confift of vitrifiable rocks; and thofe, the fummits of which are flat, contain, for the moft part, marbles, and hard ftones full of fea-bodies. The fame remark holds with regard to hills; for thofe compofed of granite or free-ftone are generally interfected with points, eminences, cavities, and fmall valleys. But thofe compofed of calcinable ftone are nearly of an equal height, and are only interrupted by larger and more regular valleys, with correfponding angles; and they are crowned with rocks, uniform and level in their pofition.

Though thefe two fpecies of mountains feem to be very different, their figures have been produced by the fame caufe, as has already been fhown: But, it may be remarked, that the calcinable ftones have fuffered no change fince the original formation of the horizontal ftrata. The vitrifiable fands, however, may have been changed and interrupted by the fubfequent production of rocks and angular blocks which take place in fand-beds. Both fpecies have fiffures. Thofe in calcinable rocks are almoft always perpendicular; but thofe of granite and free-ftone are fomewhat more irregular in their direction. It is in thefe fiffures that metals, minerals, cryftals, fulphur, and all the fubftances of our fecond clafs, are found. Below the fiffures, the waters affemble, penetrate the earth, and give rife to the veins of water which every where appear under the furface.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE X.

Of Rivers.

I HAVE already remarked, that, in general, the greateft mountains occupy the middle of continents; that thofe of a fmaller kind divide iflands, peninfulas, and promontories; that, in the Old Continent, the direction of the greateft chains of mountains is from weft to eaft; and that thofe which run to the north or fouth are only branches of the principal chains. It will appear on examination, that the greateft rivers have the fame direction, and few of them follow the courfe of the branches of mountains. To be convinced of this fact, we have only to run our eye over a common globe; and, beginning with Spain, we fhall find that the Vigo, the Douro,

Douro, the Tagus, and the Guadiana, run from eaſt to weſt, and the Ebro from weſt to eaſt; and that there is not a river of any conſideration which runs from ſouth to north, or from north to ſouth, although Spain be almoſt entirely environed by the ſea on the northern and ſouthern parts. This remark concerning the rivers of Spain demonſtrates, that the direction of the mountains is from weſt to eaſt; that the ſouthern provinces near the Straits are more elevated than the coaſt of Portugal; that, in the northern parts, the mountains of Galicia, the Aſturias, &c. are a continuation only of the Pyrennees; and that this elevation of the country, both in the ſouth and north, is the cauſe which prevents the rivers from running to the ſea in theſe directions.

In examining the map of France, it is apparent that the Rhone is the only river which runs from north to ſouth; and, even near one half of its courſe, from the mountains to Lyons, is from eaſt to weſt: But the direction of all the great rivers, as the Loire, the Charente, the Garonne, and even the Seine, is from eaſt to weſt.

The ſame obſervation holds with regard to Germany. The Rhine, like the Rhone, has the greateſt part of its courſe from ſouth to north: But the other large rivers, as the Danube, the Drave, and all the rivers which fall into them, run from weſt to eaſt, and empty themſelves in the Black Sea,

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The Black Sea, which ſhould rather be regarded as a large lake, is, from eaſt to weſt, nearly three times as long as from ſouth to north; and conſequently its direction is ſimilar to that of the rivers. The ſame remark is applicable to the Mediterranean, which is nearly ſix times longer from eaſt to weſt than from north to ſouth.

The Caſpian, it muſt be acknowledged, according to the chart made by order of the Czar Peter I. extends more from north to ſouth, than from eaſt to weſt. But the ancient charts repreſented it as nearly round, or rather as extending more from eaſt to weſt than in the oppoſite direction. If, however, the lake Aral be conſidered as a part of the Caſpian, from which it is ſeparated by a ſandy plain only, the greateſt extent of this ſea will ſtill be from weſt to eaſt.

The courſe of the Euphrates, of the Perſic gulf, and of almoſt all the rivers of China, is likewiſe from weſt to eaſt. The rivers of the interior parts of Africa obſerve the ſame direction, running either from weſt to eaſt, or from eaſt to weſt. The Nile, and the rivers of Barbary, are the only ones which run from ſouth to north. There are, it is true, large rivers in Aſia, as the Don, the Wolga, &c. which partly run from north to ſouth: But they only obſerve this direction in order to fall into the Black

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and Caſpian ſeas, which are lakes in the interior parts of the country.

We may, therefore, lay it down as a fact, that, in general, the rivers and mediterranean waters of Europe, Aſia, and Africa, run or ſtretch more from eaſt to weſt than from north to ſouth. This is a natural conſequence of the parallel direction of the different chains of mountains. Beſides, the whole continent of Europe and of Aſia is broader from eaſt to weſt than from north to ſouth: For the direction of mountains may be conſidered in two points of view. In a long and narrow continent, like that of South America, which contains only one principal chain of mountains, extending from ſouth to north, the rivers, not being reſtrained by any parallel chain, muſt run in channels perpendicular to the range of theſe mountains, that is, either from eaſt to weſt, or from weſt to eaſt; and this, in fact, is the direction of all the great rivers in America. But though, both in the Old and New Continent, the great rivers run in the ſame direction, this effect is produced by different cauſes. The rivers, in the Old Continent, run from eaſt to weſt, becauſe they are confined by many parallel chains of mountains which ſtretch from weſt to eaſt; but thoſe of America obſerve the ſame direction, becauſe there is only one chain of mountains ſtretching from ſouth to north.

