

OXFORD WORLD'S CLASSICS



LEONARDO DA VINCI

*Notebooks*



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OXFORD  
UNIVERSITY PRESS

# I

## TRUE SCIENCE

*Leonardo's view of what science should be foreshadows the critical and constructive methods of modern times. He proceeded step by step. (1) Experience of the world around us as gained through the senses is taken as the starting-point. (2) Reason and contemplation, which, though linked to the senses, stands above and outside them, deduces eternal and general laws from transitory and particular experiences. (3) These general laws must be demonstrated in logical sequence like mathematical propositions, and finally (4) they must be tested and verified by experiment, and then applied to the production of works of utility or of art according to plan. Truth could therefore be verified. He was opposed to philosophical systems founded solely on words.*

### I. EXPERIENCE

Consider now, O reader! what trust can we place in the ancients, who tried to define what the Soul and Life are—which are beyond proof—whereas those things which can at any time be clearly known and proved by experience remained for many centuries unknown or falsely understood.

Many will think that they can with reason blame me, alleging that my proofs are contrary to the authority of certain men held in great reverence by their inexperienced judgements, not considering that my works are the issue of simple and plain experience which is the true mistress.

These rules enable you to know the true from the false—and this induces men to look only for things that are possible and with due moderation—and they forbid you to use a cloak of ignorance, which will bring about that you attain to no result and in despair abandon yourself to melancholy.

I am fully aware that the fact of my not being a man of letters may cause certain presumptuous persons to think that they may with reason blame me, alleging that I am a man without learning. Foolish folk! Do they not know that I might retort by saying, as did Marius to the Roman Patricians: ‘They who adorn themselves in the labours of others will not permit me my own.’\* They will say that because I have no book learning, I cannot properly express what I desire to treat of—but they do not know that my subjects require for their exposition experience rather than the words of others. Experience has been the mistress of whoever has written well; and so as mistress I will cite her in all cases.<sup>1</sup>

Though I have no power to quote from authors as they have, I shall rely on a far bigger and more worthy thing—on experience, the instructress of their masters. They strut about puffed up and pompous, decked out and adorned not with their own labours, but by those of others, and they will not even allow me my own. And if they despise me who am an inventor, how much more should they be blamed who are not inventors but trumpeters and reciters of the works of others.

Those who are inventors and interpreters between Nature and Man as compared with the reciters and trumpeters of the works of others, are to be regarded simply as is an object in front of a mirror in comparison with its image seen in the mirror, the one being something in itself, the other nothing: people whose debt to nature is small, since they are only by chance invested with the human form, and but for this, I might class them with the herds of beasts.<sup>2</sup>

Seeing that I cannot find any subject of great utility or pleasure, because the men who have come before me have taken for their own all useful and necessary themes, I will do like one who, because of his poverty, is the last to arrive at the fair, and not being able otherwise to provide for himself, takes all the things which others have already seen and not taken but refused as being of little value; I will load my modest pack

with these despised and rejected wares, the leavings of many buyers; and will go about distributing, not indeed in great cities, but in the poor hamlets, taking such reward as the thing I give may be worth.<sup>1</sup>

The abbreviators\* (of works) do harm to knowledge and to love, for the love of anything is the offspring of knowledge, love being more fervent in proportion as knowledge is more certain. And this certainty springs from a complete knowledge of all the parts which united compose the whole of the thing which ought to be loved.

