

Another lays his hands on the table and looks fixedly. Another puffs out his cheeks, his mouth full. Another leans forward to see the speaker, shading his eyes with his hand. Another draws back behind him who is leaning forward and sees the speaker between the wall and the man who is leaning forward.

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III

THOUGHTS ON SCIENCE

\* \*

\*

[Sidenote: Necessity of Experience in Science]

There is no human experience that can be termed true science unless it can be mathematically demonstrated. And if thou sayest that the sciences which begin and end in the mind are true, this cannot be conceded, but must be denied for many reasons, and firstly because in such mental discourses experience is eliminated, and without experience there can be no certainty.

[Sidenote: Theory and Practice]

2.

You must first propound the theory and then explain the practice.

3.

Let no man who is not a mathematician read the principles of my work.

4.

In the course of scientific exposition the demonstration of a general rule derived from a previous conclusion is not to be censured.

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[Sidenote: Certainty of Mathematics]

5.

He who blames the supreme certainty of mathematics feeds on confusion and will never be able to silence the contradictions or sophistical

sciences which lead to an everlasting clamour.

[Sidenote: Of Science]

6.

There is no certainty [in science] where one of the mathematical sciences cannot be applied, or in those [sciences] which are not in harmony with mathematics.

[Sidenote: From Leonardo's Dictionary]

7.

Syllogism: to speak doubtfully.

Sophism: to speak confusedly; falsehood for truth.

Theory: knowledge without practice.

[Sidenote: Definition of Science]

8.

Science is that discourse of the mind which derives its origin from ultimate principles beyond which nothing in nature can be found which forms a part of that science: as in the continued quantity, that is to say, the science of geometry, which, starting from the surfaces of bodies, has its origin in the line, which is the end of the superficies; and we are not satisfied by this, because we know that the line terminates in the point, and the point is that which is the least of things. Therefore the point is the first principle of geometry, and nothing else can exist either {143} in nature or in the human mind from which the point can issue. Because if you say that the contact between a surface and the extreme point of an iron instrument is the creation of the point, it is not true; but let us say that this point of contact is a superficies which surrounds its centre, and in the centre the point dwells. And such a point is not a part of the substance of the superficies, neither it nor all the points of the universe can, even if combined,--it being granted that they could be combined,--compose any part of a superficies. And granted, as you imagined, a whole composed of a thousand points, if we divide any part of this quantity of a thousand, we can very well say that this part shall equal its whole; and this we can prove by zero, or naught, that is, the tenth figure of arithmetic, which is represented by a cipher as being nothing, and placed after unity it will signify 10, and if two ciphers are placed after unity it will signify 100, and thus the number will go on increasing by ten to infinity whenever a cipher is added, and the cipher in itself is worth nothing more than naught, and all the naughts in the universe are equal to one naught alone, in regard to their substance and value.

[Sidenote: True Science based on the Testimony of the Senses]

9.

Knowledge which is the issue of experience is termed mechanical; that which is born and ends {144} in the mind is termed scientific; that which issues from science and ends in manual work is termed semi-mechanical. But I consider vain and full of error that science which is not the offspring of experience, mother of all certitude, and which does not result in established experience, that is to say, whose origin, middle and end do not pass through any of the five senses. And if we doubt of everything we perceive by the senses, should we not doubt much more of what is contrary to the senses, such as the existence of God and of the soul, and similar matters constantly under dispute and contention?

And it is truly the case that where reason is lacking it is supplemented by noise, which never happens in matters of certainty. On account of this we will say that where there is noise there is no true science, because truth has one end only, which, when it is made known, eternally silences controversy, and should controversy come to life again, it is lying and confused knowledge which is reborn, and not certainty. But true science is that which has penetrated into the senses through experience and silenced the tongue of the disputers, and which does not feed those who investigate it with dreams, but proceeds

from the basis of primary truths and established principles successively and by true sequence to the end; as, for instance, what comes under the heading of elementary mathematics, {145} that is, numeration and measurement, termed arithmetic and geometry, which treat with the highest truth of the discontinued and continued quantity. Here there will be no dispute as to whether twice three make more or less than six, nor whether two angles of a triangle are less than two right angles, but eternal silence shall ignore all controversy, and the devotees of the true science will finish their studies in peace, which the lying mental sciences cannot do. And if thou sayest that true and established science of this kind is a species of mechanics, because they can only be completed by the hand, I will say the same of all the arts, such as that which passes through the hand of the sculptor, which is a kind of drawing, a part of painting; and astrology and the other sciences pass through manual operation, but they are mental in the first place, as painting, which first of all exists in the mind of the composer, and cannot attain to fulfilment without manual labour. With regard to painting, its true and scientific principles must be established: what constitutes a shaded body, what constitutes a primary shade, a derivative shade, what constitutes light: that is, darkness, light, colour, size, shape, position, distance, propinquity, motion, rest, which are comprehended by the mind only, and without manual labour. And this is the science of painting which remains in the mind of those who meditate on it, from which {146} issues the work in due time, and is infinitely superior to the aforesaid contemplation or science.

[Sidenote: Mechanics]

10.

Mechanics are the paradise of scientific mathematics, because with them we arrive at the fruits of mathematics.

[Sidenote: Mechanics and Experience]

11.

Experience is indispensable for the making of any instrument.

12.

Proportion is not only to be found in figures and measurements, but also in sound, weight, time and position, and in whatever power which exists.

[Sidenote: Reason and Experience]

13.

The power of the projecting force increases in proportion as the object projected is smaller; the acceleration of the motion increases to infinity proportionately to this diminution. It would follow that an atom would be almost as rapid as the imagination or the eye, which in a moment attains to the height of the stars, and consequently its voyage would be infinite, because the thing which can be infinitely diminished would have an infinite velocity and would travel on an infinite course (because every continuous quantity is divisible to infinity). And this opinion is {147} condemned by reason and consequently by experience.