The rivers generally occupy the middle of the valleys, or the loweſt ground between two oppoſite hills: If the two hills have nearly an equal declivity, the river runs nearly in the middle between them, whether the intermediate valley be broad or narrow. If, on the contrary, the declivity of one of the hills be greater than that of the other, the river will not occupy the middle of the valley, but will approach to the ſteepeſt hill, in proportion to the ſuperiority of its declivity. In this caſe, the middle of the valley is not the loweſt ground between the two hills, but lies much nearer the ſteepeſt of them; and conſequently the river muſt occupy that ſpace. This obſervation holds univerſally wherever the difference in declivity is remarkable; and the rivers never recede from the ſteepeſt hills, unleſs, in their courſe, they meet with other hills of equal declivity. In proceſs of time, however, the declivity of the ſteepeſt hill is diminiſhed by the rains, the melting of ſnow, &c. The ſteeper any hill is, it loſes greater quantities of earth, ſand, and gravel, by the operation of rains, and theſe ſubſtances are carried down into the plain with a proportionably greater rapidity, and, of courſe, force the river to change its channel, or, in other words, to retire into a lower part of the valley. It may be added, that, as all rivers occaſionally ſwell, and overflow their banks, they carry off mud and ſand, which they depoſit in different parts of the valley; and, as fand and gravel are often accumulated in the channels themfelves, thefe circumftances make the waters overflow, and alter the direction of their courfe. Nothing, accordingly, is more common, than to find in valleys many old channels in which the river has formerly run, efpecially when it is rapid, fubject to frequent inundations, and carries down great quantities of fand and mud.

In plains, and extenfive valleys, watered by large rivers, the channels of the rivers are commonly the loweft parts: But the furface of the water in the river is fometimes higher than the adjacent ground. When a river, for inftance, begins to overflow, it foon covers a confiderable part of the plain; but the banks remain longeft uncovered by the water. This circumftance plainly fhows that the banks of rivers are higher than the neighbouring ground; and that, from the banks to a certain part of the plain, there is a fmall declivity or flope. When, therefore, the water rifes to the margin of the banks, it muft be higher than the plain. This elevation of the ground on the banks of rivers is occafioned by mud and fand being depofited in the time of inundations. The water, during great fwells, is always exceedingly foul and muddy: When it begins to overflow, it runs flowly over the banks, and, by depofiting the mud and fand, it gradually purifies as it advances into the plain: Thus, all the mud, and other fubftances, which are

are not carried down by the current, are depofited upon the banks, and gradually elevate them above the reft of the plain.

Rivers are always wideft at their mouths, and turn gradually narrower towards their fources: But it is more worthy of remark, that, in the interior parts of a country, and at great diftances from the fea, their courfe is ftraight, and the frequency of their windings increafes proportionally as they approach to their termination. I have been informed by M. Fabry, who performed many journeys in the weftern parts of North America, that travellers, and even the favages, form pretty accurate computations of their diftance from the fea, by obferving the courfes of the rivers. If a river ran ftraight for 15 or 20 leagues, they knew themfelves to be a great way from the coaft; but, if the finuofities were frequent, they concluded that the fea was not very diftant. M. Fabry, when travelling through unknown and uninhabited regions, derived much advantage from this obfervation. Near the fides of great rivers, the regorging of the water is likewife lefs apparent the farther from the fea, which furnifhes another medium of judging concerning the diftance: And, as the finuofities multiply the nearer rivers approach to their mouths, it is not furprifing that fome of them fhould yield to the preffure of the water, and give rife to feveral branches or divifions, before they reach the fea.

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The motion of the water in rivers is very different from the reprefentation given of it by mathematicians. The furface, taken from bank to bank, is not level; but the middle of the ftream is either higher or lower, according to circumftances, than the water at the fides. When a river fwells fuddenly by the melting of fnow, or any other caufe, its rapidity increafes; and, if its courfe be ftraight, the middle of the ftream, where the current is greateft, rifes and forms a fenfible convexity. This elevation is fometimes very confiderable. M. Hupeau, who meafured this difference of level between the fides and the ftream of the Aveiron, found it to be three feet. This effect muft always be produced when the rapidity of the current is great; for the quicknefs of the motion, by diminifhing, or partly preventing the action of gravity, allows not to the water, in the middle of the ftream, time fufficient to bring it to a level with that on the fides, and, therefore, it remains higher. On the other hand, near the mouths, though the current be very rapid, the water near the fides is commonly more elevated than that of the middle: The river, in this fituation, has a concave form, the loweft point of which is the middle of the ftream. This effect is always produced as far as the influence of the tides is perceptible, which, in large rivers, extends fometimes to 100 or 200 leagues from the fea. It is likewife a fact well known, that the ftreams of rivers

rivers continue their motion a confiderable way through the waters of the fea. In this cafe, the water of the river has two oppofite motions. The middle, or current, precipitates itfelf towards the fea; but the action of the tide produces a counter current, or regorging, which elevates the water on the fides, while that in the middle defcends; and, as all the water muft be carried down by the current, that on the fides conftantly defcends towards the middle of the ftream, with a quicknefs proportioned to the elevation it receives from the regorging of the tide.

There are two fpecies of regorging, or damming up, in rivers: The firft is that juft now defcribed, and is occafioned by the action of the tide, which not only oppofes the natural defcent of the water, but even communicates to it a contrary motion or current: The other is produced by an inactive caufe, as a projection of the land, an ifland, &c. Though this kind of regorging gives not rife to any extraordinary counter current, it often fenfibly retards the progrefs of fmall boats, and produces what is called *dead water*, which obferves not the natural courfe of the river, but turns about in fuch a manner as greatly obftructs the progrefs of veffels. Thefe dead waters are fenfibly felt in paffing through the arches of a bridge, efpecially if the river be rapid. The celerity with which water runs, when the height or preffure is the fame, increafes in proportion as the diameter of the canal, through

through which it paſſes, is diminiſhed. The celerity of a river, therefore, in paſſing through a bridge, increaſes in the inverſe proportion of the width of the whole arches, to the total width of the river. This increaſe of celerity, in paſſing through the arch of a bridge, is ſo conſiderable, that it puſhes the water from the ſtream towards the banks, from which it is reflected, and ſometimes forms violent eddies or whirlpools. In paſſing under the bridge of St. Eſprit, the mariners are obliged ſcrupulouſly to keep the ſtream, even after leaving the bridge; for, if they allowed the boat to decline either to the right or left, it would be driven with violence againſt the banks, or, at leaſt, would be forced into the whirling or dead waters, from which they would find ſome difficulty of eſcaping. When the eddy is conſiderable, it forms a ſmall gulf with a cylindrical void in the middle, round which the water turns with rapidity. This cylindrical cavity is an effect of the centrifugal force, which makes the water endeavour to fly off from the centre of the whirlpool.

