Eudoxus, Platonis auditor, in astrologia judicio doctissimorum hominum facile princeps, sic opinatur (id quod scriptum reliquit): Chaldaeis in praedictione et in notatione cujusque vitae ex natali die minime esse credendum." He then quotes the condemnatory verdict of other philosophers as to the teaching of the Chaldaeans but says nothing as to the antiquity and origin of astronomy. CICERO further notes De oratore I, 16 that Aratus was "ignarus astrologiae" but that is all. So far as I know the word occurs nowhere else in CICERO; and the word Astronomia he does not seem to have used at all. (H. MULLER-STRUBING.)]

Of time and its divisions (916-918).

916.

Although time is included in the class of Continuous Quantities, being indivisible and immaterial, it does not come entirely under the head of Geometry, which represents its divisions by means of figures and bodies of infinite variety, such as are seen to be continuous in their visible and material properties. But only with its first principles does it agree, that is with the Point and the Line; the point may be compared to an instant of time, and the line may be likened to the length of a certain quantity of time, and just as a line begins and terminates in a point, so such a space of time. begins and terminates in an instant. And whereas a line is infinitely divisible, the divisibility of a space of time is of the

same nature; and as the divisions of the line may bear a certain proportion to each other, so may the divisions of time.

[Footnote: This passage is repeated word for word on page 190b of the same manuscript and this is accounted for by the text in Vol. I, No. 4. Compare also No. 1216.]

917.

Describe the nature of Time as distinguished from the Geometrical definitions.

918.

Divide an hour into 3000 parts, and this you can do with a clock by making the pendulum lighter or heavier.

XVI.

Physical Geography.

Leonardo's researches as to the structure of the earth and sea were made at a time, when the extended voyages of the Spaniards and Portuguese had also excited a special interest in geographical questions in Italy, and particularly in Tuscany. Still, it need scarcely surprise us to find that in deeper questions, as to the

structure of the globe, the primitive state of the earth's surface, and the like, he was far in advance of his time.

The number of passages which treat of such matters is relatively considerable; like almost all Leonardo's scientific notes they deal partly with theoretical and partly with practical questions. Some of his theoretical views of the motion of water were collected in a copied manuscript volume by an early transcriber, but without any acknowledgment of the source whence they were derived. This copy is now in the Library of the Barberini palace at Rome and was published under the title: "De moto e misura dell'acqua," by FRANCESCO CARDINALI, Bologna 1828. In this work the texts are arranged under the following titles: Libr. I. Della spera dell'acqua; Libr. II. Del moto dell'acqua; Libr. III. Dell'onda dell'acqua; Libr. IV. Dei retrosi d'acqua; Libr. V. Dell'acqua cadente; Libr. VI. Delle rotture fatte dall'acqua; Libr. VII Delle cose portate dall'acqua; Libr. VIII. Dell'oncia dell'acqua e delle canne; Libr. IX. De molini e d'altri ordigni d'acqua.

The large number of isolated observations scattered through the manuscripts, accounts for our so frequently finding notes of new schemes for the arrangement of those relating to water and its motions, particularly in the Codex Atlanticus: I have printed several of these plans as an introduction to the Physical Geography, and I have actually arranged the texts in accordance with the clue afforded by one of them which is undoubtedly one of the latest notes

referring to the subject (No. 920). The text given as No. 930 which is also taken from a late note-book of Leonardo's, served as a basis for the arrangement of the first of the seven books--or sections--, bearing the title: Of the Nature of Water (Dell'acque in se).

As I have not made it any part of this undertaking to print the passages which refer to purely physical principles, it has also been necessary to exclude those practical researches which, in accordance with indications given in 920, ought to come in as Books 13, 14 and 15. I can only incidentally mention here that Leonardo--as it seems to me, especially in his youth--devoted a great deal of attention to the construction of mills. This is proved by a number of drawings of very careful and minute execution, which are to be found in the Codex Atlanticus. Nor was it possible to include his considerations on the regulation of rivers, the making of canals and so forth (No. 920, Books 10, 11 and 12); but those passages in which the structure of a canal is directly connected with notices of particular places will be found duly inserted under section XVII (Topographical notes). In Vol. I, No. 5 the text refers to canal-making in general.

On one point only can the collection of passages included under the general heading of Physical Geography claim to be complete. When comparing and sorting the materials for this work I took particular care not to exclude or omit any text in which a geographical name

was mentioned even incidentally, since in all such researches the chief interest, as it appeared to me, attached to the question whether these acute observations on the various local characteristics of mountains, rivers or seas, had been made by Leonardo himself, and on the spot. It is self-evident that the few general and somewhat superficial observations on the Rhine and the Danube, on England and Flanders, must have been obtained from maps or from some informants, and in the case of Flanders Leonardo himself acknowledges this (see No. 1008). But that most of the other and more exact observations were made, on the spot, by Leonardo himself, may be safely assumed from their method and the style in which he writes of them; and we should bear it in mind that in all investigations, of whatever kind, experience is always spoken of as the only basis on which he relies. Incidentally, as in No. 984, he thinks it necessary to allude to the total absence of all recorded observations.

I.

INTRODUCTION.

Schemes for the arrangement of the materials (919-928).

919.

These books contain in the beginning: Of the nature of water itself

in its motions; the others treat of the effects of its currents, which change the world in its centre and its shape.

920.

DIVISIONS OF THE BOOK.

Book 1 of water in itself.

Book 2 of the sea.

Book 3 of subterranean rivers.

Book 4 of rivers.

Book 5 of the nature of the abyss.

Book 6 of the obstacles.

Book 7 of gravels.

Book 8 of the surface of water.

Book 9 of the things placed therein.