Thus, you who observe rely not on authors who have merely by their imagination wished to be interpreters between nature and man, but on those alone who have applied their minds not to the hints of nature but to the results of their experience. And you must realize the deceptiveness of experiments; because those which often appear to be one and the same are often different, as is shown here.

[Sidenote: Effects correspond to the Force of their Cause]

14.

A spherical body which possesses a dense and resisting superficies will move as much in the rebound resulting from the resistance of a smooth and solid plane as it would if you threw it freely through the air, if the force applied be equal in both cases.

Oh, admirable justice of thine, thou first mover! thou hast not permitted that any tone should fail to produce its necessary effects, either as regards order or quantity. Seeing that a force impels an object which it overcomes a distance of one hundred arms' length, and if in obeying this law it meets with resistance, thou hast ordained that the force of the shock will cause afresh a further movement, which in its various bounds recuperates the whole sum of the distance it should have travelled. And if you measure the distance {148} accomplished by the aforesaid bounds you will find that they equal the length of distance through which a similar object set in motion by an equal force would travel freely through the air.

15.

Every action must be caused by motion.

16.

Motion is the cause of all life.

[Sidenote: Of Force]

17.

What is force? Force, I say, is a spiritual virtue, an invisible power, which by accidental external violence is caused by motion, and communicated and infused into bodies which are inert by nature, giving them an active life of marvellous power.

18.

What is force? I say that force is a spiritual, incorporate and invisible power, which for a brief duration is produced in bodies that by accidental violence are displaced from their natural state of inertia.

[Sidenote: Origin of Force]

19.

Force arises from dearth or abundance; it is the child of physical motion and the grandchild of spiritual motion, and the mother and origin of gravity. Gravity is confined to the elements of {149} water and earth, and this force is infinite, because infinite worlds could be moved by it if instruments could be made by which the force could be generated. Force, with physical motion, and gravity, with resistance, are the four accidental powers by which all mortal things live and die. Force has its origin in spiritual motion, and this motion, flowing through the limbs of sentient animals, enlarges their muscles, and thus

enlarged the muscles are shrunk in length and contract the tendons with which they are connected, and this is the cause of the strength in human limbs. The quality and quantity of the strength of a man can generate a further force, which will increase in proportion to the duration of the motions produced by them.

[Sidenote: Aspects of Force]

20.

Gravity, force and casual motion together with resistance are the four external powers by which all the visible actions of man live and die.

[Sidenote: Of Inertia]

21.

A motion tends to be continuous; a body set in motion continues to move as long as the impression of the motive power lasts in it.

[Sidenote: Can Man imitate a Bird's Flight?]

22.

The bird is an instrument which operates by mathematical laws, and man can reproduce all {150} the movements of this instrument, but cannot attain to the intensity of its power; and can only succeed in acquiring balance. Thus we will say that such an instrument constructed by man lacks only the soul of the bird, and the soul of man must counterfeit the soul of the bird. The spirit in the frame of the bird doubtless would respond to needs of that frame better than would the spirit of man, whose frame is different, more especially in the almost insensible motions of balance; and since we see the bird make provision for the many sensible varieties of movement, we can conclude by such experience that man can acquire knowledge of the more markedly sensible of these movements, and that he will be able to make ample provision against the destruction of that instrument of which he has made himself the spirit and the guide.

[Sidenote: Of Inertia]

23.

A natural and continuous motion seeks to preserve its course along the line of its starting-point, that is to say, let us call starting-point whatever place in which it varies.

24.

Everything maintains itself by motion. And if it were possible to describe a diameter of air on the sphere of the earth, like to a well, which would extend from one superficies to the other, {151} and if a weighty body were dropped into this well, the body would seek to remain stationary at the centre, but so strong would be the impetus that for many years it would prevent it from so doing.

[Sidenote: Transmission of Motion]

25.

Impetus is a virtue created by motion and communicated by the motive force to the object moved, and this object acquires motion in proportion to the energy of the impetus.

[Sidenote: Matter is Inert]

26.

No lifeless matter moves of itself, but its motion is caused from without.

27.

All elements displaced from their natural place seek to return to it, and more especially fire, water and earth.

28.

All matter universally seeks to maintain itself in its natural state; hence, water in motion seeks to maintain its course according to the force by which it is propelled, and if it meets with opposition it finishes the length of the course it began in a circular and reflex motion.

[Sidenote: Conception of Energy]

29.

Impetus is the impression of motion conveyed by the motive power to the object moved. Every {152} impression tends to permanence or seeks to attain permanence. That every impression seeks after permanence is proved by the impression made by the sun on the eye which regards it, and in the impression of sound made by the hammer which strikes a bell. Every impression seeks after permanence, as is shown in the image of impetus communicated to the object moved.

30.

A weight seeks to fall to the centre of the earth by the most direct way.

[Sidenote: In Praise of the Sun]

31.

If you look at the stars, warding off the rays (as may be done by looking through a small hole made by the extreme point of a fine needle placed so as almost to touch the eye), they will appear so small as to seem as though nothing could be smaller; it is owing to their great distance that they appear so small, for many of them are very many times larger than the star which is the earth with its water. Now reflect what appearance this our star must have from so great a distance, and then consider how many stars might be placed--both in longitude and latitude--between those stars which are sown in the dark space. I can never refrain from blaming many of the ancients who said that the size of the sun was no greater than {153} it appears; among whom was Epicurus. I believe he founded his reasoning on a light placed in our atmosphere equidistant from the centre of the earth, which, to any one looking at it, never appears to diminish in size from whatever distance it is seen.

32.