When a great ſwell of the river is about to happen, the water-men perceive a particular motion, which they call a *moving at the bottom*; that is, when the water at the bottom moves with an unuſual velocity, which, according to them, always indicates the approach of a ſudden ſwell. The motion and weight of the ſuperior waters, thought not yet arrived, fail not to act upon the waters

waters in the inferior parts of the river, and to communicate motion to them: For a river, in ſome reſpects, muſt be conſidered as a column of water contained in a tube, and its channel as a long canal, in which every motion muſt be communicated from one end of it to the other. Now, independent of the motion of the ſuperior waters, their weight alone may increaſe the celerity of the river, and perhaps make it move quickeſt at the bottom; for it is well known, that, when ſeveral boats are at once puſhed into a river, they increaſe the motion of the water below, and retard that of the ſuperior water.

The celerity of running waters is not in exact proportion to the declivity of their channels. A river with a uniform declivity, and double to that of another, ought not, it would appear, to run with more than a double celerity: But its celerity is much more quick, being ſometimes triple, ſometimes quadruple, &c. The celerity depends more upon the quantity of water, and the weight of the ſuperior waters, than upon the degree of deſcent. In digging the bed of a river or drain, it is unneceſſary to make the deſcent uniform through its whole extent. A quick motion is more eaſily produced by making the declivity much greater at the ſource than at the mouth, where, like the beds of natural rivers, it is almoſt imperceptible, and yet they preſerve their celerity, which is more or leſs, according to the quantity they contain; for in in great rivers, even where the ground is level, the water ftill runs, not only with the velocity originally acquired, but with the accumulated velocity produced by the action and weight of the fuperior waters*. To make this matter ftill more plain, let us fuppofe the Seine from Pont-neuf to Pont-royal to be perfectly level, and to be ten feet deep; let us alfo fuppofe the bed of the river below Pont-royal and above Pont-neuf to be fuddenly dried up; the waters, in this cafe, would run both up and down the channel, till their equilibrium was perfectly reftored. This effect is produced folely by the weight of the water, which never allows it to remain at reft till its particles are equally preffed on all fides, and its furface reduced to a perfect level. The weight of water, therefore, contributes greatly to increafe the celerity of its motion. This is the reafon why the greateft celerity in a current of water is neither at the bottom nor at the furface, but nearly in the middle, which is preffed both by the column above, and by the reaction from the bottom. But, what is ftill more, when a river acquires a great celerity, it will not only preferve it, though running through a level country, but even furmount heights, without

* By not attending to thefe circumftances, M. Khun was led falfely to affirm, that the fource of the Danube was at leaft two German miles higher than its mouth; that the Mediterranean is $6\frac{1}{4}$ German miles lower than the fources of the Nile; that the Atlantic ocean is half a mile lower than the Mediterranean, &c.

fpreading

fpreading much to a fide, or, at leaft, without producing an inundation of any moment.

One would be apt to imagine, that bridges, and other obftacles erected in rivers, would create a confiderable diminution of celerity in their whole courfe. But the difference is very fmall. The water, upon meeting with any obftacle, rifes, in order to furmount it; and the increafe of celerity communicated by its fall, nearly compenfates the retardation occafioned by the obftacle. Thus, finuofities, projections from the land, and iflands, create but a fmall variation on the total celerity of a river's courfe. The moft confiderable alterations are produced by the greater or leffer quantities of water; when the quantity is fmall, a river runs flow, when great, it runs with rapidity.

If rivers were always equally full, to enlarge their channels would be the beft method of diminifhing their rapidity, and to contain them within their banks. But, as almoft all rivers rife and fall, it is more neceffary, for this latter purpofe, to narrow their channels; for fmall waters, with large channels, generally fcoop out winding beds in the middle; and, when they fwell, they follow the direction of thefe particular beds, and by ftriking with violence againft the banks, often do much injury to mills and other works. Thefe bad effects might be prevented, by digging gulfs in the earth at convenient diftances. To accomplifh this purpofe, a

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part of one of the banks ſhould be cut through, and the earth removed for a conſiderable ſpace. Theſe ſmall gulfs ſhould be made in the obtuſe angles of the river; for the water, in turning, would run into them; and, of courſe, its celerity would be diminiſhed. This method might be uſeful in preventing the fall of bridges in places where ſufficient barriers cannot be erected to reſiſt the weight of the water.

The manner in which inundations are produced, merits particular attention. When a river ſwells, its celerity uniformly increaſes, till it begins to overflow the banks: From that moment its rapidity is checked, which is the reaſon why inundations always continue ſeveral days; for, though the quantity of water ſhould be diminiſhed after the commencement of the inundation, it would, notwithſtanding, continue to overflow; becauſe this circumſtance depends more on the celerity than on the quantity of water. If it were otherwiſe, rivers would often overflow their banks for an hour or two, and then retire to their channels, which never happens. An inundation, on the contrary, always laſts ſome days, although the rains have ceaſed, and leſs water runs in the river; becauſe the overflowing of waters diminiſhes their celerity; and, conſequently, although the ſame quantity of water arrives not in the ſame time as formerly, the effect is the ſame as if a larger quantity had been brought down. It may like-

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wiſe be here remarked, that, if a high wind blows contrary to the current of the river, the inundation will be increaſed by this occaſional cauſe, which diminiſhes the celerity of the water; but, if the wind blows in the direction of the current, the inundation will be leſs, and retire more quickly.

