currents of the ſea have ſcooped out the valleys, elevated the hills, and beſtowed on them their correſponding directions; that the ſame waters of the ocean, by tranſporting and depoſiting earth, &c. have given riſe to the parallel ſtrata; that the waters from the heavens gradually deſtroy the effects of the ſea, by continually diminiſhing the height of the mountains, filling up the valleys, and choaking the mouths of rivers; and, by reducing every thing to its former level, they will, in time, reſtore the earth to the ſea, which, by its natural operations, will again create new continents, interſperſed with mountains and valleys, every way ſimilar to thoſe which we now inhabit.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE I.

Of the Formation of Planets.

AS natural hiſtory is our proper ſubject, we would willingly diſpenſe with aſtronomical obſervations. But, as the earth is ſo nearly related to the heavenly bodies, and, as obſervations of this kind illuſtrate more fully thoſe doctrines we have already advanced, it is neceſſary to give ſome general ideas concerning the formation, motion, and figure, of the earth, and other planets.

The earth is a globe of about 3000 leagues in diameter; it is ſituated 30 million of leagues from the ſun, round which it revolves in 365 days. This annual revolution is the effect of two forces; the one may be conſidered as an impulſe from right to left, or from left to right;

the other as an attraction from above downwards, or from below upwards, to a common centre. The direction and quantity of these forces are combined, and so nicely adjusted, that they produce a uniform motion in an ellipse approaching to a circle. Like the other planets, the earth is opaque, throws out a shadow, and reflects the rays of the sun, about which it revolves in a time proportioned to its relative distance and density. It likewise revolves about its own axis in 24 hours; and its axis is inclined to the plane of its orbit $66\frac{1}{2}$ degrees. Its figure is that of a spheroid, the two axes of which differ from each other about an 165th part; and it revolves round the shortest axis.

These are the principal phænomena of the earth, the results of discoveries made by means of geometry, astronomy, and navigation. It is unnecessary here to enumerate the proofs and observations by which these facts have been established. We shall confine our remarks to such objects as are still doubtful; and shall therefore proceed to give our ideas concerning the formation of planets, and the changes they have undergone, previous to their arriving at the state in which we now perceive them. To the many systems and hypotheses which have been framed concerning the formation of the earth, and the different states it has passed through, we may be allowed to add our own conjectures, especially as we are determined to support them with a superior

superior degree of probability; and we are the more encouraged to deliver our notions on this subject, because we hope to enable the reader to distinguish between an hypothesis which consists only of possibilities, and a theory supported by facts; between a system, such as we are about to give, of the formation and primitive state of the earth, and a physical history of its real condition, which has been delivered in the preceding discourse.

Galileo traced the laws of falling bodies; and Kepler observed, that the areas which the principal planets describe in moving round the sun, and those of the satellites round their principal planets, were proportioned to the periods of their revolutions, and that these periods were as the square roots of the cubes of their distances from the sun, or from the principal planets. Newton discovered that the power of gravity extended to the moon, and retained it in its orbit; that the force of gravity diminished in exact proportion to the squares of the distances, and, consequently, that the moon is attracted by the earth; that the earth, and all planets, are attracted by the sun; and, in general, that all bodies which revolve about a centre, and describe areas proportioned to the periods of their revolution, are attracted by that luminary. Gravity, therefore, is a general law of nature. The planets, comets, the sun, the earth, are all subject to its laws; and it is the source of that harmony

mony which prevails in the univerſe. Nothing in phyſics is better eſtabliſhed than the exiſtence of this power in every material body. Repeated experience has confirmed the effects of its influence, and the labour and ingenuity of geometers have determined its quantity and relations.

This general law being once diſcovered, the effects of it would be eaſily explained, if the action of thoſe bodies which produce them were not too complicated. A ſlight view of the ſolar ſyſtem will convince us of the difficulties which attend this ſubject. The principal planets are attracted by the ſun, the ſun by the planets, the ſatellites by the principal planets, and each planet attracts all the others, and is attracted by them. All theſe actions and re-actions vary according to the quantities of matter and the diſtances, and give riſe to great inequalities, and even irregularities. How are ſo many relations to be combined and eſtimated? Among ſuch a number of objects, how is it poſſible to trace any individual? Theſe difficulties, however, have been ſurmounted; the reaſonings of theory have been confirmed by calculation; every obſervation has produced a new demonſtration; and the ſyſtematic order of the univerſe is now laid open to every man who is able to diſtinguiſh truth from error.

The force of impulſion, or what is commonly called the centrifugal force, is ſtill unknown; but

but it affects not the general theory. It is evident, that, as the attractive force continually draws all the planets towards the ſun, they would fall in a perpendicular line into that luminary, if they were not kept at a diſtance by ſome other power, forcing them to move in a ſtraight line. If, again, this impulſive force were not counteracted by that of attraction, all the planets would fly off in the tangents of their reſpective orbits. This progreſſive or impulſive force was unqueſtionably at firſt communicated to the planets by the Supreme Being. But, in phyſical ſubjects, we ought, as much as poſſible, to avoid having recourſe to ſupernatural cauſes; and, I imagine, a probable reaſon may be aſſigned for the impulſive force of the planets, which will be agreeable to the laws of mechanics, and not more ſurpriſing than many revolutions that muſt have happened in the univerſe.

The ſphere of the ſun's attraction is not limited by the orbits of the planets, but extends to an indefinite diſtance, always decreaſing according as the ſquares of the augmented diſtances. The comets, it is evident, which eſcape our ſight in the heavenly regions, are, like the planets, ſubject to the attraction of the ſun, and by it their motions are regulated. All theſe bodies, the directions of which are ſo various, move round the ſun, and deſcribe areas proportioned to their periods, the planets in ellipſes, more or leſs circular, and the comets, in narrow ellipſes of vaſt extent.

extent. The motions, therefore, both of planets and comets, are regulated by impulſive and attractive forces continually acting upon them, and obliging them to deſcribe curves. But it is worthy of remark, that comets run through the ſyſtem in all directions; that the inclinations of the planes of their orbits are ſo very different, that though, like the planets, they be ſubject to the law of attraction, they have nothing in common with regard to their progreſſive or impulſive motions, but appear, in this reſpect, to be abſolutely independent of each other. The planets, on the contrary, move round the ſun in the ſame direction, and nearly in the ſame plane, the greateſt inclination of their planes not exceeding $7\frac{1}{2}$ degrees. This ſimilarity in the poſition and motion of the planets indicates, that their impulſive and centrifugal forces muſt have originated from one common cauſe.