Book 10 of the repairing of rivers.

Book 11 of conduits.

Book 12 of canals.

Book 13 of machines turned by water.

Book 14 of raising water.

Book 15 of matters worn away by water.

921.

First you shall make a book treating of places occupied by fresh waters, and the second by salt waters, and the third, how by the disappearance of these, our parts of the world were made lighter and in consequence more remote from the centre of the world.

922.

First write of all water, in each of its motions; then describe all its bottoms and their various materials, always referring to the propositions concerning the said waters; and let the order be good, for otherwise the work will be confused.

Describe all the forms taken by water from its greatest to its

smallest wave, and their causes.

923.

Book 9, of accidental risings of water.

924.

THE ORDER OF THE BOOK.

Place at the beginning what a river can effect.

925.

A book of driving back armies by the force of a flood made by releasing waters.

A book showing how the waters safely bring down timber cut in the mountains.

A book of boats driven against the impetus of rivers.

A book of raising large bridges higher. Simply by the swelling of the waters.

A book of guarding against the impetus of rivers so that towns may

not be damaged by them.

926.

A book of the ordering of rivers so as to preserve their banks.

A book of the mountains, which would stand forth and become land, if our hemisphere were to be uncovered by the water.

A book of the earth carried down by the waters to fill up the great abyss of the seas.

A book of the ways in which a tempest may of itself clear out filled up sea-ports.

A book of the shores of rivers and of their permanency.

A book of how to deal with rivers, so that they may keep their bottom scoured by their own flow near the cities they pass.

A book of how to make or to repair the foundations for bridges over the rivers.

A book of the repairs which ought to be made in walls and banks of rivers where the water strikes them.

A book of the formation of hills of sand or gravel at great depths in water.

927.

Water gives the first impetus to its motion.

A book of the levelling of waters by various means,

A book of diverting rivers from places where they do mischief.

A book of guiding rivers which occupy too much ground.

A book of parting rivers into several branches and making them fordable.

A book of the waters which with various currents pass through seas.

A book of deepening the beds of rivers by means of currents of water.

A book of controlling rivers so that the little beginnings of mischief, caused by them, may not increase.

A book of the various movements of waters passing through channels of different forms.

A book of preventing small rivers from diverting the larger one into which their waters run.

A book of the lowest level which can be found in the current of the surface of rivers.

A book of the origin of rivers which flow from the high tops of mountains.

A book of the various motions of waters in their rivers.

928.

[1] Of inequality in the concavity of a ship. [Footnote 1: The first line of this passage was added subsequently, evidently as a correction of the following line.]

[1] A book of the inequality in the curve of the sides of ships.

[1] A book of the inequality in the position of the tiller.

[1] A book of the inequality in the keel of ships.

[2] A book of various forms of apertures by which water flows out.

[3] A book of water contained in vessels with air, and of its movements.

[4] A book of the motion of water through a syphon. [Footnote 7: cicognole, see No. 966, 11, 17.]

[5] A book of the meetings and union of waters coming from different directions.

[6] A book of the various forms of the banks through which rivers pass.

[7] A book of the various forms of shoals formed under the sluices of rivers.

[8] A book of the windings and meanderings of the currents of rivers.

[9] A book of the various places whence the waters of rivers are derived.

[10] A book of the configuration of the shores of rivers and of their permanency.

[11] A book of the perpendicular fall of water on various objects.

[12] Abook of the course of water when it is impeded in various places.

[12] A book of the various forms of the obstacles which impede the course of waters.

[13] A book of the concavity and globosity formed round various objects at the bottom.

[14] Abook of conducting navigable canals above or beneath the rivers which intersect them.

[15] A book of the soils which absorb water in canals and of repairing them.

[16] Abook of creating currents for rivers, which quit their beds, [and] for rivers choked with soil.

General introduction.

929.

THE BEGINNING OF THE TREATISE ON WATER.

By the ancients man has been called the world in miniature; and certainly this name is well bestowed, because, inasmuch as man is

composed of earth, water, air and fire, his body resembles that of the earth; and as man has in him bones the supports and framework of his flesh, the world has its rocks the supports of the earth; as man has in him a pool of blood in which the lungs rise and fall in breathing, so the body of the earth has its ocean tide which likewise rises and falls every six hours, as if the world breathed; as in that pool of blood veins have their origin, which ramify all over the human body, so likewise the ocean sea fills the body of the earth with infinite springs of water. The body of the earth lacks sinews and this is, because the sinews are made expressely for movements and, the world being perpetually stable, no movement takes place, and no movement taking place, muscles are not necessary. --But in all other points they are much alike.

I.

OF THE NATURE OF WATER.

The arrangement of Book I.

930.

THE ORDER OF THE FIRST BOOK ON WATER.

Define first what is meant by height and depth; also how the elements are situated one inside another. Then, what is meant by

solid weight and by liquid weight; but first what weight and lightness are in themselves. Then describe why water moves, and why its motion ceases; then why it becomes slower or more rapid; besides this, how it always falls, being in contact with the air but lower than the air. And how water rises in the air by means of the heat of the sun, and then falls again in rain; again, why water springs forth from the tops of mountains; and if the water of any spring higher than the ocean can pour forth water higher than the surface of that ocean. And how all the water that returns to the ocean is higher than the sphere of waters. And how the waters of the equatorial seas are higher than the waters of the North, and higher beneath the body of the sun than in any part of the equatorial circle; for experiment shows that under the heat of a burning brand the water near the brand boils, and the water surrounding this ebullition always sinks with a circular eddy. And how the waters of the North are lower than the other seas, and more so as they become colder, until they are converted into ice.

Definitions (931. 932).

931.

OF WHAT IS WATER.