'The inundation of the Nile,' ſays M. Granger, 'has long been a ſubject of diſcuſſion 'among the learned. Moſt of them have conſidered it as a ſingular and wonderful phænomenon, though nothing be more natural or 'more common; for it takes place in every 'country, as well as in Egypt. The inundation 'of the Nile is occaſioned by the rains which fall 'in Ethiopia and Abyſſinia; but the north wind 'may be regarded as the principal cauſe of it: '1. Becauſe the north wind drives the clouds 'which contain this rain into Abyſſinia: 2. Becauſe it prevents the water from running out 'of the mouths of the river in any great quantity, by damming up the ſtream. The great 'effect of this wind may be remarked every 'ſeaſon; for, when it changes from north, the 'Nile loſes more water in one day than in four.'

Inundations are generally greateſt in the ſuperior parts of rivers; becauſe, as formerly obſerved, the velocity of a river uniformly increaſes till it empties itſelf in the ocean. Father Caſtelli, a ſenſible writer on this ſubject, remarks, that the banks, raiſed for the purpoſe of

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keeping the Po from overflowing, gradually diminiſh in height, as the river approaches to the ſea; that, at Ferrara, which is 60 or 70 miles from the mouth of the river, the banks are about 20 feet above the ordinary level of the water; but that, at 10 or 12 miles from the ſea, though the channel be equally narrow as at Ferrara, they are not above 12 feet*.

In fine, the theory of running waters is ſubject to many difficulties. It is not eaſy to give general rules which will apply to every particular caſe. For this purpoſe, experience is preferable to ſpeculation: It is not enough that we know the common effects of rivers in general; but, if we would reaſon juſtly, and give ſtability to our labours, we ought to ſtudy the peculiarities of particular rivers in which we have an intereſt. Though the remarks I have made be generally new, a greater collection is neceſſary. Perhaps we ſhall in time acquire a diſtinct knowledge of this ſubject, and be enabled to give certain rules for directing and confining rivers in ſuch a manner as will prevent the deſtruction of bridges, banks, and other damages occaſioned by the impetuoſity of the waters.

The greateſt rivers of Europe are, the Wolga, the courſe of which, from Reſchow to Aſtracan on the Caſpian Sea, is about 650 leagues; the Danube, which runs about 450 leagues,

* See Racolta d'autori che trattano del moto dell'acque, vol. i. p. 123.

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from the mountains of Switzerland to the Black Sea; the Don, the courſe of which, from the ſource of the Soſna, which receives it, to the Black Sea, is 400 leagues; the Nieper, which likewiſe falls into the Black Sea, after running 350 leagues; the Duine, which empties itſelf in the White Sea, runs a courſe of about 300 leagues, &c.

The greateſt rivers of Aſia are the Hoanho, in China, which riſes at Raja-Ribron, and after running 850 leagues, falls into the middle of the gulf of Changi, in the Chineſe ſea; the Jeniſca, which runs from Lake Selinga to the northern ſea of Tartary, a courſe of about 800 leagues; the Oby, the courſe of which, from Lake Kila to the north ſea beyond Waigat's Straits, is about 600 leagues; the river Amour, in eaſt Tartary, has a courſe of 575 leagues, from the head of the river Kerlon, which falls into it, to the ſea of Kamtſchatka; the river Menancon may be meaſured from the ſource of the Longmu, which falls into it, to its mouth at Poulo-condor; the Kian, the courſe of which is about 550 leagues, from the ſource of the Kinxa, which it receives, to its termination in the ſea of China; the Ganges, which has a courſe nearly of the ſame extent with the Kian; the Euphrates, computing from the ſource of the Irma, which it receives, runs about 500 leagues; the Indus, which runs about 400 leagues, and falls into the Arabian ſea on the eaſt of Guzarat;

rat; and the Sirderoias, which runs about 400 leagues, and falls into Lake Aral.

The greateſt rivers of Africa are, the Senegal, the courſe of which, comprehending the Niger, which is a continuation of it, and the ſource of the Gombarou, which falls into the Niger, is about 1125 leagues; the Nile, which riſes in Upper Ethiopia, runs about 970 leagues. There are others, the courſes of which are but partially known, as the Zaira, the Coanza, the Couama, and the Quilmanci, each of which we are acquainted with to the extent of 400 leagues.

Laſtly, in America, the river of the Amazons runs more than 1200 leagues, if we reckon from the lake near Guanuco, 30 leagues from Lima, where the Maragnon riſes; or, even computing from the ſource of the river Napo, near Quito, the courſe of the Amazons is more than 1000 leagues*.

The courſe of the river St. Lawrence in Canada is more than 900 leagues, computing from its mouth to Lake Ontario, from that to Lake Huron, Lake Superior, Lake Alemipigo, Lake Chriſtinaux, and the lake of the Aſſiniboils, the waters of all which fall into one another, and at laſt into the river St. Lawrence.

The river Miſſiſippi runs more than 700 leagues, from its mouth to any of its ſources, which are not far from the lake of the Aſſiniboils.

* See Voyage de Condamine, p. 15.

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The river Plata extends more than 800 leagues, from its mouth to the ſource of the Parana, which it receives.

The river Oronoko runs more than 575 leagues, reckoning from the ſource of the river Caketa, near Paſto, which partly falls into the Oronoko, and partly runs towards the river of the Amazons*.

The Madera, which falls into the Amazons, extends more than 660 leagues.