May we not conjecture, that a comet falling into the body of the ſun might drive off ſome parts from its ſurface, and communicate to them a violent impulſive force, which they ſtill retain? This conjecture appears to be as well founded as that of Mr Leibnitz, which ſuppoſed the earth and planets to have formerly been ſuns; and his ſyſtem, of which an abridgment will be given in Art. V. would have been more comprehenſive, and more conſonant to probability, if it had embraced the above idea. We agree with him, that this effect was produced at the

the time when God is ſaid by Moſes to have ſeparated the light from the darkneſs; for, according to Leibnitz, the light was ſeparated from the darkneſs when the planets were extinguiſhed. But, on our ſuppoſition, there was a real phyſical ſeparation; becauſe the opaque bodies of the planets were detached from the luminous matter of which the ſun is compoſed*.

This notion concerning the cauſe of the centrifugal force of the planets will appear to be leſs exceptionable, after we have collected the analogies, and eſtimated the degrees of probability by which it may be ſupported. We ſhall firſt mention, that the motion of the planets have one common direction, namely, from weſt to eaſt. By the doctrine of chances, it is eaſy to demonſtrate, that this circumſtance makes it as 64 to 1, that the planets could not at all move in the ſame direction, if their centrifugal forces had not proceeded from the ſame cauſe.

This probability will be greatly augmented, if we conſider the ſimilarity in the inclinations of the planes of their orbits, which exceed not $7\frac{1}{2}$ degrees; for, by calculations, it has been diſcovered, that it is 24 to 1 againſt any two planets being found, at the ſame time, in the moſt diſtant parts of their orbits; and, conſequently, 24^5, or 7692624 to 1, that this effect could not

* If the Count de Buffon had known, that the nucleus of the ſun was a ſolid and opaque matter, a diſcovery lately made by the ingenious Dr. Wilſon of Glaſgow, his hypotheſis would have laboured under fewer difficulties.

be produced by accident; or, what amounts to the ſame, there is this great degree of probability, that the planets have been impreſſed with one common moving force, from which they have derived this ſingular poſition. But nothing could beſtow this common centrifugal motion, except the force and direction of the bodies by which it was originally communicated. We may, therefore, conclude, that all the planets have probably received their centrifugal motion by one ſingle ſtroke. Having eſtabliſhed this degree of probability, which almoſt amounts to a certainty, I next inquire what moving bodies could produce this effect; and I can find nothing but comets capable of communicating motion to ſuch vaſt maſſes.

Upon examining the courſe of comets, it is eaſy to believe that ſome of them muſt occaſionally fall into the ſun. The comet 1680 approached ſo near, that, at its perihelion, it was not more diſtant from the ſun than a ſixteenth part of his diameter; and, if it returns, which is extremely probable, in the year 2255, it may then fall into the ſun. This event muſt depend upon the accidents it meets with in its courſe, and the retardations it ſuffers in paſſing through the ſun's atmoſphere*.

We may, therefore, preſume, with the great Newton, that comets ſometimes fall into the ſun. But they may fall in different directions.

* See Newt. edit. 3. p. 525.

If they fall perpendicularly, or in a direction not very oblique, they will remain in the body of the ſun, ſerve the purpoſes of fewel, and, by their impulſe, remove the ſun from his place, in proportion to the quantity of matter they contain*. But, if a comet falls in a very oblique direction, which will moſt frequently happen, it will only graze the furface, or penetrate to no great depth. In this caſe, it may force its way paſt the ſun, detach certain portions of his body, to which it will communicate a common impulſive motion; and theſe portions puſhed off from the ſun, and even the comet itſelf, may turn planets, which will revolve round this luminary in the ſame direction, and nearly in the ſame plane. A calculation, perhaps, might be made of the quantity of matter, velocity, and direction, a comet ought to have, in order to force from the ſun maſſes equal to thoſe which compoſe the ſix planets and their ſatellites. But it is ſufficient here to obſerve, that the whole planets, with their ſatellites, make not a 650th part of the ſun's maſs†; for although the denſity of Saturn and Jupiter be leſs than that of the ſun, and though the earth be four times, and the moon near five times, more denſe than the ſun; yet they are only atoms when compared to his immenſe volume.

* Quær. Would not ſuch an event, by augmenting the ſun's quantity of matter, and, conſequently, his attractive power, produce other changes in the ſolar ſyſtem? † See Newt. p. 405.

It muſt be acknowledged, that, although a 650th part of a whole may ſeem inconſiderable, it would require a very large comet to detach this part from the ſun. But, if we conſider the prodigious rapidity of comets in their perihelion; the near approach they make to the ſun; the denſity and ſtrong coheſion of parts neceſſary to ſuſtain, without deſtruction, the inconceivable heat they undergo; and the ſolid and brilliant nucleus which ſhines through their dark atmoſpheres; it cannot be doubted that comets are compoſed of matters extremely denſe and ſolid; that they contain, in ſmall limits, a great quantity of matter; and, conſequently, that a comet of no enormous ſize may remove the ſun from his place, and give a projectile motion to a maſs of matter equal to the 650th part of his body. This remark correſponds with what we know concerning the reſpective denſities of the planets, which always decreaſe in proportion to their diſtances from the ſun, having leſs force of heat to reſiſt. Accordingly, Saturn is leſs denſe than Jupiter, and Jupiter much leſs than the earth. Thus, if the denſity of the planets, as Newton alleges, be in proportion to the quantity of heat they ſupport, Mercury will be ſeven times denſer than the earth, and 28 times denſer than the ſun, and the comet 1680, 28,000 times more denſe than the earth, or 112,000 times denſer than the ſun. Now, ſuppoſing the quantity of matter in this comet to be equal to a ninth

ninth part of the ſun, or allowing it to be only 100dth part of the bulk of the earth, its quantity of matter would ſtill be equal to a 900th part of the ſun: Hence a body of this kind, which would be but a ſmall comet, might puſh off from the ſun a 900th or a 650th part, eſpecially when the amazing rapidity of comets, in their perihelion, is taken into the calculation.