Among the four elements water is the second both in weight and in instability.

932.

THE BEGINNING OF THE BOOK ON WATER.

Sea is the name given to that water which is wide and deep, in which the waters have not much motion.

[Footnote: Only the beginning of this passage is here given, the remainder consists of definitions which have no direct bearing on the subject.]

Of the surface of the water in relation to the globe (933-936).

933.

The centres of the sphere of water are two, one universal and common to all water, the other particular. The universal one is that which is common to all waters not in motion, which exist in great quantities. As canals, ditches, ponds, fountains, wells, dead rivers, lakes, stagnant pools and seas, which, although they are at various levels, have each in itself the limits of their superficies equally distant from the centre of the earth, such as lakes placed at the tops of high mountains; as the lake near Pietra Pana and the lake of the Sybil near Norcia; and all the lakes that give rise to great rivers, as the Ticino from Lago Maggiore, the Adda from the

lake of Como, the Mincio from the lake of Garda, the Rhine from the lakes of Constance and of Chur, and from the lake of Lucerne, like the Tigris which passes through Asia Minor carrying with it the waters of three lakes, one above the other at different heights of which the highest is Munace, the middle one Pallas, and the lowest Triton; the Nile again flows from three very high lakes in Ethiopia.

[Footnote 5: Pietra Pana, a mountain near Florence. If for Norcia, we may read Norchia, the remains of the Etruscan city near Viterbo, there can be no doubt that by 'Lago della Sibilla'--a name not known elsewhere, so far as I can learn--Leonardo meant Lago di Vico (Lacus Ciminus, Aen. 7).]

934.

OF THE CENTRE OF THE OCEAN.

The centre of the sphere of waters is the true centre of the globe of our world, which is composed of water and earth, having the shape of a sphere. But, if you want to find the centre of the element of the earth, this is placed at a point equidistant from the surface of the ocean, and not equidistant from the surface of the earth; for it is evident that this globe of earth has nowhere any perfect rotundity, excepting in places where the sea is, or marshes or other still waters. And every part of the earth that rises above the water is farther from the centre.

935.

OF THE SEA WHICH CHANGES THE WEIGHT OF THE EARTH.

The shells, oysters, and other similar animals, which originate in sea-mud, bear witness to the changes of the earth round the centre of our elements. This is proved thus: Great rivers always run turbid, being coloured by the earth, which is stirred by the friction of their waters at the bottom and on their shores; and this wearing disturbs the face of the strata made by the layers of shells, which lie on the surface of the marine mud, and which were produced there when the salt waters covered them; and these strata were covered over again from time to time, with mud of various thickness, or carried down to the sea by the rivers and floods of more or less extent; and thus these layers of mud became raised to such a height, that they came up from the bottom to the air. At the present time these bottoms are so high that they form hills or high mountains, and the rivers, which wear away the sides of these mountains, uncover the strata of these shells, and thus the softened side of the earth continually rises and the antipodes sink closer to the centre of the earth, and the ancient bottoms of the seas have become mountain ridges.

936.

Let the earth make whatever changes it may in its weight, the surface of the sphere of waters can never vary in its equal distance from the centre of the world.

Of the proportion of the mass of water to that of the earth (937. 938).

937.

WHETHER THE EARTH IS LESS THAN THE WATER.

Some assert that it is true that the earth, which is not covered by water is much less than that covered by water. But considering the size of 7000 miles in diameter which is that of this earth, we may conclude the water to be of small depth.

938.

OF THE EARTH.

The great elevations of the peaks of the mountains above the sphere of the water may have resulted from this that: a very large portion of the earth which was filled with water that is to say the vast cavern inside the earth may have fallen in a vast part of its vault towards the centre of the earth, being pierced by means of the course of the springs which continually wear away the place where

they pass.

Sinking in of countries like the Dead Sea in Syria, that is Sodom and Gomorrah.

It is of necessity that there should be more water than land, and the visible portion of the sea does not show this; so that there must be a great deal of water inside the earth, besides that which rises into the lower air and which flows through rivers and springs.

[Footnote: The small sketch below on the left, is placed in the original close to the text referring to the Dead Sea.]

The theory of Plato.

939.

THE FIGURES OF THE ELEMENTS.

Of the figures of the elements; and first as against those who deny the opinions of Plato, and who say that if the elements include one another in the forms attributed to them by Plato they would cause a vacuum one within the other. I say it is not true, and I here prove it, but first I desire to propound some conclusions. It is not necessary that the elements which include each other should be of corresponding magnitude in all the parts, of that which includes and

of that which is included. We see that the sphere of the waters varies conspicuously in mass from the surface to the bottom, and that, far from investing the earth when that was in the form of a cube that is of 8 angles as Plato will have it, that it invests the earth which has innumerable angles of rock covered by the water and various prominences and concavities, and yet no vacuum is generated between the earth and water; again, the air invests the sphere of waters together with the mountains and valleys, which rise above that sphere, and no vacuum remains between the earth and the air, so that any one who says a vacuum is generated, speaks foolishly.

But to Plato I would reply that the surface of the figures which according to him the elements would have, could not exist.

That the flow of rivers proves the slope of the land.

940.

PROVES HOW THE EARTH IS NOT GLOBULAR AND NOT BEING GLOBULAR CANNOT

HAVE A COMMON CENTRE.

We see the Nile come from Southern regions and traverse various provinces, running towards the North for a distance of 3000 miles and flow into the Mediterranean by the shores of Egypt; and if we will give to this a fall of ten braccia a mile, as is usually

allowed to the course of rivers in general, we shall find that the Nile must have its mouth ten miles lower than its source. Again, we see the Rhine, the Rhone and the Danube starting from the German parts, almost the centre of Europe, and having a course one to the East, the other to the North, and the last to Southern seas. And if you consider all this you will see that the plains of Europe in their aggregate are much higher than the high peaks of the maritime mountains; think then how much their tops must be above the sea shores.