In order to compute the quantity of water diſcharged into the ſea by all the rivers, we ſhall ſuppoſe, which is nearly the truth, that one half of the earth's ſurface is ſea, and the other half dry land: We ſhall likewiſe ſuppoſe the mean depth of the ſea to be about 230 fathoms. The total ſurface of the earth is 170981012 ſquare miles, and that of the ſea is 85490506 ſquare miles, which being multiplied by 1-fourth, the depth of the ſea, gives 21372626 cubic miles for the quantity of water contained in the whole ocean. Now, to compute the quantity diſcharged into the ocean by the rivers, let us take a river, the velocity and quantity of whoſe waters are known; the Po, for example, which paſſes through Lombardy, and waters a country of 380 miles in length. According to Riccioli, the breadth of the Po, before it divides into branches, is 100 perches of Boulogne, or 1000 feet; and its depth is 10 feet; and it runs at the rate of 4 miles in an

* See M. Condamine's Map.

hour:

hour: Confequently the Po difcharges into the fea 200,000 cubical perches of water in an hour, or 4,800,000 in a day. But a cubic mile contains 125,000,000 cubic perches; of courfe, it will require 26 days to difcharge into the fea a cubic mile of water. It only remains to determine the proportion that the Po bears to all the rivers of the earth taken together, which cannot be done exactly. But, to approach nearly to the truth, let us fuppofe that the quantity of water which the fea receives from the great rivers in every country, is proportioned to the extent of the furfaces of thefe countries; and, confequently, that the country watered by the Po, and by the rivers which fall into it, is to the total furface of the dry land as the Po is to all the rivers of the earth. Now, by the moft exact charts, it appears that the Po, from its origin to its mouth, traverfes a country of 380 miles in length; and the rivers which fall into it on each fide arife from fources which are about 60 miles diftant from the Po. Thus, the Po, and the rivers it receives, water a country 380 miles long, and 120 broad, which makes 45600 fquare miles. But the furface of the dry land is 85490506 fquare miles; confequently, the quantity of water carried to the fea by all the rivers will be 1874 times greater than the quantity difcharged by the Po. But, as 26 rivers, equal to the Po, furnifh a cubic mile of water each day, it follows, that, in the fpace of a year, 1874

1874 rivers equal to the Po, will carry to the fea 26308 cubic miles of water; and that in 812 years, all thefe rivers would difcharge 21372626 cubic miles, which is a quantity equal to what is contained in the ocean; of courfe, if the ocean were empty, 812 years would be neceffary to fill it by the rivers*.

It is a refult of this calculation, that the quantity of water raifed from the fea by evaporation, and tranfported upon land by the winds, is from 20 to 21 inches in the year, or about $\frac{2}{3}$ of a French line each day. This evaporation, though tripled to make allowance for what falls back into the fea from the clouds, is very inconfiderable. Mr. Halley † has clearly demonftrated, that the vapours tranfported from the fea, and difcharged upon the land, are fufficient to maintain all the rivers and lakes in the world.

After the Nile, the Jordan is the largeft river in the Levant, or even in Barbary. It difcharges each day into the Dead Sea about 6,000,000 of tons. All this water, and more, is carried off by evaporation; for, according to Halley's calculation of 6914 tons evaporated from each fuperficial mile, the Dead Sea, which is 72 miles long, and 18 broad, muft lofe every day, by evaporation, near 9,000,000 of tons; that is, not only all the water it receives from the Jordan, but from the fmaller rivers which come

* See Keil's Examination of Burnet's Theory, p. 126.
† See Phil. Tranf. num. 192.

from

from the mountains of Moab, and elfewhere. Of courfe, this fea has no occafion to communicate with any other by fubterraneous paffages*.

The moft rapid of all rivers are, the Tigris, the Indus, the Danube, the Yrtis in Siberia, the Malmiftra in Cilicia, &c †. But, as was formerly remarked, the velocity of rivers depends both on the declivity and the weight of water. In examining the globe, we find that the Danube has lefs declivity than the Po, the Rhine, or the Rhone; for the courfe of the Danube is longer, and it falls into the Black Sea, which is higher than the Mediterranean, and perhaps than the ocean.

Great rivers, in their courfe, are conftantly receiving fmall ones into their channels. The Danube, for example, receives more than 200 brooks and rivulets. But if we reckon only rivers of fome confideration, we will find, that the Danube receives 30 or 31, the Wolga 32 or 33, the Don 5 or 6, the Nieper 19 or 20, the Duine 11 or 12. The Hoanho, in Afia, receives 34 or 35 rivers, the Jenifca more than 60, the Oby an equal number, the Amour about 40, the Kian, or river Nankin, 30, the Ganges more than 20, the Euphrates 10 or 11, &c. In Africa, the Senegal receives more than 20 rivers; the Nile receives none lower than 500 leagues from its mouth, the laft which falls into it being the Moraba; and from this place to its

* See Shaw's Travels.

† See Varenii Geog. p. 178.

fource

fource, it receives about 12 or 13. In America, the Amazons receives more than 60 confiderable rivers, St. Lawrence about 40, reckoning thofe which fall into the lakes, the Miffifippi more than 40, the Plata above 50, &c.

Upon the furface of the earth, there are elevated countries which feem to be points of partition marked out by nature for the diftribution of the waters. In Europe, one of thefe points is Mont Saint-Godard, and its environs. Another point is the country fituated between the provinces of Belozera and Wologda in Mufcovy, from which many rivers defcend, fome into the White Sea, fome into the Black, and others into the Cafpian. In Afia, there are feveral points of partition, as the country of the Mogul Tartars, fome of whofe rivers run into the fea of Nova Zembla, others into the gulf of Linchidolin, others into the fea of Corea, and others into that of China; and the Leffer Thibet, the rivers of which run into the Chinefe fea, into the gulf of Bengal, the gulf of Cambaia, and the Lake Aral. The province of Quito, in America, difcharges its rivers into the fouth and north feas, and into the gulf of Mexico.

In the Old Continent, there are about 430 rivers which directly fall either into the Ocean, or into the Mediterranean and Black Seas. But, in the New Continent, we know of only 135 rivers which fall immediately into the fea. In

this

this number I have reckoned none which are not as large as the river Somme in Picardy.