The correſpondence between the denſity of the whole planets, and that of the ſun, deſerves alſo to be noticed. Upon, and near the ſurface of the earth, there are ſubſtances 1400 or 1500 times denſer than others; the denſities of air and gold are nearly in this proportion. But the interior parts of the earth and planets are more uniform, and differ little with regard to denſity; and the correſpondence in the denſity of the planets and that of the ſun is ſo great, that, out of 650 parts, which comprehend the whole denſity of the planets, there are more than 640 nearly of the ſame denſity with the ſolar matter; and there are only ten of thoſe 650 which are of a ſuperior denſity; for the denſity of Saturn and Jupiter is nearly the ſame with that of the ſun; and the quantity of matter in thoſe two planets is at leaſt 64 times greater than what is contained in the four inferior planets, Mars, the Earth, Venus, and Mercury. We may, therefore, conclude, that, in general, the matter of the planets is very nearly of the ſame

kind with the ſolar matter, and, of courſe, that the former may have been ſeparated from the latter.

To this theory it may be objected, that, if the planets had been driven off from the ſun by a comet, in place of deſcribing circles round him, they muſt, according to the law of projectiles, have returned to the ſame place from whence they had been forced? and, therefore, that the projectile force of the planets cannot be attributed to the impulſe of a comet.

I reply, that the planets iſſued not from the ſun in the form of globes, but in the form of torrents, the motion of whoſe anterior particles muſt have been accelerated by thoſe behind, and the attraction of the anterior particles would alſo accelerate the motion of the poſterior; and that this acceleration, produced by one or both of theſe cauſes, might be ſuch as would neceſſarily change the original motion ariſing from the impulſe of the comet, and that, from this cauſe, might reſult a motion ſimilar to what takes place in the planets, eſpecially when it is conſidered, that the ſhock of the comet removes the ſun out of its former ſtation. This reaſoning may be illuſtrated by an example. Suppoſe a muſket-ball diſcharged from the top of a mountain, and that the force of the powder was ſufficient to puſh it beyond a ſemidiameter of the earth, it is certain that this ball would revolve round the

the earth, and return at every revolution to the place from whence it had been diſcharged. But, inſtead of a muſket-ball, if a rocket were employed, the continued action of the fire would greatly accelerate the original impulſive motion. This rocket would by no means return to the ſame point, like the ball; but, *cæteris paribus*, would deſcribe an orbit, the perigee of which would be more or leſs diſtant from the earth in proportion to the greatneſs of the change produced in its direction by the accelerating force of the fire. In the ſame manner, if the original projectile force impreſſed by the comet on the torrent of ſolar matter was accelerated, it is probable, that the planets formed by this torrent acquired their preſent circular or elliptical movements around the ſun.

The appearances exhibited in great eruptions from volcano's may give ſome idea of this acceleration of motion. When Veſuvius begins to groan and throw out inflamed matter, it has been often remarked, that the motion of the cloud firſt ejected is ſlower than the ſucceeding ones, and that they go on increaſing in celerity, till at laſt ſulphur, lava, melted metal, and huge ſtones are thrown up; and that, though theſe obſerve nearly the ſame direction, they alter conſiderably that of the firſt cloud, and elevate it to a greater height than it would otherwiſe have reached.

The objection will be ſtill farther obviated, if it is conſidered, that the impulſe of the comet muſt, in ſome degree, have communicated a motion to the ſun, and removed it from its former ſituation; and that, although this motion may now be ſo ſmall as to eſcape the notice of aſtronomers, it may ſtill, however, exiſt, and make the ſun deſcribe a curve round the centre of gravity of the ſyſtem. If this be allowed, as I preſume it will, the planets, inſtead of returning to the ſun's body, would deſcribe orbits, the perihelions of which would be as diſtant from the ſun as the ſpace that he preſently occupies is diſtant from his original ſtation.

It may be farther objected, that, if motion be accelerated in the ſame direction, no change in the perihelion could take place. But is it credible, that no change of direction can happen in a torrent whoſe particles ſucceed each other? On the contrary, it is extremely probable, that a change was actually produced ſufficient to make the planets move in their preſent orbits.

It may ſtill be objected, that, if the ſituation of the ſun had been changed by the ſhock of a comet, it would move uniformly; and, of courſe, this motion being common to the whole ſyſtem, no alteration would be effected. But, previous to the ſhock, might not the ſun move round the centre of the cometary ſyſtem; and might not

not this primary motion be augmented or diminiſhed by the ſtroke of the comet? Is not this ſufficient to account for the actual motion of the planets?

If none of theſe ſuppoſitions be admitted, may it not be preſumed, that the elaſticity of the ſun might elevate the torrent above his ſurface, in place of puſhing it directly forward? This circumſtance alone would be ſufficient to remove the perihelion, and endow the planets with their preſent movements. Neither is this ſuppoſition deſtitute of foundation: The ſolar matter may be exceedingly elaſtic; ſince light, the only part of it we are acquainted with, ſeems, by its effects, to be perfectly elaſtic. I acknowledge that I cannot determine which of the cauſes above aſſigned has actually produced an alteration in the projectile force of the planets; but they at leaſt ſhow that ſuch a change is not only poſſible, but probable, which is enough for my preſent purpoſe.