Of what use, then, is he who in order to abridge the part of the things of which he professes to give complete information leaves out the greater part of the things of which the whole is composed. True it is that impatience, the mother of folly, is she who praises brevity, as if such persons had not life long enough to acquire a complete knowledge of one single subject, such as the human body. And then they want to comprehend the mind of God which embraces the whole universe, weighing and mincing it into infinite parts as if they had dissected it. O human stupidity! do you not perceive that you have spent your whole life with yourself, and yet are not aware of the thing you chiefly possess, that is of your folly? And so with the crowd of sophists you deceive yourself and others, despising the mathematical sciences in which is contained the true information about the subjects of which they treat. And then you would fain occupy yourself with miracles and write and give information of those things of which the human mind is incapable, and which cannot be proved by any instance from nature. And you fancy you have wrought miracles when you have spoiled the work of some ingenuous mind and do not perceive that you are falling into the same error as he who strips a tree of its adornment of branches laden with leaves intermingled with fragrant flowers or fruit in order to demonstrate the suitability of the tree for making planks. As did Justinus,\* abridging the histories of Trogius Pompeius, who had written in an ornate style all the great

deeds of his forefathers full of admirable and picturesque descriptions; and by so doing composed a bald work fit only for such impatient minds who fancy they are wasting time when they spend it usefully in the study of works of nature and the deeds of men.<sup>3</sup>

All our knowledge has its origin in our perceptions.<sup>4</sup>

The eye, which is called the window of the soul, is the chief means whereby the understanding may most fully and abundantly appreciate the infinite works of nature.<sup>5</sup>

Experience never errs; it is only your judgement that errs in promising itself results as are not caused by your experiments. Because, given a beginning, what follows from it must be its true consequence unless there is an impediment. And should there be an impediment, the result which ought to follow from the aforesaid beginning will partake of this impediment in a greater or less degree in proportion as this impediment is more or less powerful than the aforesaid beginning. Experience does not err, it is only your judgement that errs in expecting from her what is not in her power. Wrongly do men complain of Experience and with bitter reproaches accuse her of leading them astray. Let Experience alone, and rather turn your complaints against your own ignorance, which causes you to be carried away by your vain and foolish desires as to expect from Experience things which are not within her power; saying that she is fallacious. Wrongly do men complain of innocent Experience, accusing her often of deceit and lying demonstrations.<sup>6</sup>

To me it seems that all sciences are vain and full of errors that are not born of Experience, mother of all certainty, and that are not tested by Experience; that is to say, that do not at their origin, middle, or end, pass through any of the five senses. For if we are doubtful about the certainty of things that pass through the senses how much more should we question the

many things against which these senses rebel, such as the nature of God and the soul and the like, about which there are endless disputes and controversies. And truly it so happens that where reason is not, its place is taken by clamour. This never occurs when things are certain. Therefore, where there are quarrels, there true science is not; because truth can only end one way—wherever it is known controversy is silenced for all time, and should controversy nevertheless again arise, then our conclusions must have been uncertain and confused and not truth reborn.

All true sciences are the result of Experience which has passed through our senses, thus silencing the tongues of litigants. Experience does not feed investigators on dreams, but always proceeds from accurately determined first principles, step by step in true sequences to the end; as can be seen in the elements of mathematics. . . . Here no one argues as to whether twice three is more or less than six or whether the angles of a triangle are less than two right angles. Here all arguments are ended by eternal silence and these sciences can be enjoyed by their devotees in peace. This the deceptive purely speculative sciences cannot achieve.<sup>7</sup>

Beware of the teaching of these speculators, because their reasoning is not confirmed by Experience.<sup>8</sup>

## II. REASON AND NATURE'S LAWS

The senses are of the earth; reason stands apart from them in contemplation.<sup>9</sup>

Wisdom is the daughter of experience.\*<sup>10</sup>

Experience, the interpreter between formative nature and the human species, teaches that that which this nature works among mortals constrained by necessity cannot operate in any other way than that in which reason, which is its rudder, teaches it to work.<sup>11</sup>

First I shall test by experiment before I proceed further, because my intention is to consult experience first and then with reasoning show why such experience is bound to operate in such a way. And this is the true rule by which those who analyse the effects of nature must proceed: and although nature begins with the cause and ends with the experience, we must follow the opposite course, namely, begin with the experience, and by means of it investigate the cause.<sup>12</sup>

O marvellous necessity, thou with supreme reason constrainest all effects to be the direct result of their causes, and by a supreme and irrevocable law every natural action obeys thee by the shortest possible process.<sup>13</sup>

Nature does not break her law; nature is constrained by the logical necessity of her law which is inherent in her.<sup>14</sup>

Necessity is the mistress and guide of nature.

