft*
[s] *Schwung*
[t] *systematische Verfassung des Weltbaues*
[u] *Weltbau*

Universal
Natural History and Theory of the Heavens.

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PART ONE.

Concerning the systematic constitution among the fixed stars.

The theory[v] of the universal constitution of the universe has attained no noticeable increase since the times of Huygens.[22] We know no more now than was known at that time, namely that six planets with ten satellites, all of which have the circles of their orbits directed nearly onto one plane, and the eternal cometic spheres spreading out in all directions make a system, the centre of which is the Sun, towards which everything sinks, around which all their motions go, and by which they are all lit, warmed, and filled with life;[w] that, finally, the fixed stars are the suns of just as many similar systems, in which everything may be just as large and arranged in just so orderly a way as in our system, and that infinite space is brimming with solar systems,[x] the number and excellence of which has a relationship to the immeasurableness of their creator.

The systematic aspects that took place in the connection of the planets orbiting around their suns disappeared here in the multitude of the fixed stars, and it seemed that the relationships that were found on a small scale and had the character of laws, did not apply on the large scale among the parts of the universe; the fixed stars were not given any law by which their situations in relation to each other were restricted and they were seen to fill all the heavens and all the heavens of heavens without any 1:248
order or intention. Ever since mankind's desire for knowledge has placed these limits upon itself, no one has done anything more than to deduce from it and admire the greatness of the one who has revealed himself in such inconceivably great works.

It was given to Herr **Wright of Durham**,[23] an Englishman, to undertake a fortunate step towards an observation that he does not seem to have put to any very useful purpose and the useful application of which he did not observe sufficiently. He regarded the fixed stars not as a disorderly mass distributed without any intent, but rather found a systematic

[v] *Lehrbegriff*
[w] *belebt*
[x] *Weltgebäuden*

constitution in the whole and a universal relationship between these stars and a main plane of the space they occupy.[y]

We shall try to improve upon the idea he advanced and to give it that turn by which it can be productive of important consequences, the full confirmation of which will be reserved for future times.

Anyone who looks at the sky full of stars on a clear night will be aware of the bright band that, because of the large number of stars that are concentrated there more than elsewhere and because of the fact that in the enormous distances they can no longer be seen as individual stars, exhibits a uniform light, which has been given the name of the **Milky Way**. It is amazing that observers of the heavens were not moved long ago by the nature of this noticeably different zone to adduce particular characteristics in the position of the fixed stars from it. For it can be seen to occupy the direction of a great circle and in an uninterrupted connection around the entire heavens, two conditions that contain within themselves such a precise determination and characteristics that are so noticeably different from the vagueness of the arbitrary that attentive astronomers ought naturally to have been inspired by this to seek an explanation of such a phenomenon with diligence.

Because the stars are not placed on the apparently concave heavenly sphere but rather, with one being further from our point of view than the other, lose themselves in the depths of the heavens, it follows from this phenomenon that at the distances in which they stand from us one
1:249 behind the other, they are not distributed in all directions arbitrarily, but must relate principally to a particular plane that passes through our point of view and to which they are set to be found as close as possible.

This relationship is so undoubted a phenomenon that even the remaining stars that are not included in the whitish band of the Milky Way, are nonetheless seen to be more concentrated and more dense the closer their position is to the circle of the Milky Way, such that, of the 2,000 stars visible to the naked eye, the greater part is found in a not very wide zone of which the Milky Way is the centre.

Now, if we think a plane drawn through the firmament in unlimited distances and assume that all the fixed stars and systems stand in a universal relationship to this plane so that they are closer to it than to other regions, then an eye situated in this plane of reference will perceive, in its view into the field of stars at the concave spherical surface of the firmament, this densest concentration of stars in the direction of such a drawn plane in the form of a zone illuminated by much more light. This light band will extend in the direction of a largest circle because the position of the observer is in the plane itself. In this zone there will be a

[y] *gegen einen Hauptplan der Räume, die sie einnehmen*

multitude of stars which, because they are so small as to be indistinguishable as individual bright points and because of their apparent density, appear as a uniform whitish shimmering, in a word, as a milky way. The remaining heavenly array, the relationship of which to the drawn plane gradually diminishes or which may also be closer to the standpoint of the observer, will be perceived as more widely distributed even though still related to this plane on account of its concentration. Finally, it follows from this that, because from our solar system[z] this system of fixed stars is perceived in the direction of a largest circle, it is part of this very same great plane and constitutes a system with them.

In order to delve better into the nature of the universal connection ruling the universe,[a] we shall try to discover the reason why the places of the fixed stars are related to a common plane.

The Sun does not limit the extent of its attractive force to the narrow region of the planetary system. To all appearances, it extends it to infinity. The comets, which travel very far beyond the orbit of Saturn, are forced by the attraction of the Sun to return again and to proceed in orbits. Although, therefore, it is in the nature of a force that appears to be incorporated into the essence of matter that it should be more appropriate to it to be unlimited, and it really is acknowledged as such by those who accept Newton's laws, we want it to be admitted only that this attraction of the Sun extends approximately to the nearest fixed star, and that the fixed stars are efficacious to the same extent as so many suns, so that it follows that the entire host of these is striving to draw closer to each other by attraction; thus all the solar systems[b] are in the situation that, by unceasing and unhindered reciprocal approaching, they would sooner or later collapse into one lump were it not that this destruction was prevented, just as the spheres in our own planetary system are, by forces fleeing the centre point, because they divert the heavenly bodies from a straight fall and, together with the forces of attraction, create the eternal orbits, as a result of which the edifice[c] of creation is protected from destruction and made appropriate to an unending duration. 1:250

Thus all the suns of the firmament have orbital motions either around one universal centre point or around many. In this context, we may use the analogy of what has been observed in the orbits of our solar system,[d] namely that the same cause that has imparted centrifugal force[e] to the planets as a result of which they describe their orbits, has also arranged them in such a way that they all relate to one plane, which is therefore also the cause, whatever it may be, that what has given the

[z] *Sonnenwelt*
[a] *Weltbau*
[b] *Weltsysteme*
[c] *Gebäude*
[d] *Sonnenwelt*
[e] *Centerfliehkraft*

power of rotation[f,24] to the suns of the upper world, as so many moving stars of higher orders of worlds, has, at the same time, brought their orbits into one plane as much as possible and striven to limit deviations therefrom.

According to this representation, the system of the fixed stars may be described approximately by the planetary one, if the latter is extended infinitely. Because if, instead of the six planets with their ten satellites, we assume as many thousands of them and instead of the twenty-eight or
1:251 thirty comets that have been observed, we assume a hundred or thousand times as many, if we think of these very bodies as self-illuminating, then to the eye of an observer looking from the Earth, they would create the appearance as of the fixed stars of the Milky Way. Because the planets under consideration, through their proximity to their common plane of reference, would exhibit for us, who are in precisely the same plane on our Earth, a zone brightly illuminated by countless stars directed towards the greatest circle; this bright band would be filled with plenty of stars everywhere, even though according to the hypothesis, they would be moving stars and thus not attached to one place, because there would always be enough stars on one side through its displacement, even though others had changed their place.

The width of this illuminated zone, which represents a kind of zodiac, will be caused by the different degrees of deviation of the aforementioned planets[g] from their plane of reference and by the inclination of their orbits towards the same surface, and because most of them are close to this plane, their number will appear more dispersed according to the degree of their distance from this plane, but the comets, which occupy all regions without distinction, will cover the field of the heavens on both sides.

The shape of the heavens of the fixed stars therefore has no other cause than being exactly the same systematic constitution on a large scale as the planetary system has on a small one, in that all suns make up one system, whose universal plane of reference is the Milky Way. Those with the least reference to this plane are seen as being to one side, but they are less concentrated precisely because they are more widely dispersed and rarer. They are, as it were, the comets among the suns.

This new doctrine, however, attributes to the suns a motion away from each other, but everyone cognizes them as unmoving and fixed in their places from the beginning. The name that was given to the fixed stars for this reason appears to be confirmed and undoubted through the observations of all the centuries. This difficulty would destroy the doctrine advanced above if it were with foundation. However, to all

[f] *Kraft der Umwendung* [g] *Irrsterne*

appearances, this lack of motion is merely apparent.[b] It is either only an exceptional slowness brought about by the great distance from the common centrepoint of their orbit, or by its imperceptible nature on 1:252
account of the distance from the point of observation. Let us estimate the probability of this conception by calculating the motion that a fixed star near our Sun would have if we assume that our Sun were the centre point of its orbit. If its radius is assumed to be more than 21,000 times greater than the distance of the Sun from the Earth, using Huygens' figures, then according to the established law of the duration of orbits, which are in the ratio of the square root of the cube of the distance from the centre, the time it would take to complete its orbit around the Sun once would be more than one and a half million years and this would posit a change in its position of only one degree in 4,000 years.[25] Now since perhaps only very few fixed stars are as close to the Sun as Huygens supposed Sirius to be, since the distance of the rest of the mass of the heavenly bodies perhaps exceeds the latter enormously and would therefore require very much longer times for such a periodic revolution and, furthermore, it is more probable that the motion of the suns of the starry heavens proceeds around a common centre point, the distance of which is uncommonly great and the progress of the stars may therefore be extremely slow, we can probably deduce from this that the whole time in which we have been observing the heavens is perhaps still not sufficient to notice the changes that have taken place in their positions. We should not, however, give up hope that these will be discovered in time. Subtle and careful observers as well as a comparison of widely separated observations will be required for this. These observations would have to be directed principally at the stars of the Milky Way,* which is the main plane of all motion. Herr **Bradley** has observed some scarcely perceptible motions of the stars. The Ancients noticed stars at certain points of the heavens and we see new stars at other points. Who knows whether these were the same ones that had merely changed position. The excellence of the tools and the perfection of astronomy give us well-founded hope of discovering such 1:253
strange peculiarities.† The credibility of the matter itself for reasons of nature and analogy support this hope so well that they can stimulate the attention of researchers of nature to bring them to fulfilment.

* Similarly with those concentrations of stars, many of which are close to one another in a small space, such as for example the Seven Sisters, which may perhaps constitute a small system within a larger one.

† **De la Hire**[26] observes in the *Mémoires* of the Academy in Paris of 1693 that he has perceived a major change in the positions of the stars in the Seven Sisters in his own observations as well as by comparison of these with those by Ricciolus.[27]

[b] *etwas Scheinbares*

The Milky Way is, so to speak, also the zodiac of new stars that can be seen first to appear and then to disappear as in almost no other region of the heavens than in this one. When this alternation in its visibility results from its periodic distance and proximity to us, it seems from the systematic constitution of the stars noted above that such a phenomenon can only be seen in the region of the Milky Way. For, as these are stars that orbit in very oblong circles around other fixed stars as satellites around their main planets, then the analogy with our planetary system, in which only those heavenly bodies near the common plane have satellites orbiting around them, requires that only the stars that are in the Milky Way have suns orbiting around them.[28]

I now come to that part of the doctrine advanced that makes it most attractive because of the sublime view it presents of the plan of creation. The sequence of thoughts that have led me to it is short and plain. It consists of the following. If a system of fixed stars, in which their positions are in a common plane, such as we have sketched the Milky Way, is so far away from us that all recognition of the individual stars of which it consists cannot be detected even by a telescope; if its distance relative to the distance of the stars of the Milky Way is the same as the distance of the Sun to us – in short, if such a world of fixed stars is viewed at such an immeasurable distance from the eye of the observer which is outside it,
1:254 then it will appear under a small angle as a minute space illuminated by a weak light, the shape of which will be round as a circle when its plane presents itself straight to the eye and elliptical when it is seen from the side. The weakness of the light, the figure and the perceptible magnitude of its diameter will clearly distinguish such a phenomenon, if it is present, from all other stars that can be observed individually.

We need not search long for this phenomenon among the observations of the astronomers. It has been perceived clearly by various observers. People have been surprised by its rarity; they have made assumptions and sometimes imagined wondrous things and sometimes given way to apparent conceptions that, however, turned out to be as unfounded as the first. We refer here to the nebulous stars, or rather one type of them, which Herr von Maupertius describes as follows:* **That they are small places illuminated a little more than the darkness of the empty space of the heavens, which all have in common that they represent more or less open ellipses but whose light is much weaker than any other that we perceive in the heavens.**[29] The author of astrotheology imagined that they were openings in the firmament through which he believed he could see the fiery heavens.[30] A philosopher of more enlightened insights, the Herr von Maupertius

* Treatise on the figure of stars.

already mentioned, regards them, on the basis of their shape and knowable diameters, as amazingly large heavenly bodies which, viewed from the side, exhibit elliptical shapes because of the great flattening caused by the rotational motion.[i]

It is easy to see that this latter explanation cannot be true either. Because this kind of nebulous star must without doubt be at least as distant from us as the other fixed stars, not only would their size be astounding, since it would exceed that of the largest stars by many thousands of times, but it would be most strange that, given that they are self-illuminating bodies and suns, they would show the dullest and weakest light with this extraordinary size.

It is much more natural and conceivable that these are not single stars of such size, but systems of many stars, whose distance from us exhibits 1:255
them as being in so narrow a space that the light, which is imperceptible from each one individually, becomes a uniform pale shimmering with their immeasurable number. The analogy with the solar system in which we exist, its shape which is just as it must be according to our theory, the weakness of the light, which requires us to presuppose an infinite distance: all this is in agreement with holding the elliptical figures to be the same solar systems and, so to speak, Milky Ways, the constitution of which we have just developed; and if presumptions in which analogy and observation correspond to support each other completely have the same value as formal proofs, then we will have to regard the certainty of these systems as proved.[31]

Now the attention of the observers of the heavens has enough motivation to occupy themselves with this suggestion. The fixed stars, as we know, all relate to a common plane and thus constitute an orderly whole, which is a world of worlds. One can see that in the immeasurable distances, there are more such star systems, and that creation in the entire infinite scope of its size is everywhere systematic and interrelated.

One could also speculate that these higher orders of worlds are not without connection to one another and that, through this mutual relationship, they constitute in turn an even more immeasurable system. Indeed, it can be seen that the elliptical figures of this type of nebulous star adduced by Herr von Maupertius are very closely related to the plane of the Milky Way. A vast field is open here to discoveries, for which the key must be provided by observation. Those stars that are called nebulous and those about which there is argument would have to be examined and tested in terms of this doctrine. If the parts of nature are observed according to intentions[j] and a discovered plan, certain properties are revealed that would otherwise be overlooked and remain hidden if our observation is spread over all objects without any guidance.

[i] *Drehungsschwunge*

[j] *Absichten*

The theory we have put forward opens a perspective onto the infinite
1:256 field of creation for us and presents some inkling of God's work that is appropriate to the infinitude of the great architect.[k] If the magnitude of a planetary system in which the Earth is as a grain of sand and scarcely noticeable puts our reason into a state of wonderment, then with what amazement are we delighted when we contemplate the infinite multitude of worlds and systems that constitute the sum total of the Milky Way; but how much does this amazement increase when one becomes aware that all these immeasurable orders of stars in turn are the unit of a number whose end we do not know, and which is perhaps just as inconceivably great as these and yet is in turn only the unit of a new combination of numbers. We see the first members of a progressive relationship of worlds and systems, and the first part of this infinite progression already gives us to understand what we can suppose about the whole. There is no end here but rather an abyss of a true immeasurability into which all capacity of human concepts sinks even if it is raised with the help of mathematics. The wisdom, the goodness, the power that has revealed itself, is infinite and in the same measure fruitful and industrious; the plan of its revelation must for that reason be as infinite and without limits as it is.

Important discoveries that serve to extend the idea we have of the magnitude of creation are, however, to be made not only on the large scale of things. On the smaller scale there is no less that is as yet undiscovered, and we see even in our solar system the parts of a system that are immeasurably distant from each other and between which the intermediate parts have not yet been discovered. Should there not be between Saturn, the outermost of the planets we know, and the least eccentric comet, which come down to us from a perhaps ten or more times greater distance, any other planet whose motion is closer to the cometic one than to that of Saturn? And should there not be still others that change the planets gradually into comets through a convergence of their determinations by means of a series of intermediate links, and the latter type be connected to the former?

The law according to which the eccentricity of the planetary orbits is inversely proportional to its distance from the Sun supports this assump-
1:257 tion. The eccentricity in the motions of the planets increases with their distance from the Sun and the remote planets thus come closer to the properties of the comets. It is therefore to be assumed that there will be other planets beyond Saturn, which, being even more eccentric and thus more closely related to comets, will ultimately, by a continuous ladder, turn them into comets. The eccentricity of Venus is 1/126th of half the axis of its elliptical orbit, that of the Earth is 1/58th, of Jupiter 1/20th

[k] *Werkmeister*

and of Saturn 1/17th; it therefore evidently increases with the distances. It is true that Mercury and Mars are exceptions to this law because their eccentricity is much greater than the measure of their distance from the Sun permits, but we shall learn in what follows that precisely the same cause why some planets were granted a smaller mass at their formation also resulted in a lack of the tangential force[l] necessary for an orbital motion, consequently in eccentricity, consequently has left them incomplete in both these respects.

As a result, is it not probable that the decrease[32] in the eccentricity of the heavenly bodies immediately beyond Saturn should be just as moderate as it is in the closer ones, and that the planets, because of less sudden decreases,[m] are related to the class of comets? For it is certain that precisely this eccentricity constitutes the essential difference between comets and planets and that their tails and nebulous spheres are merely a consequence thereof; similarly it is certain that the same cause, whatever it may be, that has given the heavenly bodies their orbits, was not only weaker at greater distances to make the tangential force[n] equal to the sinking force[o] and has thus left the motions eccentric, but was for that reason also less able to bring the orbits of these spheres to a common plane on which the lower ones move and has thus brought about the deviation of the comets in all directions.

According to this assumption, we might perhaps still have hopes for the discovery of new planets beyond Saturn that would be more eccentric than and thus closer to the cometic property; but for just this reason we would be able to see it for only a brief time, namely in the time of its perihelion, which circumstance, together with the low degree 1:258
of approach and the weakness of the light, has so far prevented their discovery and must make it difficult in the future as well. The last planet and the first comet could, if people so wished, be called that one whose eccentricity would be so great that in its perihelion it would transect the orbit of the planet closest to it, perhaps, therefore, that of Saturn.

[l] *Schwunges*
[m] *Abfälle*
[n] *Drehungsschwung*
[o] *Senkungskraft*

Natural History and Theory of the Heavens

Part Two

On the first state of nature, the formation of the heavenly bodies, the causes of their motion and their systematic relations within the planetary structure in particular as well as in respect of the whole of creation

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See plastic Nature working to this end,
The single atoms each to other tend.
Attract, attracted to, the next in place,
Formed and impelled its neighbour to embrace,
See Matter next, with various life endu'd,
Press to one centre still.

Pope.[33]

1:261

Universal
Natural History and Theory of the Heavens.

PART TWO.
CHAPTER ONE.

Concerning the origin of the planetary system[p] *as such and the causes of its motions.*

Observation of the universe shows, in consideration of the changed relationships its parts have to one another and by which they show the cause from which they originate, two sides that are both equally probable and acceptable. If, on the one hand, we consider that six planets with ten satellites describe orbits around the Sun as their centre and all of them move towards one side, namely that side to which the Sun itself turns, which rules over all their orbits through the force of its attraction, that the orbits do not deviate far from a common plane, namely that of the extended equator of the suns, that in the case of the heavenly bodies most distant but still belonging to our solar system, where the common cause of the motion, according to what we can assume, was not as powerful as it was near the centre, deviations from those precise determinations took place that have a sufficient relation to the lack of impressed motion, if, as I say, we consider all these connections: then we are moved to believe that one cause, whatever it may be, has had a pervasive influence in the entire space of the system, and that the unity in the direction and posi-
1:262 tion of the planetary orbits is a consequence of the agreement they all must have had with the material cause by which they were set in motion.

On the other hand, if we consider the space in which the planets of our system orbit, it is completely empty* and deprived of any matter that might bring about a community of influence on these heavenly bodies and the agreement among their motions. This circumstance has been established with complete certainty and exceeds, if possible, the previous probability. Persuaded by this reason, Newton could not allow any material cause that would maintain the community of motions by extending it into the realm of the planetary system. He asserted that the

* I am here not examining whether this space can be called empty in the most proper sense. For here it suffices to note that all matter that might be encountered in this space is far too powerless to have any influence on the moved masses at issue.

[p] *Weltbau*

direct hand of God had arranged this order without the application of the forces of nature.

An impartial examination shows that the reasons are equally strong on both sides and both are to be regarded as being completely certain. However, it is just as clear that there must be a concept in which these apparently mutually conflicting reasons can and should be united and that we may seek the true system in this new concept. We propose to indicate it briefly. In the current constitution of space, in which the spheres of the entire world of planets orbit, there is no material cause that could impress or direct their motions. This space is completely empty or at least as good as empty; therefore it must once have been constituted differently and been filled with matter sufficiently powerful to transmit motion onto all the heavenly bodies contained in it and to make it consonant with its own and thus with that of all the others, and after the attraction had purified all the above-mentioned spaces and assembled all the dispersed matter in particular lumps, the planets, with the motions once impressed on them, must then continue their orbits freely and unchanged in a non-resisting space. The reasons for the probability first proposed certainly require this concept, and because there is no third possibility between these two cases, it may be regarded with an excellent kind of approval that elevates it above the appearance of a hypothesis. One might, if one wished to be expansive, ultimately arrive at the framework I propose to present of the origin of the universe[q] by pursuing on one's own a series of conclusions following from one another in the way of a mathematical method with all the splendour this involves and with even greater lustre than the presentation of physical matters generally tends to display; however I would prefer to present my opinions in the form of a hypothesis and leave it to the insight of the reader to examine their worthiness rather than to make their validity suspect by the illusion of a fallacious argument and, by convincing the ignorant, to lose the approval of the experts. 1:263

I assume that when all matter of which the spheres that constitute our solar system, all the planets and comets, consist, was dissolved into its elementary basic material at the beginning of all things, it occupied the entire space of the universe[r] in which these formed bodies now orbit. This state of nature, even if one considers it in and for itself without regard to any system, appears to be the simplest that could follow upon nothingness. At that time, nothing had formed yet. The arrangement of heavenly bodies distant from one another, their distance moderated by attraction, and their shape that derives from the equilibrium of the assembled matter, are a later state. Nature as it bordered directly on

[q] *Weltgebäude*

[r] *Weltgebäude*

creation, was as raw, as unformed as possible. However, even in the essential properties of the elements that make up chaos, the characteristic of that perfection can be felt that they have from their origin, in that their essence is a consequence of the eternal idea of divine reason. The simplest, the most universal properties that appear to have been designed without any intention, matter that seems to be merely passive and in need of forms and arrangement, has, in its simplest state, an endeavour to form itself into a more perfect state by a natural development. However, the **difference in the kinds of elements** contributes the greatest part to the
1:264 regulation of nature and the formation from chaos by which the state of rest that would prevail under a universal equality among the dispersed elements, is eliminated and the chaos in the points of the more strongly attracting particles begins to form. The species of this basic material are without doubt infinitely varied judging by the immeasurability nature shows in all directions. For that reason, those with the greatest specific density and attractive force, which, on their own, occupy less space and are also less common, will, with the same distribution throughout the space of the world, be more widely dispersed than the lighter types. Elements of 1,000 times greater specific mass are a thousand, perhaps a million times more dispersed than those lighter by the same measure. And since these gradations have to be thought of as being as infinite as possible, the former type of dispersed elements will be distant by a so much greater distance from one another as the latter, just as there can be bodily constituents of one type that exceeds another in density in the same measure as a sphere that has been described with the radius of the solar system does another that has a diameter of one thousandth of a line.[34]

In a space filled in such a way, universal rest lasts only a moment. The elements have essential forces to put each other into motion and they are a source of life for themselves. Matter immediately endeavours to form itself. The dispersed elements of the denser type collect all the matter of lesser specific weight from a sphere around themselves by means of attraction, but they themselves, together with the matter they have united within themselves, collect at those points where particles of even greater density are found, and these collect in the same way at yet denser ones and so forth. By following this self-forming nature in thought through the entire space of chaos, one will easily realize that all consequences of this activity would ultimately consist of the composition of various lumps, which would, after they had completed their formation, remain at rest and eternally unmoving because of the equality of attraction.

Nature, however, has still other forces in store which are expressed primarily when matter is dissolved into its particles, by which forces
1:265 they can repel one another and, by their conflict with the attractive force, bring about that motion that is, as it were, a continuous life in

nature.[35] Through this repulsive force, which is revealed in the elasticity of vapours, in the emission of strong-smelling bodies, and in the dispersion of all spirituous matter, and which is an undisputed phenomenon of nature, the elements descending to their attraction points are deflected from the straight line of their motion to one side, and the vertical descent ultimately changes into orbital motions encompassing the centre point of the descent.[36] In order to understand clearly the formation of the universe,[s] we shall now limit our observation from the infinite sum total of nature to one particular system, such as the one belonging to our Sun. After we have considered its creation, we shall proceed in a similar manner to the origin of the higher world orders and be able to summarize the infinity of the whole of creation in one doctrine.