Without farther inſiſting on the objections which may be made againſt my hypotheſis, or the analogical proofs that might be brought in ſupport of it, I ſhall proſecute my ſubject, and draw the proper concluſions. Let us firſt examine what might happen to the planets, and particularly to the earth, when they were impreſſed with their projectile forces, and what was their ſtate after their ſeparation from the body of the ſun.

ſun. A projectile motion having been communicated, by the ſtroke of a comet, to a quantity of matter equal to a 650th part of the ſun's maſs, the light particles would ſeparate from the denſe, and, by their mutual attractions, form globes of different ſolidities. Saturn being compoſed of the largeſt and lighteſt parts, would be removed to the greateſt diſtance from the ſun; Jupiter, being denſer than Saturn, would have a nearer ſtation; and ſo of the reſt. The largeſt and leaſt ſolid planets are moſt diſtant, becauſe they received a greater projectile force than the ſmaller and denſer; for the projectile force being proportioned to the ſurface to which it is applied, the ſame ſtroke would make the larger and lighter parts of the ſolar matter move with more rapidity than the ſmaller and heavier. The parts, therefore, which differed in denſity, would ſeparate from each other in ſuch a manner, that, if the denſity of the ſolar matter be equal to 100, that of Saturn will be equal to 67, of Jupiter, = 94½, of Mars, = 200, of the Earth, = 400, of Venus, = 800, of Mercury, = 2800. But, as the attractive force acts not in proportion to the ſurface, but to the quantity of matter, it would retard the progreſs of the more denſe parts of the ſolar matter; and it is for this reaſon that we find the moſt denſe planets neareſt the ſun, and which move round him with more rapidity than thoſe that are more diſtant, and leſs denſe.

The

The denſity and projectile motion of Saturn and Jupiter, the two largeſt planets in the ſyſtem, have the moſt exact proportion. The denſity of Saturn is to that of Jupiter as 67 to $94\frac{1}{2}$, and their velocities are nearly as $88\frac{2}{3}$ to $120\frac{1}{7\frac{1}{2}}$, or as 67 to $90\frac{1}{1\frac{1}{6}}$. How rarely do pure conjectures correſpond ſo exactly to the phænomena of nature? It is true, according to this relation between the celerity and denſity of the planets, the denſity of the earth ought not to exceed $206\frac{7}{1\frac{1}{8}}$, inſtead of 400, which is its real denſity; hence it may be ſuppoſed, that the earth has now double its original denſity. With regard to the other planets, Mars, Venus, and Mercury, as their denſities are only conjectural, we know not whether this circumſtance would confirm or weaken our hypotheſis. Newton ſays, that the denſities of the planets are proportioned to the degrees of heat they are expoſed to; and it is in conſequence of this idea that we have mentioned Mars as being one time leſs denſe than the earth, Venus one time, Mercury ſeven times, and the comet 1680, 28,000 times denſer than the earth. But, if we attend to Saturn and Jupiter, the two principal planets, we will find, that this ſuppoſed proportion between the denſities of the planets, and the heat they ſuſtain, is not well founded: For, according to this hypotheſis, the denſity of Saturn would be as $4\frac{7}{1\frac{1}{8}}$, and that of Jupiter as $14\frac{1}{2\frac{1}{2}}$, inſtead of the proportions of 67 and $94\frac{1}{2}$; differences ſo great as

to

to deſtroy the principles upon which they are founded. Thus, notwithſtanding the regard due to the conjectures of Newton, I cannot refrain from thinking that the denſities of the planets have a nearer relation to their celerities than to the degrees of heat to which they are expoſed. This, indeed, is only a final cauſe; but the other is a phyſical relation, the exactneſs of which is remarkable in Saturn and Jupiter. It is certain, however, that the denſity of the earth, inſtead of being $206\frac{7}{8}$, is 400; and, conſequently, the earth muſt have ſuffered a condenſation in the proportion of $206\frac{7}{8}$ to 400.

But have the condenſations of the planets no relation to the quantity of ſolar heat they ſuſtain? In that caſe, Saturn, which is at the greateſt diſtance from the ſun, would have ſuffered little or no condenſation; and Jupiter would be condenſed from $90\frac{1}{16}$ to $94\frac{1}{2}$. Now, the ſun's heat in Jupiter being to his heat in the earth as $14\frac{17}{25}$ to 400, their condenſation ought to be in the ſame proportion. Thus, if Jupiter be condenſed as $90\frac{1}{16}$ to $94\frac{1}{2}$, the earth, if it had been in the orbit of Jupiter, would have been condenſed from $206\frac{7}{8}$ to $215\frac{999}{1451}$; but the earth being much nearer the ſun, and receiving heat, in proportion to that of Jupiter, as 400 to $14\frac{17}{25}$, the quantity of condenſation it would have undergone in the orbit of Jupiter muſt be multiplied by the proportion of 400 to $14\frac{17}{25}$, which will give nearly $234\frac{1}{3}$ for the condenſation

tion the earth muſt have received. The denſity of the earth was $206\frac{7}{8}$; by adding its acquired condenſation, its actual denſity will be $400\frac{7}{8}$, which is nearly the ſame with 400, its real denſity determined by the moon's parallax. With regard to the other planets, I pretend not to give exact proportions, but only approximations, tending to ſhew, that their denſities have a ſtrong connection with the celerity of their motions in their reſpective orbits.

The comet, by falling obliquely on the ſun, as mentioned above, muſt have forced off from his ſurface a quantity of matter equal to a 650th part of his body. This matter, being in a liquid ſtate, would at firſt form a torrent, of which the largeſt and rareſt parts would fly to the greateſt diſtances; the ſmaller and more denſe, having received only an equal impulſe, would remain nearer the ſun; his power of attraction would operate upon all the parts detached from his body, and make them circulate round him; and, at the ſame time, the mutual attraction of the particles of matter would cauſe all the detached parts to aſſume the form of globes, at different diſtances from the ſun, the nearer moving with greater rapidity in their orbits than the more remote.