I shall reserve the reasons of its size and power for later. But I greatly marvel that Socrates should have depreciated such a body, and that he should have said that it resembled an incandescent stone; and he who opposed him as regards this error acted rightly. But I wish I had words to blame those who seek to exalt the worship of men more than that of the sun, since in the universe there is no body of greater magnitude and power to be seen than the sun. And its light illumines all the celestial bodies which are distributed throughout the universe; and the vital spark descends from it, because the heat which is in living beings comes from the soul, and there is no other centre of heat and light in the universe, as will be shown later; and it is certain that those who have elected to worship men as gods--as Jupiter, Saturn, Mars, &c.--have fallen into a profound error, since even if a man were as great as our earth, he would have the appearance of a little star, which appears like a dot in the universe; and moreover these men are mortal, and decay and corrupt in their sepulchres.

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33.

Epicurus perhaps saw the shadows of columns on the walls in front of them equal to the diameter of the column which cast the shadow; and since the breadth of the shadows are parallel from beginning to end he considered that he might infer that the sun also was directly opposite

to this parallel, and consequently no broader than the column; and he did not perceive that the diminution of the shadow was insensibly small owing to the great distance of the sun. If the sun were smaller than the earth, the stars in a great portion of our hemisphere would be without light--in contradiction to Epicurus, who says the sun is only as large as it appears to be.

34.

Epicurus says the sun is the size it seems to be; hence, as it seems to be a foot in breadth, we must consider that to be its size. It follows that when the moon eclipses the sun, the sun ought not to appear the larger, as it does; hence, the moon being smaller than the sun, the moon must be less than a foot in breadth, and consequently when the earth eclipses the moon it must be less than a foot by a finger's breadth; inasmuch as if the sun is a foot in breadth, and the earth casts a conical shadow on the moon, it is inevitable that the luminous cause of the conical shadow {155} must be greater than the opaque body which causes it.

35.

Measure how many times the diameter of the sun will go into its course in twenty-four hours. And thus we can see whether Epicurus was correct in saying the sun was only as large as it appeared to be; for as the

apparent diameter of the sun is about a foot, and as the sun would go a thousand times into its course in twenty-four hours, it would have travelled a thousand feet, that is, three hundred arms' length, which is the sixth of a mile. Thus the course of the sun during twenty-four hours would have been the sixth part of a mile, and this venerable snail, the sun, would have travelled twenty-five arms' length in an hour.

[Sidenote: The Sun's Heat]

36.

They say that the sun is not hot because it is not the colour of fire but whiter and clearer. And the answer to this is that when molten bronze is hottest it resembles the colour of the sun, and when it is less hot it has the colour of fire.

37.

It is proved that the sun is by nature hot and not cold, as has already been stated. If rays of fire play on a concave mirror when it is cold, the rays refracted by the mirror will be hotter than {156} the fire. The rays emitted from a sphere of glass filled with cold water, which are reflected from a fire, will be warmer than the fire. It follows from these two experiments that the heat of the rays reflected by the

mirror or the sphere of cold water are hot by virtue, and not because the mirror or the sphere is hot; and in this case it occurs that the sun, passing through these bodies, heats them by its virtue. And owing to this they have inferred that the sun is not hot,--which by the aforesaid experiments has been proved to be exceedingly hot, by the experiment of the mirror and the sphere, which are cold in themselves, and reflect the hot rays of the fire and render them hotter, because the first cause is hot; and the same thing occurs as regards the sun, which, being hot in itself, and passing through these cold mirrors, refracts great heat. It is not the light of the sun which gives warmth, but its natural heat.

[Sidenote: Rays of the Sun]

38.

The rays of the sun pass through the cold region of the air without any change being effected in their nature, they pass through glasses full of cold water without suffering change; through whatever transparent spot they pass, it is as though they passed through so much air.

[Sidenote: Light of the Stars]

39.

Some writers allege that the stars shine of {157} themselves, saying that if Venus and Mercury did not shine of themselves, when their light comes between them and the sun they would darken as much of the sun as they could hide from our eye; this is false, because it is proved that a dark body placed against a luminous body is enveloped and altogether covered by the lateral rays of the remaining part of that body, and thus remains invisible; as may be proved when the sun is seen through the boughs of a leafless tree at a long distance, the boughs do not hide any portion of the sun from our eyes. The same thing occurs with the above-mentioned planets, which, though they have no light in themselves, do not, as has been said, hide any portion of the sun from our eyes.

Second proof. They say that the stars shine most brightly at night in proportion as they are high; and that, if they did not shine of themselves, the shadow cast by the earth between them and the sun would darken them, since they would not see nor be seen by the sun. But these have not taken into consideration that the conical shadow of the moon does not reach many of the stars, and even for those it does reach the shadow is diminished to such an extent that it covers very little of the star, and the remaining part is illumined by the sun.

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[Sidenote: On the Nature of the Moon]

40.

The moon having density and gravity, how does it stand?

41.

i. No very light object is opaque.

ii. Nothing light can remain beneath that which is heavier.

iii. Whether the moon is the centre of its elements or not. And if it has no fixed position like the earth in the centre of its elements, why does it not fall to the centre of our elements? And if the moon is not in the centre of its elements and does not fall, it must then be lighter than any other element. And if the moon is lighter than the other elements, why is it opaque and not transparent?

42.

No body which has density is lighter than the air. Having proved that the part of the moon which shines consists of water which mirrors the body of the sun and reflects for us the splendour it receives from the sun, and that if there were no waves in these waters, it would appear small, but almost as bright as the sun--it must now be shown whether the moon is a heavy or a light body; if it is a heavy body--admitting

that from the earth upwards with every grade of distance lightness must increase, so that water is lighter than earth, air is lighter than water, and {159} fire lighter than air, and so on in succession--it would seem that if the moon had density, as it has, it must have gravity, and if it has gravity the space in which it lies could not contain it, and consequently it would fall towards the centre of the universe and be joined to the earth, or if not the moon itself, its waters would fall from the moon and strip it and fall towards the centre, leaving the moon bare and lustreless; whence, as this could not happen, as reason would tell us, it is manifest that the moon is surrounded by its elements, that is to say, water, air and fire, and thus it sustains itself by itself in that space as our earth is suspended with its elements in this part of space; heavy bodies act in their elements there just as other heavy bodies act in ours.

