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The Notebooks of Leonardo Da Vinci

Volume 1

PREFACE.

A singular fatality has ruled the destiny of nearly all the most famous of Leonardo da Vinci's works. Two of the three most important were never completed, obstacles having arisen during his life-time, which obliged him to leave them unfinished; namely the Sforza Monument and the Wall-painting of the Battle of Anghiari, while the third--the picture of the Last Supper at Milan--has suffered irremediable injury from decay and the repeated restorations to which it was recklessly subjected during the XVIIth and XVIIIth centuries. Nevertheless, no other picture of the Renaissance has become so wellknown and popular through copies of every description.

Vasari says, and rightly, in his Life of Leonardo, "that he laboured much more by his word than in fact or by deed", and the biographer evidently had in his mind the numerous works in Manuscript which have been preserved to this day. To us, now, it seems almost inexplicable that these valuable and interesting original texts should have remained so long unpublished, and indeed forgotten. It is certain that during the XVIth and XVIIth centuries their exceptional value was highly appreciated. This is proved not merely by the prices which they commanded, but also by the exceptional interest which has been attached to the change of ownership of merely a few pages of Manuscript.

That, notwithstanding this eagerness to possess the Manuscripts, their contents remained a mystery, can only be accounted for by the many and great difficulties attending the task of deciphering them. The handwriting is so peculiar that it requires considerable practice to read even a few detached phrases, much more to solve with any certainty the numerous difficulties of alternative readings, and to master the sense as a connected whole. Vasari observes with reference to Leonardos writing: "he wrote backwards, in rude characters, and with the left hand, so that any one who is not practised in reading them, cannot understand them". The aid of a mirror in reading reversed handwriting appears to me available only for a first experimental reading. Speaking from my own experience, the persistent use of it is too fatiguing and inconvenient to be practically advisable, considering the enormous mass of Manuscripts

to be deciphered. And as, after all, Leonardo's handwriting runs backwards just as all Oriental character runs backwards--that is to say from right to left--the difficulty of reading direct from the writing is not insuperable. This obvious peculiarity in the writing is not, however, by any means the only obstacle in the way of mastering the text. Leonardo made use of an orthography peculiar to himself; he had a fashion of amalgamating several short words into one long one, or, again, he would quite arbitrarily divide a long word into two separate halves; added to this there is no punctuation whatever to regulate the division and construction of the sentences, nor are there any accents--and the reader may imagine that such difficulties were almost sufficient to make the task seem a desperate one to a beginner. It is therefore not surprising that the good intentions of some of Leonardo's most reverent admirers should have failed.

Leonardo's literary labours in various departments both of Art and of Science were those essentially of an enquirer, hence the analytical method is that which he employs in arguing out his investigations and dissertations. The vast structure of his scientific theories is consequently built up of numerous separate researches, and it is much to be lamented that he should never have collated and arranged them. His love for detailed research--as it seems to me--was the reason that in almost all the Manuscripts, the different paragraphs appear to us to be in utter confusion; on one and the same page, observations on the most dissimilar subjects follow each other without any connection. A page, for instance, will begin with some principles of astronomy, or the motion of the earth; then come the laws of sound, and finally some precepts as to colour. Another page will begin with his investigations on the structure of the intestines, and end with philosophical remarks as to the relations of poetry to painting; and so forth.

Leonardo himself lamented this confusion, and for that reason I do not think that the publication of the texts in the order in which they occur in the originals would at all fulfil his intentions. No reader could find his way through such a labyrinth; Leonardo himself could not have done it.

Added to this, more than half of the five thousand manuscript pages which now remain to us, are written on loose leaves, and at present arranged in a manner which has no justification beyond the fancy of the collector who first brought them together to make volumes of more or less extent. Nay, even in the volumes, the pages of which were numbered by Leonardo himself, their order, so far as the connection of the texts was concerned, was obviously a matter of indifference to him. The only point he seems to have kept in view, when first writing down his notes, was that each observation should be complete to the end on the page on which it was begun. The exceptions to this rule are extremely few, and it is certainly noteworthy that we find in such cases, in bound volumes with his numbered pages, the written observations: "turn over", "This is the continuation of the previous page", and the like. Is not this

sufficient to prove that it was only in quite exceptional cases that the writer intended the consecutive pages to remain connected, when he should, at last, carry out the often planned arrangement of his writings?

What this final arrangement was to be, Leonardo has in most cases indicated with considerable completeness. In other cases this authoritative clue is wanting, but the difficulties arising from this are not insuperable; for, as the subject of the separate paragraphs is always distinct and well defined in itself, it is quite possible to construct a well-planned whole, out of the scattered materials of his scientific system, and I may venture to state that I have devoted especial care and thought to the due execution of this responsible task.

The beginning of Leonardo's literary labours dates from about his thirty-seventh year, and he seems to have carried them on without any serious interruption till his death. Thus the Manuscripts that remain represent a period of about thirty years. Within this space of time his handwriting altered so little that it is impossible to judge from it of the date of any particular text. The exact dates, indeed, can only be assigned to certain note-books in which the year is incidentally indicated, and in which the order of the leaves has not been altered since Leonardo used them. The assistance these afford for a chronological arrangement of the Manuscripts is generally self evident. By this clue I have assigned to the original Manuscripts now scattered through England, Italy and France, the order of their production, as in many matters of detail it is highly important to be able to verify the time and place at which certain observations were made and registered. For this purpose the Bibliography of the Manuscripts given at the end of Vol. II, may be regarded as an Index, not far short of complete, of all Leonardo's literary works now extant. The consecutive numbers (from 1 to 1566) at the head of each passage in this work, indicate their logical sequence with reference to the subjects; while the letters and figures to the left of each paragraph refer to the original Manuscript and number of the page, on which that particular passage is to be found. Thus the reader, by referring to the List of Manuscripts at the beginning of Volume I, and to the Bibliography at the end of Volume II, can, in every instance, easily ascertain, not merely the period to which the passage belongs, but also exactly where it stood in the original document. Thus, too, by following the sequence of the numbers in the Bibliographical index, the reader may reconstruct the original order of the Manuscripts and recompose the various texts to be found on the original sheets--so much of it, that is to say, as by its subject-matter came within the scope of this work. It may, however, be here observed that Leonardo's Manuscripts contain, besides the passages here printed, a great number of notes and dissertations on Mechanics, Physics, and some other subjects, many of which could only be satisfactorily dealt with by specialists. I have given as complete a review of these writings as seemed necessary in the Bibliographical notes.

In 1651, Raphael Trichet Dufresne, of Paris, published a selection from Leonardo's writings on painting, and this treatise became so popular that it has since been reprinted about two-and-twenty times, and in six different languages. But none of these editions were derived from the original texts, which were supposed to have been lost, but from early copies, in which Leonardo's text had been more or less mutilated, and which were all fragmentary. The oldest and on the whole the best copy of Leonardo's essays and precepts on Painting is in the Vatican Library; this has been twice printed, first by Manzi, in 1817, and secondly by Ludwig, in 1882. Still, this ancient copy, and the published editions of it, contain much for which it would be rash to hold Leonardo responsible, and some portions--such as the very important rules for the proportions of the human figure--are wholly wanting; on the other hand they contain passages which, if they are genuine, cannot now be verified from any original Manuscript extant. These copies, at any rate neither give us the original order of the texts, as written by Leonardo, nor do they afford any substitute, by connecting them on a rational scheme; indeed, in their chaotic confusion they are anything rather than satisfactory reading. The fault, no doubt, rests with the compiler of the Vatican copy, which would seem to be the source whence all the published and extensively known texts were derived; for, instead of arranging the passages himself, he was satisfied with recording a suggestion for a final arrangement of them into eight distinct parts, without attempting to carry out his scheme. Under the mistaken idea that this plan of distribution might be that, not of the compiler, but of Leonardo himself, the various editors, down to the present day, have very injudiciously continued to adopt this order--or rather disorder.

I, like other enquirers, had given up the original Manuscript of the Trattato della Pittura for lost, till, in the beginning of 1880, I was enabled, by the liberality of Lord Ashburnham, to inspect his Manuscripts, and was so happy as to discover among them the original text of the best-known portion of the Trattato in his magnificent library at Ashburnham Place. Though this discovery was of a fragment only--but a considerable fragment--inciting me to further search, it gave the key to the mystery which had so long enveloped the first origin of all the known copies of the Trattato. The extensive researches I was subsequently enabled to prosecute, and the results of which are combined in this work, were only rendered possible by the unrestricted permission granted me to investigate all the Manuscripts by Leonardo dispersed throughout Europe, and to reproduce the highly important original sketches they contain, by the process of "photogravure". Her Majesty the Queen graciously accorded me special permission to copy for publication the Manuscripts at the Royal Library at Windsor. The Commission Centrale Administrative de l'Institut de France, Paris, gave me, in the most liberal manner, in answer to an application from Sir Frederic Leighton, P. R. A., Corresponding member of the Institut, free permission to work for several months in their private collection at deciphering the Manuscripts preserved there. The same favour which Lord Ashburnham had already granted me was extended to me by the

Earl of Leicester, the Marchese Trivulsi, and the Curators of the Ambrosian Library at Milan, by the Conte Manzoni at Rome and by other private owners of Manuscripts of Leonardo's; as also by the Directors of the Louvre at Paris; the Accademia at Venice; the Uffizi at Florence; the Royal Library at Turin; and the British Museum, and the South Kensington Museum. I am also greatly indebted to the Librarians of these various collections for much assistance in my labours; and more particularly to Monsieur Louis Lalanne, of the Institut de France, the Abbate Ceriani, of the Ambrosian Library, Mr. Maude Thompson, Keeper of Manuscripts at the British Museum, Mr. Holmes, the Queens Librarian at Windsor, the Revd Vere Bayne, Librarian of Christ Church College at Oxford, and the Revd A. Napier, Librarian to the Earl of Leicester at Holkham Hall.

In correcting the Italian text for the press, I have had the advantage of valuable advice from the Commendatore Giov. Morelli, Senatore del Regno, and from Signor Gustavo Frizzoni, of Milan. The translation, under many difficulties, of the Italian text into English, is mainly due to Mrs. R. C. Bell; while the rendering of several of the most puzzling and important passages, particularly in the second half of Vol. I, I owe to the indefatigable interest taken in this work by Mr. E. J. Poynter R. A. Finally I must express my thanks to Mr. Alfred Marks, of Long Ditton, who has most kindly assisted me throughout in the revision of the proof sheets.

The notes and dissertations on the texts on Architecture in Vol. II I owe to my friend Baron Henri de Geymuller, of Paris.

I may further mention with regard to the illustrations, that the negatives for the production of the "photo-gravures" by Monsieur Dujardin of Paris were all taken direct from the originals.

It is scarcely necessary to add that most of the drawings here reproduced in facsimile have never been published before. As I am now, on the termination of a work of several years' duration, in a position to review the general tenour of Leonardos writings, I may perhaps be permitted to add a word as to my own estimate of the value of their contents. I have already shown that it is due to nothing but a fortuitous succession of unfortunate circumstances, that we should not, long since, have known Leonardo, not merely as a Painter, but as an Author, a Philosopher, and a Naturalist. There can be no doubt that in more than one department his principles and discoveries were infinitely more in accord with the teachings of modern science, than with the views of his contemporaries. For this reason his extraordinary gifts and merits are far more likely to be appreciated in our own time than they could have been during the preceding centuries. He has been unjustly accused of having squandered his powers, by beginning a variety of studies and then, having hardly begun, throwing them aside. The truth is that the labours of three centuries have hardly sufficed for the elucidation of some of the problems which occupied his mighty mind.

Alexander von Humboldt has borne witness that "he was the first to

start on the road towards the point where all the impressions of our senses converge in the idea of the Unity of Nature" Nay, yet more may be said. The very words which are inscribed on the monument of Alexander von Humboldt himself, at Berlin, are perhaps the most appropriate in which we can sum up our estimate of Leonardo's genius:

"Majestati naturae par ingenium."

LONDON, April 1883.

F. P. R.

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The author's intention to publish his MSS.

1.

How by a certain machine many may stay some time under water. And how and wherefore I do not describe my method of remaining under water and how long I can remain without eating. And I do not publish nor divulge these, by reason of the evil nature of men, who would use them for assassinations at the bottom of the sea by destroying ships, and sinking them, together with the men in them. Nevertheless I will impart others, which are not dangerous because the mouth of the tube through which you breathe is above the water, supported on air sacks or cork.

[Footnote: The leaf on which this passage is written, is headed with the words \_Casi\_ 39, and most of these cases begin with the word

'\_Come\_', like the two here given, which are the 26th and 27th. 7.  
\_Sughero\_. In the Codex Atlanticus 377a; 1170a there is a sketch,  
drawn with the pen, representing a man with a tube in his mouth, and  
at the farther end of the tube a disk. By the tube the word  
'\_Channa\_' is written, and by the disk the word '\_sughero\_'.]

The preparation of the MSS. for publication.

2.

When you put together the science of the motions of water, remember  
to include under each proposition its application and use, in order  
that this science may not be useless.--

[Footnote: A comparatively small portion of Leonardo's notes on  
water-power was published at Bologna in 1828, under the title: "\_Del  
moto e misura dell'Acqua, di L. da Vinci\_".]

Admonition to readers.

3.

Let no man who is not a Mathematician read the elements of my work.

The disorder in the MSS.

4.

Begun at Florence, in the house of Piero di Braccio Martelli, on the  
22nd day of March 1508. And this is to be a collection without  
order, taken from many papers which I have copied here, hoping to  
arrange them later each in its place, according to the subjects of  
which they may treat. But I believe that before I am at the end of  
this [task] I shall have to repeat the same things several times;  
for which, O reader! do not blame me, for the subjects are many and  
memory cannot retain them [all] and say: 'I will not write this  
because I wrote it before.' And if I wished to avoid falling into  
this fault, it would be necessary in every case when I wanted to  
copy [a passage] that, not to repeat myself, I should read over all  
that had gone before; and all the more since the intervals are long  
between one time of writing and the next.

[Footnote: 1. In the history of Florence in the early part of the  
XVIth century \_Piero di Braccio Martelli\_ is frequently mentioned as  
\_Commissario della Signoria\_. He was famous for his learning and at  
his death left four books on Mathematics ready for the press; comp.  
LITTA, \_Famiglie celebri Italiane\_, \_Famiglia Martelli di  
Firenze\_.--In the Official Catalogue of MSS. in the Brit. Mus., New  
Series Vol. I., where this passage is printed, \_Barto\_ has been  
wrongly given for Braccio.

2. \_addi 22 di marzo 1508\_. The Christian era was computed in  
Florence at that time from the Incarnation (Lady day, March 25th).

Hence this should be 1509 by our reckoning.

3. *racolto tratto di molte carte le quali io ho qui copiate*. We must suppose that Leonardo means that he has copied out his own MSS. and not those of others. The first thirteen leaves of the MS. in the Brit. Mus. are a fair copy of some notes on physics.]

Suggestions for the arrangement of MSS treating of particular subjects.(5-8).

5.

Of digging a canal. Put this in the Book of useful inventions and in proving them bring forward the propositions already proved. And this is the proper order; since if you wished to show the usefulness of any plan you would be obliged again to devise new machines to prove its utility and thus would confuse the order of the forty Books and also the order of the diagrams; that is to say you would have to mix up practice with theory, which would produce a confused and incoherent work.

6.

I am not to blame for putting forward, in the course of my work on science, any general rule derived from a previous conclusion.

7.

The Book of the science of Mechanics must precede the Book of useful inventions.--Have your books on anatomy bound! [Footnote: 4. The numerous notes on anatomy written on loose leaves and now in the Royal collection at Windsor can best be classified in four Books, corresponding to the different character and size of the paper. When Leonardo speaks of '*li tua libri di notomia*', he probably means the MSS. which still exist; if this hypothesis is correct the present condition of these leaves might seem to prove that he only carried out his purpose with one of the Books on anatomy. A borrowed book on Anatomy is mentioned in F.O.]

8.

The order of your book must proceed on this plan: first simple beams, then (those) supported from below, then suspended in part, then wholly [suspended]. Then beams as supporting other weights [Footnote: 4. Leonardo's notes on Mechanics are extraordinarily numerous; but, for the reasons assigned in my introduction, they have not been included in the present work.].

General introductions to the book on Painting (9-13).

9.

INTRODUCTION.

Seeing that I can find no subject specially useful or pleasing--since the men who have come before me have taken for their own every useful or necessary theme--I must do like one who, being poor, comes last to the fair, and can find no other way of providing himself than by taking all the things already seen by other buyers, and not taken but refused by reason of their lesser value. I, then, will load my humble pack with this despised and rejected merchandise, the refuse of so many buyers; and will go about to distribute it, not indeed in great cities, but in the poorer towns, taking such a price as the wares I offer may be worth. [Footnote: It need hardly be pointed out that there is in this 'Proemio' a covert irony. In the second and third prefaces, Leonardo characterises his rivals and opponents more closely. His protest is directed against Neo-Latinism as professed by most of the humanists of his time; its futility is now no longer questioned.]

10.

#### INTRODUCTION.

I know that many will call this useless work [Footnote: 3. questa essere opera inutile. By opera we must here understand libro di pittura and particularly the treatise on Perspective.]; and they will be those of whom Demetrius [Footnote: 4. Demetrio. "With regard to the passage attributed to Demetrius", Dr. H. MÜLLER STRÜBING writes, "I know not what to make of it. It is certainly not Demetrius Phalereus that is meant and it can hardly be Demetrius Poliorcetes. Who then can it be--for the name is a very common one? It may be a clerical error for Demades and the maxim is quite in the spirit of his writings I have not however been able to find any corresponding passage either in the 'Fragments' (C. MULLER, \_Orat. Att.\_, II. 441) nor in the Supplements collected by DIETZ (\_Rhein. Mus.\_, vol. 29, p. 108)."]

The same passage occurs as a simple Memorandum in the MS. Tr. 57, apparently as a note for this '\_Proemio\_' thus affording some data as to the time where these introductions were written.] declared that he took no more account of the wind that came out their mouth in words, than of that they expelled from their lower parts: men who desire nothing but material riches and are absolutely devoid of that of wisdom, which is the food and the only true riches of the mind. For so much more worthy as the soul is than the body, so much more noble are the possessions of the soul than those of the body. And often, when I see one of these men take this work in his hand, I wonder that he does not put it to his nose, like a monkey, or ask me if it is something good to eat.

[Footnote: In the original, the Proemio di prospettiva cioè dell'uffitio dell'occhio (see No. 21) stands between this and the preceding one, No. 9.]

#### INTRODUCTION.

I am fully conscious that, not being a literary man, certain presumptuous persons will think that they may reasonably blame me; alleging that I am not a man of letters. Foolish folks! do they not know that I might retort as Marius did to the Roman Patricians [Footnote 21: *„Come Mario disse ai patriti Romani\_.* "I am unable to find the words here attributed by Leonardo to Marius, either in Plutarch's *Life of Marius* or in the *Apophthegmata (Moralia,* p.202). Nor do they occur in the writings of Valerius Maximus (who frequently mentions Marius) nor in Velleius Paterculus (II, 11 to 43), Dio Cassius, Aulus Gellius, or Macrobius. Professor E. MENDELSON of Dorpat, the editor of Herodian, assures me that no such passage is found in that author" (communication from Dr. MULLER STRUBING). Leonardo evidently meant to allude to some well known incident in Roman history and the mention of Marius is the result probably of some confusion. We may perhaps read, for Marius, Menenius Agrippa, though in that case it is true we must alter Patriti to Plebei. The change is a serious one. but it would render the passage perfectly clear.] by saying: That they, who deck themselves out in the labours of others will not allow me my own. They will say that I, having no literary skill, cannot properly express that which I desire to treat of [Footnote 26: *„le mie cose .... che d'altra parola\_.* This can hardly be reconciled with Mons. RAVAISSON'S estimate of L. da Vinci's learning. "*Leonard de Vinci etait un admirateur et un disciple des anciens, aussi bien dans l'art que dans la science et il tenait a passer pour tel meme aux yeux de la posterite.\_*" *Gaz. des Beaux arts.* Oct. 1877.]; but they do not know that my subjects are to be dealt with by experience rather than by words [Footnote 28: See Footnote 26]; and [experience] has been the mistress of those who wrote well. And so, as mistress, I will cite her in all cases.

11.

Though I may not, like them, be able to quote other authors, I shall rely on that which is much greater and more worthy:--on experience, the mistress of their Masters. They go about puffed up and pompous, dressed and decorated with [the fruits], not of their own labours, but of those of others. And they will not allow me my own. They will scorn me as an inventor; but how much more might they--who are not inventors but vaunters and declaimers of the works of others--be blamed.

#### INTRODUCTION.

And those men who are inventors and interpreters between Nature and Man, as compared with boasters and declaimers of the works of others, must be regarded and not otherwise esteemed than as the object in front of a mirror, when compared with its image seen in the mirror. For the first is something in itself, and the other nothingness.--Folks little indebted to Nature, since it is only by chance that they wear the human form and without it I might class them with the herds of beasts.

12.

Many will think they may reasonably blame me by alleging that my proofs are opposed to the authority of certain men held in the highest reverence by their inexperienced judgments; not considering that my works are the issue of pure and simple experience, who is the one true mistress. These rules are sufficient to enable you to know the true from the false--and this aids men to look only for things that are possible and with due moderation--and not to wrap yourself in ignorance, a thing which can have no good result, so that in despair you would give yourself up to melancholy.

13.

Among all the studies of natural causes and reasons Light chiefly delights the beholder; and among the great features of Mathematics the certainty of its demonstrations is what preeminently (tends to) elevate the mind of the investigator. Perspective, therefore, must be preferred to all the discourses and systems of human learning. In this branch [of science] the beam of light is explained on those methods of demonstration which form the glory not so much of Mathematics as of Physics and are graced with the flowers of both [Footnote: 5. Such of Leonardo's notes on Optics or on Perspective as bear exclusively on Mathematics or Physics could not be included in the arrangement of the *\_libro di pittura\_* which is here presented to the reader. They are however but few.]. But its axioms being laid down at great length, I shall abridge them to a conclusive brevity, arranging them on the method both of their natural order and of mathematical demonstration; sometimes by deduction of the effects from the causes, and sometimes arguing the causes from the effects; adding also to my own conclusions some which, though not included in them, may nevertheless be inferred from them. Thus, if the Lord--who is the light of all things--vouchsafe to enlighten me, I will treat of Light; wherefore I will divide the present work into 3 Parts [Footnote: 10. In the middle ages--for instance, by ROGER BACON, by VITELLONE, with whose works Leonardo was certainly familiar, and by all the writers of the Renaissance Perspective and Optics were not regarded as distinct sciences. Perspective, indeed, is in its widest application the science of seeing. Although to Leonardo the two sciences were clearly separate, it is not so as to their names; thus we find axioms in Optics under the heading Perspective. According to this arrangement of the materials for the theoretical portion of the *\_libro di pittura\_* propositions in Perspective and in Optics stand side by side or occur alternately. Although this particular chapter deals only with Optics, it is not improbable that the words *\_partirò la presente opera in 3 parti\_* may refer to the same division into three sections which is spoken of in chapters 14 to 17.].

The plan of the book on Painting (14--17).

14.



## ON THE THREE BRANCHES OF PERSPECTIVE.

There are three branches of perspective; the first deals with the reasons of the (apparent) diminution of objects as they recede from the eye, and is known as Diminishing Perspective.--The second contains the way in which colours vary as they recede from the eye. The third and last is concerned with the explanation of how the objects [in a picture] ought to be less finished in proportion as they are remote (and the names are as follows):

Linear Perspective. The Perspective of Colour. The Perspective of Disappearance.

[Footnote: 13. From the character of the handwriting I infer that this passage was written before the year 1490.]

15.

## ON PAINTING AND PERSPECTIVE.

The divisions of Perspective are 3, as used in drawing; of these, the first includes the diminution in size of opaque objects; the second treats of the diminution and loss of outline in such opaque objects; the third, of the diminution and loss of colour at long distances.

[Footnote: The division is here the same as in the previous chapter No. 14, and this is worthy of note when we connect it with the fact that a space of about 20 years must have intervened between the writing of the two passages.]

16.

## THE DISCOURSE ON PAINTING.

Perspective, as bearing on drawing, is divided into three principal sections; of which the first treats of the diminution in the size of bodies at different distances. The second part is that which treats of the diminution in colour in these objects. The third [deals with] the diminished distinctness of the forms and outlines displayed by the objects at various distances.

17.

## ON THE SECTIONS OF [THE BOOK ON] PAINTING.

The first thing in painting is that the objects it represents should appear in relief, and that the grounds surrounding them at different distances shall appear within the vertical plane of the foreground of the picture by means of the 3 branches of Perspective, which are: the diminution in the distinctness of the forms of the objects, the diminution in their magnitude; and the diminution in their colour. And of these 3 classes of Perspective the first results from [the

structure of] the eye, while the other two are caused by the atmosphere which intervenes between the eye and the objects seen by it. The second essential in painting is appropriate action and a due variety in the figures, so that the men may not all look like brothers, &c.

[Footnote: This and the two foregoing chapters must have been written in 1513 to 1516. They undoubtedly indicate the scheme which Leonardo wished to carry out in arranging his researches on Perspective as applied to Painting. This is important because it is an evidence against the supposition of H. LUDWIG and others, that Leonardo had collected his principles of Perspective in one book so early as before 1500; a Book which, according to the hypothesis, must have been lost at a very early period, or destroyed possibly, by the French (!) in 1500 (see H. LUDWIG. L. da Vinci: \_Das Buch van der Malerei\_. Vienna 1882 III, 7 and 8).]

The use of the book on Painting.

18.

These rules are of use only in correcting the figures; since every man makes some mistakes in his first compositions and he who knows them not, cannot amend them. But you, knowing your errors, will correct your works and where you find mistakes amend them, and remember never to fall into them again. But if you try to apply these rules in composition you will never make an end, and will produce confusion in your works.

These rules will enable you to have a free and sound judgment; since good judgment is born of clear understanding, and a clear understanding comes of reasons derived from sound rules, and sound rules are the issue of sound experience--the common mother of all the sciences and arts. Hence, bearing in mind the precepts of my rules, you will be able, merely by your amended judgment, to criticise and recognise every thing that is out of proportion in a work, whether in the perspective or in the figures or any thing else.

Necessity of theoretical knowledge (19. 20).

19.

OF THE MISTAKES MADE BY THOSE WHO PRACTISE WITHOUT KNOWLEDGE.

Those who are in love with practice without knowledge are like the sailor who gets into a ship without rudder or compass and who never can be certain whether he is going. Practice must always be founded on sound theory, and to this Perspective is the guide and the gateway; and without this nothing can be done well in the matter of drawing.

20.

The painter who draws merely by practice and by eye, without any reason, is like a mirror which copies every thing placed in front of it without being conscious of their existence.

The function of the eye (21-23).

21.

INTRODUCTION TO PERSPECTIVE:--THAT IS OF THE FUNCTION OF THE EYE.

Behold here O reader! a thing concerning which we cannot trust our forefathers, 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 ages unknown or falsely understood. The eye, whose function we so certainly know by experience, has, down to my own time, been defined by an infinite number of authors as one thing; but I find, by experience, that it is quite another. [Footnote 13: Compare the note to No. 70.]

[Footnote: In section 13 we already find it indicated that the study of Perspective and of Optics is to be based on that of the functions of the eye. Leonardo also refers to the science of the eye, in his astronomical researches, for instance in MS. F 25b 'Ordine del provare la terra essere una stella: Imprima difinisce l'occhio', &c. Compare also MS. E 15b and F 60b. The principles of astronomical perspective.]

22.

Here [in the eye] forms, here colours, here the character of every part of the universe are concentrated to a point; and that point is so marvellous a thing ... Oh! marvellous, O stupendous Necessity--by thy laws thou dost compel every effect to be the direct result of its cause, by the shortest path. These [indeed] are miracles;...

In so small a space it can be reproduced and rearranged in its whole expanse. Describe in your anatomy what proportion there is between the diameters of all the images in the eye and the distance from them of the crystalline lens.

23.

OF THE 10 ATTRIBUTES OF THE EYE, ALL CONCERNED IN PAINTING.

Painting is concerned with all the 10 attributes of sight; which are:--Darkness, Light, Solidity and Colour, Form and Position, Distance and Propinquity, Motion and Rest. This little work of mine will be a tissue [of the studies] of these attributes, reminding the painter of the rules and methods by which he should use his art to imitate all the works of Nature which adorn the world.

24.

#### ON PAINTING.

Variability of the eye.

1st. The pupil of the eye contracts, in proportion to the increase of light which is reflected in it. 2nd. The pupil of the eye expands in proportion to the diminution in the day light, or any other light, that is reflected in it. 3rd. [Footnote: 8. The subject of this third proposition we find fully discussed in MS. G. 44a.]. The eye perceives and recognises the objects of its vision with greater intensity in proportion as the pupil is more widely dilated; and this can be proved by the case of nocturnal animals, such as cats, and certain birds--as the owl and others--in which the pupil varies in a high degree from large to small, &c., when in the dark or in the light. 4th. The eye [out of doors] in an illuminated atmosphere sees darkness behind the windows of houses which [nevertheless] are light. 5th. All colours when placed in the shade appear of an equal degree of darkness, among themselves. 6th. But all colours when placed in a full light, never vary from their true and essential hue.

25.

#### OF THE EYE.

Focus of sight.

If the eye is required to look at an object placed too near to it, it cannot judge of it well--as happens to a man who tries to see the tip of his nose. Hence, as a general rule, Nature teaches us that an object can never be seen perfectly unless the space between it and the eye is equal, at least, to the length of the face.

Differences of perception by one eye and by both eyes (26-29).

26.

#### OF THE EYE.

When both eyes direct the pyramid of sight to an object, that object becomes clearly seen and comprehended by the eyes.

27.

Objects seen by one and the same eye appear sometimes large, and sometimes small.

28.

The motion of a spectator who sees an object at rest often makes it seem as though the object at rest had acquired the motion of the

moving body, while the moving person appears to be at rest.

#### ON PAINTING.

Objects in relief, when seen from a short distance with one eye, look like a perfect picture. If you look with the eye a, b at the spot c, this point c will appear to be at d, f, and if you look at it with the eye g, h will appear to be at m. A picture can never contain in itself both aspects.

29.

Let the object in relief t be seen by both eyes; if you will look at the object with the right eye m, keeping the left eye n shut, the object will appear, or fill up the space, at a; and if you shut the right eye and open the left, the object (will occupy the) space b; and if you open both eyes, the object will no longer appear at a or b, but at e, r, f. Why will not a picture seen by both eyes produce the effect of relief, as [real] relief does when seen by both eyes; and why should a picture seen with one eye give the same effect of relief as real relief would under the same conditions of light and shade?

[Footnote: In the sketch, m is the left eye and n the right, while the text reverses this lettering. We must therefore suppose that the face in which the eyes m and n are placed is opposite to the spectator.]

30.

The comparative size of the image depends on the amount of light (30-39).

The eye will hold and retain in itself the image of a luminous body better than that of a shaded object. The reason is that the eye is in itself perfectly dark and since two things that are alike cannot be distinguished, therefore the night, and other dark objects cannot be seen or recognised by the eye. Light is totally contrary and gives more distinctness, and counteracts and differs from the usual darkness of the eye, hence it leaves the impression of its image.

31.

Every object we see will appear larger at midnight than at midday, and larger in the morning than at midday.

This happens because the pupil of the eye is much smaller at midday than at any other time.

32.

The pupil which is largest will see objects the largest. This is evident when we look at luminous bodies, and particularly at those

in the sky. When the eye comes out of darkness and suddenly looks up at these bodies, they at first appear larger and then diminish; and if you were to look at those bodies through a small opening, you would see them smaller still, because a smaller part of the pupil would exercise its function.

[Footnote: 9. \_buso\_ in the Lomb. dialect is the same as \_buco\_.]

33.

When the eye, coming out of darkness suddenly sees a luminous body, it will appear much larger at first sight than after long looking at it. The illuminated object will look larger and more brilliant, when seen with two eyes than with only one. A luminous object will appear smaller in size, when the eye sees it through a smaller opening. A luminous body of an oval form will appear rounder in proportion as it is farther from the eye.

34.

Why when the eye has just seen the light, does the half light look dark to it, and in the same way if it turns from the darkness the half light look very bright?

35.

#### ON PAINTING.

If the eye, when [out of doors] in the luminous atmosphere, sees a place in shadow, this will look very much darker than it really is. This happens only because the eye when out in the air contracts the pupil in proportion as the atmosphere reflected in it is more luminous. And the more the pupil contracts, the less luminous do the objects appear that it sees. But as soon as the eye enters into a shady place the darkness of the shadow suddenly seems to diminish. This occurs because the greater the darkness into which the pupil goes the more its size increases, and this increase makes the darkness seem less.

[Footnote 14: \_La luce entrerà\_. \_Luce\_ occurs here in the sense of pupil of the eye as in no 51: C. A. 84b; 245a; I--5; and in many other places.]

36.

#### ON PERSPECTIVE.

The eye which turns from a white object in the light of the sun and goes into a less fully lighted place will see everything as dark. And this happens either because the pupils of the eyes which have rested on this brilliantly lighted white object have contracted so much that, given at first a certain extent of surface, they will have lost more than 3/4 of their size; and, lacking in size, they

are also deficient in [seeing] power. Though you might say to me: A little bird (then) coming down would see comparatively little, and from the smallness of his pupils the white might seem black! To this I should reply that here we must have regard to the proportion of the mass of that portion of the brain which is given up to the sense of sight and to nothing else. Or--to return--this pupil in Man dilates and contracts according to the brightness or darkness of (surrounding) objects; and since it takes some time to dilate and contract, it cannot see immediately on going out of the light and into the shade, nor, in the same way, out of the shade into the light, and this very thing has already deceived me in painting an eye, and from that I learnt it.

37.

Experiment [showing] the dilatation and contraction of the pupil, from the motion of the sun and other luminaries. In proportion as the sky is darker the stars appear of larger size, and if you were to light up the medium these stars would look smaller; and this difference arises solely from the pupil which dilates and contracts with the amount of light in the medium which is interposed between the eye and the luminous body. Let the experiment be made, by placing a candle above your head at the same time that you look at a star; then gradually lower the candle till it is on a level with the ray that comes from the star to the eye, and then you will see the star diminish so much that you will almost lose sight of it.

[Footnote: No reference is made in the text to the letters on the accompanying diagram.]

38.

The pupil of the eye, in the open air, changes in size with every degree of motion from the sun; and at every degree of its changes one and the same object seen by it will appear of a different size; although most frequently the relative scale of surrounding objects does not allow us to detect these variations in any single object we may look at.

39.

The eye--which sees all objects reversed--retains the images for some time. This conclusion is proved by the results; because, the eye having gazed at light retains some impression of it. After looking (at it) there remain in the eye images of intense brightness, that make any less brilliant spot seem dark until the eye has lost the last trace of the impression of the stronger light.

\_II.

Linear Perspective.

We see clearly from the concluding sentence of section 49, where the

author directly addresses the painter, that he must certainly have intended to include the elements of mathematics in his Book on the art of Painting. They are therefore here placed at the beginning. In section 50 the theory of the "Pyramid of Sight" is distinctly and expressly put forward as the fundamental principle of linear perspective, and sections 52 to 57 treat of it fully. This theory of sight can scarcely be traced to any author of antiquity. Such passages as occur in Euclid for instance, may, it is true, have proved suggestive to the painters of the Renaissance, but it would be rash to say any thing decisive on this point.

Leon Battista Alberti treats of the "Pyramid of Sight" at some length in his first Book of Painting; but his explanation differs widely from Leonardo's in the details. Leonardo, like Alberti, may have borrowed the broad lines of his theory from some views commonly accepted among painters at the time; but he certainly worked out its application in a perfectly original manner.

The axioms as to the perception of the pyramid of rays are followed by explanations of its origin, and proofs of its universal application (58--69). The author recurs to the subject with endless variations; it is evidently of fundamental importance in his artistic theory and practice. It is unnecessary to discuss how far this theory has any scientific value at the present day; so much as this, at any rate, seems certain: that from the artist's point of view it may still claim to be of immense practical utility.

According to Leonardo, on one hand, the laws of perspective are an inalienable condition of the existence of objects in space; on the other hand, by a natural law, the eye, whatever it sees and wherever it turns, is subjected to the perception of the pyramid of rays in the form of a minute target. Thus it sees objects in perspective independently of the will of the spectator, since the eye receives the images by means of the pyramid of rays "just as a magnet attracts iron".

In connection with this we have the function of the eye explained by the Camera obscura, and this is all the more interesting and important because no writer previous to Leonardo had treated of this subject\_ (70--73). \_Subsequent passages, of no less special interest, betray his knowledge of refraction and of the inversion of the image in the camera and in the eye\_ (74--82).

\_From the principle of the transmission of the image to the eye and to the camera obscura he deduces the means of producing an artificial construction of the pyramid of rays or--which is the same thing--of the image. The fundamental axioms as to the angle of sight and the vanishing point are thus presented in a manner which is as complete as it is simple and intelligible\_ (86--89).

\_Leonardo distinguishes between simple and complex perspective\_ (90, 91). \_The last sections treat of the apparent size of objects at various distances and of the way to estimate it\_ (92--109).



General remarks on perspective (40-41).

40.

ON PAINTING.

Perspective is the best guide to the art of Painting.

[Footnote: 40. Compare 53, 2.]

41.

The art of perspective is of such a nature as to make what is flat appear in relief and what is in relief flat.

The elements of perspective--Of the Point (42-46).

42.

All the problems of perspective are made clear by the five terms of mathematicians, which are:--the point, the line, the angle, the superficies and the solid. The point is unique of its kind. And the point has neither height, breadth, length, nor depth, whence it is to be regarded as indivisible and as having no dimensions in space. The line is of three kinds, straight, curved and sinuous and it has neither breadth, height, nor depth. Hence it is indivisible, excepting in its length, and its ends are two points. The angle is the junction of two lines in a point.

43.

A point is not part of a line.

44.

OF THE NATURAL POINT.

The smallest natural point is larger than all mathematical points, and this is proved because the natural point has continuity, and any thing that is continuous is infinitely divisible; but the mathematical point is indivisible because it has no size.

[Footnote: This definition was inserted by Leonardo on a MS. copy on parchment of the well-known "Trattato d'Architettura civile e militare" &c. by FRANCESCO DI GIORGIO; opposite a passage where the author says: "In prima he da sapere che punto Ł quella parie della quale he nulla--Linia he luncheza senza àpieza; &c.]

45.

1, The superficies is a limitation of the body. 2, and the limitation of a body is no part of that body. 4, and the limitation

of one body is that which begins another. 3, that which is not part of any body is nothing. Nothing is that which fills no space.

If one single point placed in a circle may be the starting point of an infinite number of lines, and the termination of an infinite number of lines, there must be an infinite number of points separable from this point, and these when reunited become one again; whence it follows that the part may be equal to the whole.

46.

The point, being indivisible, occupies no space. That which occupies no space is nothing. The limiting surface of one thing is the beginning of another. 2. That which is no part of any body is called nothing. 1. That which has no limitations, has no form. The limitations of two conterminous bodies are interchangeably the surface of each. All the surfaces of a body are not parts of that body.

Of the line (47-48).

47.

DEFINITION OF THE NATURE OF THE LINE.

The line has in itself neither matter nor substance and may rather be called an imaginary idea than a real object; and this being its nature it occupies no space. Therefore an infinite number of lines may be conceived of as intersecting each other at a point, which has no dimensions and is only of the thickness (if thickness it may be called) of one single line.

HOW WE MAY CONCLUDE THAT A SUPERFICIES TERMINATES IN A POINT?

An angular surface is reduced to a point where it terminates in an angle. Or, if the sides of that angle are produced in a straight line, then--beyond that angle--another surface is generated, smaller, or equal to, or larger than the first.

48.

OF DRAWING OUTLINE.

Consider with the greatest care the form of the outlines of every object, and the character of their undulations. And these undulations must be separately studied, as to whether the curves are composed of arched convexities or angular concavities.

49.

The nature of the outline.

The boundaries of bodies are the least of all things. The

proposition is proved to be true, because the boundary of a thing is a surface, which is not part of the body contained within that surface; nor is it part of the air surrounding that body, but is the medium interposted between the air and the body, as is proved in its place. But the lateral boundaries of these bodies is the line forming the boundary of the surface, which line is of invisible thickness. Wherefore O painter! do not surround your bodies with lines, and above all when representing objects smaller than nature; for not only will their external outlines become indistinct, but their parts will be invisible from distance.

50.

Definition of Perspective.

[Drawing is based upon perspective, which is nothing else than a thorough knowledge of the function of the eye. And this function simply consists in receiving in a pyramid the forms and colours of all the objects placed before it. I say in a pyramid, because there is no object so small that it will not be larger than the spot where these pyramids are received into the eye. Therefore, if you extend the lines from the edges of each body as they converge you will bring them to a single point, and necessarily the said lines must form a pyramid.]

[Perspective is nothing more than a rational demonstration applied to the consideration of how objects in front of the eye transmit their image to it, by means of a pyramid of lines. The Pyramid is the name I apply to the lines which, starting from the surface and edges of each object, converge from a distance and meet in a single point.]

[Perspective is a rational demonstration, by which we may practically and clearly understand how objects transmit their own image, by lines forming a Pyramid (centred) in the eye.]

Perspective is a rational demonstration by which experience confirms that every object sends its image to the eye by a pyramid of lines; and bodies of equal size will result in a pyramid of larger or smaller size, according to the difference in their distance, one from the other. By a pyramid of lines I mean those which start from the surface and edges of bodies, and, converging from a distance meet in a single point. A point is said to be that which [having no dimensions] cannot be divided, and this point placed in the eye receives all the points of the cone.

[Footnote: 50. 1-5. Compare with this the Proem. No. 21. The paragraphs placed in brackets: lines 1-9, 10-14, and 17--20, are evidently mere sketches and, as such, were cancelled by the writer; but they serve as a commentary on the final paragraph, lines 22-29.]

51.

## IN WHAT WAY THE EYE SEES OBJECTS PLACED IN FRONT OF IT.

The perception of the object depends on the direction of the eye.

Supposing that the ball figured above is the ball of the eye and let the small portion of the ball which is cut off by the line *s t* be the pupil and all the objects mirrored on the centre of the face of the eye, by means of the pupil, pass on at once and enter the pupil, passing through the crystalline humour, which does not interfere in the pupil with the things seen by means of the light. And the pupil having received the objects, by means of the light, immediately refers them and transmits them to the intellect by the line *a b*. And you must know that the pupil transmits nothing perfectly to the intellect or common sense excepting when the objects presented to it by means of light, reach it by the line *a b*; as, for instance, by the line *b c*. For although the lines *m n* and *f g* may be seen by the pupil they are not perfectly taken in, because they do not coincide with the line *a b*. And the proof is this: If the eye, shown above, wants to count the letters placed in front, the eye will be obliged to turn from letter to letter, because it cannot discern them unless they lie in the line *a b*; as, for instance, in the line *a c*. All visible objects reach the eye by the lines of a pyramid, and the point of the pyramid is the apex and centre of it, in the centre of the pupil, as figured above.

[Footnote: 51. In this problem the eye is conceived of as fixed and immovable; this is plain from line 11.]

Experimental proof of the existence of the pyramid of sight (52-55).

52.

Perspective is a rational demonstration, confirmed by experience, that all objects transmit their image to the eye by a pyramid of lines.

By a pyramid of lines I understand those lines which start from the edges of the surface of bodies, and converging from a distance, meet in a single point; and this point, in the present instance, I will show to be situated in the eye which is the universal judge of all objects. By a point I mean that which cannot be divided into parts; therefore this point, which is situated in the eye, being indivisible, no body is seen by the eye, that is not larger than this point. This being the case it is inevitable that the lines which come from the object to the point must form a pyramid. And if any man seeks to prove that the sense of sight does not reside in this point, but rather in the black spot which is visible in the middle of the pupil, I might reply to him that a small object could never diminish at any distance, as it might be a grain of millet or of oats or of some similar thing, and that object, if it were larger than the said [black] spot would never be seen as a whole; as may be seen in the diagram below. Let *a* be the seat of sight, *b e* the lines which reach the eye. Let *e d* be the grains of millet within

these lines. You plainly see that these will never diminish by distance, and that the body  $mn$  could not be entirely covered by it. Therefore you must confess that the eye contains within itself one single indivisible point  $a$ , to which all the points converge of the pyramid of lines starting from an object, as is shown below. Let  $a$ .  $b$ . be the eye; in the centre of it is the point above mentioned. If the line  $ef$  is to enter as an image into so small an opening in the eye, you must confess that the smaller object cannot enter into what is smaller than itself unless it is diminished, and by diminishing it must take the form of a pyramid.

53.

#### PERSPECTIVE.

Perspective comes in where judgment fails [as to the distance] in objects which diminish. The eye can never be a true judge for determining with exactitude how near one object is to another which is equal to it [in size], if the top of that other is on the level of the eye which sees them on that side, excepting by means of the vertical plane which is the standard and guide of perspective. Let  $n$  be the eye,  $ef$  the vertical plane above mentioned. Let  $abcd$  be the three divisions, one below the other; if the lines  $an$  and  $cn$  are of a given length and the eye  $n$  is in the centre, then  $ab$  will look as large as  $bc$ .  $cd$  is lower and farther off from  $n$ , therefore it will look smaller. And the same effect will appear in the three divisions of a face when the eye of the painter who is drawing it is on a level with the eye of the person he is painting.

54.

#### TO PROVE HOW OBJECTS REACH THE EYE.

If you look at the sun or some other luminous body and then shut your eyes you will see it again inside your eye for a long time. This is evidence that images enter into the eye.

The relations of the distance points to the vanishing point (55-56).

55.

#### ELEMENTS OF PERSPECTIVE.

All objects transmit their image to the eye in pyramids, and the nearer to the eye these pyramids are intersected the smaller will the image appear of the objects which cause them. Therefore, you may intersect the pyramid with a vertical plane [Footnote 4:  $\text{\_Pariete\_}$ . Compare the definitions in 85, 2-5, 6-27. These lines refer exclusively to the third diagram. For the better understanding of this it should be observed that  $cs$  must be regarded as representing the section or profile of a square plane, placed horizontally (comp. lines 11, 14, 17) for which the word  $\text{\_pianura\_}$

is subsequently employed (20, 22). Lines 6-13 contain certain preliminary observations to guide the reader in understanding the diagram; the last three seem to have been added as a supplement. Leonardo's mistake in writing *t* denota (line 6) for *f* denota has been rectified.] which reaches the base of the pyramid as is shown in the plane *a n*.

The eye *f* and the eye *t* are one and the same thing; but the eye *f* marks the distance, that is to say how far you are standing from the object; and the eye *t* shows you the direction of it; that is whether you are opposite, or on one side, or at an angle to the object you are looking at. And remember that the eye *f* and the eye *t* must always be kept on the same level. For example if you raise or lower the eye from the distance point *f* you must do the same with the direction point *t*. And if the point *f* shows how far the eye is distant from the square plane but does not show on which side it is placed--and, in the same way, the point *t* show *s* the direction and not the distance, in order to ascertain both you must use both points and they will be one and the same thing. If the eye *f* could see a perfect square of which all the sides were equal to the distance between *s* and *c*, and if at the nearest end of the side towards the eye a pole were placed, or some other straight object, set up by a perpendicular line as shown at *r s*--then, I say, that if you were to look at the side of the square that is nearest to you it will appear at the bottom of the vertical plane *r s*, and then look at the farther side and it would appear to you at the height of the point *n* on the vertical plane. Thus, by this example, you can understand that if the eye is above a number of objects all placed on the same level, one beyond another, the more remote they are the higher they will seem, up to the level of the eye, but no higher; because objects placed upon the level on which your feet stand, so long as it is flat--even if it be extended into infinity--would never be seen above the eye; since the eye has in itself the point towards which all the cones tend and converge which convey the images of the objects to the eye. And this point always coincides with the point of diminution which is the extreme of all we can see. And from the base line of the first pyramid as far as the diminishing point

[Footnote: The two diagrams above the chapter are explained by the first five lines. They have, however, more letters than are referred to in the text, a circumstance we frequently find occasion to remark.]

56.

there are only bases without pyramids which constantly diminish up to this point. And from the first base where the vertical plane is placed towards the point in the eye there will be only pyramids without bases; as shown in the example given above. Now, let *a b* be the said vertical plane and *r* the point of the pyramid terminating in the eye, and *n* the point of diminution which is always in a straight line opposite the eye and always moves as the

eye moves--just as when a rod is moved its shadow moves, and moves with it, precisely as the shadow moves with a body. And each point is the apex of a pyramid, all having a common base with the intervening vertical plane. But although their bases are equal their angles are not equal, because the diminishing point is the termination of a smaller angle than that of the eye. If you ask me: "By what practical experience can you show me these points?" I reply--so far as concerns the diminishing point which moves with you --when you walk by a ploughed field look at the straight furrows which come down with their ends to the path where you are walking, and you will see that each pair of furrows will look as though they tried to get nearer and meet at the [farther] end.

[Footnote: For the easier understanding of the diagram and of its connection with the preceding I may here remark that the square plane shown above in profile by the line *c s* is here indicated by *e d o p*. According to lines 1, 3 *a b* must be imagined as a plane of glass placed perpendicularly at *o p*.]

57.

How to measure the pyramid of vision.

As regards the point in the eye; it is made more intelligible by this: If you look into the eye of another person you will see your own image. Now imagine 2 lines starting from your ears and going to the ears of that image which you see in the other man's eye; you will understand that these lines converge in such a way that they would meet in a point a little way beyond your own image mirrored in the eye. And if you want to measure the diminution of the pyramid in the air which occupies the space between the object seen and the eye, you must do it according to the diagram figured below. Let *m n* be a tower, and *e f a*, rod, which you must move backwards and forwards till its ends correspond with those of the tower [Footnote 9: *l sua stremi .. della storre* (its ends ... of the tower) this is the case at *e f*]; then bring it nearer to the eye, at *c d* and you will see that the image of the tower seems smaller, as at *r o*. Then [again] bring it closer to the eye and you will see the rod project far beyond the image of the tower from *a* to *b* and from *t* to *b*, and so you will discern that, a little farther within, the lines must converge in a point.

The Production of pyramid of Vision (58-60).

58.

PERSPECTIVE.

The instant the atmosphere is illuminated it will be filled with an infinite number of images which are produced by the various bodies and colours assembled in it. And the eye is the target, a loadstone, of these images.

59.

The whole surface of opaque bodies displays its whole image in all the illuminated atmosphere which surrounds them on all sides.

60.

That the atmosphere attracts to itself, like a loadstone, all the images of the objects that exist in it, and not their forms merely but their nature may be clearly seen by the sun, which is a hot and luminous body. All the atmosphere, which is the all-pervading matter, absorbs light and heat, and reflects in itself the image of the source of that heat and splendour and, in each minutest portion, does the same. The Northpole does the same as the loadstone shows; and the moon and the other planets, without suffering any diminution, do the same. Among terrestrial things musk does the same and other perfumes.

61.

All bodies together, and each by itself, give off to the surrounding air an infinite number of images which are all-pervading and each complete, each conveying the nature, colour and form of the body which produces it.

It can clearly be shown that all bodies are, by their images, all-pervading in the surrounding atmosphere, and each complete in itself as to substance form and colour; this is seen by the images of the various bodies which are reproduced in one single perforation through which they transmit the objects by lines which intersect and cause reversed pyramids, from the objects, so that they are upside down on the dark plane where they are first reflected. The reason of this is--

[Footnote: The diagram intended to illustrate the statement (Pl. II No. i) occurs in the original between lines 3 and 4. The three circles must be understood to represent three luminous bodies which transmit their images through perforations in a wall into a dark chamber, according to a law which is more fully explained in 75?81. So far as concerns the present passage the diagram is only intended to explain that the images of the three bodies may be made to coalesce at any given spot. In the circles are written, giallo--yellow, biàcho--white, rosso--red.

The text breaks off at line 8. The paragraph No.40 follows here in the original MS.]

62.

Every point is the termination of an infinite number of lines, which diverge to form a base, and immediately, from the base the same lines converge to a pyramid [imaging] both the colour and form. No sooner is a form created or compounded than suddenly infinite lines



and angles are produced from it; and these lines, distributing themselves and intersecting each other in the air, give rise to an infinite number of angles opposite to each other. Given a base, each opposite angle, will form a triangle having a form and proportion equal to the larger angle; and if the base goes twice into each of the 2 lines of the pyramid the smaller triangle will do the same.

63.

Every body in light and shade fills the surrounding air with infinite images of itself; and these, by infinite pyramids diffused in the air, represent this body throughout space and on every side. Each pyramid that is composed of a long assemblage of rays includes within itself an infinite number of pyramids and each has the same power as all, and all as each. A circle of equidistant pyramids of vision will give to their object angles of equal size; and an eye at each point will see the object of the same size. The body of the atmosphere is full of infinite pyramids composed of radiating straight lines, which are produced from the surface of the bodies in light and shade, existing in the air; and the farther they are from the object which produces them the more acute they become and although in their distribution they intersect and cross they never mingle together, but pass through all the surrounding air, independently converging, spreading, and diffused. And they are all of equal power [and value]; all equal to each, and each equal to all. By these the images of objects are transmitted through all space and in every direction, and each pyramid, in itself, includes, in each minutest part, the whole form of the body causing it.

64.

The body of the atmosphere is full of infinite radiating pyramids produced by the objects existing in it. These intersect and cross each other with independent convergence without interfering with each other and pass through all the surrounding atmosphere; and are of equal force and value--all being equal to each, each to all. And by means of these, images of the body are transmitted everywhere and on all sides, and each receives in itself every minutest portion of the object that produces it.

Proof by experiment (65-66).

65.

PERSPECTIVE.

The air is filled with endless images of the objects distributed in it; and all are represented in all, and all in one, and all in each, whence it happens that if two mirrors are placed in such a manner as to face each other exactly, the first will be reflected in the second and the second in the first. The first being reflected in the second takes to it the image of itself with all the images represented in it, among which is the image of the second mirror,

and so, image within image, they go on to infinity in such a manner as that each mirror has within it a mirror, each smaller than the last and one inside the other. Thus, by this example, it is clearly proved that every object sends its image to every spot whence the object itself can be seen; and the converse: That the same object may receive in itself all the images of the objects that are in front of it. Hence the eye transmits through the atmosphere its own image to all the objects that are in front of it and receives them into itself, that is to say on its surface, whence they are taken in by the common sense, which considers them and if they are pleasing commits them to the memory. Whence I am of opinion: That the invisible images in the eyes are produced towards the object, as the image of the object to the eye. That the images of the objects must be disseminated through the air. An instance may be seen in several mirrors placed in a circle, which will reflect each other endlessly. When one has reached the other it is returned to the object that produced it, and thence--being diminished--it is returned again to the object and then comes back once more, and this happens endlessly. If you put a light between two flat mirrors with a distance of 1 braccio between them you will see in each of them an infinite number of lights, one smaller than another, to the last. If at night you put a light between the walls of a room, all the parts of that wall will be tinted with the image of that light. And they will receive the light and the light will fall on them, mutually, that is to say, when there is no obstacle to interrupt the transmission of the images. This same example is seen in a greater degree in the distribution of the solar rays which all together, and each by itself, convey to the object the image of the body which causes it. That each body by itself alone fills with its images the atmosphere around it, and that the same air is able, at the same time, to receive the images of the endless other objects which are in it, this is clearly proved by these examples. And every object is everywhere visible in the whole of the atmosphere, and the whole in every smallest part of it; and all the objects in the whole, and all in each smallest part; each in all and all in every part.

66.

The images of objects are all diffused through the atmosphere which receives them; and all on every side in it. To prove this, let  $a$   $c$   $e$  be objects of which the images are admitted to a dark chamber by the small holes  $n$   $p$  and thrown upon the plane  $f$   $i$  opposite to these holes. As many images will be produced in the chamber on the plane as the number of the said holes.

67.

General conclusions.

All objects project their whole image and likeness, diffused and mingled in the whole of the atmosphere, opposite to themselves. The image of every point of the bodily surface, exists in every part of the atmosphere. All the images of the objects are in every part of

the atmosphere. The whole, and each part of the image of the atmosphere is [reflected] in each point of the surface of the bodies presented to it. Therefore both the part and the whole of the images of the objects exist, both in the whole and in the parts of the surface of these visible bodies. Whence we may evidently say that the image of each object exists, as a whole and in every part, in each part and in the whole interchangeably in every existing body. As is seen in two mirrors placed opposite to each other.

68.

That the contrary is impossible.

It is impossible that the eye should project from itself, by visual rays, the visual virtue, since, as soon as it opens, that front portion [of the eye] which would give rise to this emanation would have to go forth to the object and this it could not do without time. And this being so, it could not travel so high as the sun in a month's time when the eye wanted to see it. And if it could reach the sun it would necessarily follow that it should perpetually remain in a continuous line from the eye to the sun and should always diverge in such a way as to form between the sun and the eye the base and the apex of a pyramid. This being the case, if the eye consisted of a million worlds, it would not prevent its being consumed in the projection of its virtue; and if this virtue would have to travel through the air as perfumes do, the winds would bent it and carry it into another place. But we do [in fact] see the mass of the sun with the same rapidity as [an object] at the distance of a braccio, and the power of sight is not disturbed by the blowing of the winds nor by any other accident.

[Footnote: The view here refuted by Leonardo was maintained among others by Bramantino, Leonardo's Milanese contemporary. LOMAZZO writes as follows in his Trattato dell' Arte della pittura &c.

(Milano 1584. Libr. V cp. XXI): Sovviemmi di aver già letto in certi scritti alcune cose di Bramantino milanese, celebratissimo pittore, attenente alla prospettiva, le quali ho voluto riferire, e quasi intessere in questo luogo, affinché sappiamo qual fosse l'opinione di così chiaro e famoso pittore intorno alla prospettiva . . . Scrive Bramantino che la prospettiva è una cosa che contraffà il naturale, e che così fa in tre modi

Circa il primo modo che si fa con ragione, per essere la cosa in poche parole conclusa da Bramantino in maniera che giudico non potersi dir meglio, contenendovi sì tutta Parte del principio al fine, io riferirò per appunto le proprie parole sue (cp. XXII, Prima prospettiva di Bramantino). La prima prospettiva fa le cose di punto, e l'altra non mai, e la terza più appresso. Adunque la prima si dimanda prospettiva, cioè ragione, la quale fa l'effetto dell'occhio, facendo crescere e calare secondo gli effetti degli occhi. Questo crescere e calare non procede della cosa propria, che in se per esser lontana, ovvero vicina, per quello effetto non può crescere e sminuire, ma procede dagli effetti degli occhi, i quali

sono piccioli, e perciò volendo vedere tanto gran cosa\_, bisogna che mandino fuori la virtø visiva, \_la quale si dilata in tanta larghezza, che piglia tutto quello che vuoi vedere, ed\_ arrivando a quella cosa la vede dove Ł: \_e da lei agli occhi per quello circuito fino all' occhio, e tutto quello termine Ł pieno di quella cosa\_.