But it may be objected, that, if the planets had been detached from the ſun, they muſt have been burning and luminous, not cold and opaque bodies; nothing can have leſs reſemblance

ſemblance to a globe of fire than a globe compoſed of earth and water; and, by compariſon, the matter of the earth is totally different from that of the ſun.

It may be replied to this objection, that the matter changed its form after its ſeparation, and that the fire, or light, was extinguiſhed by the projectile motion communicated by the ſtroke. Beſides, may it not be ſuppoſed, that the ſun, or a burning ſtar, moving with a rapidity equal to that of the planets, would ſoon be extinguiſhed; and that this may be the reaſon why all the luminous, or burning ſtars, are fixed, and without motion; and why thoſe called new ſtars, which have probably changed their ſtations, are frequently extinguiſhed and diſappear? To confirm this remark, comets, when in their perihelia, ought to be inflamed even to their centre; but they never become luminous ſtars; they only emit a burning vapour, a conſiderable portion of which they leave behind them in their courſe.

In a medium which has little reſiſtance, I acknowledge, that fire may ſubſiſt, although the burning body be moved with great rapidity. It muſt likewiſe be acknowledged, that what I have ſaid applies only to thoſe ſtars which diſappear for ever, not to thoſe that appear and diſappear at ſtated intervals, without changing their ſituations in the heavens. Of theſe Maupertuis, in his diſcourſe on the figure of the ſtars, has given a moſt ſatisfactory account. But thoſe which

which have appeared, and then vaniſhed for ever, muſt unqueſtionably have been extinguiſhed either by the quickneſs of their motion, or ſome other cauſe. There is not a ſingle example of a luminous ſtar revolving round another; and not one of the ſixteen planets which revolve round the ſun have any light in themſelves.

Farther, fire, in ſmall maſſes, cannot ſubſiſt ſo long as in large ones. The planets would burn a conſiderable time after they iſſued from the ſun; but, at length, would extinguiſh for want of combuſtible matter. For the ſame reaſon, the ſun itſelf will be extinguiſhed; but at a period as much beyond that which extinguiſhed the planets, as the quantity of matter in the ſun exceeds that of the planets. However this may be, the ſeparation of the planets from the ſun, by the ſhock of a comet, appears ſufficient to account for their extinction.

The earth and planets, when they iſſued from the ſun, were totally compoſed of liquid fire; in which ſtate they would continue no longer than the violence of the heat that kept them in fuſion. But this heat would gradually decay from the moment they left the ſun. During their fluid ſtate, they neceſſarily aſſumed circular figures; and their diurnal motion would elevate their equators, and flatten their poles. I agree with M. Leibnitz *, that this figure corre-

* Vid. Act. Erud. Lipſ. an. 1692.

ſponds

ſponds ſo exactly with the laws of hydroſtatics, that the earth and planets muſt neceſſarily have been once in a ſtate of fluidity occaſioned by fire; and, conſequently, that the interior parts of the earth muſt be compoſed of vitrified matter, of which ſand, free-ſtone, granite, and perhaps clay, are fragments, or ſcoriæ.

It is therefore extremely probable, that the planets were originally parts of the ſun ſeparated by a ſtroke which communicated to them a projectile motion; and that their different diſtances proceeded ſolely from the difference of their denſities. To complete this theory, it only remains to account for the diurnal motion of the planets, and the origin of their ſatellites; which, inſtead of adding freſh difficulties, will tend greatly to confirm my hypotheſis: For rotation, or what is called diurnal motion, entirely depends on the obliquity of the ſtroke; an oblique impulſe on the ſurface of a body neceſſarily gives it a rotatory motion. If the body which receives the impulſe be homogeneous, the rotatory motion will always be equal and uniform; but it will be unequal, if the body conſiſt of heterogeneous parts, or of parts different in denſity. Hence we may conclude, that the matter of each planet is homogeneous, becauſe the diurnal motion of each is uniformly performed in the ſame time; and this circumſtance is an additional proof, that portions of different denſities were originally ſeparated from the ſun.

But

But the obliquity of the ſtroke might be ſo great as to throw off ſmall quantities of matter from the principal planet, which would neceſſarily move in the ſame direction. Theſe parts, by mutual attraction, would reunite, according to their denſities, at different diſtances from the planet, follow its courſe round the ſun, and at the ſame time revolve about the body of the planet, nearly in the plane of its orbit. It is eaſy to perceive that the portions we mean are the ſatellites: Thus the formation, poſition, and motion, of the ſatellites correſpond, in the moſt perfect manner, with our theory; for they all move in the ſame direction, and in concentric circles round their principal planets, and nearly in the plane of their orbits. All theſe common effects, depending on an impulſive force, muſt have proceeded from a common cauſe, which was a projectile force communicated to them by the ſame oblique ſtroke. This account of the motion and formation of the ſatellites will be ſtrongly ſupported, if the other circumſtances and phænomena attending them be duly weighed. Thoſe planets which are furniſhed with ſatellites move quickeſt round their axes. The revolution of the earth is quicker than that of Mars, in the proportion nearly of 24 to 15; the earth has a ſatellite, and Mars has none; Jupiter, whoſe diurnal motion is 500 or 600 times more rapid than that of the earth, has four ſatellites; and it is extremely probable, that Saturn, who

has five ſatellites and a ring, revolves much more quickly than Jupiter.

We may even conjecture, with ſome probability, that the plane of the equator of Saturn's ring is nearly the ſame with that of the planet; for, ſuppoſing, according to the preceding theory, the obliquity of the impulſe which put Saturn in motion to have been very great, his diurnal motion would at firſt be in proportion to the exceſs of the centrifugal force above that of gravity, and, of courſe, a conſiderable quantity of matter would be thrown off from his equatorial regions, and neceſſarily aſſume the figure of a ring, the plane of which would be nearly the ſame with that of his own equator. This quantity of matter, detached from the equatorial regions of Saturn, muſt have flattened the equator of that planet; which is the reaſon why, notwithſtanding the rapidity with which we have ſuppoſed him to revolve round his axis, the diameters of Saturn are not ſo unequal as thoſe of Jupiter, which differ from each other more than an eleventh part.