[Sidenote: On the Harmony of the Spheres]

43.

A sound is produced by the movement of the air in friction against a dense body, and should it be produced by two weighty bodies it is owing to the atmosphere which surrounds them, and this friction consumes the bodies, so that it follows that the spheres in their friction, owing to there being no atmosphere between them, do not generate sound. And if this friction were a fact, during the many centuries the spheres have revolved they would be consumed by the immense velocity expended daily;

and even if they produce sound, the sound could not travel, {160} because the sound caused by percussion under water is scarcely noticeable, and it would be less than noticeable in the case of dense bodies. The friction of polished bodies produces no sound, and similar result would be produced in the contact or friction of the spheres; and if the spheres are not polished in their contact and friction, it follows that they are rough.

Again, their contact is not continuous; this being the case a vacuum is produced, which it has been proved does not exist in nature. Therefore we conclude that friction would have consumed the ends of each sphere, and in proportion as a sphere has a greater velocity in the centre than at the poles, it would be consumed to a higher degree at the centre than at the poles; and then the friction would cease, and the sound would cease also, and the spheres would cease to revolve unless one sphere revolved eastward and the other northward.

44.

Worlds gravitate in the midst of their own elements. The yellow or yolk of an egg remains in the middle of the albumen without moving on either side, and is lighter or heavier or equal to this albumen; and if it is lighter it ought to rise above all the albumen and stop in contact with the shell of the egg; and if it is heavier it ought {161} to sink; and if it is equal to it, it can stand at one of the ends as well as in the centre or below.

[Sidenote: The Earth appears a Star]

45.

The object of my book is to prove that the ocean, with the other seas, by means of the sun causes our world to shine like the moon and to appear as a star to other worlds; and this I will prove.

[Sidenote: The Earth a Star]

46.

In your discourse you must prove that the earth is a star like the moon, and thus you will bear witness to the glory of our universe! And thus you must discourse on the size of many stars.

47.

How the earth is a star. The earth, in the midst of the sphere of water which clothes the greater part of it, taking its light from the sun and shining in the universe like the other stars, shows itself to be a star as well.

[Sidenote: To prove the Earth a Star]

48.

First of all define the eye; then show how the twinkling of a star exists really in the eye, and why one star should twinkle more than another, and how the rays of the stars are born in the eye. Say, that if the twinkling of the stars were, as it appears to be, really in the stars, that this {162} twinkling appears to extend in proportion to the body of the star. The star, therefore, being larger than the earth, this motion made in an instant of time would in its velocity double the size of the star. Then prove that the surface of the atmosphere, contiguous to fire and the surface of fire, where it ends, is the point in which the rays of the sun penetrate and bear the image of the celestial bodies which are large when they rise and set, and small when they are on the meridian.

[Sidenote: Earth not the Center of Universe]

49.

The earth is not the centre of the orbit of the sun, nor the centre of the universe, but in the centre of its companion elements and united with them; and if any one were to stand on the moon when the moon and the sun are beneath us, our earth, with its element of water, would

appear and shine for him just as the moon appears and shines for us.

50.

The earth, shining like the moon, has lost a great part of its ancient splendour by the decrease of the waters.

51.

Nothing is generated in a place where is no sentient vegetable and rational life; feathers grow on birds and change every year; coats grow on animals and are changed every year, with some {163} exceptions, like the lion's beard and the cat's fur, and such; grass grows in the fields and leaves on the trees; and every year they are renewed in great part. Thus we can say that the spirit of growth is the soul of the earth, the soil its flesh, the ordered arrangement of rocks its bones, of which mountains are formed, the tufa its tendons; its blood the veins of water which surround its heart, which is the ocean; its breathing and increase and decrease of blood in the pulses the ebb and flood of the sea; and the heat of the spirit of the world is fire which pervades the earth, and the vital soul dwells in the fires which from various apertures of the earth issue in springs and sulphur minerals and volcanoes, as at Mount Etna in Sicily and in many other places.

52.

The ancients called man the world in miniature, and certainly the name is a happy one, because man being composed of earth, water, air and fire, the body of the earth resembles the body of man. As man has in him bones for the support and framework of his flesh, likewise in the world the rocks are the supports of the earth; as man has in him a pool of blood in which the lungs rise and fall in their breathing, so the body of the earth has its ocean which rises and falls every six hours as if the world breathed; as from the aforesaid pool of blood veins issue which {164} ramify throughout the human body, so does the ocean fill the body of the earth with innumerable veins of water. The body of the earth lacks sinews, which do not exist because sinews are made for movement, and the world being in perpetual stability no movement occurs, and there being no movement, sinews are not necessary; but in all other points they resemble each other greatly.

53.

Water is the driver of nature.

[Sidenote: Experience the Basis of Science]

54.

In explaining the action of water remember to cite experience first and then reason.

55.

Do not forget that you must put forward propositions adducing the above-mentioned facts as illustrations, not as propositions,--that would be too simple.

56.

Water in itself has no stability and cannot move of its own accord, save to descend. Water of its own accord does not cease to move unless it is shut in.

57.

The body of the earth, like the body of animals, is intersected with ramifying veins, which are all {165} united and constructed for the nourishment and life of the earth and of its creatures.

[Sidenote: Water is the Blood of the World]

58.

The water which rises in the mountains is the blood which keeps the mountain alive, and through this conduit or vein, nature, the helper of her creatures, prompt in the desire to repair the loss of the moisture expended, proffers the desired aid abundantly; just as in a stricken spot in man you will see, owing to the aid which is brought, the blood abound under the skin in a swelling, so as to succour the spot which has been stricken; likewise, in the case of the vine, when it is cut at its extremity, nature causes its moisture to rise from the lowest root to the end of the extremity which has been cut, and when this moisture has been expended nature ceases not to supply it with vital moisture to the end of its life.

59.