It is worthy of note that Leonardo had made his memorandum refuting this view, at Milan in 1492]

69.

A parallel case.

Just as a stone flung into the water becomes the centre and cause of many circles, and as sound diffuses itself in circles in the air: so any object, placed in the luminous atmosphere, diffuses itself in circles, and fills the surrounding air with infinite images of itself. And is repeated, the whole every-where, and the whole in every smallest part. This can be proved by experiment, since if you shut a window that faces west and make a hole [Footnote: 6. Here the text breaks off.] . .

[Footnote: Compare LIBRI, \_Histoire des sciences mathØmatiques en Italie\_. Tome III, p. 43.]

The function of the eye as explained by the camera obscura (70. 71).

70.

If the object in front of the eye sends its image to the eye, the eye, on the other hand, sends its image to the object, and no portion whatever of the object is lost in the images it throws off, for any reason either in the eye or the object. Therefore we may rather believe it to be the nature and potency of our luminous atmosphere which absorbs the images of the objects existing in it, than the nature of the objects, to send their images through the air. If the object opposite to the eye were to send its image to the eye, the eye would have to do the same to the object, whence it might seem that these images were an emanation. But, if so, it would be necessary [to admit] that every object became rapidly smaller; because each object appears by its images in the surrounding atmosphere. That is: the whole object in the whole atmosphere, and in each part; and all the objects in the whole atmosphere and all of them in each part; speaking of that atmosphere which is able to contain in itself the straight and radiating lines of the images projected by the objects. From this it seems necessary to admit that it is in the nature of the atmosphere, which subsists between the objects, and which attracts the images of things to itself like a loadstone, being placed between them.

PROVE HOW ALL OBJECTS, PLACED IN ONE POSITION, ARE ALL EVERYWHERE AND ALL IN EACH PART.

I say that if the front of a building--or any open piazza or field--which is illuminated by the sun has a dwelling opposite to it, and if, in the front which does not face the sun, you make a small round hole, all the illuminated objects will project their images through that hole and be visible inside the dwelling on the opposite wall which may be made white; and there, in fact, they will be upside down, and if you make similar openings in several places in the same wall you will have the same result from each. Hence the images of the illuminated objects are all everywhere on this wall and all in each minutest part of it. The reason, as we clearly know, is that this hole must admit some light to the said dwelling, and the light admitted by it is derived from one or many luminous bodies. If these bodies are of various colours and shapes the rays forming the images are of various colours and shapes, and so will the representations be on the wall.

[Footnote: 70. 15--23. This section has already been published in the "*Saggio delle Opere di Leonardo da Vinci*" Milan 1872, pp. 13, 14. G. Govi observes upon it, that Leonardo is not to be regarded as the inventor of the Camera obscura, but that he was the first to explain by it the structure of the eye. An account of the Camera obscura first occurs in CESARE CESARINI's Italian version of Vitruvius, pub. 1523, four years after Leonardo's death. Cesarini expressly names Benedettino Don Papnutio as the inventor of the Camera obscura. In his explanation of the function of the eye by a comparison with the Camera obscura Leonardo was the precursor of G. CARDANO, Professor of Medicine at Bologna (died 1576) and it appears highly probable that this is, in fact, the very discovery which Leonardo ascribes to himself in section 21 without giving any further details.]

71.

#### HOW THE IMAGES OF OBJECTS RECEIVED BY THE EYE INTERSECT WITHIN THE CRYSTALLINE HUMOUR OF THE EYE.

An experiment, showing how objects transmit their images or pictures, intersecting within the eye in the crystalline humour, is seen when by some small round hole penetrate the images of illuminated objects into a very dark chamber. Then, receive these images on a white paper placed within this dark room and rather near to the hole and you will see all the objects on the paper in their proper forms and colours, but much smaller; and they will be upside down by reason of that very intersection. These images being transmitted from a place illuminated by the sun will seem actually painted on this paper which must be extremely thin and looked at from behind. And let the little perforation be made in a very thin plate of iron. Let *a b e d e* be the object illuminated by the sun and *o r* the front of the dark chamber in which is the said hole at *n m*. Let *s t* be the sheet of paper intercepting the rays of the images of these objects upside down, because the rays being straight, *a* on the right hand becomes *k* on the left, and *e* on the left becomes *f* on the right; and the same takes place inside the pupil.

[Footnote: This chapter is already known through a translation into French by VENTURI. Compare his 'Essai sur les ouvrages physico-mathématiques de L. da Vinci avec des fragments tirés de ses Manuscrits, apportés de l'Italie. Lu à la première classe de l'Institut national des Sciences et Arts.' Paris, An V\_ (1797).]

The practice of perspective (72. 73).

72.

In the practice of perspective the same rules apply to light and to the eye.

73.

The object which is opposite to the pupil of the eye is seen by that pupil and that which is opposite to the eye is seen by the pupil.

Refraction of the rays falling upon the eye (74. 75)

74.

The lines sent forth by the image of an object to the eye do not reach the point within the eye in straight lines.

75.

If the judgment of the eye is situated within it, the straight lines of the images are refracted on its surface because they pass through the rarer to the denser medium. If, when you are under water, you look at objects in the air you will see them out of their true place; and the same with objects under water seen from the air.

The intersection of the rays (76-82).

76.

The inversion of the images.

All the images of objects which pass through a window [glass pane] from the free outer air to the air confined within walls, are seen on the opposite side; and an object which moves in the outer air from east to west will seem in its shadow, on the wall which is lighted by this confined air, to have an opposite motion.

77.

THE PRINCIPLE ON WHICH THE IMAGES OF BODIES PASS IN BETWEEN THE MARGINS OF THE OPENINGS BY WHICH THEY ENTER.

What difference is there in the way in which images pass through narrow openings and through large openings, or in those which pass

by the sides of shaded bodies? By moving the edges of the opening through which the images are admitted, the images of immovable objects are made to move. And this happens, as is shown in the 9th which demonstrates: [Footnote 11: *\_per la 9a che dicie\_*. When Leonardo refers thus to a number it serves to indicate marginal diagrams; this can in some instances be distinctly proved. The ninth sketch on the page W. L. 145 b corresponds to the middle sketch of the three reproduced.] the images of any object are all everywhere, and all in each part of the surrounding air. It follows that if one of the edges of the hole by which the images are admitted to a dark chamber is moved it cuts off those rays of the image that were in contact with it and gets nearer to other rays which previously were remote from it &c.

#### OF THE MOVEMENT OF THE EDGE AT THE RIGHT OR LEFT, OR THE UPPER, OR LOWER EDGE.

If you move the right side of the opening the image on the left will move [being that] of the object which entered on the right side of the opening; and the same result will happen with all the other sides of the opening. This can be proved by the 2nd of this which shows: all the rays which convey the images of objects through the air are straight lines. Hence, if the images of very large bodies have to pass through very small holes, and beyond these holes recover their large size, the lines must necessarily intersect.

[Footnote: 77. 2. In the first of the three diagrams Leonardo had drawn only one of the two margins, *et \_m\_*.]

78.

Necessity has provided that all the images of objects in front of the eye shall intersect in two places. One of these intersections is in the pupil, the other in the crystalline lens; and if this were not the case the eye could not see so great a number of objects as it does. This can be proved, since all the lines which intersect do so in a point. Because nothing is seen of objects excepting their surface; and their edges are lines, in contradistinction to the definition of a surface. And each minute part of a line is equal to a point; for *\_smallest\_* is said of that than which nothing can be smaller, and this definition is equivalent to the definition of the point. Hence it is possible for the whole circumference of a circle to transmit its image to the point of intersection, as is shown in the 4th of this which shows: all the smallest parts of the images cross each other without interfering with each other. These demonstrations are to illustrate the eye. No image, even of the smallest object, enters the eye without being turned upside down; but as it penetrates into the crystalline lens it is once more reversed and thus the image is restored to the same position within the eye as that of the object outside the eye.

79.

## OF THE CENTRAL LINE OF THE EYE.

Only one line of the image, of all those that reach the visual virtue, has no intersection; and this has no sensible dimensions because it is a mathematical line which originates from a mathematical point, which has no dimensions.

According to my adversary, necessity requires that the central line of every image that enters by small and narrow openings into a dark chamber shall be turned upside down, together with the images of the bodies that surround it.

80.

## AS TO WHETHER THE CENTRAL LINE OF THE IMAGE CAN BE INTERSECTED, OR NOT, WITHIN THE OPENING.

It is impossible that the line should intersect itself; that is, that its right should cross over to its left side, and so, its left side become its right side. Because such an intersection demands two lines, one from each side; for there can be no motion from right to left or from left to right in itself without such extension and thickness as admit of such motion. And if there is extension it is no longer a line but a surface, and we are investigating the properties of a line, and not of a surface. And as the line, having no centre of thickness cannot be divided, we must conclude that the line can have no sides to intersect each other. This is proved by the movement of the line  $af$  to  $ab$  and of the line  $eb$  to  $ef$ , which are the sides of the surface  $afeb$ . But if you move the line  $ab$  and the line  $ef$ , with the frontends  $ae$ , to the spot  $c$ , you will have moved the opposite ends  $fb$  towards each other at the point  $d$ . And from the two lines you will have drawn the straight line  $cd$  which cuts the middle of the intersection of these two lines at the point  $n$  without any intersection. For, you imagine these two lines as having breadth, it is evident that by this motion the first will entirely cover the other--being equal with it--without any intersection, in the position  $cd$ . And this is sufficient to prove our proposition.

81.

## HOW THE INNUMERABLE RAYS FROM INNUMERABLE IMAGES CAN CONVERGE TO A POINT.

Just as all lines can meet at a point without interfering with each other--being without breadth or thickness--in the same way all the images of surfaces can meet there; and as each given point faces the object opposite to it and each object faces an opposite point, the converging rays of the image can pass through the point and diverge again beyond it to reproduce and re-magnify the real size of that image. But their impressions will appear reversed--as is shown in the first, above; where it is said that every image intersects as it enters the narrow openings made in a very thin substance.



Read the marginal text on the other side.

In proportion as the opening is smaller than the shaded body, so much less will the images transmitted through this opening intersect each other. The sides of images which pass through openings into a dark room intersect at a point which is nearer to the opening in proportion as the opening is narrower. To prove this let *a b* be an object in light and shade which sends not its shadow but the image of its darkened form through the opening *d e* which is as wide as this shaded body; and its sides *a b*, being straight lines (as has been proved) must intersect between the shaded object and the opening; but nearer to the opening in proportion as it is smaller than the object in shade. As is shown, on your right hand and your left hand, in the two diagrams *a b c n m o* where, the right opening *d e*, being equal in width to the shaded object *a b*, the intersection of the sides of the said shaded object occurs half way between the opening and the shaded object at the point *c*. But this cannot happen in the left hand figure, the opening *o* being much smaller than the shaded object *n m*.

It is impossible that the images of objects should be seen between the objects and the openings through which the images of these bodies are admitted; and this is plain, because where the atmosphere is illuminated these images are not formed visibly.

When the images are made double by mutually crossing each other they are invariably doubly as dark in tone. To prove this let *d e h* be such a doubling which although it is only seen within the space between the bodies in *b* and *i* this will not hinder its being seen from *f g* or from *f m*; being composed of the images *a b i k* which run together in *d e h*.

[Footnote: 81. On the original diagram at the beginning of this chapter Leonardo has written "*azzurro*" (blue) where in the facsimile I have marked *A*, and "*giallo*" (yellow) where *B* stands.]

[Footnote: 15--23. These lines stand between the diagrams I and III.]

[Footnote: 24--53. These lines stand between the diagrams I and II.]

[Footnote: 54--97 are written along the left side of diagram I.]

82.

An experiment showing that though the pupil may not be moved from its position the objects seen by it may appear to move from their places.

If you look at an object at some distance from you and which is below the eye, and fix both your eyes upon it and with one hand firmly hold the upper lid open while with the other you push up the

under lid--still keeping your eyes fixed on the object gazed at--you will see that object double; one [image] remaining steady, and the other moving in a contrary direction to the pressure of your finger on the lower eyelid. How false the opinion is of those who say that this happens because the pupil of the eye is displaced from its position.

How the above mentioned facts prove that the pupil acts upside down in seeing.

[Footnote: 82. 14--17. The subject indicated by these two headings is fully discussed in the two chapters that follow them in the original; but it did not seem to me appropriate to include them here.]

Demonstration of perspective by means of a vertical glass plane (83-85).

83.

#### OF THE PLANE OF GLASS.

Perspective is nothing else than seeing place [or objects] behind a plane of glass, quite transparent, on the surface of which the objects behind that glass are to be drawn. These can be traced in pyramids to the point in the eye, and these pyramids are intersected on the glass plane.

84.

Pictorial perspective can never make an object at the same distance, look of the same size as it appears to the eye. You see that the apex of the pyramid  $_f c d_$  is as far from the object  $_c_ d_$  as the same point  $_f_$  is from the object  $_a_ b_$ ; and yet  $_c_ d_$ , which is the base made by the painter's point, is smaller than  $_a_ b_$  which is the base of the lines from the objects converging in the eye and refracted at  $_s_ t_$ , the surface of the eye. This may be proved by experiment, by the lines of vision and then by the lines of the painter's plumbline by cutting the real lines of vision on one and the same plane and measuring on it one and the same object.

85.

#### PERSPECTIVE.

The vertical plane is a perpendicular line, imagined as in front of the central point where the apex of the pyramids converge. And this plane bears the same relation to this point as a plane of glass would, through which you might see the various objects and draw them on it. And the objects thus drawn would be smaller than the originals, in proportion as the distance between the glass and the eye was smaller than that between the glass and the objects.

## PERSPECTIVE.

The different converging pyramids produced by the objects, will show, on the plane, the various sizes and remoteness of the objects causing them.

## PERSPECTIVE.

All those horizontal planes of which the extremes are met by perpendicular lines forming right angles, if they are of equal width the more they rise to the level of eye the less this is seen, and the more the eye is above them the more will their real width be seen.

## PERSPECTIVE.

The farther a spherical body is from the eye the more you will see of it.

The angle of sight varies with the distance (86-88)

86.

A simple and natural method; showing how objects appear to the eye without any other medium.

The object that is nearest to the eye always seems larger than another of the same size at greater distance. The eye  $m$ , seeing the spaces  $ovx$ , hardly detects the difference between them, and the reason of this is that it is close to them [Footnote 6: It is quite inconceivable to me why M. RAVAISSON, in a note to his French translation of this simple passage should have remarked: *Il est clair que c'est par erreur que Leonard a écrit per esser visino au lieu de per non esser visino.* (See his printed ed. of MS. A. p. 38.)]; but if these spaces are marked on the vertical plane  $no$  the space  $ov$  will be seen at  $or$ , and in the same way the space  $vx$  will appear at  $rq$ . And if you carry this out in any place where you can walk round, it will look out of proportion by reason of the great difference in the spaces  $or$  and  $rq$ . And this proceeds from the eye being so much below [near] the plane that the plane is foreshortened. Hence, if you wanted to carry it out, you would have [to arrange] to see the perspective through a single hole which must be at the point  $m$ , or else you must go to a distance of at least 3 times the height of the object you see. The plane  $op$  being always equally remote from the eye will reproduce the objects in a satisfactory way, so that they may be seen from place to place.

87.

How every large mass sends forth its images, which may diminish through infinity.

The images of any large mass being infinitely divisible may be

infinitely diminished.

88.

Objects of equal size, situated in various places, will be seen by different pyramids which will each be smaller in proportion as the object is farther off.

89.

Perspective, in dealing with distances, makes use of two opposite pyramids, one of which has its apex in the eye and the base as distant as the horizon. The other has the base towards the eye and the apex on the horizon. Now, the first includes the [visible] universe, embracing all the mass of the objects that lie in front of the eye; as it might be a vast landscape seen through a very small opening; for the more remote the objects are from the eye, the greater number can be seen through the opening, and thus the pyramid is constructed with the base on the horizon and the apex in the eye, as has been said. The second pyramid is extended to a spot which is smaller in proportion as it is farther from the eye; and this second perspective [= pyramid] results from the first.

90.

#### SIMPLE PERSPECTIVE.

Simple perspective is that which is constructed by art on a vertical plane which is equally distant from the eye in every part. Complex perspective is that which is constructed on a ground-plan in which none of the parts are equally distant from the eye.

91.

#### PERSPECTIVE.

No surface can be seen exactly as it is, if the eye that sees it is not equally remote from all its edges.

92.

#### WHY WHEN AN OBJECT IS PLACED CLOSE TO THE EYE ITS EDGES ARE INDISTINCT.

When an object opposite the eye is brought too close to it, its edges must become too confused to be distinguished; as it happens with objects close to a light, which cast a large and indistinct shadow, so is it with an eye which estimates objects opposite to it; in all cases of linear perspective, the eye acts in the same way as the light. And the reason is that the eye has one leading line (of vision) which dilates with distance and embraces with true discernment large objects at a distance as well as small ones that are close. But since the eye sends out a multitude of lines which

surround this chief central one and since these which are farthest from the centre in this cone of lines are less able to discern with accuracy, it follows that an object brought close to the eye is not at a due distance, but is too near for the central line to be able to discern the outlines of the object. So the edges fall within the lines of weaker discerning power, and these are to the function of the eye like dogs in the chase which can put up the game but cannot take it. Thus these cannot take in the objects, but induce the central line of sight to turn upon them, when they have put them up. Hence the objects which are seen with these lines of sight have confused outlines.

The relative size of objects with regard to their distance from the eye (93-98).

93.

PERSPECTIVE.

Small objects close at hand and large ones at a distance, being seen within equal angles, will appear of the same size.

94.

PERSPECTIVE.

There is no object so large but that at a great distance from the eye it does not appear smaller than a smaller object near.

95.

Among objects of equal size that which is most remote from the eye will look the smallest. [Footnote: This axiom, sufficiently clear in itself, is in the original illustrated by a very large diagram, constructed like that here reproduced under No. 108.

The same idea is repeated in C. A. I a; I a, stated as follows:  
\_Infra le cose d'equal grandezza quella si dimostra di minor figura che sara piø distante dall' ochio\_--]

96.

Why an object is less distinct when brought near to the eye, and why with spectacles, or without the naked eye sees badly either close or far off [as the case may be].

97.

PERSPECTIVE.

Among objects of equal size, that which is most remote from the eye will look the smallest.

98.

PERSPECTIVE.

No second object can be so much lower than the first as that the eye will not see it higher than the first, if the eye is above the second.

PERSPECTIVE.

And this second object will never be so much higher than the first as that the eye, being below them, will not see the second as lower than the first.

PERSPECTIVE.

If the eye sees a second square through the centre of a smaller one, that is nearer, the second, larger square will appear to be surrounded by the smaller one.

PERSPECTIVE--PROPOSITION.

Objects that are farther off can never be so large but that those in front, though smaller, will conceal or surround them.

DEFINITION.

This proposition can be proved by experiment. For if you look through a small hole there is nothing so large that it cannot be seen through it and the object so seen appears surrounded and enclosed by the outline of the sides of the hole. And if you stop it up, this small stopping will conceal the view of the largest object.

The apparent size of objects defined by calculation (99-105)

99.

OF LINEAR PERSPECTIVE.

Linear Perspective deals with the action of the lines of sight, in proving by measurement how much smaller is a second object than the first, and how much the third is smaller than the second; and so on by degrees to the end of things visible. I find by experience that if a second object is as far beyond the first as the first is from the eye, although they are of the same size, the second will seem half the size of the first and if the third object is of the same size as the 2nd, and the 3rd is as far beyond the second as the 2nd from the first, it will appear of half the size of the second; and so on by degrees, at equal distances, the next farthest will be half the size of the former object. So long as the space does not exceed the length of 20 braccia. But, beyond 20 braccia figures of equal size will lose  $\frac{2}{4}$  and at 40 braccia they will lose  $\frac{9}{10}$ , and  $\frac{19}{20}$  at 60 braccia, and so on diminishing by degrees. This is if the

picture plane is distant from you twice your own height. If it is only as far off as your own height, there will be a great difference between the first braccia and the second.

[Footnote: This chapter is included in DUFRESNE'S and MANZI'S editions of the Treatise on Painting. H. LUDWIG, in his commentary, calls this chapter "\_eines der wichtigsten im ganzen Tractat\_", but at the same time he asserts that its substance has been so completely disfigured in the best MS. copies that we ought not to regard Leonardo as responsible for it. However, in the case of this chapter, the old MS. copies agree with the original as it is reproduced above. From the chapters given later in this edition, which were written at a subsequent date, it would appear that Leonardo corrected himself on these points.]

100.

#### OF THE DIMINUTION OF OBJECTS AT VARIOUS DISTANCES.

A second object as far distant from the first as the first is from the eye will appear half the size of the first, though they be of the same size really.

#### OF THE DEGREES OF DIMINUTION.

If you place the vertical plane at one braccio from the eye, the first object, being at a distance of 4 braccia from your eye will diminish to  $\frac{3}{4}$  of its height at that plane; and if it is 8 braccia from the eye, to  $\frac{7}{8}$ ; and if it is 16 braccia off, it will diminish to  $\frac{15}{16}$  of its height and so on by degrees, as the space doubles the diminution will double.

101.

Begin from the line  $mf$  with the eye below; then go up and do the same with the line  $nf$ , then with the eye above and close to the 2 gauges on the ground look at  $mn$ ; then as  $cm$  is to  $mn$  so will  $nm$  be to  $ns$ .

If  $an$  goes 3 times into  $fb$ ,  $mp$  will do the same into  $pg$ . Then go backwards so far as that  $cd$  goes twice into  $an$  and  $pg$  will be equal to  $gh$ . And  $mp$  will go into  $hp$  as often as  $dc$  into  $op$ .

[Footnote: The first three lines are unfortunately very obscure.]

102.

#### I GIVE THE DEGREES OF THE OBJECTS SEEN BY THE EYE AS THE MUSICIAN DOES THE NOTES HEARD BY THE EAR.

Although the objects seen by the eye do, in fact, touch each other as they recede, I will nevertheless found my rule on spaces of 20

braccia each; as a musician does with notes, which, though they can be carried on one into the next, he divides into degrees from note to note calling them 1st, 2nd, 3rd, 4th, 5th; and has affixed a name to each degree in raising or lowering the voice.

103.

#### PERSPECTIVE.

Let  $f$  be the level and distance of the eye; and  $a$  the vertical plane, as high as a man; let  $e$  be a man, then I say that on the plane this will be the distance from the plane to the 2nd man.

104.

The differences in the diminution of objects of equal size in consequence of their various remoteness from the eye will bear among themselves the same proportions as those of the spaces between the eye and the different objects.

Find out how much a man diminishes at a certain distance and what its length is; and then at twice that distance and at 3 times, and so make your general rule.

105.

The eye cannot judge where an object high up ought to descend.

106.

#### PERSPECTIVE.

If two similar and equal objects are placed one beyond the other at a given distance the difference in their size will appear greater in proportion as they are nearer to the eye that sees them. And conversely there will seem to be less difference in their size in proportion as they are remote from the eye.

This is proved by the proportions of their distances among themselves; for, if the first of these two objects were as far from the eye, as the 2nd from the first this would be called the second proportion: since, if the first is at 1 braccia from the eye and the 2nd at two braccia, two being twice as much as one, the first object will look twice as large as the second. But if you place the first at a hundred braccia from you and the second at a hundred and one, you will find that the first is only so much larger than the second as 100 is less than 101; and the converse is equally true. And again, the same thing is proved by the 4th of this book which shows that among objects that are equal, there is the same proportion in the diminution of the size as in the increase in the distance from the eye of the spectator.

On natural perspective (107--109).



107.

OF EQUAL OBJECTS THE MOST REMOTE LOOK THE SMALLEST.

The practice of perspective may be divided into ... parts [Footnote 4: \_in\_ ... \_parte\_. The space for the number is left blank in the original.], of which the first treats of objects seen by the eye at any distance; and it shows all these objects just as the eye sees them diminished, without obliging a man to stand in one place rather than another so long as the plane does not produce a second foreshortening.

But the second practice is a combination of perspective derived partly from art and partly from nature and the work done by its rules is in every portion of it, influenced by natural perspective and artificial perspective. By natural perspective I mean that the plane on which this perspective is represented is a flat surface, and this plane, although it is parallel both in length and height, is forced to diminish in its remoter parts more than in its nearer ones. And this is proved by the first of what has been said above, and its diminution is natural. But artificial perspective, that is that which is devised by art, does the contrary; for objects equal in size increase on the plane where it is foreshortened in proportion as the eye is more natural and nearer to the plane, and as the part of the plane on which it is figured is farther from the eye.

And let this plane be \_d e\_ on which are seen 3 equal circles which are beyond this plane \_d e\_, that is the circles \_a b c\_. Now you see that the eye \_h\_ sees on the vertical plane the sections of the images, largest of those that are farthest and smallest of the nearest.

108.

Here follows what is wanting in the margin at the foot on the other side of this page.

Natural perspective acts in a contrary way; for, at greater distances the object seen appears smaller, and at a smaller distance the object appears larger. But this said invention requires the spectator to stand with his eye at a small hole and then, at that small hole, it will be very plain. But since many (men's) eyes endeavour at the same time to see one and the same picture produced by this artifice only one can see clearly the effect of this perspective and all the others will see confusion. It is well therefore to avoid such complex perspective and hold to simple perspective which does not regard planes as foreshortened, but as much as possible in their proper form. This simple perspective, in which the plane intersects the pyramids by which the images are conveyed to the eye at an equal distance from the eye is our constant experience, from the curved form of the pupil of the eye on

which the pyramids are intersected at an equal distance from the visual virtue.

[Footnote 24: *la prima di sopra* i. e. the first of the three diagrams which, in the original MS., are placed in the margin at the beginning of this chapter.]

109.

#### OF A MIXTURE OF NATURAL AND ARTIFICIAL PERSPECTIVE.

This diagram distinguishes natural from artificial perspective. But before proceeding any farther I will define what is natural and what is artificial perspective. Natural perspective says that the more remote of a series of objects of equal size will look the smaller, and conversely, the nearer will look the larger and the apparent size will diminish in proportion to the distance. But in artificial perspective when objects of unequal size are placed at various distances, the smallest is nearer to the eye than the largest and the greatest distance looks as though it were the least of all; and the cause of this is the plane on which the objects are represented; and which is at unequal distances from the eye throughout its length. And this diminution of the plane is natural, but the perspective shown upon it is artificial since it nowhere agrees with the true diminution of the said plane. Whence it follows, that when the eye is somewhat removed from the [station point of the] perspective that it has been gazing at, all the objects represented look monstrous, and this does not occur in natural perspective, which has been defined above. Let us say then, that the square *a b c d* figured above is foreshortened being seen by the eye situated in the centre of the side which is in front. But a mixture of artificial and natural perspective will be seen in this tetragon called *el main* [Footnote 20: *el main* is quite legibly written in the original; the meaning and derivation of the word are equally doubtful.], that is to say *e f g h* which must appear to the eye of the spectator to be equal to *a b c d* so long as the eye remains in its first position between *c* and *d*. And this will be seen to have a good effect, because the natural perspective of the plane will conceal the defects which would [otherwise] seem monstrous.

*III.*

*Six books on Light and Shade.*

Linear Perspective cannot be immediately followed by either the "prospettiva de' perdimenti" or the "prospettiva de' colori" or the aerial perspective; since these branches of the subject presuppose a knowledge of the principles of Light and Shade. No apology, therefore, is here needed for placing these immediately after Linear Perspective.

We have various plans suggested by Leonardo for the arrangement of the mass of materials treating of this subject. Among these I have

given the preference to a scheme propounded in No. III, because, in all probability, we have here a final and definite purpose expressed. Several authors have expressed it as their opinion that the Paris Manuscript C is a complete and finished treatise on Light and Shade. Certainly, the Principles of Light and Shade form by far the larger portion of this MS. which consists of two separate parts; still, the materials are far from being finally arranged. It is also evident that he here investigates the subject from the point of view of the Physicist rather than from that of the Painter.

The plan of a scheme of arrangement suggested in No. III and adopted by me has been strictly adhered to for the first four Books. For the three last, however, few materials have come down to us; and it must be admitted that these three Books would find a far more appropriate place in a work on Physics than in a treatise on Painting. For this reason I have collected in Book V all the chapters on Reflections, and in Book VI I have put together and arranged all the sections of MS. C that belong to the book on Painting, so far as they relate to Light and Shade, while the sections of the same MS. which treat of the "Prospettiva de' perdimenti" have, of course, been excluded from the series on Light and Shade.

[Footnote III: This text has already been published with some slight variations in Dozio's pamphlet *Degli scritti e disegni di Leonardo da Vinci*, Milan 1871, pp. 30--31. Dozio did not transcribe it from the original MS. which seems to have remained unknown to him, but from an old copy (MS. H. 227 in the Ambrosian Library).]

#### GENERAL INTRODUCTION.

Prolegomena.

110.

You must first explain the theory and then the practice. First you must describe the shadows and lights on opaque objects, and then on transparent bodies.

Scheme of the books on Light and shade.

111.

#### INTRODUCTION.

[Having already treated of the nature of shadows and the way in which they are cast [Footnote 2: *Avendo io tractato.*--We may suppose that he here refers to some particular MS., possibly Paris C.], I will now consider the places on which they fall; and their curvature, obliquity, flatness or, in short, any character I may be able to detect in them.]

Shadow is the obstruction of light. Shadows appear to me to be of

supreme importance in perspective, because, without them opaque and solid bodies will be ill defined; that which is contained within their outlines and their boundaries themselves will be ill-understood unless they are shown against a background of a different tone from themselves. And therefore in my first proposition concerning shadow I state that every opaque body is surrounded and its whole surface enveloped in shadow and light. And on this proposition I build up the first Book. Besides this, shadows have in themselves various degrees of darkness, because they are caused by the absence of a variable amount of the luminous rays; and these I call Primary shadows because they are the first, and inseparable from the object to which they belong. And on this I will found my second Book. From these primary shadows there result certain shaded rays which are diffused through the atmosphere and these vary in character according to that of the primary shadows whence they are derived. I shall therefore call these shadows Derived shadows because they are produced by other shadows; and the third Book will treat of these. Again these derived shadows, where they are intercepted by various objects, produce effects as various as the places where they are cast and of this I will treat in the fourth Book. And since all round the derived shadows, where the derived shadows are intercepted, there is always a space where the light falls and by reflected dispersion is thrown back towards its cause, it meets the original shadow and mingles with it and modifies it somewhat in its nature; and on this I will compose my fifth Book. Besides this, in the sixth Book I will investigate the many and various diversities of reflections resulting from these rays which will modify the original [shadow] by [imparting] some of the various colours from the different objects whence these reflected rays are derived. Again, the seventh Book will treat of the various distances that may exist between the spot where the reflected rays fall and that where they originate, and the various shades of colour which they will acquire in falling on opaque bodies.

Different principles and plans of treatment (112--116).

112.

First I will treat of light falling through windows which I will call Restricted [Light] and then I will treat of light in the open country, to which I will give the name of diffused Light. Then I will treat of the light of luminous bodies.

113.

OF PAINTING.

The conditions of shadow and light [as seen] by the eye are 3. Of these the first is when the eye and the light are on the same side of the object seen; the 2nd is when the eye is in front of the object and the light is behind it. The 3rd is when the eye is in front of the object and the light is on one side, in such a way as that a line drawn from the object to the eye and one from the object

to the light should form a right angle where they meet.

114.

OF PAINTING.

This is another section: that is, of the nature of a reflection (from) an object placed between the eye and the light under various aspects.

115.

OF PAINTING.

As regards all visible objects 3 things must be considered. These are the position of the eye which sees: that of the object seen [with regard] to the light, and the position of the light which illuminates the object, \_b\_ is the eye, \_a\_ the object seen, \_c\_ the light, \_a\_ is the eye, \_b\_ the illuminating body, \_c\_ is the illuminated object.

116.

Let \_a\_ be the light, \_b\_ the eye, \_c\_ the object seen by the eye and in the light. These show, first, the eye between the light and the body; the 2nd, the light between the eye and the body; the 3rd the body between the eye and the light, \_a\_ is the eye, \_b\_ the illuminated object, \_c\_ the light.

117.

OF PAINTING.

OF THE THREE KINDS OF LIGHT THAT ILLUMINATE OPAQUE BODIES.

The first kind of Light which may illuminate opaque bodies is called Direct light--as that of the sun or any other light from a window or flame. The second is Diffused [universal] light, such as we see in cloudy weather or in mist and the like. The 3rd is Subdued light, that is when the sun is entirely below the horizon, either in the evening or morning.

118.

OF LIGHT.

The lights which may illuminate opaque bodies are of 4 kinds. These are: diffused light as that of the atmosphere, within our horizon. And Direct, as that of the sun, or of a window or door or other opening. The third is Reflected light; and there is a 4th which is that which passes through [semi] transparent bodies, as linen or paper or the like, but not transparent like glass, or crystal, or other diaphanous bodies, which produce the same effect as though

nothing intervened between the shaded object and the light that falls upon it; and this we will discuss fully in our discourse.

Definition of the nature of shadows (119--122).

119.

WHAT LIGHT AND SHADOW ARE.

Shadow is the absence of light, merely the obstruction of the luminous rays by an opaque body. Shadow is of the nature of darkness. Light [on an object] is of the nature of a luminous body; one conceals and the other reveals. They are always associated and inseparable from all objects. But shadow is a more powerful agent than light, for it can impede and entirely deprive bodies of their light, while light can never entirely expel shadow from a body, that is from an opaque body.

120.

Shadow is the diminution of light by the intervention of an opaque body. Shadow is the counterpart of the luminous rays which are cut off by an opaque body.

This is proved because the shadow cast is the same in shape and size as the luminous rays were which are transformed into a shadow.

121.

Shadow is the diminution alike of light and of darkness, and stands between darkness and light.

A shadow may be infinitely dark, and also of infinite degrees of absence of darkness.

The beginnings and ends of shadow lie between the light and darkness and may be infinitely diminished and infinitely increased. Shadow is the means by which bodies display their form.

The forms of bodies could not be understood in detail but for shadow.

122.

OF THE NATURE OF SHADOW.

Shadow partakes of the nature of universal matter. All such matters are more powerful in their beginning and grow weaker towards the end, I say at the beginning, whatever their form or condition may be and whether visible or invisible. And it is not from small beginnings that they grow to a great size in time; as it might be a great oak which has a feeble beginning from a small acorn. Yet I may say that the oak is most powerful at its beginning, that is where it

springs from the earth, which is where it is largest (To return:)  
Darkness, then, is the strongest degree of shadow and light is its least. Therefore, O Painter, make your shadow darkest close to the object that casts it, and make the end of it fading into light, seeming to have no end.

Of the various kinds of shadows. (123-125).

123.

Darkness is absence of light. Shadow is diminution of light. Primitive shadow is that which is inseparable from a body not in the light. Derived shadow is that which is disengaged from a body in shadow and pervades the air. A cast transparent shadow is that which is surrounded by an illuminated surface. A simple shadow is one which receives no light from the luminous body which causes it. A simple shadow begins within the line which starts from the edge of the luminous body \_a b\_.

124.

A simple shadow is one where no light at all interferes with it.

A compound shadow is one which is somewhat illuminated by one or more lights.

125.

WHAT IS THE DIFFERENCE BETWEEN A SHADOW THAT IS INSEPARABLE FROM A BODY AND A CAST SHADOW?

An inseparable shadow is that which is never absent from the illuminated body. As, for instance a ball, which so long as it is in the light always has one side in shadow which never leaves it for any movement or change of position in the ball. A separate shadow may be and may not be produced by the body itself. Suppose the ball to be one braccio distant from a wall with a light on the opposite side of it; this light will throw upon the wall exactly as broad a shadow as is to be seen on the side of the ball that is turned towards the wall. That portion of the cast shadow will not be visible when the light is below the ball and the shadow is thrown up towards the sky and finding no obstruction on its way is lost.

126.

HOW THERE ARE 2 KINDS OF LIGHT, ONE SEPARABLE FROM, AND THE OTHER INSEPARABLE FROM BODIES.

Of the various kinds of light (126, 127).

Separate light is that which falls upon the body. Inseparable light is the side of the body that is illuminated by that light. One is called primary, the other derived. And, in the same way there are

two kinds of shadow:--One primary and the other derived. The primary is that which is inseparable from the body, the derived is that which proceeds from the body conveying to the surface of the wall the form of the body causing it.

127.

How there are 2 different kinds of light; one being called diffused, the other restricted. The diffused is that which freely illuminates objects. The restricted is that which being admitted through an opening or window illuminates them on that side only.

[Footnote: At the spot marked \_A\_ in the first diagram Leonardo wrote \_lume costretto\_ (restricted light). At the spot \_B\_ on the second diagram he wrote \_lume libero\_ (diffused light).]

General remarks (128. 129).

128.

Light is the chaser away of darkness. Shade is the obstruction of light. Primary light is that which falls on objects and causes light and shade. And derived lights are those portions of a body which are illuminated by the primary light. A primary shadow is that side of a body on which the light cannot fall.

The general distribution of shadow and light is that sum total of the rays thrown off by a shaded or illuminated body passing through the air without any interference and the spot which intercepts and cuts off the distribution of the dark and light rays.

And the eye can best distinguish the forms of objects when it is placed between the shaded and the illuminated parts.

129.

MEMORANDUM OF THINGS I REQUIRE TO HAVE GRANTED [AS AXIOMS] IN MY EXPLANATION OF PERSPECTIVE.

I ask to have this much granted me--to assert that every ray passing through air of equal density throughout, travels in a straight line from its cause to the object or place it falls upon.

FIRST BOOK ON LIGHT AND SHADE.

On the nature of light (130. 131).

130.

The reason by which we know that a light radiates from a single centre is this: We plainly see that a large light is often much broader than some small object which nevertheless--and although the rays [of the large light] are much more than twice the extent [of



the small body]--always has its shadow cast on the nearest surface very visibly. Let  $c f$  be a broad light and  $n$  be the object in front of it, casting a shadow on the plane, and let  $a b$  be the plane. It is clear that it is not the broad light that will cast the shadow  $n$  on the plane, but that the light has within it a centre is shown by this experiment. The shadow falls on the plane as is shown at  $m o t r$ .

[Footnote 13: In the original MS. no explanatory text is placed after this title-line; but a space is left for it and the text beginning at line 15 comes next.] Why, to two [eyes] or in front of two eyes do 3 objects appear as two?

Why, when you estimate the direction of an object with two sights the nearer appears confused. I say that the eye projects an infinite number of lines which mingle or join those reaching it which come to it from the object looked at. And it is only the central and sensible line that can discern and discriminate colours and objects; all the others are false and illusory. And if you place 2 objects at half an arm's length apart if the nearer of the two is close to the eye its form will remain far more confused than that of the second; the reason is that the first is overcome by a greater number of false lines than the second and so is rendered vague.

Light acts in the same manner, for in the effects of its lines (=rays), and particularly in perspective, it much resembles the eye; and its central rays are what cast the true shadow. When the object in front of it is too quickly overcome with dim rays it will cast a broad and disproportionate shadow, ill defined; but when the object which is to cast the shadow and cuts off the rays near to the place where the shadow falls, then the shadow is distinct; and the more so in proportion as the light is far off, because at a long distance the central ray is less overcome by false rays; because the lines from the eye and the solar and other luminous rays passing through the atmosphere are obliged to travel in straight lines. Unless they are deflected by a denser or rarer air, when they will be bent at some point, but so long as the air is free from grossness or moisture they will preserve their direct course, always carrying the image of the object that intercepts them back to their point of origin. And if this is the eye, the intercepting object will be seen by its colour, as well as by form and size. But if the intercepting plane has in it some small perforation opening into a darker chamber--not darker in colour, but by absence of light--you will see the rays enter through this hole and transmitting to the plane beyond all the details of the object they proceed from both as to colour and form; only every thing will be upside down. But the size [of the image] where the lines are reconstructed will be in proportion to the relative distance of the aperture from the plane on which the lines fall [on one hand] and from their origin [on the other]. There they intersect and form 2 pyramids with their point meeting [a common apex] and their bases opposite. Let  $a b$  be the point of origin of the lines,  $d e$  the first plane, and  $c$  the aperture with the intersection of the lines;  $f g$  is the inner

plane. You will find that a falls upon the inner plane below at g, and b which is below will go up to the spot f; it will be quite evident to experimenters that every luminous body has in itself a core or centre, from which and to which all the lines radiate which are sent forth by the surface of the luminous body and reflected back to it; or which, having been thrown out and not intercepted, are dispersed in the air.

131.

THE RAYS WHETHER SHADED OR LUMINOUS HAVE GREATER STRENGTH AND EFFECT AT THEIR POINTS THAN AT THEIR SIDES.

Although the points of luminous pyramids may extend into shaded places and those of pyramids of shadow into illuminated places, and though among the luminous pyramids one may start from a broader base than another; nevertheless, if by reason of their various length these luminous pyramids acquire angles of equal size their light will be equal; and the case will be the same with the pyramids of shadow; as may be seen in the intersected pyramids a b c and d e f, which though their bases differ in size are equal as to breadth and light.

[Footnote: 51--55: This supplementary paragraph is indicated as being a continuation of line 45, by two small crosses.]

The difference between light and lustre (132--135).

132.

Of the difference between light and lustre; and that lustre is not included among colours, but is saturation of whiteness, and derived from the surface of wet bodies; light partakes of the colour of the object which reflects it (to the eye) as gold or silver or the like.

133.

OF THE HIGHEST LIGHTS WHICH TURN AND MOVE AS THE EYE MOVES WHICH SEES THE OBJECT.

Suppose the body to be the round object figured here and let the light be at the point a, and let the illuminated side of the object be b c and the eye at the point d: I say that, as lustre is every where and complete in each part, if you stand at the point d the lustre will appear at c, and in proportion as the eye moves from d to a, the lustre will move from c to n.

134.

OF PAINTING.

High light or lustre on any object is not situated [necessarily] in the middle of an illuminated object, but moves as and where the eye

moves in looking at it.

135.

#### OF LIGHT AND LUSTRE.

What is the difference between light and the lustre which is seen on the polished surface of opaque bodies?

The lights which are produced from the polished surface of opaque bodies will be stationary on stationary objects even if the eye on which they strike moves. But reflected lights will, on those same objects, appear in as many different places on the surface as different positions are taken by the eye.

#### WHAT BODIES HAVE LIGHT UPON THEM WITHOUT LUSTRE?

Opaque bodies which have a hard and rough surface never display any lustre in any portion of the side on which the light falls.

#### WHAT BODIES WILL DISPLAY LUSTRE BUT NOT LOOK ILLUMINATED?

Those bodies which are opaque and hard with a hard surface reflect light [lustre] from every spot on the illuminated side which is in a position to receive light at the same angle of incidence as they occupy with regard to the eye; but, as the surface mirrors all the surrounding objects, the illuminated [body] is not recognisable in these portions of the illuminated body.

136.

The relations of luminous to illuminated bodies.

The middle of the light and shade on an object in light and shade is opposite to the middle of the primary light. All light and shadow expresses itself in pyramidal lines. The middle of the shadow on any object must necessarily be opposite the middle of its light, with a direct line passing through the centre of the body. The middle of the light will be at \_a\_, that of the shadow at \_b\_. [Again, in bodies shown in light and shade the middle of each must coincide with the centre of the body, and a straight line will pass through both and through that centre.]

[Footnote: In the original MS., at the spot marked \_a\_ of the first diagram Leonardo wrote \_primitiuo\_, and at the spot marked \_c\_ \_primitiva\_ (primary); at the spot marked \_b\_ he wrote \_dirivatiuo\_ and at \_d\_ deriuatiua\_ (derived).]

Experiments on the relation of light and shadow within a room (137--140).

137.

SHOWS HOW LIGHT FROM ANY SIDE CONVERGES TO ONE POINT.

Although the balls *a b c* are lighted from one window, nevertheless, if you follow the lines of their shadows you will see they intersect at a point forming the angle *n*.

[Footnote: The diagram belonging to this passage is slightly sketched on Pl. XXXII; a square with three balls below it. The first three lines of the text belonging to it are written above the sketch and the six others below it.]

138.

Every shadow cast by a body has a central line directed to a single point produced by the intersection of luminous lines in the middle of the opening and thickness of the window. The proposition stated above, is plainly seen by experiment. Thus if you draw a place with a window looking northwards, and let this be *s f*, you will see a line starting from the horizon to the east, which, touching the 2 angles of the window *o f*, reaches *d*; and from the horizon on the west another line, touching the other 2 angles *r s*, and ending at *c*; and their intersection falls exactly in the middle of the opening and thickness of the window. Again, you can still better confirm this proof by placing two sticks, as shown at *g h*; and you will see the line drawn from the centre of the shadow directed to the centre *m* and prolonged to the horizon *n f*.

[Footnote: *B* here stands for *cerchio del' orizonte tramontano* on the original diagram (the circle of the horizon towards the North); *A* for *levante* (East) and *C* for *ponete* (West).]

139.

Every shadow with all its variations, which becomes larger as its distance from the object is greater, has its external lines intersecting in the middle, between the light and the object. This proposition is very evident and is confirmed by experience. For, if *a b* is a window without any object interposed, the luminous atmosphere to the right hand at *a* is seen to the left at *d*. And the atmosphere at the left illuminates on the right at *c*, and the lines intersect at the point *m*.

[Footnote: *A* here stands for *levante* (East), *B* for *ponente* (West).]

140.

Every body in light and shade is situated between 2 pyramids one dark and the other luminous, one is visible the other is not. But this only happens when the light enters by a window. Supposing *a b* to be the window and *r* the body in light and shade, the light to the right hand *z* will pass the object to the left and go on to *p*; the light to the left at *k* will pass to the right of the

object at i and go on to m and the two lines will intersect at c and form a pyramid. Then again a b falls on the shaded body at i g and forms a pyramid f i g. f will be dark because the light a b can never fall there; i g c will be illuminated because the light falls upon it.

Light and shadow with regard to the position of the eye (141--145).

141.

Every shaded body that is larger than the pupil and that interposes between the luminous body and the eye will be seen dark.

When the eye is placed between the luminous body and the objects illuminated by it, these objects will be seen without any shadow.

[Footnote: The diagram which in the original stands above line 1 is given on Plate II, No 2. Then, after a blank space of about eight lines, the diagram Plate II No 3 is placed in the original. There is no explanation of it beyond the one line written under it.]

142.

Why the 2 lights one on each side of a body having two pyramidal sides of an obtuse apex leave it devoid of shadow.

[Footnote: The sketch illustrating this is on Plate XLI No 1.]

143.

A body in shadow situated between the light and the eye can never display its illuminated portion unless the eye can see the whole of the primary light.

[Footnote: A stands for corpo (body), B for lume (light).]

144.

The eye which looks (at a spot) half way between the shadow and the light which surrounds the body in shadow will see that the deepest shadows on that body will meet the eye at equal angles, that is at the same angle as that of sight.

[Footnote: In both these diagrams A stands for lume (light) B for ombra (shadow).]

145.

OF THE DIFFERENT LIGHT AND SHADE IN VARIOUS ASPECTS AND OF OBJECTS PLACED IN THEM.

If the sun is in the East and you look towards the West you will see every thing in full light and totally without shadow because you see

them from the same side as the sun: and if you look towards the South or North you will see all objects in light and shade, because you see both the side towards the sun and the side away from it; and if you look towards the coming of the sun all objects will show you their shaded side, because on that side the sun cannot fall upon them.

The law of the incidence of light.

146.

The edges of a window which are illuminated by 2 lights of equal degrees of brightness will not reflect light of equal brightness into the chamber within.

If *b* is a candle and *a* our hemisphere both will illuminate the edges of the window *m* *n*, but light *b* will only illuminate *f* *g* and the hemisphere *a* will light all of *d* *e*.

147.

OF PAINTING.

That part of a body which receives the luminous rays at equal angles will be in a higher light than any other part of it.

And the part which the luminous rays strike between less equal angles will be less strongly illuminated.

SECOND BOOK ON LIGHT AND SHADE.

Gradations of strength in the shadows (148. 149).

148.

THAT PORTION OF A BODY IN LIGHT AND SHADE WILL BE LEAST LUMINOUS WHICH IS SEEN UNDER THE LEAST AMOUNT OF LIGHT.

That part of the object which is marked *m* is in the highest light because it faces the window *a* *d* by the line *a* *f*; *n* is in the second grade because the light *b* *d* strikes it by the line *b* *e*; *o* is in the third grade, as the light falls on it from *c* *d* by the line *c* *h*; *p* is the lowest light but one as *c* *d* falls on it by the line *d* *v*; *q* is the deepest shadow for no light falls on it from any part of the window.

In proportion as *c* *d* goes into *a* *d* so will *n* *r* *s* be darker than *m*, and all the rest is space without shadow.

[Footnote: The diagram belonging to this chapter is No. 1 on Plate III. The letters *a* *b* *e* *d* and *r* are not reproduced in facsimile of the original, but have been replaced by ordinary type in the margin. 5-12. The original text of these lines is reproduced within

the diagram.--Compare No 275.]

149.

The light which falls on a shaded body at the acutest angle receives the highest light, and the darkest portion is that which receives it at an obtuse angle and both the light and the shadow form pyramids. The angle *\_c\_* receives the highest grade of light because it is directly in front of the window *\_a b\_* and the whole horizon of the sky *\_m x\_*. The angle *\_a\_* differs but little from *\_c\_* because the angles which divide it are not so unequal as those below, and only that portion of the horizon is intercepted which lies between *\_y\_* and *\_x\_*. Although it gains as much on the other side its line is nevertheless not very strong because one angle is smaller than its fellow. The angles *\_e i\_* will have less light because they do not see much of the light *\_m s\_* and the light *\_v x\_* and their angles are very unequal. The angle *\_k\_* and the angle *\_f\_* are each placed between very unequal angles and therefore have but little light, because at *\_k\_* it has only the light *\_p t\_*, and at *\_f\_* only *\_t q\_*; *\_o g\_* is the lowest grade of light because this part has no light at all from the sky; and thence come the lines which will reconstruct a pyramid that is the counterpart of the pyramid *\_c\_*; and this pyramid *\_l\_* is in the first grade of shadow; for this too is placed between equal angles directly opposite to each other on either side of a straight line which passes through the centre of the body and goes to the centre of the light. The several luminous images cast within the frame of the window at the points *\_a\_* and *\_b\_* make a light which surrounds the derived shadow cast by the solid body at the points 4 and 6. The shaded images increase from *\_o g\_* and end at 7 and 8.

[Footnote: The diagram belonging to this chapter is No. 2 on Plate III. In the original it is placed between lines 3 and 4, and in the reproduction these are shown in part. The semi circle above is marked *\_orizonte\_* (horizon). The number 6 at the left hand side, outside the facsimile, is in the place of a figure which has become indistinct in the original.]

On the intensity of shadows as dependent on the distance from the light (150-152).

150.

The smaller the light that falls upon an object the more shadow it will display. And the light will illuminate a smaller portion of the object in proportion as it is nearer to it; and conversely, a larger extent of it in proportion as it is farther off.

A light which is smaller than the object on which it falls will light up a smaller extent of it in proportion as it is nearer to it, and the converse, as it is farther from it. But when the light is larger than the object illuminated it will light a larger extent of the object in proportion as it is nearer and the converse when they are farther apart.

151.

That portion of an illuminated object which is nearest to the source of light will be the most strongly illuminated.

152.

That portion of the primary shadow will be least dark which is farthest from the edges.

The derived shadow will be darker than the primary shadow where it is contiguous with it.

On the proportion of light and shade (153-157).

153.

That portion of an opaque body will be more in shade or more in light, which is nearer to the dark body, by which it is shaded, or to the light that illuminates it.

Objects seen in light and shade show in greater relief than those which are wholly in light or in shadow.

154.

OF PERSPECTIVE.

The shaded and illuminated sides of opaque objects will display the same proportion of light and darkness as their objects [Footnote 6: The meaning of *\_obbietti\_* (objects) is explained in no 153, lines 1-4.--Between the title-line and the next there is, in the original, a small diagram representing a circle described round a square.].

155.

OF PAINTING.

The outlines and form of any part of a body in light and shade are indistinct in the shadows and in the high lights; but in the portions between the light and the shadows they are highly conspicuous.

156.

OF PAINTING.

Among objects in various degrees of shade, when the light proceeds from a single source, there will be the same proportion in their shadows as in the natural diminution of the light and the same must be understood of the degrees of light.



157.

A single and distinct luminous body causes stronger relief in the object than a diffused light; as may be seen by comparing one side of a landscape illuminated by the sun, and one overshadowed by clouds, and so illuminated only by the diffused light of the atmosphere.

### THIRD BOOK ON LIGHT AND SHADE.

Definition of derived shadow (158. 159).

158.

Derived shadow cannot exist without primary shadow. This is proved by the first of this which says: Darkness is the total absence of light, and shadow is an alleviation of darkness and of light, and it is more or less dark or light in proportion as the darkness is modified by the light.

159.

Shadow is diminution of light.

Darkness is absence of light.

Shadow is divided into two kinds, of which the first is called primary shadow, the second is derived shadow. The primary shadow is always the basis of the derived shadow.

The edges of the derived shadow are straight lines.

[Footnote: The theory of the *\_ombra\_ dirivativa\_*--a technical expression for which there is no precise English equivalent is elaborately treated by Leonardo. But both text and diagrams (as Pl. IV, 1-3 and Pl. V) must at once convince the student that the distinction he makes between *\_ombra primitiva\_* and *\_ombra dirivativa\_* is not merely justifiable but scientific. *\_Ombra dirivativa\_* is by no means a mere abstract idea. This is easily proved by repeating the experiment made by Leonardo, and by filling with smoke the room in which the existence of the *\_ombra dirivativa\_* is investigated, when the shadow becomes visible. Nor is it difficult to perceive how much of Leonardo's teaching depended on this theory. The recognised, but extremely complicated science of cast shadows--*\_percussione dell' ombre dirivativa\_* as Leonardo calls them--is thus rendered more intelligible if not actually simpler, and we must assume this theory as our chief guide through the investigations which follow.]

The darkness of the derived shadow diminishes in proportion as it is remote from the primary shadow.

Different sorts of derived shadows (160-162).

160.

#### SHADOW AND LIGHT.

The forms of shadows are three: inasmuch as if the solid body which casts the shadow is equal (in size) to the light, the shadow resembles a column without any termination (in length). If the body is larger than the light the shadow resembles a truncated and inverted pyramid, and its length has also no defined termination. But if the body is smaller than the light, the shadow will resemble a pyramid and come to an end, as is seen in eclipses of the moon.

161.

#### OF SIMPLE DERIVED SHADOWS.

The simple derived shadow is of two kinds: one kind which has its length defined, and two kinds which are undefined; and the defined shadow is pyramidal. Of the two undefined, one is a column and the other spreads out; and all three have rectilinear outlines. But the converging, that is the pyramidal, shadow proceeds from a body that is smaller than the light, and the columnar from a body equal in size to the light, and the spreading shadow from a body larger than the light; &c.

#### OF COMPOUND DERIVED SHADOWS.

Compound derived shadows are of two kinds; that is columnar and spreading.

162.

#### OF SHADOW.

Derived shadows are of three kinds of which one is spreading, the second columnar, the third converging to the point where the two sides meet and intersect, and beyond this intersection the sides are infinitely prolonged or straight lines. And if you say, this shadow must terminate at the angle where the sides meet and extend no farther, I deny this, because above in the first on shadow I have proved: that a thing is completely terminated when no portion of it goes beyond its terminating lines. Now here, in this shadow, we see the converse of this, in as much as where this derived shadow originates we obviously have the figures of two pyramids of shadow which meet at their angles. Hence, if, as [my] opponent says, the first pyramid of shadow terminates the derivative shadow at the angle whence it starts, then the second pyramid of shadow--so says the adversary--must be caused by the angle and not from the body in shadow; and this is disproved with the help of the 2nd of this which says: Shadow is a condition produced by a body casting a shadow, and interposed between this shadow and the luminous body. By this it is

made clear that the shadow is not produced by the angle of the derived shadow but only by the body casting the shadow; &c. If a spherical solid body is illuminated by a light of elongated form the shadow produced by the longest portion of this light will have less defined outlines than that which is produced by the breadth of the same light. And this is proved by what was said before, which is: That a shadow will have less defined outlines in proportion as the light which causes it is larger, and conversely, the outlines are clearer in proportion as it is smaller.

[Footnote: The two diagrams to this chapter are on Plate IV, No. 1.]

On the relation of derived and primary shadow (163-165).

163.

The derived shadow can never resemble the body from which it proceeds unless the light is of the same form and size as the body causing the shadow.

The derived shadow cannot be of the same form as the primary shadow unless it is intercepted by a plane parallel to it.

164.

HOW A CAST SHADOW CAN NEVER BE OF THE SAME SIZE AS THE BODY THAT CASTS IT.

If the rays of light proceed, as experience shows, from a single point and are diffused in a sphere round this point, radiating and dispersed through the air, the farther they spread the wider they must spread; and an object placed between the light and a wall is always imaged larger in its shadow, because the rays that strike it [Footnote: 7. The following lines are wanting to complete the logical connection.] would, by the time they have reached the wall, have become larger.

165.

Any shadow cast by a body in light and shade is of the same nature and character as that which is inseparable from the body. The centre of the length of a shadow always corresponds to that of the luminous body [Footnote 6: This second statement of the same idea as in the former sentence, but in different words, does not, in the original, come next to the foregoing; sections 172 and 127 are placed between them.]. It is inevitable that every shadow must have its centre in a line with the centre of the light.

On the shape of derived shadows (166-174).

166.

OF THE PYRAMIDAL SHADOW.

The pyramidal shadow produced by a columnar body will be narrower than the body itself in proportion as the simple derived shadow is intersected farther from the body which casts it.

[Footnote 166: Compare the first diagram to No. 161. If we here conceive of the outlines of the pyramid of shadow on the ground as prolonged beyond its apex this gives rise to a second pyramid; this is what is spoken of at the beginning of No. 166.]

167.

The cast shadow will be longest when the light is lowest.

The cast shadow will be shortest when the light is highest.

168.

Both the primary and derived shadow will be larger when caused by the light of a candle than by diffused light. The difference between the larger and smaller shadows will be in inverse proportion to the larger and smaller lights causing them.