If, accordingly, in a very large space, there is one point at which the attraction of the elements present there has a greater effect than elsewhere around it, then the basic material[t] of the elementary particles dispersed all around will descend to this point. The first effect of this universal descent is the formation of a body in this centre point of attraction, which grows, so to speak, from an infinitely small seed in rapid steps,[37] but at precisely the same rate as this mass increases, it also moves the surrounding particles with greater force to unite with it. When the mass of this central body has grown to the extent that the velocity with which it attracts the particles from great distances, is bent sideways by the weak degrees of repulsion by which the particles hinder each other, and changes into sideways motions that are capable of encompassing the central body in a circle through centrifugal force,[u] then great eddies of particles are created, each of which describes its own curved line as a result of the combination of attractive force and the turning force directed sideways, which types of orbits all intersect each other, for which their great dispersion in this space gives them room.[38] These motions that are in conflict with one another in many ways, however, naturally strive to bring themselves into line with each other, that is, into a state in which one motion is as little hindrance to the other as possible. This occurs, firstly, by the particles of one restricting 1:266
the motion of the other until they are all moving in the same direction; secondly, that the particles restrict their vertical motion, by which they approach the centre of attraction until they are all as it were horizontal, that is, moving in parallel orbits with the Sun as the centre point until they no longer traverse each other and maintain themselves eternally in free orbits at the height at which they hover because of the equality of the tangential force[v] with the descending force, so that ultimately only

[s] *Weltbau*
[t] *Grundstoff*
[u] *Centerfliehkraft*
[v] *Schwungskraft*

those particles remain floating in the area of the space that have attained a speed through their descent and, through the resistance of the others, a direction such that they can continue a **free orbital motion**.[39] In this state, where all particles move in one direction and in parallel circles, namely in free orbital motion around the central body by means of the tangential forces[w] they have attained, the conflict and the convergence of the elements is resolved and everything is in the state of least interaction. This is the natural result into which matter, in all cases when it is involved in conflicting motions, is placed. It is clear therefore that of the dispersed particles a large number must arrive at such precise determinations by the resistance through which they seek to bring one another to this state, although an even much greater number does not arrive at it and merely serves to augment the lump of the central body into which they descend, since they cannot freely maintain themselves at the height at which they hover, but they transect the circles of the lower ones and finally lose all motion through their resistance. This body at the centre point of attraction, which according to the above has become the main piece of the planetary structure through the quantity of its collected matter, is the Sun, even though at that time it does not yet have the flaming heat that breaks out upon its surface after its formation is entirely complete.

It should be noted further that, since all the elements of self-forming nature are thus, as proved above, moving in one direction around the centre point of the Sun, in such orbits directed to a single region that run on a single common axis as it were, the rotation of fine matter cannot continue in this manner, because in accordance with the laws of central
1:267 motion, all orbits must transect the centre point of attraction with the plane of their orbits, but among all these orbits running in one direction around a common axis, there is only one that transects the centre point of the Sun, for which reason all matter rushes from both sides of this axis drawn in thought to that circle which goes through the axis of the rotation exactly in the centre point of the common descent. Which circle is the plane of reference of all the floating elements, around which they accumulate as much as possible and leave the regions distant from this area empty; for those that cannot come so close to the area to which everything is crowding, will not always be able to maintain themselves in the places where they hover, but rather will bring about their ultimate fall to the Sun by bumping into the elements floating around.

If, therefore, one considers this basic material[x] of the universe[y] floating around in such a state into which it places itself by attraction and by the mechanical result of the general laws of resistance, then we see a

[w] *Schwungskräfte*
[x] *Grundstoff*
[y] *Weltmaterie*

space contained between two areas not far removed from one another, in the middle of which there is the general plane of reference, spread out from the centre point of the Sun into unknown distances, in which all the included particles, each according to its height and the attraction prevalent there, carry out measured circular motions in free orbits and thus, since in this state they hinder each other as little as possible anymore, would always remain in that state, if the attraction of these particles of the basic material among each other did not begin to have its effect and bring about new formations which are the seeds of planets that are to come into being. For since the elements moving around the Sun in parallel circles, taken in not too great a difference of their distance from the Sun, are almost at rest in respect to each other because of the equality of their parallel motion, the pull of the elements found there immediately has a considerable effect,* through superior specific attraction, of beginning the accumulation of the next particles for the 1:268
formation of a body, which extends its attraction in accordance with the degree of the growth of its lump and moves the elements from a large distance to constitute it.

The formation of the planets in this system has this advantage over any other possible doctrine: that the origin of the masses also represents the origin of the motions and the position of the orbits at one and the same time; indeed, that even the deviations from the greatest precision in these determinations, as well as the agreements, are revealed from one perspective. The planets are formed out of particles that have precise motions as circular orbits[z] at the height at which they hover: **thus the masses that are constituted by them will continue exactly the same motions in exactly the same degree in exactly the same direction**. This is sufficient to have insight into why the motion of the planets is approximately circular in form and their orbits are on one plane. Indeed they would be completely precise circles† if the distance out of which they

* The beginning of forming planets cannot be sought in Newtonian attraction alone. In the case of a small particle of such exceptional fineness, it would be too slow and too weak. One would rather say that in this space, the first formation would occur through the flowing together of some elements which unite according to the ordinary laws of combination, until the lump that resulted from it has gradually grown so much that Newtonian attractive force would enable it to become ever larger through its activity in the distance.

† The measured orbital motion actually affects only the planets near the Sun: for at the great distances where the furthest planets or even the comets were formed, it can easily be supposed that because the descending motion of the basic material is much weaker there, the enormity of the spaces in which they are dispersed is also greater, the elements there deviate by themselves from the circular motion and thus must be the cause of the bodies formed from them.

[z] *Zirkelkreisen*

accumulate the elements for their formation were very small and the differences in their motions were thus very slight. But since for this it is necessary for there to be a wide circumference to form a dense lump of a planet out of the fine basic matter that is so very much dispersed in the heavens: thus the difference between the distances of these elements from the Sun and thus also the difference between their velocities is no longer insignificant, so that it would be necessary that, in order for the equality of the central forces and the circular velocity to be maintained for the planets with this difference between the motions, the particles
1:269 that accumulate on it from different levels with different motions, would replace the deficits of each other precisely, which, though it in fact happens fairly precisely,* nonetheless, since there is something missing in this complete replacement, affects the decline of the orbital motions and the eccentricity. It is equally clear that, even though the orbits of all the planets really ought to be in one plane, we do nonetheless encounter a slight deviation in this because, as already mentioned, the elementary particles, since they are as close as possible to the general maintenance plane of their motions, nonetheless include some space on either side of it; since it would then be altogether too great a coincidence if all the planets were to begin forming exactly in the centre between these two sides in the plane of the relation, which would already cause some inclination of their orbits towards each other, even though the endeavour of the particles to limit this deviation as much as possible from both sides, allows it only narrow limits. One should therefore not be surprised to come upon the most precise determinations here no more than in all things of nature because in general the large number of different circumstances that form part of any aspect of nature does not permit a measured regularity.

CHAPTER TWO.

Concerning the varying density of the planets and the ratios of their masses.

We have shown that the particles of the elementary basic material, since they were, considered by themselves, equally dispersed throughout the universe, have, through their descent towards the Sun, remained hovering in those places where the velocity they attained in their fall was
1:270 equal to the attractive force and thus their direction was deflected vertically against the orbital ray such as it should be with an orbital motion.

* For the particles from the region nearer the Sun, which have a greater orbital velocity than is required where they accumulate on the planet, replace the velocity that is lacking in the particles further from the Sun that are incorporated into the same body, in order to move in a circular manner at the distance of the planet.

However, if we now consider particles of differential specific density at the same distance from the Sun, then those of greater specific weight penetrate further through the resistance of the others to the Sun and are not deflected as quickly from their path as the lighter ones, with the result that their motion becomes circular only with a greater proximity to the Sun. The elements of the lighter kind, by contrast, which are more readily deflected from the straight line of their fall, will change into orbital motions before they have penetrated so deeply to the centre, and will thus remain hovering at greater distances, and cannot penetrate so far through the filled space of the elements without their motion through these being weakened by their resistance and they are unable to achieve the high degree of velocity required for orbiting closer to the centre;[40] thus, after the equality of the motions has been attained, the specifically lighter particles will orbit at greater distances from the Sun, while the heavier ones will be found at closer distances and the planets formed by them will therefore be of a denser kind and closer to the Sun than those forming themselves out of the accumulation of those atoms further from it.

It is thus a kind of a static law that determines the heights of the matter of the universe in inverse ratio to their density. Even so it is just as easy to comprehend that any height need not admit only particles of the same specific density. Of the particles of a certain specific type, those that have descended to their orbit from greater distances, remain hovering at greater distances from the Sun and attain the moderation of their descent necessary for a constant orbit at a greater distance, while those whose original position was nearer the Sun at the universal distribution of matter in the chaos will come closer to the Sun for their orbit, even if they are not necessarily denser. And therefore since the positions of the materials in respect of the centre point of their descent are determined not only by their specific weight but also by their original positions in the first state of rest in nature, it is easy to consider that their very different types will come together at any given distance from the Sun, remaining hanging[41] there, but that generally the denser matter will be encountered closer to the centre point than further from it, and that therefore, even though the planets will be a mixture of very different matters, their masses must be altogether denser the closer they are to the Sun, and of lower density the greater their distance from it. 1:271

In consideration of this law of the density of planets, our system shows an excellent perfection compared to all those concepts people have had, or might yet have, about their cause. **Newton**, who had established the density of some planets through calculation, believed he had found the cause of their ratio arranged according to distance in the propriety of God's choice and in the motivations of his final purpose: because the

planets closer to the Sun have to tolerate greater heat from it and the more distant ones have to manage with fewer degrees of warmth, which appears not to be possible if the planets closer to the Sun were not of a denser kind and the more distant ones not composed of lighter matter.[42] However, it does not take a great deal of reflection to have insight into the inadequacy of such an explanation. A planet, for instance our Earth, is composed of very greatly differing types of matter; among these it was necessary that the lighter ones, which are penetrated more and moved by the same effect of the Sun and whose composition has a ratio to the warmth by which its rays have their effect, had to be spread out on the surface; but it does not follow from this that the mixture of the other matter in the whole of the lump must have the same ratio; since the Sun has no effect upon the inside of the planet at all. Newton feared that if the Earth were lowered into the rays of the Sun as far as the distance of Mercury, it would burn like a comet and its matter would not have sufficient resistance to fire not to be dispersed by this heat. But how much more would the matter of the Sun itself, which is four times lighter than that of which the Earth consists, be destroyed by this heat, or why is the Moon twice as dense as the Earth when it orbits at the same distance from the Sun? Thus one cannot ascribe the
1:272 proportionate densities to their relation to the Sun's warmth without involving oneself in the greatest contradictions. Rather one will see that a cause that distributes the positions of the planets according to the density of their lumps, would have to have a ratio to the interior of its matter and not the surface; regardless of this consequence which it determined, it must also allow a difference in the matter in that same heavenly body and establish this relationship of density only in terms of the whole of the composition; and I leave it to the insight of the reader to judge whether there is any law of statics other than that advanced in our doctrines that will do justice to all of this.

The ratio of the densities of the planets involves another issue that confirms the correctness of our doctrine by way of the complete correspondence with the explanation outlined earlier. That heavenly body that stands at the centre of other spheres orbiting around it is usually of a lighter kind than the body orbiting next to it. The Earth in relation to the Moon and the Sun in relation to the Earth evince such a ratio of their densities. According to the conception we have presented, this is a necessary state of affairs. For, since the lower planets were formed mainly from the remainders of elementary matter, which by the advantage of its density have been able to make their way to such a proximity to the centre point with the requisite degree of velocity, whereas the body at the centre point itself has been piled together without any difference out of the materials of all available types which have not attained

their motion in accordance with law,[a] among which since the lighter materials constitute the largest proportion, it is easy to see that, because the heavenly body, or bodies, orbiting nearest to the centre point contains within itself as it were a separation of denser types, while the central body contains an undifferentiated mixture, the former will be of a denser kind than the latter. In fact, the Moon is twice as dense as the Earth and the Earth is four times denser than the Sun, which, according to what we can suppose, will be surpassed in yet greater degrees of density by the still lower planets, Venus and Mercury.[43]

We now turn our attention to the ratio that the masses of the heavenly bodies ought to have according to our doctrine in comparison to 1:273
their distances in order to test the result of our system against Newton's infallible calculations. We do not need many words to make it comprehensible that the central body must always be the main part of its system and that therefore the Sun must be much greater in mass than all the planets, just as this will apply to Jupiter in relation to its satellites and to Saturn in relation to its own. The central body is formed from the precipitation of all the particles out of the entire area of its sphere of attraction, which have not been able to obtain the most precise determination of the orbital motion and the close relationship to the common plane and of which there must be a very much greater number than the latter. To apply this observation primarily to the Sun: if we were to wish to estimate the extent of the space by which the orbiting particles that served the planets as their basic matter have deviated from the common plane at the furthest point, then we may assume it to be approximately somewhat larger than the extent of the greatest deviation of the planetary orbits from one another. Now, however, their greatest inclination towards one another, when they deviate in both directions from the common plane, is hardly seven and a half degrees. We can therefore represent all the matter from which the planets were formed as having been dispersed in that space which was between two surfaces encompassing an angle of seven and a half degrees from the perspective of the centre point of the Sun. Now, a zone of seven and a half degrees breadth in the direction of the greatest orbit is a little more than one seventeenth part of the surface area of the sphere, that is, the physical space between the two planes that excise the spheroidal space in the size of the aforementioned angle is somewhat more than one seventeenth part of the physical content of the whole sphere. According to this hypothesis, therefore, all the matter that was required for the formation of the planets, constitutes approximately one seventeenth part of that matter which the Sun has accumulated from both sides for its composition from the distance of the outermost planet.

[a] *gesetzmäßige Bewegung*

This central body, however, has an advantage of the lump as against the total content of all planets which is not in a ratio of 17:1, but of 650 to 1, as determined by Newton's calculations;[44] but it is also easy to see that in
1:274 the higher spaces above Saturn, where planetary formations either cease or are rare, where only a few cometic bodies have formed,[45] and where primarily the motions of the basic matter, in that they are not suited to attaining that equality of the central powers governed by the laws of nature, as in the areas close to the centre, precipitate only an almost universal descent to the centre point and supplement the Sun with all the matter from such widely distributed spaces that, I say, for these reasons the lump of the Sun would have to reach such a particularly large size of mass.

However, to compare the planets in respect of their masses, we note firstly that, in accordance with the method of formation shown above, the quantity of matter in the composition of a planet depends on its distance from the Sun: 1) because the Sun limits the sphere of attraction of a planet by its own attraction, but it does not limit the more distant ones as much as the closer ones under the same circumstances; 2) because the orbits from which all the particles have accumulated to constitute a more distant planet are described by a larger radius, that is, more basic matter than is contained in the smaller orbits; 3) because for the reason just given, the width between the two planes of the largest deviation is greater at greater heights at the same number of degrees than in smaller ones. By contrast, this advantage of the more distant planets compared to the closer ones is limited by the fact that the particles closer to the Sun will be of a more dense kind and, by all appearances, less spread out than those at a great distance; it is, however, easy to appreciate that the former advantages for the formation of large masses nonetheless greatly surpass the latter limitations and that altogether, the planets that form at a great distance from the Sun must receive greater masses than those closer. This, then, takes place insofar as we imagine the formation of a planet only in the presence of the Sun; but if we have several planets form at varying distances, then one will limit the extent of the attraction of the other by its sphere of attraction, and this creates an exception to the above law. For that planet which is close to another of exceptional mass,
1:275 will lose a great deal of the sphere of its formation and thus become much smaller than the ratio of its distance from the Sun alone would require. Although, therefore, in general the planets are of greater mass the further they are from the Sun, as altogether Saturn and Jupiter, the two main elements of our system, are in fact the largest because they are most distant from the Sun, there are nonetheless departures from this analogy, in which however the characteristic of the general formation, which we assert for all heavenly bodies, shines forth at all times: namely that a planet of exceptional size will deprive those planets nearest to it on

both sides of the mass that would be due to them because of their distance from the Sun, by absorbing part of the matter that should have belonged to their formation. In fact, Mars, which should be larger than the Earth given its position, has lost some of its mass through the attractive force of Jupiter which is so large and close to it; and Saturn itself, even though it has an advantage over Mars on account of its distance, has not been entirely free from suffering a considerable loss from Jupiter's attraction, and it seems to me that Mercury owes the exceptional smallness of its mass not only to the attraction of the mighty Sun so close to it, but also to the proximity of Venus, which, if we were to compare its density with its size, must be a planet of considerable mass.

Now since everything fits together in as excellent a manner as one might wish to confirm the adequacy of a mechanical doctrine at the origin of the universe and the heavenly bodies, we will now, by estimating the space in which the basic matter of the planets was spread before their formation, consider to what degree of thinness this intermediate space was then filled, and with what freedom, or with how few hindrances, the floating particles were able to behave in it according to the laws of their motion. If the space that encompassed all the matter of the planets was contained in that part of the sphere of Saturn which, viewed from the centre point of the Sun, was encompassed between two planes separated from each other at all heights by seven degrees and was therefore one seventeenth part of the whole sphere that one can describe with the radius of the height of Saturn, then, to calculate the thinness of the planetary 1:276
basic matter when it filled this space, we will assume the height of Saturn to be only 100,000 diameters of the Earth; therefore the whole sphere of the orbit of Saturn will exceed the volume of the Earth's sphere 1000 billion[46] times,[47] of which, if we assume only a twentieth instead of a seventeenth part, the space in which the elementary basic material hovered, must still exceed the volume of the Earth's sphere 50 billion times. Now if we assume with Newton that the mass of all the planets and their satellites is 1/650 of that of the Sun, then the ratio of the Earth, which is only 1/169282 of it, to the total mass of all planetary matter is 1 to 276 1/2, and if one were then to bring all this matter to the same specific density of the Earth, a body would be created that would occupy a space 277 1/2 times that of the Earth. If, therefore, we assume the density of the Earth in its entire lump to be not much greater than the density of the firm matter we find under the topmost surface, as the properties of the figure of the Earth require, and assume that these upper materials are approximately 4 to 5 times denser than water and water 1,000 times heavier than air,[48] then the matter of all planets, if it were spread out to the thinness of the air, would occupy a space almost 14 times a hundred thousand times greater than the Earth. This space, compared with the space in which, according to our assumption, all the

matter of the planets was spread out, is thirty million times smaller: therefore the dispersion of the matter of the planets in this space also constitutes a thinning as many times greater than that which the particles of our atmosphere have. In fact, this magnitude of dispersion, as incredible as it may seem, was neither unnecessary nor unnatural. It had to be as great as possible to permit all freedom of motion to the hovering particles almost as though they were in empty space, and to reduce infinitely the resistance they can offer to each other, but they were also able to take on such a state of thinning by themselves, which one may not doubt if one knows a little of the expansion that matter suffers when it is transformed into vapours, or if, to remain with the heavens, one
1:277 considers the thinning of matter in the tails of comets, which, despite so enormous a thickness of their cross-section, which probably exceeds the diameter of the Earth a hundred times, are nonetheless so transparent that small stars can be seen through them,[49] which our air does not permit when it is illuminated by the Sun at a height that is many thousand times smaller.

I shall conclude this chapter by adding an analogy which, all by itself, is able to raise the present theory of the mechanical formation of the heavenly bodies from the probability of a hypothesis to a certainty. If the Sun is made up of the particles of the same basic material of which the planets have constituted themselves, and if the only difference lies in the fact that in the former the matter of all types has been gathered without any differentiation, while in the latter they have been distributed at various distances in accordance with the constitution of the density of their varieties by their very own attractive forces,[50] and so if the matter of all the planets together is considered in its entire distribution, a density will have to emerge which is almost equivalent to the density of the Sun's body. Now this necessary consequence of our system finds a fortunate confirmation in the comparison that **Herr von Buffon**,[51] that so deservedly famous philosopher, has proposed between the densities of the entire planetary matter and of the suns; he found a similarity between the two of them that was 640 to 650. If the necessary consequences that result from a doctrine in a non-artificial way are confirmed by the actual relations in nature, then can we believe that mere arbitrariness has caused this agreement between theory and observation?

CHAPTER THREE.

On the eccentricity of the planetary orbits and the origin of comets.

It is not possible to create a special type of heavenly bodies out of the comets that is entirely distinct from the family of planets. Nature acts

here, as elsewhere, through imperceptible gradations, and, by passing 1:278
through all stages of change, it connects the distant properties to the closer ones by means of a chain of links. Eccentricity in the planets is a consequence of the deficiency in that effort by which nature strives to make the planetary motions like a circle, which, however, it can never attain completely because various circumstances get in the way, but from which it deviates more at greater distances than at smaller ones.

This determination leads, through all possible stages of eccentricity, via a continuous ladder from the planets finally to the comets and although this connection appears to be severed at Saturn by a great chasm, which completely separates the cometic family from the planets, we did note in the first part that there may well be other planets beyond Saturn, which approach the orbits of the comets more closely by a greater deviation from the circular nature of the orbits, and that it is only as a result of a lack of observation, or of the difficulty of observation, that this relationship is not just as visible to the eye as it has been shown to be for the understanding.

In the first chapter of this part we already cited one cause that may make eccentric the orbit of a heavenly body that is formed from the basic material hovering about, even if one assumes that this possesses in all of its places forces that correspond exactly to circular motion. For, since the planet gathers them from heights that are very distant from each other where the velocities of the orbits are different, they encounter it with different degrees of inherent orbital motion that deviate from the degree of velocity appropriate to the distance of the planet and in this way give it an eccentricity to the extent that these varying impressions of the particles are unable to replace completely one another's deviation.

If the eccentricity had no other cause, then it would be moderate everywhere: it would be less in planets that are smaller and more distant from the Sun than in those that are closer and larger: that is, if one were to assume that the particles of the basic material really did previously have precisely circular motions. Now, as these conditions do not correspond 1:279
to observation in that, as already noted, the eccentricity increases with the distance from the Sun, and the smallness of the masses appears rather to constitute an exception to the increase, as we see in the case of Mars, so we are forced to restrict the hypothesis of the precise circular motion of the particles of the basic material in such a way that we admit that they come very close to this precise determination in those regions close to the Sun but deviate from it more the further these elementary particles have floated away from the Sun. Moderating the principle of free circular motion of the basic material in this way is more appropriate to nature. For, irrespective of the thinness of space that seems to leave them the freedom to limit each other to the point of a perfectly balanced equality

of central forces, the causes, nonetheless, are no less considerable to prevent this purpose of nature from reaching its fulfilment. The further the dispersed parts of the original material are distant from the Sun, the weaker the force that causes it to descend: The resistance of the lower parts, which are to bend their fall sidewards and force it to arrange its direction horizontally to the orbital ray, is reduced to the extent that these sink away from under it, either to become incorporated into the Sun, or to begin orbits in closer regions. The specific eminent lightness of this higher matter does not permit them to arrange the falling motion that is the ground of everything with the pressure that is required to cause the resisting particles to give way; and perhaps that these distant particles limit one another and finally reach this uniformity after a long period: thus, small masses have already formed as the beginnings of so many heavenly bodies which, because they condense out of weakly moved matter, have only an eccentric motion by which they sink towards the Sun and in so doing are increasingly bent away from a vertical fall by incorporating faster moving particles, but ultimately do remain comets when those spaces in which they have formed have become purified and empty by descending to the Sun or by condensing into separate lumps. This is the cause of the eccentricity of the planets increasing with
1:280 their distance from the Sun and of those heavenly bodies that are called comets because they greatly exceed the former in this property. It is true that there are still two exceptions that violate the law of eccentricity increasing with the distance from the Sun, and these may be observed with the two smallest planets of our system, Mars and Mercury; but in the case of the former, the cause is presumably the proximity of the great Jupiter, which, because it deprives Mars of the particles for its formation by its attraction towards its side, leaving it mainly only room to expand in the direction of the Sun, thus attains an excess of central force and eccentricity. As concerns Mercury, however, the lowest and also most eccentric of the planets, it is easy to see that, since the Sun does not come anywhere close to the speed of Mercury in its axial rotation, the resistance it offers to matter in the space around it would not deprive the nearest particles of their central motion but could easily extend this resistance as far as Mercury and in this way reduce its orbital speed considerably.

Eccentricity is the principal distinguishing feature of comets. Their atmospheres and tails, which expand when they approach the Sun due to its heat, are only consequences of the former, even though in times of ignorance they served as frightening images to announce imaginary fates to the rabble. Those astronomers who devoted more attention to the laws of motion than to the strangeness of their form, noticed a second property that distinguishes the family of comets from that of the planets, namely that they, unlike the others, are not bound to the zones of the

zodiac but arrange their orbits freely in all regions of the heavens. This peculiarity has the same cause as the eccentricity. If the planets have enclosed their orbits in the narrow regions of the zodiac because the elementary matter near the Sun attains circular motions, which attempt to cross the plane of reference at every orbit and will not allow the body once formed to deviate from this plane, to which all matter strives from both sides: therefore, the basic material of the spaces distant from the centre point, which, moved weakly by attraction, cannot attain a free circular orbit, precisely for the same reason that creates eccentricity must not be capable of consolidating itself at this level to the plane of reference of all planetary motion to maintain the bodies formed there in this track; rather, the dispersed basic material, because it is not restricted to a particular region as the lower planets are, will be formed into heavenly bodies just as easily on one side as on the other and far from the plane of reference just as often as close to it. For this reason the comets will come down to us from all regions with complete freedom; but those whose place of first formation is not elevated much above the orbit of the planets, will show less deviation from the boundaries of their orbits as well as less eccentricity. This lawless freedom of the comets, in relation to their deviations, increases with the distance from the centre point of the system, and loses itself in the depths of the heavens in a total absence of rotation, which leaves the bodies that are formed furthest away to fall freely to the Sun and sets the last borders to the systematic constitution. 1:281

In this outline of the motions of comets, I presuppose that for the most part, they will have they same direction as that of the planets. For the nearest comets this seems to me to be beyond doubt, and this uniformity cannot be lost in the depths of the heavens before the point where the elementary basic material in the greatest dullness[b] of motion brings about a rotation in any direction caused by, say, the descent, because the time required to unify them in regards to direction through the community of the lower motions, is, on account of the great distance, too long for it to extend that far while the formation of nature in the lower regions is taking place. There may therefore perhaps be comets that complete their orbits in the opposite direction, that is from east to west, even though, for reasons I would be reluctant to elaborate upon here, I would almost be persuaded that of the 19 comets where this peculiarity has been observed, optical illusions may have been the cause.

I must still note something about the masses of comets and about the density of their material. For reasons adduced in the previous chapter, in the upper areas of the formation of these heavenly bodies, greater masses ought by rights to form in relation to the distance. And it is also 1:282

[b] *Mattigkeit*

credible that some comets are larger than Saturn and Jupiter; but it is just not credible that this size of the masses will continue to increase in this way. The dispersion of the basic material, the specific lightness of its particles slow the formation in the most distant region of space; its indeterminate spreading in the whole immeasurable extent of this distance without any determination to become more condensed in the direction of a particular plane, brings about many smaller formations instead of a single considerable one and the lack of any central force attracts the greater part of the particles down to the Sun without having condensed into masses.