Necessity is the theme and inventor of nature, its eternal curb and law.<sup>15</sup>

Nature is full of infinite causes that have never occurred in experience.<sup>16</sup>

In nature there is no effect without cause; understand the cause and you will have no need of the experiment.<sup>17</sup>

### III. MATHEMATICAL DEMONSTRATION

*The method recommended by Leonardo for submitting the results of his investigations corresponds to Euclidean geometry.*

*The presentation must be made in logical sequence. First came the statement of the theorem, the 'proposition'; then came 'concessions' or 'petitions', i.e. axioms which neither require nor are capable of proof and must be taken for granted; whereupon followed the examination of the subjects under consideration.*

Let no man who is not a mathematician read the elements of my work.<sup>18</sup>

There is no certainty where one can neither apply any of the mathematical sciences nor any of those which are connected with the mathematical sciences.<sup>19</sup>

Whoever condemns the supreme certainty of mathematics feeds on confusion, and can never silence the contradictions of the sophistical sciences, which lead to an eternal quackery.<sup>20</sup>

Science is an investigation by the mind which begins with the ultimate origin of a subject beyond which nothing in nature can be found to form part of the subject. Take, for example, the continuous quantity in the science of geometry: if we begin with the surface of a body we find that it is derived from lines, the boundaries of the surface. But we do not let the matter rest there, for we know that the line in its turn is terminated by points, and that the point is that ultimate unit than which there is nothing smaller. Therefore the point is the first beginning of geometry, and neither in nature nor in the human mind can there be anything which can originate the point. . . . No human investigation can be called true science without passing through mathematical tests; and if you say that the sciences which begin and end in the mind contain truth, this cannot be conceded and must be denied for many reasons. First and foremost because in such mental discourses experience does not come in, without which nothing reveals itself with certainty.<sup>21</sup>

Specification of what I ask should be taken for granted in my proofs with perspective. I ask, let it be granted that all rays passing through the air be of the same kind and travel in straight lines from their source to the objects that they strike.<sup>22</sup>

Here you must proceed methodically; that is, you must distinguish between the various parts of the proposition so

that there may be no confusion and you may be well understood.<sup>23</sup>

See to it that the examples and proofs that are given in this work are defined before you cite them.<sup>24</sup>

#### IV. EXPERIMENT

But before you base a law on this case test it two or three times and see whether the tests produce the same effects.<sup>25</sup>

This experiment should be made many times so that no accident may occur to hinder or falsify this proof, for the experiment may be false whether it deceived the investigator or no.<sup>26</sup>

When you put together the science of the motion of water, remember to include in each proposition its application and use, in order that these sciences may not be useless.<sup>27</sup>

Science is the captain and practice the soldiers.<sup>28</sup>

O speculator on things, boast not of knowing the things that nature ordinarily brings about; but rejoice if you know the end of those things which you yourself devise.<sup>29</sup>

Those who fall in love with practice without science are like a sailor who enters a ship without helm or compass, and who never can be certain whither he is going.<sup>30</sup>

Mechanics is the paradise of mathematical science, because by means of it one comes to the fruits of mathematics.<sup>31</sup>

#### V. SEARCH FOR TRUE KNOWLEDGE

##### ALCHEMY

*Leonardo admonishes alchemists to observe the processes of nature rather than search for gold. These early chemists whose operations*

*extended through the Middle Ages left behind an extensive literature. Until men like Leonardo began to observe Nature for the sake of learning her ways, no real progress was made. In the following quotation modern scientific views are intermingled with medieval poetical fancies—gold is called an emblem of the sun, natural organisms are called ‘elements’.*

Nature is concerned with the production of elementary things. But man from these elementary things produces an infinite number of compounds; although he is unable to create any element except another life like himself—that is, in his children.