Though this theory of the formation of the planets and their ſatellites appears to be extremely probable; yet, as every man has his own ſtandard of eſtimating probabilities of this nature, and as this ſtandard varies according to the different capacities of combining analogies more or leſs remote, I pretend not to convince thoſe who are unwilling to believe. I have offered theſe

ideas to the public, not only becauſe I thought them rational, and calculated to unravel a ſubject upon which, however important, nothing has hitherto been written; but becauſe the impulſive motion of the planets gives riſe to numberleſs phænomena in the univerſe, which admit not of an explanation by gravity alone. To thoſe who may be diſpoſed to deny the poſſibility of my theory, I would propoſe the following queries:

1. Is it not natural to imagine, that a moving body has received its motion from the impulſe of ſome other body?

2. When ſeveral bodies move in the ſame direction, is it not exceedingly probable, that they received this direction from a ſingle ſtroke, or, at leaſt, from ſtrokes every way ſimilar?

3. When ſeveral bodies in motion have not only the ſame direction, but are placed in the ſame plane, is it not more natural to think that they received this direction and poſition from one impulſe than from many?

4. Is it not probable, that a body put in motion by impulſe, ſhould receive it in an oblique direction; and conſequently that it ſhould be forced to move round its axis with a rapidity proportioned to the obliquity of the ſtroke? If theſe queries be not unreaſonable, the theory of which we have given a ſketch will no longer have the appearance of abſurdity.

Let us now proceed to a more intereſting object; let us examine the figure of the earth upon which ſo many inquiries and obſervations have been made. As it appears, from the equality of the earth's diurnal motion, and the uniformity in the inclination of its axis, that it is compoſed of homogeneous parts which mutually attract each other in proportion to their quantities of matter; if its impulſive motion had been communicated in a direction perpendicular to its ſurface, it would neceſſarily have aſſumed the figure of a perfect ſphere: But, having been ſtruck obliquely, it moved round its axis at the inſtant it received its figure; and, from the combination of the projectile force and that of attraction, there reſulted a ſpheroid figure, more elevated at the equator than at the poles; becauſe the centrifugal force, ariſing from the diurnal rotation of the earth, muſt diminiſh the action of gravity, or that power which makes all the parts tend to the centre. Thus the earth, being compoſed of homogeneous parts, and having been endowed with a rotatory motion, muſt neceſſarily have aſſumed a ſpheroidal figure, the two axes of which differ from each other by a 230th part. To ſhow that this is the real figure of the earth, we need not have recourſe to hypotheſes; it is capable of the cleareſt demonſtration. The laws of gravitation are well known: That bodies attract each other directly

directly as their quantities of matter, and inverſely as the ſquares of their diſtances, admits not of a doubt. It can as little be doubted, that the total action of any body is compoſed of all the particular actions of its parts.

The parts of bodies are all mutually attracted in the above proportion; and all theſe attractions, when the body has no rotation, neceſſarily produce a ſphere, and a ſpheroid, when the body is endowed with a rotatory motion. This ſpheroid is more or leſs flattened at the poles in proportion to the quickneſs of the diurnal motion; and the earth, in conſequence of the celerity of its rotation, and the mutual attraction of its parts, has aſſumed the figure of a ſpheroid, of which the two axes are to one another as 229 to 230.

Thus the earth, at the time of its formation, from the original conſtitution and homogeneity of its parts, and independent of every hypotheſis derived from the direction of gravity, took the figure of a ſpheroid; and, from the known laws of mechanics, its equatorial diameter was neceſſarily elevated about ſix leagues and a half more than its poles.

I ſhall dwell the longer on this article, becauſe there are ſome geometers, who, from a ſyſtem of philoſophy they have adopted, and from a ſuppoſed direction of gravity, ſtill imagine that the figure of the earth depends upon theory. The firſt thing to be demonſtrated is

the mutual attraction of the parts of matter; and the ſecond, the homogeneity of the terreſtrial globe. When theſe two facts are clearly proved, there will be no occaſion to have recourſe to any theory derived from the direction of gravity; becauſe the earth's figure, in this caſe, muſt neceſſarily be as Newton determined it; and all the other figures aſſigned to it, in conſequence of vortexes, and other hypotheſes, can have no exiſtence.

It will not be doubted, even by the moſt incredulous, that the planets are retained in their orbits by the power of gravity. The ſatellites of Saturn gravitate towards that planet; thoſe of Jupiter towards Jupiter; the moon gravitates towards the earth; and Saturn, Jupiter, Mars, the Earth, Venus, and Mercury, gravitate towards the ſun. In the ſame manner, Saturn, Jupiter, and the Earth, gravitate towards their reſpective ſatellites, and the ſun gravitates towards the whole planets. Gravitation is therefore a general law, by which the whole planetary ſyſtem is mutually affected; for action cannot exiſt without re-action. This mutual attraction of the planets is the law which regulates all their motions; and its exiſtence is demonſtrated by its effects. When Saturn and Jupiter are in conjunction, their mutual attraction produces an irregularity in their motion round the ſun. The earth and the moon, alſo, mutually attract each other; but the irregularities in the moon's motion

tion proceed principally from the attraction of the ſun; and hence the ſun, the earth, and the moon, mutually act upon each other. Now, the reciprocal attraction of the planets, when the diſtances are equal, is proportioned to their quantities of matter; and the ſame power of gravity, which makes heavy bodies fall to the earth, and which extends as far as the moon, is likewiſe in proportion to the quantity of matter: The total gravity of a planet, therefore, is compoſed of the gravity of all its parts: Hence all the parts of matter, whether in the earth or planets, mutually attract each other; and, of courſe, the rotation of the earth round its axis muſt neceſſarily have beſtowed on it the figure of a ſpheroid, the axes of which are as 229 to 230. But the direction of gravity muſt be perpendicular to the earth's ſurface; and, conſequently, unleſs the general and mutual attraction of the parts of matter be denied, no hypotheſis derived from the direction of gravity can have any ſolid foundation. But this mutual attraction, as we have ſeen, is demonſtrated by actual obſervation; and the experiments made by pendulums prove its univerſal extenſion. No hypotheſis, therefore, founded on the direction of gravity, can be admitted, without contradicting both reaſon and experience.