The specific density of the material of which the comets are formed is of greater interest than the size of their masses. Presumably, since they form in the uppermost region of the universe,[c] the particles of their constituents are of the lightest type; and we cannot doubt that this is the principal cause of the vaporous spheres and the tails that characterize them in relation to other heavenly bodies. We cannot regard the effects of the heat of the Sun as the principal cause of this dispersion of the cometic matter into a vapour; some comets scarcely reach down to the Earth's orbit in their proximity to the Sun; many remain between the orbit of the Earth and that of Venus and then return. If so moderate a degree of heat dissolves and thins the materials on the surface of these bodies to such an extent, then they must consist of the lightest matter, which suffers greater thinning through heat than any other material in all of nature.

Nor can we attribute these vapours that rise so frequently from the comets to the heat that its body has retained from some earlier proximity to the Sun: for while it can be presumed that a comet, at the time of its formation, has covered numerous orbits with greater eccentricity and that they have only gradually been decreased, the other planets, of which we might suppose the same, do not exhibit this phenomenon.
1:283 They would, however, display it themselves if the kinds of the lightest matter that are included in the constitution of the planet were present as commonly as they are in the comets.

The Earth has something about it that may be compared to the dispersion of the cometic vapours and their tails.* The finest particles that the Sun's activity draws from its surface are concentrated around one of its poles, when the Sun proceeds through half of its orbit towards the opposite hemisphere. The smallest and most active particles that rise up in the burning belt[52] of the Earth, after they have reached a certain height of the atmosphere, are forced by the activity of the Sun's rays to

* These are the Northern Lights.

[c] *Weltgebäude*

retreat to and to condense in those areas which are then turned away from the Sun and buried in a long night, and so compensate the inhabitants of the Arctic for the absence of the great light, which sends the effects of its warmth even at this distance. Precisely the same force of the Sun's rays that creates the Northern Lights would also bring about a vapour circle with a tail if the finest and most fleeting particles were to be found as commonly on Earth as they are on the comets.

CHAPTER FOUR.

Concerning the origin of the moons and the motion of the planets around their axes.

A planet's endeavour to form itself out of the surroundings of the elementary matter is at the same time the cause of its revolving around its axis and brings about the moons that are to orbit around it. What the Sun is to its planets on a large scale is represented on a smaller one by a planet that has a widely dispersed sphere of attraction, namely the main part of a system, the parts of which have been set in motion by the attraction of the central body. As the planet forms, by moving the particles of the basic material out of the entire surroundings to form it, it will create circular motions out of all these sinking motions by means of their reciprocal effects and indeed finally create such motions that will 1:284
adopt a common direction and of these one part receives an appropriate measure[d] of the free orbit and in this limitation will find itself close to a common plane. In this space, moons will form around it, just as the main planets do around the Sun, if the distance of the attraction of such heavenly bodies provides favourable circumstances for their creation. What has been said in addition about the origin of the solar system can be applied with sufficient similarity to the system of Jupiter and that of Saturn. The moons will all have arranged the circles of their orbits in one direction and almost in one plane and this, indeed, for the same reasons as determine the analogy on the large scale. But why do these satellites move in their common direction in the direction in which the planets move rather than in any other? Their orbits are, after all, not created by the circular motions: They merely recognize the attraction of the main planet as the cause, and in consideration of this, all directions are equivalent; some merely arbitrary thing will decide the direction out of all those possible that the descending motion of the material will take in orbits. In fact, the orbit of the main planet does nothing to impress any revolutions into the material that is to form the moons around it; all the particles around the planet move in the same motion with it around

[d] *Mäßigung*

the Sun and are thus at rest relative to it. The attraction of the planet alone does everything. But the circular motion which is to arise from it, because in and of itself it is equivalent in relation to all directions, requires only a small external determination to move in one direction rather than another; and it receives this small degree of direction from the advancement of the elementary particles which also orbit around the Sun but with greater velocity and come into the planet's sphere of attraction. For this forces the particles nearer the Sun, which orbit with a greater tangential force,[e] to depart from the direction of their track and to elevate themselves above the planet in an oblong deviation. Because they have a greater degree of velocity than the planet itself, when these
1:285 are brought to descend by its attraction, they impart to their straight fall and also to the fall of the others a deviation from west to east and this slight steering is all that is required to cause the orbit that the fall, brought about by the attraction, takes on, to adopt this direction rather than any other. For this reason, all the moons will coincide with the direction of the orbit of the main planet. However, the plane of its path cannot depart much from the plane of the planetary orbit, because the matter from which they are formed is steered, for the same reason that we have advanced about directions altogether, to its most precise determination, namely the coincidence with the plane of the main orbits.

From all this one can see clearly under what circumstances a planet might acquire satellites. Its attractive force must be great and consequently the extent of its sphere of activity must be extensive, so that the particles, moved by a lengthy fall towards the planet, regardless of what the resistance cancels out, can attain a sufficient velocity for a free orbit and in addition there must be enough material present in the area for the formation of the moons, which cannot occur if the attraction is too small. Therefore only planets with a great mass and at a great distance are endowed with satellites. Jupiter and Saturn, the two largest and most distant of the planets have the largest number of moons. The Earth, which is much smaller than they, has only received one; and Mars, which would deserve some share in this advantage on account of its distance goes empty-handed because its mass is so small.

It gives one some pleasure to observe how the same attraction of the planet that supplied the material for the formation of the moons and, at the same time, determined their motion, also extends to its own body and that this, through the same action by which it forms itself, gives itself a rotation around its axis in the general direction of west to east. The particles of the falling basic material, which, as mentioned above, acquire a general motion from west to east, fall for the most part onto the surface of the planet and are mixed with its lump, because they do

[e] *Schwung*

not have the degrees requisite to maintain themselves in free suspension in orbital motions. Now when they combine with the planet, being parts 1:286
of it, they must continue the same rotation in the same direction that they had before they were united with it. And because it can be seen from the above in any case that the number of particles that the lack of the requisite motion causes to crash onto the central body must greatly exceed the number of those others which have been able to acquire the requisite degree of velocity, it is easy to understand why this body will not have nearly the velocity to achieve a balance between the gravity on its surface and the centrifugal force, but nonetheless the velocity will be much larger with planets of great mass and far away than with small and close ones. In fact Jupiter has the fastest axial rotation that we are aware of[53] and I do not know according to what system one could make it compatible with a body whose lump exceeds all others unless one considers its motions as themselves the effect of that attraction which this celestial body exercises in accordance with the measure of this very lump. If the axial rotation were an effect of an external cause, then Mars would have to have a faster one than Jupiter, because the very same motive force moves a smaller body more than a larger one, and, in addition, one would rightly be astonished at this, how, since all motions decrease the further they are from the centre point, the velocities of the rotations increase with the same distances and in the case of Jupiter are even three and a half times greater than its annual motion itself could be.

Since one is therefore forced to recognize the same cause in the daily rotation of the planets that is the universal source of motion in nature, namely attraction, this manner of explanation will validate its legitimacy by the natural prerogative of its basic concept and by the effortless consequences thereof.

If, however, it is the formation of a body itself that causes rotation around an axis, then it stands to reason that all spheres in the universe[f] must have it; but why does the Moon not have it, which appears to some, albeit wrongly, to have that kind of rotation by which it always shows the same side to the earth because of a kind of excess weight of one of its hemispheres rather than from an actual motion[g] of revolution? Could it 1:287
be that it once rotated more rapidly around its axis and has since, for I know not what reason, slowed down to this slight and definite remainder? One has only to answer this question in relation to one of the planets to see that the result applies to all. I shall save this solution for another occasion[54] because it is necessarily related to the topic set for the prize by the Royal Academy of Sciences in Berlin for 1754.

[f] *Weltbau*

[g] *Schwung*

Any theory seeking to explain the origin of rotations must also be capable of deducing the position of their axes in relation to the plane of their orbits from the same causes. We have reason to wonder why the equator of daily rotation is not in the same plane as the surface of the moons that orbit the same planet; because the same motion that has determined the orbit of a satellite ought, by extending to the body of the planet, also to bring about rotation around the axis and to give it the same direction and position. Heavenly bodies that have no satellites orbiting around them would nonetheless set themselves into an axial rotation through the very same motion of particles that served as their material and through the same law that restricted them to the plane of their periodic orbit, which had to correspond to the direction of its plane of orbit for the same reason. As a consequence of these causes, the axes of all heavenly bodies would properly have to be vertical to the universal plane of reference of the planetary system, which does not deviate far from the ecliptic. They are, however, vertical only in the two most significant parts of this solar system, namely in the case of Jupiter and of the Sun; the others whose rotations are known to us, incline their axes towards the plane of their orbits, Saturn more than the others, and the Earth more than Mars, whose axis is almost vertical to the ecliptic. The equator of Saturn (insofar as we can consider it given by the direction of its ring) inclines at an angle of 31 degrees to the plane of its orbit, while that of
1:288 the Earth is only 23 1/2. One can perhaps also attribute the cause of these deviations to the difference in the motions of the material that have come together to form the planet. In the direction of the plane of its orbit the principal motion of the particles was around its centre and the plane of reference was there around which the elementary particles accumulated in order to make the motion there as close to a circle as possible and to accumulate material to form satellites, which never deviate far from the orbit for this reason. If the planet had been formed for the most part only of these particles, its axial rotation would have deviated from it at its original formation only as little as the satellites which circle around it; but it formed, as the theory has shown, more out of the particles that descended on both sides and the number and velocity of which does not appear to have been so completely balanced that one hemisphere may not have received a slightly greater impulse of motion than the other and therefore some deviation from its axis.

Despite these reasons, I am advancing this explanation only as a conjecture I do not trust myself to decide. My real opinion comes to this: that the rotation of the planets around their axes in the original state of their first formation coincided fairly exactly with the plane of their annual orbit and that there were causes present to push this axis out of its original position. A heavenly body changing from its first fluid state into a solid state undergoes a great change in the regularity of its

surface when it forms completely in this way. The surface becomes firm and hardened while the deeper matters have not yet sunk sufficiently in accordance with their specific gravity;[b] the lighter types that were intermingled with their lumps, after they have separated out from the others, finally move underneath the topmost crust that has become firm and create the great caves, the largest and most extensive of which, for reasons that would take too long to adduce here, are to be found at or near the equator, into which the aforementioned crust finally sinks and creates all types of irregularities, mountains, and caves. Now, if the surface has become uneven in this way, as evidently happened with the Earth, the Moon, and Venus, then it can no longer achieve a rotational balance[i] in 1:289
its axial rotation on all sides. Some protruding parts of considerable mass, which had nothing on the other side that could provide them a counter-effect to their tangential force,[j] would then have had to shift the axis of the rotation and strive to put it into a position such that all the matter remains in balance. Therefore, the very same cause that changed the surface of a heavenly body from a level state to broken-off irregularities during its complete formation, this universal cause has necessitated some change in the original position of the axis of all the heavenly bodies that can be observed clearly enough with a telescope. This change, however, has its limits so that it will not deviate too far. As already mentioned, the irregularities are generated more near the equator of a rotating heavenly sphere than far from it; towards the poles, they disappear almost entirely, the causes of which I propose to explain on another occasion. For this reason the masses protruding furthest above the even surface will be found near the equinoctial circle and as these strive to approach the circle through the advantage of tangential force,[k] they will be able to raise the axis of the heavenly body at most by only a few degrees from a position vertical to the plane of its orbit. As a consequence, a heavenly body that is not yet fully formed will still retain this right-angled position of its axis to its orbit, which it will perhaps change only over the course of many centuries. Jupiter appears to be in this state still. The advantage of its mass and size, the lightness of its matter have forced it to overcome the firm state of its matter several centuries later than other heavenly bodies. Perhaps the interior of its lump is still in the motion of lowering the parts of its constituents to the centre in accordance with their mass and by separating the thinner types from the heavier ones to overcome the state of firmness. In this state of affairs its surface cannot yet appear calm. Devastation and ruins rule there. Even the telescope has assured us of this. The appearance of this planet is constantly changing while the Moon, Venus, and the Earth retain theirs unchanged. Also,

[b] *Schwere*
[i] *das Gleichgewicht des Umschwunges*
[j] *Schwung*
[k] *Schwung*

1:290 one can probably rightly imagine the completion of the period of formation as being several centuries later in the case of a heavenly body that surpasses our Earth in size by more than twenty thousand times and is only a quarter as dense. When its surface has attained a calm condition, then without doubt far greater irregularities than those that cover the Earth will, related to the speed[l] of its rotation,[m] give its rotation that constant position which the balance of forces on it will demand in a not very long time.

Saturn, three times smaller than Jupiter, may have obtained an advantage of a more rapid formation ahead of Jupiter, perhaps because of its greater distance; at least its much faster axial rotation and the large ratio of its centrifugal force[n] to the gravity on its surface (which is to be presented in the following chapter) will bring it about that the irregularities presumably caused thereby on the surface will soon have been decisive on the side of the superior force by a shift in the axis. I freely admit that this part of my system, which is related to the position of the planetary axes, is still incomplete and rather far from being subjected to geometric calculations. I preferred to reveal this honestly rather than to detract from the power the rest of the doctrine has to be convincing by having recourse to all kinds of borrowed implausible reasons and thus giving it a weak side. The following chapter can provide a confirmation of the credibility of the whole hypothesis by which we have sought to explain the motions of the universe.[o]

CHAPTER FIVE.

On the origin of Saturn's ring and calculation of the daily rotation of this planet from its ratios.[55]

Thanks to the systematic constitution in the universe,[p] its parts are connected by a gradual alteration of their properties, and one may assume
1:291 that a planet in the furthermost region of the universe would have approximately such determinations as the next comet might take on if it were to be elevated to the family of planets through a reduction of its eccentricity. Accordingly, we shall consider Saturn in such a way as though it had travelled numerous orbits with greater eccentricity in the manner of cometic motion and had gradually been brought onto a track more

[l] *Schnelligkeit*
[m] *Schwung*
[n] *Centerfliehkraft*
[o] *Weltbau*
[p] *Weltgebäude*

similar to a circle.* The heat it acquired when it was close to the Sun raised from its surface the light material, which, as we know from the previous chapters, is exceedingly thin on the highest heavenly bodies, and lets it expand by slight degrees of heat. However, after the planet had been brought to its current distance after numerous revolutions, in such a temperate climate it gradually lost the heat it had acquired, and the gases that continued to spread around it gradually ceased to rise as far as into the tails. Nor did any new ones arise frequently enough to increase the old ones; in short, the vapours that already surrounded it continued to hover around it for reasons we shall give in a moment and retained for it the characteristic of its former comet-like nature in a constant ring, while its body emitted the heat and finally became a quiet and purified planet. Now we shall reveal the secret that has enabled the heavenly body to retain its risen vapours hovering freely, indeed to transform it from an atmosphere spread out all around it into the shape of a ring at a distance all around. I am assuming that Saturn has had an axial rotation and nothing more than this is needed to reveal the whole secret. No other mechanism[q] than this single one has, by means of a direct mechanical result, brought about the above-mentioned phenomenon for the planet and I venture to assert that in all of nature, there are only a few things that can be attributed to so comprehensible an origin as this peculiarity 1:292
of the heavens can be developed from the raw state of its first formation.

The vapours rising from Saturn had motion in themselves and continued it freely at the height to which they had risen and that they had as parts at its axial rotation. Those particles that rose near the equator of the planet must have had the fastest motion while the motion was weaker further away towards the poles in proportion to the latitude of the place from which they rose. The particles were assigned to the various heights to which they rose according to the ratio of their specific gravity, but only those particles were able to maintain the places of their distance in a constantly free orbital motion whose distances, into which they had been placed, required such a central force as they were able to achieve with the velocity they had from the orbital motion; the remaining ones, insofar as they cannot be brought to this precision by the interaction of the others, must either depart from the sphere of the planet with the excess motion, or else be forced to sink back onto the planet by a lack of motion. The particles dispersed through the entire extent of the vapour

* Or, what may be more probable, that in its comet-like nature, which it still has about it now thanks to its eccentricity, before its lightest surface matter had been completely dispersed, it spread a cometic atmosphere.

[q] *Triebwerk*

sphere will seek, by means of the very same central laws, in the motion of its revolution, to transect the equatorial plane of the planet from both sides and they will accumulate there when they detain one another, by meeting one another in this plane from both hemispheres; and because I assume that the aforementioned vapours are the ones that the planet sends up last in its cooling, all the dispersed vaporous matter will accumulate next to this plane in a narrow space and leave the spaces empty on both sides. But in this new and changed direction, they will nonetheless continue the same motion that maintains them hovering in free concentric orbits. In this way the vapour circle changes its shape, which was a filled sphere, into the shape of an extended plane which coincides exactly with Saturn's equator; but for the same mechanical reasons, this shape too must ultimately adopt the form of a ring, the outer edge of which is determined by the effect of the Sun's rays, which disperses and removes those particles that have moved to a certain distance from the
1:293 centre point of the planet; this is the same effect as happens in the case of comets and in this way it delineates the outer border of its circle of vapour. The interior edge of this emerging ring is determined by the ratio of the velocity of the planet at its equator. For, at the distance from its centre where this velocity achieves a balance with the attraction of the place is the greatest proximity in which the particles that have risen from its body can describe circular orbits through the motion peculiar to the axial rotation. The closer particles, because they require greater speed for such an orbit, which they cannot have since the motion is no faster even at the equator of the planet, will by this means acquire eccentric orbits that cross each other, weaken each other's motion, and finally all crash onto the planet from which they had risen. Here we now see that wondrously strange phenomenon, the sight of which has always filled astronomers with admiration since it was first discovered and to discover the cause of which no one has had even a probable hope, emerge in an easy mechanical manner, free from all hypotheses. What has happened to Saturn would, as can be seen from the above, happen just as regularly to every comet that had sufficient axial rotation, if it were placed in a constant height at which its body could gradually cool down. Even in chaos, nature is productive of excellent developments when its forces are left to themselves, and the ensuing formation brings with it such glorious connections and harmonies for the common benefit of creation that even in the eternal and immutable laws of its essential properties, they reveal with unanimous certainty that great Being in which they, as a result of their common[r] dependence, combine in a total harmony. Saturn has great advantages from its rings; it lengthens its day and lights up the night under so many moons to such an extent that it would be

[r] *gemeinschaftlichen*

easy to forget the absence of the Sun there. But must one therefore deny that the universal development[s] of matter in accordance with mechanical laws has been able to bring about connections that have created benefits 1:294
for creatures with reason without requiring laws other than their universal determinations? All beings are related as a result of one cause, which is the understanding of God; therefore they can have no consequences other than those that include a representation of perfection in that very same divine idea.

We shall now try to calculate the time of the axial rotation of this heavenly body from the ratios of its ring in accordance with the above hypothesis of its genesis. Because all motion of the particles of the ring is a motion embodied by the axial rotation of Saturn on whose surface they were placed, the most rapid motion of these particles coincides with the fastest rotation that can be found on the surface of Saturn; that is, the velocity with which the particles of the ring circle at the inside edge is equal to what the planet has at its equator. However, this can easily be found by seeking it in the velocity of one of Saturn's satellites by taking it in the ratio of the square root of the distances from the centre of the planet. From the velocity calculated, the duration of Saturn's rotation on its axis follows directly; *it is six hours twenty-three minutes and fifty-three seconds*.[56] This mathematical calculation of an unknown motion of a heavenly body, which is perhaps the only prediction of its kind in natural science proper, still awaits confirmation by the observation of future times. The telescopes known at present do not enlarge Saturn sufficiently to enable us to discover the spots we can assume to be on its surface so that we might see its rotation on its axis by their shifting. But telescopes have perhaps not yet attained the perfection one might hope from them and which the hard work and skill of the artisans seems to promise us. If in future we were to give proof to our conjectures by observation, what certainty would the theory of Saturn be given and what splendid credibility would the whole system have that is based upon the same reasons. The time of the daily rotation of Saturn also entails the ratio of the centrifugal force[t] of its equator to the gravity on its surface: this ratio 1:295
is 20:32. That is, gravity is only about 3/5th greater than the centrifugal force.[u] So great a ratio necessarily causes a very considerable difference in the diameters[57] of this planet and one might be concerned that it would have to emerge so large that observation of this planet, although magnified only a little by the telescope, would nonetheless show this only too clearly, which does not occur in reality, and that there could therefore be a detrimental effect on the theory. A thorough examination removes this difficulty completely. According to Huygens' hypothesis, which assumes

[s] *Entwickelung*
[t] *fliehende Kraft*
[u] *Centerfliehkraft*

that the gravity in the interior of a planet is the same throughout, the difference of the diameters is in a ratio to the diameter of the equator two times smaller than the centrifugal force[v] has to the gravity at the poles. For example, since in the case of Earth the centrifugal force[w] of the equator is 1/289th of the gravity at the poles, according to Huygens' hypothesis[58] the diameter of the equatorial plane must be 1/578th greater than the Earth's axis. The cause is this: since, according to the assumption, the gravity in the interior of the Earth's lump is as great at all distances from the centre as on the surface, while the centrifugal force[x] decreases as it approaches the centre, it is not 1/289th of the gravity everywhere but rather the whole decrease of gravity of the fluid column in the equatorial plane for this reason amounts not to 1/289th but to half of it, namely 1/578th. On the contrary, on Newton's hypothesis,[59] the centrifugal force,[y] which causes the axial rotation, has the same ratio to the gravity of the place in the whole plane of the Equator to the centre point; because, in the interior of the planet (if it is assumed to be of uniform density throughout), this decreases with the distance from the centre in the same proportion as the centrifugal force,[z] that is, it is always 1/289th of the former. This causes a lightening of the fluid column in the equatorial plane and also raises it by 1/289th, which difference of the diameters is further increased, according to this doctrine, by the shortening of the axis bringing about a convergence of the parts to the centre, that is an increase in the gravity, while the lengthening of the equatorial diameter results in a distancing of the
1:296 parts from the same centre and thus a decrease of its gravity and for this reason increases the flattening of the Newtonian spheroid in such a way that the difference of the diameters is raised from 1/289th to 1/250th.

For these reasons, the diameters of Saturn ought to stand in a greater ratio to one another than 20 to 32; they ought to come close to a proportion of 1 to 2, a difference that is so great that even the least attention could not fail to notice it, small though Saturn might appear in telescopes. However, from this it can be seen that the assumption of equal density that seems to be fairly correctly applied to the Earth deviates far too far from the truth for Saturn; which in itself is already probable for a planet the lump of which consists of the lightest materials for the greatest part of its content and in its composition[a] allows those of the heavier kind much greater freedom in sinking to the centre in accordance with their gravity than those heavenly bodies whose much denser matter delays the deposition of the matter and allows them to solidify before the sinking can take place. Thus, when we suppose that the density of

[v] *Centerfliehkraft*
[w] *fliehende Kraft*
[x] *Centrifugalkraft*
[y] *Centerfliehkraft*
[z] *Centerfliehkraft*
[a] *Zusammensatz*

the materials in Saturn's interior increases as it approaches the centre, the gravity no longer decreases in this ratio; rather the increasing density compensates for the absence of the parts that are positioned above the height of the point in the planet and do not contribute anything to its gravity[b] by their attractive force.* If this particular density of the deepest matters is very great, then in accordance with the laws of attraction, it changes the gravity that decreases as it nears the centre of the interior into an almost uniform one and brings the ratio of the diameters close to Huygens' ratio, which is always half of the ratio between the centrifugal force[c] and the gravity; consequently as these were to each other as 2:3, the difference of the diameters of this planet will be not 1/3rd but 1/6th of the equatorial diameter; this difference, finally, is hidden due to the fact that Saturn, whose axis forms an angle of 31 degrees to the plane of its orbit at all times, never shows its position towards its equator, the way Jupiter does, which reduces the appearance of the aforementioned difference by almost one third. Under such conditions and especially in view of the great distance of this planet, one can easily understand that the flattened shape of its body is not as easily visible as one might think; nonetheless, astronomy, whose progress depends primarily on the perfection of its tools, will be put in a position to discover so remarkable a property by their assistance, if I do not flatter myself too much. 1:297

What I say about the figure of Saturn can to some extent serve as a general remark concerning the doctrine of nature concerning the heavens. Jupiter, which according to a precise calculation has a ratio of gravity to centrifugal force[d] at its equator of at least 9 1/4:1, ought to present an even greater difference than 1/9 between its axis and the equatorial diameter if its lump were of uniform density throughout, according to Newton's theorems.[60] Cassini,[61] however, found it to be only 1/16th and Pound[62] 1/12th or 1/14th; all these different observations, which confirm the difficulty of this measurement by their differences, at least agree in positing it as much smaller than it ought to be according to Newton's system, or rather according to his hypothesis of uniform density. And if therefore one were to change the precondition of the uniform density that causes such a great deviation of the theory from observation into the much more probable one in which the density of the planetary lump

* For according to Newton's laws of attraction, a body in the interior of a sphere is attracted only by that part of it which has been described spherically around it at the distance it is from the centre point. The concentric parts outside this distance, because of the balance of their attractions that cancel each other out, add nothing to move the body either towards the centre or away from it.

[b] *Gravität*
[c] *Centrifugalkraft*
[d] *Centrifugalkraft*

is supposed to increase towards its centre, one will not only justify the observation in the case of Jupiter, but also, in the case of Saturn, a planet much more difficult to measure, have a more distinct insight into the cause of a lesser flattening of its spheroid body.

1:298 We have used the opportunity of the generation of Saturn's ring to take the bold step of determining by calculation the time of its axial rotation, which telescopes are not able to discover. Let us add another to this attempt at a physical prediction on this same planet which will await the proof of its correctness from the more perfect tools of future times.