Theory of the elevation of water within the mountains.

941.

OF THE HEAT THAT IS IN THE WORLD.

Where there is life there is heat, and where vital heat is, there is movement of vapour. This is proved, inasmuch as we see that the element of fire by its heat always draws to itself damp vapours and thick mists as opaque clouds, which it raises from seas as well as lakes and rivers and damp valleys; and these being drawn by degrees as far as the cold region, the first portion stops, because heat and moisture cannot exist with cold and dryness; and where the first portion stops the rest settle, and thus one portion after another being added, thick and dark clouds are formed. They are often wafted about and borne by the winds from one region to another, where by

their density they become so heavy that they fall in thick rain; and if the heat of the sun is added to the power of the element of fire, the clouds are drawn up higher still and find a greater degree of cold, in which they form ice and fall in storms of hail. Now the same heat which holds up so great a weight of water as is seen to rain from the clouds, draws them from below upwards, from the foot of the mountains, and leads and holds them within the summits of the mountains, and these, finding some fissure, issue continuously and cause rivers.

The relative height of the surface of the sea to that of the land (942-945).

942.

OF THE SEA, WHICH TO MANY FOOLS APPEARS TO BE HIGHER THAN THE EARTH

WHICH FORMS ITS SHORE.

b d is a plain through which a river flows to the sea; this plain ends at the sea, and since in fact the dry land that is uncovered is not perfectly level--for, if it were, the river would have no motion--as the river does move, this place is a slope rather than a plain; hence this plain d b so ends where the sphere of water begins that if it were extended in a continuous line to b a it would go down beneath the sea, whence it follows that the sea a c

b looks higher than the dry land.

Obviously no portions of dry land left uncovered by water can ever be lower than the surface of the watery sphere.

943.

OF CERTAIN PERSONS WHO SAY THE WATERS WERE HIGHER THAN THE DRY LAND.

Certainly I wonder not a little at the common opinion which is contrary to truth, but held by the universal consent of the judgment of men. And this is that all are agreed that the surface of the sea is higher than the highest peaks of the mountains; and they allege many vain and childish reasons, against which I will allege only one simple and short reason; We see plainly that if we could remove the shores of the sea, it would invest the whole earth and make it a perfect sphere. Now, consider how much earth would be carried away to enable the waves of the sea to cover the world; therefore that which would be carried away must be higher than the sea-shore.

944.

THE OPINION OF SOME PERSONS WHO SAY THAT THE WATER OF SOME SEAS IS

HIGHER THAN THE HIGHEST SUMMITS OF MOUNTAINS; AND NEVERTHELESS THE

WATER WAS FORCED UP TO THESE SUMMITS.

Water would not move from place to place if it were not that it seeks the lowest level and by a natural consequence it never can return to a height like that of the place where it first on issuing from the mountain came to light. And that portion of the sea which, in your vain imagining, you say was so high that it flowed over the summits of the high mountains, for so many centuries would be swallowed up and poured out again through the issue from these mountains. You can well imagine that all the time that Tigris and Euphrates

945.

have flowed from the summits of the mountains of Armenia, it must be believed that all the water of the ocean has passed very many times through these mouths. And do you not believe that the Nile must have sent more water into the sea than at present exists of all the element of water? Undoubtedly, yes. And if all this water had fallen away from this body of the earth, this terrestrial machine would long since have been without water. Whence we may conclude that the water goes from the rivers to the sea, and from the sea to the rivers, thus constantly circulating and returning, and that all the sea and the rivers have passed through the mouth of the Nile an infinite number of times [Footnote: Moti Armeni, Ermini in the original, in M. RAVAISSON'S transcript "monti ernini [le loro

ruine?]". He renders this "Le Tigre et l'Euphrate se sont deverses par les sommets des montagnes [avec leurs eaux destructives?] on pent cro're" &c. Leonardo always writes Ermini, Erminia, for Armeni, Armenia (Arabic: Irminiah). M. RAVAISSON also deviates from the original in his translation of the following passage: "Or tu ne crois pas que le Nil ait mis plus d'eau dans la mer qu'il n'y en a a present dans tout l'element de l'eau. Il est certain que si cette eau etait tombee" &c.]

II.

ON THE OCEAN.

Refutation of Pliny's theory as to the saltness of the sea (946. 947).

946.

WHY WATER IS SALT.

Pliny says in his second book, chapter 103, that the water of the sea is salt because the heat of the sun dries up the moisture and drinks it up; and this gives to the wide stretching sea the savour of salt. But this cannot be admitted, because if the saltness of the sea were caused by the heat of the sun, there can be no doubt that lakes, pools and marshes would be so much the more salt, as their

waters have less motion and are of less depth; but experience shows us, on the contrary, that these lakes have their waters quite free from salt. Again it is stated by Pliny in the same chapter that this saltness might originate, because all the sweet and subtle portions which the heat attracts easily being taken away, the more bitter and coarser part will remain, and thus the water on the surface is fresher than at the bottom [Footnote 22: Compare No. 948.]; but this is contradicted by the same reason given above, which is, that the same thing would happen in marshes and other waters, which are dried up by the heat. Again, it has been said that the saltness of the sea is the sweat of the earth; to this it may be answered that all the springs of water which penetrate through the earth, would then be salt. But the conclusion is, that the saltness of the sea must proceed from the many springs of water which, as they penetrate into the earth, find mines of salt and these they dissolve in part, and carry with them to the ocean and the other seas, whence the clouds, the begetters of rivers, never carry it up. And the sea would be salter in our times than ever it was at any time; and if the adversary were to say that in infinite time the sea would dry up or congeal into salt, to this I answer that this salt is restored to the earth by the setting free of that part of the earth which rises out of the sea with the salt it has acquired, and the rivers return it to the earth under the sea.