[Footnote: In the diagrams *\_A\_* stands for *\_celo\_* (sky), *\_B\_* for *\_cadela\_* (candle).]

169.

ALL BODIES, IN PROPORTION AS THEY ARE NEARER TO, OR FARTHER FROM THE SOURCE OF LIGHT, WILL PRODUCE LONGER OR SHORTER DERIVED SHADOWS.

Among bodies of equal size, that one which is illuminated by the largest light will have the shortest shadow. Experiment confirms this proposition. Thus the body *\_m\_ n\_* is surrounded by a larger amount of light than the body *\_p\_ q\_*, as is shown above. Let us say that *\_v\_ c\_ a\_ b\_ d\_ x\_* is the sky, the source of light, and that *\_s\_ t\_* is a window by which the luminous rays enter, and so *\_m\_ n\_* and *\_p\_ q\_* are bodies in light and shade as exposed to this light; *\_m\_ n\_* will have a small derived shadow, because its original shadow will be small; and the derivative light will be large, again, because the original light *\_c\_ d\_* will be large and *\_p\_ q\_* will have more derived shadow because its original shadow will be larger, and its derived light will be smaller than that of the body *\_m\_ n\_* because that portion of the hemisphere *\_a\_ b\_* which illuminates it is smaller than the hemisphere *\_c\_ d\_* which illuminates the body *\_m\_ n\_*.

[Footnote: The diagram, given on Pl. IV, No. 2, stands in the original between lines 2 and 7, while the text of lines 3 to 6 is written on its left side. In the reproduction of this diagram the letter *\_v\_* at the outer right-hand end has been omitted.]

170.

The shadow  $_{m}$  bears the same proportion to the shadow  $_{n}$  as the line  $_{b c}$  to the line  $_{f c}$ .

171.

#### OF PAINTING.

Of different shadows of equal strength that which is nearest the eye will seem the least strong.

Why is the shadow  $_{e a b}$  in the first grade of strength,  $_{b c}$  in the second;  $_{c d}$  in the third? The reason is that as from  $_{e a b}$  the sky is nowhere visible, it gets no light whatever from the sky, and so has no direct [primary] light.  $_{b c}$  faces the portion of the sky  $_{f g}$  and is illuminated by it.  $_{c d}$  faces the sky at  $_{h k}$ .  $_{c d}$ , being exposed to a larger extent of sky than  $_{b c}$ , it is reasonable that it should be more lighted. And thus, up to a certain distance, the wall  $_{a d}$  will grow lighter for the reasons here given, until the darkness of the room overpowers the light from the window.

172.

When the light of the atmosphere is restricted [by an opening] and illuminates bodies which cast shadows, these bodies being equally distant from the centre of the window, that which is most obliquely placed will cast the largest shadow beyond it.

173.

These bodies standing apart in a room lighted by a single window will have derivative shadows more or less short according as they are more or less opposite to the window. Among the shadows cast by bodies of equal mass but at unequal distances from the opening by which they are illuminated, that shadow will be the longest of the body which is least in the light. And in proportion as one body is better illuminated than another its shadow will be shorter than another. The proportion  $_{n m}$  and  $_{e v k}$  bear to  $_{r t}$  and  $_{v x}$  corresponds with that of the shadow  $_{x}$  to 4 and  $_{y}$ .

The reason why those bodies which are placed most in front of the middle of the window throw shorter shadows than those obliquely situated is:--That the window appears in its proper form and to the obliquely placed ones it appears foreshortened; to those in the middle, the window shows its full size, to the oblique ones it appears smaller; the one in the middle faces the whole hemisphere that is  $_{e f}$  and those on the side have only a strip; that is  $_{q r}$  faces  $_{a b}$ ; and  $_{m n}$  faces  $_{c d}$ ; the body in the middle having a larger quantity of light than those at the sides is lighted from a point much below its centre, and thus the shadow is shorter. And the pyramid  $_{g_4}$  goes into  $_{l y}$  exactly as often as  $_{a b}$  goes into  $_{e f}$ . The axis of every derivative shadow passes through  $6 \frac{1}{2}$  [Footnote 31:  $_{passa per} 6 \frac{1}{2}$  (passes through  $6 \frac{1}{2}$ ). The meaning

of these words is probably this: Each of the three axes of the derived shadow intersects the centre (*\_mezzo\_*) of the primary shadow (*\_ombra originale\_*) and, by prolongation upwards crosses six lines.

This is self evident only in the middle diagram; but it is equally true of the side figures if we conceive of the lines *4 \_f\_*, *\_x n v m\_*, *\_y l k v\_*, and *4 \_e\_*, as prolonged beyond the semicircle of the horizon.] and is in a straight line with the centre of the primary shadow, with the centre of the body casting it and of the derivative light and with the centre of the window and, finally, with the centre of that portion of the source of light which is the celestial hemisphere, *\_y h\_* is the centre of the derived shade, *\_l h\_* of the primary shadow, *\_l\_* of the body throwing it, *\_l k\_* of the derived light, *\_v\_* is the centre of the window, *\_e\_* is the final centre of the original light afforded by that portion of the hemisphere of the sky which illuminates the solid body.

[Footnote: Compare the diagram on Pl. IV, No. 3. In the original this drawing is placed between lines 3 and 22; the rest, from line 4 to line 21, is written on the left hand margin.]

174.

THE FARTHER THE DERIVED SHADOW IS PROLONGED THE LIGHTER IT BECOMES.

You will find that the proportion of the diameter of the derived shadow to that of the primary shadow will be the same as that between the darkness of the primary shadow and that of the derived shadow.

[Footnote 6: Compare No. 177.] Let *\_a b\_* be the diameter of the primary shadow and *\_c d\_* that of the derived shadow, I say that *\_a b\_* going, as you see, three times into *\_d c\_*, the shadow *\_d c\_* will be three times as light as the shadow *\_a b\_*. [Footnote 8: Compare No. 177.]

If the size of the illuminating body is larger than that of the illuminated body an intersection of shadow will occur, beyond which the shadows will run off in two opposite directions as if they were caused by two separate lights.

On the relative intensity of derived shadows (175-179).

175.

ON PAINTING.

The derived shadow is stronger in proportion as it is nearer to its place of origin.

176.

HOW SHADOWS FADE AWAY AT LONG DISTANCES.

Shadows fade and are lost at long distances because the larger quantity of illuminated air which lies between the eye and the object seen tints the shadow with its own colour.

177.

$\_a b\_$  will be darker than  $\_c d\_$  in proportion as  $\_c d\_$  is broader than  $\_a b\_$ .

[Footnote: In the original MS. the word  $\_lume\_$  (light) is written at the apex of the pyramid.]

178.

It can be proved why the shadow  $\_o p c h\_$  is darker in proportion as it is nearer to the line  $\_p h\_$  and is lighter in proportion as it is nearer to the line  $\_o c\_$ . Let the light  $\_a b\_$ , be a window, and let the dark wall in which this window is, be  $\_b s\_$ , that is, one of the sides of the wall.

Then we may say that the line  $\_p h\_$  is darker than any other part of the space  $\_o p c h\_$ , because this line faces the whole surface in shadow of [Footnote: In the original the diagram is placed between lines 27 and 28.] the wall  $\_b s\_$ . The line  $\_o c\_$  is lighter than the other part of this space  $\_o p c h\_$ , because this line faces the luminous space  $\_a b\_$ .

Where the shadow is larger, or smaller, or equal the body which casts it.

[First of the character of divided lights. [Footnote 14:  $\_lumi\ divisi\_$ . The text here breaks off abruptly.]

OF THE COMPOUND SHADOW  $\_f, R, C, H\_$  CAUSED BY A SINGLE LIGHT.

The shadow  $\_f r c h\_$  is under such conditions as that where it is farthest from its inner side it loses depth in proportion. To prove this:

Let  $\_d a\_$ , be the light and  $\_f n\_$  the solid body, and let  $\_a e\_$  be one of the side walls of the window that is  $\_d a\_$ . Then I say--according to the 2nd [proposition]: that the surface of any body is affected by the tone of the objects surrounding it,--that the side  $\_r c\_$ , which faces the dark wall  $\_a e\_$  must participate of its darkness and, in the same way that the outer surface which faces the light  $\_d a\_$  participates of the light; thus we get the outlines of the extremes on each side of the centre included between them.]

This is divided into four parts. The first the extremes, which include the compound shadow, secondly the compound shadow between these extremes.

179.

#### THE ACTION OF THE LIGHT AS FROM ITS CENTRE.

If it were the whole of the light that caused the shadows beyond the bodies placed in front of it, it would follow that any body much smaller than the light would cast a pyramidal shadow; but experience not showing this, it must be the centre of the light that produces this effect.

[Footnote: The diagram belonging to this passage is between lines 4 and 5 in the original. Comp. the reproduction Pl. IV, No. 4. The text and drawing of this chapter have already been published with tolerable accuracy. See M. JORDAN: "Das Malerbuch des Leonardo da Vinci". Leipzig 1873, P. 90.]

#### PROOF.

Let a b be the width of the light from a window, which falls on a stick set up at one foot from a c [Footnote 6: bastone (stick). The diagram has a sphere in place of a stick.]. And let a d be the space where all the light from the window is visible. At c e that part of the window which is between l b cannot be seen. In the same way a m cannot be seen from d f and therefore in these two portions the light begins to fail.

Shadow as produced by two lights of different size (180. 181).

180.

A body in light and shade placed between two equal lights side by side will cast shadows in proportion to the [amount of] light. And the shadows will be one darker than the other in proportion as one light is nearer to the said body than the other on the opposite side.

A body placed at an equal distance between two lights will cast two shadows, one deeper than the other in proportion, as the light which causes it is brighter than the other.

[Footnote: In the MS. the larger diagram is placed above the first line; the smaller one between l. 4 & 5.]

181.

A light which is smaller than the body it illuminates produces shadows of which the outlines end within [the surface of] the body, and not much compound shadow; and falls on less than half of it. A light which is larger than the body it illuminates, falls on more than half of it, and produces much compound shadow.

The effect of light at different distances.



182.

#### OF THE SHADOW CAST BY A BODY PLACED BETWEEN 2 EQUAL LIGHTS.

A body placed between 2 equal lights will cast 2 shadows of itself in the direction of the lines of the 2 lights; and if you move this body placing it nearer to one of the lights the shadow cast towards the nearer light will be less deep than that which falls towards the more distant one.

Further complications in the derived shadows (183-187).

183.

The greatest depth of shadow is in the simple derived shadow because it is not lighted by either of the two lights *\_a b, c d\_*.

The next less deep shadow is the derived shadow *\_e f n\_*; and in this the shadow is less by half, because it is illuminated by a single light, that is *\_c d\_*.

This is uniform in natural tone because it is lighted throughout by one only of the two luminous bodies [10]. But it varies with the conditions of shadow, inasmuch as the farther it is away from the light the less it is illuminated by it [13].

The third degree of depth is the middle shadow [Footnote 15: We gather from what follows that *\_q g r\_* here means *\_ombra media\_* (the middle shadow)]. But this is not uniform in natural tone; because the nearer it gets to the simple derived shadow the deeper it is [Footnote 18: Compare lines 10-13], and it is the uniformly gradual diminution by increase of distance which is what modifies it [Footnote 20: See Footnote 18]: that is to say the depth of a shadow increases in proportion to the distance from the two lights.

The fourth is the shadow *\_k r s\_* and this is all the darker in natural tone in proportion as it is nearer to *\_k s\_*, because it gets less of the light *\_a o\_*, but by the accident [of distance] it is rendered less deep, because it is nearer to the light *\_c d\_*, and thus is always exposed to both lights.

The fifth is less deep in shadow than either of the others because it is always entirely exposed to one of the lights and to the whole or part of the other; and it is less deep in proportion as it is nearer to the two lights, and in proportion as it is turned towards the outer side *\_x t\_*; because it is more exposed to the second light *\_a b\_*.

[Footnote: The diagram to this section is given on Pl. V. To the left is the facsimile of the beginning of the text belonging to it.]

184.

## OF SIMPLE SHADOWS.

Why, at the intersections  $a$ ,  $b$  of the two compound shadows  $ef$  and  $me$ , is a simple shadow produced as at  $eh$  and  $mg$ , while no such simple shadow is produced at the other two intersections  $cd$  made by the very same compound shadows?

## ANSWER.

Compound shadows are a mixture of light and shade and simple shadows are simply darkness. Hence, of the two lights  $n$  and  $o$ , one falls on the compound shadow from one side, and the other on the compound shadow from the other side, but where they intersect no light falls, as at  $ab$ ; therefore it is a simple shadow. Where there is a compound shadow one light or the other falls; and here a difficulty arises for my adversary since he says that, where the compound shadows intersect, both the lights which produce the shadows must of necessity fall and therefore these shadows ought to be neutralised; inasmuch as the two lights do not fall there, we say that the shadow is a simple one and where only one of the two lights falls, we say the shadow is compound, and where both the lights fall the shadow is neutralised; for where both lights fall, no shadow of any kind is produced, but only a light background limiting the shadow. Here I shall say that what my adversary said was true: but he only mentions such truths as are in his favour; and if we go on to the rest he must conclude that my proposition is true. And that is: That if both lights fell on the point of intersection, the shadows would be neutralised. This I confess to be true if [neither of] the two shadows fell in the same spot; because, where a shadow and a light fall, a compound shadow is produced, and wherever two shadows or two equal lights fall, the shadow cannot vary in any part of it, the shadows and the lights both being equal. And this is proved in the eighth [proposition] on proportion where it is said that if a given quantity has a single unit of force and resistance, a double quantity will have double force and double resistance.

## DEFINITION.

The intersection  $n$  is produced by the shadows caused by the light  $b$ , because this light  $b$  produces the shadow  $xb$ , and the shadow  $sb$ , but the intersection  $m$  is produced by the light  $a$  which causes the shadow  $sa$ , and the shadow  $xa$ .

But if you uncover both the lights  $ab$ , then you get the two shadows  $nm$  both at once, and besides these, two other, simple shadows are produced at  $ro$  where neither of the two lights falls at all. The grades of depth in compound shadows are fewer in proportion as the lights falling on, and crossing them are less numerous.

186.

Why the intersections at  $n$  being composed of two compound derived

shadows, forms a compound shadow and not a simple one, as happens with other intersections of compound shadows. This occurs, according to the 2nd [diagram] of this [prop.] which says:--The intersection of derived shadows when produced by the intersection of columnar shadows caused by a single light does not produce a simple shadow. And this is the corollary of the 1st [prop.] which says:--The intersection of simple derived shadows never results in a deeper shadow, because the deepest shadows all added together cannot be darker than one by itself. Since, if many deepest shadows increased in depth by their duplication, they could not be called the \_deepest\_ shadows, but only part-shadows. But if such intersections are illuminated by a second light placed between the eye and the intersecting bodies, then those shadows would become compound shadows and be uniformly dark just as much at the intersection as throughout the rest. In the 1st and 2nd above, the intersections \_i k\_ will not be doubled in depth as it is doubled in quantity. But in this 3rd, at the intersections \_g n\_ they will be double in depth and in quantity.

187.

#### HOW AND WHEN THE SURROUNDINGS IN SHADOW MINGLE THEIR DERIVED SHADOW WITH THE LIGHT DERIVED FROM THE LUMINOUS BODY.

The derived shadow of the dark walls on each side of the bright light of the window are what mingle their various degrees of shade with the light derived from the window; and these various depths of shade modify every portion of the light, except where it is strongest, at \_c\_. To prove this let \_d a\_ be the primary shadow which is turned towards the point \_e\_, and darkens it by its derived shadow; as may be seen by the triangle \_a e d\_, in which the angle \_e\_ faces the darkened base \_d a e\_ ; the point \_v\_ faces the dark shadow \_a s\_ which is part of \_a d\_ , and as the whole is greater than a part, \_e\_ which faces the whole base [of the triangle], will be in deeper shadow than \_v\_ which only faces part of it. In consequence of the conclusion [shown] in the above diagram, \_t\_ will be less darkened than \_v\_ , because the base of the \_t\_ is part of the base of the \_v\_ ; and in the same way it follows that \_p\_ is less in shadow than \_t\_ , because the base of the \_p\_ is part of the base of the \_t\_ . And \_c\_ is the terminal point of the derived shadow and the chief beginning of the highest light.

[Footnote: The diagram on Pl. IV, No. 5 belongs to this passage; but it must be noted that the text explains only the figure on the right-hand side.]

#### FOURTH BOOK ON LIGHT AND SHADE.

On the shape of the cast shadows (188-191).

188.

The form of the shadow cast by any body of uniform density can never

be the same as that of the body producing it. [Footnote: Comp. the drawing on Pl. XXVIII, No. 5.]

189.

No cast shadow can produce the true image of the body which casts it on a vertical plane unless the centre of the light is equally distant from all the edges of that body.

190.

If a window *a b* admits the sunlight into a room, the sunlight will magnify the size of the window and diminish the shadow of a man in such a way as that when the man makes that dim shadow of himself, approach to that which defines the real size of the window, he will see the shadows where they come into contact, dim and confused from the strength of the light, shutting off and not allowing the solar rays to pass; the effect of the shadow of the man cast by this contact will be exactly that figured above.

[Footnote: It is scarcely possible to render the meaning of this sentence with strict accuracy; mainly because the grammatical construction is defective in the most important part--line 4. In the very slight original sketch the shadow touches the upper arch of the window and the correction, here given is perhaps not justified.]

191.

A shadow is never seen as of uniform depth on the surface which intercepts it unless every portion of that surface is equidistant from the luminous body. This is proved by the 7th which says:--The shadow will appear lighter or stronger as it is surrounded by a darker or a lighter background. And by the 8th of this:--The background will be in parts darker or lighter, in proportion as it is farther from or nearer to the luminous body. And:--Of various spots equally distant from the luminous body those will always be in the highest light on which the rays fall at the smallest angles: The outline of the shadow as it falls on inequalities in the surface will be seen with all the contours similar to those of the body that casts it, if the eye is placed just where the centre of the light was.

The shadow will look darkest where it is farthest from the body that casts it. The shadow *c d*, cast by the body in shadow *a b* which is equally distant in all parts, is not of equal depth because it is seen on a back ground of varying brightness. [Footnote: Compare the three diagrams on Pl. VI, no 1 which, in the original accompany this section.]

On the outlines of cast shadows (192-195).

192.

The edges of a derived shadow will be most distinct where it is cast nearest to the primary shadow.

193.

As the derived shadow gets more distant from the primary shadow, the more the cast shadow differs from the primary shadow.

194.

OF SHADOWS WHICH NEVER COME TO AN END.

The greater the difference between a light and the body lighted by it, the light being the larger, the more vague will be the outlines of the shadow of that object.

The derived shadow will be most confused towards the edges of its interception by a plane, where it is remotest from the body casting it.

195.

What is the cause which makes the outlines of the shadow vague and confused?

Whether it is possible to give clear and definite outlines to the edges of shadows.

On the relative size of shadows (196. 197).

196.

THE BODY WHICH IS NEAREST TO THE LIGHT CASTS THE LARGEST SHADOW, AND WHY?

If an object placed in front of a single light is very close to it you will see that it casts a very large shadow on the opposite wall, and the farther you remove the object from the light the smaller will the image of the shadow become.

WHY A SHADOW LARGER THAN THE BODY THAT PRODUCES IT BECOMES OUT OF PROPORTION.

The disproportion of a shadow which is larger than the body producing it, results from the light being smaller than the body, so that it cannot be at an equal distance from the edges of the body [Footnote 11: H. LUDWIG in his edition of the old copies, in the Vatican library--in which this chapter is included under Nos. 612, 613 and 614 alters this passage as follows: *\_quella parte ch'e piu propinqua piu cresce che le distanti\_*, although the Vatican copy agrees with the original MS. in having *\_distante\_* in the former and *\_propinque\_* in the latter place. This supposed amendment seems to me to invert the facts. Supposing for instance, that on Pl. XXXI No. 3.

\_f\_ is the spot where the light is that illuminates the figure there represented, and that the line behind the figure represents a wall on which the shadow of the figure is thrown. It is evident, that in that case the nearest portion, in this case the under part of the thigh, is very little magnified in the shadow, and the remoter parts, for instance the head, are more magnified.; and the portions which are most remote are made larger than the nearer portions for this reason [Footnote 12: See Footnote 11].

#### WHY A SHADOW WHICH IS LARGER THAN THE BODY CAUSING IT HAS ILL-DEFINED OUTLINES.

The atmosphere which surrounds a light is almost like light itself for brightness and colour; but the farther off it is the more it loses this resemblance. An object which casts a large shadow and is near to the light, is illuminated both by that light by the luminous atmosphere; hence this diffused light gives the shadow ill-defined edges.

197.

A luminous body which is long and narrow in shape gives more confused outlines to the derived shadow than a spherical light, and this contradicts the proposition next following: A shadow will have its outlines more clearly defined in proportion as it is nearer to the primary shadow or, I should say, the body casting the shadow; [Footnote 14: The lettering refers to the lower diagram, Pl. XLI, No. 5.] the cause of this is the elongated form of the luminous body \_a c\_, &c. [Footnote 16: See Footnote 14].

Effects on cast shadows by the tone of the back ground.

198.

#### OF MODIFIED SHADOWS.

Modified shadows are those which are cast on light walls or other illuminated objects.

A shadow looks darkest against a light background. The outlines of a derived shadow will be clearer as they are nearer to the primary shadow. A derived shadow will be most defined in shape where it is intercepted, where the plane intercepts it at the most equal angle.

Those parts of a shadow will appear darkest which have darker objects opposite to them. And they will appear less dark when they face lighter objects. And the larger the light object opposite, the more the shadow will be lightened.

And the larger the surface of the dark object the more it will darken the derived shadow where it is intercepted.

A disputed proposition.

199.

OF THE OPINION OF SOME THAT A TRIANGLE CASTS NO SHADOW ON A PLANE SURFACE.

Certain mathematicians have maintained that a triangle, of which the base is turned to the light, casts no shadow on a plane; and this they prove by saying [5] that no spherical body smaller than the light can reach the middle with the shadow. The lines of radiant light are straight lines [6]; therefore, suppose the light to be  $g$   $h$  and the triangle  $l$   $m$   $n$ , and let the plane be  $i$   $k$ ; they say the light  $g$  falls on the side of the triangle  $l$   $n$ , and the portion of the plane  $i$   $q$ . Thus again  $h$  like  $g$  falls on the side  $l$   $m$ , and then on  $m$   $n$  and the plane  $p$   $k$ ; and if the whole plane thus faces the lights  $g$   $h$ , it is evident that the triangle has no shadow; and that which has no shadow can cast none. This, in this case appears credible. But if the triangle  $n$   $p$   $g$  were not illuminated by the two lights  $g$  and  $h$ , but by  $i$   $p$  and  $g$  and  $k$  neither side is lighted by more than one single light: that is  $i$   $p$  is invisible to  $h$   $g$  and  $k$  will never be lighted by  $g$ ; hence  $p$   $q$  will be twice as light as the two visible portions that are in shadow.

[Footnote: 5--6. This passage is so obscure that it would be rash to offer an explanation. Several words seem to have been omitted.]

On the relative depth of cast shadows (200-202).

200.

A spot is most in the shade when a large number of darkened rays fall upon it. The spot which receives the rays at the widest angle and by darkened rays will be most in the dark;  $a$  will be twice as dark as  $b$ , because it originates from twice as large a base at an equal distance. A spot is most illuminated when a large number of luminous rays fall upon it.  $d$  is the beginning of the shadow  $d$   $f$ , and tinges  $c$  but  $a$  little;  $d$   $e$  is half of the shadow  $d$   $f$  and gives a deeper tone where it is cast at  $b$  than at  $f$ . And the whole shaded space  $e$  gives its tone to the spot  $a$ . [Footnote: The diagram here referred to is on Pl. XLI, No. 2.]

201.

$A$   $n$  will be darker than  $c$   $r$  in proportion to the number of times that  $a$   $b$  goes into  $c$   $d$ .

202.

The shadow cast by an object on a plane will be smaller in proportion as that object is lighted by feebler rays. Let  $d$   $e$  be the object and  $d$   $c$  the plane surface; the number of times that  $d$   $e$  will go into  $f$   $g$  gives the proportion of light at  $f$   $h$  to  $d$

c\_. The ray of light will be weaker in proportion to its distance from the hole through which it falls.

#### FIFTH BOOK ON LIGHT AND SHADE.

Principles of reflection (203. 204).

203.

#### OF THE WAY IN WHICH THE SHADOWS CAST BY OBJECTS OUGHT TO BE DEFINED.

If the object is the mountain here figured, and the light is at the point *a*, I say that from *b d* and also from *c f* there will be no light but from reflected rays. And this results from the fact that rays of light can only act in straight lines; and the same is the case with the secondary or reflected rays.

204.

The edges of the derived shadow are defined by the hues of the illuminated objects surrounding the luminous body which produces the shadow.

On reverberation.

205.

#### OF REVERBERATION.

Reverberation is caused by bodies of a bright nature with a flat and semi opaque surface which, when the light strikes upon them, throw it back again, like the rebound of a ball, to the former object.

#### WHERE THERE CAN BE NO REFLECTED LIGHTS.

All dense bodies have their surfaces occupied by various degrees of light and shade. The lights are of two kinds, one called original, the other borrowed. Original light is that which is inherent in the flame of fire or the light of the sun or of the atmosphere. Borrowed light will be reflected light; but to return to the promised definition: I say that this luminous reverberation is not produced by those portions of a body which are turned towards darkened objects, such as shaded spots, fields with grass of various height, woods whether green or bare; in which, though that side of each branch which is turned towards the original light has a share of that light, nevertheless the shadows cast by each branch separately are so numerous, as well as those cast by one branch on the others, that finally so much shadow is the result that the light counts for nothing. Hence objects of this kind cannot throw any reflected light on opposite objects.

Reflection on water (206. 207).



206.

#### PERSPECTIVE.

The shadow or object mirrored in water in motion, that is to say in small wavelets, will always be larger than the external object producing it.

207.

It is impossible that an object mirrored on water should correspond in form to the object mirrored, since the centre of the eye is above the surface of the water.

This is made plain in the figure here given, which demonstrates that the eye sees the surface *a b*, and cannot see it at *l f*, and at *r t*; it sees the surface of the image at *r t*, and does not see it in the real object *c d*. Hence it is impossible to see it, as has been said above unless the eye itself is situated on the surface of the water as is shown below [13].

[Footnote: *A* stands for *ochio* [eye], *B* for *aria* [air], *C* for *acqua* [water], *D* for *cateto* [cathetus].--In the original MS. the second diagram is placed below line 13.]

Experiments with the mirror (208-210).

208.

#### THE MIRROR.

If the illuminated object is of the same size as the luminous body and as that in which the light is reflected, the amount of the reflected light will bear the same proportion to the intermediate light as this second light will bear to the first, if both bodies are smooth and white.

209.

Describe how it is that no object has its limitation in the mirror but in the eye which sees it in the mirror. For if you look at your face in the mirror, the part resembles the whole in as much as the part is everywhere in the mirror, and the whole is in every part of the same mirror; and the same is true of the whole image of any object placed opposite to this mirror, &c.

210.

No man can see the image of another man in a mirror in its proper place with regard to the objects; because every object falls on [the surface of] the mirror at equal angles. And if the one man, who sees the other in the mirror, is not in a direct line with the image he will not see it in the place where it really falls; and if he gets

into the line, he covers the other man and puts himself in the place occupied by his image. Let  $n_o$  be the mirror,  $b$  the eye of your friend and  $d$  your own eye. Your friend's eye will appear to you at  $a$ , and to him it will seem that yours is at  $c$ , and the intersection of the visual rays will occur at  $m$ , so that either of you touching  $m$  will touch the eye of the other man which shall be open. And if you touch the eye of the other man in the mirror it will seem to him that you are touching your own.

Appendix:--On shadows in movement (211. 212).

211.

#### OF THE SHADOW AND ITS MOTION.

When two bodies casting shadows, and one in front of the other, are between a window and the wall with some space between them, the shadow of the body which is nearest to the plane of the wall will move if the body nearest to the window is put in transverse motion across the window. To prove this let  $a$  and  $b$  be two bodies placed between the window  $n m$  and the plane surface  $o p$  with sufficient space between them as shown by the space  $a b$ . I say that if the body  $a$  is moved towards  $s$  the shadow of the body  $b$  which is at  $c$  will move towards  $d$ .

212.

#### OF THE MOTION OF SHADOWS.

The motion of a shadow is always more rapid than that of the body which produces it if the light is stationary. To prove this let  $a$  be the luminous body, and  $b$  the body casting the shadow, and  $d$  the shadow. Then I say that in the time while the solid body moves from  $b$  to  $c$ , the shadow  $d$  will move to  $e$ ; and this proportion in the rapidity of the movements made in the same space of time, is equal to that in the length of the space moved over. Thus, given the proportion of the space moved over by the body  $b$  to  $c$ , to that moved over by the shadow  $d$  to  $e$ , the proportion in the rapidity of their movements will be the same.

But if the luminous body is also in movement with a velocity equal to that of the solid body, then the shadow and the body that casts it will move with equal speed. And if the luminous body moves more rapidly than the solid body, the motion of the shadow will be slower than that of the body casting it.

But if the luminous body moves more slowly than the solid body, then the shadow will move more rapidly than that body.

#### SIXTH BOOK ON LIGHT AND SHADE.

The effect of rays passing through holes (213. 214).

213.

#### PERSPECTIVE.

If you transmit the rays of the sun through a hole in the shape of a star you will see a beautiful effect of perspective in the spot where the sun's rays fall.

[Footnote: In this and the following chapters of MS. C the order of the original paging has been adhered to, and is shown in parenthesis. Leonardo himself has but rarely worked out the subject of these propositions. The space left for the purpose has occasionally been made use of for quite different matter. Even the numerous diagrams, most of them very delicately sketched, lettered and numbered, which occur on these pages, are hardly ever explained, with the exception of those few which are here given.]

214.

No small hole can so modify the convergence of rays of light as to prevent, at a long distance, the transmission of the true form of the luminous body causing them. It is impossible that rays of light passing through a parallel [slit], should not display the form of the body causing them, since all the effects produced by a luminous body are [in fact] the reflection of that body: The moon, shaped like a boat, if transmitted through a hole is figured in the surface [it falls on] as a boatshaped object. [Footnote 8: In the MS. a blank space is left after this question.] Why the eye sees bodies at a distance, larger than they measure on the vertical plane?.

[Footnote: This chapter, taken from another MS. may, as an exception, be placed here, as it refers to the same subject as the preceding section.]

On gradation of shadows (215. 216).

215.

Although the breadth and length of lights and shadow will be narrower and shorter in foreshortening, the quality and quantity of the light and shade is not increased nor diminished.

[3]The function of shade and light when diminished by foreshortening, will be to give shadow and to illuminate an object opposite, according to the quality and quantity in which they fall on the body.

[5]In proportion as a derived shadow is nearer to its penultimate extremities the deeper it will appear,  $g z$  beyond the intersection faces only the part of the shadow [marked]  $y z$ ; this by intersection takes the shadow from  $m n$  but by direct line it takes the shadow  $a m$  hence it is twice as deep as  $g z$ .  $Y x$ , by intersection takes the shadow  $n o$ , but by direct line the shadow

\_n m a\_, therefore \_x y\_ is three times as dark as \_z g\_; \_x f\_, by intersection faces \_o b\_ and by direct line \_o n m a\_, therefore we must say that the shadow between \_f x\_ will be four times as dark as the shadow \_z g\_, because it faces four times as much shadow.

Let \_a b\_ be the side where the primary shadow is, and \_b c\_ the primary light, \_d\_ will be the spot where it is intercepted, \_f g\_ the derived shadow and \_f e\_ the derived light.

And this must be at the beginning of the explanation.

[Footnote: In the original MS. the text of No. 252 precedes the one given here. In the text of No. 215 there is a blank space of about four lines between the lines 2 and 3. The diagram given on Pl. VI, No. 2 is placed between lines 4 and 5. Between lines 5 and 6 there is another space of about three lines and one line left blank between lines 8 and 9. The reader will find the meaning of the whole passage much clearer if he first reads the final lines 11--13. Compare also line 4 of No. 270.]

On relative proportion of light and shadows (216--221).

216.

That part of the surface of a body on which the images [reflection] from other bodies placed opposite fall at the largest angle will assume their hue most strongly. In the diagram below, 8 is a larger angle than 4, since its base \_a n\_ is larger than \_e n\_ the base of 4. This diagram below should end at \_a n\_ 4 8. [4] That portion of the illuminated surface on which a shadow is cast will be brightest which lies contiguous to the cast shadow. Just as an object which is lighted up by a greater quantity of luminous rays becomes brighter, so one on which a greater quantity of shadow falls, will be darker.

Let 4 be the side of an illuminated surface 4 8, surrounding the cast shadow \_g e\_ 4. And this spot 4 will be lighter than 8, because less shadow falls on it than on 8. Since 4 faces only the shadow \_i n\_ and 8 faces and receives the shadow \_a e\_ as well as \_i n\_ which makes it twice as dark. And the same thing happens when you put the atmosphere and the sun in the place of shade and light.

[12] The distribution of shadow, originating in, and limited by, plane surfaces placed near to each other, equal in tone and directly opposite, will be darker at the ends than at the beginning, which will be determined by the incidence of the luminous rays. You will find the same proportion in the depth of the derived shadows \_a n\_ as in the nearness of the luminous bodies \_m b\_, which cause them; and if the luminous bodies were of equal size you would still farther find the same proportion in the light cast by the luminous circles and their shadows as in the distance of the said luminous bodies.

[Footnote: The diagram originally placed between lines 3 and 4 is on

Pl. VI, No. 3. In the diagram given above line 14 of the original, and here printed in the text, the words *\_corpo luminoso\_* [luminous body] are written in the circle *\_m\_*, *\_luminoso\_* in the circle *\_b\_* and *\_ombroso\_* [body in shadow] in the circle *\_o\_*.

217.

THAT PART OF THE REFLECTION WILL BE BRIGHTEST WHERE THE REFLECTED RAYS ARE SHORTEST.

[2] The darkness occasioned by the casting of combined shadows will be in conformity with its cause, which will originate and terminate between two plane surfaces near together, alike in tone and directly opposite each other.

[4] In proportion as the source of light is larger, the luminous and shadow rays will be more mixed together. This result is produced because wherever there is a larger quantity of luminous rays, there is most light, but where there are fewer there is least light, consequently the shadow rays come in and mingle with them.

[Footnote: Diagrams are inserted before lines 2 and 4.]

218.

In all the proportions I lay down it must be understood that the medium between the bodies is always the same. [2] The smaller the luminous body the more distinct will the transmission of the shadows be.

[3] When of two opposite shadows, produced by the same body, one is twice as dark as the other though similar in form, one of the two lights causing them must have twice the diameter that the other has and be at twice the distance from the opaque body. If the object is slowly moved across the luminous body, and the shadow is intercepted at some distance from the object, there will be the same relative proportion between the motion of the derived shadow and the motion of the primary shadow, as between the distance from the object to the light, and that from the object to the spot where the shadow is intercepted; so that though the object is moved slowly the shadow moves fast.

[Footnote: There are diagrams inserted before lines 2 and 3 but they are not reproduced here. The diagram above line 6 is written upon as follows: at *\_A lume\_* (light), at *\_B obbietto\_* (body), at *\_C ombra d'obbietto\_* (shadow of the object).]

219.

A luminous body will appear less brilliant when surrounded by a bright background.

[2] I have found that the stars which are nearest to the horizon

look larger than the others because light falls upon them from a larger proportion of the solar body than when they are above us; and having more light from the sun they give more light, and the bodies which are most luminous appear the largest. As may be seen by the sun through a mist, and overhead; it appears larger where there is no mist and diminished through mist. No portion of the luminous body is ever visible from any spot within the pyramid of pure derived shadow.

[Footnote: Between lines 1 and 2 there is in the original a large diagram which does not refer to this text. ]

220.

A body on which the solar rays fall between the thin branches of trees far apart will cast but a single shadow.

[2] If an opaque body and a luminous one are (both) spherical the base of the pyramid of rays will bear the same proportion to the luminous body as the base of the pyramid of shade to the opaque body.

[4] When the transmitted shadow is intercepted by a plane surface placed opposite to it and farther away from the luminous body than from the object [which casts it] it will appear proportionately darker and the edges more distinct.

[Footnote: The diagram which, in the original, is placed above line 2, is similar to the one, here given on page 73 (section 120).--The diagram here given in the margin stands, in the original, between lines 3 and 4.]

221.

A body illuminated by the solar rays passing between the thick branches of trees will produce as many shadows as there are branches between the sun and itself.

Where the shadow-rays from an opaque pyramidal body are intercepted they will cast a shadow of bifurcate outline and various depth at the points. A light which is broader than the apex but narrower than the base of an opaque pyramidal body placed in front of it, will cause that pyramid to cast a shadow of bifurcate form and various degrees of depth.

If an opaque body, smaller than the light, casts two shadows and if it is the same size or larger, casts but one, it follows that a pyramidal body, of which part is smaller, part equal to, and part larger than, the luminous body, will cast a bifurcate shadow.

[Footnote: Between lines 2 and 3 there are in the original two large diagrams.]

\_IV.\_

\_Perspective of Disappearance.\_

\_The theory of the\_ "Prospettiva de' perdimenti" \_would, in many important details, be quite unintelligible if it had not been led up by the principles of light and shade on which it is based. The word\_ "Prospettiva" \_in the language of the time included the principles of optics; what Leonardo understood by\_ "Perdimenti" \_will be clearly seen in the early chapters, Nos.\_ 222--224. \_It is in the very nature of the case that the farther explanations given in the subsequent chapters must be limited to general rules. The sections given as\_ 227--231 \_"On indistinctness at short distances" have, it is true, only an indirect bearing on the subject; but on the other hand, the following chapters,\_ 232--234, \_"On indistinctness at great distances," go fully into the matter, and in chapters\_ 235--239, \_which treat "Of the importance of light and shade in the Perspective of Disappearance", the practical issues are distinctly insisted on in their relation to the theory. This is naturally followed by the statements as to "the effect of light or dark backgrounds on the apparent size of bodies" \_ (\_Nos.\_ 240--250). \_At the end I have placed, in the order of the original, those sections from the MS.\_ C \_which treat of the "Perspective of Disappearance" and serve to some extent to complete the treatment of the subject\_ (251--262).

Definition (222. 223).

222.

OF THE DIMINISHED DISTINCTNESS OF THE OUTLINES OF OPAQUE BODIES.

If the real outlines of opaque bodies are indistinguishable at even a very short distance, they will be more so at long distances; and, since it is by its outlines that we are able to know the real form of any opaque body, when by its remoteness we fail to discern it as a whole, much more must we fail to discern its parts and outlines.

223.

OF THE DIMINUTION IN PERSPECTIVE OF OPAQUE OBJECTS.

Among opaque objects of equal size the apparent diminution of size will be in proportion to their distance from the eye of the spectator; but it is an inverse proportion, since, where the distance is greater, the opaque body will appear smaller, and the less the distance the larger will the object appear. And this is the fundamental principle of linear perspective and it follows:--[11]every object as it becomes more remote loses first those parts which are smallest. Thus of a horse, we should lose the legs before the head, because the legs are thinner than the head; and the neck before the body for the same reason. Hence it follows that the last part of the horse which would be discernible by the

eye would be the mass of the body in an oval form, or rather in a cylindrical form and this would lose its apparent thickness before its length--according to the 2nd rule given above, &c. [Footnote 23: Compare line 11.].

If the eye remains stationary the perspective terminates in the distance in a point. But if the eye moves in a straight [horizontal] line the perspective terminates in a line and the reason is that this line is generated by the motion of the point and our sight; therefore it follows that as we move our sight [eye], the point moves, and as we move the point, the line is generated, &c.

An illustration by experiment.

224.

Every visible body, in so far as it affects the eye, includes three attributes; that is to say: mass, form and colour; and the mass is recognisable at a greater distance from the place of its actual existence than either colour or form. Again, colour is discernible at a greater distance than form, but this law does not apply to luminous bodies.

The above proposition is plainly shown and proved by experiment; because: if you see a man close to you, you discern the exact appearance of the mass and of the form and also of the colouring; if he goes to some distance you will not recognise who he is, because the character of the details will disappear, if he goes still farther you will not be able to distinguish his colouring, but he will appear as a dark object, and still farther he will appear as a very small dark rounded object. It appears rounded because distance so greatly diminishes the various details that nothing remains visible but the larger mass. And the reason is this: We know very well that all the images of objects reach the senses by a small aperture in the eye; hence, if the whole horizon *a d* is admitted through such an aperture, the object *b c* being but a very small fraction of this horizon what space can it fill in that minute image of so vast a hemisphere? And because luminous bodies have more power in darkness than any others, it is evident that, as the chamber of the eye is very dark, as is the nature of all colored cavities, the images of distant objects are confused and lost in the great light of the sky; and if they are visible at all, appear dark and black, as every small body must when seen in the diffused light of the atmosphere.

[Footnote: The diagram belonging to this passage is placed between lines 5 and 6; it is No. 4 on Pl. VI. ]

A guiding rule.

225.

OF THE ATMOSPHERE THAT INTERPOSES BETWEEN THE EYE AND VISIBLE



## OBJECTS.

An object will appear more or less distinct at the same distance, in proportion as the atmosphere existing between the eye and that object is more or less clear. Hence, as I know that the greater or less quantity of the air that lies between the eye and the object makes the outlines of that object more or less indistinct, you must diminish the definiteness of outline of those objects in proportion to their increasing distance from the eye of the spectator.

An experiment.

226.

When I was once in a place on the sea, at an equal distance from the shore and the mountains, the distance from the shore looked much greater than that from the mountains.

On indistinctness at short distances (227-231).

227.

If you place an opaque object in front of your eye at a distance of four fingers' breadth, if it is smaller than the space between the two eyes it will not interfere with your seeing any thing that may be beyond it. No object situated beyond another object seen by the eye can be concealed by this [nearer] object if it is smaller than the space from eye to eye.

228.

The eye cannot take in a luminous angle which is too close to it.

229.

That part of a surface will be better lighted on which the light falls at the greater angle. And that part, on which the shadow falls at the greatest angle, will receive from those rays least of the benefit of the light.

230.

## OF THE EYE.

The edges of an object placed in front of the pupil of the eye will be less distinct in proportion as they are closer to the eye. This is shown by the edge of the object \_n\_ placed in front of the pupil \_d\_; in looking at this edge the pupil also sees all the space \_a c\_ which is beyond the edge; and the images the eye receives from that space are mingled with the images of the edge, so that one image confuses the other, and this confusion hinders the pupil from distinguishing the edge.

231.

The outlines of objects will be least clear when they are nearest to the eye, and therefore remoter outlines will be clearer. Among objects which are smaller than the pupil of the eye those will be less distinct which are nearer to the eye.

On indistinctness at great distances (232-234).

232.

Objects near to the eye will appear larger than those at a distance.

Objects seen with two eyes will appear rounder than if they are seen with only one.

Objects seen between light and shadow will show the most relief.

233.

OF PAINTING.

Our true perception of an object diminishes in proportion as its size is diminished by distance.

234.

PERSPECTIVE.

Why objects seen at a distance appear large to the eye and in the image on the vertical plane they appear small.

PERSPECTIVE.

I ask how far away the eye can discern a non-luminous body, as, for instance, a mountain. It will be very plainly visible if the sun is behind it; and could be seen at a greater or less distance according to the sun's place in the sky.

[Footnote: The clue to the solution of this problem (lines 1-3) is given in lines 4-6, No. 232. Objects seen with both eyes appear solid since they are seen from two distinct points of sight separated by the distance between the eyes, but this solidity cannot be represented in a flat drawing. Compare No. 535.]

The importance of light and shade in the perspective of disappearance (235-239).

235.

An opaque body seen in a line in which the light falls will reveal no prominences to the eye. For instance, let  $a$  be the solid body and  $c$  the light;  $cm$  and  $cn$  will be the lines of incidence of

the light, that is to say the lines which transmit the light to the object \_a\_. The eye being at the point \_b\_, I say that since the light \_c\_ falls on the whole part \_m n\_ the portions in relief on that side will all be illuminated. Hence the eye placed at \_c\_ cannot see any light and shade and, not seeing it, every portion will appear of the same tone, therefore the relief in the prominent or rounded parts will not be visible.

236.

#### OF PAINTING.

When you represent in your work shadows which you can only discern with difficulty, and of which you cannot distinguish the edges so that you apprehend them confusedly, you must not make them sharp or definite lest your work should have a wooden effect.

237.

#### OF PAINTING.

You will observe in drawing that among the shadows some are of undistinguishable gradation and form, as is shown in the 3rd [proposition] which says: Rounded surfaces display as many degrees of light and shade as there are varieties of brightness and darkness reflected from the surrounding objects.

238.

#### OF LIGHT AND SHADE.

You who draw from nature, look (carefully) at the extent, the degree, and the form of the lights and shadows on each muscle; and in their position lengthwise observe towards which muscle the axis of the central line is directed.

239.

An object which is [so brilliantly illuminated as to be] almost as bright as light will be visible at a greater distance, and of larger apparent size than is natural to objects so remote.

The effect of light or dark backgrounds on the apparent size of objects (240-250).

240.

A shadow will appear dark in proportion to the brilliancy of the light surrounding it and conversely it will be less conspicuous where it is seen against a darker background.

241.

#### OF ORDINARY PERSPECTIVE.

An object of equal breadth and colour throughout, seen against a background of various colours will appear unequal in breadth.

And if an object of equal breadth throughout, but of various colours, is seen against a background of uniform colour, that object will appear of various breadth. And the more the colours of the background or of the object seen against the ground vary, the greater will the apparent variations in the breadth be though the objects seen against the ground be of equal breadth [throughout].

242.

A dark object seen against a bright background will appear smaller than it is.

A light object will look larger when it is seen against a background darker than itself.

243.

#### OF LIGHT.

A luminous body when obscured by a dense atmosphere will appear smaller; as may be seen by the moon or sun veiled by mists.

#### OF LIGHT.

Of several luminous bodies of equal size and brilliancy and at an equal distance, that will look the largest which is surrounded by the darkest background.

#### OF LIGHT.

I find that any luminous body when seen through a dense and thick mist diminishes in proportion to its distance from the eye. Thus it is with the sun by day, as well as the moon and the other eternal lights by night. And when the air is clear, these luminaries appear larger in proportion as they are farther from the eye.

244.

That portion of a body of uniform breadth which is against a lighter background will look narrower [than the rest].

[4] *e* is a given object, itself dark and of uniform breadth; *a b* and *c d* are two backgrounds one darker than the other; *b c* is a bright background, as it might be a spot lighted by the sun through an aperture in a dark room. Then I say that the object *e g* will appear larger at *e f* than at *g h*; because *e f* has a darker background than *g h*; and again at *f g* it will look narrower from being seen by the eye *o*, on the light background *b c*. [Footnote

12: The diagram to which the text, lines 1-11, refers, is placed in the original between lines 3 and 4, and is given on Pl. XLI, No. 3. Lines 12 to 14 are explained by the lower of the two diagrams on Pl. XLI, No. 4. In the original these are placed after line 14.] That part of a luminous body, of equal breadth and brilliancy throughout, will look largest which is seen against the darkest background; and the luminous body will seem on fire.

245.

#### WHY BODIES IN LIGHT AND SHADE HAVE THEIR OUTLINES ALTERED BY THE COLOUR AND BRIGHTNESS OF THE OBJECTS SERVING AS A BACKGROUND TO THEM.

If you look at a body of which the illuminated portion lies and ends against a dark background, that part of the light which will look brightest will be that which lies against the dark [background] at \_d\_. But if this brighter part lies against a light background, the edge of the object, which is itself light, will be less distinct than before, and the highest light will appear to be between the limit of the background \_m f\_ and the shadow. The same thing is seen with regard to the dark [side], inasmuch as that edge of the shaded portion of the object which lies against a light background, as at \_l\_, it looks much darker than the rest. But if this shadow lies against a dark background, the edge of the shaded part will appear lighter than before, and the deepest shade will appear between the edge and the light at the point \_o\_.

[Footnote: In the original diagram \_o\_ is inside the shaded surface at the level of \_d\_.]

246.

An opaque body will appear smaller when it is surrounded by a highly luminous background, and a light body will appear larger when it is seen against a darker background. This may be seen in the height of buildings at night, when lightning flashes behind them; it suddenly seems, when it lightens, as though the height of the building were diminished. For the same reason such buildings look larger in a mist, or by night than when the atmosphere is clear and light.

247.

#### ON LIGHT BETWEEN SHADOWS

When you are drawing any object, remember, in comparing the grades of light in the illuminated portions, that the eye is often deceived by seeing things lighter than they are. And the reason lies in our comparing those parts with the contiguous parts. Since if two [separate] parts are in different grades of light and if the less bright is conterminous with a dark portion and the brighter is conterminous with a light background--as the sky or something equally bright--, then that which is less light, or I should say

less radiant, will look the brighter and the brighter will seem the darker.

248.

Of objects equally dark in themselves and situated at a considerable and equal distance, that will look the darkest which is farthest above the earth.

249.

TO PROVE HOW IT IS THAT LUMINOUS BODIES APPEAR LARGER, AT A DISTANCE, THAN THEY ARE.

If you place two lighted candles side by side half a braccio apart, and go from them to a distance 200 braccia you will see that by the increased size of each they will appear as a single luminous body with the light of the two flames, one braccio wide.

TO PROVE HOW YOU MAY SEE THE REAL SIZE OF LUMINOUS BODIES.

If you wish to see the real size of these luminous bodies, take a very thin board and make in it a hole no bigger than the tag of a lace and place it as close to your eye as possible, so that when you look through this hole, at the said light, you can see a large space of air round it. Then by rapidly moving this board backwards and forwards before your eye you will see the light increase [and diminish].

Propositions on perspective of disappearance from MS. C. (250-262).

250.

Of several bodies of equal size and equally distant from the eye, those will look the smallest which are against the lightest background.

Every visible object must be surrounded by light and shade. A perfectly spherical body surrounded by light and shade will appear to have one side larger than the other in proportion as one is more highly lighted than the other.

251.

PERSPECTIVE.

No visible object can be well understood and comprehended by the human eye excepting from the difference of the background against which the edges of the object terminate and by which they are bounded, and no object will appear [to stand out] separate from that background so far as the outlines of its borders are concerned. The moon, though it is at a great distance from the sun, when, in an eclipse, it comes between our eyes and the sun, appears to the eyes

of men to be close to the sun and affixed to it, because the sun is then the background to the moon.

252.

A luminous body will appear more brilliant in proportion as it is surrounded by deeper shadow. [Footnote: The diagram which, in the original, is placed after this text, has no connection with it.]

253.

The straight edges of a body will appear broken when they are conterminous with a dark space streaked with rays of light. [Footnote: Here again the diagrams in the original have no connection with the text.]

254.

Of several bodies, all equally large and equally distant, that which is most brightly illuminated will appear to the eye nearest and largest. [Footnote: Here again the diagrams in the original have no connection with the text.]

255.

If several luminous bodies are seen from a great distance although they are really separate they will appear united as one body.

256.

If several objects in shadow, standing very close together, are seen against a bright background they will appear separated by wide intervals.

257.

Of several bodies of equal size and tone, that which is farthest will appear the lightest and smallest.

258.

Of several objects equal in size, brightness of background and length that which has the flattest surface will look the largest. A bar of iron equally thick throughout and of which half is red hot, affords an example, for the red hot part looks thicker than the rest.

259.

Of several bodies of equal size and length, and alike in form and in depth of shade, that will appear smallest which is surrounded by the most luminous background.

260.

DIFFERENT PORTIONS OF A WALL SURFACE WILL BE DARKER OR BRIGHTER IN PROPORTION AS THE LIGHT OR SHADOW FALLS ON THEM AT A LARGER ANGLE.

The foregoing proposition can be clearly proved in this way. Let us say that  $m q$  is the luminous body, then  $f g$  will be the opaque body; and let  $a e$  be the above-mentioned plane on which the said angles fall, showing [plainly] the nature and character of their bases. Then:  $a$  will be more luminous than  $b$ ; the base of the angle  $a$  is larger than that of  $b$  and it therefore makes a greater angle which will be  $a m q$ ; and the pyramid  $b p m$  will be narrower and  $m o c$  will be still finer, and so on by degrees, in proportion as they are nearer to  $e$ , the pyramids will become narrower and darker. That portion of the wall will be the darkest where the breadth of the pyramid of shadow is greater than the breadth of the pyramid of light.

At the point  $a$  the pyramid of light is equal in strength to the pyramid of shadow, because the base  $f g$  is equal to the base  $r f$ . At the point  $d$  the pyramid of light is narrower than the pyramid of shadow by so much as the base  $s f$  is less than the base  $f g$ .

Divide the foregoing proposition into two diagrams, one with the pyramids of light and shadow, the other with the pyramids of light [only].

261.

Among shadows of equal depth those which are nearest to the eye will look least deep.

262.

The more brilliant the light given by a luminous body, the deeper will the shadows be cast by the objects it illuminates.

V.

Theory of colours.

Leonardo's theory of colours is even more intimately connected with his principles of light and shade than his Perspective of Disappearance and is in fact merely an appendix or supplement to those principles, as we gather from the titles to sections 264, 267, and 276, while others again (Nos. 281, 282) are headed Prospettiva.

A very few of these chapters are to be found in the oldest copies and editions of the Treatise on Painting, and although the material they afford is but meager and the connection between them but slight, we must still attribute to them a special theoretical value



as well as practical utility--all the more so because our knowledge of the theory and use of colours at the time of the Renaissance is still extremely limited.\_

The reciprocal effects of colours on objects placed opposite each other (263-272).

263.

#### OF PAINTING.

The hue of an illuminated object is affected by that of the luminous body.

264.

#### OF SHADOW.

The surface of any opaque body is affected by the colour of surrounding objects.

265.

A shadow is always affected by the colour of the surface on which it is cast.

266.

An image produced in a mirror is affected by the colour of the mirror.

267.

#### OF LIGHT AND SHADE.

Every portion of the surface of a body is varied [in hue] by the [reflected] colour of the object that may be opposite to it.

#### EXAMPLE.

If you place a spherical body between various objects that is to say with [direct] sunlight on one side of it, and on the other a wall illuminated by the sun, which wall may be green or of any other colour, while the surface on which it is placed may be red, and the two lateral sides are in shadow, you will see that the natural colour of that body will assume something of the hue reflected from those objects. The strongest will be [given by] the luminous body; the second by the illuminated wall, the third by the shadows. There will still be a portion which will take a tint from the colour of the edges.

268.

The surface of every opaque body is affected by the colour of the objects surrounding it. But this effect will be strong or weak in proportion as those objects are more or less remote and more or less strongly [coloured].

269.

#### OF PAINTING.

The surface of every opaque body assumes the hues reflected from surrounding objects.

The surface of an opaque body assumes the hues of surrounding objects more strongly in proportion as the rays that form the images of those objects strike the surface at more equal angles.

And the surface of an opaque body assumes a stronger hue from the surrounding objects in proportion as that surface is whiter and the colour of the object brighter or more highly illuminated.

270.

#### OF THE RAYS WHICH CONVEY THROUGH THE AIR THE IMAGES OF OBJECTS.

All the minutest parts of the image intersect each other without interfering with each other. To prove this let  $r$  be one of the sides of the hole, opposite to which let  $s$  be the eye which sees the lower end  $o$  of the line  $no$ . The other extremity cannot transmit its image to the eye  $s$  as it has to strike the end  $r$  and it is the same with regard to  $m$  at the middle of the line. The case is the same with the upper extremity  $n$  and the eye  $u$ . And if the end  $n$  is red the eye  $u$  on that side of the holes will not see the green colour of  $o$ , but only the red of  $n$  according to the 7th of this where it is said: Every form projects images from itself by the shortest line, which necessarily is a straight line, &c.

[Footnote: 13. This probably refers to the diagram given under No. 66.]

271.

#### OF PAINTING.

The surface of a body assumes in some degree the hue of those around it. The colours of illuminated objects are reflected from the surfaces of one to the other in various spots, according to the various positions of those objects. Let  $o$  be a blue object in full light, facing all by itself the space  $b c$  on the white sphere  $a b e d e f$ , and it will give it a blue tinge,  $m$  is a yellow body reflected onto the space  $a b$  at the same time as  $o$  the blue body, and they give it a green colour (by the 2nd [proposition] of this which shows that blue and yellow make a beautiful green &c.)

And the rest will be set forth in the Book on Painting. In that Book it will be shown, that, by transmitting the images of objects and the colours of bodies illuminated by sunlight through a small round perforation and into a dark chamber onto a plane surface, which itself is quite white, &c.

But every thing will be upside down.

Combination of different colours in cast shadows.

272.

That which casts the shadow does not face it, because the shadows are produced by the light which causes and surrounds the shadows. The shadow caused by the light *\_e\_*, which is yellow, has a blue tinge, because the shadow of the body *\_a\_* is cast upon the pavement at *\_b\_*, where the blue light falls; and the shadow produced by the light *\_d\_*, which is blue, will be yellow at *\_c\_*, because the yellow light falls there and the surrounding background to these shadows *\_b\_ c\_* will, besides its natural colour, assume a hue compounded of yellow and blue, because it is lighted by the yellow light and by the blue light both at once.

Shadows of various colours, as affected by the lights falling on them. That light which causes the shadow does not face it.

[Footnote: In the original diagram we find in the circle *\_e\_* "*\_giallo\_*" (yellow) and the circle *\_d\_* "*\_azzurro\_*" (blue) and also under the circle of shadow to the left "*\_giallo\_*" is written and under that to the right "*\_azzurro\_*".

In the second diagram where four circles are placed in a row we find written, beginning at the left hand, "*\_giallo\_*" (yellow), "*\_azzurro\_*" (blue), "*\_verde\_*" (green), "*\_rosso\_*" (red).]

The effect of colours in the camera obscura (273-274).

273.

The edges of a colour(ed object) transmitted through a small hole are more conspicuous than the central portions.

The edges of the images, of whatever colour, which are transmitted through a small aperture into a dark chamber will always be stronger than the middle portions.

274.

OF THE INTERSECTIONS OF THE IMAGES IN THE PUPIL OF THE EYE.

The intersections of the images as they enter the pupil do not mingle in confusion in the space where that intersection unites them; as is evident, since, if the rays of the sun pass through two

panes of glass in close contact, of which one is blue and the other yellow, the rays, in penetrating them, do not become blue or yellow but a beautiful green. And the same thing would happen in the eye, if the images which were yellow or green should mingle where they [meet and] intersect as they enter the pupil. As this does not happen such a mingling does not exist.