Water is that which is given to supply vital moisture to this arid earth; and the cause which propels it through its ramifications against the natural course of weighty matter is the same which stirs the humours in every kind of animal body.

[Sidenote: Water on Mountains]

60.

Water, the vital moisture of the earthly machine, moves by reason of its natural heat.

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[Sidenote: On the Water of Rivers]

61.

Rivers, with their ruinous inundations, seem to me the most potent of all causes of terrestrial losses, and not fire, as some have maintained; because the violence of fire is exhausted where there is nothing forthcoming to feed it. The flowing of water, which is maintained by sloping valleys, ends and dies at the lowest depth of the valley; but fire is caused by fuel and the movement of water by incline. The fuel of fire is disunited, and its damage is disunited and isolated, and fire dies where there is no fuel. The incline of valleys is united, and damage caused by water is collective, along with the ruinous course of the river, until with its valley it winds into the sea, the universal base and sole haven of the wandering waters of rivers. But what voice or words shall I find to express the disastrous ravages, the incredible upheavals, the insatiable rapacity, caused by the headstrong rivers? What can I say? Certainly I do not feel myself equal to such a demonstration, yet by experience I will try to relate the process of ruin of the rivers which destroy their banks and against

which no mortal bastion can prevail.

62.

The recesses of the bottom of the sea are perennial, the summits of mountains are transitory, whence it follows that the earth will become {167} spherical and covered with waters, and will be uninhabitable.

[Sidenote: Transformations in Past and Future]

63.

The shores of the sea continually increase in soil, towards the middle of the sea; the cliffs and promontories of the sea are continually being ruined and consumed; the mediterranean seas will dry up and all that will remain will be the channel of the greatest river which enters into them; this will flow to the ocean and pour out its waters together with that of all the rivers which are its tributaries.

[Sidenote: On the Earth's Vibration]

64.

The subterranean courses of water, like those which are made between

the air and the earth, are those which continually consume and deepen the beds of their currents. The earth which is carried by rivers is discharged at the end of their course, that is to say, the earth carried from the highest part of the river's course is discharged at the lowest depth of its course. Where fresh water arises in the sea, the miracle of the creation of an island is manifest, which will be discovered sooner or later in proportion as the quantity of water is greater or less. And an island of this kind is formed by the deposit of earth and stones made by the subterranean current of water in the channels through which it passes.

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[Sidenote: Nature's Law]

65.

Nature never breaks her laws.

66.

Nature is constrained by the cause of her laws which dwells inborn in her.

67.

Without reason no effect is produced in nature; understand the reason and you will not need experience.

[Sidenote: Cause discovered by Effect]

68.

Before I proceed further I will make some experiments, because it is my intention to cite the experiment first and then to demonstrate by reasoning how such an experiment must necessarily take effect in such a manner. And this is the true rule by which investigations of natural phenomena must proceed; and although nature herself begins from the reason and ends in the result, we must pursue the contrary course and begin, as I said above, from experience and by it seek out the reason.

[Sidenote: Repetition of Experiment]

69.

Before deducing a general rule from this case repeat the experiment two or three times and see if the same results are produced.

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[Sidenote: Example of preceding Rule]

70.

It several bodies of equal weight and shape are dropped one after another at equal intervals of time, the distances between each successive body will be equally increased.

The experiment to prove the above-mentioned theorem respecting motion must be made thus: Take two balls of equal weight and shape and let them fall from a great height so that when they start falling they touch one another, and let the investigator stand on the ground and watch whether the contact is maintained during their fall. This experiment must be repeated several times, so that the trial may not be marred by any accident and the experiment vitiated and the spectator deceived.

[Sidenote: Necessity of Analysis]

71.

We know definitely that sight is infinitely swift and in an instant of time perceives countless shapes, nevertheless it only sees one object at a time. Let us take an example. You, O reader, will see the whole of this written page at a glance, and you will instantly realize that

it is full of various letters, but you will not realize at that moment what these letters are nor what they signify; wherefore you will have to proceed word by word and line by line to take cognizance of these letters. Again, if you wish to reach the summit of a building you must mount step by step, {170} otherwise it will be impossible for you to reach the summit. And therefore I say to you whom nature has drawn to this art, if you wish to attain to a thorough knowledge of the forms of objects, you will begin by studying the details, and not proceed to the second until you have committed the first to memory and mastered it in practice, and if you do otherwise you will be wasting your time and protracting your studies. And remember first of all to acquire diligence, which signifies speed.

[Sidenote: Vision]

72.

Of the nature of the eye. Here are the forms, here the colours, here the form of every part of the universe are concentrated in a point, and that point is so great a marvel! O marvellous and stupendous necessity! thou dost compel by thy law, and by the most direct path, every effect to proceed from its cause. These things are verily miracles! I wrote in my Anatomy how in so small a space the visual faculty can be reproduced and formed again in its whole expanse.

73.

In many cases one and the same thing is attracted by two violent forces,--necessity and power. The water falls in rain and by necessity the earth absorbs the humidity; the sun causes it to evaporate, not of necessity, but by power.

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[Sidenote: Unconscious Reasoning]

74.

The pupil of the eye in the air expands and contracts according to every degree of motion made by the sun. And with every dilation or contraction the same object will appear of a different size, although frequently the relative scale of surrounding circumstances does not allow us to perceive these variations in any single object we look at.

[Sidenote: The Eye]

75.

The pupil of the eye dilates and contracts in proportion to the variety of bright and dark objects which are reflected in it. In this case nature has afforded compensation to the visual faculty by contracting

the pupil of the eye when it is offended by excess of light and by causing it to dilate when offended by excess of darkness, like the opening of the purse. And nature here behaves like the man who has too much light in his house and closes half the window, or more or less of it according to need; and when night comes he opens the window altogether so as to see better inside his house, and nature here adopts a continued process of compensation, by continually regulating and readjusting the expansion and contracting of the pupil, in proportion to the aforesaid obscurity and light which are continually reflected in it.