[Footnote: See PLINY, Hist. Nat. II, CIII [C]. Itaque Solis ardore siccatur liquor: et hoc esse masculum sidus accepimus, torrens

cuncta sorbensque. (cp. CIV.) Sic mari late patenti saporem incoqui salis, aut quia exhausto inde dulci tenuique, quod facillime trahat vis ignea, omne asperius crassiusque linquatur: ideo summa aequorum aqua dulciorem profundam; hanc esse veriorem causam, quam quod mare terrae sudor sit aeternus: aut quia plurimum ex arido misceatur illi vapore: aut quia terrae natura sicut medicatas aquas inficiat ... (cp. CV): altissimum mare XV. stadiorum Fabianus tradit. Alii n Ponto coadverso Coraxorum gentis (vocant B Ponti) trecentis fere a continenti stadiis immensam altitudinem maris tradunt, vadis nunquam repertis. (cp. CVI [CIII]) Mirabilius id faciunt aquae dulces, juxta mare, ut fistulis emicantes. Nam nec aquarum natura a miraculis cessat. Dulces mari invehuntur, leviores haud dubie. Ideo et marinae, quarum natura gravior, magis invecta sustinent. Quaedam vero et dulces inter se supermeant alias.]

947.

For the third and last reason we will say that salt is in all created things; and this we learn from water passed over the ashes and cinders of burnt things; and the urine of every animal, and the superfluities issuing from their bodies, and the earth into which all things are converted by corruption.

But,--to put it better,--given that the world is everlasting, it must be admitted that its population will also be eternal; hence the human species has eternally been and would be consumers of salt; and

if all the mass of the earth were to be turned into salt, it would not suffice for all human food [Footnote 27: That is, on the supposition that salt, once consumed, disappears for ever.]; whence we are forced to admit, either that the species of salt must be everlasting like the world, or that it dies and is born again like the men who devour it. But as experience teaches us that it does not die, as is evident by fire, which does not consume it, and by water which becomes salt in proportion to the quantity dissolved in it,--and when it is evaporated the salt always remains in the original quantity--it must pass through the bodies of men either in the urine or the sweat or other excretions where it is found again; and as much salt is thus got rid of as is carried every year into towns; therefore salt is dug in places where there is urine.-- Sea hogs and sea winds are salt.

We will say that the rains which penetrate the earth are what is under the foundations of cities with their inhabitants, and are what restore through the internal passages of the earth the saltness taken from the sea; and that the change in the place of the sea, which has been over all the mountains, caused it to be left there in the mines found in those mountains, &c.

The characteristics of sea water (948. 949).

948.

The waters of the salt sea are fresh at the greatest depths.

949.

THAT THE OCEAN DOES NOT PENETRATE UNDER THE EARTH.

The ocean does not penetrate under the earth, and this we learn from the many and various springs of fresh water which, in many parts of the ocean make their way up from the bottom to the surface. The same thing is farther proved by wells dug beyond the distance of a mile from the said ocean, which fill with fresh water; and this happens because the fresh water is lighter than salt water and consequently more penetrating.

Which weighs most, water when frozen or when not frozen?

FRESH WATER PENETRATES MORE AGAINST SALT WATER THAN SALT WATER AGAINST FRESH WATER.

That fresh water penetrates more against salt water, than salt water against fresh is proved by a thin cloth dry and old, hanging with the two opposite ends equally low in the two different waters, the surfaces of which are at an equal level; and it will then be seen how much higher the fresh water will rise in this piece of linen than the salt; by so much is the fresh lighter than the salt.

On the formation of Gulfs (950. 951).

950.

All inland seas and the gulfs of those seas, are made by rivers which flow into the sea.

951.

HERE THE REASON IS GIVEN OF THE EFFECTS PRODUCED BY THE WATERS IN THE ABOVE MENTIONED PLACE.

All the lakes and all the gulfs of the sea and all inland seas are due to rivers which distribute their waters into them, and from impediments in their downfall into the Mediterranean --which divides Africa from Europe and Europe from Asia by means of the Nile and the Don which pour their waters into it. It is asked what impediment is great enough to stop the course of the waters which do not reach the ocean.

On the encroachments of the sea on the land and vice versa (952-954).

952.

OF WAVES.

A wave of the sea always breaks in front of its base, and that portion of the crest will then be lowest which before was highest.

[Footnote: The page of FRANCESCO DI GIORGIO'S Trattato, on which Leonardo has written this remark, contains some notes on the construction of dams, harbours &c.]

953.

That the shores of the sea constantly acquire more soil towards the middle of the sea; that the rocks and promontories of the sea are constantly being ruined and worn away; that the Mediterranean seas will in time discover their bottom to the air, and all that will be left will be the channel of the greatest river that enters it; and this will run to the ocean and pour its waters into that with those of all the rivers that are its tributaries.

954.

How the river Po, in a short time might dry up the Adriatic sea in the same way as it has dried up a large part of Lombardy.

The ebb and flow of the tide (955-960).

955.

Where there is a larger quantity of water, there is a greater flow and ebb, but the contrary in narrow waters.

Look whether the sea is at its greatest flow when the moon is half way over our hemisphere [on the meridian].

956.

Whether the flow and ebb are caused by the moon or the sun, or are the breathing of this terrestrial machine. That the flow and ebb are different in different countries and seas.