All thefe rivers tranfport, from the countries through which they pafs, into the fea, great quantities of mineral and faline particles. The particles of falt, which diffolve in water, are eafily carried down to the fea. Several philofophers, and particularly Halley, have alledged, that the faltnefs of the fea proceeds alone from the particles of falt tranfported by the rivers: Others maintain, that this faltnefs was coeval with the fea itfelf, and that the falt was created to prevent the waters from corrupting. But the agitation of the fea by the winds and the tides is, I imagine, a caufe equally powerful as the falt in preferving it againft putrifaction; for, when barrelled up, it corrupts in a few days. And Boyle informs us of a navigator who was overtaken with a calm which lafted 13 days, and who affured him, that the water became fo putrid, that, if the calm had continued much longer, the whole crew would have perifhed*. Sea-water is alfo impregnated with a bituminous oil, which renders it both unwholefome and difagreeable to the tafte. The quantity of falt in fea-water is about a fortieth part, and it is nearly of an equal faltnefs at the furface and at the bottom, under the Line and at the Cape of Good Hope; though there are fome particular places, as off the Mofambique coaft, where it is more falt than

* See Boyle, vol. iii. p. 222.

in others*. It is likewife faid to be lefs falt within the Arctic circle: But this phænomenon may proceed from the immenfe quantities of fnow, and the large rivers which fall into thefe feas, and from the proportional defect of evaporation.

However this matter ftands, I believe, that the faltnefs of the ocean is not only occafioned by the many banks of falt at the bottom of the fea, and along the coafts, but likewife by the falts continually brought down by the rivers; that Halley was right in his conjecture that there was originally little or no falt in the fea, but that its faltnefs gradually augmented in proportion as falt was fupplied by the rivers; that the degree of faltnefs is perpetually increafing; and, confequently, that, by computing the total quantity of falt carried down by the rivers, we might be enabled to difcover the real age of the world. Mr. Boyle affirms, on the authority of divers and pearl-fifhers, that the water is colder in proportion to its depth; and that, at great depths, the cold becomes fo exceffive as to oblige them to come up much fooner than ufual. But the weight of the water may be as much the caufe of their uneafinefs as the intenfenefs of the cold, efpecially when they defcend 300 or 400 fathom. Divers, however, feldom go deeper than 100 feet. The fame author relates, that, in a voyage to the Eaft Indies, when they ar-

* See Boyle, vol. iii. p. 217.

rived at the 35th degree of fouth latitude, they founded to the depth of 400 fathoms, and when the lead, which weighed about 30 pounds, was drawn up, it had become as cold as ice. It is likewife a common practice at fea to fink the bottles feveral fathoms, in order to cool their wine; and it is faid, that the deeper the bottles are funk, the wine becomes the cooler.

Thefe facts would lead us to imagine, that the fea-water was falter at the bottom than at the furface. But they are oppofed by facts of a contrary nature: Experiments have been made with veffels which opened only at a certain depth, and the water was not found to be falter than that at the furface: There are even examples of the water at the bottom being frefher than at the furface: This phænomenon is exhibited in all thofe places where fprings arife from the bottom of the fea, as near Goa, at Ormus, and in the fea of Naples, in which there are many warm fprings.

In other places, fulphureous fprings and beds of bitumen have been difcovered at the bottom of the fea; and, upon land, there are numerous fprings of bitumen which run into the fea. At Barbadoes, there is a fountain of bitumen which runs from the rocks into the fea. Bitumen and falt, then, are the principal ingredients in fea-water. But it is blended with many other fubftances; for its tafte differs confiderably in different parts of the ocean: Befides, agitation and the

the heat of the fun change the natural tafte of fea-water; and the different colours of different feas, and even of the fame fea at different times, prove it to be mixed with many heterogeneous bodies, which are detached either from the bottom, or carried down by the rivers.

Moft countries that are furnifhed with large rivers are fubject to periodical inundations; and thofe rivers which have long courfes overflow with the greateft regularity. Every body has heard of the inundations of the Nile, the waters of which, though fpread over a large track of country, and at a great diftance from the fea, preferve their fweetnefs and tranfparency. Strabo and other ancient authors tell us, that the Nile had feven mouths; but now only two which are navigable remain: A third canal, indeed, fupplies the cifterns of Alexandria; and there is a fourth, which is ftill lefs confiderable. As the cleaning of thefe canals has long been neglected, they are moftly in ruins. In thefe works the ancients employed annually a vaft number of workmen and foldiers, who carried off the mud and fand which this river brings down in great quantities. The overflowing of the Nile is occafioned by the rains which fall in Ethiopia: They begin in April, and end not till September. During the firft three months, the days are ferene and beautiful; but the fun no fooner fets, than the rains begin, continue inceffantly till funrifing, and are commonly accompanied with

 thunder

thunder and lightning. The inundation in Egypt begins about the 17th of June; it generally takes 40 days in fwelling, and as many in fubfiding. The whole flat country of Egypt is overflowed: But the inundation is not now fo great as in ancient times; for Herodotus affirms, that the Nile fwelled 100 days, and required an equal time to fubfide. If this fact be true, the difference can be afcribed to no other caufes but the gradual elevation of the land by the mud brought down and depofited, and the diminution in the height of the mountains from which this river derives its fource. It is natural to think, that the height of the mountains is diminifhed; for the heavy rains that fall in thefe regions during one half of the year, bring down great quantities of fand and earth from the tops of the mountains into the valleys, from which they are tranfported by torrents into the channel of the Nile, and are partly depofited on the land by the inundations.

The Nile is not the only river that has regular and annual overflowings: The Pegu, which is equally regular in its inundations, has, from this circumftance, got the name of the *Indian Nile*. It overflows the country for 30 leagues beyond its banks, and, like the Nile, leaves great quantities of mud and flime, which enrich the ground fo much, that it produces excellent pafture for cattle, and enables the inhabitants to export

export rice*. The Niger, or, which is the fame thing, the upper part of the Senegal, overflows and covers the whole flat country of Nigritia. Its inundations, like thofe of the Nile, begin about the middle of June, and increafe for 40 days. The Plata, in Brafil, overflows annually, and at the fame time with the Nile. The Ganges, the Indus, the Euphrates, and fome other rivers, produce annual inundations. But all rivers are not fubject to periodic inundations: Thefe proceed from a combination of caufes, which, at the fame time, augment the quantity of water, and diminifh its velocity.