#### OF THE NATURE OF THE RAYS COMPOSED OF THE IMAGES OF OBJECTS, AND OF THEIR INTERSECTIONS.

The directness of the rays which transmit the forms and colours of the bodies whence they proceed does not tinge the air nor can they affect each other by contact where they intersect. They affect only the spot where they vanish and cease to exist, because that spot faces and is faced by the original source of these rays, and no other object, which surrounds that original source can be seen by the eye where these rays are cut off and destroyed, leaving there the spoil they have conveyed to it. And this is proved by the 4th [proposition], on the colour of bodies, which says: The surface of every opaque body is affected by the colour of surrounding objects; hence we may conclude that the spot which, by means of the rays which convey the image, faces--and is faced by the cause of the image, assumes the colour of that object.

On the colours of derived shadows (275. 276).

275.

ANY SHADOW CAST BY AN OPAQUE BODY SMALLER THAN THE LIGHT CAUSING THE SHADOW WILL THROW A DERIVED SHADOW WHICH IS TINGED BY THE COLOUR OF THE LIGHT.

Let  $n$  be the source of the shadow  $ef$ ; it will assume its hue. Let  $o$  be the source of  $he$  which will in the same way be tinged by its hue and so also the colour of  $vh$  will be affected by  $p$  which causes it; and the shadow of the triangle  $zky$  will be affected by the colour of  $q$ , because it is produced by it. [7] In proportion as  $cd$  goes into  $ad$ , will  $nrs$  be darker than  $m$ ; and the rest of the space will be shadowless [11].  $fg$  is the highest light, because here the whole light of the window  $ad$  falls; and thus on the opaque body  $me$  is in equally high light;  $zky$  is a triangle which includes the deepest shadow, because the light  $ad$  cannot reach any part of it.  $xh$  is the 2nd grade of shadow, because it receives only  $1/3$  of the light from the window, that is  $cd$ . The third grade of shadow is  $he$ , where two thirds of the light from the window is visible. The last grade of shadow is  $bd ef$ , because the highest grade of light from the window falls at  $f$ .

[Footnote: The diagram Pl. III, No. 1 belongs to this chapter as well as the text given in No. 148. Lines 7-11 (compare lines 8-12 of No. 148) which are written within the diagram, evidently apply to both sections and have therefore been inserted in both.]

276.

#### OF THE COLOURS OF SIMPLE DERIVED SHADOWS.

The colour of derived shadows is always affected by that of the body towards which they are cast. To prove this: let an opaque body be placed between the plane *s c t d* and the blue light *d e* and the red light *a b*, then I say that *d e*, the blue light, will fall on the whole surface *s c t d* excepting at *o p* which is covered by the shadow of the body *q r*, as is shown by the straight lines *d q o e r p*. And the same occurs with the light *a b* which falls on the whole surface *s c t d* excepting at the spot obscured by the shadow *q r*; as is shown by the lines *d q o*, and *e r p*. Hence we may conclude that the shadow *n m* is exposed to the blue light *d e*; but, as the red light *a b* cannot fall there, *n m* will appear as a blue shadow on a red background tinted with blue, because on the surface *s c t d* both lights can fall. But in the shadows only one single light falls; for this reason these shadows are of medium depth, since, if no light whatever mingled with the shadow, it would be of the first degree of darkness &c. But in the shadow at *o p* the blue light does not fall, because the body *q r* interposes and intercepts it there. Only the red light *a b* falls there and tinges the shadow of a red hue and so a ruddy shadow appears on the background of mingled red and blue.

The shadow of *q r* at *o p* is red, being caused by the blue light *d e*; and the shadow of *q r* at *o' p'* is blue being caused by the red light *a b*. Hence we say that the blue light in this instance causes a red derived shadow from the opaque body *q' r'*, while the red light causes the same body to cast a blue derived shadow; but the primary shadow [on the dark side of the body itself] is not of either of those hues, but a mixture of red and blue.

The derived shadows will be equal in depth if they are produced by lights of equal strength and at an equal distance; this is proved.

[Footnote 53: The text is unfinished in the original.]

[Footnote: In the original diagram Leonardo has written within the circle *q r corpo obroso* (body in shadow); at the spot marked *A*, *luminoso azzurro* (blue luminous body); at *B*, *luminoso rosso* (red luminous body). At *E* we read *ombra azzurra* (blue tinted shadow) and at *D* *ombra rossa* (red tinted shadow).]

On the nature of colours (277. 278).

277.

No white or black is transparent.

278.

#### OF PAINTING.

[Footnote 2: See Footnote 3] Since white is not a colour but the neutral recipient of every colour [Footnote 3: *il bianco non e colore ma e in potentia ricettiva d'ogni colore* (white is not a colour, but the neutral recipient of every colour). LEON BATT. ALBERTI "*Della pittura*" libro I, asserts on the contrary: "*Il bianco e' il nero non sono veri colori, ma sono alteratione delli altri colori*" (ed. JANITSCHKEK, p. 67; Vienna 1877).], when it is seen in the open air and high up, all its shadows are bluish; and this is caused, according to the 4th [prop.], which says: the surface of every opaque body assumes the hue of the surrounding objects. Now this white [body] being deprived of the light of the sun by the interposition of some body between the sun and itself, all that portion of it which is exposed to the sun and atmosphere assumes the colour of the sun and atmosphere; the side on which the sun does not fall remains in shadow and assumes the hue of the atmosphere. And if this white object did not reflect the green of the fields all the way to the horizon nor get the brightness of the horizon itself, it would certainly appear simply of the same hue as the atmosphere.

On gradations in the depth of colours (279. 280).

279.

Since black, when painted next to white, looks no blacker than when next to black; and white when next to black looks no whiter than white, as is seen by the images transmitted through a small hole or by the edges of any opaque screen ...

280.

OF COLOURS.

Of several colours, all equally white, that will look whitest which is against the darkest background. And black will look intensest against the whitest background.

And red will look most vivid against the yellowest background; and the same is the case with all colours when surrounded by their strongest contrasts.

On the reflection of colours (281-283).

281.

PERSPECTIVE.

Every object devoid of colour in itself is more or less tinged by the colour [of the object] placed opposite. This may be seen by experience, inasmuch as any object which mirrors another assumes the colour of the object mirrored in it. And if the surface thus partially coloured is white the portion which has a red reflection

will appear red, or any other colour, whether bright or dark.

PERSPECTIVE.

Every opaque and colourless body assumes the hue of the colour reflected on it; as happens with a white wall.

282.

PERSPECTIVE.

That side of an object in light and shade which is towards the light transmits the images of its details more distinctly and immediately to the eye than the side which is in shadow.

PERSPECTIVE.

The solar rays reflected on a square mirror will be thrown back to distant objects in a circular form.

PERSPECTIVE.

Any white and opaque surface will be partially coloured by reflections from surrounding objects.

[Footnote 281. 282: The title line of these chapters is in the original simply *"pro"*, which may be an abbreviation for either *Propositione* or *Prospettiva*--taking *Prospettiva* of course in its widest sense, as we often find it used in Leonardo's writings. The title *"pro"* has here been understood to mean *Prospettiva*, in accordance with the suggestion afforded by page 10b of this same MS., where the first section is headed *Prospettiva* in full (see No. 94), while the four following sections are headed merely *"pro"* (see No. 85).]

283.

WHAT PORTION OF A COLOURED SURFACE OUGHT IN REASON TO BE THE MOST INTENSE.

If *a* is the light, and *b* illuminated by it in a direct line, *c*, on which the light cannot fall, is lighted only by reflection from *b* which, let us say, is red. Hence the light reflected from it, will be affected by the hue of the surface causing it and will tinge the surface *c* with red. And if *c* is also red you will see it much more intense than *b*; and if it were yellow you would see there a colour between yellow and red.

On the use of dark and light colours in painting (284--286).

284.

WHY BEAUTIFUL COLOURS MUST BE IN THE [HIGHEST] LIGHT.

Since we see that the quality of colour is known [only] by means of light, it is to be supposed that where there is most light the true character of a colour in light will be best seen; and where there is most shadow the colour will be affected by the tone of that. Hence, O Painter! remember to show the true quality of colours in bright lights.

285.

An object represented in white and black will display stronger relief than in any other way; hence I would remind you O Painter! to dress your figures in the lightest colours you can, since, if you put them in dark colours, they will be in too slight relief and inconspicuous from a distance. And the reason is that the shadows of all objects are dark. And if you make a dress dark there is little variety in the lights and shadows, while in light colours there are many grades.

286.

OF PAINTING.

Colours seen in shadow will display more or less of their natural brilliancy in proportion as they are in fainter or deeper shadow.

But if these same colours are situated in a well-lighted place, they will appear brighter in proportion as the light is more brilliant.

THE ADVERSARY.

The variety of colours in shadow must be as great as that of the colours in the objects in that shadow.

THE ANSWER.

Colours seen in shadow will display less variety in proportion as the shadows in which they lie are deeper. And evidence of this is to be had by looking from an open space into the doorways of dark and shadowy churches, where the pictures which are painted in various colours all look of uniform darkness.

Hence at a considerable distance all the shadows of different colours will appear of the same darkness.

It is the light side of an object in light and shade which shows the true colour.

On the colours of the rainbow (287. 288).

287.

Treat of the rainbow in the last book on Painting, but first write



the book on colours produced by the mixture of other colours, so as to be able to prove by those painters' colours how the colours of the rainbow are produced.

288.

#### WHETHER THE COLOURS OF THE RAINBOW ARE PRODUCED BY THE SUN.

The colours of the rainbow are not produced by the sun, for they occur in many ways without the sunshine; as may be seen by holding a glass of water up to the eye; when, in the glass--where there are those minute bubbles always seen in coarse glass--each bubble, even though the sun does not fall on it, will produce on one side all the colours of the rainbow; as you may see by placing the glass between the day light and your eye in such a way as that it is close to the eye, while on one side the glass admits the [diffused] light of the atmosphere, and on the other side the shadow of the wall on one side of the window; either left or right, it matters not which. Then, by turning the glass round you will see these colours all round the bubbles in the glass &c. And the rest shall be said in its place.

#### THAT THE EYE HAS NO PART IN PRODUCING THE COLOURS OF THE RAINBOW.

In the experiment just described, the eye would seem to have some share in the colours of the rainbow, since these bubbles in the glass do not display the colours except through the medium of the eye. But, if you place the glass full of water on the window sill, in such a position as that the outer side is exposed to the sun's rays, you will see the same colours produced in the spot of light thrown through the glass and upon the floor, in a dark place, below the window; and as the eye is not here concerned in it, we may evidently, and with certainty pronounce that the eye has no share in producing them.

#### OF THE COLOURS IN THE FEATHERS OF CERTAIN BIRDS.

There are many birds in various regions of the world on whose feathers we see the most splendid colours produced as they move, as we see in our own country in the feathers of peacocks or on the necks of ducks or pigeons, &c.

Again, on the surface of antique glass found underground and on the roots of turnips kept for some time at the bottom of wells or other stagnant waters [we see] that each root displays colours similar to those of the real rainbow. They may also be seen when oil has been placed on the top of water and in the solar rays reflected from the surface of a diamond or beryl; again, through the angular facet of a beryl every dark object against a background of the atmosphere or any thing else equally pale-coloured is surrounded by these rainbow colours between the atmosphere and the dark body; and in many other circumstances which I will not mention, as these suffice for my purpose.

\_VI.\_

\_'Prospettiva de' colori' (Perspective of Colour)\_

\_and\_

\_'Prospettiva aerea' (Aerial Perspective).\_

\_Leonardo distinctly separates these branches of his subject, as may be seen in the beginning of No.\_ 295. \_Attempts have been made to cast doubts on the results which Leonardo arrived at by experiment on the perspective of colour, but not with justice, as may be seen from the original text of section\_ 294.

\_The question as to the composition of the atmosphere, which is inseparable from a discussion on Aerial Perspective, forms a separate theory which is treated at considerable length. Indeed the author enters into it so fully that we cannot escape the conviction that he must have dwelt with particular pleasure on this part of his subject, and that he attached great importance to giving it a character of general applicability.\_

General rules (289--291).

289.

The variety of colour in objects cannot be discerned at a great distance, excepting in those parts which are directly lighted up by the solar rays.

290.

As to the colours of objects: at long distances no difference is perceptible in the parts in shadow.

291.

OF THE VISIBILITY OF COLOURS.

Which colour strikes most? An object at a distance is most conspicuous, when it is lightest, and the darkest is least visible.

An exceptional case.

292.

Of the edges [outlines] of shadows. Some have misty and ill defined edges, others distinct ones.

No opaque body can be devoid of light and shade, except it is in a mist, on ground covered with snow, or when snow is falling on the open country which has no light on it and is surrounded with darkness.

And this occurs [only] in spherical bodies, because in other bodies which have limbs and parts, those sides of limbs which face each other reflect on each other the accidental [hue and tone] of their surface.

An experiment.

293.

ALL COLOURS ARE AT A DISTANCE UNDISTINGUISHABLE AND UNDISCERNIBLE.

All colours at a distance are undistinguishable in shadow, because an object which is not in the highest light is incapable of transmitting its image to the eye through an atmosphere more luminous than itself; since the lesser brightness must be absorbed by the greater. For instance: We, in a house, can see that all the colours on the surface of the walls are clearly and instantly visible when the windows of the house are open; but if we were to go out of the house and look in at the windows from a little distance to see the paintings on those walls, instead of the paintings we should see an uniform deep and colourless shadow.

The practice of the *prospettiva de colori*.

294.

HOW A PAINTER SHOULD CARRY OUT THE PERSPECTIVE OF COLOUR IN PRACTICE.

In order to put into practice this perspective of the variation and loss or diminution of the essential character of colours, observe at every hundred braccia some objects standing in the landscape, such as trees, houses, men and particular places. Then in front of the first tree have a very steady plate of glass and keep your eye very steady, and then, on this plate of glass, draw a tree, tracing it over the form of that tree. Then move it on one side so far as that the real tree is close by the side of the tree you have drawn; then colour your drawing in such a way as that in colour and form the two may be alike, and that both, if you close one eye, seem to be painted on the glass and at the same distance. Then, by the same method, represent a second tree, and a third, with a distance of a hundred braccia between each. And these will serve as a standard and guide whenever you work on your own pictures, wherever they may apply, and will enable you to give due distance in those works. [14] But I have found that as a rule the second is  $\frac{4}{5}$  of the first when it is 20 braccia beyond it.

[Footnote: This chapter is one of those copied in the Manuscript of the Vatican library Urbinas 1270, and the original text is rendered here with no other alterations, but in the orthography. H. LUDWIG, in his edition of this copy translates lines 14 and 15 thus: "\_Ich finde aber als Regel, dass der zweite um vier Funftel des ersten

abnimmt, wenn er namlich zwanzig Ellen vom ersten entfernt ist (?)". He adds in his commentary: "\_Das Ende der Nummer ist wohl jedenfalls verstummelt\_". However the translation given above shows that it admits of a different rendering.]

The rules of aerial perspective (295--297).

295.

#### OF AERIAL PERSPECTIVE.

There is another kind of perspective which I call Aerial Perspective, because by the atmosphere we are able to distinguish the variations in distance of different buildings, which appear placed on a single line; as, for instance, when we see several buildings beyond a wall, all of which, as they appear above the top of the wall, look of the same size, while you wish to represent them in a picture as more remote one than another and to give the effect of a somewhat dense atmosphere. You know that in an atmosphere of equal density the remotest objects seen through it, as mountains, in consequence of the great quantity of atmosphere between your eye and them--appear blue and almost of the same hue as the atmosphere itself [Footnote 10: *\_quado il sole e per leuante\_* (when the sun is in the East). Apparently the author refers here to morning light in general. H. LUDWIG however translates this passage from the Vatican copy "*\_wenn namlich die Sonne (dahinter) im Osten steht\_*".] when the sun is in the East [Footnote 11: See Footnote 10]. Hence you must make the nearest building above the wall of its real colour, but the more distant ones make less defined and bluer. Those you wish should look farthest away you must make proportionately bluer; thus, if one is to be five times as distant, make it five times bluer. And by this rule the buildings which above a [given] line appear of the same size, will plainly be distinguished as to which are the more remote and which larger than the others.

296.

The medium lying between the eye and the object seen, tinges that object with its colour, as the blueness of the atmosphere makes the distant mountains appear blue and red glass makes objects seen beyond it, look red. The light shed round them by the stars is obscured by the darkness of the night which lies between the eye and the radiant light of the stars.

297.

Take care that the perspective of colour does not disagree with the size of your objects, that is to say: that the colours diminish from their natural [vividness] in proportion as the objects at various distances diminish from their natural size.

On the relative density of the atmosphere (298--299).

298.

#### WHY THE ATMOSPHERE MUST BE REPRESENTED AS PALER TOWARDS THE LOWER PORTION.

Because the atmosphere is dense near the earth, and the higher it is the rarer it becomes. When the sun is in the East if you look towards the West and a little way to the South and North, you will see that this dense atmosphere receives more light from the sun than the rarer; because the rays meet with greater resistance. And if the sky, as you see it, ends on a low plain, that lowest portion of the sky will be seen through a denser and whiter atmosphere, which will weaken its true colour as seen through that medium, and there the sky will look whiter than it is above you, where the line of sight travels through a smaller space of air charged with heavy vapour. And if you turn to the East, the atmosphere will appear darker as you look lower down because the luminous rays pass less freely through the lower atmosphere.

299.

#### OF THE MODE OF TREATING REMOTE OBJECTS IN PAINTING.

It is easy to perceive that the atmosphere which lies closest to the level ground is denser than the rest, and that where it is higher up, it is rarer and more transparent. The lower portions of large and lofty objects which are at a distance are not much seen, because you see them along a line which passes through a denser and thicker section of the atmosphere. The summits of such heights are seen along a line which, though it starts from your eye in a dense atmosphere, still, as it ends at the top of those lofty objects, ceases in a much rarer atmosphere than exists at their base; for this reason the farther this line extends from your eye, from point to point the atmosphere becomes more and more rare. Hence, O Painter! when you represent mountains, see that from hill to hill the bases are paler than the summits, and in proportion as they recede beyond each other make the bases paler than the summits; while, the higher they are the more you must show of their true form and colour.

On the colour of the atmosphere (300-307).

300.

#### OF THE COLOUR OF THE ATMOSPHERE.

I say that the blueness we see in the atmosphere is not intrinsic colour, but is caused by warm vapour evaporated in minute and insensible atoms on which the solar rays fall, rendering them luminous against the infinite darkness of the fiery sphere which lies beyond and includes it. And this may be seen, as I saw it by any one going up [Footnote 5: With regard to the place spoken of as \_M'oboso\_ (compare No. 301 line 20) its identity will be discussed

under Leonardo's Topographical notes in Vol. II.] Monboso, a peak of the Alps which divide France from Italy. The base of this mountain gives birth to the four rivers which flow in four different directions through the whole of Europe. And no mountain has its base at so great a height as this, which lifts itself almost above the clouds; and snow seldom falls there, but only hail in the summer, when the clouds are highest. And this hail lies [unmelted] there, so that if it were not for the absorption of the rising and falling clouds, which does not happen twice in an age, an enormous mass of ice would be piled up there by the hail, and in the middle of July I found it very considerable. There I saw above me the dark sky, and the sun as it fell on the mountain was far brighter here than in the plains below, because a smaller extent of atmosphere lay between the summit of the mountain and the sun. Again as an illustration of the colour of the atmosphere I will mention the smoke of old and dry wood, which, as it comes out of a chimney, appears to turn very blue, when seen between the eye and the dark distance. But as it rises, and comes between the eye and the bright atmosphere, it at once shows of an ashy grey colour; and this happens because it no longer has darkness beyond it, but this bright and luminous space. If the smoke is from young, green wood, it will not appear blue, because, not being transparent and being full of superabundant moisture, it has the effect of condensed clouds which take distinct lights and shadows like a solid body. The same occurs with the atmosphere, which, when overcharged with moisture appears white, and the small amount of heated moisture makes it dark, of a dark blue colour; and this will suffice us so far as concerns the colour of the atmosphere; though it might be added that, if this transparent blue were the natural colour of the atmosphere, it would follow that wherever a larger mass air intervened between the eye and the element of fire, the azure colour would be more intense; as we see in blue glass and in sapphires, which are darker in proportion as they are larger. But the atmosphere in such circumstances behaves in an opposite manner, inasmuch as where a greater quantity of it lies between the eye and the sphere of fire, it is seen much whiter. This occurs towards the horizon. And the less the extent of atmosphere between the eye and the sphere of fire, the deeper is the blue colour, as may be seen even on low plains. Hence it follows, as I say, that the atmosphere assumes this azure hue by reason of the particles of moisture which catch the rays of the sun. Again, we may note the difference in particles of dust, or particles of smoke, in the sun beams admitted through holes into a dark chamber, when the former will look ash grey and the thin smoke will appear of a most beautiful blue; and it may be seen again in the dark shadows of distant mountains when the air between the eye and those shadows will look very blue, though the brightest parts of those mountains will not differ much from their true colour. But if any one wishes for a final proof let him paint a board with various colours, among them an intense black; and over all let him lay a very thin and transparent [coating of] white. He will then see that this transparent white will nowhere show a more beautiful blue than over the black--but it must be very thin and finely ground.

[Footnote 7: \_reta\_ here has the sense of \_malanno\_.]

301.

Experience shows us that the air must have darkness beyond it and yet it appears blue. If you produce a small quantity of smoke from dry wood and the rays of the sun fall on this smoke, and if you then place behind the smoke a piece of black velvet on which the sun does not shine, you will see that all the smoke which is between the eye and the black stuff will appear of a beautiful blue colour. And if instead of the velvet you place a white cloth smoke, that is too thick smoke, hinders, and too thin smoke does not produce, the perfection of this blue colour. Hence a moderate amount of smoke produces the finest blue. Water violently ejected in a fine spray and in a dark chamber where the sun beams are admitted produces these blue rays and the more vividly if it is distilled water, and thin smoke looks blue. This I mention in order to show that the blueness of the atmosphere is caused by the darkness beyond it, and these instances are given for those who cannot confirm my experience on Monboso.

302.

When the smoke from dry wood is seen between the eye of the spectator and some dark space [or object], it will look blue. Thus the sky looks blue by reason of the darkness beyond it. And if you look towards the horizon of the sky, you will see the atmosphere is not blue, and this is caused by its density. And thus at each degree, as you raise your eyes above the horizon up to the sky over your head, you will see the atmosphere look darker [blue] and this is because a smaller density of air lies between your eye and the [outer] darkness. And if you go to the top of a high mountain the sky will look proportionately darker above you as the atmosphere becomes rarer between you and the [outer] darkness; and this will be more visible at each degree of increasing height till at last we should find darkness.

That smoke will look bluest which rises from the driest wood and which is nearest to the fire and is seen against the darkest background, and with the sunlight upon it.

303.

A dark object will appear bluest in proportion as it has a greater mass of luminous atmosphere between it and the eye. As may be seen in the colour of the sky.

304.

The atmosphere is blue by reason of the darkness above it because black and white make blue.

305.

In the morning the mist is denser above than below, because the sun draws it upwards; hence tall buildings, even if the summit is at the same distance as the base have the summit invisible. Therefore, also, the sky looks darkest [in colour] overhead, and towards the horizon it is not blue but rather between smoke and dust colour.

The atmosphere, when full of mist, is quite devoid of blueness, and only appears of the colour of clouds, which shine white when the weather is fine. And the more you turn to the west the darker it will be, and the brighter as you look to the east. And the verdure of the fields is bluish in a thin mist, but grows grey in a dense one.

The buildings in the west will only show their illuminated side, where the sun shines, and the mist hides the rest. When the sun rises and chases away the haze, the hills on the side where it lifts begin to grow clearer, and look blue, and seem to smoke with the vanishing mists; and the buildings reveal their lights and shadows; through the thinner vapour they show only their lights and through the thicker air nothing at all. This is when the movement of the mist makes it part horizontally, and then the edges of the mist will be indistinct against the blue of the sky, and towards the earth it will look almost like dust blown up. In proportion as the atmosphere is dense the buildings of a city and the trees in a landscape will look fewer, because only the tallest and largest will be seen.

Darkness affects every thing with its hue, and the more an object differs from darkness, the more we see its real and natural colour. The mountains will look few, because only those will be seen which are farthest apart; since, at such a distance, the density increases to such a degree that it causes a brightness by which the darkness of the hills becomes divided and vanishes indeed towards the top. There is less [mist] between lower and nearer hills and yet little is to be distinguished, and least towards the bottom.

306.

The surface of an object partakes of the colour of the light which illuminates it; and of the colour of the atmosphere which lies between the eye and that object, that is of the colour of the transparent medium lying between the object and the eye; and among colours of a similar character the second will be of the same tone as the first, and this is caused by the increased thickness of the colour of the medium lying between the object and the eye.

307. OF PAINTING.

Of various colours which are none of them blue that which at a great distance will look bluest is the nearest to black; and so, conversely, the colour which is least like black will at a great distance best preserve its own colour.



Hence the green of fields will assume a bluer hue than yellow or white will, and conversely yellow or white will change less than green, and red still less.

\_VII.\_

\_On the Proportions and on the Movements of the Human Figure.\_

\_Leonardo's researches on the proportions and movements of the human figure must have been for the most part completed and written before the year\_ 1498; \_for LUCA PACIOLO writes, in the dedication to Ludovico il Moro, of his book\_ Divina Proportione, \_which was published in that year:\_ "Leonardo da venci ... hauedo gia co tutta diligetia al degno libro de pictura e movimenti humani posto fine".

\_The selection of Leonardo's axioms contained in the Vatican copy attributes these words to the author:\_ "e il resto si dira nella universale misura del huomo". (\_MANZI, p. 147; LUDWIG, No. 264\_). \_LOMAZZO, again, in his\_ Idea del Tempio della Pittura Milano 1590, cap. IV, \_says:\_ "Lionardo Vinci ... dimostro anco in figura tutte le proporzioni dei membri del corpo umano".

\_The Vatican copy includes but very few sections of the\_ "Universale misura del huomo" \_and until now nothing has been made known of the original MSS. on the subject which have supplied the very extensive materials for this portion of the work. The collection at Windsor, belonging to her Majesty the Queen, includes by far the most important part of Leonardo's investigations on this subject, constituting about half of the whole of the materials here published; and the large number of original drawings adds greatly to the interest which the subject itself must command. Luca Paciolo would seem to have had these MSS. (which I have distinguished by the initials W. P.) in his mind when he wrote the passage quoted above. Still, certain notes of a later date--such as Nos. 360, 362 and 363, from MS. E, written in 1513--14, sufficiently prove that Leonardo did not consider his earlier studies on the Proportions and Movements of the Human Figure final and complete, as we might suppose from Luca Paciolo's statement. Or else he took the subject up again at a subsequent period, since his former researches had been carried on at Milan between 1490 and 1500. Indeed it is highly probable that the anatomical studies which he was pursuing with so much zeal between 1510--16 should have led him to reconsider the subject of Proportion.

Preliminary observations (308. 309).

308.

Every man, at three years old is half the full height he will grow to at last.

309.

If a man 2 braccia high is too small, one of four is too tall, the medium being what is admirable. Between 2 and 4 comes 3; therefore take a man of 3 braccia in height and measure him by the rule I will give you. If you tell me that I may be mistaken, and judge a man to be well proportioned who does not conform to this division, I answer that you must look at many men of 3 braccia, and out of the larger number who are alike in their limbs choose one of those who are most graceful and take your measurements. The length of the hand is  $\frac{1}{3}$  of a braccio [8 inches] and this is found 9 times in man. And the face [Footnote 7: The account here given of the \_braccio\_ is of importance in understanding some of the succeeding chapters. \_Testa\_ must here be understood to mean the face. The statements in this section are illustrated in part on Pl. XI.] is the same, and from the pit of the throat to the shoulder, and from the shoulder to the nipple, and from one nipple to the other, and from each nipple to the pit of the throat.

Proportions of the head and face (310-318).

310.

The space between the parting of the lips [the mouth] and the base of the nose is one-seventh of the face.

The space from the mouth to the bottom of the chin \_c d\_ is the fourth part of the face and equal to the width of the mouth.

The space from the chin to the base of the nose \_e f\_ is the third part of the face and equal to the length of the nose and to the forehead.

The distance from the middle of the nose to the bottom of the chin \_g h\_, is half the length of the face.

The distance from the top of the nose, where the eyebrows begin, to the bottom of the chin, \_i k\_, is two thirds of the face.

The space from the parting of the lips to the top of the chin \_l m\_, that is where the chin ends and passes into the lower lip of the mouth, is the third of the distance from the parting of the lips to the bottom of the chin and is the twelfth part of the face. From the top to the bottom of the chin \_m n\_ is the sixth part of the face and is the fifty fourth part of a man's height.

From the farthest projection of the chin to the throat \_o p\_ is equal to the space between the mouth and the bottom of the chin, and a fourth of the face.

The distance from the top of the throat to the pit of the throat below \_q r\_ is half the length of the face and the eighteenth part of a man's height.

From the chin to the back of the neck \_s t\_, is the same distance as

between the mouth and the roots of the hair, that is three quarters of the head.

From the chin to the jaw bone v x is half the head and equal to the thickness of the neck in profile.

The thickness of the head from the brow to the nape is once and 3/4 that of the neck.

[Footnote: The drawings to this text, lines 1-10 are on Pl. VII, No. I. The two upper sketches of heads, Pl. VII, No. 2, belong to lines 11-14, and in the original are placed immediately below the sketches reproduced on Pl. VII, No. 1.]

311.

The distance from the attachment of one ear to the other is equal to that from the meeting of the eyebrows to the chin, and in a fine face the width of the mouth is equal to the length from the parting of the lips to the bottom of the chin.

312.

The cut or depression below the lower lip of the mouth is half way between the bottom of the nose and the bottom of the chin.

The face forms a square in itself; that is its width is from the outer corner of one eye to the other, and its height is from the very top of the nose to the bottom of the lower lip of the mouth; then what remains above and below this square amounts to the height of such another square, a b is equal to the space between c d; d n in the same way to n c, and likewise s r, q p, h k are equal to each other.

It is as far between m and s as from the bottom of the nose to the chin. The ear is exactly as long as the nose. It is as far from x to j as from the nose to the chin. The parting of the mouth seen in profile slopes to the angle of the jaw. The ear should be as high as from the bottom of the nose to the top of the eye-lid. The space between the eyes is equal to the width of an eye. The ear is over the middle of the neck, when seen in profile. The distance from 4 to 5 is equal to that from s to r.

[Footnote: See Pl. VIII, No. I, where the text of lines 3-13 is also given in facsimile.]

313.

(a b) is equal to (c d).

[Footnote: See Pl. VII, No. 3. Reference may also be made here to two pen and ink drawings of heads in profile with figured measurements, of which there is no description in the MS. These are

given on Pl. XVII, No. 2.--A head, to the left, with part of the torso [W. P. 5a], No. 1 on the same plate is from MS. A 2b and in the original occurs on a page with wholly irrelevant text on matters of natural history. M. RAVAISSON in his edition of the Paris MS. A has reproduced this head and discussed it fully [note on page 12]; he has however somewhat altered the original measurements. The complicated calculations which M. RAVAISSON has given appear to me in no way justified. The sketch, as we see it, can hardly have been intended for any thing more than an experimental attempt to ascertain relative proportions. We do not find that Leonardo made use of circular lines in any other study of the proportions of the human head. At the same time we see that the proportions of this sketch are not in accordance with the rules which he usually observed (see for instance No. 310).]

The head  $a_f$   $\frac{1}{6}$  larger than  $n_f$ .

315.

From the eyebrow to the junction of the lip with the chin, and the angle of the jaw and the upper angle where the ear joins the temple will be a perfect square. And each side by itself is half the head.

The hollow of the cheek bone occurs half way between the tip of the nose and the top of the jaw bone, which is the lower angle of the setting on of the ear, in the frame here represented.

From the angle of the eye-socket to the ear is as far as the length of the ear, or the third of the face.

[Footnote: See Pl. IX. The text, in the original is written behind the head. The handwriting would seem to indicate a date earlier than 1480. On the same leaf there is a drawing in red chalk of two horsemen of which only a portion of the upper figure is here visible. The whole leaf measures  $22 \frac{1}{2}$  centimetres wide by 29 long, and is numbered 127 in the top right-hand corner.]

316.

From  $a$  to  $b$ --that is to say from the roots of the hair in front to the top of the head--ought to be equal to  $c_d$ --that is from the bottom of the nose to the meeting of the lips in the middle of the mouth. From the inner corner of the eye  $m$  to the top of the head  $a$  is as far as from  $m$  down to the chin  $s$ .  $s_c$   $f_b$  are all at equal distances from each other.

[Footnote: The drawing in silver-point on bluish tinted paper--Pl. X--which belongs to this chapter has been partly drawn over in ink by Leonardo himself.]

317.

From the top of the head to the bottom of the chin is  $\frac{1}{9}$ , and from

the roots of the hair to the chin is  $\frac{1}{9}$  of the distance from the roots of the hair to the ground. The greatest width of the face is equal to the space between the mouth and the roots of the hair and is  $\frac{1}{12}$  of the whole height. From the top of the ear to the top of the head is equal to the distance from the bottom of the chin to the lachrymatory duct of the eye; and also equal to the distance from the angle of the chin to that of the jaw; that is the  $\frac{1}{16}$  of the whole. The small cartilage which projects over the opening of the ear towards the nose is half-way between the nape and the eyebrow; the thickness of the neck in profile is equal to the space between the chin and the eyes, and to the space between the chin and the jaw, and it is  $\frac{1}{18}$  of the height of the man.

318.

a b, c d, e f, g h, i k are equal to each other in size excepting that d f is accidental.

[Footnote: See Pl. XI.]

Proportions of the head seen in front (319-321).

319.

a n o f are equal to the mouth.

a c and a f are equal to the space between one eye and the other.

n m o f q r are equal to half the width of the eye lids, that is from the inner [lachrymatory] corner of the eye to its outer corner; and in like manner the division between the chin and the mouth; and in the same way the narrowest part of the nose between the eyes. And these spaces, each in itself, is the 19th part of the head, n o is equal to the length of the eye or of the space between the eyes.

m c is  $\frac{1}{3}$  of n m measuring from the outer corner of the eyelids to the letter c. b s will be equal to the width of the nostril.

[Footnote: See Pl. XII.]

320.

The distance between the centres of the pupils of the eyes is  $\frac{1}{3}$  of the face. The space between the outer corners of the eyes, that is where the eye ends in the eye socket which contains it, thus the outer corners, is half the face.

The greatest width of the face at the line of the eyes is equal to the distance from the roots of the hair in front to the parting of the lips.

[Footnote: There are, with this section, two sketches of eyes, not

reproduced here.]

321.

The nose will make a double square; that is the width of the nose at the nostrils goes twice into the length from the tip of the nose to the eyebrows. And, in the same way, in profile the distance from the extreme side of the nostril where it joins the cheek to the tip of the nose is equal to the width of the nose in front from one nostril to the other. If you divide the whole length of the nose--that is from the tip to the insertion of the eyebrows, into 4 equal parts, you will find that one of these parts extends from the tip of the nostrils to the base of the nose, and the upper division lies between the inner corner of the eye and the insertion of the eyebrows; and the two middle parts [together] are equal to the length of the eye from the inner to the outer corner.

[Footnote: The two bottom sketches on Pl. VII, No. 4 face the six lines of this section.--With regard to the proportions of the head in profile see No. 312.]

322.

The great toe is the sixth part of the foot, taking the measure in profile, on the inside of the foot, from where this toe springs from the ball of the sole of the foot to its tip a b; and it is equal to the distance from the mouth to the bottom of the chin. If you draw the foot in profile from the outside, make the little toe begin at three quarters of the length of the foot, and you will find the same distance from the insertion of this toe as to the farthest prominence of the great toe.

323.

For each man respectively the distance between a b is equal to c d.

324.

Relative proportion of the hand and foot.

The foot is as much longer than the hand as the thickness of the arm at the wrist where it is thinnest seen facing.

Again, you will find that the foot is as much longer than the hand as the space between the inner angle of the little toe to the last projection of the big toe, if you measure along the length of the foot.

The palm of the hand without the fingers goes twice into the length of the foot without the toes.

If you hold your hand with the fingers straight out and close

together you will find it to be of the same width as the widest part of the foot, that is where it is joined onto the toes.

And if you measure from the prominence of the inner angle to the end of the great toe you will find this measure to be as long as the whole hand.

From the top angle of the foot to the insertion of the toes is equal to the hand from wrist joint to the tip of the thumb.

The smallest width of the hand is equal to the smallest width of the foot between its joint into the leg and the insertion of the toes.

The width of the heel at the lower part is equal to that of the arm where it joins the hand; and also to the leg where it is thinnest when viewed in front.

The length of the longest toe, from its first division from the great toe to its tip is the fourth of the foot from the centre of the ankle bone to the tip, and it is equal to the width of the mouth. The distance between the mouth and the chin is equal to that of the knuckles and of the three middle fingers and to the length of their first joints if the hand is spread, and equal to the distance from the joint of the thumb to the outset of the nails, that is the fourth part of the hand and of the face.

The space between the extreme poles inside and outside the foot called the ankle or ankle bone *\_a b\_* is equal to the space between the mouth and the inner corner of the eye.

325.

The foot, from where it is attached to the leg, to the tip of the great toe is as long as the space between the upper part of the chin and the roots of the hair *\_a b\_*; and equal to five sixths of the face.

326.

*\_a d\_* is a head's length, *\_c b\_* is a head's length. The four smaller toes are all equally thick from the nail at the top to the bottom, and are 1/13 of the foot.

[Footnote: See Pl. XIV, No. 1, a drawing of a foot with the text in three lines below it.]

327.

The whole length of the foot will lie between the elbow and the wrist and between the elbow and the inner angle of the arm towards the breast when the arm is folded. The foot is as long as the whole head of a man, that is from under the chin to the topmost part of the head[Footnote 2: *\_nel modo che qui i figurato\_*. See Pl. VII, No.

4, the upper figure. The text breaks off at the end of line 2 and the text given under No. 321 follows below. It may be here remarked that the second sketch on W. P. 311 has in the original no explanatory text.] in the way here figured.

Proportions of the leg (328-331).

328.

The greatest thickness of the calf of the leg is at a third of its height  $a_b$ , and is a twentieth part thicker than the greatest thickness of the foot.

$a_c$  is half of the head, and equal to  $d_b$  and to the insertion of the five toes  $e_f$ .  $d_k$  diminishes one sixth in the leg  $g_h$ .  $g_h$  is  $1/3$  of the head;  $m_n$  increases one sixth from  $a_e$  and is  $7/12$  of the head,  $o_p$  is  $1/10$  less than  $d_k$  and is  $6/17$  of the head.  $a$  is at half the distance between  $b_q$ , and is  $1/4$  of the man.  $r$  is half way between  $s$  and  $b$  [Footnote 11:  $b$  is here and later on measured on the right side of the foot as seen by the spectator.]. The concavity of the knee outside  $r$  is higher than that inside  $a$ . The half of the whole height of the leg from the foot  $r$ , is half way between the prominence  $s$  and the ground  $b$ .  $v$  is half way between  $t$  and  $b$ . The thickness of the thigh seen in front is equal to the greatest width of the face, that is  $2/3$  of the length from the chin to the top of the head;  $z_r$  is  $5/6$  of  $7$  to  $v$ ;  $m_n$  is equal to  $7_v$  and is  $1/4$  of  $r_b$ ,  $x_y$  goes 3 times into  $r_b$ , and into  $r_s$ .

[Footnote 22-35: The sketch illustrating these lines is on Pl. XIII, No. 2.]

[Footnote 22:  $a_b$  entra in  $c_f$  6  $e_6$  in  $c_n$ . Accurate measurement however obliges us to read 7 for 6.]  $a_b$  goes six times into  $c_f$  and six times into  $c_n$  and is equal to  $g_h$ ;  $i_k$   $l_m$  goes 4 times into  $d_f$ , and 4 times into  $d_n$  and is  $3/7$  of the foot;  $p_q$   $r_s$  goes 3 times into  $d_f$ , and 3 times into  $b_n$ ; [Footnote: 25.  $y$  is not to be found on the diagram and  $x$  occurs twice; this makes the passage very obscure.]  $x_y$  is  $1/8$  of  $x_f$  and is equal to  $n_q$ .  $3_7$  is  $1/9$  of  $n_f$ ;  $4_5$  is  $1/10$  of  $n_f$  [Footnote: 22-27. Compare with this lines 18-24 of No. 331, and the sketch of a leg in profile Pl. XV.].

I want to know how much a man increases in height by standing on tip-toe and how much  $p_g$  diminishes by stooping; and how much it increases at  $n_q$  likewise in bending the foot.

[Footnote 34:  $e_f$  4 dal cazo. By reading  $i$  for  $e$  the sense of this passage is made clear.]  $e_f$  is four times in the distance between the genitals and the sole of the foot; [Footnote 35: 2 is not to be found in the sketch which renders the passage obscure. The two last lines are plainly legible in the facsimile.]  $3_7$  is six times from 3 to 2 and is equal to  $g_h$  and  $i_k$ .



[Footnote: The drawing of a leg seen in front Pl. XIII, No. 1 belongs to the text from lines 3-21. The measurements in this section should be compared with the text No. 331, lines 1-13, and the sketch of a leg seen in front on Pl. XV.]

329.

The length of the foot from the end of the toes to the heel goes twice into that from the heel to the knee, that is where the leg bone [fibula] joins the thigh bone [femur].

330.

\_a n b\_ are equal; \_c n d\_ are equal; \_n c\_ makes two feet; \_n d\_ makes 2 feet.

[Footnote: See the lower sketch, Pl. XIV, No. 1.]

331.

\_m n o\_ are equal. The narrowest width of the leg seen in front goes 8 times from the sole of the foot to the joint of the knee, and is the same width as the arm, seen in front at the wrist, and as the longest measure of the ear, and as the three chief divisions into which we divide the face; and this measurement goes 4 times from the wrist joint of the hand to the point of the elbow. [14] The foot is as long as the space from the knee between \_a\_ and \_b\_; and the patella of the knee is as long as the leg between \_r\_ and \_s\_.

[18] The least thickness of the leg in profile goes 6 times from the sole of the foot to the knee joint and is the same width as the space between the outer corner of the eye and the opening of the ear, and as the thickest part of the arm seen in profile and between the inner corner of the eye and the insertion of the hair.

\_a b c\_ [\_d\_] are all relatively of equal length, \_c d\_ goes twice from the sole of the foot to the centre of the knee and the same from the knee to the hip.

[28] \_a b c\_ are equal; \_a\_ to \_b\_ is 2 feet--that is to say measuring from the heel to the tip of the great toe.

[Footnote: See Pl. XV. The text of lines 2-17 is to the left of the front view of the leg, to which it refers. Lines 18-27 are in the middle column and refer to the leg seen in profile and turned to the left, on the right hand side of the writing. Lines 20-30 are above, to the left and apply to the sketch below them.

Some farther remarks on the proportion of the leg will be found in No. 336, lines 6, 7.]

On the central point of the whole body.

332.

In kneeling down a man will lose the fourth part of his height.

When a man kneels down with his hands folded on his breast the navel will mark half his height and likewise the points of the elbows.

Half the height of a man who sits--that is from the seat to the top of the head--will be where the arms fold below the breast, and below the shoulders. The seated portion--that is from the seat to the top of the head--will be more than half the man's [whole height] by the length of the scrotum.

[Footnote: See Pl. VIII, No. 2.]

The relative proportions of the torso and of the whole figure.

333.

The cubit is one fourth of the height of a man and is equal to the greatest width of the shoulders. From the joint of one shoulder to the other is two faces and is equal to the distance from the top of the breast to the navel. [Footnote 9: *\_dalla detta somita\_*. It would seem more accurate to read here *\_dal detto ombilico\_*.] From this point to the genitals is a face's length.

[Footnote: Compare with this the sketches on the other page of the same leaf. Pl. VIII, No. 2.]

The relative proportions of the head and of the torso.

334.

From the roots of the hair to the top of the breast *\_a b\_* is the sixth part of the height of a man and this measure is equal.

From the outside part of one shoulder to the other is the same distance as from the top of the breast to the navel and this measure goes four times from the sole of the foot to the lower end of the nose.

The [thickness of] the arm where it springs from the shoulder in front goes 6 times into the space between the two outside edges of the shoulders and 3 times into the face, and four times into the length of the foot and three into the hand, inside or outside.

[Footnote: The three sketches Pl. XIV, No. 2 belong to this text.]

The relative proportions of the torso and of the leg (335. 336).

335.

\_a b c\_ are equal to each other and to the space from the armpit of the shoulder to the genitals and to the distance from the tip of the fingers of the hand to the joint of the arm, and to the half of the breast; and you must know that \_c b\_ is the third part of the height of a man from the shoulders to the ground; \_d e f\_ are equal to each other and equal to the greatest width of the shoulders.

[Footnote: See Pl. XVI, No. 1.]

336.

--Top of the chin--hip--the insertion of the middle finger. The end of the calf of the leg on the inside of the thigh.--The end of the swelling of the shin bone of the leg. [6] The smallest thickness of the leg goes 3 times into the thigh seen in front.

[Footnote: See Pl. XVII, No. 2, middle sketch.]

The relative proportions of the torso and of the foot.

337.

The torso \_a b\_ in its thinnest part measures a foot; and from \_a\_ to \_b\_ is 2 feet, which makes two squares to the seat--its thinnest part goes 3 times into the length, thus making 3 squares.

[Footnote: See Pl. VII, No. 2, the lower sketch.]

The proportions of the whole figure (338-341).

338.

A man when he lies down is reduced to 1/9 of his height.

339.

The opening of the ear, the joint of the shoulder, that of the hip and the ankle are in perpendicular lines; \_a n\_ is equal to \_m o\_.

[Footnote: See Pl. XVI, No. 2, the upper sketch.]

340.

From the chin to the roots of the hair is 1/10 of the whole figure. From the joint of the palm of the hand to the tip of the longest finger is 1/10. From the chin to the top of the head 1/8; and from the pit of the stomach to the top of the breast is 1/6, and from the pit below the breast bone to the top of the head 1/4. From the chin to the nostrils 1/3 Part of the face, the same from the nostrils to the brow and from the brow to the roots of the hair, and the foot is 1/6, the elbow 1/4, the width of the shoulders 1/4.

341.

The width of the shoulders is  $\frac{1}{4}$  of the whole. From the joint of the shoulder to the hand is  $\frac{1}{3}$ , from the parting of the lips to below the shoulder-blade is one foot.

The greatest thickness of a man from the breast to the spine is one 8th of his height and is equal to the space between the bottom of the chin and the top of the head.

The greatest width is at the shoulders and goes 4.

The torso from the front and back.

342.

The width of a man under the arms is the same as at the hips.

A man's width across the hips is equal to the distance from the top of the hip to the bottom of the buttock, when a man stands equally balanced on both feet; and there is the same distance from the top of the hip to the armpit. The waist, or narrower part above the hips will be half way between the arm pits and the bottom of the buttock.

[Footnote: The lower sketch Pl. XVI, No. 2, is drawn by the side of line 1.]

Vitruvius' scheme of proportions.

343.

Vitruvius, the architect, says in his work on architecture that the measurements of the human body are distributed by Nature as follows: that is that 4 fingers make 1 palm, and 4 palms make 1 foot, 6 palms make 1 cubit; 4 cubits make a man's height. And 4 cubits make one pace and 24 palms make a man; and these measures he used in his buildings. If you open your legs so much as to decrease your height  $\frac{1}{14}$  and spread and raise your arms till your middle fingers touch the level of the top of your head you must know that the centre of the outspread limbs will be in the navel and the space between the legs will be an equilateral triangle.

The length of a man's outspread arms is equal to his height.

From the roots of the hair to the bottom of the chin is the tenth of a man's height; from the bottom of the chin to the top of his head is one eighth of his height; from the top of the breast to the top of his head will be one sixth of a man. From the top of the breast to the roots of the hair will be the seventh part of the whole man. From the nipples to the top of the head will be the fourth part of a man. The greatest width of the shoulders contains in itself the fourth part of the man. From the elbow to the tip of the hand will be the fifth part of a man; and from the elbow to the angle of the armpit will be the eighth part of the man. The whole hand will be

the tenth part of the man; the beginning of the genitals marks the middle of the man. The foot is the seventh part of the man. From the sole of the foot to below the knee will be the fourth part of the man. From below the knee to the beginning of the genitals will be the fourth part of the man. The distance from the bottom of the chin to the nose and from the roots of the hair to the eyebrows is, in each case the same, and like the ear, a third of the face.

[Footnote: See Pl. XVIII. The original leaf is 21 centimetres wide and 33 1/2 long. At the ends of the scale below the figure are written the words *\_diti\_* (fingers) and *\_palmi\_* (palms). The passage quoted from Vitruvius is Book III, Cap. 1, and Leonardo's drawing is given in the editions of Vitruvius by FRA GIOCONDO (Venezia 1511, fol., Firenze 1513, 8vo.) and by CESARIANO (Como 1521).]

The arm and head.

344.

From *\_b\_* to *\_a\_* is one head, as well as from *\_c\_* to *\_a\_* and this happens when the elbow forms a right angle.

[Footnote: See Pl. XLI, No. 1.]

Proportions of the arm (345-349).

345.

From the tip of the longest finger of the hand to the shoulder joint is four hands or, if you will, four faces.

*\_a b c\_* are equal and each interval is 2 heads.

[Footnote: Lines 1-3 are given on Pl. XV below the front view of the leg; lines 4 and 5 are below again, on the left side. The lettering refers to the bent arm near the text.]

346.

The hand from the longest finger to the wrist joint goes 4 times from the tip of the longest finger to the shoulder joint.

347.

*\_a b c\_* are equal to each other and to the foot and to the space between the nipple and the navel *\_d e\_* will be the third part of the whole man.

*\_f g\_* is the fourth part of a man and is equal to *\_g h\_* and measures a cubit.

[Footnote: See Pl. XIX, No. 1. 1. *\_mamolino\_* (= *\_bambino\_*, little child) may mean here the navel.]

348.

\_a b\_ goes 4 times into \_a c\_ and 9 into \_a m\_. The greatest thickness of the arm between the elbow and the hand goes 6 times into \_a m\_ and is equal to \_r f\_. The greatest thickness of the arm between the shoulder and the elbow goes 4 times into \_c m\_, and is equal to \_h n g\_. The smallest thickness of the arm above the elbow \_x y\_ is not the base of a square, but is equal to half the space \_h\_ 3 which is found between the inner joint of the arm and the wrist joint.

[11]The width of the wrist goes 12 times into the whole arm; that is from the tip of the fingers to the shoulder joint; that is 3 times into the hand and 9 into the arm.

The arm when bent is 4 heads.

The arm from the shoulder to the elbow in bending increases in length, that is in the length from the shoulder to the elbow, and this increase is equal to the thickness of the arm at the wrist when seen in profile. And the space between the bottom of the chin and the parting of the lips, is equal to the thickness of the 2 middle fingers, and to the width of the mouth and to the space between the roots of the hair on the forehead and the top of the head [Footnote: \_Queste cose\_. This passage seems to have been written on purpose to rectify the foregoing lines. The error is explained by the accompanying sketch of the bones of the arm.]. All these distances are equal to each other, but they are not equal to the above-mentioned increase in the arm.

The arm between the elbow and wrist never increases by being bent or extended.

The arm, from the shoulder to the inner joint when extended.

When the arm is extended, \_p n\_ is equal to \_n a\_. And when it is bent \_n a\_ diminishes 1/6 of its length and \_p n\_ does the same. The outer elbow joint increases 1/7 when bent; and thus by being bent it increases to the length of 2 heads. And on the inner side, by bending, it is found that whereas the arm from where it joins the side to the wrist, was 2 heads and a half, in bending it loses the half head and measures only two: one from the [shoulder] joint to the end [by the elbow], and the other to the hand.

The arm when folded will measure 2 faces up to the shoulder from the elbow and 2 from the elbow to the insertion of the four fingers on the palm of the hand. The length from the base of the fingers to the elbow never alters in any position of the arm.

If the arm is extended it decreases by 1/3 of the length between \_b\_ and \_h\_ ; and if--being extended--it is bent, it will increase the half of \_o e\_. [Footnote 59-61: The figure sketched in the margin is

however drawn to different proportions.] The length from the shoulder to the elbow is the same as from the base of the thumb, inside, to the elbow *\_a b c\_*.

[Footnote 62-64: The arm sketch on the margin of the MS. is identically the same as that given below on Pl. XX which may therefore be referred to in this place. In line 62 we read therefore *\_z c\_ for \_m n\_*.] The smallest thickness of the arm in profile *\_z c\_* goes 6 times between the knuckles of the hand and the dimple of the elbow when extended and 14 times in the whole arm and 42 in the whole man [64]. The greatest thickness of the arm in profile is equal to the greatest thickness of the arm in front; but the first is placed at a third of the arm from the shoulder joint to the elbow and the other at a third from the elbow towards the hand.

[Footnote: Compare Pl. XVII. Lines 1-10 and 11-15 are written in two columns below the extended arm, and at the tips of the fingers we find the words: *\_fine d'unghie\_* (ends of the nails). Part of the text--lines 22 to 25--is visible by the side of the sketches on Pl. XXXV, No. 1.]

349.

From the top of the shoulder to the point of the elbow is as far as from that point to the joints of the four fingers with the palm of the hand, and each is 2 faces.

[5] *\_a e\_* is equal to the palm of the hand, *\_r f\_* and *\_o g\_* are equal to half a head and each goes 4 times into *\_a b\_* and *\_b c\_*. From *\_c\_* to *\_m\_* is 1/2 a head; *\_m n\_* is 1/3 of a head and goes 6 times into *\_c b\_* and into *\_b a\_*; *\_a b\_* loses 1/7 of its length when the arm is extended; *\_c b\_* never alters; *\_o\_* will always be the middle point between *\_a\_* and *\_s\_*.

*\_y l\_* is the fleshy part of the arm and measures one head; and when the arm is bent this shrinks 2/5 of its length; *\_o a\_* in bending loses 1/6 and so does *\_o r\_*.

*\_a b\_* is 1/7 of *\_r c\_*. *\_f s\_* will be 1/8 of *\_r c\_*, and each of those 2 measurements is the largest of the arm; *\_k h\_* is the thinnest part between the shoulder and the elbow and it is 1/8 of the whole arm *\_r c\_*; *\_o p\_* is 1/5 of *\_r l\_*; *\_c z\_* goes 13 times into *\_r c\_*.

[Footnote: See Pl. XX where the text is also seen from lines 5-23.]

The movement of the arm (350-354).

350.

In the innermost bend of the joints of every limb the reliefs are converted into a hollow, and likewise every hollow of the innermost bends becomes a convexity when the limb is straightened to the utmost. And in this very great mistakes are often made by those who

have insufficient knowledge and trust to their own invention and do not have recourse to the imitation of nature; and these variations occur more in the middle of the sides than in front, and more at the back than at the sides.

351.

When the arm is bent at an angle at the elbow, it will produce some angle; the more acute the angle is, the more will the muscles within the bend be shortened; while the muscles outside will become of greater length than before. As is shown in the example; *\_d c e\_* will shrink considerably; and *\_b n\_* will be much extended.

[Footnote: See Pl. XIX, No. 2.]

352.

#### OF PAINTING.

The arm, as it turns, thrusts back its shoulder towards the middle of the back.

353.

The principal movements of the hand are 10; that is forwards, backwards, to right and to left, in a circular motion, up or down, to close and to open, and to spread the fingers or to press them together.

354.

#### OF THE MOTIONS OF THE FINGERS.

The movements of the fingers principally consist in extending and bending them. This extension and bending vary in manner; that is, sometimes they bend altogether at the first joint; sometimes they bend, or extend, half way, at the 2nd joint; and sometimes they bend in their whole length and in all the three joints at once. If the 2 first joints are hindered from bending, then the 3rd joint can be bent with greater ease than before; it can never bend of itself, if the other joints are free, unless all three joints are bent. Besides all these movements there are 4 other principal motions of which 2 are up and down, the two others from side to side; and each of these is effected by a single tendon. From these there follow an infinite number of other movements always effected by two tendons; one tendon ceasing to act, the other takes up the movement. The tendons are made thick inside the fingers and thin outside; and the tendons inside are attached to every joint but outside they are not.

[Footnote 26: This head line has, in the original, no text to follow.] Of the strength [and effect] of the 3 tendons inside the fingers at the 3 joints.



The movement of the torso (355-361).

355.

Observe the altered position of the shoulder in all the movements of the arm, going up and down, inwards and outwards, to the back and to the front, and also in circular movements and any others.

And do the same with reference to the neck, hands and feet and the breast above the lips &c.

356.

Three are the principal muscles of the shoulder, that is b c d, and two are the lateral muscles which move it forward and backward, that is a o; a moves it forward, and o pulls it back; and bed raises it; a b c moves it upwards and forwards, and c d o upwards and backwards. Its own weight almost suffices to move it downwards.

The muscle d acts with the muscle c when the arm moves forward; and in moving backward the muscle b acts with the muscle c.

[Footnote: See Pl. XXI. In the original the lettering has been written in ink upon the red chalk drawing and the outlines of the figures have in most places been inked over.]

357.

OF THE LOINS, WHEN BENT.

The loins or backbone being bent. The breasts are always lower than the shoulderblades of the back.

If the breast bone is arched the breasts are higher than the shoulderblades.

If the loins are upright the breast will always be found at the same level as the shoulderblades.

[Footnote: See Pl. XXII, No. 1.]

358.

a b the tendon and ankle in raising the heel approach each other by a finger's breadth; in lowering it they separate by a finger's breadth.

[Footnote: See Pl. XXII, No. 2. Compare this facsimile and text with Pl. III, No. 2, and p. 152 of MANZI'S edition. Also with No. 274 of LUDWIG'S edition of the Vatican Copy.]

359.

Just so much as the part \_d a\_ of the nude figure decreases in this position so much does the opposite part increase; that is: in proportion as the length of the part \_d a\_ diminishes the normal size so does the opposite upper part increase beyond its [normal] size. The navel does not change its position to the male organ; and this shrinking arises because when a figure stands on one foot, that foot becomes the centre [of gravity] of the superimposed weight. This being so, the middle between the shoulders is thrust above it out of its perpendicular line, and this line, which forms the central line of the external parts of the body, becomes bent at its upper extremity [so as to be] above the foot which supports the body; and the transverse lines are forced into such angles that their ends are lower on the side which is supported. As is shown at \_a b c\_.

[Footnote: See Pl. XXII, No. 3.]

360.