[Footnote: 1. Allusion may here be made to the mythological explanation of the ebb and flow given in the Edda. Utgardloki says to Thor (Gylfaginning 48): "When thou wert drinking out of the horn, and it seemed to thee that it was slow in emptying a wonder befell, which I should not have believed possible: the other end of the horn lay in the sea, which thou sawest not; but when thou shalt go to the sea, thou shalt see how much thou hast drunk out of it. And that men now call the ebb tide."

Several passages in various manuscripts treat of the ebb and flow. In collecting them I have been guided by the rule only to transcribe those which named some particular spot.]

957.

Book 9 of the meeting of rivers and their flow and ebb. The cause is the same in the sea, where it is caused by the straits of Gibraltar. And again it is caused by whirlpools.

958.

OF THE FLOW AND EBB.

All seas have their flow and ebb in the same period, but they seem to vary because the days do not begin at the same time throughout the universe; in such wise as that when it is midday in our hemisphere, it is midnight in the opposite hemisphere; and at the Eastern boundary of the two hemispheres the night begins which follows on the day, and at the Western boundary of these hemispheres begins the day, which follows the night from the opposite side. Hence it is to be inferred that the above mentioned swelling and diminution in the height of the seas, although they take place in one and the same space of time, are seen to vary from the above mentioned causes. The waters are then withdrawn into the fissures which start from the depths of the sea and which ramify inside the body of the earth, corresponding to the sources of rivers, which are constantly taking from the bottom of the sea the water which has flowed into it. A sea of water is incessantly being drawn off from

the surface of the sea. And if you should think that the moon, rising at the Eastern end of the Mediterranean sea must there begin to attract to herself the waters of the sea, it would follow that we must at once see the effect of it at the Eastern end of that sea. Again, as the Mediterranean sea is about the eighth part of the circumference of the aqueous sphere, being 3000 miles long, while the flow and ebb only occur 4 times in 24 hours, these results would not agree with the time of 24 hours, unless this Mediterranean sea were six thousand miles in length; because if such a superabundance of water had to pass through the straits of Gibraltar in running behind the moon, the rush of the water through that strait would be so great, and would rise to such a height, that beyond the straits it would for many miles rush so violently into the ocean as to cause floods and tremendous seething, so that it would be impossible to pass through. This agitated ocean would afterwards return the waters it had received with equal fury to the place they had come from, so that no one ever could pass through those straits. Now experience shows that at every hour they are passed in safety, but when the wind sets in the same direction as the current, the strong ebb increases [Footnote 23: In attempting to get out of the Mediterranean, vessels are sometimes detained for a considerable time; not merely by the causes mentioned by Leonardo but by the constant current flowing eastwards through the middle of the straits of Gibraltar.]. The sea does not raise the water that has issued from the straits, but it checks them and this retards the tide; then it makes up with furious haste for the time it has lost until the

end of the ebb movement.

959.

That the flow and ebb are not general; for on the shore at Genoa there is none, at Venice two braccia, between England and Flanders 18 braccia. That in the straits of Sicily the current is very strong because all the waters from the rivers that flow into the Adriatic pass there.

[Footnote: A few more recent data may be given here to facilitate comparison. In the Adriatic the tide rises 2 and 1/2 feet, at Terracina 1 1/4. In the English channel between Calais and Kent it rises from 18 to 20 feet. In the straits of Messina it rises no more than 2 1/2 feet, and that only in stormy weather, but the current is all the stronger. When Leonardo accounts for this by the southward flow of all the Italian rivers along the coasts, the explanation is at least based on a correct observation; namely that a steady current flows southwards along the coast of Calabria and another northwards, along the shores of Sicily; he seems to infer, from the direction of the fust, that the tide in the Adriatic is caused by it.]

960.

In the West, near to Flanders, the sea rises and decreases every 6

hours about 20 braccia, and 22 when the moon is in its favour; but 20 braccia is the general rule, and this rule, as it is evident, cannot have the moon for its cause. This variation in the increase and decrease of the sea every 6 hours may arise from the damming up of the waters, which are poured into the Mediterranean by the quantity of rivers from Africa, Asia and Europe, which flow into that sea, and the waters which are given to it by those rivers; it pours them to the ocean through the straits of Gibraltar, between Abila and Calpe [Footnote 5: Abila, Lat. Abyla, Gr. , now Sierra Ximiera near Ceuta; Calpe, Lat. Calpe. Gr., now Gibraltar. Leonardo here uses the ancient names of the rocks, which were known as the Pillars of Hercules.]. That ocean extends to the island of England and others farther North, and it becomes dammed up and kept high in various gulfs. These, being seas of which the surface is remote from the centre of the earth, have acquired a weight, which as it is greater than the force of the incoming waters which cause it, gives this water an impetus in the contrary direction to that in which it came and it is borne back to meet the waters coming out of the straits; and this it does most against the straits of Gibraltar; these, so long as this goes on, remain dammed up and all the water which is poured out meanwhile by the aforementioned rivers, is pent up [in the Mediterranean]; and this might be assigned as the cause of its flow and ebb, as is shown in the 21st of the 4th of my theory.

III.

SUBTERRANEAN WATER COURSES.

Theory of the circulation of the waters (961. 962).

961.

Very large rivers flow under ground.

962.

This is meant to represent the earth cut through in the middle, showing the depths of the sea and of the earth; the waters start from the bottom of the seas, and ramifying through the earth they rise to the summits of the mountains, flowing back by the rivers and returning to the sea.

Observations in support of the hypothesis (963-969).

963.