Let us now examine whether the parts compoſing the terreſtrial globe be homogeneous. I acknowledge, that, if the globe be ſuppoſed to

conſiſt of parts differing in denſity, the direction of gravity would be different from that we have aſſigned, and that the earth's figure would vary according to the different ſuppoſitions which might be made concerning the direction of gravity. But, why make ſuppoſitions of this kind? Why, for example, do we ſuppoſe the parts near the centre to be more denſe than thoſe more diſtant from it? Are not all the particles which compoſe the globe united by their mutual attraction? Every particle, therefore, is a centre; and there is no reaſon to believe that the parts which ſurround the centre are denſer than thoſe which ſurround any other point. Beſides, if any conſiderable part of the earth were more denſe than another, the axis of rotation would approach nearer that part, and create an inequality in the diurnal revolution of the globe: It would produce an inequality in the apparent motion of the fixed ſtars; they would appear to move more quickly or ſlowly in the zenith or horizon, according as we happened to be ſituated on the heavy or light parts of the earth; and the axis of the globe, not paſſing through its centre of gravity, would make a perceptible change in its poſition. But nothing of this kind ever takes place. On the contrary, the diurnal revolution of the earth is equal and uniform. At every point of the earth's ſurface, the ſtars appear to move with the ſame quickneſs; and, if there be any nutation in its axis, it is too inconſiderable to

to attract obſervation. Hence it may be concluded, that all the parts of the globe are at leaſt nearly homogeneous.

If the earth were hollow, the cruſt of which, for example, exceeded not three leagues in thickneſs, it would give riſe to the following phænomena. 1. The mountains would bear ſo great a proportion to the total thickneſs of the cruſt, that vaſt irregularities in the earth's motion would be occaſioned by the attraction of the moon and of the ſun: When the moon was in the meridian of the more elevated parts, as the Cordeliers, her attraction upon the whole globe would be much greater than when ſhe was in the meridian of the lower parts. 2. The comparative attraction of the mountains would be greatly increaſed; and the experiments made on Mount Chimboraco, in Peru, would have given more degrees in the deviation of the plumb-line than they actually gave ſeconds. 3. The weight of bodies would be greater on the tops of mountains than in the plains; and men would find themſelves more weighty, and would walk with more difficulty, in high than in low grounds. Theſe obſervations, and many others which might be made, ſhould convince us, that the interior parts of the earth are not hollow, but that they are compoſed of matter of a conſiderable denſity.

If, on the other hand, the earth, at the depth of two or three leagues, conſiſted of matter much

much denſer than that we are acquainted with, upon deſcending even into ordinary pits, we ſhould find ourſelves conſiderably heavier; and the motion of pendulums would there be more accelerated than they actually are when brought down from a hill to a plain. Hence we may preſume that the interior parts of the earth conſiſt of matter nearly ſimilar to that on its ſurface. Of this, we will be ſtill farther convinced, if we conſider that the earth, at the time of its original formation, when it aſſumed its preſent ſpheroidal figure, was in a ſtate of fuſion, and, conſequently, that all its parts were homogeneous, and nearly of equal denſity. The matter on the ſurface, though originally the ſame with that of the interior parts, has, in the revolutions of time, undergone many changes from external cauſes; and to theſe are to be aſcribed the production of materials ſo different in their denſities. But it ought to be remarked, that the denſeſt bodies, as gold, and other metals, are moſt rarely to be met with; and, conſequently, that the greateſt quantity of materials at the ſurface, have ſuffered little alteration with regard to denſity. The moſt common materials, indeed, as ſand and clay, differ ſo little in denſity, that we may conjecture, with much probability, the internal parts of the earth to conſiſt of a vitrified matter, the denſity of which is nearly equal to that of ſand; and, conſequently, that

that the whole globe may be conſidered as one homogeneous maſs.

But, it may be ſaid, that, though the earth were compoſed of concentric beds, of different denſities, the equality of its diurnal motion, and the uniform inclination of its axis, would remain equally undiſturbed, as upon the ſuppoſition of its conſiſting wholly of homogeneous matter. This I allow; but I demand, at the ſame time, whether there be any reaſon for believing that theſe beds of different denſities really exiſt? Whether this method of ſolving difficulties be not an attempt to adjuſt the works of nature to our own imaginations? And whether ſuppoſitions, neither founded on obſervation nor analogy, ought to find admittance into phyſical reaſoning?

Hence, it is apparent, that the earth received its ſpheroidal figure in conſequence of its diurnal motion, and the mutual attraction of its parts; that this figure neceſſarily reſulted from the globe's being in a liquid ſtate; that, according to the laws of gravity and of a centrifugal force, it could not poſſibly aſſume any other figure; that, at the moment of its formation, the difference between its two diameters was, as at preſent, equal to a 230th part; and, of courſe, that all other hypotheſes which make this difference greater or leſs, are mere fictions, and deſerve no attention.

Perhaps

Perhaps it may be objected, that, if this theory be well founded, and if the proportion of the axes of the two diameters be as 229 to 230, how came the mathematicians ſent to Lapland and Peru to concur in making it as 174 to 175? Why ſhould ſuch a difference ſubſiſt between practice and theory? And, is it not more reaſonable to give the preference to actual meaſurement, eſpecially when executed by the ableſt mathematicians in Europe*, and furniſhed with all the neceſſary apparatus?