In accordance with our assumption that the ring of Saturn is an accumulation of particles which, after they rose from the surface of this heavenly body as vapours, constantly maintain themselves freely in orbits at the height of their distance by means of the tangential force[e] they have and continue from the axial rotation, so they do not have the same periodic revolutions at all distances from the centre; rather, their ratio is as the square roots of the cubes of their distance if they are to maintain themselves hovering by the laws of the central forces.[63] Now, the time in which the particles of the inner edge complete their orbit is, according to this hypothesis, about 10 hours and the orbital time of the particles in the outer edge is 15 hours, after due calculation; that is, when the lowest parts of the ring have completed their orbits three times, the most distant ones have done so only twice. However, though we might estimate the interference the particles exert against one another in their great dispersion in the plane of the ring to be as low as we like, it is probable that the slowness of the more distant particles in each of their orbits gradually delays and holds up the faster moving lower parts, while these must impress a part of their motion on the higher parts for a more rapid orbit, which, if this interaction were not ultimately interrupted, would continue until the higher and lower particles of the ring had all been brought to the point of orbiting in the same time, so that in that state they would be at rest in relation to each other and by moving away they would have no effect on each other. But if the motion of the ring were to turn out like this, such a state would totally destroy the ring, because, if one takes the middle of the plane of the ring and assumes that the motion of the ring there would remain in

1:299 the state it previously was and must be in order to be able to perform a free orbit, the lower particles, since they had been held back considerably, would not maintain their height suspended, but would rather transect each other in oblique and eccentric motions, but the more distant ones, through the impression of a motion larger than it ought to be for the central force of its distance, would have to turn further away from

[e] *Schwung*

Saturn than the effect of the Sun determines the outer border of the ring, would, by the same effect, have to be scattered behind the planet and carried away.

However, we need not fear all this disorder. The mechanism of the motion that created the ring leads to a determination which puts the ring into a secure state by means of precisely the same causes that should destroy it, because it is divided into numerous concentric circular bands, which, due to the spaces separating them, have nothing more in common with each other. For when the particles circling the interior edge of the ring carry the higher ones along with them somewhat through their more rapid motion and accelerate their orbits, the increased degrees of velocity bring about in these an excess of centrifugal force[f] and a motion away from the position in which they were suspended. If, however, one presupposes that, when these endeavoured to separate themselves from the lower ones, they have a certain connection to overcome that appears to be not entirely insignificant in them even though they are scattered vapours, then this increased level of tangential force[g] will endeavour to overcome the connection mentioned above, but will not overcome it as long as the excess of centrifugal force[b] that it uses in the same orbiting time as the lowest ones does not exceed this cohesion beyond the central force[i] of its place.[j] And for this reason, the connection must remain in a certain breadth of a band of this ring, even though the upper ones must apply an endeavour to tear themselves away from the lower ones, since its parts complete their rotation in the same time; but not in a greater breadth, because while the velocity of these particles that are moved in equal times increases with the distance, hence more than it ought to according to the central laws, when it has exceeded the degree that the connection of the vapour particles can manage, they tear themselves away from these and must adopt a distance which is appropriate to the excess of the rotational force[k] over the central force of the place. In 1:300
this way the distance that separates the first band of the ring from the others is established; and in the same way, the accelerated motion of the upper particles resulting from the rapid revolution of the lower ones and their connection that strives to prevent the separation, creates the second concentric ring, from which the third stands apart by a moderate interval. We could calculate the number of these circular bands and the width of the intervals between them if we knew the degree of attraction that connects the particles to each other; however, we can be content with having surmised with a good degree of probability the composition

[f] *Centrifugalkraft*
[g] *des Schwunges*
[b] *Centerfliehkraft*
[i] *Centralkraft*
[j] *Anhängen*
[k] *Umwendungskraft*

of Saturn's ring, which prevents its destruction and maintains it hovering by means of free motions.

This conjecture pleases me not a little because of the hope of seeing it confirmed by actual observation one day. A few years ago, news came from London that, in observing Saturn through a new Newtonian telescope improved by Herr **Bradley**, it appeared that its ring was actually a combination of many concentric rings separated by spaces.
1:301 This news has not been continued since then.* The tools of vision have opened the furthest regions of the universe[l] to our understanding. Now if it depends primarily on them to take new steps here, then the attentiveness of the century to everything that can extend the insights of human beings will in all probability give us hope that it will primarily turn to a side that presents it with the greatest hope of important discoveries.

But if Saturn has been so fortunate as to acquire a ring for itself, why then has no other planet been able to participate in this advantage? The cause is clear. Because a ring is supposed to emerge from the evaporation of a planet given off in its raw state, and the axial rotation must give them the tangential force[m] that they have merely to continue once they have attained the height at which they can produce an exact balance with this established motion countering the gravitation towards the planet, we can easily calculate the height to which these vapours must rise above a planet for them to maintain free orbital motion by means of the motions they had at the planet's equator, if we know the diameter of the planet, the duration of its revolution, and the gravity on its surface. According to the law of central motion, the distance of a body that can freely circle a planet with a velocity equal to that of its axial rotation will be in the

* After I wrote this, I discovered a confirmation of this conjecture, which leaves virtually no doubt as to its correctness, in the *Mémoires* of the Royal Academy of Sciences in Paris for the year 1705 in a treatise by **Herr Cassini** *On the satellites and the ring of Saturn* on page 571 of Part two of the von Steinwehr translation.[64] After Herr Cassini has advanced an idea that could to some extent have been a small approach to the truth we have brought out, even though it is improbable in itself, namely that perhaps this ring could be a swarm of small satellites which, seen from Saturn, would look as the Milky Way does from the Earth (which thought could be considered if one takes the vapour particles that circle around it with the same motion to be the small satellites). He then goes on to say: **This thought is confirmed by the observations made in those years when the ring of Saturn appeared broader and more open. For the breadth of the ring was seen as being divided into two parts by a dark elliptical line, with the part nearest to the sphere brighter than the most distant one. This line marked as it were a small space between the two parts, just as the distance of the sphere from the rings is indicated by the greatest darkness between them both**.

[l] *Weltgebäudes* [m] *Schwung*

same ratio to half the diameter of the planet as the centrifugal force[n] at its equator is to its gravity. For these reasons, the distance of the inner edge of Saturn's ring was as 8, if the half diameter is assumed to be 5, which two numbers are in the same ratio as 32:20 and which, as we have noted above, express the proportion between the gravity and the centrifugal force[o] at the equator. For the same reasons, if one were to suppose that Jupiter had a ring produced in the same way, its smallest semi-diameter would exceed half the width of Jupiter 10 times, which would place it exactly where its most distant satellite revolves around it 1:302
and hence, for these reasons as well as because the evaporation of a planet cannot extend so far from it, it is impossible. If one wished to know why the Earth has not acquired a ring, one would find the answer in the size of the semi-diameter its inner edge would have to have, which would have to be 289 semi-diameters of the Earth in size. In the case of the slower moving planets, the production of a ring is even further removed from possibility; therefore, no case remains where a planet could have acquired a ring in the manner we have explained, other than that of the planet that really does have one, which is no small increase in the credibility of our mode of explanation.

However, what makes me almost sure that the ring around Saturn did not come about in the usual manner and was not produced by the universal laws of formation[p] that applied throughout the whole planetary system and provided Saturn with its satellites as well, that, I say this external matter did not supply its materials for this purpose but is rather a creature of the planet itself, which has raised its most volatile parts by means of heat and given them the tangential force[q] for orbiting[r] through its own axial rotation, is this: that the ring, unlike the planet's other satellites and all rotating bodies located in the company of the main planets in general is not directed in the general plane of reference of planetary motions, but deviates from it very much, which is a sure proof that it is not formed out of the universal basic material and did not receive its motion from its sinking, but rather rose from the planet long after its formation was complete and received motion and direction as a separate part of it based on the planet's axial rotation through its established rotational force.[s]

The pleasure at having understood one of the rarest peculiarities of the heavens in the entirety of its being and generation has involved us in so extensive a discussion. Let us, with the approval of our obliging readers, carry it further to the point of excess as much as we like so that, after we have abandoned ourselves in a pleasant way to arbitrary opinions

[n] *fliehende Kraft*
[o] *Centerfliehkraft*
[p] *Bildungsgesetze*
[q] *Schwung*
[r] *Umwendung*
[s] *Umschwungskräfte*

1:303 with a kind of lack of restraint, we can return again to the truth with all the greater care and caution.

Could we not imagine that the Earth once had a ring like Saturn? It could have risen from its surface just as Saturn's did and have remained for a long time while the Earth was slowed down by who knows what cause from a much faster rotation to its present rate, or that we can consider that universal basic material falling sideways was capable of having formed it in accordance with the rules explained above, which we do not have to take completely seriously if we want to indulge our penchant for oddities. But what a stock of lovely explanations and consequences such an idea presents us with! A ring around the Earth! What a beautiful sight for those created to inhabit the Earth as a paradise; what comfort for those on which nature smiles from all sides! But this is nothing compared with the confirmation such a hypothesis can borrow from the chronicle of the story of creation and which is no small recommendation for applause for those who believe they are not desecrating but rather confirming the honour of revealed religion when they make use of it to give the excesses of their wits some prestige. The water of the firmament mentioned in Moses' description has already caused the interpreters some effort. Could one not use this ring to help to get oneself out of this difficulty? Without a doubt this ring consisted of watery vapours, and in addition to the advantage it was able to provide the first inhabitants of the Earth, there is the additional one of having it break when required so that floods could punish the world which had made itself unworthy of such beauty. Either a comet, whose attraction brought confusion into the regular motions of its parts, or the cooling of the area of its location unified its dispersed vaporous particles and hurled it down onto the earth in one of the most gruesome cloudbursts. It is easy to know what the consequences of this were. The whole world disappeared under the water and in the strange and volatile vapours of this unnatural
1:304 rain also absorbed that slow poison which brought all creatures closer to death and destruction. Now the figure of a pale and light arc had disappeared from the horizon and the new world, which could never remember this sight without feeling terror in the face of this terrible tool of divine revenge, perhaps saw, with not a little consternation, in the first rain that coloured arc that appeared to copy the first in shape but, through the assurance of the reconciled heavens, was to be a sign of grace and a memorial of a continuing preservation of the Earth, changed as it now was. The similarity of the shape of this memorial sign with the event it signified could commend such a hypothesis to those who are devoted to the dominant tendency of bringing the miracles of revelation into the same system as the ordinary laws of nature. I consider it more advisable completely to forgo the fleeting applause such correspondences might arouse for the true pleasure that arises from the perception of regular

connections when physical analogies support each other to designate physical truths.

CHAPTER SIX.

On the light of the Zodiac.

The Sun is surrounded by a subtle and vaporous essence[t] which surrounds it in the plane of its equator with a very small width on both sides up to a great height and where we cannot be certain whether it abuts the surface of the Sun in the shape of an elevated polished glass (*figura lenticulari*) as **Herr von Mairan**[65] depicts it, or whether, like the ring of Saturn, it is separated from it all around. Regardless of whether it is the one or the other, there is sufficient similarity to permit a comparison of this phenomenon with the rings of Saturn and to derive it from a common origin. If this dispersed matter is an outflow from the Sun, as is the most probable way of viewing it, then we cannot fail to see the cause that has brought it into a common plane with the Sun's equator. The lightest 1:305
and most volatile material that the Sun's fire lifts from its surface and has done for a long time, is driven away far above it through its activity[u] and, in accordance with its lightness, remains hovering at a distance at which the repelling activity[v] of the rays achieves a balance with the gravity of these vaporous particles, or they are supported by the influx of new particles which are added to them continuously. Now, because the Sun, in turning on its axis, imparts its motion evenly to these vapours torn from its surface, they retain a certain tangential force[w] for rotation, such that, in accordance with the laws of central forces, they endeavour from both sides to transect the extended equatorial plane of the Sun in the circle of their motion; and therefore, since they push towards it from both hemispheres with the same quantity, they accumulate there with equal forces and form an extended level in the plane of reference of the Sun's equator.

Regardless of this similarity with the ring of Saturn, however, there remains an essential difference that makes the phenomenon of the zodiacal light very different from the former. The particles of the former maintain their free floating orbits by means of the rotational motion impressed on them, but the particles of the latter are maintained at their height by the force of the Sun's rays, without which the motion imparted to them by solar rotation would be insufficient by far to prevent them, in their free rotation, from falling. Because, as the centrifugal force[x] of

[t] *Wesen*
[u] *Wirkung*
[v] *forttreibende Wirkung*
[w] *Schwung*
[x] *fliehende Kraft*

the axial rotation on the surface of the Sun is not even 1/40,000 of the attraction, these risen vapours would have to be at a distance of 40,000 solar semi-diameters from it before it encountered a gravitation that could achieve a balance with that of the motion imparted to it. We are therefore sure that we cannot attribute this phenomenon to the Sun in the same way as was the case with the ring of Saturn.

Nonetheless, there remains a not inconsiderable probability that this necklace of the Sun perhaps has the same origin that all of nature has, namely its formation from the universal basic material, whose parts, since they had hovered around in the highest regions of the solar system, sank down to the Sun in a late fall only after the formation of the whole
1:306 system had been completely finished, in a weakened motion that still, however, curved from west to east, and, by means of this type of circular motion, transected the extended solar equatorial plane and, by staying there through their accumulation from both sides, adopted an extended plane in that position, in which they now maintain themselves continually, by being driven back partly by the Sun's rays, partly by the circular motion they have actually attained. The present explanation has no merit other than that which is due to conjectures and no claim other than for arbitrary approval; the judgement of the reader may turn to whichever side seems the most acceptable.

CHAPTER SEVEN.

On Creation in the entire extent of its infinity both in space and in time.

By its immeasurable magnitude and by the infinite diversity and beauty that shines forth from it on all sides, the universe[y] puts us into silent astonishment. While the representation of all this perfection moves the imagination, another sort of delight captures our understanding when it contemplates how so much splendour, so much grandeur flows from a single universal rule with an eternal and right[z] order. The planetary system,[a] in which the Sun, from the centre point of all orbits, makes the inhabited spheres of its system circle around in eternal orbits by means of its mighty attraction, is, as we have seen, entirely formed from the originally dispersed basic material of all worldly matter.[b] All the fixed stars that the eye discovers in the hollow depth of the heavens and that appear to demonstrate a kind of extravagance, are suns and centre points of similar systems. The analogy thus does not permit any doubt here that these were formed and generated in the same manner as the one in

[y] *Weltgebäude*
[z] *richtigen*
[a] *planetische Weltbau*
[b] *aller Weltmaterie*

which we find ourselves, out of the smallest parts of elementary matter that filled empty space, that infinite extent[c] of divine presence.

Now if all the worlds and world-orders recognize[d] the same type of origin, if the attraction is unlimited and universal, while the repulsion of the elements is similarly constantly active, if the large and the small are both small for the infinite being: Should not all the planetary systems[e] have adopted an interrelated constitution and a systematic relation to one another, in the same way as the heavenly bodies of our solar system have on a small scale, like Saturn, Jupiter, and the Earth, which are separate systems by themselves and yet are related to each other as parts in a yet much greater system? If one were to assume a point in the immeasurable space in which all the suns of the Milky Way have formed, around which for I know not what cause the first formation of nature began out of chaos, then the greatest mass and a body of the most uncommon attraction will have arisen there, which in this way became capable of forcing all the systems that were in the process of formation within a vast sphere to descend towards it as their centre point and to establish around itself a system that is identical on the scale of the whole as the same elementary basic matter that formed the planets has made around the Sun on a small scale. Observation makes this conjecture almost indubitable. Through its position relative to a common plane, the army of stars constitutes a system just as much as the planets of our solar system do around the Sun. The Milky Way is the zodiac of these higher world-orders, which deviate as little as possible from its zone, and whose band is always illuminated by its light, just as the zodiac of the planets shimmers from the light of these spheres now and then, albeit only at very few points. Each one of these suns with its circulating planets constitutes a separate system for itself; but this does not prevent them from being parts of a still greater system, just as Jupiter or Saturn, their own satellites notwithstanding, is contained within the systematic constitution of an even larger system.[f] Can we not recognize the same cause and manner of generation in so precise an agreement in their constitution? 1:307

Now if the fixed stars constitute a system the extent of which is determined by the attractive sphere of the body in the centre, will not more solar systems and, so to speak, more milky ways have arisen in the limitless field of space?[g] We have seen with astonishment shapes in the heavens that are nothing other than systems of such fixed stars limited to a common plane, such milky ways, if I may express myself in this way, that exhibit elliptical shapes in different positions in relation to the eye with a weakened shimmering as is appropriate to their infinite distance; they 1:308

[c] *Umfang*
[d] *erkennen*
[e] *Weltgebäude*
[f] *Weltbaues*
[g] *Weltraumes*

are systems of, so to speak, infinity times infinity greater diameter than that of our solar system,[b] but that, without doubt, are generated in the same way, ordered and arranged by the same causes, and that maintain themselves by the same mechanism[i] as this one in its constitution.

If we consider these star systems in turn as links in the great chain of all nature, then we have just as much cause as before to think of them as being in a reciprocal relationship and in connections which, by the power of the law of first formation that governs all nature, constitutes a new, even larger system that is ruled by the attraction of a body of incomparably more powerful attraction than the ones mentioned previously from the centre point of their regular positions. The attraction that is the cause of the systematic constitution among the fixed stars of the Milky Way is effective even at the distance of precisely these world-orders to bring them out of their positions and to bury the world in an inevitably imminent chaos if there were not regularly distributed tangential forces[j] providing a counterbalance to the attraction and both together produce that relationship that is the basis for the systematic constitution. Attraction is without doubt a quality of matter that is just as pervasive as the coexistence that makes space in that it combines substances by reciprocal dependences, or, to put it more accurately, attraction is precisely that universal relationship that unites the parts of nature in one space: it therefore extends to the entire expanse of space into all the reaches of its infinity. If the light from these distant systems reaches us, light, which is merely an impressed motion, then must not rather attraction, this original source of motion, which is earlier than all motion and which
1:309 requires no external causes and cannot be held up by any impediment, because it acts on what is innermost in matter without any impact even in a universal stasis of nature, must not, I say, attraction have set these systems of fixed stars in motion, despite their immeasurable distances, at the formless dispersion of its material at the beginning movement[k] of nature, which, just as we have seen on a small scale, is the source of the systematic connection and of the lasting constancy of its parts that secures them from destruction?

But what then will ultimately be the end[l] of the systematic arrangements? Where will creation itself stop? It is easy to see that, in order to think of it in relationship to the might of the infinite being, it must have no limits at all. We do not come any closer to the infinitude of God's creative power if we enclose the space of its revelation within a sphere described by the radius of the Milky Way than if we were to limit it to a ball of one inch diameter. Everything that is finite, that has its

[b] *Sonnenbaues*
[i] *Triebwerk*
[j] *Schwungskräfte*
[k] *Regung*
[l] *das Ende*

limits and a determinate relationship to a unit, is equally distant from the infinite. Now it would be nonsense to posit the deity as active[m] in an infinitely small part of its creative capacity and to consider its infinite force, the store of a true immeasurability of natures and worlds, as being idle and locked in an eternal state of not being exercised.[n] Is it not instead more appropriate[o] or, expressed better, is it not necessary to describe the sum[p] of creation as it must be, in order to be a testimonial of that power that cannot be measured by any measuring stick? For this reason the field of the revelation of divine qualities is just as infinite as these are themselves.* Eternity is insufficient to grasp the manifestations of the 1:310
highest being unless it is related to the infinity of space. It is true that the formation, the shape, the beauty and perfection are relationships of the building blocks[q] and of the substances that constitute the material of the universe;[r] and we observe it in the measures that the wisdom of God is still taking all the time; and it is most appropriate to it that they evolve[s] by an unforced succession from these universal laws implanted in them. Therefore we can posit with good reason that the ordering and arrangement of the universes[t] occurs from the store of the created material of nature gradually in a temporal sequence; only the basic matter itself, the properties and forces of which underlie all changes, is a direct consequence of the divine existence: this must therefore be at once so rich, so perfect that the development of its compositions could, in the passage of eternity, spread over a plane that contains in itself everything that can exist, that adopts no measure,[u] in short, that is infinite.

* The concept of an infinite extension of the world has enemies among the advocates of metaphysics and has found one in Herr M. **Weitenkampf** [66] only recently. If these gentlemen cannot bring themselves to accept this idea because of the alleged impossibility of a quantity without number or limits, then for the time being I would just ask whether the future succession of eternity will not encompass in itself a true infinity of manifolds and changes, and whether this infinite order is not already fully present all at once in the divine understanding. Now, if it were possible that God can make actual the concept of infinity that is in his mind all at once, in a sequence in which one follows 1:310
upon the other, why should God not be able to exhibit the concept of another infinity in a **spatially combined connection** and in this way make the extent of the world without limits? While people will try to answer this question, I will take the opportunity that presents itself to eliminate the supposed difficulty by means of an explanation from the nature of numbers, insofar as one can, with due consideration, still view it as a question requiring discussion: whether the relation between what a force accompanied by the highest wisdom **has brought about** in order to reveal itself and what it **could have brought about** is that of a differential coefficient.

[m] *in Wirksamkeit zu setzen*
[n] *Ausübung*
[o] *Anständig*
[p] *Inbegriff*
[q] *Grundstücke*
[r] *Weltbau*
[s] *herauswickeln*
[t] *der Weltgebäude*
[u] *Maß* [e.g., no unit of measurement]

Now, if creation is therefore infinite as regards spaces, or really has been since the beginning at least with respect to matter, but is prepared to become so according to the form or development,[v] the space of the **universe**[w] will be enlivened with worlds without number and without end. Will then that systematic relationship that we considered earlier in all parts separately now extend to the whole and encompass the entire universe,[x] everything in nature, in a single system through the combination of attraction and centrifugal force[y]? I say yes; if there were only
1:311 separate galaxies[z] that, between them, have no unified connection to a whole, then, if one were to assume this chain of links to be actually infinite, one could well think that an exactly equal attraction of its parts from all sides could keep these systems safe from the destruction with which the inner reciprocal attraction threatens them. This, however, would require such a precisely measured determination in the distances balanced according to the attraction, that even the slightest disarrangement would bring about the destruction of the **universe**[a] and deliver it unto collapse in long periods that would ultimately still have to come to an end. A world constitution[b] that could not sustain itself without a miracle does not have the character of permanence that is a feature of God's choice; thus it is far more appropriate if we were to make one system out of the whole of creation, one that relates all worlds and world-orders that fill the entirety of infinite space to a single centre point. A dispersed plethora[c] of galaxies,[d] even though they may be separated by ever such great distances from one another, would rush with an unimpeded tendency to ruin and destruction if a certain arrangement relating towards a universal centre point, the centre of attraction of the **universe**[e] and the supporting point of all nature, had not been made through systematic motions.

We can assume as probable that it was around this universal centre point of the sinking of all nature, both formed and raw, at which the lump with the most exceptional attraction is doubtless to be found, which embraces in its sphere of attraction all the worlds and orders that time has produced and that eternity will produce, that nature made the beginning of its formation, and that the systems will be most densely concentrated there but that further away in the infinitude of space, they will become lost with ever greater degrees of dispersion. We could deduce this rule from the analogy with our solar system,[f] and this constitution can in any

[v] *Ausbildung*
[w] *Weltraum*
[x] Universum
[y] *fliehende Kraft*
[z] *Weltgebäude*
[a] Universo
[b] *Weltverfassung*
[c] *Gewimmel*
[d] *Weltgebäuden*
[e] Universi
[f] *Sonnenbaues*

case serve to show that at great distances, not only the universal central body but also all the systems orbiting next to it unite their attraction together and exert it from one lump, as it were, towards the systems at an even greater distance. This will then be one of the things that will be 1:312
helpful in understanding the whole of nature in the whole infinitude of its extent within a single system.

Now, in order to trace the establishment of this universal system of nature from the mechanical laws of matter endeavouring towards formation, at some place in the infinite space of the spread out elementary basic material, this basic material must have had its densest concentration, in order to have provided, through the initial formation occurring there, a mass for the entire universe[g] that would serve it as a supporting point. It is certainly true that in an infinite space, no point can properly have the prerogative of being called the centre point; but by means of a certain relationship that is based on the essential degrees of the density of the original material, according to which, at its creation, this is initially more densely concentrated at a particular place and increases in its dispersion with distance from that place, such a point can have the prerogative of being called the centre point and it actually does become such through the formation of the central mass of the strongest attraction therein, to which all the remaining elementary matter that is in the process of coalescing into particular formations descends and thereby, however far the evolution[h] of nature might extend, makes just a single system out of the whole of the universe[i] in the infinite sphere of creation.