Old alchemists will be my witnesses, who have never either by chance or by experiment succeeded in creating the smallest element which can be created by nature; however, the creators of compounds deserve unmeasured praise for the usefulness of the things invented for the use of men, and would deserve it even more if they had not been the inventors of noxious things like poisons and other similar things which destroy life or mind; for which they are not exempt from blame. Moreover, by much study and experiment they are seeking to create not the meanest of Nature’s products, but the most excellent, namely gold, true son of the sun, inasmuch as of all created things it has most resemblance to the sun. No created thing is more enduring than this gold. It is immune from destruction by fire, which has power over all other created things, reducing them to ashes, glass, or smoke. And if gross avarice must drive you into such error, why do you not go to the mines where Nature produces such gold, and there become her disciple? She will in faith cure you of your folly, showing you that nothing which you use in your furnace will be among any of the things which she uses in order to produce this gold. Here there is no quicksilver, no sulphur of any kind, no fire nor other heat than that of Nature giving life to our world; and she will show you the veins of the gold spreading through the blue lapis lazuli, whose colour is unaffected by the power of the fire.

And examine well this ramification of the gold and you will see that the extremities are continuously expanding in slow movement, transmuting into gold whatever they touch; and note that therein is a living organism which it is not in your power to produce.<sup>32</sup>

Of all human opinions that is the most foolish which believes in necromancy, the sister of alchemy. But it is more open to reprehension than alchemy because it never gives birth to anything except things like itself, that is to say, lies; this does not happen in alchemy, whose function cannot be exercised by nature herself, because there are in her no organic instruments wherewith she might do the work that man performs with his hands, by the use of which he has made glass, &c. But this necromancy, the flag and flying banner blown by the wind, the guide of the stupid multitude, which is constantly witness to the limitless effects of this art; and they have filled books, declaring that enchantments and spirits can work and speak without tongues, and can speak without organic instruments—without which speech is impossible—and can carry the heaviest weights and bring tempest and rain; and that men can be turned into cats and wolves and other beasts, although indeed it is those who affirm such things who first become beasts. And surely if this necromancy did exist, as is believed by shallow wits, there is nothing on earth that would have so much importance alike for the harm and the service of man; if it were true that there were in such an art a power to disturb the tranquil serenity of the air, and convert it into darkness, to create coruscations and winds with dreadful thunder and lightning flashing through the darkness, and with impetuous storms to overthrow high buildings and to uproot forests; and with these to shake armies and break and overthrow them, and—more important than this—to create the devastating tempests and thereby deprive the peasants of the reward of their labours. For what method of warfare can there be which can inflict such damage upon the enemy as the power to deprive him of his harvests? What naval battle could

be compared with that which he could wage who has command of the winds and can make ruinous gales that would submerge any fleet whatsoever? Surely whoever commands such violent forces will be lord of the nations, and no human ingenuity will be able to resist his destructive forces. The buried treasures, the jewels that lie in the body of the earth, will all be made manifest to him. No lock or fortress, however impregnable, will avail to save anyone against the will of such a necromancer. He will have himself carried through the air from East to West, and through all the opposite parts of the universe. But why should I enlarge further on this? What is there which could not be done by a craftsman such as this? Almost nothing, except the escape from death.

We have, therefore, explained in part the mischief and the usefulness that belong to such an art if it is real. And if it is real, why has it not remained among men who desire it so much, not having regard to any deity? For I know that there are numberless people who, in order to gratify one of their appetites, would destroy God and the whole of the universe. If this art has never remained among men, although so necessary to them, it never existed, and never will exist.<sup>33</sup>

It is impossible that anything of itself alone can be the cause of its creation; and those things which are of themselves are eternal.<sup>34</sup>