We formerly remarked, that the declivity of rivers gradually diminifh till they arrive at the fea. But, in fome places, the declivity is more fudden, and forms what is called *a cataract*, which is nothing more than an unufually rapid fall of the water. In the Rhine, for example, there are two cataracts, one at Bilefeld, and the other near Schafhoufe. The Nile has feveral cataracts: Two of the moft remarkable fall from a great height between two mountains. In the Wologda, in Mufcovy, there are alfo two, near Ladoga. The Zaire, a river in Congo, commences with a large cataract, which falls from the top of a mountain. But the moft celebrated cataract is that of the river Niagara in Canada: It falls, in a prodigious torrent, 156 feet of perpendicular height, and is a fourth part of

* See Les Voyages d'Ovington, tom. ii. p. 290.

 a league

a league in breadth. The vapour of the water rises to the clouds, is seen at the distance of five leagues, and, when the sun shines above it, exhibits a beautiful rainbow. Below this cataract, the whirlpools and commotions of the waters are so tremendous, as to render navigation impracticable for six miles: and immediately above the cataract, the river is much narrower than higher up *. Charlevoix † describes it in the following manner:

'My first care, after my arrival, was to visit 'the noblest cascade, perhaps, in the world; but 'I presently found the Baron de la Hontan had 'committed such a mistake with respect to its 'height and figure, as to create a suspicion that 'he had never seen it. If, however, you measure its height by that of the three mountains 'you are obliged to climb to get at it, it does 'not fall much short of what the map of M. 'Deslisle makes it, that is, 600 feet. He has 'probably adopted this paradox, either on the 'faith of the Baron de la Hontan, or of Father 'Hennepin. But, after I arrived at the summit 'of the third mountain, I observed, that, in the 'space of three leagues, which I had to walk 'before I came to this piece of water, though 'you are sometimes obliged to ascend, you must 'yet descend still more; a circumstance to which 'travellers seem not to have sufficiently attended. As it is impossible to approach it but on 'one

* See Phil. Transf. Abridg. vol. vi. part ii. p. 119.

† Tom. iii. p. 353.

'one side, and consequently to see it, except in 'profile, it is no easy matter to measure its 'height with instruments. It has, however, 'been attempted by means of a pole tied to a 'long line, and, after many trials, it has been 'found to be only 115, or 120 feet high. But 'it is impossible to be sure that the pole has not 'been stopt by some projecting rock; for, 'though it was always drawn up wet, as well 'as the end of the line to which it was tied, 'this circumstance proves nothing, as the water 'which precipitates itself from the mountain, 'rises very high in foam. For my own part, 'after having examined it on all sides, where it 'could be viewed to the greatest advantage, I 'am inclined to think that we cannot allow it 'to be less than a hundred and forty or fifty 'feet high.

'As to its figure, it resembles that of a horse-'shoe, and is about 400 paces in circumference. 'It is divided into two, exactly in the middle, 'by a very narrow island, half a quarter of a 'league long. It is true, these two parts very 'soon unite; that on my side, and which I 'could have a side view of only, has several 'branches which project from the body of the 'cascade, but that which I viewed in front, ap-'peared to me quite entire. The Baron de la 'Hontan mentions a torrent, coming from the 'west, which, if this author has not invented it, 'must certainly fall through some channel dur-'ing the melting of the snows only.'

Three

Three leagues from Albany, in the province of New York, there is a cataract of 50 feet perpendicular height, the vapour of which likewise gives rise to a rainbow*.

In every country where the number of men is too inconsiderable for forming and supporting polished societies, the surface of the earth is more unequal and rugged, and the channels of rivers are more extended, irregular, and often interrupted by cataracts. The Rhone and the Loire would require the operation of several ages before they became navigable. It is by confining and directing the waters, and clearing the bottoms of rivers, that they acquire a fixed and determinate course. In thinly inhabited regions, nature is always rude, and sometimes deformed.

Some rivers lose themselves in the sands, and others seem to precipitate into the bowels of the earth. The Guadalquiver in Spain, the river of Gottenburg in Sweden, and even the Rhine, disappear under ground. It is affirmed, that, in the west part of the Island of St. Domingo, there is a pretty high mountain, at the foot of which are several large caverns that receive the rivers and brooks; and the noise of their fall is heard at the distance of seven or eight leagues†. The number of rivers, however, which disappear in the earth, is very small; and they seem not to descend very deep. It is more probable, that, like the Rhine, they lose themselves by dividing and dispersing through a large surface of sand, which is very common with those small rivers that run through dry and sandy ground, of which there are many examples in Africa, Persia, Arabia, &c.

* See Phil. Transf. Abridg. vol. vi. part ii. p. 119.

† See Varen. Geogr. p. 43.

The rivers of the north carry down to the sea prodigious quantities of ice, which, by accumulating, form those enormous masses, so dangerous to the mariner. The straits of Waigat, which is frozen during the greatest part of the year, is most remarkable for these masses of ice, that are constantly brought into the straits by the river Oby. They attach themselves all along the coasts, and rise to great heights. The middle of the strait freezes last, and the ice, of course, does not rise so high as on each side. When the north wind ceases, and it blows in the direction of the straits, the ice begins to melt and to break in the middle; then large masses are detached and transported into the open sea. The wind, which blows during the whole winter from the north, over the frozen country of Nova Zembla, renders the regions watered by the Oby, and all Siberia, so cold, that, at Tobolski, in the 57th degree, there are no fruit trees, though at Stockholm in Sweden, and even in higher latitudes, they have fruit trees and leguminous plants. This difference proceeds not, as has been imagined, from the sea of Lapland being

being colder than that of the ftraits, nor from the country of Nova Zembla being colder than that of Lapland, but from this circumftance alone, that the Baltic and the fea of Bothnia foften the rigour of the north wind; whereas, in Siberia, there is nothing to check its activity. This folution is a refult of experience. The cold is never fo intenfe near the fea-coafts as in the interior parts of a country. There are plants which endure the open air all winter at London, which cannot be preferved at Paris: and Siberia, which is a vaft continent, is, for this reafon, colder than Sweden, which is almoft furrounded with the fea.