But this is something important, which, insofar as it gains approval, is worthy of the greatest attention, that according to the order of nature in our system, creation, or rather the formation of nature, first begins at this centre point and in a constant advance is gradually dispersed into all distant expanses to fill infinite space with worlds and orders in the progress of eternity. Let us pursue this concept for a moment with quiet pleasure. I find nothing that can raise the human spirit to nobler astonishment, by giving us a perspective[j] on the unending field of the almighty, than this part of the theory that concerns the successive completion of creation. If people concede to me that matter, which is the material for the formation of all worlds, was not uniformly spread out in the whole infinite space of the divine presence, but according to a certain law that perhaps related to the density of the particles and according to 1:313
which the dispersion of the original material increased with the distance from a certain point that was the place of the densest concentration: then,

[g] Universo
[h] *Auswickelung*
[i] *aus dem ganzen All*
[j] *Aussicht*

in the original movement[k] of nature, the formation will have begun nearest this centre and then in a progressive time sequence the more distant space will gradually have formed worlds and world-orders with a systematic constitution related to that centre. Every finite period, the length of which stands in a relationship to the size of the work to be fulfilled, will only ever bring one finite sphere of this centre point to formation; the remaining infinite part meanwhile will still be in conflict with confusion and chaos and will be as much further from the state of perfected formation the greater its distance from the sphere of already formed nature. As a consequence of this, even though from the place of our abode in the universe[l] we have a perspective[m] on an apparently completely perfected world and, so to speak, into an infinite host of world orders that are systematically connected, we actually find ourselves only in a proximity to the centre point of all nature, where it has already evolved from chaos and attained the perfection appropriate to it. If we were able to transcend a certain sphere, we would see there the chaos and dispersion of the elements, that in proportion to how close they are to this centre point have partly left the raw state and are nearer to completing their formation but are gradually lost in complete dispersal with the degrees of distance. We would see how the infinite space of the divine presence, where the store[n] of all possible formations of nature can be found, lies buried in a silent night full of matter to serve as the material for worlds to be generated in the future, and of the driving force[o] to set them in motion, that, with a slight movement,[p] will begin those motions with which the infinitude of those empty spaces is to be brought to life in the future. Perhaps a number of millions of years has passed before the sphere of formed nature in which we find ourselves has grown to the perfection that now attends it; and perhaps an equally long period will elapse before
1:314 nature takes an equally large step in the chaos: but the sphere of formed nature is incessantly occupied in spreading itself. Creation is not the work of one moment. After it has made a beginning with the production of an infinity of substances and matter, it is effective throughout the entire sequence of eternity with ever increasing degrees of fruitfulness. Millions and whole mountain ranges of millions of centuries will pass within which ever new worlds and world-orders will form and attain completion one after another in the remote distances from the centre point of nature; regardless of the systematic constitution among its parts, they will attain a universal relationship to the centre point that has become the first point of formation and the centre of creation by the attractive capacity

[k] *Regung*
[l] Universo
[m] *Aussicht*
[n] *Vorrath*
[o] *Triebfeder*
[p] *Regung*

of its pre-eminent[q] mass. The infinity of future temporal succession with respect to which eternity is inexhaustible, will fill all the spaces of the presence of God completely and gradually put them into the regularity that is appropriate to the excellence of his design; and if, with a bold idea, one were able to summarize all eternity, so to speak, into one concept, then one would also be able to see the whole of infinite space filled with world-orders and creation completed. But because in fact the part of the time of eternity that still remains is always infinite and the elapsed part is finite, the sphere of formed nature is always only an infinitely small part of that essence which has within it the seed of future worlds and strives to evolve[r] out of the raw state of chaos over longer or shorter periods. Creation is never complete. It is true that it began once, but it will never stop. It is always occupied with bringing forth more phenomena[s] of nature, new things and new worlds. The work it brings about is proportionate to the time it spends on it. It requires nothing less than eternity to fill the whole limitless expanse of the infinite spaces with worlds without number and without end. We can say of it what the most sublime among the German poets writes of eternity:

Infinity! Who misses you? 1:315
Before you, worlds are days and people moments;
Perhaps the thousandth sun is turning now,
And a thousand are behind it still.
Like a clock, enlivened by a weight,
A sun hurries, moved by God's power:
Its force expires, and another sounds,
But you remain and count them not.

v. Haller.[67]

It is a not inconsiderable pleasure to allow one's imagination to roam freely beyond the limits of perfected creation into the realm of chaos and to see half raw nature in the proximity of the sphere of the formed world lose itself bit by bit through all stages and shadings of incompletion in the whole of unformed space. But is it not reprehensible boldness, people will say, to set up a hypothesis and to praise it as an object[t] of delight for our understanding when it is perhaps only much too arbitrary if it is maintained that nature is formed only in an infinitely small part and infinite spaces are still in conflict with chaos so as to present whole hosts of worlds and world-orders in all proper order and beauty in the sequence of future times? I am not so devoted to the consequences my theory offers that I would not recognize how the conjecture about the

[q] *vorzüglich*
[r] *auszuwickeln*
[s] *Auftritte*
[t] *Vorwurf*

successive expansion of creation through the infinite spaces that contain the material for this in themselves could not completely reject the objection of unprovability. I do, however, expect from those who are in a position to appreciate degrees of probability that such a map of infinity, even though it encompasses a proposal that appears to be determined to remain forever obscured from human understanding, will not immediately be regarded as a fantasy for this reason, especially if one appeals to analogy, which must always guide us in such cases where understanding lacks the thread of infallible proofs.

But analogy can also be supported by acceptable reasons and the insight of the reader, in so far as I can flatter myself with such approval, will perhaps be able to add to them with even more important ones.
1:316 For if one considers that constancy is not a characteristic of creation if it does not oppose the universal endeavour of the attraction that is effective throughout all its parts, to an equally pervasive determination that can sufficiently resist the tendency of the former towards destruction and lack of order, if it did not distribute tangential forces[u] which, in combination with the central inclination, establish a universal systematic constitution; then one is obliged to assume a universal central point of the whole universe that holds all of its parts together in a connected relationship and makes just one system out of the sum total[v] of nature. If one adds to this the concept of the formation of the celestial bodies out of the dispersed elementary matter, as we have outlined above, but does not restrict it here to a particular system, but rather extends it over the whole of nature, then one is obliged to consider a dispersion of the basic material in the space of original chaos such that it naturally includes one centre point of the whole of creation so that the active mass that encompasses the whole of nature in its sphere can be brought together in it and a thoroughgoing relation can be produced, whereby all worlds constitute only a single structure.[w] But, in infinite space, it is hardly possible to think of any kind of dispersion of the original basic material that could posit a true centre and sinking point of all nature other than that it is arranged in accordance with a law of increasing dispersion from this point onwards into all the furthest distances. This law, however, also posits a difference in the time that a system requires in the various areas of infinite space to attain the maturity of its formation, so that this period is shorter the closer the formation place of a world structure[x] is situated to the centre of creation, because there, the elements of the material are more densely concentrated, and it requires a longer time, by contrast, the greater the distance is, because the particles there are more widely dispersed and come to formation later.

[u] *Schwungskräfte*
[v] *aus dem ganzen Inbegriff*
[w] *Gebäude*
[x] *Weltgebäde*

If one considers the entire hypothesis I am outlining in the whole extent of both what I have said and what I will still actually present, then one will at least not regard the boldness of its demands as incapable of accepting an apology. The inevitable tendency of every perfected world 1:317
structure[y] gradually towards its destruction can be reckoned among the grounds that can establish that the **universe**[z] will, by contrast, be productive of worlds in other regions in order to replace the deficiency it has suffered in one place. The whole piece of nature that we know, even if it be merely an atom in view of what remains concealed above or below our field of vision, still confirms this fruitfulness of nature that is without limits because it is nothing other than the exercise of divine omnipotence itself. Countless animals and plants are destroyed daily and are victims of transience, but through an unexhausted generative capacity nature brings forth no less again in other places and fills the void. Considerable areas of the earth that we inhabit are buried again in the sea from which a favourable period had dragged them; but in other places, nature replaces the deficiency and brings forth other regions that had been concealed in the depths of the water to spread new riches of its fruitfulness over them. In the same way, worlds and world-orders pass away and are swallowed by the abyss of eternities; by contrast, creation is ever busy carrying out new formations in other regions of the heavens and replacing what has gone with advantage.

We should not be astonished at allowing transience even in the greatness of God's works. Everything that is finite, that has a beginning and an origin, has in itself the quality of its limited nature; it must pass and have an end. The duration of a world structure[a] has, thanks to the excellence of its arrangement, a constancy that approaches an infinite duration in terms of our concepts. Perhaps a thousand, perhaps a million centuries will not destroy it, but because the vanity that attaches to finite natures is constantly working at its destruction, eternity will contain all possible periods and, by a gradual decay, bring about the time of its destruction. **Newton**, that great admirer of God's qualities from the perfection of his works, who combined the most profound insight into the excellence of nature with the greatest reverence towards the revelation of divine omnipotence, saw himself obliged to proclaim to nature its decay 1:318
through the natural tendency that the mechanics of motion has. If a systematic constitution, through the essential[b] consequence of its frailty over great periods of time, brings even the tiniest part one can imagine closer to the state of its confusion, then in the infinite passage of eternity there must surely be a point in time when the gradual diminution has exhausted all motion.

[y] *Weltgebäude*
[z] das Universum
[a] *Weltgebäude*
[b] *wesentliche*

However, we must not lament the end of a world structure[c] as a true loss of nature. Nature shows its bounty in a kind of extravagance, which, while some parts pay their tribute to transience, maintains itself regardless through countless new creations in the whole extent of its perfection. What a countless mass of flowers and insects does not a single cold day destroy; but how little do we miss them even though they are splendid artworks of nature and proofs of divine omnipotence! In another place, this loss is replaced again with abundance. Human beings, who appear to be the masterpiece of creation, are themselves not excluded from this law. Nature shows that it is just as bountiful, just as inexhaustible in the production of the most excellent of creatures as it is in that of those of low regard, and that even their end is a necessary gradation in the diversity of its suns, because their creation costs it nothing. The deleterious effects of infected air, earthquakes, floods eradicate whole peoples from the face of the earth, but it does not appear that nature has suffered any disadvantage through this. In a similar way, whole worlds and systems leave the scene after they have finished playing their roles. The infinity of creation is great enough for us to view a world or a Milky Way of worlds in comparison to it, just as we view a flower or an insect in comparison to the Earth. Meanwhile, so that nature will beautify eternity with changeable scenes, God remains busy in ceaseless creation to make the material[d] for the formation of even greater worlds.

> He who, being the creator of everything, with the same eye
> Sees a hero perish and a little sparrow fall,
> Sees a water bubble burst and a whole world end.
> **Pope** in **Brocke**'s translation.[68]

1:319 Let us therefore accustom our eye to these frightening upheavals as being the ordinary ways of providence and even regard them with a kind of appreciation. And indeed nothing is more appropriate to the bounty of nature than this. For when, in the long sequence of its duration, a world system[e] exhausts all the diversity that its arrangement can encompass, when it has now become a superfluous link in the chain of beings, then nothing is more proper than that it should play the final role in the play of changes unfolding in the **universe**[f] that is given to every finite thing, namely to pay its dues to transience. Nature shows, as mentioned above, even in the small part of its essence[g] this rule of its method that eternal destiny has prescribed for it in the whole, and I say it again, the greatness of what is to come to an end is not in the least a hindrance in this, for all that is great will become small, indeed it will become, as it were, only

[c] *Weltgebäude*
[d] *Zeug*
[e] *Weltsystem*
[f] Universi
[g] *Inbegriff*

a point when compared to the infinitude that creation will represent in unlimited space throughout the sequence of eternity.

It appears that this end[b] that has been imposed on the worlds as well as on all things in nature is subject to a certain law, the consideration of which gives the theory a new touch of propriety. According to this, it begins with those celestial bodies that are nearest the centre point of the universe, just as the generation and formation initially began next to this centre; from there decay and destruction spread bit by bit into the more remote distances in order finally to bury all the worlds that have completed their term through a gradual decline of motions in one total chaos. On the other hand, on the opposite border of the formed universe,[i] nature is constantly occupied in forming new worlds out of the raw material of the dispersed elements, and while it is ageing on the side near the centre, it is young and fruitful with new creations on the other. According to this, the formed world is restricted in the middle between the ruins of destroyed nature and between the chaos of unformed nature and if, as is probable, one imagines that a world already grown to perfection could last for a longer time than it required to be formed, then, in spite of all the devastation that transience unceasingly causes, the extent of the universe[j] in general will still increase. 1:320

However, if finally people are prepared to leave space for an idea that is just as probable as it is proper to the constitution of divine works, then the satisfaction stimulated by such a description of changes in nature will be raised to the highest degree of pleasure. Can one not believe that nature, which was capable of placing itself out of chaos into a regular order and into a clever system, is equally in a position to produce itself again just as easily out of the chaos in which the diminution of its motions had sunk it, and to renew the original combination? Can the springs that brought the material of dispersed matter into motion and order, after the standstill of the machine has brought them to a stop, not become effective again through extended forces and restrict themselves to a harmony in accordance with just the same universal laws through which the original formation was brought into being? People will not have reservations about admitting this for long when they consider that, after the final exhaustion[k] of the orbital motions in the solar system[l] has hurled the planets and comets all together down onto the Sun, the heat of which must increase immeasurably as a result of the mixing of so many and such large lumps, principally because, according to our theory proven above, the distant spheres of the solar system contain the material that is lightest in all nature and most effective in a fire. This fire, changed

[b] *Ende*
[i] *Welt*
[j] Universi
[k] *endliche Mattigkeit*
[l] *Weltgebäude*

into the greatest intensity by new fuel and the most volatile matter, will, without a doubt, not only dissolve everything into the smallest elements again, but will also disperse and distribute them in this way with an expansive force appropriate to the heat and with a velocity that is not weakened by any resistance of the surrounding space into the same huge spaces again that they have occupied before the first formation of nature, and, after the intensity of the central fire has been reduced by the almost total dispersion of its mass, by a combination of the attractive and repelling forces, repeat the old creations[m] and systematically related motions with no less regularity and represent a new world structure.[n] If
1:321 then a particular planetary system has fallen into decay in this manner and has generated itself again by means of essential forces, if indeed it repeats this game more than once: then finally that period will approach which will in the same way gather the great system of which the fixed stars are members into one chaos through the decay of its motions. One will have even fewer doubts here that the unification of so infinite a quantity of flammable matter as these burning suns represent, together with the retinue of their planets dissolved by the ineffable heat, will disperse the material of their masses in the old space of their sphere of formation and there the materials for new formations are provided through the same mechanical laws, through which again the empty space can be populated with worlds and systems. If we follow this phoenix of nature, which burns itself only to rise rejuvenated from its ashes to new life through all infinity of time and space; when one sees how, even in the region where it decays and ages, it continues unexhausted with new appearances and on the other border of creation it proceeds in the space of unformed raw matter with constant steps for the expansion of the plan of divine revelation to fill eternity as well as all the spaces with its wonders: then the mind that contemplates all this sinks into a profound astonishment; and yet still unsatisfied with this so great object, whose transience cannot satisfy the soul sufficiently, he wishes to get to know at close quarters that being whose understanding, whose greatness is the source of that light which spreads over all of nature as though from one centre point. With what kind of reverence does not the soul have to regard even its own being, when it considers that it is to survive all these changes, it can then say to itself what the philosophical poet says of eternity:

> When then a second nothingness will bury this world,
> When of every thing itself nothing remains but the place,
> When even many a sky, illuminated by other stars
> Will have completed its course:

[m] *Zeugungen*

[n] *Weltgebäude*

You shall be as young as now, just as far from your death,
Just as eternally future as today.

v. Haller.[69]

O happy if, among the tumult of the elements and the ruins of nature, 1:322
it is always positioned at a height from which it can see the devastations that frailty causes the things of the world to rush past under its feet, so to speak! A happiness such as reason may not even have the temerity to wish for, revelation teaches us to hope for with conviction. When the shackles that hold us to the vanity of creatures have fallen off at the moment that has been determined for the transfiguration of our being, then the immortal spirit, liberated from dependence on finite things, and in the company of the infinite being, will find the enjoyment of true happiness. The whole of nature, which has a universal harmonious relationship with the pleasure of the divinity, cannot fill that reasonable creature that is at one with this original source of all perfection with anything other than everlasting satisfaction. Nature, seen from this centre point, will show nothing but certainty, nothing but propriety from all sides. The changeable scenes of nature are not capable of disturbing the peace of happiness of a spirit that has been raised to such heights. While it tastes this state in advance through a sweet hope, it can exercise its mouth in those paeans of praise with which all eternities will one day resound.

When one day the structure of the world has hurried back into its
nothingness
And the work of your hands is no longer separated by night and day
Then shall my moved spirit, strengthened by you, attempt
Always to stand before your throne in adoration of your omnipotence
My mouth, filled with thanks, shall through all eternities
Present you and your majesty with unending praise;
Even if I can say no perfect praise: for, O Lord! you are so great
Eternity would not suffice to praise you as you are worthy of it.

Addisson [sic]
In Gottsched's translation.[70]

SUPPLEMENT TO CHAPTER SEVEN. 1:323

Universal theory and history of the Sun.

There is one major question the resolution of which is indispensable in the doctrine of nature of the heavens and in a complete cosmogony. Why is the centre point of every system occupied by a flaming body?

Our planetary system[o] has the Sun as its central body and the fixed stars we see are to all appearances centre points of similar systems.

In order to understand why, in the formation of a planetary structure[p] the body that serves as the middle point of the attraction had to be a fiery body, while the remaining spheres in its range of attraction stayed dark and cold celestial bodies, one need only recall the manner in which a system[q] is generated that we have outlined in detail above. In the widely spread space in which the dispersed elementary basic material embarks on formations and systematic motions, planets and comets form only out of that part of the elementary basic material sinking towards the centre point of attraction that has been determined by the fall and the interaction of all the particles for the precise restriction of direction and velocity required for rotation. This part is, as shown above, the least of the whole sum[r] of the matter sinking downwards, and in fact only the detritus of denser kinds that have been able to attain this degree of precision through the resistance of the others. In this mix[s] there are upwards floating kinds of outstanding lightness, which, hindered by the resistance of space, do not reach the appropriate velocity[t] of periodic rotation through their fall and which as a result are all thrown down to the central body in the decrease of their tangential force.[u] Now because precisely these lighter and volatile parts are also the most effective in maintaining fire, we can see that, by adding them, the body and central point of the system attains the advantage of becoming a flaming sphere, in a word, a sun. Conversely, the heavier and powerless material and the
1:324 absence of these fire-feeding particles will make of the planets only cold and dead lumps that are deprived of this quality.

It is also through this addition of such light matters that the Sun has attained the lesser specific density by which it is four times inferior even to our Earth, the third planet in distance from it; although it is natural to believe that the heaviest and densest types of matter should be found in this centre point of the world structure,[v] being its lowest point so that it would surpass the density of all planets without the addition of such a large quantity of the lightest material.

The blending of denser and heavier types of elements with these lighter and more volatile ones also serves to prepare the central body for the fiercest heat that is to burn and be maintained on its surface. For we know that a fire, in the feeding material of which dense matters are blended with volatile ones, has a great advantage of fierceness over those flames that are maintained only by light types. However, this

[o] *Weltbau*
[p] *Weltgebäude*
[q] *Weltbau*
[r] *Menge*
[s] *Gemenge*
[t] *Schnelligkeit*
[u] *in der Mattigkeit ihres Schwunges*
[v] *Weltbau*

intermingling of some heavy types among the lighter ones is a necessary consequence of our doctrine of the formation of the celestial bodies and additionally has this benefit, that the force of the heat does not suddenly disperse the combustible matter of the surface and that it is gradually and constantly fed by the influx of fuel from the interior.

After the question has now been resolved why the central body of a great stellar system is a flaming sphere, that is, a sun, it does not seem superfluous to occupy ourselves with this subject[w] for a while and to explore the state of such a heavenly body with a careful examination, particularly as conjectures here can be derived from more valid reasons than they generally tend to be with studies of the constitution of distant heavenly bodies.

First of all, I establish that there can be no doubt that the Sun really is a flaming body and not merely a mass of molten and glowing matter heated to an extreme degree as some have tried to conclude from certain difficulties they thought they had encountered with the first opinion. For if one considers that a flaming fire has this essential advantage over every other kind of heat that it, so to speak, is active out of itself instead 1:325
of diminishing or exhausting itself by transference, but rather thereby acquires more strength and fierceness and thus requires only material and feeding for its maintenance in order to continue on and on; the incandescence[x] of a mass heated to the highest degree, by contrast, is a merely passive state that incessantly diminishes by community with the matter it touches and has no powers of its own to spread from a small beginning or to come back to life again after being diminished, if, I say, one considers this, one will be able to see clearly from this, and I say nothing about the other reasons, that the sun, the source of light and heat in every world structure,[y] will in all probability have to be accorded this quality.

Now, if the Sun, or suns altogether, are flaming spheres, then the first quality of their surface that can be deduced from this is that air must be there, since no fire will burn without air. This circumstance gives rise to noteworthy conclusions. For if we first place the atmosphere of the Sun and its mass in relation to the lump of the Sun, in what state of pressure will this air not be, and how capable will it not thereby become of maintaining the most violent degrees of fire through its elastic force?[z] In all probability smoke clouds from the matter burnt by the flames also rise in this atmosphere, and there can be no doubt that this matter contains a mix of coarse and lighter particles which, after they have risen to a height that fosters cooler air for them, crash down in heavy rains of pitch and sulphur and provide new nourishment for the flames. Precisely

[w] *Vorwurfe*
[x] *Gluth*
[y] *Weltbau*
[z] *Federkraft*

this atmosphere is not free from the motions of the winds[a] for the same reasons as on our Earth, but which from all appearances must greatly exceed in vehemence everything the imagination can picture for itself. Whenever some region on the surface of the Sun lessens the outbreak of the flame, either as a result of the asphyxiating force of the vapours breaking out or by the sparing influx of flammable matter, the air above
1:326 cools somewhat and, as it contracts, it makes room for the air next to it, with a force appropriate to the excess of its expansion, to reignite the extinguished flame.

Nonetheless all flames always devour much air and there is no doubt that the elastic force[b] of the liquid element of air that surrounds the Sun must suffer over time a not inconsiderable disadvantage thereby. If we were to apply on a large scale what Herr **Hales**[71] has confirmed through careful experiments about the action[c] of flame in our atmosphere, then we can consider the continuous endeavour of the smoke particles deriving from the flame to destroy the elasticity of the Sun's atmosphere as one principal knot, the solution of which is bound up with difficulties. For because the flame that burns over the entire surface of the Sun takes away from itself the air that is necessary for it to burn, the Sun is in danger of being completely extinguished when the greatest part of its atmosphere has been consumed. It is true that fire also creates air by the dissolution of certain matters, but experiments prove that more is always consumed than is produced. On the one hand, when one part of the sun's fire is robbed of the air that serves to maintain it through suffocating vapours, then, as we have noted above, violent storms will try to disperse them and conduct them away. On the other hand, in general we can make the replacement of this required element understandable in the following way if we take into consideration that, since in a flaming fire the heat acts almost only above and only very little below it, when it has been suffocated by the cause mentioned above, it turns its vigour towards the interior of the Sun's body and forces the deep chasms there to let the air locked in its caverns to break out and to stoke the fire anew; if, by taking a liberty that is not forbidden in the case of so unknown an object, we primarily posit in its innards matters that, like saltpetre, are inexhaustibly productive of elastic air, then the Sun's fire will not readily suffer the absence of a constantly renewed air supply over very long periods.

Nonetheless we can see the distinct characteristics of transience even in this immeasurable[d] fire that nature has set up as a torch for the world. There will come a time when it will be extinguished. The removal of
1:327 the most volatile and finest matters, which, dispersed by the violence

[a] *Wege*
[b] *Federkraft*
[c] *Wirkung*
[d] *unschätzbaren*

of the heat, will never return and increase the material of the zodiacal light, the accumulation of non-combustible and burnt out matter, e.g., the ash on the surface, and finally too the absence of air will set an end[e] to the Sun's days as its flame will go out one day and its place, now the centre point of light and life for the whole planetary system,[f] will be occupied by eternal darkness. The alternating endeavour of its fire to flare up again by opening up new caverns, by means of which it perhaps rejuvenates itself repeatedly in the face of its demise, could be an explanation for the disappearance and reappearance of some fixed stars. These would be suns that are close to their extinction and that attempt to revive themselves out of their ashes a number of times. This explanation may deserve approval or not, but in any case we will certainly have to let this observation serve to make us realize that, since, one way or another, the perfection of all world-orders is threatened by inevitable destruction, we shall find no difficulty in the aforementioned law of their demise by means of the tendency of the mechanical arrangement, which, however, becomes acceptable, principally because it bears within itself the seed of renewal even in being conjoined with chaos.

Finally, let us have our imagination represent a wonderfully strange object such as a burning sun as it were from close up. In one glance, we see broad lakes of fire lifting their flames up to the sky, raging storms whose fury redoubles the violence of the former, which, by making them swell up over their banks, now cover the raised areas of this celestial body, now make them sink back to within their borders; burnt-out rocks that stretch their terrible peaks out of the flaming maws, and whose flooding or uncovering by the surging fiery element is the cause of the alternating appearance and disappearance of the sunspots; dense vapours that choke the fire and, raised by the force of the winds, constitute dark clouds which in turn crash down in fiery showers of rain and, in the form of burning rivers, pour into the flaming valleys from the heights of the firm land of the Sun*, the crashing of the elements, the detritus of burnt-out 1:328
matters, and nature wrestling with destruction, which even in the most

* It is not without cause that I ascribe to the suns all the unevennesses of firm land, mountains, and valleys that we encounter on our Earth and other celestial bodies. The formation of a world sphere that is transforming itself from a liquid into a solid state necessarily brings about such unevennesses on its surface. As the surface hardens, while in the fluid interior parts of such a mass, the matters are still sinking towards the centre point in accordance with their weights, the particles of the elastic air or fire element that is mixed in with these matters are driven out and accumulate under the meanwhile solidified crust under which they generate large caves immense in proportion to the lump of the sun, into which the topmost crust mentioned above ultimately sinks with various folds and in this way prepares raised regions and mountain ranges as well as valleys and flood plains of broad fire lakes.

[e] *Ziel* [f] *Weltgebäude*

loathsome state of its disorder brings about the beauty of the world and the benefit of the creatures.

If therefore the centre points of all great world systems[g] are flaming bodies, then this can be assumed to apply most to the central body of that immeasurable system that the fixed stars constitute. But if it were a self-illuminating body or a sun, would not this body, the mass of which must stand in a ratio to the magnitude of its system, be obvious through its pre-eminent brilliance and magnitude? Despite this, we do not see any such exceptionally distinct fixed star shining forth among the heavenly hosts. Indeed we should not be surprised if this does not happen. Even if it exceeded our Sun 10,000 times in size, and we were to assume its distance to be 100 times greater than that of Sirius, it could not appear larger and brighter than that star.