#### OF PAINTING.

Note in the motions and attitudes of figures how the limbs vary, and their feeling, for the shoulderblades in the motions of the arms and shoulders vary the [line of the] back bone very much. And you will find all the causes of this in my book of Anatomy.

361.

#### OF [CHANGE OF] ATTITUDE.

The pit of the throat is over the feet, and by throwing one arm forward the pit of the throat is thrown off that foot. And if the leg is thrown forward the pit of the throat is thrown forward; and so it varies in every attitude.

362.

#### OF PAINTING.

Indicate which are the muscles, and which the tendons, which become prominent or retreat in the different movements of each limb; or which do neither [but are passive]. And remember that these indications of action are of the first importance and necessity in any painter or sculptor who professes to be a master &c.

And indicate the same in a child, and from birth to decrepitude at every stage of its life; as infancy, childhood, boyhood, youth &c.

And in each express the alterations in the limbs and joints, which swell and which grow thinner.

363.

O Anatomical Painter! beware lest the too strong indication of the bones, sinews and muscles, be the cause of your becoming wooden in your painting by your wish to make your nude figures display all their feeling. Therefore, in endeavouring to remedy this, look in what manner the muscles clothe or cover their bones in old or lean persons; and besides this, observe the rule as to how these same muscles fill up the spaces of the surface that extend between them, which are the muscles which never lose their prominence in any amount of fatness; and which too are the muscles of which the attachments are lost to sight in the very least plumpness. And in many cases several muscles look like one single muscle in the increase of fat; and in many cases, in growing lean or old, one single muscle divides into several muscles. And in this treatise, each in its place, all their peculiarities will be explained--and particularly as to the spaces between the joints of each limb &c. Again, do not fail [to observe] the variations in the forms of the above mentioned muscles, round and about the joints of the limbs of any animal, as caused by the diversity of the motions of each limb; for on some side of those joints the prominence of these muscles is wholly lost in the increase or diminution of the flesh of which these muscles are composed, &c.

[Footnote: DE ROSSI remarks on this chapter, in the Roman edition of the Trattato, p. 504: "\_Non in questo luogo solo, ma in altri ancora osserverà il lettore, che Lionardo va fungendo quelli che fanno abuso della loro dottrina anatomica, e sicuramente con ciò ha in mira il suo rivale Bonarroti, che di anatomia faceva tanta pompa\_." Note, that Leonardo wrote this passage in Rome, probably under the immediate impression of MICHAELANGELO'S paintings in the Sistine Chapel and of RAPHAEL'S Isaiah in Sant' Agostino.]

364.

#### OF THE DIFFERENT MEASUREMENTS OF BOYS AND MEN.

There is a great difference in the length between the joints in men and boys for, in man, from the top of the shoulder [by the neck] to the elbow, and from the elbow to the tip of the thumb and from one shoulder to the other, is in each instance two heads, while in a boy it is but one because Nature constructs in us the mass which is the home of the intellect, before forming that which contains the vital elements.

365.

#### OF PAINTING.

Which are the muscles which subdivide in old age or in youth, when becoming lean? Which are the parts of the limbs of the human frame where no amount of fat makes the flesh thicker, nor any degree of leanness ever diminishes it?

The thing sought for in this question will be found in all the

external joints of the bones, as the shoulder, elbow, wrists, finger-joints, hips, knees, ankle-bone and toes and the like; all of which shall be told in its place. The greatest thickness acquired by any limb is at the part of the muscles which is farthest from its attachments.

Flesh never increases on those portions of the limb where the bones are near to the surface.

At \_b r d a c e f\_ the increase or diminution of the flesh never makes any considerable difference. Nature has placed in front of man all those parts which feel most pain under a blow; and these are the shin of the leg, the forehead, and the nose. And this was done for the preservation of man, since, if such pain were not felt in these parts, the number of blows to which they would be exposed must be the cause of their destruction.

Describe why the bones of the arm and leg are double near the hand and foot [respectively].

And where the flesh is thicker or thinner in the bending of the limbs.

366.

#### OF PAINTING.

Every part of the whole must be in proportion to the whole. Thus, if a man is of a stout short figure he will be the same in all his parts: that is with short and thick arms, wide thick hands, with short fingers with their joints of the same character, and so on with the rest. I would have the same thing understood as applying to all animals and plants; in diminishing, [the various parts] do so in due proportion to the size, as also in enlarging.

367.

#### OF THE AGREEMENT OF THE PROPORTION OF THE LIMBS.

And again, remember to be very careful in giving your figures limbs, that they must appear to agree with the size of the body and likewise to the age. Thus a youth has limbs that are not very muscular not strongly veined, and the surface is delicate and round, and tender in colour. In man the limbs are sinewy and muscular, while in old men the surface is wrinkled, rugged and knotty, and the sinews very prominent.

#### HOW YOUNG BOYS HAVE THEIR JOINTS JUST THE REVERSE OF THOSE OF MEN, AS TO SIZE.

Little children have all the joints slender and the portions between them are thick; and this happens because nothing but the skin covers the joints without any other flesh and has the character of sinew,

connecting the bones like a ligature. And the fat fleshiness is laid on between one joint and the next, and between the skin and the bones. But, since the bones are thicker at the joints than between them, as a mass grows up the flesh ceases to have that superfluity which it had, between the skin and the bones; whence the skin clings more closely to the bone and the limbs grow more slender. But since there is nothing over the joints but the cartilaginous and sinewy skin this cannot dry up, and, not drying up, cannot shrink. Thus, and for this reason, children are slender at the joints and fat between the joints; as may be seen in the joints of the fingers, arms, and shoulders, which are slender and dimpled, while in man on the contrary all the joints of the fingers, arms, and legs are thick; and wherever children have hollows men have prominences.

The movement of the human figure (368-375).

368.

Of the manner of representing the 18 actions of man. Repose, movement, running, standing, supported, sitting, leaning, kneeling, lying down, suspended. Carrying or being carried, thrusting, pulling, striking, being struck, pressing down and lifting up.

[As to how a figure should stand with a weight in its hand [Footnote 8: The original text ends here.] Remember].

369.

A sitting man cannot raise himself if that part of his body which is front of his axis [centre of gravity] does not weigh more than that which is behind that axis [or centre] without using his arms.

A man who is mounting any slope finds that he must involuntarily throw the most weight forward, on the higher foot, rather than behind--that is in front of the axis and not behind it. Hence a man will always, involuntarily, throw the greater weight towards the point whither he desires to move than in any other direction.

The faster a man runs, the more he leans forward towards the point he runs to and throws more weight in front of his axis than behind. A man who runs down hill throws the axis onto his heels, and one who runs up hill throws it into the points of his feet; and a man running on level ground throws it first on his heels and then on the points of his feet.

This man cannot carry his own weight unless, by drawing his body back he balances the weight in front, in such a way as that the foot on which he stands is the centre of gravity.

[Footnote: See Pl. XXII, No. 4.]

370.

How a man proceeds to raise himself to his feet, when he is sitting on level ground.

371.

A man when walking has his head in advance of his feet.

A man when walking across a long level plain first leans [rather] backwards and then as much forwards.

[Footnote 3-6: He strides forward with the air of a man going down hill; when weary, on the contrary he walks like a man going up hill.]

372.

A man when running throws less weight on his legs than when standing still. And in the same way a horse which is running feels less the weight of the man he carries. Hence many persons think it wonderful that, in running, the horse can rest on one single foot. From this it may be stated that when a weight is in progressive motion the more rapid it is the less is the perpendicular weight towards the centre.

373.

If a man, in taking a jump from firm ground, can leap 3 braccia, and when he was taking his leap it were to recede  $\frac{1}{3}$  of a braccio, that would be taken off his former leap; and so if it were thrust forward  $\frac{1}{3}$  of a braccio, by how much would his leap be increased?

374.

OF DRAWING.

When a man who is running wants to neutralise the impetus that carries him on he prepares a contrary impetus which is generated by his hanging backwards. This can be proved, since, if the impetus carries a moving body with a momentum equal to 4 and the moving body wants to turn and fall back with a momentum of 4, then one momentum neutralises the other contrary one, and the impetus is neutralised.

Of walking up and down (375-379)

375.

When a man wants to stop running and check the impetus he is forced to hang back and take short quick steps. [Footnote: Lines 5-31 refer to the two upper figures, and the lower figure to the right is explained by the last part of the chapter.] The centre of gravity of a man who lifts one of his feet from the ground always rests on the centre of the sole of the foot [he stands on].

A man, in going up stairs involuntarily throws so much weight forward and on the side of the upper foot as to be a counterpoise to the lower leg, so that the labour of this lower leg is limited to moving itself.

The first thing a man does in mounting steps is to relieve the leg he is about to lift of the weight of the body which was resting on that leg; and besides this, he gives to the opposite leg all the rest of the bulk of the whole man, including [the weight of] the other leg; he then raises the other leg and sets the foot upon the step to which he wishes to raise himself. Having done this he restores to the upper foot all the weight of the body and of the leg itself, and places his hand on his thigh and throws his head forward and repeats the movement towards the point of the upper foot, quickly lifting the heel of the lower one; and with this impetus he lifts himself up and at the same time extends the arm which rested on his knee; and this extension of the arm carries up the body and the head, and so straightens the spine which was curved.

[32] The higher the step is which a man has to mount, the farther forward will he place his head in advance of his upper foot, so as to weigh more on a than on b; this man will not be on the step m. As is shown by the line g f.

[Footnote: See Pl. XXIII, No. 1. The lower sketch to the left belongs to the four first lines.]

376.

I ask the weight [pressure] of this man at every degree of motion on these steps, what weight he gives to b and to c.

[Footnote 8: These lines are, in the original, written in ink]  
Observe the perpendicular line below the centre of gravity of the man.

[Footnote: See Pl. XXIII, No. 2.]

377.

In going up stairs if you place your hands on your knees all the labour taken by the arms is removed from the sinews at the back of the knees.

[Footnote: See Pl. XXIII, No. 3.]

378.

The sinew which guides the leg, and which is connected with the patella of the knee, feels it a greater labour to carry the man upwards, in proportion as the leg is more bent; and the muscle which acts upon the angle made by the thigh where it joins the body has less difficulty and has a less weight to lift, because it has not

the [additional] weight of the thigh itself. And besides this it has stronger muscles, being those which form the buttock.

379.

A man coming down hill takes little steps, because the weight rests upon the hinder foot, while a man mounting takes wide steps, because his weight rests on the foremost foot.

[Footnote: See Pl. XXIII, No. 4.]

On the human body in action (380-388).

380.

#### OF THE HUMAN BODY IN ACTION.

When you want to represent a man as moving some weight consider what the movements are that are to be represented by different lines; that is to say either from below upwards, with a simple movement, as a man does who stoops forward to take up a weight which he will lift as he straightens himself. Or as a man does who wants to squash something backwards, or to force it forwards or to pull it downwards with ropes passed through pullies [Footnote 10: Compare the sketch on page 198 and on 201 (S. K. M. II.1 86b).]. And here remember that the weight of a man pulls in proportion as his centre of gravity is distant from his fulcrum, and to this is added the force given by his legs and bent back as he raises himself.

381.

Again, a man has even a greater store of strength in his legs than he needs for his own weight; and to see if this is true, make a man stand on the shore-sand and then put another man on his back, and you will see how much he will sink in. Then take the man from off his back and make him jump straight up as high as he can, and you will find that the print of his feet will be made deeper by the jump than from having the man on his back. Hence, here, by 2 methods it is proved that a man has double the strength he requires to support his own body.

382.

#### OF PAINTING.

If you have to draw a man who is in motion, or lifting or pulling, or carrying a weight equal to his own, in what way must you set on his legs below his body?

[Footnote: In the MS. this question remains unanswered.]

383.



## OF THE STRENGTH OF MAN.

A man pulling a [dead] weight balanced against himself cannot pull more than his own weight. And if he has to raise it he will [be able to] raise as much more than his weight as his strength may be more than that of other men. [Footnote 7: The stroke at the end of this line finishes in the original in a sort of loop or flourish, and a similar flourish occurs at the end of the previous passage written on the same page. M. RAVAISSON regards these as numbers (compare the photograph of page 30b in his edition of MS. A). He remarks: "\_Ce chiffre\_ 8 \_et, a la fin de l'alea precedent, le chiffre\_ 7 \_sont, dans le manuscrit, des renvois\_."] The greatest force a man can apply, with equal velocity and impetus, will be when he sets his feet on one end of the balance [or lever] and then presses his shoulders against some stable body. This will raise a weight at the other end of the balance [lever], equal to his own weight and [added to that] as much weight as he can carry on his shoulders.

384.

No animal can simply move [by its dead weight] a greater weight than the sum of its own weight outside the centre of his fulcrum.

385.

A man who wants to send an arrow very far from the bow must be standing entirely on one foot and raising the other so far from the foot he stands on as to afford the requisite counterpoise to his body which is thrown on the front foot. And he must not hold his arm fully extended, and in order that he may be more able to bear the strain he must hold a piece of wood which there is in all crossbows, extending from the hand to the breast, and when he wishes to shoot he suddenly leaps forward at the same instant and extends his arm with the bow and releases the string. And if he dexterously does every thing at once it will go a very long way.

386.

When two men are at the opposite ends of a plank that is balanced, and if they are of equal weight, and if one of them wants to make a leap into the air, then his leap will be made down from his end of the plank and the man will never go up again but must remain in his place till the man at the other end dashes up the board.

[Footnote: See Pl. XXIV, No. 3.]

387.

Of delivering a blow to the right or left.

[Footnote: Four sketches on Pl. XXIV, No. 1 belong to this passage. The rest of the sketches and notes on that page are of a miscellaneous nature.]

388.

Why an impetus is not spent at once [but diminishes] gradually in some one direction? [Footnote 1: The paper has been damaged at the end of line 1.] The impetus acquired in the line a b c d is spent in the line d e but not so completely but that some of its force remains in it and to this force is added the momentum in the line d e with the force of the motive power, and it must follow that the impetus multiplied by the blow is greater than the simple impetus produced by the momentum d e.

[Footnote 8: The sketch No. 2 on Pl. XXIV stands, in the original, between lines 7 and 8. Compare also the sketches on Pl. LIV.] A man who has to deal a great blow with his weapon prepares himself with all his force on the opposite side to that where the spot is which he is to hit; and this is because a body as it gains in velocity gains in force against the object which impedes its motion.

On hair falling down in curls.

389.

Observe the motion of the surface of the water which resembles that of hair, and has two motions, of which one goes on with the flow of the surface, the other forms the lines of the eddies; thus the water forms eddying whirlpools one part of which are due to the impetus of the principal current and the other to the incidental motion and return flow.

[Footnote: See Pl. XXV. Where also the text of this passage is given in facsimile.]

On draperies (390--392).

390.

OF THE NATURE OF THE FOLDS IN DRAPERY.

That part of a fold which is farthest from the ends where it is confined will fall most nearly in its natural form.

Every thing by nature tends to remain at rest. Drapery, being of equal density and thickness on its wrong side and on its right, has a tendency to lie flat; therefore when you give it a fold or plait forcing it out of its flatness note well the result of the constraint in the part where it is most confined; and the part which is farthest from this constraint you will see relapses most into the natural state; that is to say lies free and flowing.

EXAMPLE.

[Footnote 13: a c sia. In the original text b is written instead

of \_c\_--an evident slip of the pen.] Let \_a b c\_ be the fold of the drapery spoken of above, \_a c\_ will be the places where this folded drapery is held fast. I maintain that the part of the drapery which is farthest from the plaited ends will revert most to its natural form.

Therefore, \_b\_ being farthest from \_a\_ and \_c\_ in the fold \_a b c\_ it will be wider there than anywhere else.

[Footnote: See Pl. XXVIII, No. 6, and compare the drawing from Windsor Pl. XXX for farther illustration of what is here stated.]

391.

#### OF SMALL FOLDS IN DRAPERIES.

How figures dressed in a cloak should not show the shape so much as that the cloak looks as if it were next the flesh; since you surely cannot wish the cloak to be next the flesh, for you must suppose that between the flesh and the cloak there are other garments which prevent the forms of the limbs appearing distinctly through the cloak. And those limbs which you allow to be seen you must make thicker so that the other garments may appear to be under the cloak. But only give something of the true thickness of the limbs to a nymph [Footnote 9: *Una nifa*. Compare the beautiful drawing of a Nymph, in black chalk from the Windsor collection, Pl. XXVI.] or an angel, which are represented in thin draperies, pressed and clinging to the limbs of the figures by the action of the wind.

392.

You ought not to give to drapery a great confusion of many folds, but rather only introduce them where they are held by the hands or the arms; the rest you may let fall simply where it is its nature to flow; and do not let the nude forms be broken by too many details and interrupted folds. How draperies should be drawn from nature: that is to say if you want to represent woollen cloth draw the folds from that; and if it is to be silk, or fine cloth or coarse, or of linen or of crape, vary the folds in each and do not represent dresses, as many do, from models covered with paper or thin leather which will deceive you greatly.

[Footnote: The little pen and ink drawing from Windsor (W. 102), given on Pl. XXVIII, No. 7, clearly illustrates the statement made at the beginning of this passage; the writing of the cipher 19 on the same page is in Leonardo's hand; the cipher 21 is certainly not.]

\_VIII.\_

\_Botany for Painters and Elements of Landscape Painting.\_

\_The chapters composing this portion of the work consist of

observations on Form, Light and Shade in Plants, and particularly in Trees summed up in certain general rules by which the author intends to guide the artist in the pictorial representation of landscape.\_

\_With these the first principles of a\_ Theory of Landscape painting \_are laid down--a theory as profoundly thought out in its main lines as it is lucidly worked out in its details. In reading these chapters the conviction is irresistible that such a\_ Botany for painters \_is or ought to be of similar importance in the practice of painting as the principles of the Proportions and Movements of the human figure\_ i. e. Anatomy for painters.

\_There can be no doubt that Leonardo, in laying down these rules, did not intend to write on Botany in the proper scientific sense--his own researches on that subject have no place here; it need only be observed that they are easily distinguished by their character and contents from those which are here collected and arranged under the title 'Botany for painters'. In some cases where this division might appear doubtful,--as for instance in No.\_ 402--\_the Painter is directly addressed and enjoined to take the rule to heart as of special importance in his art.\_

\_The original materials are principally derived from MS.\_ G, \_in which we often find this subject treated on several pages in succession without any of that intermixture of other matters, which is so frequent in Leonardo's writings. This MS., too, is one of the latest; when it was written, the great painter was already more than sixty years of age, so we can scarcely doubt that he regarded all he wrote as his final views on the subject. And the same remark applies to the chapters from MSS.\_ E \_and\_ M \_which were also written between\_ 1513--15.

\_For the sake of clearness, however, it has been desirable to sacrifice--with few exceptions--the original order of the passages as written, though it was with much reluctance and only after long hesitation that I resigned myself to this necessity. Nor do I mean to impugn the logical connection of the author's ideas in his MS.; but it will be easily understood that the sequence of disconnected notes, as they occurred to Leonardo and were written down from time to time, might be hardly satisfactory as a systematic arrangement of his principles. The reader will find in the Appendix an exact account of the order of the chapters in the original MS. and from the data there given can restore them at will. As the materials are here arranged, the structure of the tree as regards the growth of the branches comes first\_ (394-411) \_and then the insertion of the leaves on the stems\_ (412-419). \_Then follow the laws of Light and Shade as applied, first, to the leaves (420-434), and, secondly, to the whole tree and to groups of trees\_ (435-457). \_After the remarks on the Light and Shade in landscapes generally\_ (458-464), \_we find special observations on that of views of towns and buildings\_ (465-469). \_To the theory of Landscape Painting belong also the passages on the effect of Wind on Trees\_ (470-473) \_and on the Light and Shade of Clouds\_ (474-477), \_since we find in these certain

comparisons with the effect of Light and Shade on Trees\_ (e. g.: \_in No.\_ 476, 4. 5; \_and No.\_ 477, 9. 12). \_The chapters given in the Appendix Nos.\_ 478 \_and\_ 481 \_have hardly any connection with the subjects previously treated.\_

Classification of trees.

393.

TREES.

Small, lofty, straggling, thick, that is as to foliage, dark, light, russet, branched at the top; some directed towards the eye, some downwards; with white stems; this transparent in the air, that not; some standing close together, some scattered.

The relative thickness of the branches to the trunk (393--396).

394.

All the branches of a tree at every stage of its height when put together are equal in thickness to the trunk [below them].

All the branches of a water [course] at every stage of its course, if they are of equal rapidity, are equal to the body of the main stream.

395.

Every year when the boughs of a plant [or tree] have made an end of maturing their growth, they will have made, when put together, a thickness equal to that of the main stem; and at every stage of its ramification you will find the thickness of the said main stem; as: \_i k\_, \_g h\_, \_e f\_, \_c d\_, \_a b\_, will always be equal to each other; unless the tree is pollard--if so the rule does not hold good.

All the branches have a direction which tends to the centre of the tree \_m\_.

[Footnote: The two sketches of leafless trees one above another on the left hand side of Pl. XXVII, No. 1, belong to this passage.]

396.

If the plant n grows to the thickness shown at m, its branches will correspond [in thickness] to the junction a b in consequence of the growth inside as well as outside.

The branches of trees or plants have a twist wherever a minor branch is given off; and this giving off the branch forms a fork; this said fork occurs between two angles of which the largest will be that which is on the side of the larger branch, and in proportion, unless

accident has spoilt it.

[Footnote: The sketches illustrating this are on the right hand side of Pl. XXVII, No. I, and the text is also given there in facsimile.]

397.

There is no boss on branches which has not been produced by some branch which has failed.

The lower shoots on the branches of trees grow more than the upper ones and this occurs only because the sap that nourishes them, being heavy, tends downwards more than upwards; and again, because those [branches] which grow downwards turn away from the shade which exists towards the centre of the plant. The older the branches are, the greater is the difference between their upper and their lower shoots and in those dating from the same year or epoch.

[Footnote: The sketch accompanying this in the MS. is so effaced that an exact reproduction was impossible.]

398.

#### OF THE SCARS ON TREES.

The scars on trees grow to a greater thickness than is required by the sap of the limb which nourishes them.

399.

The plant which gives out the smallest ramifications will preserve the straightest line in the course of its growth.

[Footnote: This passage is illustrated by two partly effaced sketches. One of these closely resembles the lower one given under No. 408, the other also represents short closely set boughs on an upright trunk.]

400.

#### OF THE RAMIFICATION.

The beginning of the ramification [the shoot] always has the central line [axis] of its thickness directed to the central line [axis] of the plant itself.

401.

In starting from the main stem the branches always form a base with a prominence as is shown at \_a b c d\_.

402.

WHY, VERY FREQUENTLY, TIMBER HAS VEINS THAT ARE NOT STRAIGHT.

When the branches which grow the second year above the branch of the preceding year, are not of equal thickness above the antecedent branches, but are on one side, then the vigour of the lower branch is diverted to nourish the one above it, although it may be somewhat on one side.

But if the ramifications are equal in their growth, the veins of the main stem will be straight [parallel] and equidistant at every degree of the height of the plant.

Wherefore, O Painter! you, who do not know these laws! in order to escape the blame of those who understand them, it will be well that you should represent every thing from nature, and not despise such study as those do who work [only] for money.

The direction of growth (403-407).

403.

OF THE RAMIFICATIONS OF PLANTS.

The plants which spread very much have the angles of the spaces which divide their branches more obtuse in proportion as their point of origin is lower down; that is nearer to the thickest and oldest portion of the tree. Therefore in the youngest portions of the tree the angles of ramification are more acute. [Footnote: Compare the sketches on the lower portion of Pl. XXVII, No. 2.]

404.

The tips of the boughs of plants [and trees], unless they are borne down by the weight of their fruits, turn towards the sky as much as possible.

The upper side of their leaves is turned towards the sky that it may receive the nourishment of the dew which falls at night.

The sun gives spirit and life to plants and the earth nourishes them with moisture. [9] With regard to this I made the experiment of leaving only one small root on a gourd and this I kept nourished with water, and the gourd brought to perfection all the fruits it could produce, which were about 60 gourds of the long kind, and I set my mind diligently [to consider] this vitality and perceived that the dews of night were what supplied it abundantly with moisture through the insertion of its large leaves and gave nourishment to the plant and its offspring--or the seeds which its offspring had to produce--[21].

The rule of the leaves produced on the last shoot of the year will be that they will grow in a contrary direction on the twin branches; that is, that the insertion of the leaves turns round each branch in

such a way, as that the sixth leaf above is produced over the sixth leaf below, and the way they turn is that if one turns towards its companion to the right, the other turns to the left, the leaf serving as the nourishing breast for the shoot or fruit which grows the following year.

[Footnote: A French translation of lines 9-12 was given by M. RAVAISSON in the *Gazette des Beaux Arts*, Oct. 1877; his paper also contains some valuable information as to botanical science in the ancient classical writers and at the time of the Renaissance.]

405.

The lowest branches of those trees which have large leaves and heavy fruits, such as nut-trees, fig-trees and the like, always droop towards the ground.

The branches always originate above [in the axis of] the leaves.

406.

The upper shoots of the lateral branches of plants lie closer to the parent branch than the lower ones.

407.

The lowest branches, after they have formed the angle of their separation from the parent stem, always bend downwards so as not to crowd against the other branches which follow them on the same stem and to be better able to take the air which nourishes them. As is shown by the angle  $\_b a c\_$ ; the branch  $\_a c\_$  after it has made the corner of the angle  $\_a c\_$  bends downwards to  $\_c d\_$  and the lesser shoot  $\_c\_$  dries up, being too thin.

The main branch always goes below, as is shown by the branch  $\_f n m\_$ , which does not go to  $\_f n o\_$ .

The forms of trees (408--411).

408.

The elm always gives a greater length to the last branches of the year's growth than to the lower ones; and Nature does this because the highest branches are those which have to add to the size of the tree; and those at the bottom must get dry because they grow in the shade and their growth would be an impediment to the entrance of the solar rays and the air among the main branches of the tree.

The main branches of the lower part bend down more than those above, so as to be more oblique than those upper ones, and also because they are larger and older.

409.



In general almost all the upright portions of trees curve somewhat turning the convexity towards the South; and their branches are longer and thicker and more abundant towards the South than towards the North. And this occurs because the sun draws the sap towards that surface of the tree which is nearest to it.

And this may be observed if the sun is not screened off by other plants.

410.

The cherry-tree is of the character of the fir tree as regards its ramification placed in stages round its main stem; and its branches spring, 4 or five or 6 [together] opposite each other; and the tips of the topmost shoots form a pyramid from the middle upwards; and the walnut and oak form a hemisphere from the middle upwards.

411.

The bough of the walnut which is only hit and beaten when it has brought to perfection...

[Footnote: The end of the text and the sketch in red chalk belonging to it, are entirely effaced.]

The insertion of the leaves (412--419).

412.

#### OF THE INSERTION OF THE BRANCHES ON PLANTS.

Such as the growth of the ramification of plants is on their principal branches, so is that of the leaves on the shoots of the same plant. These leaves have [Footnote 6: *Quattro modi* (four modes)]. Only three are described in the text, the fourth is only suggested by a sketch.

This passage occurs in MANZI'S edition of the Trattato, p. 399, but without the sketches and the text is mutilated in an important part. The whole passage has been commented on, from MANZI'S version, in Part I of the *Nuovo Giornale Botanico Italiano*, by Prof. G. UZIELLI (Florence 1869, Vol. I). He remarks as to the 'four modes': "*Leonardo, come si vede nelle linee sententi da solo tre esempli. Questa ed altre inessattezze fanno desiderare, sia esaminato di nuovo il manoscritto Vaticano*". This has since been done by D. KNAPP of Tübingen, and his accurate copy has been published by H. LUDWIG, the painter. The passage in question occurs in his edition as No. 833; and there also the drawings are wanting. The space for them has been left vacant, but in the Vatican copy '*niente*' has been written on the margin; and in it, as well as in LUDWIG'S and MANZI'S edition, the text is mutilated.] four modes of growing one above another. The first, which is the most general, is that the

sixth always originates over the sixth below [Footnote 8: \_la sesta di sotto. "Disposizione 2/5 o 1/5. Leonardo osservo probabilmente soltanto la prima" \_ (UZIELLI).]; the second is that two third ones above are over the two third ones below [Footnote 10: \_terze di sotto: "Intende qui senza dubbio parlare di foglie decussate, in cui il terzo verticello e nel piano del primo" \_ (UZIELLI).]; and the third way is that the third above is over the third below [Footnote 11: 3a \_di sotto: "Disposizione 1/2" \_ (UZIELLI).].

[Footnote: See the four sketches on the upper portion of the page reproduced as fig. 2 on P1. XXVII.]

413.

#### A DESCRIPTION OF THE ELM.

The ramification of the elm has the largest branch at the top. The first and the last but one are smaller, when the main trunk is straight.

The space between the insertion of one leaf to the rest is half the extreme length of the leaf or somewhat less, for the leaves are at an interval which is about the 3rd of the width of the leaf.

The elm has more leaves near the top of the boughs than at the base; and the broad [surface] of the leaves varies little as to [angle and] aspect.

[Footnote: See Pl. XXVII, No. 3. Above the sketch and close under the number of the page is the word '\_olmo\_' (elm).]

414.

In the walnut tree the leaves which are distributed on the shoots of this year are further apart from each other and more numerous in proportion as the branch from which this shoot springs is a young one. And they are inserted more closely and less in number when the shoot that bears them springs from an old branch. Its fruits are borne at the ends of the shoots. And its largest boughs are the lowest on the boughs they spring from. And this arises from the weight of its sap which is more apt to descend than to rise, and consequently the branches which spring from them and rise towards the sky are small and slender [20]; and when the shoot turns towards the sky its leaves spread out from it [at an angle] with an equal distribution of their tips; and if the shoot turns to the horizon the leaves lie flat; and this arises from the fact that leaves without exception, turn their underside to the earth [29].

The shoots are smaller in proportion as they spring nearer to the base of the bough they spring from.

[Footnote: See the two sketches on Pl XXVII, No. 4. The second refers to the passage lines 20-30.]

415.

#### OF THE INSERTION OF THE LEAVES ON THE BRANCHES.

The thickness of a branch never diminishes within the space between one leaf and the next excepting by so much as the thickness of the bud which is above the leaf and this thickness is taken off from the branch above [the node] as far as the next leaf.

Nature has so placed the leaves of the latest shoots of many plants that the sixth leaf is always above the first, and so on in succession, if the rule is not [accidentally] interfered with; and this occurs for two useful ends in the plant: First that as the shoot and the fruit of the following year spring from the bud or eye which lies above and in close contact with the insertion of the leaf [in the axil], the water which falls upon the shoot can run down to nourish the bud, by the drop being caught in the hollow [axil] at the insertion of the leaf. And the second advantage is, that as these shoots develop in the following year one will not cover the next below, since the 5 come forth on five different sides; and the sixth which is above the first is at some distance.

416.

#### OF THE RAMIFICATIONS OF TREES AND THEIR FOLIAGE.

The ramifications of any tree, such as the elm, are wide and slender after the manner of a hand with spread fingers, foreshortened. And these are seen in the distribution [thus]: the lower portions are seen from above; and those that are above are seen from below; and those in the middle, some from below and some from above. The upper part is the extreme [top] of this ramification and the middle portion is more foreshortened than any other of those which are turned with their tips towards you. And of those parts of the middle of the height of the tree, the longest will be towards the top of the tree and will produce a ramification like the foliage of the common willow, which grows on the banks of rivers.

Other ramifications are spherical, as those of such trees as put forth their shoots and leaves in the order of the sixth being placed above the first. Others are thin and light like the willow and others.

417.

You will see in the lower branches of the elder, which puts forth leaves two and two placed crosswise [at right angles] one above another, that if the stem rises straight up towards the sky this order never fails; and its largest leaves are on the thickest part of the stem and the smallest on the slenderest part, that is towards the top. But, to return to the lower branches, I say that the leaves on these are placed on them crosswise like [those on] the upper

branches; and as, by the law of all leaves, they are compelled to turn their upper surface towards the sky to catch the dew at night, it is necessary that those so placed should twist round and no longer form a cross.

[Footnote: See Pl. XXVII, No. 5.]

418.

A leaf always turns its upper side towards the sky so that it may the better receive, on all its surface, the dew which drops gently from the atmosphere. And these leaves are so distributed on the plant as that one shall cover the other as little as possible, but shall lie alternately one above another as may be seen in the ivy which covers the walls. And this alternation serves two ends; that is, to leave intervals by which the air and sun may penetrate between them. The 2nd reason is that the drops which fall from the first leaf may fall onto the fourth or--in other trees--onto the sixth.

419.

Every shoot and every fruit is produced above the insertion [in the axil] of its leaf which serves it as a mother, giving it water from the rain and moisture from the dew which falls at night from above, and often it protects them against the too great heat of the rays of the sun.

LIGHT ON BRANCHES AND LEAVES (420--422).

420.

That part of the body will be most illuminated which is hit by the luminous ray coming between right angles.

[Footnote: See Pl. XXVIII, No. 1.]

421.

Young plants have more transparent leaves and a more lustrous bark than old ones; and particularly the walnut is lighter coloured in May than in September.

422.

OF THE ACCIDENTS OF COLOURING IN TREES.

The accidents of colour in the foliage of trees are 4. That is: shadow, light, lustre [reflected light] and transparency.

OF THE VISIBILITY OF THESE ACCIDENTS.

These accidents of colour in the foliage of trees become confused at

a great distance and that which has most breadth [whether light or shade, &c.] will be most conspicuous.

The proportions of light and shade in a leaf (423-426).

423.

#### OF THE SHADOWS OF A LEAF.

Sometimes a leaf has three accidents [of light] that is: shade, lustre [reflected light] and transparency [transmitted light]. Thus, if the light were at n as regards the leaf s, and the eye at m, it would see a in full light, b in shadow and c transparent.

424.

A leaf with a concave surface seen from the under side and up-side-down will sometimes show itself as half in shade, and half transparent. Thus, if o p is the leaf and the light m and the eye n, this will see o in shadow because the light does not fall upon it between equal angles, neither on the upper nor the under side, and p is lighted on the upper side and the light is transmitted to its under side. [Footnote: See Pl. XXVIII, No. 2, the upper sketch on the page. In the original they are drawn in red chalk.]

425.

Although those leaves which have a polished surface are to a great extent of the same colour on the right side and on the reverse, it may happen that the side which is turned towards the atmosphere will have something of the colour of the atmosphere; and it will seem to have more of this colour of the atmosphere in proportion as the eye is nearer to it and sees it more foreshortened. And, without exception the shadows show as darker on the upper side than on the lower, from the contrast offered by the high lights which limit the shadows.

The under side of the leaf, although its colour may be in itself the same as that of the upper side, shows a still finer colour--a colour that is green verging on yellow--and this happens when the leaf is placed between

426.

the eye and the light which falls upon it from the opposite side.

And its shadows are in the same positions as those were of the opposite side. Therefore, O Painter! when you do trees close at hand, remember that if the eye is almost under the tree you will see its leaves [some] on the upper and [some] on the under side, and the upper side will be bluer in proportion as they are seen more

foreshortened, and the same leaf sometimes shows part of the right side and part of the under side, whence you must make it of two colours.

Of the transparency of leaves (427-429).

427.

The shadows in transparent leaves seen from the under side are the same shadows as there are on the right side of this leaf, they will show through to the underside together with lights, but the lustre [reflected light] can never show through.

428.

When one green has another [green] behind it, the lustre on the leaves and their transparent [lights] show more strongly than in those which are [seen] against the brightness of the atmosphere.

And if the sun illuminates the leaves without their coming between it and the eye and without the eye facing the sun, then the reflected lights and the transparent lights are very strong.

It is very effective to show some branches which are low down and dark and so set off the illuminated greens which are at some distance from the dark greens seen below. That part is darkest which is nearest to the eye or which is farthest from the luminous atmosphere.

429.

Never paint leaves transparent to the sun, because they are confused; and this is because on the transparency of one leaf will be seen the shadow of another leaf which is above it. This shadow has a distinct outline and a certain depth of shade and sometimes is [as much as] half or a third of the leaf which is shaded; and consequently such an arrangement is very confused and the imitation of it should be avoided.

The light shines least through a leaf when it falls upon it at an acute angle.

The gradations of shade and colour in leaves (430-434).

430.

The shadows of plants are never black, for where the atmosphere penetrates there can never be utter darkness.

431.

If the light comes from   m   and the eye is at   n   the eye will see the colour of the leaves   a   b   all affected by the colour of   m

--that is of the atmosphere; and \_b c\_ will be seen from the under side as transparent, with a beautiful green colour verging on yellow.

If \_m\_ is the luminous body lighting up the leaf \_s\_ all the eyes that see the under side of this leaf will see it of a beautiful light green, being transparent.

In very many cases the positions of the leaves will be without shadow [or in full light], and their under side will be transparent and the right side lustrous [reflecting light].

432.

The willow and other similar trees, which have their boughs lopped every 3 or 4 years, put forth very straight branches, and their shadow is about the middle where these boughs spring; and towards the extreme ends they cast but little shade from having small leaves and few and slender branches. Hence the boughs which rise towards the sky will have but little shade and little relief; and the branches which are at an angle from the horizon, downwards, spring from the dark part of the shadow and grow thinner by degrees up to their ends, and these will be in strong relief, being in gradations of light against a background of shadow.

That tree will have the least shadow which has the fewest branches and few leaves.

433.

#### OF DARK LEAVES IN FRONT OF TRANSPARENT ONES.

When the leaves are interposed between the light and the eye, then that which is nearest to the eye will be the darkest, and the most distant will be the lightest, not being seen against the atmosphere; and this is seen in the leaves which are away from the centre of the tree, that is towards the light.

[Footnote: See Pl. XXVIII, No. 2, the lower sketch.]

434.

#### OF THE LIGHTS ON DARK LEAVES.

The lights on such leaves which are darkest, will be most near to the colour of the atmosphere that is reflected in them. And the cause of this is that the light on the illuminated portion mingles with the dark hue to compose a blue colour; and this light is produced by the blueness of the atmosphere which is reflected in the smooth surface of these leaves and adds to the blue hue which this light usually produces when it falls on dark objects.

#### OF THE LIGHTS ON LEAVES OF A YELLOWISH GREEN.

But leaves of a green verging on yellow when they reflect the atmosphere do not produce a reflection verging on blue, inasmuch as every thing which appears in a mirror takes some colour from that mirror, hence the blue of the atmosphere being reflected in the yellow of the leaf appears green, because blue and yellow mixed together make a very fine green colour, therefore the lustre of light leaves verging on yellow will be greenish yellow.

A classification of trees according to their colours.

435.

The trees in a landscape are of various kinds of green, inasmuch as some verge towards blackness, as firs, pines, cypresses, laurels, box and the like. Some tend to yellow such as walnuts, and pears, vines and verdure. Some are both yellowish and dark as chesnuts, holm-oak. Some turn red in autumn as the service-tree, pomegranate, vine, and cherry; and some are whitish as the willow, olive, reeds and the like. Trees are of various forms ...

The proportions of light and shade in trees (436-440).

436.

OF A GENERALLY DISTRIBUTED LIGHT AS LIGHTING UP TREES.

That part of the trees will be seen to lie in the least dark shadow which is farthest from the earth.

To prove it let  $a p$  be the tree,  $n b c$  the illuminated hemisphere [the sky], the under portion of the tree faces the earth  $p c$ , that is on the side  $o$ , and it faces a small part of the hemisphere at  $c d$ . But the highest part of the convexity  $a$  faces the greatest part of the hemisphere, that is  $b c$ . For this reason--and because it does not face the darkness of the earth--it is in fuller light. But if the tree has dense foliage, as the laurel, arbutus, box or holm oak, it will be different; because, although  $a$  does not face the earth, it faces the dark [green] of the leaves cut up by many shadows, and this darkness is reflected onto the under sides of the leaves immediately above. Thus these trees have their darkest shadows nearest to the middle of the tree.

437.

OF THE SHADOWS OF VERDURE.

The shadows of verdure are always somewhat blue, and so is every shadow of every object; and they assume this hue more in proportion as they are remote from the eye, and less in proportion as they are nearer. The leaves which reflect the blue of the atmosphere always present themselves to the eye edgewise.



#### OF THE ILLUMINATED PART OF VERDURE AND OF MOUNTAINS.

The illuminated portion, at a great distance, will appear most nearly of its natural colour where the strongest light falls upon it.

438.

#### OF TREES THAT ARE LIGHTED BY THE SUN AND BY THE ATMOSPHERE.

In trees that are illuminated [both] by the sun and the atmosphere and that have leaves of a dark colour, one side will be illuminated by the atmosphere [only] and in consequence of this light will tend to blueness, while on the other side they will be illuminated by the atmosphere and the sun; and the side which the eye sees illuminated by the sun will reflect light.

439.

#### OF DEPICTING A FOREST SCENE.

The trees and plants which are most thickly branched with slender branches ought to have less dark shadow than those trees and plants which, having broader leaves, will cast more shadow.

440.

#### ON PAINTING.

In the position of the eye which sees that portion of a tree illuminated which turns towards the light, one tree will never be seen to be illuminated equally with the other. To prove this, let the eye be *c* which sees the two trees *b* *d* which are illuminated by the sun *a*; I say that this eye *c* will not see the light in the same proportion to the shade, in one tree as in the other. Because, the tree which is nearest to the sun will display so much the stronger shadow than the more distant one, in proportion as one tree is nearer to the rays of the sun that converge to the eye than the other; &c.

You see that the eye *c* sees nothing of the tree *d* but shadow, while the same eye *c* sees the tree *b* half in light and half in shade.

When a tree is seen from below, the eye sees the top of it as placed within the circle made by its boughs[23].

Remember, O Painter! that the variety of depth of shade in any one particular species of tree is in proportion to the rarity or density of their branches.

[Footnote: The two lower sketches on the left of PI XXVIII, No. 3, refer to lines 21-23. The upper sketch has apparently been effaced

by Leonardo himself.]

The distribution of light and shade with reference to the position of the spectator (441-443).

441.

The shadows of trees placed in a landscape do not display themselves in the same position in the trees on the right hand and those on the left; still more so if the sun is to the right or left. As is proved by the 4th which says: Opaque bodies placed between the light and the eye display themselves entirely in shadow; and by the 5th: The eye when placed between the opaque body and the light sees the opaque body entirely illuminated. And by the 6th: When the eye and the opaque body are placed between darkness and light, it will be seen half in shadow and half in light.

[Footnote: See the figure on the right hand side of Pl. XXVIII, No. 3. The first five lines of the text are written below the diagram and above it are the last eight lines of the text, given as No. 461.]

442.

OF THE HERBS OF THE FIELD.

Of the plants which take a shadow from the plants which spring among them, those which are on this side [in front] of the shadow have the stems lighted up on a background of shadow, and the plants on which the shadows fall have their stems dark on a light background; that is on the background beyond the shadow.

OF TREES WHICH ARE BETWEEN THE EYE AND THE LIGHT.

Of the trees which are between the eye and the light the part in front will be light; but this light will be broken by the ramifications of transparent leaves--being seen from the under side--and lustrous leaves--being seen from the upper side; and the background below and behind will be dark green, being in shadow from the front portion of the said tree. This occurs in trees placed above the eye.

443.

FROM WHENCE TO DEPICT A LANDSCAPE

Landscapes should be represented so that the trees may be half in light and half in shadow; but it is better to do them when the sun is covered with clouds, for then the trees are lighted by the general light of the sky, and the general darkness of the earth. And then they are darkest in certain parts in proportion as those parts are nearest to the middle of the tree and to the earth.

The effects of morning light (444-448).

444.

#### OF TREES TO THE SOUTH.

When the sun is in the east the trees to the South and to the North have almost as much light as shadow. But a greater share of light in proportion as they lie to the West and a greater share of shadow in proportion as they lie to the East.

#### OF MEADOWS.

If the sun is in the East the verdure of the meadows and of other small plants is of a most beautiful green from being transparent to the sun; this does not occur in the meadows to the West, and in those to the South and North the grass is of a moderately brilliant green.

445.

#### OF THE 4 POINTS OF THE COMPASS [IN LANDSCAPES].

When the sun is in the East all the portions of plants lighted by it are of a most lively verdure, and this happens because the leaves lighted by the sun within the half of the horizon that is the Eastern half, are transparent; and within the Western semicircle the verdure is of a dull hue and the moist air is turbid and of the colour of grey ashes, not being transparent like that in the East, which is quite clear and all the more so in proportion as it is moister.

The shadows of the trees to the East cover a large portion of them and are darker in proportion as the foliage of the trees is thicker.

446.

#### OF TREES IN THE EAST.

When the sun is in the East the trees seen towards the East will have the light which surrounds them all round their shadows, excepting on the side towards the earth; unless the tree has been pruned [below] in the past year. And the trees to the South and North will be half in shade and half in light, and more or less in shade or in light in proportion as they are more or less to the East or to the West.

The [position of] the eye above or below varies the shadows and lights in trees, inasmuch as the eye placed above sees the tree with the little shadow, and the eye placed below with a great deal of shadow.

The colour of the green in plants varies as much as their species.

447.

#### OF THE SHADOWS IN TREES.

The sun being in the East [to the right], the trees to the West [or left] of the eye will show in small relief and almost imperceptible gradations, because the atmosphere which lies between the eye and those trees is very dense [Footnote 7: *\_per la 7a di questo\_*. This possibly referred to something written on the seventh page of this note book marked *\_G\_*. Unfortunately it has been cut out and lost.], see the 7th of this--and they have no shade; for though a shadow exists in every detail of the ramification, it results that the images of the shade and light that reach the eye are confused and mingled together and cannot be perceived on account of their minuteness. And the principal lights are in the middle of the trees, and the shadows towards the edges; and their separation is shown by the shadows of the intervals between the trees; but when the forests are thick with trees the thin edges are but little seen.

448.

#### OF TREES TO THE EAST.

When the sun is in the East the trees are darker towards the middle while their edges are light.

The effects of midday light.

449.

#### OBJECTS IN HIGH LIGHT SHOW BUT LITTLE, BUT BETWEEN LIGHT AND SHADOW THEY STAND OUT WELL.

To represent a landscape choose that the sun shall be at noon and look towards the West or East and then draw. And if you turn towards the North, every object placed on that side will have no shadow, particularly those which are nearest to the [direction of the] shadow of your head. And if you turn towards the South every object on that side will be wholly in shadow. All the trees which are towards the sun and have the atmosphere for their background are dark, and the other trees which lie against that darkness will be black [very dark] in the middle and lighter towards the edges.

The appearance of trees in the distance (450. 451).

450.

#### OF THE SPACES [SHOWING THE SKY] IN TREES THEMSELVES.

The spaces between the parts in the mass of trees, and the spaces between the trees in the air, are, at great distances, invisible to the eye; for, where it is an effort [even] to see the whole it is

most difficult to discern the parts.--But a confused mixture is the result, partaking chiefly of the [hue] which predominates. The spaces between the leaves consist of particles of illuminated air which are very much smaller than the tree and are lost sight of sooner than the tree; but it does not therefore follow that they are not there. Hence, necessarily, a compounded [effect] is produced of the sky and of the shadows of the tree in shade, which both together strike the eye which sees them.

#### OF TREES WHICH CONCEAL THESE SPACES IN ONE ANOTHER.

That part of a tree will show the fewest spaces, behind which a large number of trees are standing between the tree and the air [sky]; thus in the tree a the spaces are not concealed nor in b, as there is no tree behind. But in c only half shows the spaces filled up by the tree d, and part of the tree d is filled up by the tree e and a little farther on all the spaces in the mass of the trees are lost, and only that at the side remains.

451.

#### OF TREES.

What outlines are seen in trees at a distance against the sky which serves as their background?

The outlines of the ramification of trees, where they lie against the illuminated sky, display a form which more nearly approaches the spherical on proportion as they are remote, and the nearer they are the less they appear in this spherical form; as in the first tree a which, being near to the eye, displays the true form of its ramification; but this shows less in b and is altogether lost in c, where not merely the branches of the tree cannot be seen but the whole tree is distinguished with difficulty. Every object in shadow, of whatever form it may be, at a great distance appears to be spherical. And this occurs because, if it is a square body, at a very short distance it loses its angles, and a little farther off it loses still more of its smaller sides which remain. And thus before the whole is lost [to sight] the parts are lost, being smaller than the whole; as a man, who in such a distant position loses his legs, arms and head before [the mass of] his body, then the outlines of length are lost before those of breadth, and where they have become equal it would be a square if the angles remained; but as they are lost it is round.

[Footnote: The sketch No. 4, Pl. XXVIII, belongs to this passage.]

The cast shadow of trees (452. 453).

452.

The image of the shadow of any object of uniform breadth can never be [exactly] the same as that of the body which casts it.

[Footnote: See Pl. XXVIII, No. 5.]

Light and shade on groups of trees (453-457).

453.

All trees seen against the sun are dark towards the middle and this shadow will be of the shape of the tree when apart from others.

The shadows cast by trees on which the sun shines are as dark as those of the middle of the tree.

The shadow cast by a tree is never less than the mass of the tree but becomes taller in proportion as the spot on which it falls, slopes towards the centre of the world.

The shadow will be densest in the middle of the tree when the tree has the fewest branches.

[Footnote: The three diagrams which accompany this text are placed, in the original, before lines 7-11. At the spots marked \_B\_ Leonardo wrote \_Albero\_ (tree). At \_A\_ is the word \_Sole\_ (sun), at \_C\_ Monte\_ (mountain) at \_D\_ piano\_ (plain) and at \_E\_ cima\_ (summit).]

Every branch participates of the central shadow of every other branch and consequently [of that] of the whole tree.

The form of any shadow from a branch or tree is circumscribed by the light which falls from the side whence the light comes; and this illumination gives the shape of the shadow, and this may be of the distance of a mile from the side where the sun is.

If it happens that a cloud should anywhere overshadow some part of a hill the [shadow of the] trees there will change less than in the plains; for these trees on the hills have their branches thicker, because they grow less high each year than in the plains. Therefore as these branches are dark by nature and being so full of shade, the shadow of the clouds cannot darken them any more; but the open spaces between the trees, which have no strong shadow change very much in tone and particularly those which vary from green; that is ploughed lands or fallen mountains or barren lands or rocks. Where the trees are against the atmosphere they appear all the same colour--if indeed they are not very close together or very thickly covered with leaves like the fir and similar trees. When you see the trees from the side from which the sun lights them, you will see them almost all of the same tone, and the shadows in them will be hidden by the leaves in the light, which come between your eye and those shadows.

TREES AT A SHORT DISTANCE.

[Footnote 29: The heading \_alberi vicini\_ (trees at a short

distance) is in the original manuscript written in the margin.] When the trees are situated between the sun and the eye, beyond the shadow which spreads from their centre, the green of their leaves will be seen transparent; but this transparency will be broken in many places by the leaves and boughs in shadow which will come between you and them, or, in their upper portions, they will be accompanied by many lights reflected from the leaves.

454.

The trees of the landscape stand out but little from each other; because their illuminated portions come against the illuminated portions of those beyond and differ little from them in light and shade.

455.

Of trees seen from below and against the light, one beyond the other and near together. The topmost part of the first will be in great part transparent and light, and will stand out against the dark portion of the second tree. And thus it will be with all in succession that are placed under the same conditions.

Let  $s$  be the light, and  $r$  the eye,  $cdn$  the first tree,  $abc$  the second. Then I say that  $r$ , the eye, will see the portion  $cf$  in great part transparent and lighted by the light  $s$  which falls upon it from the opposite side, and it will see it, on a dark ground  $bc$  because that is the dark part and shadow of the tree  $abc$ .

But if the eye is placed at  $t$  it will see  $op$  dark on the light background  $ng$ .

Of the transparent and shadowy parts of trees, that which is nearest to you is the darkest.

456.

That part of a tree which has shadow for background, is all of one tone, and wherever the trees or branches are thickest they will be darkest, because there are no little intervals of air. But where the boughs lie against a background of other boughs, the brighter parts are seen lightest and the leaves lustrous from the sunlight falling on them.

457.

In the composition of leafy trees be careful not to repeat too often the same colour of one tree against the same colour of another [behind it]; but vary it with a lighter, or a darker, or a stronger green.

On the treatment of light for landscapes (458-464).

458.

The landscape has a finer azure [tone] when, in fine weather the sun is at noon than at any other time of the day, because the air is purified of moisture; and looking at it under that aspect you will see the trees of a beautiful green at the outside and the shadows dark towards the middle; and in the remoter distance the atmosphere which comes between you and them looks more beautiful when there is something dark beyond. And still the azure is most beautiful. The objects seen from the side on which the sun shines will not show you their shadows. But, if you are lower than the sun, you can see what is not seen by the sun and that will be all in shade. The leaves of the trees, which come between you and the sun are of two principal colours which are a splendid lustre of green, and the reflection of the atmosphere which lights up the objects which cannot be seen by the sun, and the shaded portions which only face the earth, and the darkest which are surrounded by something that is not dark. The trees in the landscape which are between you and the sun are far more beautiful than those you see when you are between the sun and them; and this is so because those which face the sun show their leaves as transparent towards the ends of their branches, and those that are not transparent--that is at the ends--reflect the light; and the shadows are dark because they are not concealed by any thing.

The trees, when you place yourself between them and the sun, will only display to you their light and natural colour, which, in itself, is not very strong, and besides this some reflected lights which, being against a background which does not differ very much from themselves in tone, are not conspicuous; and if you are lower down than they are situated, they may also show those portions on which the light of the sun does not fall and these will be dark.

In the Wind.

But, if you are on the side whence the wind blows, you will see the trees look very much lighter than on the other sides, and this happens because the wind turns up the under side of the leaves, which, in all trees, is much whiter than the upper sides; and, more especially, will they be very light indeed if the wind blows from the quarter where the sun is, and if you have your back turned to it.

[Footnote: At \_S\_, in the original is the word \_Sole\_ (sun) and at \_N parte di nuvolo\_ (the side of the clouds).]

459.

When the sun is covered by clouds, objects are less conspicuous, because there is little difference between the light and shade of the trees and of the buildings being illuminated by the brightness of the atmosphere which surrounds the objects in such a way that the



shadows are few, and these few fade away so that their outline is lost in haze.

460.

#### OF TREES AND LIGHTS ON THEM.

The best method of practice in representing country scenes, or I should say landscapes with their trees, is to choose them so that the sun is covered with clouds so that the landscape receives an universal light and not the direct light of the sun, which makes the shadows sharp and too strongly different from the lights.

461.

#### OF PAINTING.

In landscapes which represent [a scene in] winter. The mountains should not be shown blue, as we see in the mountains in the summer. And this is proved [Footnote 5. 6.: *Per la\_ 4\_a di questo*]. It is impossible to ascertain what this quotation refers to. *Questo* certainly does not mean the MS. in hand, nor any other now known to us. The same remark applies to the phrase in line 15: *per la\_ 2\_a di questo*] in the 4th of this which says: Among mountains seen from a great distance those will look of the bluest colour which are in themselves the darkest; hence, when the trees are stripped of their leaves, they will show a bluer tinge which will be in itself darker; therefore, when the trees have lost their leaves they will look of a gray colour, while, with their leaves, they are green, and in proportion as the green is darker than the grey hue the green will be of a bluer tinge than the gray. Also by the 2nd of this: The shadows of trees covered with leaves are darker than the shadows of those trees which have lost their leaves in proportion as the trees covered with leaves are denser than those without leaves--and thus my meaning is proved.

The definition of the blue colour of the atmosphere explains why the landscape is bluer in the summer than in the winter.

462.

#### OF PAINTING IN A LANDSCAPE.

If the slope of a hill comes between the eye and the horizon, sloping towards the eye, while the eye is opposite the middle of the height of this slope, then that hill will increase in darkness throughout its length. This is proved by the 7th of this which says that a tree looks darkest when it is seen from below; the proposition is verified, since this hill will, on its upper half show all its trees as much from the side which is lighted by the light of the sky, as from that which is in shade from the darkness of the earth; whence it must result that these trees are of a medium darkness. And from this [middle] spot towards the base of the hill,

these trees will be lighter by degrees by the converse of the 7th and by the said 7th: For trees so placed, the nearer they are to the summit of the hill the darker they necessarily become. But this darkness is not in proportion to the distance, by the 8th of this which says: That object shows darkest which is [seen] in the clearest atmosphere; and by the 10th: That shows darkest which stands out against a lighter background.

[Footnote: The quotation in this passage again cannot be verified.]

463.

#### OF LANDSCAPES.

The colours of the shadows in mountains at a great distance take a most lovely blue, much purer than their illuminated portions. And from this it follows that when the rock of a mountain is reddish the illuminated portions are violet (?) and the more they are lighted the more they display their proper colour.

464.

A place is most luminous when it is most remote from mountains.

On the treatment of light for views of towns (465-469).

465.

#### OF LIGHT AND SHADOW IN A TOWN.

When the sun is in the East and the eye is above the centre of a town, the eye will see the Southern part of the town with its roofs half in shade and half in light, and the same towards the North; the Eastern side will be all in shadow and the Western will be all in light.

466.

Of the houses of a town, in which the divisions between the houses may be distinguished by the light which fall on the mist at the bottom. If the eye is above the houses the light seen in the space that is between one house and the next sinks by degrees into thicker mist; and yet, being less transparent, it appears whiter; and if the houses are some higher than the others, since the true [colour] is always more discernible through the thinner atmosphere, the houses will look darker in proportion as they are higher up. Let  $n$  o p q represent the various density of the atmosphere thick with moisture,  $a$  being the eye, the house  $b c$  will look lightest at the bottom, because it is in a thicker atmosphere; the lines  $c d f$  will appear equally light, for although  $f$  is more distant than  $c$ , it is raised into a thinner atmosphere, if the houses  $b e$  are of the same height, because they cross a brightness which is varied by mist, but this is only because the line of the eye which starts from

above ends by piercing a lower and denser atmosphere at \_d\_ than at \_b\_. Thus the line a \_f\_ is lower at \_f\_ than at \_c\_; and the house \_f\_ will be seen darker at \_e\_ from the line \_e k\_ as far as \_m\_, than the tops of the houses standing in front of it.

467.

#### OF TOWNS OR OTHER BUILDINGS SEEN IN THE EVENING OR THE MORNING THROUGH THE MIST.

Of buildings seen at a great distance in the evening or the morning, as in mist or dense atmosphere, only those portions are seen in brightness which are lighted up by the sun which is near the horizon; and those portions which are not lighted up by the sun remain almost of the same colour and medium tone as the mist.

#### WHY OBJECTS WHICH ARE HIGH UP AND AT A DISTANCE ARE DARKER THAN THE LOWER ONES, EVEN IF THE MIST IS UNIFORMLY DENSE.