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[Sidenote: Water surrounding the Globe Spherical]

76.

When you collect facts relating to the science of the motion of water, remember to place under every proposition the uses to which it may be applied, in order that this knowledge may not be fruitless.

77.

This is a difficult question to answer, but I will nevertheless state my opinion. Water, which is clothed with air, desires naturally to

cleave to its sphere because in this position it is without gravity. This gravity is twofold,--the gravity of the whole which tends to the centre of the elements, and the gravity which tends to the centre of the waters of the spherical orb; if this were not so the water would form a half sphere only, which is the sphere described from the centre upwards. But I see no means in the human mind of acquiring knowledge with regard to this. We must say, as we say of the magnet which attracts iron, that such a virtue is an occult property of which there is an infinite quantity in nature.

78.

In the motion of earth against earth the repercussion of the portion struck is slight.

Water struck by water, eddies in circles around the spot where the shock has taken place.

The reverberation of the voice continues for a {173} great distance through the air; for a greater distance through fire. The mind travels for a still greater distance through the universe; but since it is finite it does not penetrate into infinity.

79.

If the water which rises on the summits of the mountains comes from the sea, whence it is propelled by its weight to a greater height than that of the mountains, why has this portion of the element of water the power to elevate itself to such an altitude and to penetrate the earth by so great an expenditure of labour and time, when the residue of the element of water, whose only obstacle is the air which does not impede it, is not able to raise itself to a similar altitude? And thou who didst devise this theory, go and study nature, so that thou mayst cease to acquire such opinions of which thou hast made so great a collection, together with the capital and interest which thou dost possess.

[Sidenote: On the Law of Gravity]

80.

The sphere of the earth has gravity which increases in proportion to the lightness of the element which contains it.

Fire is light in its sphere and its lightness increases in proportion to the weight of the element which contains it.

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No primary element has gravity or lightness in its own sphere.

81.

The motion made by bodies which possess gravity to the common centre is not produced by the tendency of the body to find this centre, nor is it caused by attraction made by the centre, as by a magnet, drawing the weight towards it.

82.

Why does not the weight remain in its place?

It does not remain because it has no resistance.

And whither will it tend?

It will tend to the centre of the earth.

And why not along other lines?

Because the weight which meets with no resistance will descend by the shortest way to the lowest depth, and the lowest depth is the centre of the earth.

And how does a weight find the centre of the earth with such directness?

Because it does not proceed at random, wandering by diverse courses.

[Sidenote: Phenomena governed by Mechanical Laws]

83.

Instrumental science, that is to say, mechanics, is the most noble and most useful of sciences, inasmuch as by means of it all living bodies which have movement act; and this movement has {175} its origin in the centre of gravity which is placed in the middle, dividing unequal weights, and it has dearth and wealth of muscles and lever also and counter-lever.

84.

Since these things are far more ancient than letters, it is no wonder if in our day no records exist to tell how these seas filled so many countries. But if some record had existed, conflagrations, floods, wars, changes of tongues and laws have consumed all that is ancient; sufficient for us is the testimony of objects born in the salt waters and found again in the high mountains far off from the seas of those times.

[Sidenote: Heat the Vital Principle]

85.

Heat causes moisture to move, and cold arrests it; as is seen in a cold country which arrests the motion of the clouds in the air. Where there is life there is heat, where there is vital heat there is movement of moisture.

[Sidenote: Against those desiring to correct Nature]

86.

The act of cutting out the nostrils of a horse is a piece of ludicrous folly. And the foolish indulge in this practice as though they considered nature had failed to supply necessary wants, and man had therefore to supplement her work. Nature made two apertures in the nose, which each in {176} itself is half as large as the lung pipe whence breath proceeds, and if these apertures did not exist the mouth would abundantly suffice for breathing purposes. And if you said to me, Why has nature thus provided animals with nostrils if respiration through the mouth is sufficient?--I would answer that nostrils are made to be used when the mouth is employed in masticating its food.

[Sidenote: Of Trees]

87.

If a tree has been stripped of its bark in some spot, nature makes provision for this and gives a greater supply of nourishing sap to the stripped portion than to any other, so that in place of what has been taken away the bark grows thicker than in any other spot. And so impetuous is the motion of the sap that when it reaches the spot which is to be healed, it rises higher like a bounding ball, in bubbles, not unlike boiling water.

[Sidenote: The Leaves of Plants]

88.

Nature has so placed the leaves of the latest shoots of many trees that the sixth leaf is always above the first, and thus in continued succession unless the rule is obstructed. And this she has done for two useful purposes in the plant: firstly, since the branches and the fruit of the following year spring from the bud or eye which is above and in contact with the juncture of the leaves, {177} the water which feeds the shoot may be able to run down and nourish the bud, through the drop being caught in the hollow whence the leaf springs. And the second advantage is that as these buds shoot in the following year, one will not be covered by the other, since the five shoots spring on five different sides.

[Sidenote: From Known to Unknown]

89.

In order to arrive at knowledge of the motions of birds in the air, it is first necessary to acquire knowledge of the winds, which we will prove by the motions of water in itself, and this knowledge will be a step enabling us to arrive at the knowledge of beings that fly between the air and the wind.

[Sidenote: On the Flight of Birds]

90.

The reason of this is that small birds being without down cannot support the intense cold of the high altitudes in which the vultures and eagles or and other great birds, well supplied with down and clothed with many kinds of feathers, [fly]. Again, the small birds, having delicate and thin wings, support themselves in the low air, which is denser, and they could not bear up in the rarer air, which affords slighter resistance.

[Sidenote: On the Structure of Wings]

91.

The shafts formed in the shoulders of the wings of birds have been so devised by ingenious nature {178} as to occasion a convenient pliancy in the direct impetus which often occurs in the swift flight of birds, since she found it more practical to bend a small part of the wing in the direct flight than the whole of it.