The waters circulate with constant motion from the utmost depths of the sea to the highest summits of the mountains, not obeying the nature of heavy matter; and in this case it acts as does the blood of animals which is always moving from the sea of the heart and flows to the top of their heads; and here it is that veins burst--as

one may see when a vein bursts in the nose, that all the blood from below rises to the level of the burst vein. When the water rushes out of a burst vein in the earth it obeys the nature of other things heavier than the air, whence it always seeks the lowest places. [7] These waters traverse the body of the earth with infinite ramifications.

[Footnote: The greater part of this passage has been given as No. 849 in the section on Anatomy.]

964.

The same cause which stirs the humours in every species of animal body and by which every injury is repaired, also moves the waters from the utmost depth of the sea to the greatest heights.

965.

It is the property of water that it constitutes the vital human of this arid earth; and the cause which moves it through its ramified veins, against the natural course of heavy matters, is the same property which moves the humours in every species of animal body. But that which crowns our wonder in contemplating it is, that it rises from the utmost depths of the sea to the highest tops of the mountains, and flowing from the opened veins returns to the low seas; then once more, and with extreme swiftness, it mounts again

and returns by the same descent, thus rising from the inside to the outside, and going round from the lowest to the highest, from whence it rushes down in a natural course. Thus by these two movements combined in a constant circulation, it travels through the veins of the earth.

966.

WHETHER WATER RISES FROM THE SEA TO THE TOPS OF MOUNTAINS.

The water of the ocean cannot make its way from the bases to the tops of the mountains which bound it, but only so much rises as the dryness of the mountain attracts. And if, on the contrary, the rain, which penetrates from the summit of the mountain to the base, which is the boundary of the sea, descends and softens the slope opposite to the said mountain and constantly draws the water, like a syphon [Footnote 11: Cicognola, Syphon. See Vol. I, Pl. XXIV, No. 1.] which pours through its longest side, it must be this which draws up the water of the sea; thus if s n were the surface of the sea, and the rain descends from the top of the mountain a to n on one side, and on the other sides it descends from a to m, without a doubt this would occur after the manner of distilling through felt, or as happens through the tubes called syphons [Footnote 17: Cicognola, Syphon. See Vol. I, Pl. XXIV, No. 1.]. And at all times the water which has softened the mountain, by the great rain which runs down the two opposite sides, would constantly attract the rain a n, on

its longest side together with the water from the sea, if that side of the mountain a m were longer than the other a n; but this cannot be, because no part of the earth which is not submerged by the ocean can be lower than that ocean.

967.

OF SPRINGS OF WATER ON THE TOPS OF MOUNTAINS.

It is quite evident that the whole surface of the ocean--when there is no storm--is at an equal distance from the centre of the earth, and that the tops of the mountains are farther from this centre in proportion as they rise above the surface of that sea; therefore if the body of the earth were not like that of man, it would be impossible that the waters of the sea--being so much lower than the mountains--could by their nature rise up to the summits of these mountains. Hence it is to be believed that the same cause which keeps the blood at the top of the head in man keeps the water at the summits of the mountains.

[Footnote: This conception of the rising of the blood, which has given rise to the comparison, was recognised as erroneous by Leonardo himself at a later period. It must be remembered that the MS. A, from which these passages are taken, was written about twenty years earlier than the MS. Leic. (Nos. 963 and 849) and twenty-five years before the MS. W. An. IV.

There is, in the original a sketch with No. 968 which is not reproduced. It represents a hill of the same shape as that shown at No. 982. There are veins, or branched streams, on the side of the hill, like those on the skull Pl. CVIII, No. 4]

968.

IN CONFIRMATION OF WHY THE WATER GOES TO THE TOPS OF MOUNTAINS.

I say that just as the natural heat of the blood in the veins keeps it in the head of man,--for when the man is dead the cold blood sinks to the lower parts--and when the sun is hot on the head of a man the blood increases and rises so much, with other humours, that by pressure in the veins pains in the head are often caused; in the same way veins ramify through the body of the earth, and by the natural heat which is distributed throughout the containing body, the water is raised through the veins to the tops of mountains. And this water, which passes through a closed conduit inside the body of the mountain like a dead thing, cannot come forth from its low place unless it is warmed by the vital heat of the spring time. Again, the heat of the element of fire and, by day, the heat of the sun, have power to draw forth the moisture of the low parts of the mountains and to draw them up, in the same way as it draws the clouds and collects their moisture from the bed of the sea.

969.

That many springs of salt water are found at great distances from the sea; this might happen because such springs pass through some mine of salt, like that in Hungary where salt is hewn out of vast caverns, just as stone is hewn.

[Footnote: The great mine of Wieliczka in Galicia, out of which a million cwt. of rock-salt are annually dug out, extends for 3000 metres from West to East, and 1150 metres from North to South.]

IV.

OF RIVERS.

On the way in which the sources of rivers are fed.

970.

OF THE ORIGIN OF RIVERS.

The body of the earth, like the bodies of animals, is intersected with ramifications of waters which are all in connection and are constituted to give nutriment and life to the earth and to its creatures. These come from the depth of the sea and, after many revolutions, have to return to it by the rivers created by the

bursting of these springs; and if you chose to say that the rains of the winter or the melting of the snows in summer were the cause of the birth of rivers, I could mention the rivers which originate in the torrid countries of Africa, where it never rains--and still less snows--because the intense heat always melts into air all the clouds which are borne thither by the winds. And if you chose to say that such rivers, as increase in July and August, come from the snows which melt in May and June from the sun's approach to the snows on the mountains of Scythia [Footnote 9: Scythia means here, as in Ancient Geography, the whole of the Northern part of Asia as far as India.], and that such meltings come down into certain valleys and form lakes, into which they enter by springs and subterranean caves to issue forth again at the sources of the Nile, this is false; because Scythia is lower than the sources of the Nile, and, besides, Scythia is only 400 miles from the Black sea and the sources of the Nile are 3000 miles distant from the sea of Egypt into which its waters flow.