To this I reply, that I mean not to combat the obſervations made at the equator, and near the pole; that I doubt not of their exactneſs; and that the earth may actually be elevated a 175th part more at the equator than at the poles. Still, however, I maintain my theory; and I perceive clearly how it may be reconciled to practice. The difference between the two concluſions is about four leagues in the two axes. The equatorial regions are found to have an elevation of two leagues more than they ought to have by the theory. This height of two leagues correſponds exactly with the greateſt inequalities which have been produced on the ſurface of the globe by the motion of the ſea, and the action of fluids. Here ſome illuſtration is neceſſary. At the time of the earth's formation, in conſequence of the mutual attraction of its parts, and of its centrifugal force, it muſt have aſſumed a

* M. de Maupertuis, figure de la terre.

ſpheroidal

ſpheroidal figure, with its axes different by a 230th part. This would be the real figure of the earth while it remained in a ſtate of liquefaction. But, after cooling for ſome time, the rarified vapours, like thoſe in the tail or atmoſphere of a comet, would condenſe, and fall on the ſurface in the form of air and water; and, when theſe waters begin to be agitated by a flux and reflux, ſand, and other bodies, would be gradually tranſported from the poles towards the equatorial parts. This operation, when continued for ſome time, would neceſſarily ſink the poles, and elevate the equator in the ſame proportion. The ſurface of the earth being likewiſe expoſed to the winds, to the action of the air and of the ſun; all theſe cauſes would concur with the tides in furrowing the earth, in ſcooping out valleys, in elevating the mountains, and in producing other ſuperficial irregularities, none of which, perhaps, exceed a league in thickneſs, even at the equator. This inequality of two leagues may be ſuppoſed to be the greateſt that can take place on the ſurface; for the higheſt mountains exceed not a league in height; and the moſt profound parts of the ocean, it is probable, are not above a league in depth. Thus my theory perfectly coincides with practice. The earth's equator could not, at firſt, be elevated more than ſix leagues and a half above the poles; but the changes produced on the ſurface might give it a ſtill greater elevation. Natural

hiſtory

hiſtory wonderfully ſupports this opinion; for, in the preceding diſcourſe, we have proved, that, from the tides and other motions of the waters, have proceeded mountains, and all the other inequalities on the ſurface of the globe; and that, at great depths, as well as upon the greateſt heights, bones, ſhells, and other relics of ſea and land animals, have been diſcovered.

From what has been obſerved, it may be conjectured, that, in order to find primitive earth, and ſubſtances which have never been removed from their original ſtations, we muſt dig in countries near the poles, where the bed of unmoved earth will be thinner than in ſouthern climates.

In fine, if the meaſurement by which the figure of the earth was determined be ſtrictly ſcrutinized, we ſhall find that it is not altogether free from hypothetical reaſoning: For it proceeded on the ſuppoſition that the earth was a regular curve: But, as the earth is liable to conſiderable and conſtant changes from a thouſand cauſes, it is impoſſible that it could have retained any perfectly regular figure; and hence, agreeable to our theory, and the opinion of Newton, the poles might originally be only flattened a 230th part. Beſides, though we have the exact length of a degree at the equator and polar circle, yet we have not the exact length of a degree in France; and the meaſures of M. Picard have never been confirmed. It may be added,

added, that the diminution and increaſe in the motion of the pendulum agree not with the concluſions drawn from meaſurement; and that, on the contrary, they correſpond very nearly with the theory of Newton. Theſe circumſtances tend farther to convince us, that the poles are not depreſſed above a 230th part; and that, if there be any difference, it can proceed from nothing but the inequalities produced on the ſurface by the waters, and other external cauſes. But theſe inequalities are by no means ſo regular as to juſtify any hypotheſis, which ſuppoſes the meridians to be ellipſes, or any other perfect curves. Hence it appears, that, though many degrees ſhould be ſucceſſively meaſured in different regions, we cannot, by that alone, aſcertain the exact depreſſion of the poles, nor determine how much it exceeds or falls ſhort of a 230th part.

May we not likewiſe conjecture, that, if the inclination of the earth's axis has been changed, this effect could not be produced but by the changes on the ſurface, ſince all the other parts are homogeneous; that this variation is, of courſe, too ſmall to be perceived by aſtronomers; and that, if the earth be not diſturbed by a comet, or ſome other external cauſe, its axis will for ever preſerve its preſent and original inclination?

Not to omit any conjecture that ſeems reaſonable, may we not ſuppoſe, that, as the mountains and other inequalities on the ſurface of the

the earth, have originated from the action of the tides, thoſe which we perceive in the moon have been produced by a ſimilar cauſe? The mountains of the moon are indeed higher than thoſe of the earth; but her tides are likewiſe ſtronger; becauſe the earth, the ſize of which is much larger, raiſes the tides of the moon with a ſuperior force. This effect would be greatly augmented, if the moon, like the earth, had a quick diurnal motion. But, as the moon uniformly preſents the ſame face to the earth, the tides are raiſed only in proportion to the motion occaſioned by her librations, which alternately expoſe to our view a ſmall ſegment of her other hemiſphere. This cauſe, however, muſt produce tides very different from thoſe of our ſeas; and their effects will, of courſe, be much leſs conſiderable, than if the moon had poſſeſſed a diurnal revolution round her axis, equally quick as the rotation of the earth.

I ſhould compoſe a volume equal to that of Burnet or Whiſton, were I to extend the ideas preſented by the above theory; and were I, in imitation of the laſt-mentioned author, to clothe them in a geometrical dreſs, I might add conſiderably to their importance. But I have always thought, that hypotheſes, however probable, deſerve not to be treated ſo pompouſly. It is apt to give them the air of quackery and impoſition.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE II.

Of the Syſtem of Whiſton *.

THIS author begins his theory with a diſſertation on the creation of the world. He alleges, that the account given of it by Moſes is not properly underſtood; and that, in inquiries of this kind, men, contenting themſelves with the moſt evident and ſuperficial views, give too little of their attention to nature, reaſon, and philoſophy. The common notions, he obſerves, concerning the ſix days work, are falſe; and the deſcription of Moſes is not an exact or philoſophic account of the creation and origin of the univerſe, but only an hiſtorical

* See a new Theory of the Earth by Will. Whiſton, London, 1708.