Of objects standing in a mist or other dense atmosphere, whether from vapour or smoke or distance, those will be most visible which are the highest. And among objects of equal height that will be the darkest [strongest] which has for background the deepest mist. Thus the eye \_h\_ looking at \_a b c\_, towers of equal height, one with another, sees \_c\_ the top of the first tower at \_r\_, at two degrees of depth in the mist; and sees the height of the middle tower \_b\_ through one single degree of mist. Therefore the top of the tower \_c\_ appears stronger than the top of the tower \_b\_, &c.

468.

#### OF THE SMOKE OF A TOWN.

Smoke is seen better and more distinctly on the Eastern side than on the Western when the sun is in the East; and this arises from two causes; the first is that the sun, with its rays, shines through the particles of the smoke and lights them up and makes them visible. The second is that the roofs of the houses seen in the East at this time are in shadow, because their obliquity does not allow of their being illuminated by the sun. And the same thing occurs with dust; and both one and the other look the lighter in proportion as they are denser, and they are densest towards the middle.

469.

#### OF SMOKE AND DUST.

If the sun is in the East the smoke of cities will not be visible in the West, because on that side it is not seen penetrated by the solar rays, nor on a dark background; since the roofs of the houses turn the same side to the eye as they turn towards the sun, and on this light background the smoke is not very visible.

But dust, under the same aspect, will look darker than smoke being of denser material than smoke which is moist.

The effect of wind on trees (470-473).

470.

#### OF REPRESENTING WIND.

In representing wind, besides the bending of the boughs and the reversing of their leaves towards the quarter whence the wind comes, you should also represent them amid clouds of fine dust mingled with the troubled air.

471.

Describe landscapes with the wind, and the water, and the setting and rising of the sun.

#### THE WIND.

All the leaves which hung towards the earth by the bending of the shoots with their branches, are turned up side down by the gusts of wind, and here their perspective is reversed; for, if the tree is between you and the quarter of the wind, the leaves which are towards you remain in their natural aspect, while those on the opposite side which ought to have their points in a contrary direction have, by being turned over, their points turned towards you.

472.

Trees struck by the force of the wind bend to the side towards which the wind is blowing; and the wind being past they bend in the contrary direction, that is in reverse motion.

473.

That portion of a tree which is farthest from the force which strikes it is the most injured by the blow because it bears most strain; thus nature has foreseen this case by thickening them in that part where they can be most hurt; and most in such trees as grow to great heights, as pines and the like. [Footnote: Compare the sketch drawn with a pen and washed with Indian ink on Pl. XL, No. 1. In the Vatican copy we find, under a section entitled '\_del fumo\_', the following remark: \_Era sotto di questo capitolo un rompimento di montagna, per dentro delle quali rotture scherzaua fiamme di fuoco, disegnate di penna et ombrate d'acquarella, da uedere cosa mirabile et uiua (Ed. MANZI, p. 235. Ed. LUDWIG, Vol. I, 460). This appears to refer to the left hand portion of the drawing here given from the Windsor collection, and from this it must be inferred, that the leaf as it now exists in the library of the Queen of England, was already separated from the original MS. at the time when the Vatican copy

was made.]

Light and shade on clouds (474-477).

474.

Describe how the clouds are formed and how they dissolve, and what cause raises vapour.

475.

The shadows in clouds are lighter in proportion as they are nearer to the horizon.

[Footnote: The drawing belonging to this was in black chalk and is totally effaced.]

476.

When clouds come between the sun and the eye all the upper edges of their round forms are light, and towards the middle they are dark, and this happens because towards the top these edges have the sun above them while you are below them; and the same thing happens with the position of the branches of trees; and again the clouds, like the trees, being somewhat transparent, are lighted up in part, and at the edges they show thinner.

But, when the eye is between the cloud and the sun, the cloud has the contrary effect to the former, for the edges of its mass are dark and it is light towards the middle; and this happens because you see the same side as faces the sun, and because the edges have some transparency and reveal to the eye that portion which is hidden beyond them, and which, as it does not catch the sunlight like that portion turned towards it, is necessarily somewhat darker. Again, it may be that you see the details of these rounded masses from the lower side, while the sun shines on the upper side and as they are not so situated as to reflect the light of the sun, as in the first instance they remain dark.

The black clouds which are often seen higher up than those which are illuminated by the sun are shaded by other clouds, lying between them and the sun.

Again, the rounded forms of the clouds that face the sun, show their edges dark because they lie against the light background; and to see that this is true, you may look at the top of any cloud that is wholly light because it lies against the blue of the atmosphere, which is darker than the cloud.

[Footnote: A drawing in red chalk from the Windsor collection (see Pl. XXIX), representing a landscape with storm-clouds, may serve to illustrate this section as well as the following one.]

477.

OF CLOUDS, SMOKE AND DUST AND THE FLAMES OF A FURNACE OR OF A BURNING KILN.

The clouds do not show their rounded forms excepting on the sides which face the sun; on the others the roundness is imperceptible because they are in the shade. [Footnote: The text of this chapter is given in facsimile on Pls. XXXVI and XXXVII. The two halves of the leaf form but one in the original. On the margin close to lines 4 and 5 is the note: *\_rossore d'aria inverso l'orizzonte\_*--(of the redness of the atmosphere near the horizon). The sketches on the lower portion of the page will be spoken of in No. 668.]

If the sun is in the East and the clouds in the West, the eye placed between the sun and the clouds sees the edges of the rounded forms composing these clouds as dark, and the portions which are surrounded by this dark [edge] are light. And this occurs because the edges of the rounded forms of these clouds are turned towards the upper or lateral sky, which is reflected in them.

Both the cloud and the tree display no roundness at all on their shaded side.

On images reflected in water.

478.

Painters often deceive themselves, by representing water in which they make the water reflect the objects seen by the man. But the water reflects the object from one side and the man sees it from the other; and it often happens that the painter sees an object from below, and thus one and the same object is seen from hind part before and upside down, because the water shows the image of the object in one way, and the eye sees it in another.

Of rainbows and rain (479. 480).

479.

The colours in the middle of the rainbow mingle together.

The bow in itself is not in the rain nor in the eye that sees it; though it is generated by the rain, the sun, and the eye. The rainbow is always seen by the eye that is between the rain and the body of the sun; hence if the sun is in the East and the rain is in the West it will appear on the rain in the West.

480.

When the air is condensed into rain it would produce a vacuum if the rest of the air did not prevent this by filling its place, as it does with a violent rush; and this is the wind which rises in the

summer time, accompanied by heavy rain.

Of flower seeds.

481.

All the flowers which turn towards the sun perfect their seeds; but not the others; that is to say those which get only the reflection of the sun.

IX.

\_The Practice of Painting.\_

\_It is hardly necessary to offer any excuses for the division carried out in the arrangement of the text into practical suggestions and theoretical enquiries. It was evidently intended by Leonardo himself as we conclude from incidental remarks in the MSS. (for instance No\_ 110\_). The fact that this arrangement was never carried out either in the old MS. copies or in any edition since, is easily accounted for by the general disorder which results from the provisional distribution of the various chapters in the old copies. We have every reason to believe that the earliest copyists, in distributing the materials collected by them, did not in the least consider the order in which the original MS. lay before them.\_

\_It is evident that almost all the chapters which refer to the calling and life of the painter--and which are here brought together in the first section (Nos. 482-508)--may be referred to two distinct periods in Leonardo's life; most of them can be dated as belonging to the year\_ 1492 \_or to\_ 1515. \_At about this later time Leonardo may have formed the project of completing his Libro della Pittura, after an interval of some years, as it would seem, during which his interest in the subject had fallen somewhat into the background.\_

\_In the second section, which treats first of the artist's studio, the construction of a suitable window forms the object of careful investigations; the special importance attached to this by Leonardo is sufficiently obvious. His theory of the incidence of light which was fully discussed in a former part of this work, was to him by no means of mere abstract value, but, being deduced, as he says, from experience (or experiment) was required to prove its utility in practice. Connected with this we find suggestions for the choice of a light with practical hints as to sketching a picture and some other precepts of a practical character which must come under consideration in the course of completing the painting. In all this I have followed the same principle of arrangement in the text as was carried out in the Theory of Painting, thus the suggestions for the Perspective of a picture, (Nos. 536-569\_), are followed by the theory of light and shade for the practical method of optics (Nos. 548--566\_) and this by the practical precepts or the treatment of aerial perspective (\_567--570\_). \_

\_In the passage on Portrait and Figure Painting the principles of painting as applied to a bust and head are separated and placed first, since the advice to figure painters must have some connection with the principles of the treatment of composition by which they are followed.\_

\_But this arrangement of the text made it seem advisable not to pick out the practical precepts as to the representation of trees and landscape from the close connection in which they were originally placed--unlike the rest of the practical precepts--with the theory of this branch of the subject. They must therefore be sought under the section entitled Botany for Painters.\_

\_As a supplement to the \_ Libro di Pittura \_I have here added those texts which treat of the Painter's materials,--as chalk, drawing paper, colours and their preparation, of the management of oils and varnishes; in the appendix are some notes on chemical substances. Possibly some of these, if not all, may have stood in connection with the preparation of colours. It is in the very nature of things that Leonardo's incidental indications as to colours and the like should be now-a-days extremely obscure and could only be explained by professional experts--by them even in but few instances. It might therefore have seemed advisable to reproduce exactly the original text without offering any translation. The rendering here given is merely an attempt to suggest what Leonardo's meaning may have been.\_

\_LOMAZZO tells us in his \_ Trattato dell'arte della Pittura, Scultura ed Architettura (Milano 1584, libro II, Cap. XIV): "Va scorrendo ed argomentando Leonardo Vinci in un suo libro letto da me (?) questi anni passati, ch'egli scrisse di mano stanca ai prieghi di LUDOVICO SFORZA duca di Milano, in determinazione di questa questione, se e piu nobile la pittura o la scultura; dicendo che quanto piu un'arte porta seco fatica di corpo, e sudore, tanto piu e vile, e men pregiata". \_But the existence of any book specially written for Lodovico il Moro on the superiority of Painting over sculpture is perhaps mythical. The various passages in praise of Painting as compared not merely with Sculpture but with Poetry, are scattered among MSS. of very different dates.\_

\_Besides, the way, in which the subject is discussed appears not to support the supposition, that these texts were prepared at a special request of the Duke.\_

I.

MORAL PRECEPTS FOR THE STUDENT OF PAINTING.

How to ascertain the dispositions for an artistic career.

482.

A WARNING CONCERNING YOUTHS WISHING TO BE PAINTERS.



Many are they who have a taste and love for drawing, but no talent; and this will be discernible in boys who are not diligent and never finish their drawings with shading.

The course of instruction for an artist (483-485).

483.

The youth should first learn perspective, then the proportions of objects. Then he may copy from some good master, to accustom himself to fine forms. Then from nature, to confirm by practice the rules he has learnt. Then see for a time the works of various masters. Then get the habit of putting his art into practice and work.

[Footnote: The Vatican copy and numerous abridgements all place this chapter at the beginning of the *\_Trattato\_*, and in consequence DUFRESNE and all subsequent editors have done the same. In the Vatican copy however all the general considerations on the relation of painting to the other arts are placed first, as introductory.]

484.

OF THE ORDER OF LEARNING TO DRAW.

First draw from drawings by good masters done from works of art and from nature, and not from memory; then from plastic work, with the guidance of the drawing done from it; and then from good natural models and this you must put into practice.

485.

PRECEPTS FOR DRAWING.

The artist ought first to exercise his hand by copying drawings from the hand of a good master. And having acquired that practice, under the criticism of his master, he should next practise drawing objects in relief of a good style, following the rules which will presently be given.

The study of the antique (486. 487).

486.

OF DRAWING.

Which is best, to draw from nature or from the antique? and which is more difficult to do outlines or light and shade?

487.

It is better to imitate [copy] the antique than modern work.

[Footnote 486, 487: These are the only two passages in which Leonardo alludes to the importance of antique art in the training of an artist. The question asked in No. 486 remains unanswered by him and it seems to me very doubtful whether the opinion stated in No. 487 is to be regarded as a reply to it. This opinion stands in the MS. in a connection--as will be explained later on--which seems to require us to limit its application to a single special case. At any rate we may suspect that when Leonardo put the question, he felt some hesitation as to the answer. Among his very numerous drawings I have not been able to find a single study from the antique, though a drawing in black chalk, at Windsor, of a man on horseback (Pl. LXXIII) may perhaps be a reminiscence of the statue of Marcus Aurelius at Rome. It seems to me that the drapery in a pen and ink drawing of a bust, also at Windsor, has been borrowed from an antique model (Pl. XXX). G. G. Rossi has, I believe, correctly interpreted Leonardo's feeling towards the antique in the following note on this passage in manzi's edition, p. 501: "Sappiamo dalla storia, che i valorosi artisti Toscani dell'età dell'oro dell'arte studiarono sugli antichi marmi raccolti dal Magnifico LORENZO DE' MEDICI. Pare che il Vinci a tali monumenti non si accostasse. Quest'uomo sempre riconosce per maestra la natura, e questo principio lo stringeva alla sola imitazione di essa"--Compare No. 10, 26--28 footnote.]

The necessity of anatomical knowledge (488. 489).

488.

#### OF PAINTING.

It is indispensable to a Painter who would be thoroughly familiar with the limbs in all the positions and actions of which they are capable, in the nude, to know the anatomy of the sinews, bones, muscles and tendons so that, in their various movements and exertions, he may know which nerve or muscle is the cause of each movement and show those only as prominent and thickened, and not the others all over [the limb], as many do who, to seem great draughtsmen, draw their nude figures looking like wood, devoid of grace; so that you would think you were looking at a sack of walnuts rather than the human form, or a bundle of radishes rather than the muscles of figures.

489.

#### HOW IT IS NECESSARY TO A PAINTER THAT HE SHOULD KNOW THE INTRINSIC FORMS [STRUCTURE] OF MAN.

The painter who is familiar with the nature of the sinews, muscles, and tendons, will know very well, in giving movement to a limb, how many and which sinews cause it; and which muscle, by swelling, causes the contraction of that sinew; and which sinews, expanded into the thinnest cartilage, surround and support the said muscle. Thus he will variously and constantly demonstrate the different

muscles by means of the various attitudes of his figures, and will not do, as many who, in a variety of movements, still display the very same things [modelling] in the arms, back, breast and legs. And these things are not to be regarded as minor faults.

How to acquire practice.

490.

#### OF STUDY AND THE ORDER OF STUDY.

I say that first you ought to learn the limbs and their mechanism, and having this knowledge, their actions should come next, according to the circumstances in which they occur in man. And thirdly to compose subjects, the studies for which should be taken from natural actions and made from time to time, as circumstances allow; and pay attention to them in the streets and piazze and fields, and note them down with a brief indication of the forms; [Footnote 5: Lines 5-7 explained by the lower portion of the sketch No. 1 on Pl. XXXI.] thus for a head make an o, and for an arm a straight or a bent line, and the same for the legs and the body, [Footnote 7: Lines 5-7 explained by the lower portion of the sketch No. 1 on Pl. XXXI.] and when you return home work out these notes in a complete form. The Adversary says that to acquire practice and do a great deal of work it is better that the first period of study should be employed in drawing various compositions done on paper or on walls by divers masters, and that in this way practice is rapidly gained, and good methods; to which I reply that the method will be good, if it is based on works of good composition and by skilled masters. But since such masters are so rare that there are but few of them to be found, it is a surer way to go to natural objects, than to those which are imitated from nature with great deterioration, and so form bad methods; for he who can go to the fountain does not go to the water-jar.

[Footnote: This passage has been published by Dr. M. JORDAN, Das Malerbuck des L. da Vinci, p. 89; his reading however varies slightly from mine.]

Industry and thoroughness the first conditions (491-493.)

491.

#### WHAT RULES SHOULD BE GIVEN TO BOYS LEARNING TO PAINT.

We know for certain that sight is one of the most rapid actions we can perform. In an instant we see an infinite number of forms, still we only take in thoroughly one object at a time. Supposing that you, Reader, were to glance rapidly at the whole of this written page, you would instantly perceive that it was covered with various letters; but you could not, in the time, recognise what the letters were, nor what they were meant to tell. Hence you would need to see them word by word, line by line to be able to understand the

letters. Again, if you wish to go to the top of a building you must go up step by step; otherwise it will be impossible that you should reach the top. Thus I say to you, whom nature prompts to pursue this art, if you wish to have a sound knowledge of the forms of objects begin with the details of them, and do not go on to the second [step] till you have the first well fixed in memory and in practice. And if you do otherwise you will throw away your time, or certainly greatly prolong your studies. And remember to acquire diligence rather than rapidity.

492.

#### HOW THAT DILIGENCE [ACCURACY] SHOULD FIRST BE LEARNT RATHER THAN RAPID EXECUTION.

If you, who draw, desire to study well and to good purpose, always go slowly to work in your drawing; and discriminate in. the lights, which have the highest degree of brightness, and to what extent and likewise in the shadows, which are those that are darker than the others and in what way they intermingle; then their masses and the relative proportions of one to the other. And note in their outlines, which way they tend; and which part of the lines is curved to one side or the other, and where they are more or less conspicuous and consequently broad or fine; and finally, that your light and shade blend without strokes and borders [but] looking like smoke. And when you have thus schooled your hand and your judgment by such diligence, you will acquire rapidity before you are aware.

The artist's private life and choice of company (493-494).

493.

#### OF THE LIFE OF THE PAINTER IN THE COUNTRY.

A painter needs such mathematics as belong to painting. And the absence of all companions who are alienated from his studies; his brain must be easily impressed by the variety of objects, which successively come before him, and also free from other cares [Footnote 6: Leonardo here seems to be speaking of his own method of work as displayed in his MSS. and this passage explains, at least in part, the peculiarities in their arrangement.]. And if, when considering and defining one subject, a second subject intervenes--as happens when an object occupies the mind, then he must decide which of these cases is the more difficult to work out, and follow that up until it becomes quite clear, and then work out the explanation of the other [Footnote 11: Leonardo here seems to be speaking of his own method of work as displayed in his MSS. and this passage explains, at least in part, the peculiarities in their arrangement.]. And above all he must keep his mind as clear as the surface of a mirror, which assumes colours as various as those of the different objects. And his companions should be like him as to their studies, and if such cannot be found he should keep his speculations to himself alone, so that at last he will find no more

useful company [than his own].

[Footnote: In the title line Leonardo had originally written *\_del picture filosofo\_* (the philosophical painter), but he himself struck out *\_filosofo\_*. Compare in No. 363 *\_pictora notomista\_* (anatomical painter). The original text is partly reproduced on Pl. Cl.]

494.

#### OF THE LIFE OF THE PAINTER IN HIS STUDIO.

To the end that well-being of the body may not injure that of the mind, the painter or draughtsman must remain solitary, and particularly when intent on those studies and reflections which will constantly rise up before his eye, giving materials to be well stored in the memory. While you are alone you are entirely your own [master] and if you have one companion you are but half your own, and the less so in proportion to the indiscretion of his behaviour. And if you have many companions you will fall deeper into the same trouble. If you should say: "I will go my own way and withdraw apart, the better to study the forms of natural objects", I tell you, you will not be able to help often listening to their chatter. And so, since one cannot serve two masters, you will badly fill the part of a companion, and carry out your studies of art even worse. And if you say: "I will withdraw so far that their words cannot reach me and they cannot disturb me", I can tell you that you will be thought mad. But, you see, you will at any rate be alone. And if you must have companions ship find it in your studio. This may assist you to have the advantages which arise from various speculations. All other company may be highly mischievous.

The distribution of time for studying (495-497).

495.

#### OF WHETHER IT IS BETTER TO DRAW WITH COMPANIONS OR NOT.

I say and insist that drawing in company is much better than alone, for many reasons. The first is that you would be ashamed to be seen behindhand among the students, and such shame will lead you to careful study. Secondly, a wholesome emulation will stimulate you to be among those who are more praised than yourself, and this praise of others will spur you on. Another is that you can learn from the drawings of others who do better than yourself; and if you are better than they, you can profit by your contempt for their defects, while the praise of others will incite you to farther merits.

[Footnote: The contradiction by this passage of the foregoing chapter is only apparent. It is quite clear, from the nature of the reasoning which is here used to prove that it is more improving to work with others than to work alone, that the studies of pupils only are under consideration here.]

496.

OF STUDYING, IN THE DARK, WHEN YOU WAKE, OR IN BED BEFORE YOU GO TO SLEEP.

I myself have proved it to be of no small use, when in bed in the dark, to recall in fancy the external details of forms previously studied, or other noteworthy things conceived by subtle speculation; and this is certainly an admirable exercise, and useful for impressing things on the memory.

497.

OF THE TIME FOR STUDYING SELECTION OF SUBJECTS.

Winter evenings ought to be employed by young students in looking over the things prepared during the summer; that is, all the drawings from the nude done in the summer should be brought together and a choice made of the best [studies of] limbs and bodies among them, to apply in practice and commit to memory.

OF POSITIONS.

After this in the following summer you should select some one who is well grown and who has not been brought up in doublets, and so may not be of stiff carriage, and make him go through a number of agile and graceful actions; and if his muscles do not show plainly within the outlines of his limbs that does not matter at all. It is enough that you can see good attitudes and you can correct [the drawing of] the limbs by those you studied in the winter.

[Footnote: An injunction to study in the evening occurs also in No. 524.]

On the productive power of minor artists (498-501).

498.

He is a poor disciple who does not excel his master.

499.

Nor is the painter praiseworthy who does but one thing well, as the nude figure, heads, draperies, animals, landscapes or other such details, irrespective of other work; for there can be no mind so inept, that after devoting itself to one single thing and doing it constantly, it should fail to do it well.

[Footnote: In MANZI'S edition (p. 502) the painter G. G. Bossi indignantly remarks on this passage. "\_Parla il Vince in questo luogo come se tutti gli artisti avessero quella sublimita d'ingegno capace di abbracciare tutte le cose, di cui era egli dotato"\_ And he then mentions the case of CLAUDE LORRAIN. But he overlooks the fact

that in Leonardo's time landscape painting made no pretensions to independence but was reckoned among the details (\_particulari\_, lines 3, 4).]

500.

THAT A PAINTER IS NOT ADMIRABLE UNLESS HE IS UNIVERSAL.

Some may distinctly assert that those persons are under a delusion who call that painter a good master who can do nothing well but a head or a figure. Certainly this is no great achievement; after studying one single thing for a life-time who would not have attained some perfection in it? But, since we know that painting embraces and includes in itself every object produced by nature or resulting from the fortuitous actions of men, in short, all that the eye can see, he seems to me but a poor master who can only do a figure well. For do you not perceive how many and various actions are performed by men only; how many different animals there are, as well as trees, plants, flowers, with many mountainous regions and plains, springs and rivers, cities with public and private buildings, machines, too, fit for the purposes of men, divers costumes, decorations and arts? And all these things ought to be regarded as of equal importance and value, by the man who can be termed a good painter.

501.

OF THE MISERABLE PRETENCES MADE BY THOSE WHO FALSELY AND UNWORTHILY ACQUIRE THE NAME OF PAINTERS.

Now there is a certain race of painters who, having studied but little, must need take as their standard of beauty mere gold and azure, and these, with supreme conceit, declare that they will not give good work for miserable payment, and that they could do as well as any other if they were well paid. But, ye foolish folks! cannot such artists keep some good work, and then say: this is a costly work and this more moderate and this is average work and show that they can work at all prices?

A caution against one-sided study.

502.

HOW, IN IMPORTANT WORKS, A MAN SHOULD NOT TRUST ENTIRELY TO HIS MEMORY WITHOUT CONDESCENDING TO DRAW FROM NATURE.

Any master who should venture to boast that he could remember all the forms and effects of nature would certainly appear to me to be graced with extreme ignorance, inasmuch as these effects are infinite and our memory is not extensive enough to retain them. Hence, O! painter, beware lest the lust of gain should supplant in you the dignity of art; for the acquisition of glory is a much greater thing than the glory of riches. Hence, for these and other

reasons which might be given, first strive in drawing to represent your intention to the eye by expressive forms, and the idea originally formed in your imagination; then go on taking out or putting in, until you have satisfied yourself. Then have living men, draped or nude, as you may have purposed in your work, and take care that in dimensions and size, as determined by perspective, nothing is left in the work which is not in harmony with reason and the effects in nature. And this will be the way to win honour in your art.

How to acquire universality (503-506).

503.

#### OF VARIETY IN THE FIGURES.

The painter should aim at universality, because there is a great want of self-respect in doing one thing well and another badly, as many do who study only the [rules of] measure and proportion in the nude figure and do not seek after variety; for a man may be well proportioned, or he may be fat and short, or tall and thin, or medium. And a painter who takes no account of these varieties always makes his figures on one pattern so that they might all be taken for brothers; and this is a defect that demands stern reprehension.

504.

#### HOW SOMETHING MAY BE LEARNT EVERYWHERE.

Nature has beneficently provided that throughout the world you may find something to imitate.

505.

#### OF THE MEANS OF ACQUIRING UNIVERSALITY.

It is an easy matter to men to acquire universality, for all terrestrial animals resemble each other as to their limbs, that is in their muscles, sinews and bones; and they do not vary excepting in length or in thickness, as will be shown under Anatomy. But then there are aquatic animals which are of great variety; I will not try to convince the painter that there is any rule for them for they are of infinite variety, and so is the insect tribe.

506.

#### PAINTING.

The mind of the painter must resemble a mirror, which always takes the colour of the object it reflects and is completely occupied by the images of as many objects as are in front of it. Therefore you must know, Oh Painter! that you cannot be a good one if you are not the universal master of representing by your art every kind of form



produced by nature. And this you will not know how to do if you do not see them, and retain them in your mind. Hence as you go through the fields, turn your attention to various objects, and, in turn look now at this thing and now at that, collecting a store of divers facts selected and chosen from those of less value. But do not do like some painters who, when they are wearied with exercising their fancy dismiss their work from their thoughts and take exercise in walking for relaxation, but still keep fatigue in their mind which, though they see various objects [around them], does not apprehend them; but, even when they meet friends or relations and are saluted by them, although they see and hear them, take no more cognisance of them than if they had met so much empty air.

Useful games and exercises (507. 508).

507.

#### OF GAMES TO BE PLAYED BY THOSE WHO DRAW.

When, Oh draughtsmen, you desire to find relaxation in games you should always practise such things as may be of use in your profession, by giving your eye good practice in judging accurately of the breadth and length of objects. Thus, to accustom your mind to such things, let one of you draw a straight line at random on a wall, and each of you, taking a blade of grass or of straw in his hand, try to cut it to the length that the line drawn appears to him to be, standing at a distance of 10 braccia; then each one may go up to the line to measure the length he has judged it to be. And he who has come nearest with his measure to the length of the pattern is the best man, and the winner, and shall receive the prize you have settled beforehand. Again you should take forshortened measures: that is take a spear, or any other cane or reed, and fix on a point at a certain distance; and let each one estimate how many times he judges that its length will go into that distance. Again, who will draw best a line one braccio long, which shall be tested by a thread. And such games give occasion to good practice for the eye, which is of the first importance in painting.

508.

#### A WAY OF DEVELOPING AND AROUSING THE MIND TO VARIOUS INVENTIONS.

I cannot forbear to mention among these precepts a new device for study which, although it may seem but trivial and almost ludicrous, is nevertheless extremely useful in arousing the mind to various inventions. And this is, when you look at a wall spotted with stains, or with a mixture of stones, if you have to devise some scene, you may discover a resemblance to various landscapes, beautified with mountains, rivers, rocks, trees, plains, wide valleys and hills in varied arrangement; or again you may see battles and figures in action; or strange faces and costumes, and an endless variety of objects, which you could reduce to complete and well drawn forms. And these appear on such walls confusedly, like

the sound of bells in whose jangle you may find any name or word you choose to imagine.

II.

## THE ARTIST'S STUDIO.--INSTRUMENTS AND HELPS FOR THE APPLICATION OF PERSPECTIVE.--ON JUDGING OF A PICTURE.

On the size of the studio.

509.

Small rooms or dwellings discipline the mind, large ones weaken it.

On the construction of windows (510-512).

510.

The larger the wall the less the light will be.

511.

The different kinds of light afforded in cellars by various forms of windows. The least useful and the coldest is the window at a. The most useful, the lightest and warmest and most open to the sky is the window at b. The window at c is of medium utility.

[Footnote: From a reference to the notes on the right light for painting it becomes evident that the observations made on cellar-windows have a direct bearing on the construction of the studio-window. In the diagram b as well as in that under No. 510 the window-opening is reduced to a minimum, but only, it would seem, in order to emphasize the advantage of walls constructed on the plan there shown.]

512.

## OF THE PAINTER'S WINDOW AND ITS ADVANTAGE.

The painter who works from nature should have a window, which he can raise and lower. The reason is that sometimes you will want to finish a thing you are drawing, close to the light.

Let a b c d be the chest on which the work may be raised or lowered, so that the work moves up and down and not the painter. And every evening you can let down the work and shut it up above so that in the evening it may be in the fashion of a chest which, when shut up, may serve the purpose of a bench.

[Footnote: See Pl. XXXI, No. 2. In this plate the lines have unfortunately lost their sharpness, for the accidental loss of the negative has necessitated a reproduction from a positive. But having formerly published this sketch by another process, in VON LUTZOW'S

\_Zeitschrift fur bildende Kunst\_ (Vol. XVII, pg. 13) I have reproduced it here in the text. The sharpness of the outline in the original sketch is here preserved but it gives it from the reversed side.]

On the best light for painting (513-520).

513.

Which light is best for drawing from nature; whether high or low, or large or small, or strong and broad, or strong and small, or broad and weak or small and weak?

[Footnote: The question here put is unanswered in the original MS.]

514.

OF THE QUALITY OF THE LIGHT.

A broad light high up and not too strong will render the details of objects very agreeable.

515.

THAT THE LIGHT FOR DRAWING FROM NATURE SHOULD BE HIGH UP.

The light for drawing from nature should come from the North in order that it may not vary. And if you have it from the South, keep the window screened with cloth, so that with the sun shining the whole day the light may not vary. The height of the light should be so arranged as that every object shall cast a shadow on the ground of the same length as itself.

516.

THE KIND OF LIGHT REQUISITE FOR PAINTING LIGHT AND SHADE.

An object will display the greatest difference of light and shade when it is seen in the strongest light, as by sunlight, or, at night, by the light of a fire. But this should not be much used in painting because the works remain crude and ungraceful.

An object seen in a moderate light displays little difference in the light and shade; and this is the case towards evening or when the day is cloudy, and works then painted are tender and every kind of face becomes graceful. Thus, in every thing extremes are to be avoided: Too much light gives crudeness; too little prevents our seeing. The medium is best.

OF SMALL LIGHTS.

Again, lights cast from a small window give strong differences of light and shade, all the more if the room lighted by it be large,

and this is not good for painting.

517.

#### PAINTING.

The luminous air which enters by passing through orifices in walls into dark rooms will render the place less dark in proportion as the opening cuts into the walls which surround and cover in the pavement.

518.

#### OF THE QUALITY OF LIGHT.

In proportion to the number of times that *a b* goes into *c d* will it be more luminous than *c d*. And similarly, in proportion as the point *e* goes into *c d* will it be more luminous than *c d*; and this light is useful for carvers of delicate work. [Footnote 5: For the same reason a window thus constructed would be convenient for an illuminator or a miniature painter.]

[Footnote: M. RAVAISSON in his edition of the Paris MS. A remarks on this passage: "*La figure porte les lettres f et g, auxquelles rien ne renvoie dans l'explication; par consequent, cette explication est incomplete. La figure semblerait, d'ailleurs, se rapporter a l'effet de la reflexion par un miroir concave.*" So far as I can see the text is not imperfect, nor is the sense obscure. It is hardly necessary to observe that *c d* here indicate the wall of the room opposite to the window *e* and the semicircle described by *f g* stands for the arch of the sky; this occurs in various diagrams, for example under 511. A similar semicircle, PI III, No. 2 (and compare No. 149) is expressly called '*horizonte*' in writing.]

519.

That the light should fall upon a picture from one window only. This may be seen in the case of objects in this form. If you want to represent a round ball at a certain height you must make it oval in this shape, and stand so far off as that by foreshortening it appears round.

520.

#### OF SELECTING THE LIGHT WHICH GIVES MOST GRACE TO FACES.

If you should have a court yard that you can at pleasure cover with a linen awning that light will be good. Or when you want to take a portrait do it in dull weather, or as evening falls, making the sitter stand with his back to one of the walls of the court yard. Note in the streets, as evening falls, the faces of the men and women, and when the weather is dull, what softness and delicacy you may perceive in them. Hence, Oh Painter! have a court arranged with

the walls tinted black and a narrow roof projecting within the walls. It should be 10 braccia wide and 20 braccia long and 10 braccia high and covered with a linen awning; or else paint a work towards evening or when it is cloudy or misty, and this is a perfect light.

On various helps in preparing a picture (521-530).

521.

To draw a nude figure from nature, or any thing else, hold in your hand a plumb-line to enable you to judge of the relative position of objects.

522.

OF DRAWING AN OBJECT.

When you draw take care to set up a principal line which you must observe all throughout the object you are drawing; every thing should bear relation to the direction of this principal line.

523.

OF A MODE OF DRAWING A PLACE ACCURATELY.

Have a piece of glass as large as a half sheet of royal folio paper and set thus firmly in front of your eyes that is, between your eye and the thing you want to draw; then place yourself at a distance of  $\frac{2}{3}$  of a braccia from the glass fixing your head with a machine in such a way that you cannot move it at all. Then shut or entirely cover one eye and with a brush or red chalk draw upon the glass that which you see beyond it; then trace it on paper from the glass, afterwards transfer it onto good paper, and paint it if you like, carefully attending to the arial perspective.

HOW TO LEARN TO PLACE YOUR FIGURES CORRECTLY.

If you want to acquire a practice of good and correct attitudes for your figures, make a square frame or net, and square it out with thread; place this between your eye and the nude model you are drawing, and draw these same squares on the paper on which you mean to draw the figure, but very delicately. Then place a pellet of wax on a spot of the net which will serve as a fixed point, which, whenever you look at your model, must cover the pit of the throat; or, if his back is turned, it may cover one of the vertebrae of the neck. Thus these threads will guide you as to each part of the body which, in any given attitude will be found below the pit of the throat, or the angles of the shoulders, or the nipples, or hips and other parts of the body; and the transverse lines of the net will show you how much the figure is higher over the leg on which it is posed than over the other, and the same with the hips, and the knees and the feet. But always fix the net perpendicularly so that all the

divisions that you see the model divided into by the net work correspond with your drawing of the model on the net work you have sketched. The squares you draw may be as much smaller than those of the net as you wish that your figure should be smaller than nature. Afterwards remember when drawing figures, to use the rule of the corresponding proportions of the limbs as you have learnt it from the frame and net. This should be 3 braccia and a half high and 3 braccia wide; 7 braccia distant from you and 1 braccio from the model.

[Footnote: Leonardo is commonly credited with the invention of the arrangement of a plate of glass commonly known as the "vertical plane." Professor E. VON BRUCKE in his "Bruchstucke aus der Theorie der bildenden Kunste," Leipzig 1877, pg. 3, writes on this contrivance. "Unsere Glastafel ist die sogenannte Glastafel des Leonardo da Vinci, die in Gestalt einer Glastafel vorgestellte Bildflache." ]

524.

#### A METHOD OF DRAWING AN OBJECT IN RELIEF AT NIGHT.

Place a sheet of not too transparent paper between the relievo and the light and you can draw thus very well.

[Footnote: Bodies thus illuminated will show on the surface of the paper how the copyist has to distribute light and shade.]

525.

If you want to represent a figure on a wall, the wall being foreshortened, while the figure is to appear in its proper form, and as standing free from the wall, you must proceed thus: have a thin plate of iron and make a small hole in the centre; this hole must be round. Set a light close to it in such a position as that it shines through the central hole, then place any object or figure you please so close to the wall that it touches it and draw the outline of the shadow on the wall; then fill in the shade and add the lights; place the person who is to see it so that he looks through that same hole where at first the light was; and you will never be able to persuade yourself that the image is not detached from the wall.

[Footnote: "uno piccolo spiracelo nel mezzo". M. RAVAISSON, in his edition of MS. A (Paris), p. 52, reads "nel muro"--evidently a mistake for "nel mezzo" which is quite plainly written; and he translates it "fait lui une petite ouverture dans le mur," adding in a note: "les mots 'dans le mur' paraissent etre de trop. Leonardo a du les ecrire par distraction". But "nel mezzo" is clearly legible even on the photograph facsimile given by Ravaisson himself, and the objection he raises disappears at once. It is not always wise or safe to try to prove our author's absence of mind or inadvertence by apparent difficulties in the sense or connection of the text.]

526.

TO DRAW A FIGURE ON A WALL 12 BRACCIA HIGH WHICH SHALL LOOK 24 BRACCIA HIGH.

If you wish to draw a figure or any other object to look 24 braccia high you must do it in this way. First, on the surface *m r* draw half the man you wish to represent; then the other half; then put on the vault *m n* [the rest of] the figure spoken of above; first set out the vertical plane on the floor of a room of the same shape as the wall with the coved part on which you are to paint your figure. Then, behind it, draw a figure set out in profile of whatever size you please, and draw lines from it to the point *f* and, as these lines cut *m n* on the vertical plane, so will the figure come on the wall, of which the vertical plane gives a likeness, and you will have all the [relative] heights and prominences of the figure. And the breadth or thickness which are on the upright wall *m n* are to be drawn in their proper form, since, as the wall recedes the figure will be foreshortened by itself; but [that part of] the figure which goes into the cove you must foreshorten, as if it were standing upright; this diminution you must set out on a flat floor and there must stand the figure which is to be transferred from the vertical plane *r n* [Footnote 17: *che leverai dalla pariete r n*. The letters refer to the larger sketch, No. 3 on Pl. XXXI.] in its real size and reduce it once more on a vertical plane; and this will be a good method [Footnote 18: Leonardo here says nothing as to how the image foreshortened by perspective and thus produced on the vertical plane is to be transferred to the wall; but from what is said in Nos. 525 and 523 we may conclude that he was familiar with the process of casting the enlarged shadow of a squaring net on the surface of a wall to guide him in drawing the figure.

*\_Pariete di rilieuo; "sur une parai en relief" (RAVAISSON). \_"Auf einer Schnittlinie zum Aufrichten" (LUDWIG). The explanation of this puzzling expression must be sought in No. 545, lines 15-17.]*

[Footnote: See Pl. XXXI. 3. The second sketch, which in the plate is incomplete, is here reproduced and completed from the original to illustrate the text. In the original the larger diagram is placed between lines 5 and 6.

1. 2. C. A. 157a; 463a has the similar heading: '*\_del cressciere della figura\_*', and the text begins: "*\_Se voli fare 1a figura grande\_ b c*" but here it breaks off. The translation here given renders the meaning of the passage as I think it must be understood. The MS. is perfectly legible and the construction of the sentence is simple and clear; difficulties can only arise from the very fullness of the meaning, particularly towards the end of the passage.]

527.

If you would to draw a cube in an angle of a wall, first draw the

object in its own proper shape and raise it onto a vertical plane until it resembles the angle in which the said object is to be represented.

528.

Why are paintings seen more correctly in a mirror than out of it?

529.

#### HOW THE MIRROR IS THE MASTER [AND GUIDE] OF PAINTERS.

When you want to see if your picture corresponds throughout with the objects you have drawn from nature, take a mirror and look in that at the reflection of the real things, and compare the reflected image with your picture, and consider whether the subject of the two images duly corresponds in both, particularly studying the mirror. You should take the mirror for your guide--that is to say a flat mirror--because on its surface the objects appear in many respects as in a painting. Thus you see, in a painting done on a flat surface, objects which appear in relief, and in the mirror--also a flat surface--they look the same. The picture has one plane surface and the same with the mirror. The picture is intangible, in so far as that which appears round and prominent cannot be grasped in the hands; and it is the same with the mirror. And since you can see that the mirror, by means of outlines, shadows and lights, makes objects appear in relief, you, who have in your colours far stronger lights and shades than those in the mirror, can certainly, if you compose your picture well, make that also look like a natural scene reflected in a large mirror.

[Footnote: I understand the concluding lines of this passage as follows: If you draw the upper half a figure on a large sheet of paper laid out on the floor of a room (*\_sala be piana\_*) to the same scale (*\_con le sue vere grosseze\_*) as the lower half, already drawn upon the wall (lines 10, 11) you must then reduce them on a '*\_pariete di rilievo\_*,' a curved vertical plane which serves as a model to reproduce the form of the vault.]

530.

#### OF JUDGING YOUR OWN PICTURES.

We know very well that errors are better recognised in the works of others than in our own; and that often, while reproving little faults in others, you may ignore great ones in yourself. To avoid such ignorance, in the first place make yourself a master of perspective, then acquire perfect knowledge of the proportions of men and other animals, and also, study good architecture, that is so far as concerns the forms of buildings and other objects which are on the face of the earth; these forms are infinite, and the better you know them the more admirable will your work be. And in cases where you lack experience do not shrink from drawing them from



nature. But, to carry out my promise above [in the title]--I say that when you paint you should have a flat mirror and often look at your work as reflected in it, when you will see it reversed, and it will appear to you like some other painter's work, so you will be better able to judge of its faults than in any other way. Again, it is well that you should often leave off work and take a little relaxation, because, when you come back to it you are a better judge; for sitting too close at work may greatly deceive you. Again, it is good to retire to a distance because the work looks smaller and your eye takes in more of it at a glance and sees more easily the discords or disproportion in the limbs and colours of the objects.

On the management of works (531. 532).

531.

#### OF A METHOD OF LEARNING WELL BY HEART.

When you want to know a thing you have studied in your memory proceed in this way: When you have drawn the same thing so many times that you think you know it by heart, test it by drawing it without the model; but have the model traced on flat thin glass and lay this on the drawing you have made without the model, and note carefully where the tracing does not coincide with your drawing, and where you find you have gone wrong; and bear in mind not to repeat the same mistakes. Then return to the model, and draw the part in which you were wrong again and again till you have it well in your mind. If you have no flat glass for tracing on, take some very thin kidts-kin parchment, well oiled and dried. And when you have used it for one drawing you can wash it clean with a sponge and make a second.

532.

#### THAT A PAINTER OUGHT TO BE CURIOUS TO HEAR THE OPINIONS OF EVERY ONE ON HIS WORK.

Certainly while a man is painting he ought not to shrink from hearing every opinion. For we know very well that a man, though he may not be a painter, is familiar with the forms of other men and very capable of judging whether they are hump backed, or have one shoulder higher or lower than the other, or too big a mouth or nose, and other defects; and, as we know that men are competent to judge of the works of nature, how much more ought we to admit that they can judge of our errors; since you know how much a man may be deceived in his own work. And if you are not conscious of this in yourself study it in others and profit by their faults. Therefore be curious to hear with patience the opinions of others, consider and weigh well whether those who find fault have ground or not for blame, and, if so amend; but, if not make as though you had not heard, or if he should be a man you esteem show him by argument the cause of his mistake.

On the limitations of painting (533-535)

533.

HOW IN SMALL OBJECTS ERRORS ARE LESS EVIDENT THAN IN LARGE ONES.

In objects of minute size the extent of error is not so perceptible as in large ones; and the reason is that if this small object is a representation of a man or of some other animal, from the immense diminution the details cannot be worked out by the artist with the finish that is requisite. Hence it is not actually complete; and, not being complete, its faults cannot be determined. For instance: Look at a man at a distance of 300 braccia and judge attentively whether he be handsome or ugly, or very remarkable or of ordinary appearance. You will find that with the utmost effort you cannot persuade yourself to decide. And the reason is that at such a distance the man is so much diminished that the character of the details cannot be determined. And if you wish to see how much this man is diminished [by distance] hold one of your fingers at a span's distance from your eye, and raise or lower it till the top joint touches the feet of the figure you are looking at, and you will see an incredible reduction. For this reason we often doubt as to the person of a friend at a distance.

534.

WHY A PAINTING CAN NEVER APPEAR DETACHED AS NATURAL OBJECTS DO.

Painters often fall into despair of imitating nature when they see their pictures fail in that relief and vividness which objects have that are seen in a mirror; while they allege that they have colours which for brightness or depth far exceed the strength of light and shade in the reflections in the mirror, thus displaying their own ignorance rather than the real cause, because they do not know it. It is impossible that painted objects should appear in such relief as to resemble those reflected in the mirror, although both are seen on a flat surface, unless they are seen with only one eye; and the reason is that two eyes see one object behind another as \_a\_ and \_b\_ see \_m\_ and \_n\_. \_m\_ cannot exactly occupy [the space of] \_n\_ because the base of the visual lines is so broad that the second body is seen beyond the first. But if you close one eye, as at \_s\_ the body \_f\_ will conceal \_r\_, because the line of sight proceeds from a single point and makes its base in the first body, whence the second, of the same size, can never be seen.

[Footnote: This passage contains the solution of the problem proposed in No. 29, lines 10-14. Leonardo was evidently familiar with the law of optics on which the construction of the stereoscope depends. Compare E. VON BRUCKE, \_Bruchstucke aus der Theorie der bildenden Kunst\_, pg. 69: "\_Schon Leonardo da Vinci wusste, dass ein noch so gut gemaltes Bild nie den vollen Eindruck der Korperlichkeit geben kann, wie ihn die Natur selbst giebt. Er

erklärt dies auch in Kap. LIII und Kap. CCCXLI\_ (ed. DU FRESNE)  
\_des\_ 'Trattato' \_in sachgemasser Weise aus dem Sehen mit beiden  
Augen\_."

Chap. 53 of DU FRESNE'S edition corresponds to No. 534 of this  
work.]

535.

#### WHY OF TWO OBJECTS OF EQUAL SIZE A PAINTED ONE WILL LOOK LARGER THAN A SOLID ONE.

The reason of this is not so easy to demonstrate as many others.  
Still I will endeavour to accomplish it, if not wholly, at any rate  
in part. The perspective of diminution demonstrates by reason, that  
objects diminish in proportion as they are farther from the eye, and  
this reasoning is confirmed by experience. Hence, the lines of sight  
that extend between the object and the eye, when they are directed  
to the surface of a painting are all intersected at uniform limits,  
while those lines which are directed towards a piece of sculpture  
are intersected at various limits and are of various lengths. The  
lines which are longest extend to a more remote limb than the others  
and therefore that limb looks smaller. As there are numerous lines  
each longer than the others--since there are numerous parts, each  
more remote than the others and these, being farther off,  
necessarily appear smaller, and by appearing smaller it follows that  
their diminution makes the whole mass of the object look smaller.  
But this does not occur in painting; since the lines of sight all  
end at the same distance there can be no diminution, hence the parts  
not being diminished the whole object is undiminished, and for this  
reason painting does not diminish, as a piece of sculpture does.

On the choice of a position (536-537)

536.

#### HOW HIGH THE POINT OF SIGHT SHOULD BE PLACED.

The point of sight must be at the level of the eye of an ordinary  
man, and the farthest limit of the plain where it touches the sky  
must be placed at the level of that line where the earth and sky  
meet; excepting mountains, which are independent of it.

537.

#### OF THE WAY TO DRAW FIGURES FOR HISTORICAL PICTURES.

The painter must always study on the wall on which he is to picture  
a story the height of the position where he wishes to arrange his  
figures; and when drawing his studies for them from nature he must  
place himself with his eye as much below the object he is drawing  
as, in the picture, it will have to be above the eye of the  
spectator. Otherwise the work will look wrong.

The apparent size of figures in a picture (538-539)

538.

OF PLACING A FIGURE IN THE FOREGROUND OF A HISTORICAL PICTURE.

You must make the foremost figure in the picture less than the size of nature in proportion to the number of braccia at which you place it from the front line, and make the others in proportion by the above rule.

539.

PERSPECTIVE.

You are asked, O Painter, why the figures you draw on a small scale according to the laws of perspective do not appear--notwithstanding the demonstration of distance--as large as real ones--their height being the same as in those painted on the wall.

And why [painted] objects seen at a small distance appear larger than the real ones?

The right position of the artist, when painting, and of the spectator (540-547)

540.

OF PAINTING.

When you draw from nature stand at a distance of 3 times the height of the object you wish to draw.

541.

OF DRAWING FROM RELIEF.

In drawing from the round the draughtsman should so place himself that the eye of the figure he is drawing is on a level with his own.

This should be done with any head he may have to represent from nature because, without exception, the figures or persons you meet in the streets have their eyes on the same level as your own; and if you place them higher or lower you will see that your drawing will not be true.

542.

WHY GROUPS OF FIGURES ONE ABOVE ANOTHER ARE TO BE AVOIDED.

The universal practice which painters adopt on the walls of chapels is greatly and reasonably to be condemned. Inasmuch as they represent one historical subject on one level with a landscape and

buildings, and then go up a step and paint another, varying the point [of sight], and then a third and a fourth, in such a way as that on one wall there are 4 points of sight, which is supreme folly in such painters. We know that the point of sight is opposite the eye of the spectator of the scene; and if you would [have me] tell you how to represent the life of a saint divided into several pictures on one and the same wall, I answer that you must set out the foreground with its point of sight on a level with the eye of the spectator of the scene, and upon this plane represent the more important part of the story large and then, diminishing by degrees the figures, and the buildings on various hills and open spaces, you can represent all the events of the history. And on the remainder of the wall up to the top put trees, large as compared with the figures, or angels if they are appropriate to the story, or birds or clouds or similar objects; otherwise do not trouble yourself with it for your whole work will be wrong.

543.

A PICTURE OF OBJECTS IN PERSPECTIVE WILL LOOK MORE LIFELIKE WHEN SEEN FROM THE POINT FROM WHICH THE OBJECTS WERE DRAWN.

If you want to represent an object near to you which is to have the effect of nature, it is impossible that your perspective should not look wrong, with every false relation and disagreement of proportion that can be imagined in a wretched work, unless the spectator, when he looks at it, has his eye at the very distance and height and direction where the eye or the point of sight was placed in doing this perspective. Hence it would be necessary to make a window, or rather a hole, of the size of your face through which you can look at the work; and if you do this, beyond all doubt your work, if it is correct as to light and shade, will have the effect of nature; nay you will hardly persuade yourself that those objects are painted; otherwise do not trouble yourself about it, unless indeed you make your view at least 20 times as far off as the greatest width or height of the objects represented, and this will satisfy any spectator placed anywhere opposite to the picture.

If you want the proof briefly shown, take a piece of wood in the form of a little column, eight times as high as it is thick, like a column without any plinth or capital; then mark off on a flat wall 40 equal spaces, equal to its width so that between them they make 40 columns resembling your little column; you then must fix, opposite the centre space, and at 4 braccia from the wall, a thin strip of iron with a small round hole in the middle about as large as a big pearl. Close to this hole place a light touching it. Then place your column against each mark on the wall and draw the outline of its shadow; afterwards shade it and look through the hole in the iron plate.

[Footnote: In the original there is a wide space between lines 3 and 4 in which we find two sketches not belonging to the text. It is unnecessary to give prominence to the points in which my reading

differs from that of M. RAVAISSON or to justify myself, since they are all of secondary importance and can also be immediately verified from the photograph facsimile in his edition.]

544.

A diminished object should be seen from the same distance, height and direction as the point of sight of your eye, or else your knowledge will produce no good effect.

And if you will not, or cannot, act on this principle--because as the plane on which you paint is to be seen by several persons you would need several points of sight which would make it look discordant and wrong--place yourself at a distance of at least 10 times the size of the objects.

The lesser fault you can fall into then, will be that of representing all the objects in the foreground of their proper size, and on whichever side you are standing the objects thus seen will diminish themselves while the spaces between them will have no definite ratio. For, if you place yourself in the middle of a straight row [of objects], and look at several columns arranged in a line you will see, beyond a few columns separated by intervals, that the columns touch; and beyond where they touch they cover each other, till the last column projects but very little beyond the last but one. Thus the spaces between the columns are by degrees entirely lost. So, if your method of perspective is good, it will produce the same effect; this effect results from standing near the line in which the columns are placed. This method is not satisfactory unless the objects seen are viewed from a small hole, in the middle of which is your point of sight; but if you proceed thus your work will be perfect and will deceive the beholder, who will see the columns as they are here figured.

Here the eye is in the middle, at the point a and near to the columns.

[Footnote: The diagram which stands above this chapter in the original with the note belonging to it: "a b e la ripruova" (a b is the proof) has obviously no connection with the text. The second sketch alone is reproduced and stands in the original between lines 22 and 23.]

545.

If you cannot arrange that those who look at your work should stand at one particular point, when constructing your work, stand back until your eye is at least 20 times as far off as the greatest height and width of your work. This will make so little difference when the eye of the spectator moves, that it will be hardly appreciable, and it will look very good.

If the point of sight is at t you would make the figures on the

circle \_d b e\_ all of one size, as each of them bears the same relation to the point \_t\_. But consider the diagram given below and you will see that this is wrong, and why I shall make \_b\_ smaller than \_d e\_ [Footnote 8: The second diagram of this chapter stands in the original between lines 8 and 9].

It is easy to understand that if 2 objects equal to each other are placed side by side the one at 3 braccia distance looks smaller than that placed at 2 braccia. This however is rather theoretical than for practice, because you stand close by [Footnote 11: Instead of '\_se preso\_' (= \_sie presso\_) M. RAVAISSON reads '\_sempre se\_' which gives rise to the unmeaning rendering: '\_parceque toujours\_ ...'].

All the objects in the foreground, whether large or small, are to be drawn of their proper size, and if you see them from a distance they will appear just as they ought, and if you see them close they will diminish of themselves.

[Footnote 15: Compare No. 526 line 18.] Take care that the vertical plan on which you work out the perspective of the objects seen is of the same form as the wall on which the work is to be executed.

546.

OF PAINTING.

The size of the figures represented ought to show you the distance they are seen from. If you see a figure as large as nature you know it appears to be close to the eye.

547.

WHERE A SPECTATOR SHOULD STAND TO LOOK AT A PICTURE.

Supposing \_a b\_ to be the picture and \_d\_ to be the light, I say that if you place yourself between \_c\_ and \_e\_ you will not understand the picture well and particularly if it is done in oils, or still more if it is varnished, because it will be lustrous and somewhat of the nature of a mirror. And for this reason the nearer you go towards the point \_c\_, the less you will see, because the rays of light falling from the window on the picture are reflected to that point. But if you place yourself between \_e\_ and \_d\_ you will get a good view of it, and the more so as you approach the point \_d\_, because that spot is least exposed to these reflected rays of light.

III.

THE PRACTICAL METHODS OF LIGHT AND SHADE AND AERIAL PERSPECTIVE.

Gradations of light and shade.

548.

OF PAINTING: OF THE DARKNESS OF THE SHADOWS, OR I MAY SAY, THE BRIGHTNESS OF THE LIGHTS.

Although practical painters attribute to all shaded objects--trees, fields, hair, beards and skin--four degrees of darkness in each colour they use: that is to say first a dark foundation, secondly a spot of colour somewhat resembling the form of the details, thirdly a somewhat brighter and more defined portion, fourthly the lights which are more conspicuous than other parts of the figure; still to me it appears that these gradations are infinite upon a continuous surface which is in itself infinitely divisible, and I prove it thus:--[Footnote 7: See Pl. XXXI, No. 1; the two upper sketches.] Let  $a g$  be a continuous surface and let  $d$  be the light which illuminates it; I say--by the 4th [proposition] which says that that side of an illuminated body is most highly lighted which is nearest to the source of light--that therefore  $g$  must be darker than  $c$  in proportion as the line  $d g$  is longer than the line  $d c$ , and consequently that these gradations of light--or rather of shadow, are not 4 only, but may be conceived of as infinite, because  $c d$  is a continuous surface and every continuous surface is infinitely divisible; hence the varieties in the length of lines extending between the light and the illuminated object are infinite, and the proportion of the light will be the same as that of the length of the lines between them; extending from the centre of the luminous body to the surface of the illuminated object.

On the choice of light for a picture (549-554).

549.

HOW THE PAINTER MUST PLACE HIMSELF WITH REFERENCE TO THE LIGHT, TO GIVE THE EFFECT OF RELIEF.

Let  $a b$  be the window,  $m$  the point of light. I say that on whichever side the painter places himself he will be well placed if only his eye is between the shaded and the illuminated portions of the object he is drawing; and this place you will find by putting yourself between the point  $m$  and the division between the shadow and the light on the object to be drawn.

550.

THAT SHADOWS CAST BY A PARTICULAR LIGHT SHOULD BE AVOIDED, BECAUSE THEY ARE EQUALLY STRONG AT THE ENDS AND AT THE BEGINNING.

The shadows cast by the sun or any other particular light have not a pleasing effect on the body to which they belong, because the parts remain confuse, being divided by distinct outlines of light and shade. And the shadows are of equal strength at the end and at the beginning.

551.



## HOW LIGHT SHOULD BE THROWN UPON FIGURES.

The light must be arranged in accordance with the natural conditions under which you wish to represent your figures: that is, if you represent them in the sunshine make the shadows dark with large spaces of light, and mark their shadows and those of all the surrounding objects strongly on the ground. And if you represent them as in dull weather give little difference of light and shade, without any shadows at their feet. If you represent them as within doors, make a strong difference between the lights and shadows, with shadows on the ground. If the window is screened and the walls white, there will be little difference of light. If it is lighted by firelight make the high lights ruddy and strong, and the shadows dark, and those cast on the walls and on the floor will be clearly defined and the farther they are from the body the broader and longer will they be. If the light is partly from the fire and partly from the outer day, that of day will be the stronger and that of the fire almost as red as fire itself. Above all see that the figures you paint are broadly lighted and from above, that is to say all living persons that you paint; for you will see that all the people you meet out in the street are lighted from above, and you must know that if you saw your most intimate friend with a light [on his face] from below you would find it difficult to recognise him.

552.

## OF HELPING THE APPARENT RELIEF OF A PICTURE BY GIVING IT ARTIFICIAL LIGHT AND SHADE.

To increase relief of a picture you may place, between your figure and the solid object on which its shadow falls, a line of bright light, dividing the figure from the object in shadow. And on the same object you shall represent two light parts which will surround the shadow cast upon the wall by the figure placed opposite [6]; and do this frequently with the limbs which you wish should stand out somewhat from the body they belong to; particularly when the arms cross the front of the breast show, between the shadow cast by the arms on the breast and the shadow on the arms themselves, a little light seeming to fall through a space between the breast and the arms; and the more you wish the arm to look detached from the breast the broader you must make the light; always contrive also to arrange the figures against the background in such a way as that the parts in shadow are against a light background and the illuminated portions against a dark background.

[Footnote 6: Compare the two diagrams under No. 565.]

553.