The tide in estuaries.

971.

Book 9, of the meeting of rivers and of their ebb and flow. The cause is the same in the sea, where it is caused by the straits of Gibraltar; and again it is caused by whirlpools.

[3] If two rivers meet together to form a straight line, and then below two right angles take their course together, the flow and ebb will happen now in one river and now in the other above their confluence, and principally if the outlet for their united volume is no swifter than when they were separate. Here occur 4 instances.

[Footnote: The first two lines of this passage have already been given as No. 957. In the margin, near line 3 of this passage, the text given as No. 919 is written.]

On the alterations, caused in the courses of rivers by their confluence (972-974).

972.

When a smaller river pours its waters into a larger one, and that larger one flows from the opposite direction, the course of the smaller river will bend up against the approach of the larger river; and this happens because, when the larger river fills up all its bed with water, it makes an eddy in front of the mouth of the other river, and so carries the water poured in by the smaller river with its own. When the smaller river pours its waters into the larger one, which runs across the current at the mouth of the smaller river, its waters will bend with the downward movement of the larger river. [Footnote: In the original sketches the word Arno is written at the spot here marked A, at R. Rifredi, and at M.

Mugnone.]

973.

When the fulness of rivers is diminished, then the acute angles formed at the junction of their branches become shorter at the sides and wider at the point; like the current a n and the current d n, which unite in n when the river is at its greatest fulness. I say, that when it is in this condition if, before the fullest time, d n was lower than a n, at the time of fulness d n will be full of sand and mud. When the water d n falls, it will carry away the mud and remain with a lower bottom, and the channel a n finding itself the higher, will fling its waters into the lower, d n, and will wash away all the point of the sand-spit b n c, and thus the angle a c d will remain larger than the angle a n d and the sides shorter, as I said before.

[Footnote: Above the first sketch we find, in the original, this note: "Sopra il pote rubaconte alla torricella"; and by the second, which represents a pier of a bridge, "Sotto l'ospedal del ceppo."]

974.

WATER.

OF THE MOVEMENT OF A SUDDEN RUSH MADE BY A RIVER IN ITS BED PREVIOUSLY DRY.

In proportion as the current of the water given forth by the draining of the lake is slow or rapid in the dry river bed, so will this river be wider or narrower, or shallower or deeper in one place than another, according to this proposition: the flow and ebb of the sea which enters the Mediterranean from the ocean, and of the rivers which meet and struggle with it, will raise their waters more or less in proportion as the sea is wider or narrower.

[Footnote: In the margin is a sketch of a river which winds so as to form islands.]

Whirlpools.

975.

Whirlpools, that is to say caverns; that is to say places left by precipitated waters.

On the alterations in the channels of rivers.

976.

OF THE VIBRATION OF THE EARTH.

The subterranean channels of waters, like those which exist between the air and the earth, are those which unceasingly wear away and deepen the beds of their currents.

The origin of the sand in rivers (977. 978).

977.

A river that flows from mountains deposits a great quantity of large stones in its bed, which still have some of their angles and sides, and in the course of its flow it carries down smaller stones with the angles more worn; that is to say the large stones become smaller. And farther on it deposits coarse gravel and then smaller, and as it proceeds this becomes coarse sand and then finer, and going on thus the water, turbid with sand and gravel, joins the sea; and the sand settles on the sea-shores, being cast up by the salt waves; and there results the sand of so fine a nature as to seem almost like water, and it will not stop on the shores of the sea but returns by reason of its lightness, because it was originally formed of rotten leaves and other very light things. Still, being almost--as was said--of the nature of water itself, it afterwards, when the weather is calm, settles and becomes solid at the bottom of the sea, where by its fineness it becomes compact and by its smoothness resists the waves which glide over it; and in this shells are found; and this is white earth, fit for pottery.

978.

All the torrents of water flowing from the mountains to the sea carry with them the stones from the hills to the sea, and by the influx of the sea-water towards the mountains; these stones were thrown back towards the mountains, and as the waters rose and retired, the stones were tossed about by it and in rolling, their angles hit together; then as the parts, which least resisted the blows, were worn off, the stones ceased to be angular and became round in form, as may be seen on the banks of the Elsa. And those remained larger which were less removed from their native spot; and they became smaller, the farther they were carried from that place, so that in the process they were converted into small pebbles and then into sand and at last into mud. After the sea had receded from the mountains the brine left by the sea with other humours of the earth made a concretion of these pebbles and this sand, so that the pebbles were converted into rock and the sand into tufa. And of this we see an example in the Adda where it issues from the mountains of Como and in the Ticino, the Adige and the Oglio coming from the German Alps, and in the Arno at Monte Albano [Footnote 13: At the foot of Monte Albano lies Vinci, the birth place of Leonardo. Opposite, on the other bank of the Arno, is Monte Lupo.], near Monte Lupo and Capraia where the rocks, which are very large, are all of conglomerated pebbles of various kinds and colours.

V.

ON MOUNTAINS.

The formation of mountains (979-983).

979.

Mountains are made by the currents of rivers.

Mountains are destroyed by the currents of rivers.

[Footnote: Compare 789.]

980.

That the Northern bases of some Alps are not yet petrified. And this is plainly to be seen where the rivers, which cut through them, flow towards the North; where they cut through the strata in the living stone in the higher parts of the mountains; and, where they join the plains, these strata are all of potter's clay; as is to be seen in the valley of Lamona where the river Lamona, as it issues from the Appenines, does these things on its banks.

That the rivers have all cut and divided the mountains of the great Alps one from the other. This is visible in the order of the