[Sidenote: On a Fossil Fish]

92.

O time! swift devourer of all created things! How many kings, how many nations, thou hast overthrown, how great changes of kingdoms and diverse vicissitudes have succeeded one another, since the marvellous body of this fish, which perished in the caverns and intricate recesses [of the mountain]. Now undone by time, thou liest patient in this confined spot; with thy fleshless and bare bones thou hast built the framework and the support of the mountain that is above thee.

[Sidenote: We live by Others' Death]

93.

Unconscious life remains in what is dead, which when reunited to the stomach of living men, reacquires sentient and conscious life.

[Sidenote: Against Doctors]

94.

Men are chosen to be physicians in order to minister to diseases of which they are ignorant.

95.

Every man wishes to amass money in order to give it to the physicians who are the destroyers of life; they ought therefore to be rich.

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96.

Take pains to preserve thy health; and thou wilt all the more easily do this if thou avoidest physicians, because their drugs are a kind of alchemy, and there are as many books on this subject as there are on medicine.

97.

Oh! meditators on perpetual motion, how many vain projects of similar character you have devised! Go and join the seekers of gold.

[Sidenote: Against the Seekers of Perpetual Motion]

98.

The water which flows in a river moves either because it is summoned or driven, or because it moves of its own accord. If it is summoned,--and I mean sought after,--who is the seeker? If it is driven, who is the driver? If it moves of its own accord, it gives evidence of reasoning; and reasoning in bodies which continually change their shape is impossible, because in such bodies there is no consciousness.

[Sidenote: Against Occult Sciences]

99.

I wish to work miracles. I may have less than other and less energetic men; and those who wish to grow rich in a day live a long time in great poverty, as happens, and will always happen, to alchemists, who seek to make gold and silver, and to the engineers who wish from still {180} water to obtain life and perpetual motion, and to the supreme fool,--the necromancer and the magician.

[Sidenote: Of Astrology]

100.

There is no part of astronomy which does not depend on the visual lines and on perspective, the daughter of painting; because the painter is he who by the necessity of his art has begotten perspective, and it is impossible to do without lines which include all the various figures of the bodies begotten by nature and without which the art of geometry is blind. And while the geometrist reduces every surface surrounded by lines to a square, and each body to the figure of the cube, and mathematics do the same with their cube roots and square roots, these two sciences deal only with the continuous and discontinuous quantity, but they do not deal with the quality which constitutes the beauty of the works of nature and the ornament of the world.

101.

Here the adversary will say that he does not want so much knowledge, and the mere skill of depicting nature will suffice him. To which I make reply that there is no greater error than to trust to our judgement without other reasoning, as experience, the enemy of alchemists, necromancers and other foolish intellects, has in all times proved.

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[Sidenote: Against Alchemists]

102.

The lying interpreters of nature affirm that quicksilver is the common seed of all metals. They do not bear in mind that nature raises substances according to the diversity of things which she wishes to produce in the world.

[Sidenote: Against Necromancy]

103.

The belief in necromancy is reputed to be the most foolish of all human opinions. It is the sister of alchemy which gives birth to simple and natural things; but it is all the more reprehensible than alchemy, inasmuch as it brings forth nothing but what is like itself, that is, lies. This is not the case with alchemy, which is confined to the simple products of nature, and whose function cannot be performed by nature herself, because in it there are no organic instruments with which it can work, such as the hands are to man and which have enabled him to make glass, &c. But necromancy, the flag and flying banner, blown hither and thither by the winds, is the guide of the silly

multitude, which constantly bears witness with gaping wonder to the countless effects of this art; and whole books are written which declare that incantations and spirits are efficacious and speak without tongues and without vocal organs, without which it is impossible to speak, and carry the heaviest weights, raising tempests and rain and {182} transforming men into cats, wolves and other beasts, although they who affirm such things are the first to be transformed into beasts. And certainly if such necromancy existed, as is believed by lower intellects, there is nothing on the earth which would be so effectual both as regards the service and detriment of man; because if it is true that this art has the power to disturb the calm serenity of the atmosphere, changing it into night and producing sparks and winds, with fearful thunder and lightnings that fly through the darkness, and overthrowing high buildings with violent winds and uprooting forests and striking armies and shattering and overwhelming them, and producing, in addition to this, devastating storms which rob the peasants of the fruits of their toil, what kind of warfare is there so deadly to the enemy? Who in naval warfare can be compared with him who commands the winds and generates storms which ruin and sink any fleet whatsoever? Certainly he who could dispose of such violent forces would be the lord of nations, and no human skill could resist his deadly power. The hidden treasures and gems concealed in the body of the earth would be manifest unto him. He would let himself be borne through the air from the east to the west, and through all the opposed regions of the universe. But why should I proceed further? What thing is there which could not be effected by such an art? Nothing, save {183} the discovery of immortality. And if it is true, why has it not

remained among men who so greatly desired it, and led them to disregard any deity? And I know that there are many who to satisfy a whim would destroy God and the universe. And if necromancy has not remained with man in spite of its being so necessary to him it can never have existed, nor will it ever exist according to the definition of the spirit which is invisible in the body, for in the elements there are no incorporate things, for where there is no body there is a vacuum, and a vacuum cannot exist in the elements because it would be immediately filled by them.

[Sidenote: Deceptiveness of the Senses]

104.

The eye in its given distances and by its given means deceives itself in the performance of its functions less than any other sense, because it sees in straight lines which form a cone, the base of which is the object it perceives, and transmits it to the eye, as I intend to prove. But the ear greatly deceives itself as to the position and distance of the objects it apprehends, because the sonorous waves do not reach it in straight lines, like those of the eye, but by tortuous and reflex lines, and often the most remote seem to be nearest, owing to the peregrinations of such waves, although the voice of the echo is transmitted to the sense by straight lines only. The smell is less certain of the spot whence the odour arises, but {184} taste and touch alone come into direct contact with the object which they apprehend.