## OF SITUATION.

Remember [to note] the situation of your figures; for the light and

shade will be one thing if the object is in a dark place with a particular light, and another thing if it is in a light place with direct sunlight; one thing in a dark place with a diffused evening light or a cloudy sky, and another in the diffused light of the atmosphere lighted by the sun.

554.

#### OF THE JUDGMENT TO BE MADE OF A PAINTER'S WORK.

First you must consider whether the figures have the relief required by their situation and the light which illuminates them; for the shadows should not be the same at the extreme ends of the composition as in the middle, because it is one thing when figures are surrounded by shadows and another when they have shadows only on one side. Those which are in the middle of the picture are surrounded by shadows, because they are shaded by the figures which stand between them and the light. And those are lighted on one side only which stand between the principal group and the light, because where they do not look towards the light they face the group and the darkness of the group is thrown on them: and where they do not face the group they face the brilliant light and it is their own darkness shadowing them, which appears there.

In the second place observe the distribution or arrangement of figures, and whether they are distributed appropriately to the circumstances of the story. Thirdly, whether the figures are actively intent on their particular business.

555.

#### OF THE TREATMENT OF THE LIGHTS.

First give a general shadow to the whole of that extended part which is away from the light. Then put in the half shadows and the strong shadows, comparing them with each other and, in the same way give the extended light in half tint, afterwards adding the half lights and the high lights, likewise comparing them together.

The distribution of light and shade (556-559)

556.

#### OF SHADOWS ON BODIES.

When you represent the dark shadows in bodies in light and shade, always show the cause of the shadow, and the same with reflections; because the dark shadows are produced by dark objects and the reflections by objects only moderately lighted, that is with diminished light. And there is the same proportion between the highly lighted part of a body and the part lighted by a reflection as between the origin of the lights on the body and the origin of the reflections.

557.

#### OF LIGHTS AND SHADOWS.

I must remind you to take care that every portion of a body, and every smallest detail which is ever so little in relief, must be given its proper importance as to light and shade.

558.

#### OF THE WAY TO MAKE THE SHADOW ON FIGURES CORRESPOND TO THE LIGHT AND TO [THE COLOUR] OF THE BODY.

When you draw a figure and you wish to see whether the shadow is the proper complement to the light, and neither redder nor yellower than is the nature of the colour you wish to represent in shade, proceed thus. Cast a shadow with your finger on the illuminated portion, and if the accidental shadow that you have made is like the natural shadow cast by your finger on your work, well and good; and by putting your finger nearer or farther off, you can make darker or lighter shadows, which you must compare with your own.

559.

#### OF SURROUNDING BODIES BY VARIOUS FORMS OF SHADOW.

Take care that the shadows cast upon the surface of the bodies by different objects must undulate according to the various curves of the limbs which cast the shadows, and of the objects on which they are cast.

The juxtaposition of light and shade (560, 561).

560.

#### ON PAINTING.

The comparison of the various qualities of shadows and lights not infrequently seems ambiguous and confused to the painter who desires to imitate and copy the objects he sees. The reason is this: If you see a white drapery side by side with a black one, that part of the white drapery which lies against the black one will certainly look much whiter than the part which lies against something whiter than itself. [Footnote: It is evident from this that so early as in 1492 Leonardo's writing in perspective was so far advanced that he could quote his own statements.--As bearing on this subject compare what is said in No. 280.] And the reason of this is shown in my [book on] perspective.

561.

#### OF SHADOWS.

Where a shadow ends in the light, note carefully where it is paler or deeper and where it is more or less indistinct towards the light; and, above all, in [painting] youthful figures I remind you not to make the shadow end like a stone, because flesh has a certain transparency, as may be seen by looking at a hand held between the eye and the sun, which shines through it ruddy and bright. Place the most highly coloured part between the light and shadow. And to see what shadow tint is needed on the flesh, cast a shadow on it with your finger, and according as you wish to see it lighter or darker hold your finger nearer to or farther from your picture, and copy that [shadow].

On the lighting of the background (562-565).

562.

#### OF THE BACKGROUNDS FOR PAINTED FIGURES.

The ground which surrounds the forms of any object you paint should be darker than the high lights of those figures, and lighter than their shadowed part: &c.

563.

#### OF THE BACKGROUND THAT THE PAINTER SHOULD ADOPT IN HIS WORKS.

Since experience shows us that all bodies are surrounded by light and shade it is necessary that you, O Painter, should so arrange that the side which is in light shall terminate against a dark body and likewise that the shadow side shall terminate against a light body. And by [following] this rule you will add greatly to the relief of your figures.

564.

A most important part of painting consists in the backgrounds of the objects represented; against these backgrounds the outlines of those natural objects which are convex are always visible, and also the forms of these bodies against the background, even though the colours of the bodies should be the same as that of the background. This is caused by the convex edges of the objects not being illuminated in the same way as, by the same light, the background is illuminated, since these edges will often be lighter or darker than the background. But if the edge is of the same colour as the background, beyond a doubt it will in that part of the picture interfere with your perception of the outline, and such a choice in a picture ought to be rejected by the judgment of good painters, inasmuch as the purpose of the painter is to make his figures appear detached from the background; while in the case here described the contrary occurs, not only in the picture, but in the objects themselves.

565.

That you ought, when representing objects above the eye and on one side--if you wish them to look detached from the wall--to show, between the shadow on the object and the shadow it casts a middle light, so that the body will appear to stand away from the wall.

On the lighting of white objects.

566.

#### HOW WHITE BODIES SHOULD BE REPRESENTED.

If you are representing a white body let it be surrounded by ample space, because as white has no colour of its own, it is tinged and altered in some degree by the colour of the objects surrounding it. If you see a woman dressed in white in the midst of a landscape, that side which is towards the sun is bright in colour, so much so that in some portions it will dazzle the eyes like the sun itself; and the side which is towards the atmosphere,--luminous through being interwoven with the sun's rays and penetrated by them--since the atmosphere itself is blue, that side of the woman's figure will appear steeped in blue. If the surface of the ground about her be meadows and if she be standing between a field lighted up by the sun and the sun itself, you will see every portion of those folds which are towards the meadow tinged by the reflected rays with the colour of that meadow. Thus the white is transmuted into the colours of the luminous and of the non-luminous objects near it.

The methods of aerial (567--570).

567.

#### WHY FACES [SEEN] AT A DISTANCE LOOK DARK.

We see quite plainly that all the images of visible objects that lie before us, whether large or small, reach our sense by the minute aperture of the eye; and if, through so small a passage the image can pass of the vast extent of sky and earth, the face of a man--being by comparison with such large images almost nothing by reason of the distance which diminishes it,--fills up so little of the eye that it is indistinguishable. Having, also, to be transmitted from the surface to the sense through a dark medium, that is to say the crystalline lens which looks dark, this image, not being strong in colour becomes affected by this darkness on its passage, and on reaching the sense it appears dark; no other reason can in any way be assigned. If the point in the eye is black, it is because it is full of a transparent humour as clear as air and acts like a perforation in a board; on looking into it it appears dark and the objects seen through the bright air and a dark one become confused in this darkness.

WHY A MAN SEEN AT A CERTAIN DISTANCE IS NOT RECOGNISABLE.

The perspective of diminution shows us that the farther away an object is the smaller it looks. If you look at a man at a distance from you of an arrow's flight, and hold the eye of a small needle close to your own eye, you can see through it several men whose images are transmitted to the eye and will all be comprised within the size of the needle's eye; hence, if the man who is at the distance of an arrow's flight can send his whole image to your eye, occupying only a small space in the needle's eye how can you [expect] in so small a figure to distinguish or see the nose or mouth or any detail of his person? and, not seeing these you cannot recognise the man, since these features, which he does not show, are what give men different aspects.

568.

#### THE REASON WHY SMALL FIGURES SHOULD NOT BE MADE FINISHED.

I say that the reason that objects appear diminished in size is because they are remote from the eye; this being the case it is evident that there must be a great extent of atmosphere between the eye and the objects, and this air interferes with the distinctness of the forms of the object. Hence the minute details of these objects will be indistinguishable and unrecognisable. Therefore, O Painter, make your smaller figures merely indicated and not highly finished, otherwise you will produce effects the opposite to nature, your supreme guide. The object is small by reason of the great distance between it and the eye, this great distance is filled with air, that mass of air forms a dense body which intervenes and prevents the eye seeing the minute details of objects.

569.

Whenever a figure is placed at a considerable distance you lose first the distinctness of the smallest parts; while the larger parts are left to the last, losing all distinctness of detail and outline; and what remains is an oval or spherical figure with confused edges.

570.

#### OF PAINTING.

The density of a body of smoke looks white below the horizon while above the horizon it is dark, even if the smoke is in itself of a uniform colour, this uniformity will vary according to the variety in the ground on which it is seen.

IV.

#### OF PORTRAIT AND FIGURE PAINTING.

Of sketching figures and portraits (571-572).

571.

#### OF THE WAY TO LEARN TO COMPOSE FIGURES [IN GROUPS] IN HISTORICAL PICTURES.

When you have well learnt perspective and have by heart the parts and forms of objects, you must go about, and constantly, as you go, observe, note and consider the circumstances and behaviour of men in talking, quarrelling or laughing or fighting together: the action of the men themselves and the actions of the bystanders, who separate them or who look on. And take a note of them with slight strokes thus, in a little book which you should always carry with you. And it should be of tinted paper, that it may not be rubbed out, but change the old [when full] for a new one; since these things should not be rubbed out but preserved with great care; for the forms, and positions of objects are so infinite that the memory is incapable of retaining them, wherefore keep these [sketches] as your guides and masters.

[Footnote: Among Leonardo's numerous note books of pocket size not one has coloured paper, so no sketches answering to this description can be pointed out. The fact that most of the notes are written in ink, militates against the supposition that they were made in the open air.]

572.

#### OF A METHOD OF KEEPING IN MIND THE FORM OF A FACE.

If you want to acquire facility for bearing in mind the expression of a face, first make yourself familiar with a variety of [forms of] several heads, eyes, noses, mouths, chins and cheeks and necks and shoulders: And to put a case: Noses are of 10 types: straight, bulbous, hollow, prominent above or below the middle, aquiline, regular, flat, round or pointed. These hold good as to profile. In full face they are of 11 types; these are equal thick in the middle, thin in the middle, with the tip thick and the root narrow, or narrow at the tip and wide at the root; with the nostrils wide or narrow, high or low, and the openings wide or hidden by the point; and you will find an equal variety in the other details; which things you must draw from nature and fix them in your mind. Or else, when you have to draw a face by heart, carry with you a little book in which you have noted such features; and when you have cast a glance at the face of the person you wish to draw, you can look, in private, which nose or mouth is most like, or there make a little mark to recognise it again at home. Of grotesque faces I need say nothing, because they are kept in mind without difficulty.

The position of the head.

573.

#### HOW YOU SHOULD SET TO WORK TO DRAW A HEAD OF WHICH ALL THE PARTS

SHALL AGREE WITH THE POSITION GIVEN TO IT.

To draw a head in which the features shall agree with the turn and bend of the head, pursue this method. You know that the eyes, eyebrows, nostrils, corners of the mouth, and sides of the chin, the jaws, cheeks, ears and all the parts of a face are squarely and straightly set upon the face.

[Footnote: Compare the drawings and the text belonging to them on Pl. IX. (No. 315), Pl. X (No. 316), Pl. XL (No. 318) and Pl. XII. (No. 319).]

Therefore when you have sketched the face draw lines passing from one corner of the eye to the other; and so for the placing of each feature; and after having drawn the ends of the lines beyond the two sides of the face, look if the spaces inside the same parallel lines on the right and on the left are equal [12]. But be sure to remember to make these lines tend to the point of sight.

[Footnote: See Pl. XXXI, No. 4, the slight sketch on the left hand side. The text of this passage is written by the side of it. In this sketch the lines seem intentionally incorrect and converging to the right (compare I. 12) instead of parallel. Compare too with this text the drawing in red chalk from Windsor Castle which is reproduced on Pl. XL, No. 2.]

Of the light on the face (574-576).

574.

HOW TO KNOW WHICH SIDE OF AN OBJECT IS TO BE MORE OR LESS LUMINOUS THAN THE OTHER.

Let *f* be the light, the head will be the object illuminated by it and that side of the head on which the rays fall most directly will be the most highly lighted, and those parts on which the rays fall most aslant will be less lighted. The light falls as a blow might, since a blow which falls perpendicularly falls with the greatest force, and when it falls obliquely it is less forcible than the former in proportion to the width of the angle. *Exempli gratia* if you throw a ball at a wall of which the extremities are equally far from you the blow will fall straight, and if you throw the ball at the wall when standing at one end of it the ball will hit it obliquely and the blow will not tell.

[Footnote: See Pl. XXXI. No. 4; the sketch on the right hand side.]

575.

THE PROOF AND REASON WHY AMONG THE ILLUMINATED PARTS CERTAIN PORTIONS ARE IN HIGHER LIGHT THAN OTHERS.

Since it is proved that every definite light is, or seems to be,



derived from one single point the side illuminated by it will have its highest light on the portion where the line of radiance falls perpendicularly; as is shown above in the lines *\_a g\_*, and also in *\_a h\_* and in *\_l a\_*; and that portion of the illuminated side will be least luminous, where the line of incidence strikes it between two more dissimilar angles, as is seen at *\_b c d\_*. And by this means you may also know which parts are deprived of light as is seen at *\_m k\_*.

Where the angles made by the lines of incidence are most equal there will be the highest light, and where they are most unequal it will be darkest.

I will make further mention of the reason of reflections.

[Footnote: See Pl. XXXII. The text, here given complete, is on the right hand side. The small circles above the beginning of lines 5 and 11 as well as the circle above the text on Pl. XXXI, are in a paler ink and evidently added by a later hand in order to distinguish the text as belonging to the *\_Libro di Pittura\_* (see Prolegomena. No. 12, p. 3). The text on the left hand side of this page is given as Nos. 577 and 137.]

576.

Where the shadow should be on the face.

General suggestions for historical pictures (577-581).

577.

When you compose a historical picture take two points, one the point of sight, and the other the source of light; and make this as distant as possible.

578.

Historical pictures ought not to be crowded and confused with too many figures.

579.

#### PRECEPTS IN PAINTING.

Let your sketches of historical pictures be swift and the working out of the limbs not be carried too far, but limited to the position of the limbs, which you can afterwards finish as you please and at your leisure.

[Footnote: See Pl. XXXVIII, No. 2. The pen and ink drawing given there as No. 3 may also be compared with this passage. It is in the Windsor collection where it is numbered 101.]

580.

The sorest misfortune is when your views are in advance of your work.

581.

Of composing historical pictures. Of not considering the limbs in the figures in historical pictures; as many do who, in the wish to represent the whole of a figure, spoil their compositions. And when you place one figure behind another take care to draw the whole of it so that the limbs which come in front of the nearer figures may stand out in their natural size and place.

How to represent the differences of age and sex (582-583).

582.

How the ages of man should be depicted: that is, Infancy, Childhood, Youth, Manhood, Old age, Decrepitude.

[Footnote: No answer is here given to this question, in the original MS.]

583.

Old men ought to be represented with slow and heavy movements, their legs bent at the knees, when they stand still, and their feet placed parallel and apart; bending low with the head leaning forward, and their arms but little extended.

Women must be represented in modest attitudes, their legs close together, their arms closely folded, their heads inclined and somewhat on one side.

Old women should be represented with eager, swift and furious gestures, like infernal furies; but the action should be more violent in their arms and head than in their legs.

Little children, with lively and contorted movements when sitting, and, when standing still, in shy and timid attitudes.

[Footnote: *\_bracci raccolte\_*. Compare Pl. XXXIII. This drawing, in silver point on yellowish tinted paper, the lights heightened with white, represents two female hands laid together in a lap. Above is a third finished study of a right hand, apparently holding a veil from the head across the bosom. This drawing evidently dates from before 1500 and was very probably done at Florence, perhaps as a preparatory study for some picture. The type of hand with its slender thin forms is more like the style of the *\_Vierge aux Rochers\_* in the Louvre than any later works--as the *Mona Lisa* for instance.]

Of representing the emotions.

584.

THAT A FIGURE IS NOT ADMIRABLE UNLESS IT EXPRESSES BY ITS ACTION THE PASSION OF ITS SENTIMENT.

That figure is most admirable which by its actions best expresses the passion that animates it.

HOW AN ANGRY MAN IS TO BE FIGURED.

You must make an angry person holding someone by the hair, wrenching his head against the ground, and with one knee on his ribs; his right arm and fist raised on high. His hair must be thrown up, his brow downcast and knit, his teeth clenched and the two corners of his mouth grimly set; his neck swelled and bent forward as he leans over his foe, and full of furrows.

HOW TO REPRESENT A MAN IN DESPAIR.

You must show a man in despair with a knife, having already torn open his garments, and with one hand tearing open the wound. And make him standing on his feet and his legs somewhat bent and his whole person leaning towards the earth; his hair flying in disorder.

Of representing imaginary animals.

585.

HOW YOU SHOULD MAKE AN IMAGINARY ANIMAL LOOK NATURAL.

You know that you cannot invent animals without limbs, each of which, in itself, must resemble those of some other animal. Hence if you wish to make an animal, imagined by you, appear natural--let us say a Dragon, take for its head that of a mastiff or hound, with the eyes of a cat, the ears of a porcupine, the nose of a greyhound, the brow of a lion, the temples of an old cock, the neck of a water tortoise.

[Footnote: The sketch here inserted of two men on horseback fighting a dragon is the facsimile of a pen and ink drawing belonging to BARON EDMOND DE ROTHSCHILD of Paris.]

The selection of forms.

586.

OF THE DELUSIONS WHICH ARISE IN JUDGING OF THE LIMBS.

A painter who has clumsy hands will paint similar hands in his works, and the same will occur with any limb, unless long study has taught him to avoid it. Therefore, O Painter, look carefully what part is most ill-favoured in your own person and take particular

pains to correct it in your studies. For if you are coarse, your figures will seem the same and devoid of charm; and it is the same with any part that may be good or poor in yourself; it will be shown in some degree in your figures.

587.

#### OF THE SELECTION OF BEAUTIFUL FACES.

It seems to me to be no small charm in a painter when he gives his figures a pleasing air, and this grace, if he have it not by nature, he may acquire by incidental study in this way: Look about you and take the best parts of many beautiful faces, of which the beauty is confirmed rather by public fame than by your own judgment; for you might be mistaken and choose faces which have some resemblance to your own. For it would seem that such resemblances often please us; and if you should be ugly, you would select faces that were not beautiful and you would then make ugly faces, as many painters do. For often a master's work resembles himself. So select beauties as I tell you, and fix them in your mind.

588.

Of the limbs, which ought to be carefully selected, and of all the other parts with regard to painting.

589.

When selecting figures you should choose slender ones rather than lean and wooden ones.

590.

#### OF THE MUSCLES OF ANIMALS.

The hollow spaces interposed between the muscles must not be of such a character as that the skin should seem to cover two sticks laid side by side like *\_c\_*, nor should they seem like two sticks somewhat remote from such contact so that the skin hangs in an empty loose curve as at *\_f\_*; but it should be like *\_i\_*, laid over the spongy fat that lies in the angles as the angle *\_n m o\_*; which angle is formed by the contact of the ends of the muscles and as the skin cannot fold down into such an angle, nature has filled up such angles with a small quantity of spongy and, as I may say, vesicular fat, with minute bladders [in it] full of air, which is condensed or rarefied in them according to the increase or the diminution of the substance of the muscles; in which latter case the concavity *\_i\_* always has a larger curve than the muscle.

591.

#### OF UNDULATING MOVEMENTS AND EQUIPOISE IN FIGURES AND OTHER ANIMALS.

When representing a human figure or some graceful animal, be careful to avoid a wooden stiffness; that is to say make them move with equipoise and balance so as not to look like a piece of wood; but those you want to represent as strong you must not make so, excepting in the turn of the head.

How to pose figures.

592.

#### OF GRACE IN THE LIMBS.

The limbs should be adapted to the body with grace and with reference to the effect that you wish the figure to produce. And if you wish to produce a figure that shall of itself look light and graceful you must make the limbs elegant and extended, and without too much display of the muscles; and those few that are needed for your purpose you must indicate softly, that is, not very prominent and without strong shadows; the limbs, and particularly the arms easy; that is, none of the limbs should be in a straight line with the adjoining parts. And if the hips, which are the pole of a man, are by reason of his position, placed so, that the right is higher than the left, make the point of the higher shoulder in a perpendicular line above the highest prominence of the hip, and let this right shoulder be lower than the left. Let the pit of the throat always be over the centre of the joint of the foot on which the man is leaning. The leg which is free should have the knee lower than the other, and near the other leg. The positions of the head and arms are endless and I shall therefore not enlarge on any rules for them. Still, let them be easy and pleasing, with various turns and twists, and the joints gracefully bent, that they may not look like pieces of wood.

Of appropriate gestures (593-600).

593.

A picture or representation of human figures, ought to be done in such a way as that the spectator may easily recognise, by means of their attitudes, the purpose in their minds. Thus, if you have to represent a man of noble character in the act of speaking, let his gestures be such as naturally accompany good words; and, in the same way, if you wish to depict a man of a brutal nature, give him fierce movements; as with his arms flung out towards the listener, and his head and breast thrust forward beyond his feet, as if following the speaker's hands. Thus it is with a deaf and dumb person who, when he sees two men in conversation--although he is deprived of hearing--can nevertheless understand, from the attitudes and gestures of the speakers, the nature of their discussion. I once saw in Florence a man who had become deaf who, when you spoke very loud did not understand you, but if you spoke gently and without making any sound, understood merely from the movement of the lips. Now perhaps you will say that the lips of a man who speaks loudly do not

move like those of one speaking softly, and that if they were to move them alike they would be alike understood. As to this argument, I leave the decision to experiment; make a man speak to you gently and note [the motion of] his lips.

[Footnote: The first ten lines of this text have already been published, but with a slightly different reading by Dr. M. JORDAN: \_Das Malerbuch Leonardo da Vinci's\_ p. 86.]

594.

#### OF REPRESENTING A MAN SPEAKING TO A MULTITUDE.

When you wish to represent a man speaking to a number of people, consider the matter of which he has to treat and adapt his action to the subject. Thus, if he speaks persuasively, let his action be appropriate to it. If the matter in hand be to set forth an argument, let the speaker, with the fingers of the right hand hold one finger of the left hand, having the two smaller ones closed; and his face alert, and turned towards the people with mouth a little open, to look as though he spoke; and if he is sitting let him appear as though about to rise, with his head forward. If you represent him standing make him leaning slightly forward with body and head towards the people. These you must represent as silent and attentive, all looking at the orator's face with gestures of admiration; and make some old men in astonishment at the things they hear, with the corners of their mouths pulled down and drawn in, their cheeks full of furrows, and their eyebrows raised, and wrinkling the forehead where they meet. Again, some sitting with their fingers clasped holding their weary knees. Again, some bent old man, with one knee crossed over the other; on which let him hold his hand with his other elbow resting in it and the hand supporting his bearded chin.

[Footnote: The sketches introduced here are a facsimile of a pen and ink drawing in the Louvre which Herr CARL BRUN considers as studies for the Last Supper in the church of \_Santa Maria delle Grazie\_ (see Leonardo da Vinci, LXI, pp. 21, 27 and 28 in DOHME'S \_Kunst und Künstler\_, Leipzig, Seemann). I shall not here enter into any discussion of this suggestion; but as a justification for introducing the drawing in this place, I may point out that some of the figures illustrate this passage as perfectly as though they had been drawn for that express purpose. I have discussed the probability of a connection between this sketch and the picture of the Last Supper on p. 335. The original drawing is 27 3/4 centimetres wide by 21 high.--The drawing in silver point on reddish paper given on Pl. LII. No. 1--the original at Windsor Castle--may also serve to illustrate the subject of appropriate gestures, treated in Nos. 593 and 594.]

595.

#### OF THE DISPOSITION OF LIMBS.

As regards the disposition of limbs in movement you will have to consider that when you wish to represent a man who, by some chance, has to turn backwards or to one side, you must not make him move his feet and all his limbs towards the side to which he turns his head. Rather must you make the action proceed by degrees and through the different joints; that is, those of the foot, the knee and the hip and the neck. And if you set him on the right leg, you must make the left knee bend inwards, and let his foot be slightly raised on the outside, and the left shoulder be somewhat lower than the right, while the nape of the neck is in a line directly over the outer angle of the left foot. And the left shoulder will be in a perpendicular line above the toes of the right foot. And always set your figures so that the side to which the head turns is not the side to which the breast faces, since nature for our convenience has made us with a neck which bends with ease in many directions, the eye wishing to turn to various points, the different joints. And if at any time you make a man sitting with his arms at work on something which is sideways to him, make the upper part of his body turn upon the hips.

[Footnote: Compare Pl. VII, No. 5. The original drawing at Windsor Castle is numbered 104.]

596.

When you draw the nude always sketch the whole figure and then finish those limbs which seem to you the best, but make them act with the other limbs; otherwise you will get a habit of never putting the limbs well together on the body.

Never make the head turn the same way as the torso, nor the arm and leg move together on the same side. And if the face is turned to the right shoulder, make all the parts lower on the left side than on the right; and when you turn the body with the breast outwards, if the head turns to the left side make the parts on the right side higher than those on the left.

[Footnote: In the original MS. a much defaced sketch is to be seen by the side of the second part of this chapter; its faded condition has rendered reproduction impossible. In M. RAVAISSON'S facsimile the outlines of the head have probably been touched up. This passage however is fitly illustrated by the drawings on Pl. XXI.]

597.

#### OF PAINTING.

Of the nature of movements in man. Do not repeat the same gestures in the limbs of men unless you are compelled by the necessity of their action, as is shown in \_a b\_.

[Footnote: See Pl. V, where part of the text is also reproduced. The

effaced figure to the extreme left has evidently been cancelled by Leonardo himself as unsatisfactory.]

598.

The motions of men must be such as suggest their dignity or their baseness.

599.

OF PAINTING.

Make your work carry out your purpose and meaning. That is when you draw a figure consider well who it is and what you wish it to be doing.

OF PAINTING.

With regard to any action which you give in a picture to an old man or to a young one, you must make it more energetic in the young man in proportion as he is stronger than the old one; and in the same way with a young man and an infant.

600.

OF SETTING ON THE LIMBS.

The limbs which are used for labour must be muscular and those which are not much used you must make without muscles and softly rounded.

OF THE ACTION OF THE FIGURES.

Represent your figures in such action as may be fitted to express what purpose is in the mind of each; otherwise your art will not be admirable.

V.

SUGGESTIONS FOR COMPOSITIONS.

Of painting battle pieces (601-603).

601.

OF THE WAY OF REPRESENTING A BATTLE.

First you must represent the smoke of artillery mingling in the air with the dust and tossed up by the movement of horses and the combatants. And this mixture you must express thus: The dust, being a thing of earth, has weight; and although from its fineness it is easily tossed up and mingles with the air, it nevertheless readily falls again. It is the finest part that rises highest; hence that part will be least seen and will look almost of the same colour as



the air. The higher the smoke mixed with the dust-laden air rises towards a certain level, the more it will look like a dark cloud; and it will be seen that at the top, where the smoke is more separate from the dust, the smoke will assume a bluish tinge and the dust will tend to its colour. This mixture of air, smoke and dust will look much lighter on the side whence the light comes than on the opposite side. The more the combatants are in this turmoil the less will they be seen, and the less contrast will there be in their lights and shadows. Their faces and figures and their appearance, and the musketeers as well as those near them you must make of a glowing red. And this glow will diminish in proportion as it is remote from its cause.

The figures which are between you and the light, if they be at a distance, will appear dark on a light background, and the lower part of their legs near the ground will be least visible, because there the dust is coarsest and densest [19]. And if you introduce horses galloping outside the crowd, make the little clouds of dust distant from each other in proportion to the strides made by the horses; and the clouds which are furthest removed from the horses, should be least visible; make them high and spreading and thin, and the nearer ones will be more conspicuous and smaller and denser [23]. The air must be full of arrows in every direction, some shooting upwards, some falling, some flying level. The balls from the guns must have a train of smoke following their flight. The figures in the foreground you must make with dust on the hair and eyebrows and on other flat places likely to retain it. The conquerors you will make rushing onwards with their hair and other light things flying on the wind, with their brows bent down,

[Footnote: 19--23. Compare 608. 57--75.]

602.

and with the opposite limbs thrust forward; that is where a man puts forward the right foot the left arm must be advanced. And if you make any one fallen, you must show the place where he has slipped and been dragged along the dust into blood stained mire; and in the half-liquid earth arround show the print of the tramping of men and horses who have passed that way. Make also a horse dragging the dead body of his master, and leaving behind him, in the dust and mud, the track where the body was dragged along. You must make the conquered and beaten pale, their brows raised and knit, and the skin above their brows furrowed with pain, the sides of the nose with wrinkles going in an arch from the nostrils to the eyes, and make the nostrils drawn up--which is the cause of the lines of which I speak--, and the lips arched upwards and discovering the upper teeth; and the teeth apart as with crying out and lamentation. And make some one shielding his terrified eyes with one hand, the palm towards the enemy, while the other rests on the ground to support his half raised body. Others represent shouting with their mouths open, and running away. You must scatter arms of all sorts among the feet of the combatants, as broken shields, lances, broken swords and

other such objects. And you must make the dead partly or entirely covered with dust, which is changed into crimson mire where it has mingled with the flowing blood whose colour shows it issuing in a sinuous stream from the corpse. Others must be represented in the agonies of death grinding their teeth, rolling their eyes, with their fists clenched against their bodies and their legs contorted. Some might be shown disarmed and beaten down by the enemy, turning upon the foe, with teeth and nails, to take an inhuman and bitter revenge. You might see some riderless horse rushing among the enemy, with his mane flying in the wind, and doing no little mischief with his heels. Some maimed warrior may be seen fallen to the earth, covering himself with his shield, while the enemy, bending over him, tries to deal him a deathstroke. There again might be seen a number of men fallen in a heap over a dead horse. You would see some of the victors leaving the fight and issuing from the crowd, rubbing their eyes and cheeks with both hands to clean them of the dirt made by their watering eyes smarting from the dust and smoke. The reserves may be seen standing, hopeful but cautious; with watchful eyes, shading them with their hands and gazing through the dense and murky confusion, attentive to the commands of their captain. The captain himself, his staff raised, hurries towards these auxiliaries, pointing to the spot where they are most needed. And there may be a river into which horses are galloping, churning up the water all round them into turbulent waves of foam and water, tossed into the air and among the legs and bodies of the horses. And there must not be a level spot that is not trampled with gore.

603.

#### OF LIGHTING THE LOWER PARTS OF BODIES CLOSE TOGETHER, AS OF MEN IN BATTLE.

As to men and horses represented in battle, their different parts will be dark in proportion as they are nearer to the ground on which they stand. And this is proved by the sides of wells which grow darker in proportion to their depth, the reason of which is that the deepest part of the well sees and receives a smaller amount of the luminous atmosphere than any other part.

And the pavement, if it be of the same colour as the legs of these said men and horses, will always be more lighted and at a more direct angle than the said legs &c.

604.

#### OF THE WAY TO REPRESENT A NIGHT [SCENE].

That which is entirely bereft of light is all darkness; given a night under these conditions and that you want to represent a night scene,--arrange that there shall be a great fire, then the objects which are nearest to this fire will be most tinged with its colour; for those objects which are nearest to a coloured light participate most in its nature; as therefore you give the fire a red colour, you

must make all the objects illuminated by it ruddy; while those which are farther from the fire are more tinted by the black hue of night. The figures which are seen against the fire look dark in the glare of the firelight because that side of the objects which you see is tinged by the darkness of the night and not by the fire; and those who stand at the side are half dark and half red; while those who are visible beyond the edges of the flame will be fully lighted by the ruddy glow against a black background. As to their gestures, make those which are near it screen themselves with their hands and cloaks as a defence against the intense heat, and with their faces turned away as if about to retire. Of those farther off represent several as raising their hands to screen their eyes, hurt by the intolerable glare.

Of depicting a tempest (605. 606).

605.

Describe a wind on land and at sea. Describe a storm of rain.

606.

#### HOW TO REPRESENT A TEMPEST.

If you wish to represent a tempest consider and arrange well its effects as seen, when the wind, blowing over the face of the sea and earth, removes and carries with it such things as are not fixed to the general mass. And to represent the storm accurately you must first show the clouds scattered and torn, and flying with the wind, accompanied by clouds of sand blown up from the sea shore, and boughs and leaves swept along by the strength and fury of the blast and scattered with other light objects through the air. Trees and plants must be bent to the ground, almost as if they would follow the course of the gale, with their branches twisted out of their natural growth and their leaves tossed and turned about [Footnote 11: See Pl. XL, No. 2.]. Of the men who are there some must have fallen to the ground and be entangled in their garments, and hardly to be recognized for the dust, while those who remain standing may be behind some tree, with their arms round it that the wind may not tear them away; others with their hands over their eyes for the dust, bending to the ground with their clothes and hair streaming in the wind. [Footnote 15: See Pl. XXXIV, the right hand lower sketch.] Let the sea be rough and tempestuous and full of foam whirled among the lofty waves, while the wind flings the lighter spray through the stormy air, till it resembles a dense and swathing mist. Of the ships that are therein some should be shown with rent sails and the tatters fluttering through the air, with ropes broken and masts split and fallen. And the ship itself lying in the trough of the sea and wrecked by the fury of the waves with the men shrieking and clinging to the fragments of the vessel. Make the clouds driven by the impetuosity of the wind and flung against the lofty mountain tops, and wreathed and torn like waves beating upon rocks; the air itself terrible from the deep darkness caused by the dust and fog

and heavy clouds.

Of representing the deluge (607-609).

607.

TO REPRESENT THE DELUGE.

The air was darkened by the heavy rain whose oblique descent driven aslant by the rush of the winds, flew in drifts through the air not otherwise than as we see dust, varied only by the straight lines of the heavy drops of falling water. But it was tinged with the colour of the fire kindled by the thunder-bolts by which the clouds were rent and shattered; and whose flashes revealed the broad waters of the inundated valleys, above which was seen the verdure of the bending tree tops. Neptune will be seen in the midst of the water with his trident, and [15] let AEolus with his winds be shown entangling the trees floating uprooted, and whirling in the huge waves. The horizon and the whole hemisphere were obscure, but lurid from the flashes of the incessant lightning. Men and birds might be seen crowded on the tall trees which remained uncovered by the swelling waters, originators of the mountains which surround the great abysses [Footnote 23: Compare Vol. II. No. 979.].

608.

OF THE DELUGE AND HOW TO REPRESENT IT IN A PICTURE.

Let the dark and gloomy air be seen buffeted by the rush of contrary winds and dense from the continued rain mingled with hail and bearing hither and thither an infinite number of branches torn from the trees and mixed with numberless leaves. All round may be seen venerable trees, uprooted and stripped by the fury of the winds; and fragments of mountains, already scoured bare by the torrents, falling into those torrents and choking their valleys till the swollen rivers overflow and submerge the wide lowlands and their inhabitants. Again, you might have seen on many of the hill-tops terrified animals of different kinds, collected together and subdued to tameness, in company with men and women who had fled there with their children. The waters which covered the fields, with their waves were in great part strewn with tables, bedsteads, boats and various other contrivances made from necessity and the fear of death, on which were men and women with their children amid sounds of lamentation and weeping, terrified by the fury of the winds which with their tempestuous violence rolled the waters under and over and about the bodies of the drowned. Nor was there any object lighter than the water which was not covered with a variety of animals which, having come to a truce, stood together in a frightened crowd--among them wolves, foxes, snakes and others--fleing from death. And all the waters dashing on their shores seemed to be battling them with the blows of drowned bodies, blows which killed those in whom any life remained [19]. You might have seen assemblages of men who, with weapons in their hands, defended the

small spots that remained to them against lions, wolves and beasts of prey who sought safety there. Ah! what dreadful noises were heard in the air rent by the fury of the thunder and the lightnings it flashed forth, which darted from the clouds dealing ruin and striking all that opposed its course. Ah! how many you might have seen closing their ears with their hands to shut out the tremendous sounds made in the darkened air by the raging of the winds mingling with the rain, the thunders of heaven and the fury of the thunder-bolts. Others were not content with shutting their eyes, but laid their hands one over the other to cover them the closer that they might not see the cruel slaughter of the human race by the wrath of God. Ah! how many laments! and how many in their terror flung themselves from the rocks! Huge branches of great oaks loaded with men were seen borne through the air by the impetuous fury of the winds. How many were the boats upset, some entire, and some broken in pieces, on the top of people labouring to escape with gestures and actions of grief foretelling a fearful death. Others, with desperate act, took their own lives, hopeless of being able to endure such suffering; and of these, some flung themselves from lofty rocks, others strangled themselves with their own hands, other seized their own children and violently slew them at a blow; some wounded and killed themselves with their own weapons; others, falling on their knees recommended themselves to God. Ah! how many mothers wept over their drowned sons, holding them upon their knees, with arms raised spread out towards heaven and with words and various threatening gestures, upbraiding the wrath of the gods. Others with clasped hands and fingers clenched gnawed them and devoured them till they bled, crouching with their breast down on their knees in their intense and unbearable anguish. Herds of animals were to be seen, such as horses, oxen, goats and swine already environed by the waters and left isolated on the high peaks of the mountains, huddled together, those in the middle climbing to the top and treading on the others, and fighting fiercely themselves; and many would die for lack of food. Already had the birds begun to settle on men and on other animals, finding no land uncovered which was not occupied by living beings, and already had famine, the minister of death, taken the lives of the greater number of the animals, when the dead bodies, now fermented, were leaving the depth of the waters and were rising to the top. Among the buffeting waves, where they were beating one against the other, and, like as balls full of air, rebounded from the point of concussion, these found a resting place on the bodies of the dead. And above these judgements, the air was seen covered with dark clouds, riven by the forked flashes of the raging bolts of heaven, lighting up on all sides the depth of the gloom.

The motion of the air is seen by the motion of the dust thrown up by the horse's running and this motion is as swift in again filling up the vacuum left in the air which enclosed the horse, as he is rapid in passing away from the air.

Perhaps it will seem to you that you may reproach me with having represented the currents made through the air by the motion of the

wind notwithstanding that the wind itself is not visible in the air. To this I must answer that it is not the motion of the wind but only the motion of the things carried along by it which is seen in the air.

THE DIVISIONS. [Footnote 76: These observations, added at the bottom of the page containing the full description of the deluge seem to indicate that it was Leonardo's intention to elaborate the subject still farther in a separate treatise.]

Darkness, wind, tempest at sea, floods of water, forests on fire, rain, bolts from heaven, earthquakes and ruins of mountains, overthrow of cities [Footnote 81: *\_Spianamenti di citta\_* (overthrow of cities). A considerable number of drawings in black chalk, at Windsor, illustrate this catastrophe. Most of them are much rubbed; one of the least injured is reproduced at Pl. XXXIX. Compare also the pen and ink sketch Pl. XXXVI.].

Whirlwinds which carry water [spouts] branches of trees, and men through the air.

Boughs stripped off by the winds, mingling by the meeting of the winds, with people upon them.

Broken trees loaded with people.

Ships broken to pieces, beaten on rocks.

Flocks of sheep. Hail stones, thunderbolts, whirlwinds.

People on trees which are unable to support them; trees and rocks, towers and hills covered with people, boats, tables, troughs, and other means of floating. Hills covered with men, women and animals; and lightning from the clouds illuminating every thing.

[Footnote: This chapter, which, with the next one, is written on a loose sheet, seems to be the passage to which one of the compilers of the Vatican copy alluded when he wrote on the margin of fol. 36: "*\_Qua mi ricordo della mirabile discriptione del Diluuio dello autore.\_*" It is scarcely necessary to point out that these chapters are among those which have never before been published. The description in No. 607 may be regarded as a preliminary sketch for this one. As the MS. G. (in which it is to be found) must be attributed to the period of about 1515 we may deduce from it the approximate date of the drawings on Pl. XXXIV, XXXV, Nos. 2 and 3, XXXVI and XXXVII, since they obviously belong to this text. The drawings No. 2 on Pl. XXXV are, in the original, side by side with the text of No. 608; lines 57 to 76 are shown in the facsimile. In the drawing in Indian ink given on Pl. XXXIV we see Wind-gods in the sky, corresponding to the allusion to Aeolus in No. 607 1. 15.-Plates XXXVI and XXXVII form one sheet in the original. The texts reproduced on these Plates have however no connection with the sketches, excepting the sketches of clouds on the right hand side.

These texts are given as No. 477. The group of small figures on Pl. XXXVII, to the left, seems to be intended for a ' \_congregatione d'uomini.\_' See No. 608, 1. 19.]

609.

#### DESCRIPTION OF THE DELUGE.

Let there be first represented the summit of a rugged mountain with valleys surrounding its base, and on its sides let the surface of the soil be seen to slide, together with the small roots of the bushes, denuding great portions of the surrounding rocks. And descending ruinous from these precipices in its boisterous course, let it dash along and lay bare the twisted and gnarled roots of large trees overthrowing their roots upwards; and let the mountains, as they are scoured bare, discover the profound fissures made in them by ancient earthquakes. The base of the mountains may be in great part clothed and covered with ruins of shrubs, hurled down from the sides of their lofty peaks, which will be mixed with mud, roots, boughs of trees, with all sorts of leaves thrust in with the mud and earth and stones. And into the depth of some valley may have fallen the fragments of a mountain forming a shore to the swollen waters of its river; which, having already burst its banks, will rush on in monstrous waves; and the greatest will strike upon and destroy the walls of the cities and farmhouses in the valley [14].

Then the ruins of the high buildings in these cities will throw up a great dust, rising up in shape like smoke or wreathed clouds against the falling rain; But the swollen waters will sweep round the pool which contains them striking in eddying whirlpools against the different obstacles, and leaping into the air in muddy foam; then, falling back, the beaten water will again be dashed into the air. And the whirling waves which fly from the place of concussion, and whose impetus moves them across other eddies going in a contrary direction, after their recoil will be tossed up into the air but without dashing off from the surface. Where the water issues from the pool the spent waves will be seen spreading out towards the outlet; and there falling or pouring through the air and gaining weight and impetus they will strike on the water below piercing it and rushing furiously to reach its depth; from which being thrown back it returns to the surface of the lake, carrying up the air that was submerged with it; and this remains at the outlet in foam mingled with logs of wood and other matters lighter than water. Round these again are formed the beginnings of waves which increase the more in circumference as they acquire more movement; and this movement rises less high in proportion as they acquire a broader base and thus they are less conspicuous as they die away. But if these waves rebound from various objects they then return in direct opposition to the others following them, observing the same law of increase in their curve as they have already acquired in the movement they started with. The rain, as it falls from the clouds is of the same colour as those clouds, that is in its shaded side; unless indeed the sun's rays should break through them; in that case the rain will appear less dark than the clouds. And if the heavy

masses of ruin of large mountains or of other grand buildings fall into the vast pools of water, a great quantity will be flung into the air and its movement will be in a contrary direction to that of the object which struck the water; that is to say: The angle of reflection will be equal to the angle of incidence. Of the objects carried down by the current, those which are heaviest or rather largest in mass will keep farthest from the two opposite shores. The water in the eddies revolves more swiftly in proportion as it is nearer to their centre. The crests of the waves of the sea tumble to their bases falling with friction on the bubbles of their sides; and this friction grinds the falling water into minute particles and this being converted into a dense mist, mingles with the gale in the manner of curling smoke and wreathing clouds, and at last it, rises into the air and is converted into clouds. But the rain which falls through the atmosphere being driven and tossed by the winds becomes rarer or denser according to the rarity or density of the winds that buffet it, and thus there is generated in the atmosphere a moisture formed of the transparent particles of the rain which is near to the eye of the spectator. The waves of the sea which break on the slope of the mountains which bound it, will foam from the velocity with which they fall against these hills; in rushing back they will meet the next wave as it comes and after a loud noise return in a great flood to the sea whence they came. Let great numbers of inhabitants--men and animals of all kinds--be seen driven [54] by the rising of the deluge to the peaks of the mountains in the midst of the waters aforesaid.

The wave of the sea at Piombino is all foaming water. [Footnote 55. 56: These two lines are written below the bottom sketch on Pl. XXXV, 3. The MS. Leic. being written about the year 1510 or later, it does not seem to me to follow that the sketches must have been made at Piombino, where Leonardo was in the year 1502 and possibly returned there subsequently (see Vol. II. Topographical notes).]

Of the water which leaps up from the spot where great masses fall on its surface. Of the winds of Piombino at Piombino. Eddies of wind and rain with boughs and shrubs mixed in the air. Emptying the boats of the rain water.

[Footnote: The sketches on Pl. XXXV 3 stand by the side of lines 14 to 54.]

Of depicting natural phenomena (610. 611).

610.

The tremendous fury of the wind driven by the falling in of the hills on the caves within--by the falling of the hills which served as roofs to these caverns.

A stone flung through the air leaves on the eye which sees it the impression of its motion, and the same effect is produced by the drops of water which fall from the clouds when it [16] rains.



[17] A mountain falling on a town, will fling up dust in the form of clouds; but the colour of this dust will differ from that of the clouds. Where the rain is thickest let the colour of the dust be less conspicuous and where the dust is thickest let the rain be less conspicuous. And where the rain is mingled with the wind and with the dust the clouds created by the rain must be more transparent than those of dust [alone]. And when flames of fire are mingled with clouds of smoke and water very opaque and dark clouds will be formed [Footnote 26-28: Compare Pl. XL, 1--the drawing in Indian ink on the left hand side, which seems to be a reminiscence of his observations of an eruption (see his remarks on Mount Etna in Vol II).]. And the rest of this subject will be treated in detail in the book on painting.

[Footnote: See the sketches and text on Pl. XXXVIII, No. 1. Lines 1-16 are there given on the left hand side, 17-30 on the right. The four lines at the bottom on the right are given as No. 472. Above these texts, which are written backwards, there are in the original sixteen lines in a larger writing from left to right, but only half of this is here visible. They treat of the physical laws of motion of air and water. It does not seem to me that there is any reason for concluding that this writing from left to right is spurious. Compare with it the facsimile of the rough copy of Leonardo's letter to Ludovico il Moro in Vol. II.]

611.

People were to be seen eagerly embarking victuals on various kinds of hastily made barks. But little of the waves were visible in those places where the dark clouds and rain were reflected.

But where the flashes caused by the bolts of heaven were reflected, there were seen as many bright spots, caused by the image of the flashes, as there were waves to reflect them to the eye of the spectator.

The number of the images produced by the flash of lightning on the waves of the water were multiplied in proportion to the distance of the spectator's eye.

So also the number of the images was diminished in proportion as they were nearer the eye which saw them [Footnote 22. 23: \_Com'e provato\_. See Vol. II, Nos. 874-878 and 892-901], as it has been proved in the definition of the luminosity of the moon, and of our marine horizon when the sun's rays are reflected in it and the eye which receives the reflection is remote from the sea.

VI.

THE ARTIST'S MATERIALS.

Of chalk and paper (612--617).

612.

To make points [crayons] for colouring dry. Temper with a little wax and do not dry it; which wax you must dissolve with water: so that when the white lead is thus tempered, the water being distilled, may go off in vapour and the wax may remain; you will thus make good crayons; but you must know that the colours must be ground with a hot stone.

613.

Chalk dissolves in wine and in vinegar or in aqua fortis and can be recombined with gum.

614.

PAPER FOR DRAWING UPON IN BLACK BY THE AID OF YOUR SPITTLE.

Take powdered gall nuts and vitriol, powder them and spread them on paper like a varnish, then write on it with a pen wetted with spittle and it will turn as black as ink.

615.

If you want to make foreshortened letters stretch the paper in a drawing frame and then draw your letters and cut them out, and make the sunbeams pass through the holes on to another stretched paper, and then fill up the angles that are wanting.

616.

This paper should be painted over with candle soot tempered with thin glue, then smear the leaf thinly with white lead in oil as is done to the letters in printing, and then print in the ordinary way. Thus the leaf will appear shaded in the hollows and lighted on the parts in relief; which however comes out here just the contrary.

[Footnote: This text, which accompanies a facsimile impression of a leaf of sage, has already been published in the *„Saggio delle Opere di L. da Vinci“*, Milano 1872, p. 11. G. GOVI observes on this passage: "„Forse aveva egli pensato ancora a farsi un erbario, od almeno a riprodurre facilmente su carta le forme e i particolari delle foglie di diverse piante; poiche (modificando un metodo che probabilmente gli eia stato insegnato da altri, e che piu tardi si legge ripetuto in molti ricettarii e libri di segreti), accanto a una foglia di Salvia impressa in nero su carta bianca, lascio scritto: Questa carta ...

Erano i primi tentativi di quella riproduzione immediata delle parti vegetali, che poi sotto il nome d'Impressione Naturale, fu condotta a tanta perfezione in questi ultimi tempi dal signor de Hauer e da altri\_."]

617.

Very excellent will be a stiff white paper, made of the usual mixture and filtered milk of an herb called calves foot; and when this paper is prepared and damped and folded and wrapped up it may be mixed with the mixture and thus left to dry; but if you break it before it is moistened it becomes somewhat like the thin paste called *\_lasagne\_* and you may then damp it and wrap it up and put it in the mixture and leave it to dry; or again this paper may be covered with stiff transparent white and *\_sardonio\_* and then damped so that it may not form angles and then covered up with strong transparent size and as soon as it is firm cut it two fingers, and leave it to dry; again you may make stiff cardboard of *\_sardonio\_* and dry it and then place it between two sheets of papyrus and break it inside with a wooden mallet with a handle and then open it with care holding the lower sheet of paper flat and firm so that the broken pieces be not separated; then have a sheet of paper covered with hot glue and apply it on the top of all these pieces and let them stick fast; then turn it upside down and apply transparent size several times in the spaces between the pieces, each time pouring in first some black and then some stiff white and each time leaving it to dry; then smooth it and polish it.

On the preparation and use of colours (618-627).

618.

To make a fine green take green and mix it with bitumen and you will make the shadows darker. Then, for lighter [shades] green with yellow ochre, and for still lighter green with yellow, and for the high lights pure yellow; then mix green and turmeric together and glaze every thing with it. To make a fine red take cinnabar or red chalk or burnt ochre for the dark shadows and for the lighter ones red chalk and vermilion and for the lights pure vermilion and then glaze with fine lake. To make good oil for painting. One part of oil, one of the first refining and one of the second.

619.

Use black in the shadow, and in the lights white, yellow, green, vermilion and lake. Medium shadows; take the shadow as above and mix it with the flesh tints just alluded to, adding to it a little yellow and a little green and occasionally some lake; for the shadows take green and lake for the middle shades.

[Footnote 618 and 619: If we may judge from the flourishes with which the writing is ornamented these passages must have been written in Leonardo's youth.]

620.

You can make a fine ochre by the same method as you use to make

white.

621.

A FINE YELLOW.

Dissolve realgar with one part of orpiment, with aqua fortis.

WHITE.

Put the white into an earthen pot, and lay it no thicker than a string, and let it stand in the sun undisturbed for 2 days; and in the morning when the sun has dried off the night dews.

622.

To make reddish black for flesh tints take red rock crystals from Rocca Nova or garnets and mix them a little; again armenian bole is good in part.

623.

The shadow will be burnt ,terra-verte'.

624.

THE PROPORTIONS OF COLOURS.

If one ounce of black mixed with one ounce of white gives a certain shade of darkness, what shade of darkness will be produced by 2 ounces of black to 1 ounce of white?

625.

Remix black, greenish yellow and at the end blue.

626.

Verdigris with aloes, or gall or turmeric makes a fine green and so it does with saffron or burnt orpiment; but I doubt whether in a short time they will not turn black. Ultramarine blue and glass yellow mixed together make a beautiful green for fresco, that is wall-painting. Lac and verdigris make a good shadow for blue in oil painting.

627.

Grind verdigris many times coloured with lemon juice and keep it away from yellow (?).

Of preparing the panel.

628.

## TO PREPARE A PANEL FOR PAINTING ON.

The panel should be cypress or pear or service-tree or walnut. You must coat it over with mastic and turpentine twice distilled and white or, if you like, lime, and put it in a frame so that it may expand and shrink according to its moisture and dryness. Then give it [a coat] of aqua vitae in which you have dissolved arsenic or [corrosive] sublimate, 2 or 3 times. Then apply boiled linseed oil in such a way as that it may penetrate every part, and before it is cold rub it well with a cloth to dry it. Over this apply liquid varnish and white with a stick, then wash it with urine when it is dry, and dry it again. Then pounce and outline your drawing finely and over it lay a priming of 30 parts of verdigris with one of verdigris with two of yellow.

[Footnote: M. RAVAISSON'S reading varies from mine in the following passages:

1. \_opero allor [?] bo [alloro?\_] = "\_ou bien de [laurier]\_"

6. \_fregalo bene con un panno\_. He reads \_pane\_ for \_panno\_ and renders it. "\_Frotte le bien avec un pain de facon [jusqu'a ce] qu'il\_" etc.

7. \_colla stecca po laua\_. He reads "\_polacca\_" = "\_avec le couteau de bois [?] polonais [?]\_"

The preparation of oils (629--634).

629.

OIL.

Make some oil of mustard seed; and if you wish to make it with greater ease mix the ground seeds with linseed oil and put it all under the press.

630.

TO REMOVE THE SMELL OF OIL.

Take the rank oil and put ten pints into a jar and make a mark on the jar at the height of the oil; then add to it a pint of vinegar and make it boil till the oil has sunk to the level of the mark and thus you will be certain that the oil is returned to its original quantity and the vinegar will have gone off in vapour, carrying with it the evil smell; and I believe you may do the same with nut oil or any other oil that smells badly.

631.

Since walnuts are enveloped in a thin rind, which partakes of the

nature of ..., if you do not remove it when you make the oil from them, this skin tinges the oil, and when you work with it this skin separates from the oil and rises to the surface of the painting, and this is what makes it change.

632.

#### TO RESTORE OIL COLOURS THAT HAVE BECOME DRY.

If you want to restore oil colours that have become dry keep them soaking in soft soap for a night and, with your finger, mix them up with the soft soap; then pour them into a cup and wash them with water, and in this way you can restore colours that have got dry. But take care that each colour has its own vessel to itself adding the colour by degrees as you restore it and mind that they are thoroughly softened, and when you wish to use them for tempera wash them five and six times with spring water, and leave them to settle; if the soft soap should be thick with any of the colours pass it through a filter. [Footnote: The same remark applies to these sections as to No. 618 and 619.]

633.

#### OIL.

Mustard seed pounded with linseed oil.

634.

... outside the bowl 2 fingers lower than the level of the oil, and pass it into the neck of a bottle and let it stand and thus all the oil will separate from this milky liquid; it will enter the bottle and be as clear as crystal; and grind your colours with this, and every coarse or viscid part will remain in the liquid. You must know that all the oils that have been created in seeds or fruits are quite clear by nature, and the yellow colour you see in them only comes of your not knowing how to draw it out. Fire or heat by its nature has the power to make them acquire colour. See for example the exudation or gums of trees which partake of the nature of rosin; in a short time they harden because there is more heat in them than in oil; and after some time they acquire a certain yellow hue tending to black. But oil, not having so much heat does not do so; although it hardens to some extent into sediment it becomes finer. The change in oil which occurs in painting proceeds from a certain fungus of the nature of a husk which exists in the skin which covers the nut, and this being crushed along with the nuts and being of a nature much resembling oil mixes with it; it is of so subtle a nature that it combines with all colours and then comes to the surface, and this it is which makes them change. And if you want the oil to be good and not to thicken, put into it a little camphor melted over a slow fire and mix it well with the oil and it will never harden.

[Footnote: The same remark applies to these sections as to No. 618 and 619.]

On varnishes [or powders] (635-637).

635.

VARNISH [OR POWDER].

Take cypress [oil] and distil it and have a large pitcher, and put in the extract with so much water as may make it appear like amber, and cover it tightly so that none may evaporate. And when it is dissolved you may add in your pitcher as much of the said solution, as shall make it liquid to your taste. And you must know that amber is the gum of the cypress-tree.

VARNISH [OR POWDER].

And since varnish [powder] is the resin of juniper, if you distil juniper you can dissolve the said varnish [powder] in the essence, as explained above.

636.

VARNISH [OR POWDER].

Notch a juniper tree and give it water at the roots, mix the liquor which exudes with nut-oil and you will have a perfect varnish [powder], made like amber varnish [powder], fine and of the best quality make it in May or April.

637.

VARNISH [OR POWDER].

Mercury with Jupiter and Venus,--a paste made of these must be corrected by the mould (?) continuously, until Mercury separates itself entirely from Jupiter and Venus. [Footnote: Here, and in No. 641 \_Mercurio\_ seems to mean quicksilver, \_Giove\_ stands for iron, \_Venere\_ for copper and \_Saturno\_ for lead.]

On chemical materials (638-650).

638.

Note how aqua vitae absorbs into itself all the colours and smells of flowers. If you want to make blue put iris flowers into it and for red solanum berries (?)

639.

Salt may be made from human excrement burnt and calcined and made into lees, and dried by a slow fire, and all dung in like manner

yields salt, and these salts when distilled are very pungent.

640.

Sea water filtered through mud or clay, leaves all its saltiness in it. Woollen stuffs placed on board ship absorb fresh water. If sea water is distilled under a retort it becomes of the first excellence and any one who has a little stove in his kitchen can, with the same wood as he cooks with, distil a great quantity of water if the retort is a large one.

641.

MOULD(?).

The mould (?) may be of Venus, or of Jupiter and Saturn and placed frequently in the fire. And it should be worked with fine emery and the mould (?) should be of Venus and Jupiter impasted over (?) Venus. But first you will test Venus and Mercury mixed with Jove, and take means to cause Mercury to disperse; and then fold them well together so that Venus or Jupiter be connected as thinly as possible.

[Footnote: See the note to 637.]

642.

Nitre, vitriol, cinnabar, alum, salt ammoniac, sublimated mercury, rock salt, alcali salt, common salt, rock alum, alum schist (?), arsenic, sublimate, realgar, tartar, orpiment, verdegris.

643.

Pitch four ounces virgin wax, four ounces incense, two ounces oil of roses one ounce.

644.

Four ounces virgin wax, four ounces Greek pitch, two ounces incense, one ounce oil of roses, first melt the wax and oil then the Greek pitch then the other things in powder.

645.

Very thin glass may be cut with scissors and when placed over inlaid work of bone, gilt, or stained of other colours you can saw it through together with the bone and then put it together and it will retain a lustre that will not be scratched nor worn away by rubbing with the hand.

646.

TO DILUTE WHITE WINE AND MAKE IT PURPLE.