Perhaps, however, it is given to future times at least to discover the
1:329 region where the centre point* of the fixed star system to which our Sun belongs is to be found, or perhaps even to determine where we must posit the central body of the universe[b] to which all its parts are aiming with unanimous descent. As regards the constitution of this fundamental piece of the entirety of creation and what one might find on it, we shall allow Herr **Wright of Durham** to determine, who, with a

* I have a conjecture according to which it seems very likely to me that Sirius or the Dog Star in the system of stars that make up the Milky Way is the central body and occupies the centre point to which they all refer. If one were to consider this system in terms of the outline in the first part of this treatise as a milling mass[i] of suns heaped together into a common plane, which has been strewn in all directions from its central point and yet constitutes a certain, as it were, circle-shaped space that also extends widthways from both sides as a result of minor deviations from the plane of reference; then the
1:329 Sun, which is also near this plane, will see the appearance of this circle-shaped, white-shimmering zone most broadly towards that side to which it is closest to the furthest limit of the system, for it is easy to suppose that it would hardly be at the centre point. Now the band of the Milky Way is broadest in the section between the sign of the Cygnus and that of Sagittarius, therefore this will be the side where the place of our Sun is closest to the periphery of the circle-shaped system; and it is in this section that we will consider the place where the constellations of the Aquila and the Vulpecula stand with the Anser particularly as the very closest, because it is there that the greatest apparent dispersion of stars shines forth from the space where the Milky Way divides. Therefore, if one draws a line approximately from a point next to the tail of Aquila through the middle of the plane of the Milky Way to the opposite point, then it must meet the centre point of the system and indeed it very precisely meets Sirius, the brightest star in the whole sky which, because of its fortunate coinciding that harmonizes so well with its splendid figure, seems to deserve to be regarded as the central body itself. According to this notion it would be seen precisely in the band of the Milky Way were it not that the position of our Sun, deviating somewhat from the plane at the tail of Aquila, causes the optical distance of the centre point towards the other side of that zone.

[g] *Weltsystemen*
[b] Universi
[i] *Gewimmel*

fanatical enthusiasm, raised, in this fortunate place as it were onto a throne of all nature, a powerful being of a divine sort with spiritual powers of attraction and repulsion, which, effective[j] in an infinite sphere around itself, drew all virtue to itself but drove back all vice. We do not wish to allow free rein to the boldness of our conjectures, which we perhaps have permitted only too much, to the point of arbitrary inventions. The deity is equally present in the infinity of the entire universe; wherever there are beings capable of elevating themselves above the dependence of creatures to the community of the highest being, it is equally close. All of creation is permeated by its powers but only someone who is capable of liberating oneself from being a creature, who is so noble as to 1:330
realize that the highest level of happiness is to be sought solely in partaking of this original source of perfection, that one alone is capable of being closer to this true reference point of all excellence than anything else in all of nature. However, if I, without participating in the enthusiastic ideas of the Englishman, were to make conjectures about the different grades of the spiritual world on the basis of the physical relations of their domiciles to the centre point of creation, then I would seek the most perfect classes of rational beings further away from this centre point than closer to it. The perfection of creatures endowed with reason, insofar as it is dependent on the constitution of matter, in the connection with which they are restricted, depends very much on the fineness of the material whose influence determines them in their image[k] of the world and in their reaction to it. The inertia and the resistance of matter restricts the freedom of spiritual beings for action[l] and the clarity of their sensation of external things far too much, it makes their capacities blunt in that they do not obey its motions with appropriate lightness. Therefore, if we assume, as is likely, the densest and heaviest types of matter to be near the centre point of nature, while degrees of fineness and lightness increase at greater distances in accordance with the analogy that rules our universe,[m] then the consequence is understandable. Those rational beings, whose place of origin and residence is closer to the centre point of creation, are mired in a stiff and immovable matter that contains their strength locked in an insuperable inertia and is also just as incapable of transmitting and communicating the impressions of the universe[n] with the requisite distinctness and ease. We will therefore have to reckon these thinking beings as being part of the low class; by contrast, this perfection of the spiritual world, which rests upon a mutual dependence on matter, will increase with the distances from the universal centre like a constant ladder. As a result we have to place the worst and least perfect

[j] *wirksam*
[k] *Vorstellung*
[l] *zum Wirken*
[m] *Weltbau*
[n] Universi

types of thinking natures in the most profound lowering to this sinking point, and it is in this direction that this excellence of beings, with all
1:331 shades of diminution, is finally lost in the complete absence of reflection and thinking. Indeed, when one considers that the centre point of nature constitutes simultaneously the beginning of its formation out of raw material[o] and its border with chaos; if one adds to this that the perfection of spiritual beings, which certainly has an outermost limit of its beginning, where their capabilities collide with lack of reason,[p] but no limits of continuation beyond which they could not be raised, but rather finds itself confronted on that side with complete infinity; then, if a law is to be in place according to which the domiciles of intelligent creatures are distributed in the order of their relation to the common centre point, we shall have to place the lowest and least complete type that constitutes, as it were, the beginning of the type of the spiritual world, at that region that can be called the beginning of the entire universe[q] in order to fill simultaneously with this and in equal progression all infinity of time and spaces with increasing degrees of perfection of the capacity to think and as it were gradually to approach the goal[r] of the highest excellence, namely the divinity without, however, ever being able to attain it.

CHAPTER EIGHT.

General proof of the correctness of a mechanical doctrine of the arrangement of the universe overall, particularly of the certainty of the present one.

One cannot look at the universe[s] without recognizing the most excellent order in its arrangement and the sure characteristics of the hand of God in the perfection of its relations. Reason, having considered and admired so much beauty, so much excellence, is rightly incensed at the bold foolishness that has the audacity to attribute all this to coincidence and a
1:332 fortuitous chance. The highest wisdom must have made the design and an infinite power carried it out, otherwise it would be impossible that so many intentions that come together for one purpose could be encountered in the constitution of the universe.[t] It is simply a matter of deciding whether the design of the arrangement of the universe[u] had already been placed in the essential determinations of the eternal natures and planted into the universal laws of motion by the highest understanding so that

[o] *Zeug*
[p] *Unvernunft*
[q] Universi
[r] *Ziel*
[s] *Weltgebäude*
[t] *Weltgebäudes*
[u] Universi

it developed out of them naturally in a manner proper to the most perfect order, or whether the general properties of the constituent parts of the world have a complete incapacity for harmony and not the slightest reference to any combination and definitely required an external hand to acquire that limitation and coordination that shows perfection and beauty in it. An almost universal prejudice has set most philosophers against nature's ability to produce anything orderly through its universal laws just as though it would be disputing God's governance of the world if one were to seek original formations in the forces of nature and as though these were a principle independent of the divinity and an eternal blind fate.

However, if one considers that nature and the eternal laws that are prescribed to substances for their interaction, are not a principle independent and necessary without God, that precisely because of the fact that it shows so much correspondence and order in what it produces through universal laws, we can see that the essences of all things must have their common origin in a certain primitive being[v] and that for this reason they reveal many reciprocal relationships and much harmony because their properties have their source in a single highest understanding, whose sage idea designed them in constant proportions and implanted in them that ability by which they produce much beauty, much order in the state of activity if left to themselves, if, I say, one considers this, then nature will appear to us more dignified than it is commonly regarded and one will expect from its unfolding[w] nothing but correspondence, nothing but order. If, by contrast, one gives credit to an unfounded prejudice, that the universal laws of nature in and of themselves create nothing but disorder and any useful correspondences that shine forth in the constitution of nature points to the direct hand of God, then one is required to turn the whole of nature into miracles. One will not derive from the implanted forces of matter the beautiful colourful arc that appears in raindrops when they separate the colours of sunlight, due to its beauty, the rain due to its usefulness, the winds due to the indispensable advantages they provide for human needs in endless ways, in short, all changes of the world that bring along propriety and order. The endeavours of natural scientists[x] who have involved themselves with such a philosophy will have to make an apology before the judgement seat of religion. Indeed, there will then no longer be any nature; there will be only a god in the machine bringing about the changes of the world. However, what will this strange means of proving the certainty of the highest being on the basis of the essential incapacity of nature do to convert the Epicurean? If the natures of things bring about nothing but disorder and 1:333

[v] *Grundwesen*
[w] *Auswickelungen*
[x] *Naturforscher*

nonsense through the eternal laws of their essences, then precisely by this will they prove the character of their independence from God; and what sort of a notion of a deity will one be able to make for oneself whom the universal laws of nature obey only because of a sort of compulsion and are actually in conflict with its wisest designs? Will not the enemy of providence win just as many victories over these false principles as he can demonstrate correspondences that the universal causal laws of nature bring forth without any special limitations? And could he lack such examples? On the contrary, let us conclude with greater propriety and correctness as follows: Nature, left to its own universal properties, is fertile in many beautiful and perfect fruits which not only show correspondence and excellence in themselves but also harmonize with the entire realm of their beings, with the usefulness to mankind and the glorification of the divine properties. From this it follows that their essential properties can have no independent necessity, but rather that they must have their origin in a single understanding as the ground and source of
1:334 all beings, and in which they have been designed under mutual relations. All things that relate to one another in a reciprocal harmony must be combined with each other in a single being on which they all depend. Therefore there is a being of all beings, an infinite understanding and self-sufficient[y] wisdom, out of which nature also draws its origin in the entire sum total of its determinations, even according to its possibility. Now we cannot dispute the capacity of nature to be disadvantageous to the existence of a highest being; the more perfect it is in its developments, the better its universal laws lead to order and correspondence: the surer a proof it is of the divinity from which it borrows these relations. Its productions are no longer the effects of chance and the consequences of accidents: everything flows from it according to immutable laws, which must therefore display much skill because they are nothing but aspects of the wisest design from which all disorder has been banished. It is not the accidental accumulation of **Lucretius**' atoms that formed the world; implanted forces and laws that have the wisest reason as their source, have been an immutable origin of that order that had to flow from them, not by accident, but by necessity.

If therefore we can liberate ourselves from an old and unfounded prejudice and from the lazy philosophy that tries to hide a sluggish lack of knowledge behind a pious face, then I hope to found a sure conviction on incontrovertible grounds: **that the world recognizes a mechanical development out of the universal laws of nature as the origin of its constitution**; and that secondly **the manner of its mechanical generation we have presented is the true one**. If one wants to judge whether nature has sufficient capacities to bring about the arrangement

[y] *selbständige*

of the universe[z] by a mechanical consequence of its laws of motion, then one must first consider how simple the motions are that the world bodies observe and that they have nothing about them that requires a more precise determination than the universal rules of natural forces have in themselves. The orbital motions consist of the relationship between the sinking force that is a certain result of the properties of matter and of the shooting motion that can be regarded as the effect of the former, as a velocity resulting from the sinking, in which only a certain cause was 1:335
needed to bend the vertical fall sidewards. After the determination of these motions was once attained, nothing further is needed to maintain them forever. They continue to exist in empty space by the combination of the once impressed shooting force with the attraction flowing from the essential forces of nature and suffer no further change. The analogies in the correspondence of these motions alone show the reality of a mechanical origin so clearly that one can harbour no doubts about it. For

1. these motions have a corresponding direction throughout, so that of six main planets and 10 satellites there is not a single one that moves in any direction other than from west to east, both in their forward motion and in the rotation around their axis. In addition, these directions correspond so precisely that they deviate only a little from a common plane, and this plane to which everything refers, is the equatorial plane of the body that rotates on its axis in the same direction at the centre point of the whole system and which, by its very strong attraction, has become the reference point of all motions and therefore must have participated in them as precisely as possible. One proof that all the motions arose and were determined in a mechanical manner according to the universal laws of nature and that the cause that either impressed the lateral motions or put them right dominated the entire space of the planetary structure[a] and in this obeys the laws that matter observes in a space moved in common, [is] that all different motions ultimately adopt a single direction and altogether make themselves refer as precisely as possible to a single plane.

2. the velocities are constituted in the way they have to be in a space where the moving force is in the centre point, that is, they decrease in constant degrees with the distances from it and lose themselves in the greatest distance in a complete exhaustion of motion which bends the vertical fall laterally only very little. From Mercury onwards, which has the greatest tangential force, we can see that it decreases in stages and in the outermostcomets is as slight as it possibly could be without actually 1:336
falling into the Sun. No one can object that the rules of central motions

[z] *Weltbaues*

[a] *Planetengebäudes*

in circular orbits demand that, the closer to the centre point of the universal sinking, the greater must be the rotational velocity; for, why must just those heavenly bodies close to this centre have circle-shaped orbits? Why are the closest ones not very eccentric and the more distant ones orbiting in circles? Or rather since they all deviate from this measured geometrical precision, why does this deviation increase with the distances? Do not these relationships describe the point towards which all motion originally thronged and also attained greater degrees according to the measure of proximity before other determinations altered their directions into the current ones?

However, if one were to wish to except the constitution of the universe[b] and the origin of motions from the universal laws of nature in order to attribute them to the direct hand of God, then one will rapidly become aware that the analogies mentioned evidently contradict such an idea. For, firstly, as concerns the correspondence in direction throughout, it is obvious that there is no reason here why the bodies in the universe would have to arrange their orbits in one single direction if the mechanism of their origin had not determined them to do so. For the space in which they move offers infinitely little resistance and limits their motions as little in one direction as it does in the other; thus God's choice would not bind itself to a single determination without the slightest motive, but show itself in all sorts of variations and differences with greater freedom. Furthermore: why do the orbits of the planets refer so precisely to a common plane, namely to the equatorial plane of that great body that rules their orbits from the centre point of all motion? This analogy, instead of revealing a motive for propriety in itself, is rather the cause of a certain confusion that would be resolved by a free deviation of the planetary orbits: for the attractions of the planets now disturb the uniformity of their motions to some extent and would not hinder each other at all if they did not refer to a common plane so precisely.

1:337 Even more than all these analogies, the clearest characteristic of the hand of nature is shown by the absence of the most precise determination in those relations it endeavoured to attain. If it were best for the planetary orbits to have been placed almost on a common plane, why are they not exactly so? And why has a part of that deviation remained that ought to have been avoided? Thus if the planets closer to the orbit of the Sun have received the magnitude of the tangential force holding the attraction in equilibrium, why is there still something missing in this complete equality? And why are their orbits not completely circular if merely the wisest intention supported by the greatest faculty tried to bring forth this determination? Is it not clearly to be seen that the cause that situated the orbits of the heavenly bodies by endeavouring to bring them onto

[b] *Weltbaues*

a common plane was not able to achieve this completely; similarly, that the force that ruled the space of the heavens when all matter that is now formed into spheres received its orbital velocities, certainly attempted to bring them into an equilibrium with the sinking force near the centre point but was not able to attain complete exactness? Cannot the usual procedure of nature be recognized in this, which is made to deviate from the completely precise determinations in each case by the interference of various concurrent actions[c]? And are we likely to find the reasons for this state of affairs merely in the ultimate purposes of the highest will that commands directly in this way? One can, without being stubborn, dispute that the favoured manner of explaining the properties of nature by citing their uses as a reason will not pass the test as hoped. In regard to the benefit of the world, it was certainly a matter of complete indifference whether the planetary orbits are completely circular or whether they are a little eccentric; whether they completely coincide with their universal plane of reference or may deviate somewhat from it; rather, if it was needed to be restricted in this kind of correspondence, it would be best to have them be complete. If it is true what the philosopher said, that God is constantly practising geometry; if this shines forth even in the ways of the universal laws of nature, then certainly this rule would 1:338
be completely perceptible in the immediate works of the almighty will and these would display all the perfection of geometrical precision. The comets form part of these defects[d] of nature. One cannot deny that in regard to their course and the changes they suffer thereby they are to be viewed as imperfect members of creation that neither can serve to provide comfortable dwelling places for rational beings nor become useful to the best of the whole system by, as has been proposed, serving the Sun as fuel at some stage; for it is certain that most of them would not fulfil this purpose before the destruction of the entire planetary structure.[e] In the doctrine of the direct highest ordering of the world without a natural development from universal laws of nature, such a remark would be offensive even though it is certain. But in a mechanical manner of explanation the beauty of the world and the revelation of the almighty are glorified by it in no small degree. Nature, by encompassing all possible stages of diversity in itself, extends its embrace to all types of perfection up to nothingness and the defects themselves are a sign of the superfluity in which its sum total is inexhaustible.

We would believe that the analogies adduced above might overcome prejudice to the extent that they would make the mechanical origin of the universe[f] acceptable if there were not certain grounds, taken from

[c] *Mitwirkungen*
[d] *Mangel*
[e] *planetischen Gebäudes*
[f] *Weltgebäudes*

the nature of the matter itself, that seem to contradict this doctrine completely. The space of the heavens is, as already mentioned several times, empty, or at least filled with infinitely thin matter that therefore has been unable to produce any means of impressing common motions into the heavenly bodies. This difficulty is of such significance and validity that **Newton**, who had cause to trust the insights of his philosophy as much as any mortal, saw himself compelled at this point to give up hope of resolving, by reference to the laws of nature and the forces of matter, the impression of the tangential forces attached to the planets, regardless of all the correspondence that points to a mechanical origin. Although it is a sad decision for a philosopher to give up the effort of an examination in the case of a matter that is complex and still far removed from
1:339 simple principles and to content himself with referring to the direct will of God: nonetheless, Newton recognized here the borderline that separates nature from the finger of God, the course of the established laws of the former from the hint of the latter. After the despair of so great a philosopher, it would seem to be presumptuous to hope for a happy continuation in a matter of such difficulty.

However, precisely the same difficulty that deprived Newton of hope of understanding the orbital forces imparted to the heavenly bodies, whose direction and determinations make up the systemic character of the universe[g] is the source of the doctrine we have presented in the previous chapters. It supports a mechanical doctrine, but one that is far removed from the one Newton found inadequate and for the sake of which he rejected all subordinate causes, because he (if I dare to say it) erred in that he considered it to be the only one among all the possible ones of its kind. It is quite easy and natural, even by means of Newton's difficulty, to arrive at the certainty of the mechanical manner of explanation we have sketched in this treatise by a brief and thorough line of argument. If we presuppose (as we cannot help but admit) that the above analogies establish with the greatest certainty that the motions and orbits of the heavenly bodies that are in harmony and refer to one another in an orderly manner point to a natural cause as their origin, then this cannot be the same matter as that which now fills the space of the heavens. Thus that which formerly filled these spaces and whose motion was the reason for the present orbits of the heavenly bodies after they had accumulated into these spheres and thus cleared the spaces that we now see as empty, or, what flows directly from this, the matter itself of which the planets, the comets, and indeed the Sun consist must initially have been dispersed in the space of the planetary system[h] and in this state have set themselves in a motion that they retained when they united themselves into separate lumps and formed the heavenly bodies that encompass within themselves

[g] *Weltbaues* [h] *planetischen Systems*

all the formerly dispersed material of universal matter.[i] In this, one is not 1:340
long at a loss to discover the mechanism[j] that may have set this material of forming nature into motion. The motor itself that brought about the unification of the masses, the force of attraction that is an essential part of matter and therefore is so well suited as the first cause of motion at the first stirring of nature was its source. The direction that always aims straight for the centre point in this force is no objection here; for it is certain that in its vertical motion the fine material of dispersed elements must have been deflected by the diversity of the attraction points as well as by the hindrance caused by the mutually transversing lines of direction, into various lateral motions in which a certain law of nature that says that all matter limiting itself through reciprocal action ultimately arrives at a state in which one will cause as little change in the other as possible, has henceforth brought about both the uniformity of direction as well as the appropriate degrees of velocities that are balanced at every distance according to the central force and by the combination with which the elements do not attempt to stray above or beneath themselves: all elements have thus been made to orbit not only to one side but also in almost parallel and free circles around the common sinking point in the thin heavenly space. These motions of the parts had to continue afterwards when planetary spheres had formed out of them and exist now into an unlimited future by the combination of the once imparted tangential force with the central force. On this so understandable basis rest the uniformity of directions in the planetary orbits, the precise reference to a common plane, the moderation of the tangential forces according to the attraction of the place, the decrease with distance of the precision of these analogies, and the free deviation of the outermost heavenly bodies to both sides as well as in the opposing direction. If these signs of reciprocal dependence in the determinations of generation point with evident certainty to matter originally moved and dispersed through all of space, then the total absence of any matter in this now empty heavenly space other than those which comprise the bodies of the planets, the Sun, and the comets proves that initially these must have been in a state of dispersion themselves. The ease and correctness with which all the phenomena of the universe[k] have been derived from this assumed principle in the foregoing chapters completes such a conjecture and gives it a value that is no longer arbitrary. 1:341

The certainty of a mechanical doctrine of the origin of the universe,[l] especially ours, is raised to the highest peak of conviction if one considers the formation of the heavenly bodies themselves, the significance and size of their masses in terms of the proportion they have in regard to their

[i] *Weltmaterie*
[j] *Triebwerk*
[k] *Weltbaues*
[l] *Weltgebäudes*

distance from the centre point of gravitation. For firstly the density of their material, if considered in terms of the whole of their lump, decreases in constant degrees with the distance from the Sun, a determination that aims so clearly at the mechanical determinations of the first formations that no one can ask for anything further. They are constituted of matter such that those of the heavier kind have received a lower place towards the common sinking point while those of the lighter kind received a more distant space, which condition is necessary in all types of generation in nature. However, in an arrangement flowing directly from the divine will not the slightest grounds for these relationships is to be found. For even though it might seem that the more distant spheres ought to consist of lighter material so that they might feel the requisite effect from the reduced force of the Sun's rays; yet this is merely a purpose that is directed at the composition of the matter found on the surface and not at the deeper kinds in the interior of the lump, in which the Sun's warmth never has any effect and that serve only to bring about the attraction of the planet which will make the bodies surrounding it sink towards it and therefore cannot have the slightest relation to the strength or weakness of the Sun's rays. Therefore, if one asks why the densities of the **Earth**, of **Jupiter**, and of **Saturn** as correctly calculated by Newton, are in the ratio of 400, 94.5 and 64 to each other, it would be nonsense to ascribe the cause to the intention of God, who moderated them according to the degrees of the Sun's warmth; for here our Earth
1:342 can serve as a counterexample for us, where the Sun acts on only such a slight depth under the surface by its rays that the part of its lump that must have some relation to it does not amount to one millionth of the whole, of which the rest is completely irrelevant in regard to this intention. If therefore the material of which the heavenly bodies consist has an ordered ratio harmonizing with the distances, and the planets can now not restrict one another since they are now at a distance from one another in empty space, then their matter must previously have been in a state in which they could act upon one another mutually in order to restrict themselves to the places proportionate to their specific density, which could not have happened in any way other than that their parts had been dispersed in the whole space of the system before their formation and have gained places appropriate to their density in accordance with the universal laws of motion.

The ratio of size of the planetary masses, which increases with distance, is the second reason that clearly proves the mechanical formation of the heavenly bodies and especially our theory thereof. Why do the masses of the heavenly bodies increase approximately with distance? If one follows a doctrine that ascribes everything to a choice by God, then there is no intention that can be thought of as to why the more distant planets must have greater masses other than that, by the great strength

of their attraction in their region, they could encompass one or more moons that are supposed to make a comfortable life for the inhabitants determined for them. However, this purpose could be achieved just as well by a great density in the interior of their lump and why did the lightness of the material that results from special reasons, which is counter to this ratio, have to remain and be exceeded by the advantage of the volume to such an extent that the mass of those farther away is still more important than that of those closer? If one ignores the manner in which these bodies were naturally produced, one will scarcely be able to provide a reason for this ratio, but by taking it into consideration there is nothing easier than to understand this determination. When the material of all celestial bodies was still spread out in the space of the planetary system, attraction formed spheres out of these particles, that had without 1:343
doubt to become larger the further the place of their formation was from that of the universal central body that, as much as possible, limited and prevented this unification from the centre point of the entire space by a particularly mighty attraction.

We become aware of the characteristics of this formation of the heavenly bodies out of the basic materials that had been dispersed at the beginning, taking pleasure at the extent of the intervening spaces that separate their orbits from one another and must be regarded, according to this idea, as the empty compartments from which the planets took the matter for their formation. We see how these spaces between the orbits have a proportion to the size of the masses that have been formed out of them. The distance between the orbit of **Jupiter** and that of **Mars** is so great that the area contained in it exceeds that of all the lower planets combined; but this is worthy of the largest of all the planets, the one that has greater mass than all the others combined. We cannot attribute this distance of Jupiter from Mars to the intention that their attractions should hinder each other as little as possible. For according to such a reason, the planet between two orbits would always be nearest to the planet whose attraction when combined with its own can least disturb both orbits around the Sun, consequently, the one that has the smallest mass. Now because according to the correct calculations of Newton, the force[m] with which Jupiter can act upon the orbit of Mars is to that which it exercises on Saturn by their combined attraction as 1/12512 is to 1/200, we can easily make the calculation how much closer Jupiter would have to be to the orbit of Mars than to that of Saturn if the distance between them had been determined by the intention of their external relation and not by the mechanism of their generation. However, since the facts are completely different, since in regard to the two orbits that are above and below it, a planetary orbit is often more distant from that in which

[m] *Gewalt*

a smaller planet moves than from the orbit of that of a greater mass, but the extent of the space around the orbit of each planet always has a correct ratio to its mass, it is clear that the manner of generation must have
1:344 determined these ratios and that, because these determinations appear to be related as the cause and the effects thereof, we will probably be most correct if we regard the spaces between the orbits as the containers of that material from which the planets have formed themselves, from which it follows directly that their size must be proportional to their masses, which ratio is, however, increased in the case of the more distant planets by the greater dispersion of elementary matter in these regions in the initial state. Therefore of two planets that are fairly equal in terms of mass, the further one must have a greater space for its formation, that is, a greater distance from the two nearest orbits, both because the material there was in itself of a specifically lighter type as well as because it was more dispersed than in the case of the one that formed closer to the Sun. Therefore, although the Earth together with the Moon does not yet appear equal to Venus in bodily content, it nonetheless required a larger space around it for its formation, because it had to form itself from a more dispersed material than this lower planet. For these reasons it is to be conjectured regarding Saturn that the sphere in which it forms will extend much further on the far side than on the side towards the centre point (just as this applies to almost all the planets); and therefore the space between the orbit of Saturn and the course of the next planet beyond it that we can conjecture, will be much further than the one between it and Jupiter.

Thus everything in the planetary structure[n] continues by degrees with correct relations to the initial generating force that was more effective near the centre point than at a distance, outward to all unlimited distances. The diminution of the impressed shooting force, the deviation from the most precise correspondence in the direction and placement of the orbits, the densities of the heavenly bodies, the parsimony of nature in respect of the space of their formation: All this decreases by degrees from the centre to the remote distances; all this shows that the first cause was tied to the mechanical rules of motion and did not act by free choice.