[Sidenote: On the Conception of Nothingness]

105.

The smallest natural point is larger than all mathematical points, and the proof of this is that the natural point has continuity, and everything which has continuity is infinitely divisible; but the mathematical point is indivisible because it is not a quantity. Every continuous quantity is mentally infinitely divisible. Among the magnitude of things which are among us, the chief of all is nothingness; and its function extends to matter that does not exist, and its essence is in time in the past or in the future, and it has nothing of the present. This nothingness has its part equal to the whole and the whole to the part, and the divisible to the indivisible, and produces the same result by addition or subtraction, or if it be divided or multiplied,--as is proved by arithmeticians by their tenth character, which represents nothing. And its power does not extend to the things of nature.

That which is called nothingness is found only in time and in words: in time it is found in the past and future, and not in the present; and thus in words among things which are said to be nonexistent or impossible. In time nothingness dwells in the past and the future, and not at all in the present, and in nature it resides among the things {185} which are impossible. Whence from that which has been said, it

has no being, because where there is nothingness there would be a vacuum.

[Sidenote: On Spirits]

106.

With regard to this matter, we have said on the previous page that the definition of a spirit is a power united with a body, because it cannot move of its own accord nor acquire any kind of motion. And if you say that it moves itself, this cannot be within the elements, because if the spirit is an incorporate quantity this quantity is a vacuum and the vacuum does not exist in nature, and if it did exist it would be immediately filled by the rushing in of the element in which the vacuum was formed. So according to the definition of weight which runs:

"Gravity is an accidental power created by one element attracted to or suspended in another," it follows that no element, weighing nothing in its own element, can have weight in the element which is above it and lighter than it; for instance, no one part of water has no more gravity or lightness than any other part, but if you were to draw it up into the air, it would acquire weight, and this weight cannot sustain itself by itself; and it must therefore inevitably fall, and thus wherever there is a vacuum in water it will fall in. The same thing would happen with a spirit among the elements where it would continuously generate a vacuum {186} in whatever element it might find itself, for which reason it is inevitable that it would move in a constant flight

to the sky until it had quitted these elements.

[Sidenote: Has the Spirit a Body?]

107.

We have proved that a spirit cannot exist in the elements without a body, nor move of itself by voluntary motion unless it be to rise upwards. But now we will say that if such a spirit took a body made of air it would inevitably melt into air, because if it remained united it would be separated and fall and form a vacuum, as we have described above. Therefore if it desired to remain in the air it is necessary that it should blend with a quantity of air, and if it were united with the air, two difficulties arise: that is, that it will rarefy that portion of air with which it is mingled, and this rarefied air will fly upwards and will not remain in the air which is heavier than itself; and besides this the ethereal spiritual essence is disunited, and its nature is changed, for which reason that nature loses some of its first virtue. There is in addition to these a third difficulty, and this is that a body of this kind, made of air and assumed by the spirits, is exposed to the penetrating winds which continually sunder and scatter the united portions of the air, eddying and whirling amidst the rest of the atmosphere; therefore the spirit who would pervade {187} this air would be dismembered or rent and broken up with the rending of the air of which it formed part.

108.

It is impossible that the spirit, incorporated with a certain quantity of air, should move this air; and this is proved by the passage where it is said that "the spirit rarefies that portion of the air with which it is mingled." This air therefore will rise high above the other air, and the air will be set in motion by its own lightness and not by the volition of the spirit, and if this air encounters a wind, the air will be moved by the wind and not by the spirit which is incorporated in it.

[Sidenote: Can the Spirit speak?]

109.

In order to show whether the spirit can speak or not it is first necessary to define the voice and the manner of its origin. The following will be our definition: The voice is the movement of air in friction against a dense body, or a dense body in friction against the air (which is the same idea), and by this friction of the dense and the rare what is rare is condensed, and resistance is caused; and again, when the rare in swift motion and the rare in slow motion come into contact, they condense one another and produce sound, and a great noise is made. The sound or murmur made by the rare moving through the rare {188} with slow motion is like the great flame whence sounds issue in the air; the exceedingly great noise made by the rare, when the air

which is rare and swift mingles with that which is rare and in [slow] motion, is like the flame of fire issuing from a great gun and striking against the air; likewise the flame when it issues from a cloud strikes the air as it begets the thunderbolt. Therefore we will say that the spirit cannot produce a voice unless the air be set in motion, but since there is no air within, it cannot discharge what it does not possess; and if it wishes to move that air in which it is incorporated, it is necessary that the spirit should multiply itself; but that which has no quantity cannot be multiplied. In the fourth place it is said, that no rare body can move if it has not a stable spot whence it may take its motion, and more especially is this the case when an element must move in its own element, which does not move of itself, excepting by uniform evaporation at the centre of the thing evaporated; as occurs in the case of the sponge squeezed in the hand under water, whence the water escapes in every direction with equal motion through the spaces between the fingers of the hand which squeezes it. As to whether the spirit has an articulate voice and can be heard, and as to what are hearing and sight--the wave of the voice travels through the air as the images of objects travel to the eye.

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110.

O mathematicians, clear up this error! The spirit cannot have a voice, for where there is a voice there is a body, and where there is a body there is occupation of space, which prevents the eye seeing what is

behind that space; therefore a body fills all the surrounding air, that is to say, with its own image.

111.

There can be no voice where there is no motion or percussion of the air, there can be no percussion of the air where there is no instrument, there can be no such thing as an immaterial instrument; and this being so, a spirit can have neither voice, nor shape, nor force; and if it assumes a shape it can neither penetrate nor enter where the issues are closed. If any one were to say that a spirit may take bodies of various shapes by means of concentrated and compressed air, and by means of this instrument speak and move with force--I reply to this argument that where there are no nerves or bones, no force can be expended in any movement made by these imaginary spirits.

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BIBLIOGRAPHICAL NOTE

AND

TABLE OF REFERENCES