Spitzbergen is the coldeft country in the world: It runs as far as the 78th degree of north latitude, and is compofed of fmall, pointed mountains. Thefe mountains confift of gravel, and of flat ftones, like gray flate, heaped upon one another. According to the accounts of voyagers, thefe hills are raifed by the winds, and new ones appear every feafon. In this country no quadrupeds live but the rein deer, which feeds upon mofs. Beyond thefe hills, and above a league from the fea, the maft of a fhip was lately found with a pully fixed to one end of it; from which circumftances, it has been concluded, that this is a new country, and that it was formerly covered with the fea: It is uninhabited and uninhabitable; for the hills have no confiftence, but are loofe and moveable; and a vapour proceeds from the earth, fo cold and penetrating, as to preclude the poffibility of remaining any time upon this dreary and inhofpitable land.

The whale-fifhing veffels arrive at Spitzbergen in July, and depart from it about the middle of Auguft. The ice permits them not to arrive fooner, or to remain longer. In thefe feas there are prodigious boards of ice, clear and fhining as glafs, and from 60 to 80 fathoms thick; and, in fome places the fea appears to be frozen to the bottom*.

The feas of North America are likewife much infefted with ice, as in Afcenfion-bay, in Hudfon's, Cumberland's, Davis's, and Frobifher's ftraits, &c. We are affured by Robert Lade, that the mountains of Friefland are entirely covered with fnow; and that the ice furrounds the coafts, and, like a bulwark, prevents all approach to them. 'It is remarkable,' fays he, 'that, in 'this fea, we meet with iflands of ice, more than 'half a league in circumference, exceedingly 'high, and defcend from 70 to 80 fathoms 'deep. This ice, which is fweet, is perhaps 'originally formed in the rivers or ftraits of the 'adjacent lands, &c. Thefe iflands or moun-'tains of ice are moveable, and, in ftorms, they 'follow the tract of a fhip, as if they were 'drawn after her by a rope. Some of them 'rife

* See recueil des voyages du Nord, tom. i. p. 154.

'rise so high above water, that they surmount
'the tops of the tallests masts*,' &c.

In the voyages collected for the use of the Dutch East India Company, we have the following account of the ice off Nova Zembla; 'At Cape Trooft, the weather was so foggy, as 'to oblige us to moor our vessel to a bank of 'ice, which was 36 fathoms below, and 16 'above the surface of the water. On the 10th 'of August, the ice began to separate, and to 'float; we then remarked, that the mass to 'which our vessel had been moored, touched 'the bottom; for, though the others were all 'in motion, and struck against it, and against 'each other, it remained immoveable. We 'were now afraid of being frozen in, or dashed 'to pieces; we, therefore, endeavoured to escape 'from this latitude, though the vessel, in 'her course, was obliged to push through the 'ice, which made a great noise round us for 'a considerable distance: we at last anchored 'along another board of ice, where we remain'ed that night.

'During the first watch, the ice began to 'split, with an inconceivable noise. The ship's 'head kept so strongly to the current in which 'the ice-boards floated, that we were obliged to 'veer the cable in order to get her off. We 'counted above 400 blocks of ice, which sank

* See Lade's voyages.

'10 fathoms below the water, and appeared to 'rise about two fathoms above it.

'We then moored the vessel to another block 'of ice, which was immersed below the surface 'about six fathoms. At a little distance from 'this station we perceived a large bank, which 'was pointed like a cone, and reached to the 'bottom of the sea: we approached it, and 'found it to be 20 fathoms below, and about '12 above the surface of the water.

'On the 11th, we sailed up to another bank, 'which was 18 fathoms below the surface, and '10 fathoms above it.

'The Dutch, on the 21st, advanced a great 'way between the boards of ice, and anchored 'during the night. Next morning they retired, 'and moored to a bank which was 18 fathoms 'below, and 10 above the water. They climbed 'to the top, and remarked, as a singular phæ'nomenon, that it was covered with earth, and 'that they found there about 40 eggs. Its co'lour was a fine azure blue, and totally differ'ent from that of the other masses. This cir'cumstance gave rise to various speculations; 'some imagining it to be an effect of the ice, 'and others thought the whole was a mass of 'frozen earth*.'

Wafer met with many floating pieces of ice, off Terra del Fuego, which were so large that

* See Troisieme voyage des Hollandois par le Nord, tom. i. p. 46.

he at first imagined them to be islands: some of them, he remarks, appeared to be a league or two in length, and the largest of them seemed to rise 400 or 500 feet above the surface of the water.

All these boards of ice, as I have remarked in the 6th Article, are transported from the rivers into the sea. Those in the sea of Nova Zembla and in the Straits of Waigat, come from the Oby, and, perhaps, from the Jenisca, and other great rivers in Siberia and Tartary; those of the Hudson's Straits, from Ascension-bay, into which many rivers in North America empty themselves; and those of Terra del Fuego, from the southern continent. If fewer of them appear in the northern coasts of Lapland than in those of Siberia and Waigat's Straits, it is because all the Lapland rivers fall into the gulf of Bothnia, and none of them into the north sea. They may likewise be formed in straits, where the tides rise higher than in the open sea; and, consequently, where the boards of ice which float on the surface may accumulate and produce masses or banks of several fathoms high. But, with regard to those which rise to the height of four or five hundred feet, it appears, that they can no where be produced but near very elevated coasts; and I imagine, that, when the snows which cover these coasts melt, the water runs down upon the boards of ice, and, by freezing anew, gradually augments their

 size,

size, till they arrive at this amazing height; that, in a warm summer, the action of the winds, the agitation of the sea, and perhaps their own weight, may detach them from the coasts, and set them adrift; and that they may even be transported into temperate climates before they are entirely dissolved.