1:345 However, what shows the natural formation of the heavenly spheres out of the basic material that was originally dispersed in the space of the heavens that are now empty as clearly as anything else is the correspondence I borrow from Herr **von Buffon** which, however, in his theory does not have by far the usefulness that it has in ours. For according to his remark, if one adds together those planets whose masses can be

[n] *Weltbaue*

determined by calculation, namely Saturn, Jupiter, the Earth, and the Moon, then they deliver a lump the density of which is to the density of the Sun's body as 640 to 650, against which, since these are the main items in the solar system, the remaining planets, Mars, Venus, and Mercury, hardly deserve to be counted; thus one will be rightly astonished at the remarkable equality that rules between the matter of the entire planetary structure, if it is regarded as being united in one lump and the mass of the Sun. It would be irresponsible carelessness to ascribe this analogy to chance, that among a multiplicity of such infinitely different matters, of which some are found just on our Earth alone that exceed one another in density 15 thousand times, but that nonetheless, as a whole, approach a ratio of 1 to 1; and one must admit that, if one regards the Sun as a mixture of all kinds of matter separated from one another in the planetary structure, all of them appear to have formed in a space that was once filled with uniformly dispersed material and accumulated on the central body without distinction but that was divided in accordance with the heights for the formation of the planets. I leave it to those who cannot accept the mechanical generation of the celestial bodies to explain this so special correspondence by the motivations of God's choice where they can. I want finally to cease basing a matter of such convincing clarity as is the development of the world structure[o] on the basis of the forces of nature on further proofs. If anyone is in a position to remain unmoved in the face of so much convincing evidence one must either lie too deeply in the shackles of prejudice or be completely incapable of lifting oneself above the mass of traditional opinions to the contemplation of the purest truth. In the meantime we can believe that no one except the stupid, on whose approval we cannot count, could fail to recognize the correctness 1:346
of this theory if the correspondences that the world structure,[p] in all its combinations, has to the benefit of rational creatures, did not seem to have something more at its basis than mere universal laws of nature. We also justifiably believe that skilful arrangements directed to a worthy purpose must have a wise understanding as its origin and we will be fully satisfied when we consider that, since the natures of things recognize no original source other than just this one, their essential and universal characteristics[q] must have a natural inclination to consequences that are proper and correspond well with one another. If therefore we become aware of arrangements in the constitution of the world that redound to the reciprocal advantages of creatures, we should not think it strange to attribute these to a natural consequence of the universal laws of nature,

[o] *Weltgebäude*
[p] *Welthau*
[q] *Beschaffenheiten*

for what flows from these is not the result of blind chance or an irrational necessity: It is ultimately grounded in the highest wisdom from which the universal characteristics take their correspondences. One conclusion is quite correct: If order and beauty shine forth in the constitution of the world, then there is a God. However, the other is grounded no less: If this order was able to flow from universal laws of nature, then all of nature is necessarily an effect of the highest wisdom.

But if anyone insists on recognizing the direct application of divine wisdom to all the arrangements of nature that encompass harmony and useful purposes by not considering the development from universal laws of motion capable of any harmonious consequences, then my advice would be not to turn one's eyes upon a single heavenly body in looking at the world structure[r] but rather upon the whole to tear oneself out of this illusion once and for all. If the angled position of the Earth's axis against the plane of its annual route through the cherished change of the seasons is to be a proof of the direct hand of God, then all one needs to do is to compare this characteristic with the other heavenly bodies; then one will become aware that it changes in the case of each of them and that, in this difference, there are some that do not have it at all, such as
1:347 Jupiter for example, whose axis is vertical to the plane of its orbit, and Mars whose is almost so, both of which enjoy no difference in the seasons and yet are just as much works of the highest wisdom as the others. The moons accompanying Saturn, Jupiter, and Earth would appear to be special arrangements of the highest being if the free deviation from this purpose throughout the whole system of the world structure[s] did not indicate that nature has brought forth these determinations without being interrupted in its free behaviour by any extraordinary compulsion. Jupiter has four moons, Saturn five, Earth one, the remaining planets none at all, though it seems these are in greater need of them because of their longer nights than are the former. If one admires the proportionate equality of the tangential forces impressed upon the planets to the central inclination of their distances as the cause for their orbiting around the Sun in near-circles and become suitable dwelling places of rational creatures thanks to the evenness of the warmth provided by the Sun and sees it as the direct finger of the Almighty, then all at once one is led back to the universal laws of nature, if one considers that this planetary characteristic is gradually lost with all stages of diminution in the depths of the heavens and that precisely the highest wisdom that had taken pleasure in the moderate motion of the planets, has not excluded the failings with which the system ends by stopping in complete

[r] *Weltbaues*

[s] *Weltbaues*

irregularity and disorder. Nature, despite having an essential determination to perfection and order, embraces all possible changes in the extent of its multiplicity, even to failings and deviations. It is precisely the same unlimited fertility of nature that has brought forth the inhabited heavenly spheres as well as the comets, the useful mountains and harmful cliffs, habitable landscapes and empty deserts, virtues and vices.

PART THREE,

which contains an attempt to compare the inhabitants of the different planets on the basis of the analogies of nature.

Who knows the relation of all worlds from one part to the other,
Who is familiar with the number of all suns and every planet's orbit,
who **cognizes the various inhabitants of each star**,
To him alone it is allowed,
to grasp and to explain to us why **things are as they are**.

Pope.[72]

Universal
Natural History and Theory of the Heavens.

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PART THREE.

Appendix.
On the inhabitants of the planets.

Because I am of the view that it would be a dishonour to the character of philosophy if one were to use it to maintain, in a kind of thoughtlessness, free excesses of wit with some apparent truth, even if one were to declare that this were merely as an amusement, I shall not adduce any propositions in the present essay other than those that can really contribute to the expansion of our cognition and the probability of which is at the same time grounded so well that we can hardly prevent ourselves from regarding it as valid.

Although it may seem that in this type of subject[t] the freedom to invent has no real barriers and that in judging the nature of the inhabitants of distant worlds we can give free rein to our fantasy with far greater liberty than a painter in the depiction of plants or animals of undiscovered lands and that thoughts of this type could be neither properly proved nor disproved; we nonetheless have to admit that the distances of the heavenly bodies from the Sun include certain relations that contain an essential influence on the various properties of the thinking natures present there 1:352
in terms of their way of being active or passive in relation to the nature of the matter with which they are linked, is tied to and dependent on the number of impressions that the world awakens in them according to the properties of the relation of their abode to the centre point of attraction and of heat.

I am of the opinion that it is just not necessary to assert that all planets must be inhabited, even though it would be nonsense to deny this in regard to all or even only most of them. In view of the wealth of nature in which worlds or systems are only specks of dust in the sunlight compared with the whole of creation, there might well be empty and uninhabited regions that are not being used completely for the purpose of nature, namely for the contemplation of rational beings. This would be as though one were to doubt the wisdom of God by admitting that sandy and uninhabited deserts occupy large stretches of the Earth's surface and

[t] *Vorwurfes*

that there are deserted islands in the oceans where there are no people. However, a planet is much smaller in respect of the whole of creation than a desert or island is in respect of the Earth's surface.

Perhaps not all the heavenly bodies have formed fully yet; it takes centuries or perhaps thousands of years before a large heavenly body has reached a firm state of its matter. Jupiter still appears to be in this conflict. The observable changes in its shape at various times have led astronomers long ago to suppose the it must suffer great convulsions and that its surface is not nearly calm enough for it to be a habitable planet. If it has no inhabitants and will also never have any, what an infinitely small effort of nature would this be in regard to the immeasurability of all creation? And would it not be rather a sign of poverty than of superfluity if it were to be so careful as to demonstrate all its riches in every point of space?

But we can still assume with greater satisfaction that, even if it is uninhabited now, it will be when the period of its formation is complete. Perhaps our Earth existed for a thousand or more years before it was
1:353 constituted so as to support people, animals, and plants. Now, that a planet arrives at this perfection several thousand years later does not detract from the purpose of its existence. For just this reason it will also remain in the perfection of its constitution longer in the future once it has arrived at it; for there is a certain law of nature: everything that has a beginning is constantly approaching its end and is closer to it the more it has moved away from its starting point.

The satirical view of the wit in The Hague who, after reporting the general news from the realm of the sciences, was able to present in a ridiculous way the notion of the necessary population of all the celestial bodies, can only be approved of. "Those creatures," he says, "that inhabit the forests on the head of a beggar had long regarded their abode as an immeasurable sphere and themselves as the masterpiece of creation when one of them, whom heaven had endowed with a finer soul, a little **Fontenelle** of his species, suddenly became aware of the head of a nobleman. He immediately called all the wits of his quarter together and said to them with delight: we are not the only living beings in all of nature; behold here a new country, **more lice live here**."[73] If this conclusion arouses laughter then it is not because it departs so far from the way humans make judgements; but rather because precisely the same error that is based on the same cause in the case of human beings seems to deserve more of an excuse in their case.

Let us judge without prejudice. This insect that expresses the disposition of most people very well both in the way it lives and in its insignificance, can be used as a comparison with good reason. Because in its imagination its existence matters infinitely to nature, it considers the whole of the rest of creation as in vain as far as it does not have its

species as a precise goal, as the centre point of its purposes. The human being, so infinitely removed from the highest stage of beings is so bold as to allow himself, in a similar delusion, to be flattered by the necessity of his existence. The infinity of creation encompasses in itself, with equal 1:354
necessity, all natures that its overwhelming wealth produces. From the most sublime class among thinking beings to the most despised insect, not one link is indifferent to it; and not one can be absent without the beauty of the whole, which exists in their interrelationship, being interrupted by it. Meanwhile, everything is determined by universal laws which nature effects by the connection of its originally implanted forces. Because it brings forth nothing but propriety and order in its processes, no single aim can disturb or interrupt its consequences. In its first formation, the generation of a planet was no more than an infinitely small consequence of its fruitfulness; and now it would be nonsense if their so well-founded laws should yield to the particular purposes of this atom. If the constitution of a heavenly body puts obstacles in the way of the population, it will be uninhabited, although in and of itself it would be better if it were inhabited. The excellence of creation loses nothing thereby for of all magnitudes, the infinite is the one that is not lessened by the subtraction of one finite part. It would be as if one were to complain that the space between Jupiter and Mars is so needlessly empty and that there are comets that are uninhabited. Indeed that insect may seem to us as worthless as possible, it is more important to nature to maintain its entire class than a small number of more excellent creatures, of which there are infinitely many, even if a particular region or area were to be cleared of them. Because it is inexhaustible in the creation of both, we look on with no concern as both are left to the universal laws for their maintenance and destruction. Has the owner of those inhabited forests on the head of the beggar ever created greater destruction in the families of this colony than the son of Philip[74] did among the families of his fellow-citizens when his evil genius put it into his head that the world had been created solely for his sake?

Meanwhile, most of the planets are certainly inhabited and those that are not will be at some stage. Now what sort of circumstances will be caused among the various kinds of these inhabitants by the relationship 1:355
of their place in the solar system[u] to the centre point from which the heat that gives life to everything emanates? For it is certain that this heat, among all the matter of these heavenly bodies, results in certain relations in their determinations in proportion to their distance. The human being, who is the one among all rational beings we are most familiar with, even though his inner constitution is still an unexplored problem, will have to serve as the basis and general reference point in

[u] *Weltgebäude*

this comparison. We shall consider him here not from the point of view of his moral qualities, nor from the physical aspects of his build; we shall examine only the limitations that his ability to think rationally and the motion of his body that obeys this ability would suffer as a result of the constitution of the matter to which he is bound and which is proportionate to the distance from the Sun. Despite the infinite distance between the capacity to think and the motion of matter, between the reasoning mind and the body, it is nonetheless certain that the human being, who derives all his concepts and ideas from the impressions the universe[v] stimulates in his soul through his body, depends totally on the constitution of this matter to which the creator has bound him for both their clarity as well as the skill to connect and compare them, which we call the faculty to think.

The human being has been created to receive the impressions and emotions the world will arouse in him through the body that is the visible part of his being and the matter of which serves not only the invisible spirit that inhabits him to impress the first concepts of external objects but also is indispensable to repeat, to combine, in short to think
1:356 these in the internal action.* In proportion as his body develops, the abilities of his thinking nature obtain the proper degrees of completion and do not attain a settled and masculine power[w] until the fibres of his tools have taken on the firmness and durability that is the perfection of their formation. Those abilities through which he can satisfy the needs required by his dependence on external things develop early enough in him. Some human beings remain at this stage of development. The faculty of combining abstracted concepts and controlling the tendencies of the passions by the free application of insights comes late, for some never in their whole lives; but it is weak in all people: It serves the lower forces that it is supposed to control and the governing of which constitutes the advantage of his nature. If one regards the life of most human beings, this creature seems to be created to absorb sap like a plant, to grow, to reproduce its species, finally to become old and to die. Of all creatures he achieves the purpose of his being least, because he uses up his excellent abilities for ends that the other creatures achieve much more surely and properly with far lesser means. He would also be the most despicable of all, at least in the eyes of true wisdom, were it not that

* On the basis of psychology it has been established that in virtue of the current constitution in which creation has made soul and body dependent on one another, the former not only has to take over all the concepts of the universe[x] through the latter's community and influence but also the exercise of its power of thought itself depends on its constitution and borrows the requisite ability for it from its assistance.

[v] Universum
[w] *Vermögen*
[x] Universi

the hope of what is to come elevated him and a period of the complete evolution[y] of the powers locked inside him were not in store for him.

If we examine the cause of the obstacles that hold human nature in such a state of low degradation, it may be found in the coarseness of the matter into which his spiritual part is sunk, in the rigidity of the fibres and the sluggishness and immobility of the fluids that ought to be obedient to its stirrings. The nerves and fluids of his brain supply him with only coarse and unclear concepts and because he is unable to balance the stimulation of sensory sensations in the interior of his faculty of thinking with sufficiently powerful ideas,[z] he is carried away by his passions, dulled and disturbed by the tumult of the elements that maintain his machinery. The efforts[a] of reason to rise against this and to expel this confusion by the light of the power of judgement are like the flashes of sunshine when thick clouds constantly interrupt and darken its brightness. 1:357

This coarseness of the material and the fabric in the structure of human nature is the cause of the sluggishness that keeps the soul's abilities in constant exhaustion[b] and powerlessness. The action of reflection and of ideas[c] enlightened by reason is an arduous state into which the soul cannot place itself without resistance and out of which it soon falls back into the passive state by a natural tendency of the bodily machine since the sensory stimulations determine and govern all its actions.

This sluggishness of his power of thought that is a result of his dependence on coarse and unwieldy matter is the source not only of vice but also of error. Prevented by the difficulty associated with the attempts to disperse the fog of confused concepts and to separate the universal cognition arising from the comparison of ideas from sensory impressions, it prefers to yield to overhasty approval and contents itself in the possession of an insight that scarcely allows it to give the sluggishness of its nature and the resistance of matter even glancing consideration.

In this dependency the intellectual capacities decline together with the liveliness of the body: when, because of the weakened circulation of fluids, old age cooks only thick fluids in the body, when the flexibility of the fibres and the agility in all movements decreases, the powers of the spirit ossify with a similar fatigue. The sprightliness of thoughts, the clarity of ideas,[d] the liveliness of wit and memory become weakened and cold. Concepts acquired by long experience will to some extent replace the decline of these powers and reason would betray its inability even more clearly if the intensity of the passions that require being reined in by it did not diminish at the same time or even earlier.

[y] *Auswickelung*
[z] *Vorstellungen*
[a] *Bemühungen*
[b] *Mattigkeit*
[c] *Vorstellungen*
[d] *Vorstellungen*

Accordingly, it is clear from this that the powers of the human soul are restricted and hemmed in by the obstacles of the coarse matter to which they are most intimately bound, but something even more remarkable
1:358 is that this specific constitution of the material has an essential reference to the degree of influence[e] with which the Sun enlivens them in proportion to their distance and prepares them for the performance of animal economy. This necessary reference to the fire that spreads from the centre point of the solar system[f] in order to maintain matter in the requisite movement is the basis for an analogy that is posited from just this between the various inhabitants of the planets; and by means of this ratio, each class thereof is bound by the necessity of its nature to the place that has been assigned to it in the universe.[g]

The inhabitants of the Earth and of Venus could not exchange their domiciles without the destruction of both. The former whose formation material is proportionate to the degree of heat of their distance and therefore too light and volatile for an even greater one, would, in a hotter place, suffer violent motions and a breakdown of their nature that would arise from the dispersion and desiccation of the fluids and a violent tension of their elastic fibres; the latter, whose coarser build and sluggishness of the elements of their formation requires a greater influence of the Sun, would freeze in a cooler region of the heavens and decay in lifelessness. Similarly it must be far lighter and more volatile matters that constitute the body of an inhabitant of Jupiter so that the slight stirring with which the Sun can act at this distance, can move these machines just as powerfully as it does in the lower regions, and so that I can summarize everything in one general concept: **The material of which the inhabitants of different planets, indeed even the animals and plants on them, are formed must altogether be of a lighter and finer type and the elasticity of the fibres together with the advantageous arrangement of their build be more perfect the further they are away from the Sun**.

This relationship is so natural and well founded that not only the motivations of the ultimate purpose lead to them, which in the natural sciences are generally regarded as only weak reasons, but at the same time the proportions of the specific constitution of the matter of which
1:359 the planets consist that have been established by **Newton**'s calculations as well as by reasons of cosmogony, confirm this, according to which the material forming a heavenly body is always of a lighter kind in the case of distant ones than with the nearer ones, which must necessarily

[e] *Hinflusses*. Hartenstein reads *Einflusses*.
[f] *Weltsystems*
[g] Universo

result in a similar relationship in the creatures that produce and maintain themselves on them.

We have established a comparison between the characteristics of the matter with which the creatures endowed with reason on the planets are essentially united; and after the introduction of this observation it can easily be seen that these relationships will have a consequence in regard to their **intellectual** abilities as well. If therefore these intellectual abilities have a necessary dependence on the material of the machine they inhabit, we will be able to conclude with a more than probable conjecture: **that the excellence of thinking natures, the sprightliness of their ideas**,[h] **the clarity and liveliness of the concepts they receive through external impressions, along with the faculty to put them together, and finally also the agility in the actual exercise, in short, the entire extent of their perfection stands under a certain rule, according to which they become more and more excellent and perfect in proportion to the distance of their domiciles from the Sun**.

As this proportion has a degree of credibility that is not far removed from an established certainty, we find an open field for pleasant conjectures arising from a comparison of the properties of these various inhabitants. Human nature, which occupies as it were the middle rung on the ladder of beings, sees itself as being between the two extreme limits of perfection, equally distant from both ends. If the idea[i] of the most sublime classes of rational creatures that inhabit Jupiter or Saturn arouses their jealousy and humiliates them by the knowledge of their own baseness, then they can be satisfied again and comforted by the sight of the low stages on the planets Venus and Mercury, which are lowered far below the perfection of human nature. What an amazing sight! On the one hand, we saw thinking creatures among whom a Greenlander 1:360
or Hottentot would be Newton, on the other hand, those who would admire him as an ape.

> As the higher beings recently saw,
> What not long ago quite remarkably,
> A mortal among us did,
> And as he unfolded the law of nature: they were amazed,
> That such an occurrence was possible through an earthly creature,
> And looked at our Newton just as we view an ape.
>
> **Pope**.[75]

To what progress in cognition will not the insight of those blessed beings of the uppermost spheres of heaven reach! What beautiful consequences will this illumination of insights not have on their moral

[h] *Vorstellungen*

[i] *Vorstellung*

characteristics! The insights of the understanding, if they possess the proper degrees of completeness and clarity, have far more lively stimulation than the sensory attractions and are capable of dominating these victoriously and treading them under foot. How gloriously will not the divinity, which depicts itself in all creatures, depict itself in these thinking natures that serenely take on its image and reflect it back like a sea unmoved by the storms of passion! We do not wish to extend these conjectures beyond the limits marked out for a physical treatise, we merely note again the analogy adduced above: **that the perfection of the spiritual world as well as of the material world increases and progresses in the planets from Mercury on to Saturn or perhaps even beyond it (insofar as there are yet other planets) in a correct sequence of degrees in proportion to their distances from the Sun**.

While this flows from the consequences of the physical relationship of their domiciles to the centre point of the world partly naturally, partly is caused appropriately: on the other hand, the real sight of the most excellent arrangements appropriate for the splendid perfection of these natures in the upper regions confirms this rule so clearly that it nearly ought to make a claim to complete conviction. The sprightliness of actions connected to the advantages of a sublime nature is more suited
1:361 to the rapidly alternating time periods of these spheres than the slowness of sluggish and imperfect creatures.

Telescopes teach us that the alternation of day and night on Jupiter occurs in 10 hours. What would an inhabitant of the Earth likely do with this division if he were placed on that planet? The 10 hours would hardly suffice for the rest that this coarse machine needs for its recreation through sleep. What would the preparations for the arrangements of being awake, dressing, the time spent on eating, not require as a part of the following time and how would a creature whose actions had happened so slowly not be distracted and made incapable of anything useful, whose 5 hours of activity were suddenly interrupted by the intervention of an equally long darkness? By contrast, if Jupiter is inhabited by more perfect creatures who combine a finer build with more elastic forces and a greater agility in execution, then one can believe that these 5 hours are just the same and more for them than what the 12 hours of the day amount to for the low class of human beings. We know that the need of time is something relative that cannot be cognized and understood save from the magnitude of what has to be achieved compared to the speed of the execution. Therefore the very same time that for one type of creatures is, as it were, no more than a moment can be a long period for others in which a great succession of changes unwinds by rapid action. Saturn has, according to the probable calculation of its rotation, as we have

shown above, a much shorter division of day and night and therefore allows us to conjecture even more excellent abilities in the nature of its inhabitants.

Finally, everything agrees to confirm the laws adumbrated above. Nature has evidently spread out its supplies most grandly on the distant side of the world. The moons that compensate the busy beings of these blessed regions for the deprivation of daylight with an adequate replacement are supplied there in large numbers and nature appears to have been careful to provide all assistance to their efficacy so that there is almost no time for them to prevent them from applying them. Jupiter 1:362
has an obvious advantage over all lower planets in regard to moons, and Saturn, in turn, over it as its institutions in the beautiful and useful ring that surrounds it make even greater advantages of its constitution probable; by contrast, the lower planets on which this supply would be wasted uselessly, whose class borders more closely on the lack of reason, have not been accorded such advantages at all or only in small measure.

However, one can (here I am anticipating an objection that could invalidate all this harmony cited above) regard the greater distance from the Sun, this source of light and life, not as an evil against which the extensiveness of such arrangements in the more distant planets are only advanced as a precautionary measure in order to rectify it somewhat, and object that indeed the upper planets do have a less advantageous position in the solar system[j] and a position that would be detrimental to the perfection of their arrangements because they receive a weaker influence from the Sun. For we know that the effect of light and heat is determined not by their absolute intensity but by the ability of matter to accept them and more or less resist its drive and that therefore the very same distance that can be called a temperate climate for a coarser type of matter would distribute more subtle fluids and be of damaging violence for them; therefore it takes only a finer material consisting of more mobile elements to make the distances of both Jupiter and Saturn from the Sun into a fortuitous position.

Finally, the excellence of the natures in these upper regions of the heavens appears to be combined by means of a physical connection with a durability of which it is worthy. Death and decay cannot affect these excellent creatures as much as they do us lower natures. Precisely the same sluggishness of matter and coarseness of the material that is the specific principle of the debasement of the lower stages are also the cause of the tendency they have to decay. When the fluids that nourish an animal or a human being and make them grow by incorporating themselves between his small fibres and adding to his mass, can no longer

[j] *Weltgebäude*

1:363 enlarge its vessels and channels at the same time in the spatial extension when growth is complete; then these attaching nourishing fluids, by precisely the same mechanical drive that is applied to feed the animal, must narrow and block the aperture of its vessels and, gradually becoming more and more rigid, destroy the structure of the whole machine. It is to be believed that, although transience gnaws at even the most perfect natures, the advantage in the fineness of the material, in the elasticity of the vessels and in the lightness and efficacy of the fluids out of which those more perfect beings inhabiting the distant planets are formed, nonetheless delays far longer the frailty that is a consequence of the sluggishness of coarse matter, and provides these creatures with a longevity proportionate to their perfection, just as the frailty of human life has a proper relationship to its worthlessness.

I cannot leave this observation without anticipating a doubt that might arise naturally out of a comparison of these opinions with our earlier statements. In the arrangement of the solar system[k] in terms of the number of satellites that light up the planets of the most distant orbits, of the velocity of the axial rotation, and of the materials of their constitution proportionate to the Sun's effect, we have recognized the wisdom of God which has so beneficially ordered everything for the good of the rational beings that inhabit them. However, how can one now reconcile a mechanical doctrine with the teaching of intentions in such a way that what the highest wisdom itself designed has been delegated for implementation to coarse matter and the regiment of providence to nature left to its own devices? Is the former not rather an admission that the arrangement of the solar system[l] has not been developed by the universal laws of the latter?

These doubts can easily be dispersed if we think back to what was said with the same intention earlier. Must not the mechanics of all natural motions have an essential tendency to many such consequences that accords with the project of the highest reason in the whole extent of connections? How can it have aberrant endeavours and an unbounded dispersion in its activities[m] if all its properties from which these con-
1:364 sequences develop, even have their own determination on the basis of the eternal idea of the divine understanding in which everything must necessarily relate to everything and fit together? If one thinks about it carefully, how can one justify a manner of judgement that regards nature as an offensive subject which can only be kept in the bounds of order and communal harmony by means of a kind of force that places restraints

[k] *Weltbaues*
[l] *Weltbaues*
[m] *Beginnen*

on its free conduct unless one thinks that it is a self-sufficient principle whose properties recognize no cause and which God attempts to coerce as well as possible into the plan of his intentions? The better we get to know nature, the more will we gain the insight that the universal characteristics of things are not foreign to and separate from each other. We shall be adequately convinced that they have essential affinities through which, by themselves, they prepare to support each other in the establishment of perfect constitutions, namely the interaction of the elements for the beauty of the material world and yet also at the same time for the advantages of the spiritual one and that altogether the individual natures of things in the field of eternal truths among themselves already constitute, as it were, a system in which one relates to the other; we shall also become aware that the affinity is a part of them from their common origin out of which they all drew their essential determinations.

And now to apply this repeated observation to the purpose at hand: precisely the same universal laws of motion that have accorded the highest planets a place distant from the centre point of attraction and inertia in the solar system[n] have, in so doing, at the same time put them into the most advantageous constitution to begin their formations furthest away from the reference point of the coarse matter and with greater freedom as well; but, at the same time, they also have placed them in a regular relation to the influence of heat which spreads out from the centre point according to the same law. Now since it is just these determinations that have made the formation of celestial bodies in these distant regions less restricted, the generation of motions dependent on them faster and, in brief, made the system more proper, since finally, the spiritual beings have a necessary dependence on matter to which they are 1:365
personally bound, then it is no wonder that the perfection of nature has been effected from both places in a single connection of causes and for the same reasons. This agreement is therefore, on close consideration, nothing sudden or unexpected and because the latter beings have been merged into the general constitution of material nature by a similar principle, the spiritual world will be more perfect in the distant spheres for the very reasons as the bodily one is.

Thus everything in the whole extent of nature is connected in an uninterrupted graduated sequence by the eternal harmony that refers all links to each other. God's perfections have revealed themselves clearly in our stages and are no less glorious in the lowest classes than in the more sublime ones.

[n] *Weltsystem*

What a chain, which from God its beginning takes, what natures,
From heavenly and earthly [natures], from angels [and] humans down to animals,
From seraphim to the worm! O distance that the eye can never,
Attain and contemplate,
From the Infinite to you, from you to nought!
Pope.[76]

So far we have continued the conjectures faithfully along the thread of the physical relations that has kept them on the path of a rational credibility. Shall we allow ourselves a further digression from this path into the field of fantasy? Who can show us the border where well-founded probability ends and arbitrary fictions begin? Who is so bold as to dare an answer to the question as to whether sin exercises its domination in other spheres of the solar system[0] as well or whether virtue alone holds sway there?

The stars perhaps are a seat of transfigured spirits
As here vice rules, there virtue is the master.
v. Haller.[77]

Does not a certain mean need to exist between wisdom and foolishness for the unfortunate ability of being able to sin? Who knows whether the inhabitants of those distant celestial bodies are not too noble and too
1:366 wise to lower themselves to the foolishness that resides in sin while those inhabiting the lower planets are attached too firmly to matter and equipped with far too few spiritual abilities to be permitted to bear the responsibility for their actions before the judgement seat of justice? In this way the Earth and perhaps also Mars (so that we are not deprived of the miserable consolation of having companions in misery) alone lie in the dangerous middle zone where the temptation of sensual delights has a strong power to lead astray against the domination of the spirit which, however, cannot not deny the capacity by which it is in a position to resist them if it did not rather please its sluggishness to allow itself to be carried away by them, where there is thus the dangerous mean between weakness and strength, where precisely the same advantages that raise him above the lower classes place him at a height from which he can sink infinitely far beneath them again. In fact, the two planets Earth and Mars are the middle-most members of the planetary system and we can perhaps suspect with some probability a medium position of the physical as well as of the moral characteristics between the two end-points. However, I would prefer to leave this consideration to those who find in themselves greater comfort in the face of unprovable knowledge and greater inclination to take responsibility for it.

[0] *Weltbaues*

CONCLUSION.

We are not even properly familiar with what a human being actually is, even though consciousness and our senses should inform us about it; how much less will we be able to imagine what he will become in the future! Nonetheless the human soul's desire for knowledge grasps greedily for this object so distant from it and strives to shed some light in such obscure cognition.

Should the immortal soul remain forever attached to this point in space, to our Earth for the whole infinity of its future duration, which 1:367
is not interrupted by the grave itself, but only changed? Should it never obtain a closer view of the remaining wonders of creation? Who knows whether it is not intended to get to know at close quarters those distant spheres of the solar system[p] and the excellence of their arrangements that already excite its curiosity so much from a distance? Perhaps some further spheres of the planetary system will form around them in order to prepare new places for us to reside in other heavens, after the completed passage of time prescribed for our stay here. Who knows, perhaps the satellites orbiting around Jupiter will light our way in the future?

It is permissible, it is proper to amuse oneself with such ideas; but no one will base one's hope for the future on such uncertain images of the imagination. After vanity has taken its part of human nature, the immortal spirit will rise up in a swift flight[q] over all things temporal and continue its existence in a new relation to all of nature which arises out of a closer connection with the highest being. At that time in the future, this enhanced nature, which carries the source of happiness within itself, will no longer disperse itself among external objects to find comfort with them there. The whole sum of creatures that has a necessary harmony with the approval of the highest original being, must also have it for its own and will not move it other than with eternal satisfaction.

Indeed, when one has filled one's mind with such observations and with the preceding ones, the view of the starry sky on a clear night gives one a kind of pleasure that only noble souls feel. In the universal stillness of nature and the calmness of the senses the immortal spirit's hidden faculty of cognition speaks an ineffable language and provides undeveloped concepts that can certainly be felt but not described. If, among the thinking creatures of this planet, there are any despicable beings who, in spite of all the delights with which so great an object can attract them, are yet in a position to tie themselves firmly to the service of vanity, how unfortunate is this sphere that it has been able to bring 1:368
up such miserable creatures! But how fortunate is it, on the other hand,

[p] *Weltgebäudes*

[q] *Schwung*

because under the most acceptable of conditions a way has been opened for it to attain bliss and sublimity that is exalted infinitely far above the benefits that the most advantageous arrangement of nature can attain in all celestial bodies!

[End]

5. Nicolaus Hartsoecker (1656–1725) was a Dutch mathematician and scientist, who, among other things, was the teacher of Tsar Peter I. He was known especially for his popular expositions of the mechanical philosophy.
6. Hermann Boerhaave (1668–1738) was a professor of medicine, botany, and chemistry at the university in Leiden, often credited with founding the modern system of teaching medical students at the patient's bedside. His *De Mercurio Experimenta* appeared in 1733 and 1736, and in German translation in 1753.
7. Stephen Hales (1677–1761) was a Cambridge-trained cleric and Vicar of Teddington who was interested in chemistry, botany, anatomy, and physiology. He published important experimental work on pneumatics and plant and animal physiology. His principal works were *Vegetable Staticks* (1727) and *Statical Essays: Containing Haemastaticks* (1733).
8. This town, today called Paslek, is about 50 miles south-east of Danzig (Gdansk), and about 60 miles south-west of Königsberg (Kaliningrad).

Notes to Chapter 4

1. For a convenient summary of the astronomical data that Kant relied on as well as contemporary values, see Appendix II.
2. The relevant works are Johann Lambert's *Kosmologische Briefe* [Cosmological Letters] and Pierre-Simon Laplace's *Méchanique céeleste* [Celestial Mechanics].
3. Originally in a volume titled *Kant's Cosmogony* (Glasgow, 1900). Reprinted, with a new introduction by Milton K. Munitz (Ann Arbor: Ann Arbor Paperbacks, 1969).
4. *Immanuel Kant. Universal Natural History and Theory of the Heavens*, translated with introduction and notes by Stanley L. Jaki (Edinburgh: Scottish Academic Press, 1981).
5. *Immanuel Kant*, *Universal Natural History and Theory of the Heavens*... Translated by Ian Johnston, Vancouver Island University, available at Richer Resources Publications and at http://records.viu.ca/~johnstoi/kant/kant1.htm.
6. We have relied extensively on numerous sources for the information found in the following factual notes. Of special mention are the "Sachliche Erkläuterungen" by Johannes Rahts, which accompany the text of the Academy edition (1:547–557); Gensichen's additions (which were published in *William Herschel über den Bau des Himmels. Drey Abhandlungen aus dem Englischen übersetzt. Nebst einem authentischen Auszug aus Kants Allgemeiner Naturgeschichte und Theorie des Himmels* (Königsberg: Friedrich Nicolovius, 1791)); Erich Adickes, *Kant als Naturforscher* (Berlin: De Gruyter, 1924); Hans-Joachim Waschkies, *Physik und Physikotheologie des jungen Kant. Die Vorgeschichte seiner Allgemeinen Naturgeschichte und Theorie des Himmels* (Amsterdam: Gruner, 1987); and Jaki's copious footnotes to his translation.
7. The Areopagus is a hill near the Acropolis in Athens associated with various trials for murder, e.g., that of Orestes for killing his mother. The term came to be used for any high court, real or metaphorical, that passed judgement on important matters. Here, Kant may be referring to the arbiters of orthodox Lutheranism.
8. The term "naturalist" refers to those who see nature as the ultimate ground for all things; later Kant uses it as a euphemism for atheist, e.g., at 1:223 he contrasts it with the "defender of religion". It does not have the same meaning as it does in its contemporary usage. Kant may have in mind materialists, such as La Mettrie.

9. Kant continues to object to Epicure in this way as late as § 73 of the *Critique of the Power of Judgment* (5:392–393).
10. Kant is quoting here from *Übersetzung der Algemeinen Welthistorie die in Engeland durch eine Geselschaft von Gelehrten ausgefertiget worden: nebst den Anmerkungen der holländischen Uebersetzung auch vielen neuen Kupfern und Karten genau durchgesehen und mit häufigen Anmerkungen vemehret*, by Siegmund Jacob Baumgarten (Halle: Gebauer, 1744), 1:80, though the italics are Kant's addition. The original English text is *An Universal History from the Earliest Time to the Present compiled from Original Authors and Illustrated with Maps, Cuts, Notes, Chronological and Other Tables*, vol. 1 (London: Batley, 1736). The original text reads: "However, we cannot but think the essay of that philosopher, who endeavoured to account for the formation of the world in a certain time from a rude matter, by the sole continuation of a motion once impressed, and reduced to a few simple and general laws; or of others, *who have since attempted the same, with more applause, from the original properties of matter, with which it was indued at its creation*, is so far from being criminal or injurious to GOD, as some have imagined, that it is rather giving a more sublime idea of its infinite wisdom" (p. 35).
11. Kant uses the term "Schwung" to refer to the tangential force of a body in circular motion that is accelerated by a centripetal force, that is, to the force a body has, on his account, to continue in a straight line. The tangential and the centripetal forces interact so as to produce the circular motion.
12. Thomas Wright of Durham (1711–86) was an English astronomer, mathematician, and instrument maker. He was best known for his publication of *An Original Theory or New Hypothesis of the Universe* (1750), which explains the shape of the Milky Way as due to an optical effect. He also speculated that faint nebulae were distant galaxies.
13. Wright's work was summarized in three instalments in the January 1, 5, and 8 issues of the *Freye Urtheile und Nachrichten zum Aufnehmen der Wissenschaften und der Historie überhaupt* [Free Judgments and News for Mounting the Sciences and History in General] (on pp. 1–5, 9–14, and 17–22). For detailed speculation about Kant's knowledge of this and other discussions of Wright's views, see Jaki, pp. 220–221.
14. After an early stint as vicar, James Bradley (1693–1762) was elected to the Royal Society in 1718 and then held the Savilian chair of astronomy at Oxford from 1721 until 1742. Following Halley's death, he was appointed Astronomer Royal. Through his work with Samuel Molyneux, he discovered an aberrant motion, proving that the Earth was in motion. He was also instrumental in providing a specific measurement of the speed of light.
15. See James Bradley, "A letter to the Rt. Hon. George Earl of Macclesfield concerning an apparent motion observed in some of the fixed stars," December 31, 1747, published in *Philosophical Transactions* for the year 1748, pp. 39–41.
16. Pierre-Louis Moreau de Maupertuis (1698–1759) was a prominent French mathematician, philosopher, and scientist. In addition to defending Newton's position in the *vis viva* controversy against Cartesian opponents, Maupertuis was involved in an expedition to Lapland to measure the length of a degree of the meridian so as to establish that the Earth had an oblate rather than a prolate shape. In mathematics and philosophy, he proposed and then applied broadly the principle

of least action, which Euler formulated in more precise mathematical terms. He was elected to several academies of science in Europe, becoming president of the Prussian Royal Academy of Sciences at the request of Frederick II. His *Treatise on the Figure of the Stars* was originally published as *Discours sur la figure des astres* in 1742. Kant is quoting (rather freely) from the Latin discussion of *Ouvrages divers* in the *Nova acta eruditorum, anno MDCCXL*, pp. 221–229, specifically pp. 224–226.

17. Christian Fürchtegott Gellert (1715–1769) was a popular German poet who also served as an extraordinary professor of philosophy in Leipzig for most of his career. His *Fabeln und Erzählungen* [Fables and Stories], published 1746–48, contains short poems and stories with a morally uplifting intent. "Hans Nord" is a poem that describes how a swindler, Hans Nord, cons a group of Londoners out of money by promising to squeeze himself, both "head and leg", into a jar with a narrow neck, upon advance payment of eight "*Groschen*".
18. Alexander Pope (1688–1744) is an important English poet, translator of Homer, and editor of Shakespeare's works. Kant is quoting from Brockes' German translation of Epistle I of Pope's *Essay on Man*, which reads as follows: "Seht jene große Wunderkette, die all Theile dieser Welt/Vereinet und zusammenzieht und die das große Ganz' erhält", which can be translated as: "See that great chain of miracles that unifies and draws together all the parts of this world and that preserves the great whole." Pope's original text has been reproduced above. Apparently, Herder reported that Pope and Albrecht von Haller were Kant's favourite poets and that he liked to quote them at appropriate points in his lectures (Waschkies, p. 585).
19. Christian Huygens (1629–95) was a Dutch astronomer, mathematician, and physicist. He was the first to discover one of Saturn's moons in 1655. Giovanni Domenico Cassini (1625–1712), an Italian-French astronomer, discovered four more moons (in 1671, 1672, and 1684).
20. Kant is referring to Kepler's Second Law. Johannes Kepler (1571–1630) was a German mathematician and astronomer whose observations and mathematical calculations led to the statement of three laws describing the motions of the planets in our solar system. The Second Law states that planets sweep out equal areas in equal times.
21. Kant is referring to Kepler's Third Law. Kepler's third law states that the square of the periodic times of the planets are to each other as the cubes of the mean distances.
22. In 1657 Huygens discovered the actual shape of Saturn's ring.
23. See notes 12 and 13 above.
24. Kant later replaces "the power of rotation" with "the tangential force of the orbit".
25. Kant should have doubled the numbers one and a half million and 4000. A star that was 21,000 times further from the Sun than is the Earth and Orbits the Sun due to the Sun's gravitational force would need more than 3 million years for its orbit and would change its position one degree in 8,000 years.
26. Philippe de la Hire (1640–1718) was first a painter and architect, then a professor of mathematics at the Collège royale de France.
27. Giovanni Battista Riccioli (1598–1671) was an Italian astronomer, who performed extensive observations of the moon.

28. At Kant's request, Gensichen adds the following remark: "Professor Kant had already delivered his description of the Milky Way as a system of moved suns that is similar to our own planetary system six years before Lambert made known a similar idea in his *Cosmological Letters on the Arrangement of the Universe* that was first published in 1761. Thus the former deserves the right of first possession of a thing that no one had yet owned. Further, Lambert's conception also seems to be different from, and, it seems to me inferior to, Kant's, because Lambert divided the Milky Way into countless smaller parts and assumed that our planetary system is to be found in one of the parts to which all stars beyond the Milky Way should belong." Johann Heinrich Lambert (1728–77) was a German mathematician, physicist, and philosopher who corresponded with Kant after 1765. In addition to several significant articles on mathematics, reflection, perspective, and optics, he published *Cosmologische Briefe über die Einrichtung des Weltbaues* [Cosmological Letters on the Arrangement of the Universe] in 1761, *Neues Organon* [New Organon] in 1764, and *Anlage zur Architectonic* [Appendix on Architectonics] in 1771.
29. It is unclear of which passage in Maupertuis' oeuvre this sentence is supposed to be a quote.
30. Kant is referring to William Derham (1657–1735). The title of the work is *Astro-Theology, or a demonstration of the being and attributes of God from a survey of the heavens* (1715). A German translation, *Astrotheleologie, oder himmlisches Vergnügen in Gott* (Hamburg: Felginers Wittwe), appeared in 1732.
31. At Kant's request, Gensichen adds this second remark: "Lambert seems to have been uncertain about how to view the nebulous stars. For, although one might infer on the basis of several passages in his letters that he viewed them as distant Milky Ways, other passages certainly suggest that he viewed them, or at least the glimmer in Orion, as light that the obscure central bodies that were illuminated by its neighbouring suns reflected towards us. It seems to be certain that Lambert suspected the existence of several Milky Ways, but it does not seem that he viewed the nebulous stars as such distant Milky Ways. One can thus not properly call this description a daring thought Lambert made, as Erxleben does in his physics, 1772, p. 540, and as it has remained in the later editions undertaken by Herr Lichtenberg; and since this thought was already presented by Kant in the year 1755, and, in fact, in a very specific way, there can be no more doubt on whose side the priority of this kind of description lies." Johann Christian Polycarp Erxleben (1744–77) was a German physicist, minerologist, and veterinarian, who published, among other things, *Anfangsgründe der Naturlehre* [Basic Concepts of the Doctrine of Nature] (1768), which Kant used for his lectures on physics starting in 1776. Georg Christoph Lichtenberg (1742–99) was a popular author and mathematician and the first professor in Germany for experimental physics. In addition to collections of aphorisms (in his so-called "Waste Books"), he published *Vorlesungen zur Naturlehre* [Lectures on the Doctrine of Nature] (1784), which were explicitly based on Erxleben's *Anfangsgründe*.
32. Rahts suggests "increase" rather than "decrease" here.
33. This quotation is from Epistle III of Pope's *Essay on Man*. The German translation can be translated into English as: "See forming nature move toward its great purpose / Every mite of star dust stirs each other / Each one that is pulled pulls the other to itself / So as to grasp the other in turn, to attempt to shape it. / Behold

matter in a thousand-fold way / Striving to a universal center." Kant leaves off the last half of the last line "ihr allgemeines Gut" (The general Good).

34. A line refers to a unit of length equal to 1/12 of an inch, or just over 2 millimetres.
35. The word "can" is a later addition of Kant's.
36. The word "ultimately" is a later addition of Kant's.
37. According to Gensichen, Kant amends his text as follows: "initially slowly (through chemical attraction), but then in rapid steps (through so-called Newtonian attraction)".
38. Kant presumably means centripetal, not centrifugal force here.
39. The phrase "as it were" is a later addition of Kant's.
40. Kant later amended this text as follows: "The elements of the lighter kind, by contrast, which are more readily deflected from the straight line of their fall, will change into orbital motions before they have penetrated so deeply to the centre, *because they are not permitted to penetrate so deeply into the space filled by the elements, so that their motion turned sideways by this resistance of theirs, attains the velocity required for a free orbit. Therefore, after having attained the tangential force sufficient for free motion*, they will remain hovering at greater distances, and cannot penetrate so far through the filled space of the elements without their motion through these being weakened by their resistance and they are unable to achieve the high degree of velocity required for orbiting closer to the centre." (Italics for added text.)
41. Kant later replaces "hanging" with "floating".
42. Kant may be referring to Newton's discussion of the density of the planets in Bk. III, Prop. viii, Theor. viii, Cor. 3 and 4 of the *Philosophiae Naturalis Principia Mathematica*. Kant's personal library contained a copy of the second edition of Newton's *Principia*: *Philosophiae Naturalis Principia Mathematica. Editio ultima auctior et emendatior* (Amsterdam, 1714).
43. Jaki suggests that Kant may have been influenced by Buffon on this point.
44. Jaki argues (p. 261) that Kant uncritically adopted Buffon's reference to the *Principia* in his *Histoire naturelle* (1:136) for this value.
45. Kant later replaces the phrase "where . . . formed", with "with respect to the magnitude of the space".
46. In Kant's time, a billion is a million million, not a thousand million.
47. Kant confuses radius and diameter here, such that the entire sphere of Saturn should exceed the volume of the earth by 8,000 "billion" times.
48. The value Kant uses for water here diverges from that used by Newton in the third edition of the *Principia* (Bk. III, Prop. x, Theor. x).
49. Newton mentions the sight of stars through the tail of comets in the *Principia* (Bk. III, Prop. xli, Probl. xxi).
50. The phrase "by their very own attractive forces" is a later addition of Kant's.
51. George Louis Leclerc Buffon (1707–88) was a French naturalist and philosopher, Keeper of the King's Garden in Paris, and author of an extremely influential work titled *Histoire Naturelle*, which was published in 36 volumes from 1749 to 1788.
52. Equatorial zone.
53. Cassini's observations between 1665 and 1692 led to agreement on nine hours and fifty minutes as the rotation period of Jupiter.

54. See Kant's "Examination of the Question Whether the Rotation of the Earth on its Axis by which it Brings About the Alternation of Day and Night has Undergone any Change Since its Origin and How One Can be Certain of This, Which was set by the Royal Academy of Sciences in Berlin as the Prize Question for the Current Year" in this volume.
55. Kant later starts his excerpt of this chapter with: "The origin of the ring that encircles Saturn can be explained more intelligibly than many other natural appearances if we assume that after the completion of its formation Saturn had a rotation around its axis and the lightest material at its surface was raised above it through the effects of heat."
56. For detailed discussion of the possible historical origins of this value, see Jaki, pp. 270–271.
57. Kant presumably has the polar and equatorial diameters in mind.
58. Huygen's hypothesis is stated in *Discours sur la cause de la pesanteur* (1690).
59. Newton's hypothesis is stated in Bk. III, Prop. xix, Probl. iii of the *Principia*.
60. The theorem of Newton that is most immediately relevant here is from Bk. III, Theor. xix, Probl. iii of the *Principia*.
61. Jaki states (p. 275) that Cassini's ratio is actually the same as Newton's.
62. Rev. James Pound (1669–1724) was an English astronomer and a member of the Royal Society.
63. Kepler's Third Law.
64. Wolf Balthasar Adolph von Steinwehr (1704–71) was a German writer on science, numismatics, theology, and philosophy, who published a German translation of the Memoirs of the Academy of Science in Paris.
65. Jean-Jacques D'Ortous De Mairan (1678–1771) was a French mathematician, physicist, and astronomer, who served in a variety of capacities at the Royal Academy of Sciences in Paris and became editor of the *Journal des Scavans*. His best known work, *Traite physique and historique de l'Aurore Boreale*, was published in Paris in 1733 and reprinted in the *Journal des Scavans* in 1754.
66. Johann Friedrich Weitenkampf (1726–58) was a fellow student of Kant's in Königsberg, who went on, after further studies in Leipzig and Halle, to become a pastor in Braunschweig. Two publications are at issue here, namely *Gedanken über wichtige Wahrheiten aus der Vernunft und Religion* [Thoughts on Important Truths of Reason and Religion] (Braunschweig/Hildesheim: Schröder, 1753–55) and *Das Lehrgebäude vom Untergange der Erde* [Doctrine Concerning the End of the World] (Braunschweig/Hildesheim: Schröder, 1754).
67. Albrecht von Haller (1708–77) was a Swiss physician, physiologist, and botanist, who was also a popular poet at the time. Kant is quoting from "Unvollkommene Ode über die Ewigkeit" [Incomplete Ode on Eternity], which was published in the third edition of *Versuch schweizerischer Gedichte* [Essay on Swiss Poetry] (Danzig, 1743).
68. This quotation from Epistle I of Pope's *Essay on Man* reads as follows in the original:

> Who sees with equal eye, as God of all
> A hero perish or a sparrow fall
> Atoms or systems into ruin hurl'd
> And now a bubble burst, and now a world.

69. Again, Kant quotes von Haller's poem "Unvollkommene Ode über die Ewigkeit".
70. Joseph Addison (1672–1719) was a British poet and politician, who, along with Richard Steele, founded *The Spectator* magazine. This poem was originally published in *The Spectator* 453 (Aug. 9, 1712); Gottsched's translation is in *Der Zuschauer*, 9 vols. (Leipzig: Breitkopf, 1749–51). In the original, the poem reads as follows:

    When Nature fails, and day and night
      Divide Thy works no more,
    My ever grateful heart, O Lord,
      Thy mercy shall adore.
    Through all Eternity to Thee
      A joyful song I'll raise;
    For, Oh! Eternity's too short
      To utter all Thy praise.

71. Stephen Hales (1677–1761) was an English chemist, physiologist, and inventor, who studied the role of air and water in plant and animal life. The experiments Kant refers to are reported in Hales's *Vegetable Staticks* (1727), though Kant may have been aware of them through Buffon's French translation, which was published in 1735.
72. This quotation is from Epistle I of Pope's *Essay on Man*. The original reads:

    He, who through vast immensity can pierce,
    See worlds on worlds compose one universe,
    Observe how system into system runs,
    What other planets circle other suns,
    What varied Being peoples every star,
    May tell why Heaven has made us as we are.

73. The identity of this author and of the publication from which this quotation stems are unknown. "Fontenelle" is Bernard le Bovier de Fontenelle (1657–1757), a French writer and man of letters who served as perpetual secretary to the Academy of Sciences in Paris for over forty years.
74. Alexander the Great.
75. This quotation is from Epistle II of Pope's *Essay on Man*. The original reads:

    Superior beings, when of late they saw
    A mortal man unfold all Nature's law,
    Admired such wisdom in an earthly shape,
    And show'd a NEWTON as we show an ape.

76. This quotation is from Epistle I of Pope's *Essay on Man*. The original reads:

    Vast chain of being! which from God began;
    Natures ethereal, human, angel, man,
    Beast, bird, fish, insect, who no eye can see,
    No glass can reach; from infinite to thee;
    From thee to nothing.

77. This quotation is from the Third Book of Albrecht von Haller's *Über den Ursprung des Übels* [On the Origin of Evil] (1734).