Powder gall nuts and let this stand 8 days in the white wine; and in the same way dissolve vitriol in water, and let the water stand and settle very clear, and the wine likewise, each by itself, and strain them well; and when you dilute the white wine with the water the wine will become red.

647.

Put marcasite into aqua fortis and if it turns green, know that it has copper in it. Take it out with saltpetre and soft soap.

648.

A white horse may have the spots removed with the Spanish haematite or with aqua fortis or with ... Removes the black hair on a white horse with the singeing iron. Force him to the ground.

649.

FIRE.

If you want to make a fire which will set a hall in a blaze without injury do this: first perfume the hall with a dense smoke of incense or some other odoriferous substance: It is a good trick to play. Or boil ten pounds of brandy to evaporate, but see that the hall is completely closed and throw up some powdered varnish among the fumes and this powder will be supported by the smoke; then go into the room suddenly with a lighted torch and at once it will be in a blaze.

650.

FIRE.

Take away that yellow surface which covers oranges and distill them in an alembic, until the distillation may be said to be perfect.

FIRE.

Close a room tightly and have a brasier of brass or iron with fire in it and sprinkle on it two pints of aqua vitae, a little at a time, so that it may be converted into smoke. Then make some one come in with a light and suddenly you will see the room in a blaze like a flash of lightning, and it will do no harm to any one.

VII.

PHILOSOPHY AND HISTORY OF THE ART OF PAINTING.

The relation of art and nature (651. 652).

651.

What is fair in men, passes away, but not so in art.

652.

HE WHO DESPISES PAINTING LOVES NEITHER PHILOSOPHY NOR NATURE.

If you condemn painting, which is the only imitator of all visible works of nature, you will certainly despise a subtle invention which brings philosophy and subtle speculation to the consideration of the nature of all forms--seas and plains, trees, animals, plants and flowers--which are surrounded by shade and light. And this is true knowledge and the legitimate issue of nature; for painting is born of nature--or, to speak more correctly, we will say it is the grandchild of nature; for all visible things are produced by nature, and these her children have given birth to painting. Hence we may justly call it the grandchild of nature and related to God.

Painting is superior to poetry (653. 654).

653.

THAT PAINTING SURPASSES ALL HUMAN WORKS BY THE SUBTLE CONSIDERATIONS BELONGING TO IT.

The eye, which is called the window of the soul, is the principal means by which the central sense can most completely and abundantly appreciate the infinite works of nature; and the ear is the second, which acquires dignity by hearing of the things the eye has seen. If you, historians, or poets, or mathematicians had not seen things with your eyes you could not report of them in writing. And if you, O poet, tell a story with your pen, the painter with his brush can tell it more easily, with simpler completeness and less tedious to be understood. And if you call painting dumb poetry, the painter may call poetry blind painting. Now which is the worse defect? to be blind or dumb? Though the poet is as free as the painter in the invention of his fictions they are not so satisfactory to men as paintings; for, though poetry is able to describe forms, actions and places in words, the painter deals with the actual similitude of the forms, in order to represent them. Now tell me which is the nearer to the actual man: the name of man or the image of the man. The name of man differs in different countries, but his form is never changed but by death.

654.

And if the poet gratifies the sense by means of the ear, the painter does so by the eye--the worthier sense; but I will say no more of this but that, if a good painter represents the fury of a battle, and if a poet describes one, and they are both together put before the public, you will see where most of the spectators will stop, to which they will pay most attention, on which they will bestow most praise, and which will satisfy them best. Undoubtedly painting being

by a long way the more intelligible and beautiful, will please most. Write up the name of God [Christ] in some spot and setup His image opposite and you will see which will be most revered. Painting comprehends in itself all the forms of nature, while you have nothing but words, which are not universal as form is, and if you have the effects of the representation, we have the representation of the effects. Take a poet who describes the beauty of a lady to her lover and a painter who represents her and you will see to which nature guides the enamoured critic. Certainly the proof should be allowed to rest on the verdict of experience. You have ranked painting among the mechanical arts but, in truth, if painters were as apt at praising their own works in writing as you are, it would not lie under the stigma of so base a name. If you call it mechanical because it is, in the first place, manual, and that it is the hand which produces what is to be found in the imagination, you too writers, who set down manually with the pen what is devised in your mind. And if you say it is mechanical because it is done for money, who falls into this error--if error it can be called--more than you? If you lecture in the schools do you not go to whoever pays you most? Do you do any work without pay? Still, I do not say this as blaming such views, for every form of labour looks for its reward. And if a poet should say: "I will invent a fiction with a great purpose," the painter can do the same, as Apelles painted Calumny. If you were to say that poetry is more eternal, I say the works of a coppersmith are more eternal still, for time preserves them longer than your works or ours; nevertheless they have not much imagination [29]. And a picture, if painted on copper with enamel colours may be yet more permanent. We, by our arts may be called the grandsons of God. If poetry deals with moral philosophy, painting deals with natural philosophy. Poetry describes the action of the mind, painting considers what the mind may effect by the motions [of the body]. If poetry can terrify people by hideous fictions, painting can do as much by depicting the same things in action. Supposing that a poet applies himself to represent beauty, ferocity, or a base, a foul or a monstrous thing, as against a painter, he may in his ways bring forth a variety of forms; but will the painter not satisfy more? are there not pictures to be seen, so like the actual things, that they deceive men and animals?

Painting is superior to sculpture (655. 656).

655.

THAT SCULPTURE IS LESS INTELLECTUAL THAN PAINTING, AND LACKS MANY CHARACTERISTICS OF NATURE.

I myself, having exercised myself no less in sculpture than in painting and doing both one and the other in the same degree, it seems to me that I can, without invidiousness, pronounce an opinion as to which of the two is of the greatest merit and difficulty and perfection. In the first place sculpture requires a certain light, that is from above, a picture carries everywhere with it its own light and shade. Thus sculpture owes its importance to light and

shade, and the sculptor is aided in this by the nature, of the relief which is inherent in it, while the painter whose art expresses the accidental aspects of nature, places his effects in the spots where nature must necessarily produce them. The sculptor cannot diversify his work by the various natural colours of objects; painting is not defective in any particular. The sculptor when he uses perspective cannot make it in any way appear true; that of the painter can appear like a hundred miles beyond the picture itself. Their works have no aerial perspective whatever, they cannot represent transparent bodies, they cannot represent luminous bodies, nor reflected lights, nor lustrous bodies--as mirrors and the like polished surfaces, nor mists, nor dark skies, nor an infinite number of things which need not be told for fear of tedium. As regards the power of resisting time, though they have this resistance [Footnote 19: From what is here said as to painting on copper it is very evident that Leonardo was not acquainted with the method of painting in oil on thin copper plates, introduced by the Flemish painters of the XVIIth century. J. LERMOLIEFF has already pointed out that in the various collections containing pictures by the great masters of the Italian Renaissance, those painted on copper (for instance the famous reading Magdalen in the Dresden Gallery) are the works of a much later date (see *\_Zeitschrift fur bildende Kunst\_*. Vol. X pg. 333, and: *\_Werke italienischer Master in den Galerien von Munchen, Dresden und Berlin\_*. Leipzig 1880, pg. 158 and 159.)--Compare No. 654, 29.], a picture painted on thick copper covered with white enamel on which it is painted with enamel colours and then put into the fire again and baked, far exceeds sculpture in permanence. It may be said that if a mistake is made it is not easy to remedy it; it is but a poor argument to try to prove that a work be the nobler because oversights are irremediable; I should rather say that it will be more difficult to improve the mind of the master who makes such mistakes than to repair the work he has spoiled.

656.

We know very well that a really experienced and good painter will not make such mistakes; on the contrary, with sound rules he will remove so little at a time that he will bring his work to a good issue. Again the sculptor if working in clay or wax, can add or reduce, and when his model is finished it can easily be cast in bronze, and this is the last operation and is the most permanent form of sculpture. Inasmuch as that which is merely of marble is liable to ruin, but not bronze. Hence a painting done on copper which as I said of painting may be added to or altered, resembles sculpture in bronze, which, having first been made in wax could then be altered or added to; and if sculpture in bronze is durable, this work in copper and enamel is absolutely imperishable. Bronze is but dark and rough after all, but this latter is covered with various and lovely colours in infinite variety, as has been said above; or if you will have me only speak of painting on panel, I am content to pronounce between it and sculpture; saying that painting is the more beautiful and the more imaginative and the more copious, while sculpture is the more durable but it has nothing else. Sculpture

shows with little labour what in painting appears a miraculous thing to do; to make what is impalpable appear palpable, flat objects appear in relief, distant objects seem close. In fact painting is adorned with infinite possibilities which sculpture cannot command.

Aphorisms (657-659).

657.

OF PAINTING.

Men and words are ready made, and you, O Painter, if you do not know how to make your figures move, are like an orator who knows not how to use his words.

658.

As soon as the poet ceases to represent in words what exists in nature, he in fact ceases to resemble the painter; for if the poet, leaving such representation, proceeds to describe the flowery and flattering speech of the figure, which he wishes to make the speaker, he then is an orator and no longer a poet nor a painter. And if he speaks of the heavens he becomes an astrologer, and philosopher; and a theologian, if he discourses of nature or God. But, if he restricts himself to the description of objects, he would enter the lists against the painter, if with words he could satisfy the eye as the painter does.

659.

Though you may be able to tell or write the exact description of forms, the painter can so depict them that they will appear alive, with the shadow and light which show the expression of a face; which you cannot accomplish with the pen though it can be achieved by the brush.

On the history of painting (660. 661).

660.

THAT PAINTING DECLINES AND DETERIORATES FROM AGE TO AGE, WHEN PAINTERS HAVE NO OTHER STANDARD THAN PAINTING ALREADY DONE.

Hence the painter will produce pictures of small merit if he takes for his standard the pictures of others. But if he will study from natural objects he will bear good fruit; as was seen in the painters after the Romans who always imitated each other and so their art constantly declined from age to age. After these came Giotto the Florentine who--not content with imitating the works of Cimabue his master--being born in the mountains and in a solitude inhabited only by goats and such beasts, and being guided by nature to his art, began by drawing on the rocks the movements of the goats of which he was keeper. And thus he began to draw all the animals which were to

be found in the country, and in such wise that after much study he excelled not only all the masters of his time but all those of many bygone ages. Afterwards this art declined again, because everyone imitated the pictures that were already done; thus it went on from century to century until Tomaso, of Florence, nicknamed Masaccio, showed by his perfect works how those who take for their standard any one but nature--the mistress of all masters--weary themselves in vain. And, I would say about these mathematical studies that those who only study the authorities and not the works of nature are descendants but not sons of nature the mistress of all good authors. Oh! how great is the folly of those who blame those who learn from nature [Footnote 22: *\_lasciando stare li autori\_*. In this observation we may detect an indirect evidence that Leonardo regarded his knowledge of natural history as derived from his own investigations, as well as his theories of perspective and optics. Compare what he says in praise of experience (Vol II; *\_XIX\_*).], setting aside those authorities who themselves were the disciples of nature.

661.

That the first drawing was a simple line drawn round the shadow of a man cast by the sun on a wall.

The painter's scope.

662.

The painter strives and competes with nature.

*\_X\_*.

Studies and Sketches for Pictures and Decorations.

An artist's manuscript notes can hardly be expected to contain any thing more than incidental references to those masterpieces of his work of which the fame, sounded in the writings of his contemporaries, has left a glorious echo to posterity. We need not therefore be surprised to find that the texts here reproduced do not afford us such comprehensive information as we could wish. On the other hand, the sketches and studies prepared by Leonardo for the two grandest compositions he ever executed: The Fresco of the Last Supper in the Refectory of Santa Maria delle Grazie at Milan, and the Cartoon of the Battle of Anghiari, for the Palazzo della Signoria at Florence--have been preserved; and, though far from complete, are so much more numerous than the manuscript notes, that we are justified in asserting that in value and interest they amply compensate for the meagerness of the written suggestions.

The notes for the composition of the Last Supper, which are given under nos. 665 and 666 occur in a MS. at South Kensington, II2, written in the years 1494-1495. This MS. sketch was noted down not more than three or four years before the painting was executed,

which justifies the inference that at the time when it was written the painter had not made up his mind definitely even as to the general scheme of the work; and from this we may also conclude that the drawings of apostles' heads at Windsor, in red chalk, must be ascribed to a later date. They are studies for the head of St. Matthew, the fourth figure on Christ's left hand--see Pl. XL VII, the sketch (in black chalk) for the head of St. Philip, the third figure on the left hand--see Pl. XL VIII, for St. Peter's right arm--see Pl. XLIX, and for the expressive head of Judas which has unfortunately somewhat suffered by subsequent restoration of outlines,--see Pl. L. According to a tradition, as unfounded as it is improbable, Leonardo made use of the head of Padre Bandelli, the prior of the convent, as the prototype of his Judas; this however has already been contradicted by Amoretti "Memorie storiche" cap. XIV. The study of the head of a criminal on Pl. LI has, it seems to me, a better claim to be regarded as one of the preparatory sketches for the head of Judas. The Windsor collection contains two old copies of the head of St. Simon, the figure to the extreme left of Christ, both of about equal merit (they are marked as Nos. 21 and 36)--the second was reproduced on Pl. VIII of the Grosvenor Gallery Publication in 1878. There is also at Windsor a drawing in black chalk of folded hands (marked with the old No. 212; No. LXI of the Grosvenor Gallery Publication) which I believe to be a copy of the hands of St. John, by some unknown pupil. A reproduction of the excellent drawings of heads of Apostles in the possession of H. R. H. the Grand Duchess of Weimar would have been out of my province in this work, and, with regard to them, I must confine myself to pointing out that the difference in style does not allow of our placing the Weimar drawings in the same category as those here reproduced. The mode of grouping in the Weimar drawings is of itself sufficient to indicate that they were not executed before the picture was painted, but, on the contrary, afterwards, and it is, on the face of it, incredible that so great a master should thus have copied from his own work.

The drawing of Christ's head, in the Brera palace at Milan was perhaps originally the work of Leonardo's hand; it has unfortunately been entirely retouched and re-drawn, so that no decisive opinion can be formed as to its genuineness.

The red chalk drawing reproduced on Pl. XLVI is in the Accademia at Venice; it was probably made before the text, Nos. 664 and 665, was written.

The two pen and ink sketches on Pl. XLV seem to belong to an even earlier date; the more finished drawing of the two, on the right hand, represents Christ with only St. John and Judas and a third disciple whose action is precisely that described in No. 666, Pl. 4. It is hardly necessary to observe that the other sketches on this page and the lines of text below the circle (containing the solution of a geometrical problem) have no reference to the picture of the Last Supper. With this figure of Christ may be compared a similar pen and ink drawing reproduced on page 297 below on the

left hand; the original is in the Louvre. On this page again the rest of the sketches have no direct bearing on the composition of the Last Supper, not even, as it seems to me, the group of four men at the bottom to the right hand--who are listening to a fifth, in their midst addressing them. Moreover the writing on this page (an explanation of a disk shaped instrument) is certainly not in the same style as we find constantly used by Leonardo after the year\_ 1489.

\_It may be incidentally remarked that no sketches are known for the portrait of "Mona Lisa", nor do the MS. notes ever allude to it, though according to Vasari the master had it in hand for fully four years.

Leonardo's cartoon for the picture of the battle of Anghiari has shared the fate of the rival work, Michaelangelo's "Bathers summoned to Battle". Both have been lost in some wholly inexplicable manner. I cannot here enter into the remarkable history of this work; I can only give an account of what has been preserved to us of Leonardo's scheme and preparations for executing it. The extent of the material in studies and drawings was till now quite unknown. Their publication here may give some adequate idea of the grandeur of this famous work. The text given as No.\_ 669 \_contains a description of the particulars of the battle, but for the reasons given in the note to this text, I must abandon the idea of taking this passage as the basis of my attempt to reconstruct the picture as the artist conceived and executed it.

I may here remind the reader that Leonardo prepared the cartoon in the Sala del Papa of Santa Maria Novella at Florence and worked there from the end of October 1503 till February 1504, and then was busied with the painting in the Sala del Consiglio in the Palazzo della Signoria, till the work was interrupted at the end of May 1506. (See Milanese's note to Vasari pp. 43--45 Vol. IV ed. 1880.) Vasari, as is well known, describes only one scene or episode of the cartoon--the Battle for the Standard in the foreground of the composition, as it would seem; and this only was ever finished as a mural decoration in the Sala del Consiglio. This portion of the composition is familiar to all from the disfigured copy engraved by Edelinck. Mariette had already very acutely observed that Edelinck must surely have worked from a Flemish copy of the picture. There is in the Louvre a drawing by Rubens (No. 565) which also represents four horsemen fighting round a standard and which agrees with Edelinck's engraving, but the engraving reverses the drawing. An earlier Flemish drawing, such as may have served as the model for both Rubens and Edelinck, is in the Uffizi collection (see Philpots's Photograph, No. 732). It seems to be a work of the second half of the XVIth century, a time when both the picture and the cartoon had already been destroyed. It is apparently the production of a not very skilled hand. Raphael Trichet du Fresne, 1651, mentions that a small picture by Leonardo himself of the Battle of the Standard was then extant in the Tuileries; by this he probably means the painting on panel which is now in the possession of Madame



Timbal in Paris, and which has lately been engraved by Haussoullier as a work by Leonardo. The picture, which is very carefully painted, seems to me however to be the work of some unknown Florentine painter, and probably executed within the first ten years of the XVIth century. At the same time, it would seem to be a copy not from Leonardo's cartoon, but from his picture in the Palazzo della Signoria; at any rate this little picture, and the small Flemish drawing in Florence are the oldest finished copies of this episode in the great composition of the Battle of Anghiari.

In his Life of Raphael, Vasari tells us that Raphael copied certain works of Leonardo's during his stay in Florence. Raphael's first visit to Florence lasted from the middle of October 1504 till July 1505, and he revisited it in the summer of 1506. The hasty sketch, now in the possession of the University of Oxford and reproduced on page 337 also represents the Battle of the Standard and seems to have been made during his first stay, and therefore not from the fresco but from the cartoon; for, on the same sheet we also find, besides an old man's head drawn in Leonardo's style, some studies for the figure of St. John the Martyr which Raphael used in 1505 in his great fresco in the Church of San Severo at Perugia.

Of Leonardo's studies for the Battle of Anghiari I must in the first place point to five, on three of which--Pl. LII 2, Pl. LIII, Pl. LVI--we find studies for the episode of the Standard. The standard bearer, who, in the above named copies is seen stooping, holding on to the staff across his shoulder, is immediately recognisable as the left-hand figure in Raphael's sketch, and we find it in a similar attitude in Leonardo's pen and ink drawing in the British Museum--Pl. LII, 2--the lower figure to the right. It is not difficult to identify the same figure in two more complicated groups in the pen and ink drawings, now in the Accademia at Venice--Pl. LIII, and Pl. LIV--where we also find some studies of foot soldiers fighting. On the sheet in the British Museum--Pl. LII, 2--we find, among others, one group of three horses galloping forwards: one horseman is thrown and protects himself with his buckler against the lance thrusts of two others on horseback, who try to pierce him as they ride past. The same action is repeated, with some variation, in two sketches in pen and ink on a third sheet, in the Accademia at Venice, Pl. LV; a coincidence which suggests the probability of such an incident having actually been represented on the cartoon. We are not, it is true, in a position to declare with any certainty which of these three dissimilar sketches may have been the nearest to the group finally adopted in executing the cartoon.

With regard, however, to one of the groups of horsemen it is possible to determine with perfect certainty not only which arrangement was preferred, but the position it occupied in the composition. The group of horsemen on Pl. LVII is a drawing in black chalk at Windsor, which is there attributed to Leonardo, but which appears to me to be the work of Cesare da Sesto, and the Commendatore Giov. Morelli supports me in this view. It can hardly be doubted that da Sesto, as a pupil of Leonardo's, made this

drawing from his master's cartoon, if we compare it with the copy made by Raphael--here reproduced, for just above the fighting horseman in Raphael's copy it is possible to detect a horse which is seen from behind, going at a slower pace, with his tail flying out to the right and the same horse may be seen in the very same attitude carrying a dimly sketched rider, in the foreground of Cesare da Sesto's drawing.\_

\_If a very much rubbed drawing in black chalk at Windsor--Pl. LVI--is, as it appears to be, the reversed impression of an original drawing, it is not difficult to supplement from it the portions drawn by Cesare da Sesto. Nay, it may prove possible to reconstruct the whole of the lost cartoon from the mass of materials we now have at hand which we may regard as the nucleus of the composition. A large pen and ink drawing by Raphael in the Dresden collection, representing three horsemen fighting, and another, by Cesare da Sesto, in the Uffizi, of light horsemen fighting are a further contribution which will help us to reconstruct it.\_

\_The sketch reproduced on Pl. LV gives a suggestive example of the way in which foot-soldiers may have been introduced into the cartoon as fighting among the groups of horsemen; and I may here take the opportunity of mentioning that, for reasons which it would be out of place to enlarge upon here, I believe the two genuine drawings by Raphael's hand in his "Venetian sketch-book" as it is called--one of a standard bearer marching towards the left, and one of two foot-soldiers armed with spears and fighting with a horseman--to be undoubtedly copies from the cartoon of the Battle of Anghiari.\_

\_Leonardo's two drawings, preserved in the museum at Buda-Pesth and reproduced on pages 338 and 339 are preliminary studies for the heads of fighting warriors. The two heads drawn in black chalk (pg. 338) and the one seen in profile, turned to the left, drawn in red chalk (pg. 339), correspond exactly with those of two horsemen in the scene of the fight round the standard as we see them in Madame Timbal's picture and in the other finished copies. An old copy of the last named drawing by a pupil of Leonardo is in MS. C. A. 187b; 561b (See Saggio, Tav. XXII). Leonardo used to make such finished studies of heads as those, drawn on detached sheets, before beginning his pictures from his drawings--compare the preparatory studies for the fresco of the Last Supper, given on Pl. XLVII and Pl. L. Other drawings of heads, all characterised by the expression of vehement excitement that is appropriate to men fighting, are to be seen at Windsor (No. 44) and at the Accademia at Venice (IV, 13); at the back of one of the drawings at Buda-Pesth there is the bust of a warrior carrying a spear on his left shoulder, holding up the left arm (See Csatakepek a XVI--lk Szazadbol osszeallitotta Pvlszky Karoly). These drawings may have been made for other portions of the cartoon, of which no copies exist, and thus we are unable to identify these preparatory drawings. Finally I may add that a sketch of fighting horse and foot soldiers, formerly in the possession of M. Thiers and published by Charles Blanc in his "Vies des Peintres" can hardly be accepted as genuine. It is not to be found, as I am

informed, among the late President's property, and no one appears to know where it now is.\_

\_An attempted reconstruction of the Cartoon, which is not only unsuccessful but perfectly unfounded, is to be seen in the lithograph by Bergeret, published in Charles Blanc's "Vies des peintres" and reprinted in "The great Artists. L. da Vinci", p. 80. This misleading pasticcio may now be rejected without hesitation.\_

\_There are yet a few original drawings by Leonardo which might be mentioned here as possibly belonging to the cartoon of the Battle; such as the pen and ink sketches on Pl. XXI and on Pl. XXXVIII, No. 3, but we should risk too wide a departure from the domain of ascertained fact.\_

\_With regard to the colours and other materials used by Leonardo the reader may be referred to the quotations from the accounts for the picture in question given by Milanese in his edition of Vasari (Vol. IV, p. 44, note) where we find entries of a similar character to those in Leonardo's note books for the year 1505; S. K. M. 12 (see No. 636).\_

\_That Leonardo was employed in designing decorations and other preparations for high festivals, particularly for the court of Milan, we learn not only from the writings of his contemporaries but from his own incidental allusions; for instance in MS. C. 15b (1), l. 9. In the arrangement of the texts referring to this I have placed those first, in which historical personages are named--Nos. 670-674. Among the descriptions of Allegorical subjects two texts lately found at Oxford have been included, Nos. 676 and 677. They are particularly interesting because they are accompanied by large sketches which render the meaning of the texts perfectly clear. It is very intelligible that in other cases, where there are no illustrative sketches, the notes must necessarily remain obscure or admit of various interpretations. The literature of the time affords ample evidence of the use of such allegorical representations, particularly during the Carnival and in Leonardo's notes we find the Carnival expressly mentioned--Nos. 685 and 704. Vasari in his Life of Pontormo, particularly describes that artist's various undertakings for Carnival festivities. These very graphic descriptions appear to me to throw great light in more ways than one on the meaning of Leonardo's various notes as to allegorical representations and also on mottoes and emblems--Nos. 681-702. In passing judgment on the allegorical sketches and emblems it must not be overlooked that even as pictures they were always accompanied by explanations in words. Several finished drawings of allegorical compositions or figures have been preserved, but as they have no corresponding explanation in the MSS. they had no claim to be reproduced here. The female figure on Pl. XXVI may perhaps be regarded as a study for such an allegorical painting, of which the purport would have been explained by an inscription.\_

On Madonna pictures.

[In the autumn of] 1478 I began the two Madonna [pictures].

[Footnote: Photographs of this page have been published by BRAUN, No. 439, and PHILPOT, No. 718.

1. *\_Incominciai\_*. We have no other information as to the two pictures of the Madonna here spoken of. As Leonardo here tells us that he had begun two Madonnas at the same time, the word '*\_incominciai\_*' may be understood to mean that he had begun at the same time preparatory studies for two pictures to be painted later. If this is so, the non-existence of the pictures may be explained by supposing that they were only planned and never executed. I may here mention a few studies for pictures of the Madonna which probably belong to this early time; particularly a drawing in silver-point on bluish tinted paper at Windsor--see Pl. XL, No. 3--, a drawing of which the details have almost disappeared in the original but have been rendered quite distinct in the reproduction; secondly a slight pen and ink sketch in, the Codex VALLARDI, in the Louvre, fol. 64, No. 2316; again a silver point drawing of a Virgin and child drawn over again with the pen in the His de la Salle collection also in the Louvre, No. 101. (See Vicomte BOTH DE TAUZIA, *\_Notice des dessins de la collection His de la Salle, exposes au Louvre\_*. Paris 1881, pp. 80, 81.) This drawing is, it is true, traditionally ascribed to Raphael, but the author of the catalogue very justly points out its great resemblance with the sketches for Madonnas in the British Museum which are indisputably Leonardo's. Some of these have been published by Mr. HENRY WALLIS in the *Art Journal*, New Ser. No. 14, Feb. 1882. If the non-existence of the two pictures here alluded to justifies my hypothesis that only studies for such pictures are meant by the text, it may also be supposed that the drawings were made for some comrade in VERROCCHIO'S atelier. (See VASARI, Sansoni's ed. Florence 1880. Vol. IV, p. 564): "*\_E perche a Lorenzo piaceva fuor di modo la maniera di Lionardo, la seppe cosi bene imitare, che niuno fu che nella pulitezza e nel finir l'opere con diligenza l'imitasse piø di lui\_*." Leonardo's notes give me no opportunity of discussing the pictures executed by him in Florence, before he moved to Milan. So the studies for the unfinished picture of the Adoration of the Magi--in the Uffizi, Florence--cannot be described here, nor would any discussion about the picture in the Louvre "*\_La Vierge aux Rochers\_*" be appropriate in the absence of all allusion to it in the MSS. Therefore, when I presently add a few remarks on this painting in explanation of the Master's drawings for it, it will be not merely with a view to facilitate critical researches about the picture now in the National Gallery, London, which by some critics has been pronounced to be a replica of the Louvre picture, but also because I take this opportunity of publishing several finished studies of the Master's which, even if they were not made in Florence but later in Milan, must have been prior to the painting of the Last Supper. The original picture in Paris is at present so disfigured by dust and varnish that the

current reproductions in photography actually give evidence more of the injuries to which the picture has been exposed than of the original work itself. The wood-cut given on p. 344, is only intended to give a general notion of the composition. It must be understood that the outline and expression of the heads, which in the picture is obscured but not destroyed, is here altogether missed. The facsimiles which follow are from drawings which appear to me to be studies for "La Vierge aux Rochers."

1. A drawing in silver point on brown toned paper of a woman's head looking to the left. In the Royal Library at Turin, apparently a study from nature for the Angel's head (Pl. XLII).

2. A study of drapery for the left leg of the same figure, done with the brush, Indian ink on greenish paper, the lights heightened with white.

The original is at Windsor, No. 223. The reproduction Pl. XLIII is defective in the shadow on the upper part of the thigh, which is not so deep as in the original; it should also be observed that the folds of the drapery near the hips are somewhat altered in the finished work in the Louvre, while the London copy shows a greater resemblance to this study in that particular.

3. A study in red chalk for the bust of the Infant Christ--No. 3 in the Windsor collection (Pl. XLIV). The well-known silver-point drawing on pale green paper, in the Louvre, of a boy's head (No. 363 in REISET, Notice des dessins, Ecoles d'Italie) seems to me to be a slightly altered copy, either from the original picture or from this red chalk study.

4. A silver-point study on greenish paper, for the head of John the Baptist, reproduced on p. 342. This was formerly in the Codex Vallardi and is now exhibited among the drawings in the Louvre. The lights are, in the original, heightened with white; the outlines, particularly round the head and ear, are visibly restored.

There is a study of an outstretched hand--No. 288 in the Windsor collection--which was published in the Grosvenor Gallery Publication, 1878, simply under the title of: "No. 72 Study of a hand, pointing" which, on the other hand, I regard as a copy by a pupil. The action occurs in the kneeling angel of the Paris picture and not in the London copy.

These four genuine studies form, I believe, a valuable substitute in the absence of any MS. notes referring to the celebrated Paris picture.]

Bernardo di Bandino's Portrait.

664.

A tan-coloured small cap, A doublet of black serge, A black jerkin

lined A blue coat lined, with fur of foxes' breasts, and the collar of the jerkin covered with black and white stippled velvet Bernardo di Bandino Baroncelli; black hose.

[Footnote: These eleven lines of text are by the side of the pen and ink drawing of a man hanged--Pl. LXII, No. 1. This drawing was exhibited in 1879 at the *Ecole des Beaux-Arts* in Paris and the compilers of the catalogue amused themselves by giving the victim's name as follows: "*Un pendu, vetu d'une longue robe, les mains liØes sur le dos ... Bernardo di Bendino Barontigni, marchand de pantalons*" (see *Catalogue descriptif des Dessins de Mailres anciens exposes a l'Ecole des Beaux Arts*, Paris 1879; No. 83, pp. 9-10). Now, the criminal represented here, is none other than Bernardino di Bandino Baroncelli the murderer of Giuliano de'Medici, whose name as a coadjutor in the conspiracy of the Pazzi has gained a melancholy notoriety by the tragedy of the 26th April 1478. Bernardo was descended from an ancient family and the son of the man who, under King Ferrante, was President of the High Court of Justice in Naples. His ruined fortunes, it would seem, induced him to join the Pazzi; he and Francesco Pazzi were entrusted with the task of murdering Giuliano de'Medici on the fixed day. Their victim not appearing in the cathedral at the hour when they expected him, the two conspirators ran to the palace of the Medici and induced him to accompany them. Giuliano then took his place in the chancel of the Cathedral, and as the officiating priest raised the Host--the sign agreed upon--Bernardo stabbed the unsuspecting Giuliano in the breast with a short sword; Giuliano stepped backwards and fell dead. The attempt on Lorenzo's life however, by the other conspirators at the same moment, failed of success. Bernardo no sooner saw that Lorenzo tried to make his escape towards the sacristy, than he rushed upon him, and struck down Francesco Nori who endeavoured to protect Lorenzo. How Lorenzo then took refuge behind the brazen doors of the sacristy, and how, as soon as Giuliano's death was made known, the further plans of the conspirators were defeated, while a terrible vengeance overtook all the perpetrators and accomplices, this is no place to tell. Bernardo Bandini alone seemed to be favoured by fortune; he hid first in the tower of the Cathedral, and then escaped undiscovered from Florence. Poliziano, who was with Lorenzo in the Cathedral, says in his *Conjuracionis Pactianae Commentarium*: "*Bandinus fugitans in Tiphernatem incidit, a quo in aciem receptus Senas pervenit*." And Gino Capponi in summing up the reports of the numerous contemporary narrators of the event, says: "*Bernardo Bandini ricoverato in Costantinopoli, fu per ordine del Sultano preso e consegnato a un Antonio di Bernardino dei Medici, che Lorenzo aveva mandato apposta in Turchia: così era grande la potenza di quest' uomo e grande la voglia di farne mostra e che non restasse in vita chi aveagli ucciso il fratello, fu egli applicato appena giunto*" (*Storia della Repubblica di Firenze II*, 377, 378). Details about the dates may be found in the *Chronichetta di Belfredello Strinati Alfieri*: "*Bernardo di Bandino Bandini sopradetto ne venne preso da Gostantinopoti a dì 14. Dicembre 1479 e disaminato, che fu al Bargello, fu impiccato alle finestre di detto Bargello allato alla Doana a dì 29. Dicembre MCCCCLXXIX che pochi dì*

stette\_." It may however be mentioned with reference to the mode of writing the name of the assassin that, though most of his contemporaries wrote Bernardo Bandini, in the *\_Breve Chronicon Caroli Petri de Joanninis\_* he is called Bernardo di Bandini Baroncelli; and, in the *\_Sententiae Domini Matthaei de Toscana\_*, Bernardus Joannis Bandini de Baroncellis, as is written on Leonardo's drawing of him when hanged. Now VASARI, in the life of *\_Andrea del Castagno\_* (Vol. II, 680; ed. Milanese 1878), tells us that in 1478 this painter was commissioned by order of the Signoria to represent the members of the Pazzi conspiracy as traitors, on the facade of the Palazzo del Podestà-the Bargello. This statement is obviously founded on a mistake, for Andrea del Castagno was already dead in 1457. He had however been commissioned to paint Rinaldo degli Albizzi, when declared a rebel and exiled in 1434, and his adherents, as hanging head downwards; and in consequence he had acquired the nickname of Andrea degl' Impiccati. On the 21st July 1478 the Council of Eight came to the following resolution: "*\_item servatis etc. deliberaverunt et santiaverunt Sandro Botticelli pro ejus labore in pingendo proditores flor. quadraginta largos\_*" (see G. MILANESI, *\_Arch. star. VI\_* (1862) p. 5 note.)

As has been told, Giuliano de' Medici was murdered on the 26th April 1478, and we see by this that only three months later Botticelli was paid for his painting of the "*\_proditores\_*". We can however hardly suppose that all the members of the conspiracy were depicted by him in fresco on the facade of the palace, since no fewer than eighty had been condemned to death. We have no means of knowing whether, besides Botticelli, any other painters, perhaps Leonardo, was commissioned, when the criminals had been hanged in person out of the windows of the Palazzo del Podestato represent them there afterwards in effigy in memory of their disgrace. Nor do we know whether the assassin who had escaped may at first not have been provisionally represented as hanged in effigy. Now, when we try to connect the historical facts with this drawing by Leonardo reproduced on Pl. LXII, No. I, and the full description of the conspirator's dress and its colour on the same sheet, there seems to be no reasonable doubt that Bernardo Bandini is here represented as he was actually hanged on December 29th, 1479, after his capture at Constantinople. The dress is certainly not that in which he committed the murder. A long furred coat might very well be worn at Constantinople or at Florence in December, but hardly in April. The doubt remains whether Leonardo described Bernardo's dress so fully because it struck him as remarkable, or whether we may not rather suppose that this sketch was actually made from nature with the intention of using it as a study for a wall painting to be executed. It cannot be denied that the drawing has all the appearance of having been made for this purpose. Be this as it may, the sketch under discussion proves, at any rate, that Leonardo was in Florence in December 1479, and the note that accompanies it is valuable as adding one more characteristic specimen to the very small number of his MSS. that can be proved to have been written between 1470 and 1480.]

Notes on the Last Supper (665-668).

665.

One who was drinking and has left the glass in its position and turned his head towards the speaker.

Another, twisting the fingers of his hands together turns with stern brows to his companion [6]. Another with his hands spread open shows the palms, and shrugs his shoulders up his ears making a mouth of astonishment [8].

[9] Another speaks into his neighbour's ear and he, as he listens to him, turns towards him to lend an ear [10], while he holds a knife in one hand, and in the other the loaf half cut through by the knife. [13] Another who has turned, holding a knife in his hand, upsets with his hand a glass on the table [14].

[Footnote 665, 666: In the original MS. there is no sketch to accompany these passages, and if we compare them with those drawings made by Leonardo in preparation for the composition of the picture--Pl. XLV, XLVI--, (compare also Pl. LII, 1 and the drawings on p. 297) it is impossible to recognise in them a faithful interpretation of the whole of this text; but, if we compare these passages with the finished picture (see p. 334) we shall see that in many places they coincide. For instance, compare No. 665, 1. 6--8, with the fourth figure on the right hand of Christ. The various actions described in lines 9--10, 13--14 are to be seen in the group of Peter, John and Judas; in the finished picture however it is not a glass but a salt cellar that Judas is upsetting.]

666.

Another lays his hand on the table and is looking. Another blows his mouthful. [3] Another leans forward to see the speaker shading his eyes with his hand. [5] Another draws back behind the one who leans forward, and sees the speaker between the wall and the man who is leaning [Footnote: 6. *\_chinato\_*. I have to express my regret for having misread this word, written *\_cinato\_* in the original, and having altered it to *\_"ciclo"\_* when I first published this text, in 'The Academy' for Nov. 8, 1879 immediately after I had discovered it, and subsequently in the small biography of Leonardo da Vinci (Great Artists) p. 29.].

[Footnote: In No. 666. Line 1 must refer to the furthest figure on the left; 3, 5 and 6 describe actions which are given to the group of disciples on the left hand of Christ.]

667.

CHRIST.

Count Giovanni, the one with the Cardinal of Mortaro.



[Footnote: As this note is in the same small Manuscript as the passage here immediately preceding it, I may be justified in assuming that Leonardo meant to use the features of the person here named as a suitable model for the figure of Christ. The celebrated drawing of the head of Christ, now hanging in the Brera Gallery at Milan, has obviously been so much restored that it is now impossible to say, whether it was ever genuine. We have only to compare it with the undoubtedly genuine drawings of heads of the disciples in Pl. XLVII, XLVIII and L, to admit that not a single line of the Milan drawing in its present state can be by the same hand.]

668.

Philip, Simon, Matthew, Thomas, James the Greater, Peter, Philip, Andrew, Bartholomew.

[Footnote: See Pl. XLVI. The names of the disciples are given in the order in which they are written in the original, from right to left, above each head. The original drawing is here slightly reduced in scale; it measures 39 centimetres in length by 26 in breadth.]

669.

On the battle of Anghiari.

Florentine

Neri di Gino Capponi

Bernardetto de' Medici

Micheletto,

Niccolo da Pisa

Conte Francesco

Pietro Gian Paolo

Guelfo Orsino,

Messer Rinaldo degli

Albizzi

Begin with the address of Niccolo Piccinino to the soldiers and the banished Florentines among whom are Messer Rinaldo degli Albizzi and other Florentines. Then let it be shown how he first mounted on horseback in armour; and the whole army came after him--40 squadrons of cavalry, and 2000 foot soldiers went with him. Very early in the morning the Patriarch went up a hill to reconnoitre the country, that is the hills, fields and the valley watered by a river; and from thence he beheld Niccolo Piccinino coming from Borgo San Sepolcro with his people, and with a great dust; and perceiving them he returned to the camp of his own people and addressed them. Having spoken he prayed to God with clasped hands, when there appeared a cloud in which Saint Peter appeared and spoke to the Patriarch.--500 cavalry were sent forward by the Patriarch to hinder or check the rush of the enemy. In the foremost troop Francesco the son of Niccolo Piccinino [24] was the first to attack the bridge which was held by the Patriarch and the Florentines. Beyond the bridge to his left he sent forward some infantry to engage ours, who drove them

back, among whom was their captain Micheletto [29] whose lot it was to be that day at the head of the army. Here, at this bridge there is a severe struggle; our men conquer and the enemy is repulsed. Here Guido and Astorre, his brother, the Lord of Faenza with a great number of men, re-formed and renewed the fight, and rushed upon the Florentines with such force that they recovered the bridge and pushed forward as far as the tents. But Simonetto advanced with 600 horse, and fell upon the enemy and drove them back once more from the place, and recaptured the bridge; and behind him came more men with 2000 horse soldiers. And thus for a long time they fought with varying fortune. But then the Patriarch, in order to divert the enemy, sent forward Niccolo da Pisa [44] and Napoleone Orsino, a beardless lad, followed by a great multitude of men, and then was done another great feat of arms. At the same time Niccolo Piccinino urged forward the remnant of his men, who once more made ours give way; and if it had not been that the Patriarch set himself at their head and, by his words and deeds controlled the captains, our soldiers would have taken to flight. The Patriarch had some artillery placed on the hill and with these he dispersed the enemy's infantry; and the disorder was so complete that Niccolo began to call back his son and all his men, and they took to flight towards Borgo. And then began a great slaughter of men; none escaped but the foremost of those who had fled or who hid themselves. The battle continued until sunset, when the Patriarch gave his mind to recalling his men and burying the dead, and afterwards a trophy was erected.

[Footnote: 669. This passage does not seem to me to be in Leonardo's hand, though it has hitherto been generally accepted as genuine. Not only is the writing unlike his, but the spelling also is quite different. I would suggest that this passage is a description of the events of the battle drawn up for the Painter by order of the Signoria, perhaps by some historian commissioned by them, to serve as a scheme or programme of the work. The whole tenor of the style seems to me to argue in favour of this theory; and besides, it would be in no way surprising that such a document should have been preserved among Leonardo's autographs.]

Allegorical representations referring to the duke of Milan (670-673).

670.

Ermine with blood Galeazzo, between calm weather and a representation of a tempest.

[Footnote: 670. Only the beginning of this text is legible; the writing is much effaced and the sense is consequently obscure. It seems to refer like the following passage to an allegorical picture.]

671.

Il Moro with spectacles, and Envy depicted with False Report and Justice black for il Moro.

Labour as having a branch of vine [\_or\_ a screw] in her hand.

672.

Il Moro as representing Good Fortune, with hair, and robes, and his hands in front, and Messer Gualtieri taking him by the robes with a respectful air from below, having come in from the front [5].

Again, Poverty in a hideous form running behind a youth. Il Moro covers him with the skirt of his robe, and with his gilt sceptre he threatens the monster.

A plant with its roots in the air to represent one who is at his last;--a robe and Favour.

Of tricks [\_or\_ of magpies] and of burlesque poems [\_or\_ of starlings].

Those who trust themselves to live near him, and who will be a large crowd, these shall all die cruel deaths; and fathers and mothers together with their families will be devoured and killed by cruel creatures.

[Footnote: 1--10 have already been published by Amoretti in Memorie Storiche cap. XII. He adds this note with regard to Gualtieri: "A questo M. Gualtieri come ad uomo generoso e benefico scrive il Bellincioni un Sonetto (pag, 174) per chiedergli un piacere; e 'l Tantio rendendo ragione a Lodovico il Moro, perche pubblicasse le Rime del Bellincioni; ciòhammi imposto, gli dice: l'humano fidele, prudente e sollicito executore delli tuoi comandamenti Gualtero, che fa in tutte le cose ove tu possi far utile, ogni studio vi metti." A somewhat mysterious and evidently allegorical composition--a pen and ink drawing--at Windsor, see PL LVIII, contains a group of figures in which perhaps the idea is worked out which is spoken of in the text, lines 1-5.]

673.

He was blacker than a hornet, his eyes were as red as a burning fire and he rode on a tall horse six spans across and more than 20 long with six giants tied up to his saddle-bow and one in his hand which he gnawed with his teeth. And behind him came boars with tusks sticking out of their mouths, perhaps ten spans.

Allegorical representations (674--678).

674.

Above the helmet place a half globe, which is to signify our hemisphere, in the form of a world; on which let there be a peacock,

richly decorated, and with his tail spread over the group; and every ornament belonging to the horse should be of peacock's feathers on a gold ground, to signify the beauty which comes of the grace bestowed on him who is a good servant.

On the shield a large mirror to signify that he who truly desires favour must be mirrored in his virtues.

On the opposite side will be represented Fortitude, in like manner in her place with her pillar in her hand, robed in white, to signify ... And all crowned; and Prudence with 3 eyes. The housing of the horse should be of plain cloth of gold closely sprinkled with peacock's eyes, and this holds good for all the housings of the horse, and the man's dress. And the man's crest and his neck-chain are of peacock's feathers on golden ground.

On the left side will be a wheel, the centre of which should be attached to the centre of the horse's hinder thigh piece, and in the centre Prudence is seen robed in red, Charity sitting in a fiery chariot and with a branch of laurel in her hand, to signify the hope which comes of good service.

[21] Messer Antonio Grimani of Venice companion of Antonio Maria [23].

[Footnote: \_Messer Antonio Gri\_. His name thus abbreviated is, there can be no doubt, Grimani. Antonio Grimani was the famous Doge who in 1499 commanded the Venetian fleet in battle against the Turks. But after the abortive conclusion of the expedition--Ludovico being the ally of the Turks who took possession of Friuli--, Grimani was driven into exile; he went to live at Rome with his son Cardinal Domenico Grimani. On being recalled to Venice he filled the office of Doge from 1521 to 1523. \_Antonio Maria\_ probably means Antonio Maria Grimani, the Patriarch of Aquileia.]

675.

Fame should be depicted as covered all over with tongues instead of feathers, and in the figure of a bird.

676.

Pleasure and Pain represent as twins, since there never is one without the other; and as if they were united back to back, since they are contrary to each other.

[6] Clay, gold.

[Footnote: 7. \_oro. fango\_: gold, clay. These words stand below the allegorical figure.]

If you take Pleasure know that he has behind him one who will deal you Tribulation and Repentance.

[9] This represents Pleasure together with Pain, and show them as twins because one is never apart from the other. They are back to back because they are opposed to each other; and they exist as contraries in the same body, because they have the same basis, inasmuch as the origin of pleasure is labour and pain, and the various forms of evil pleasure are the origin of pain. Therefore it is here represented with a reed in his right hand which is useless and without strength, and the wounds it inflicts are poisoned. In Tuscany they are put to support beds, to signify that it is here that vain dreams come, and here a great part of life is consumed. It is here that much precious time is wasted, that is, in the morning, when the mind is composed and rested, and the body is made fit to begin new labours; there again many vain pleasures are enjoyed; both by the mind in imagining impossible things, and by the body in taking those pleasures that are often the cause of the failing of life. And for these reasons the reed is held as their support.

[Footnote: 676. The pen and ink drawing on Pl. LIX belongs to this passage.]

[Footnote: 8. *\_tribolazione\_*. In the drawing caltrops may be seen lying in the old man's right hand, others are falling and others again are shewn on the ground. Similar caltrops are drawn in MS. Tri. p. 98 and underneath them, as well as on page 96 the words *\_triboli di ferro\_* are written. From the accompanying text it appears that they were intended to be scattered on the ground at the bottom of ditches to hinder the advance of the enemy. Count Giulio Porro who published a short account of the Trivulzio MS. in the "*\_Archivio Storico Lombardo\_*", Anno VIII part IV (Dec. 31, 1881) has this note on the passages treating of "*\_triboli\_*": "*\_E qui aggiungerò che anni sono quando venne fabbricata la nuova cavallerizza presso il castello di Milano, ne furono trovati due che io ho veduto ed erano precisamente quali si trovano descritti e disegnati da Leonardo in questo codice\_*".

There can therefore be no doubt that this means of defence was in general use, whether it were originally Leonardo's invention or not. The play on the word "*\_tribolazione\_*", as it occurs in the drawing at Oxford, must then have been quite intelligible.]

[Footnote: 9--22. These lines, in the original, are written on the left side of the page and refer to the figure shown on Pl. LXI. Next to it is placed the group of three figures given in Pl. LX No. I. Lines 21 and 22, which are written under it, are the only explanation given.]

Evil-thinking is either Envy or Ingratitude.

677.

Envy must be represented with a contemptuous motion of the hand towards heaven, because if she could she would use her strength

against God; make her with her face covered by a mask of fair seeming; show her as wounded in the eye by a palm branch and by an olive-branch, and wounded in the ear by laurel and myrtle, to signify that victory and truth are odious to her. Many thunderbolts should proceed from her to signify her evil speaking. Let her be lean and haggard because she is in perpetual torment. Make her heart gnawed by a swelling serpent, and make her with a quiver with tongues serving as arrows, because she often offends with it. Give her a leopard's skin, because this creature kills the lion out of envy and by deceit. Give her too a vase in her hand full of flowers and scorpions and toads and other venomous creatures; make her ride upon death, because Envy, never dying, never tires of ruling. Make her bridle, and load her with divers kinds of arms because all her weapons are deadly.

Toleration.

Intolerable.

No sooner is Virtue born than Envy comes into the world to attack it; and sooner will there be a body without a shadow than Virtue without Envy.

[Footnote: The larger of the two drawings on Pl. LXI is explained by the first 21 lines of this passage. L. 22 and 23, which are written above the space between the two drawings, do not seem to have any reference to either. L. 24-27 are below the allegorical twin figure which they serve to explain.]

678.

When Pluto's Paradise is opened, then there may be devils placed in twelve pots like openings into hell. Here will be Death, the Furies, ashes, many naked children weeping; living fires made of various colours....

679.

John the Baptist  
Saint Augustin  
Saint Peter  
Paul  
Elisabeth  
Saint Clara.  
Bernardino  
Our Lady Louis  
Bonaventura  
Anthony of Padua.  
Saint Francis.  
Francis,  
Anthony, a lily and book;  
Bernardino with the [monogram of] Jesus,  
Louis with 3 fleur de lys on his breast and

the crown at his feet,  
Bonaventura with Seraphim,  
Saint Clara with the tabernacle,  
Elisabeth with a Queen's crown.

[Footnote: 679. The text of the first six lines is written within a square space of the same size as the copy here given. The names are written in the margin following the order in which they are here printed. In lines 7--12 the names of those saints are repeated of whom it seemed necessary to point out the emblems.]

List of drawings.

680.

A head, full face, of a young man  
with fine flowing hair,  
Many flowers drawn from nature,  
A head, full face, with curly hair,  
Certain figures of Saint Jerome,  
[6] The measurements of a figure,  
Drawings of furnaces.  
A head of the Duke,  
[9] many designs for knots,  
4 studies for the panel of Saint Angelo  
A small composition of Girolamo da Fegline,  
A head of Christ done with the pen,  
[13] 8 Saint Sebastians,  
Several compositions of Angels,  
A chalcedony,  
A head in profile with fine hair,  
Some pitchers seen in(?) perspective,  
Some machines for ships,  
Some machines for waterworks,  
A head, a portrait of Atalanta raising her  
face;  
The head of Geronimo da Fegline,  
The head of Gian Francisco Borso,  
Several throats of old women,  
Several heads of old men,  
Several nude figures, complete,  
Several arms, eyes, feet, and positions,  
A Madonna, finished,  
Another, nearly in profile,  
Head of Our Lady ascending into Heaven,  
A head of an old man with long chin,  
A head of a gypsy girl,  
A head with a hat on,  
A representation of the Passion, a cast,  
A head of a girl with her hair gathered in a knot,  
A head, with the brown hair dressed.

[Footnote: 680. This has already been published by AMORETTI \_Memorie

storiche\_ cap. XVI. His reading varies somewhat from that here given, \_e. g.\_ I. 5 and 6. \_Certi Sangirolami in su d'una figura\_; and instead of I. 13. \_Un San Bastiano\_.]

[Footnote: 680. 9. \_Molti disegni di gruppi\_. VASARI in his life of Leonardo (IV, 21, ed. MILANESI 1880) says: "\_OltrechØ perse tempo fino a disegnare\_ gruppi \_di corde fatti con ordine, e che da un capo seguissi tutto il resto fino all' altro, tanto che s'empiesi un tondo; che se ne vede in istampa uno difficilissimo e molto bello, e nel mezzo vi sono queste parole: Leonardus Vinci Accademia\_". \_Gruppi\_ must here be understood as a technical expression for those twisted ornaments which are well known through wood cuts. AMORETTI mentions six different ones in the Ambrosian Library. I am indebted to M. DELABORDE for kindly informing me that the original blocks of these are preserved in his department in the BibliothŁque Nationale in Paris. On the cover of these volumes is a copy from one of them. The size of the original is 23 1/2 centimetres by 26 1/4. The centre portion of another is given on p. 361. G. Govi remarks on these ornaments (\_Saggio\_ p. 22): "\_Codesti gruppi eran probabilmente destinati a servir di modello a ferri da rilegatori per adornar le cartelle degli scolari (?). Fregi somigliantissimi a questi troviamo infatti impressi in oro sui cartoni di vari volumi contemporanei, e li vediam pur figurare nelle lettere iniziali di alcune edizioni del tempo.\_"

Dürer who copied them, omitting the inscription, added to the second impressions his own monogram. In his diary he designates them simply as "\_Die sechs Knoten\_" (see THAUSING, Life of A. Dürer I, 362, 363). In Leonardo's MSS. we find here and there little sketches or suggestions for similar ornaments. Compare too G. MONGERI, \_L'Arte in Milano\_, p. 315 where an ornament of the same character is given from the old decorations of the vaulted ceiling of the Sacristy of S. Maria delle Grazie.]

[Footnote: 680, 17. The meaning in which the word \_coppi\_, literally pitchers, is here used I am unable to determine; but a change to \_copie\_ seems to me too doubtful to be risked.]

681.

Stubborn rigour.  
Doomed rigour.

[Footnote: See Pl. LXII, No. 2, the two upper pen and ink drawings. The originals, in the Windsor collection are slightly washed with colour. The background is blue sky; the plough and the instrument with the compass are reddish brown, the sun is tinted yellow].

682.

Obstacles cannot crush me  
Every obstacle yields to stern resolve  
He who is fixed to a star does not change



his mind.

[Footnote: This text is written to elucidate two sketches which were obviously the first sketches for the drawings reproduced on PL LXII, No. 2.]

683.

Ivy is [a type] of longevity.

[Footnote: In the original there is, near this text, a sketch of a coat wreathed above the waist with ivy.]

684.

Truth the sun.  
falsehood a mask.  
innocence,  
malignity.

Fire destroys falsehood,  
that is sophistry, and  
restores truth, driving out  
darkness.

Fire may be represented as the destroy of  
all sophistry, and as the  
image and demonstration of truth;  
because it is light and drives  
out darkness which conceals  
all essences [or subtle things].

[Footnote: See Pl. LXIII. L. 1-8 are in the middle of the page; 1. 9-14 to the right below; 1. 15-22 below in the middle column. The rest of the text is below the sketches on the left. There are some other passages on this page relating to geometry.]

TRUTH.

Fire destroys all sophistry, that is deceit;  
and maintains truth alone, that is gold.

Truth at last cannot be hidden.  
Dissimulation is of no avail. Dissimulation is  
to no purpose before  
so great a judge.  
Falsehood puts on a mask.  
Nothing is hidden under the sun.

Fire is to represent truth because it  
destroys all sophistry and lies; and the  
mask is for lying and falsehood  
which conceal truth.

685.

Movement will cease before we are  
weary  
of being useful.

Movement will fail sooner than usefulness.  
Death sooner than I am never weary of  
weariness. being useful,  
In serving others I is a motto for carnival.  
cannot do enough. Without fatigue.

No labour is  
sufficient to tire me.

Hands into which  
ducats and precious  
stones fall like snow; they  
never become tired by serving,  
but this service is only for its  
utility and not for our I am never weary  
own benefit. of being useful.

Naturally  
nature has so disposed me.

686.

This shall be placed in the  
hand of Ingratitude.  
Wood nourishes the fire that  
consumes it.

687.

TO REPRESENT INGRATITUDE.

When the sun appears  
which dispels darkness in  
general, you put out the  
light which dispelled it  
for you in particular  
for your need and convenience.

688.

On this side Adam and Eve on the other;  
O misery of mankind, of how many things do  
you make yourself the slave for money!

[Footnote: See Pl. LXIV. The figures of Adam and Eve in the clouds  
here alluded to would seem to symbolise their superiority to all

earthly needs.]

689.

Thus are base unions sundered.

[Footnote: A much blurred sketch is on the page by this text. It seems to represent an unravelled plait or tissue.]

690.

Constancy does not begin, but is that  
which perseveres.

[Footnote: A drawing in red chalk, also rubbed, which stands in the original in the middle of this text, seems to me to be intended for a sword hilt, held in a fist.]

691.

Love, Fear, and Esteem,--  
Write these on three stones. Of servants.

692.

Prudence Strength.

693.

Fame alone raises herself to Heaven,  
because virtuous things are in favour with God.

Disgrace should be represented upside  
down, because all her deeds are contrary to  
God and tend to hell.

694.

Short liberty.

695.

Nothing is so much to be feared as Evil  
Report.  
This Evil Report is born of life.

696.

Not to disobey.

697.

A felled tree which is shooting

again.

I am still hopeful.  
A falcon,  
Time.

[Footnote: I. Albero tagliato. This emblem was displayed during the Carnival at Florence in 1513. See VASARI VI, 251, ed. MILANESI 1881. But the coincidence is probably accidental.]

698.

Truth here makes Falsehood torment  
lying tongues.

699.

Such as harm is when it hurts me not,  
is good which avails me not.

[Footnote: See PI. LX, No. 2. Compare this sketch with that on PI. LXII, No. 2. Below the two lines of the text there are two more lines: li gøchi (giunchi) che ritØgòle paglucole (pagliucole) chelli (che li) anniegano.]

700.

He who offends others, does not secure himself.

[Footnote: See PI. LX, No. 3.]

701.

Ingratitude.

[Footnote: See PI. LX, No. 4. Below the bottom sketches are the unintelligible words "sta stilli." For "Ingratitudo" compare also Nos. 686 and 687.]

702.

One's thoughts turn towards Hope.

[Footnote: 702. By the side of this passage is a sketch of a cage with a bird sitting in it.]

Ornaments and Decorations for feasts (703-705).

703.

A bird, for a comedy.

[Footnote: The biographies say so much, and the author's notes say

so little of the invention attributed to Leonardo of making artificial birds fly through the air, that the text here given is of exceptional interest from being accompanied by a sketch. It is a very slight drawing of a bird with outspread wings, which appears to be sliding down a stretched string. Leonardo's flying machines and his studies of the flight of birds will be referred to later.]

704.

#### A DRESS FOR THE CARNIVAL.

To make a beautiful dress cut it in thin cloth and give it an odoriferous varnish, made of oil of turpentine and of varnish in grain, with a pierced stencil, which must be wetted, that it may not stick to the cloth; and this stencil may be made in a pattern of knots which afterwards may be filled up with black and the ground with white millet.[Footnote 7: The grains of black and white millet would stick to the varnish and look like embroidery.]

[Footnote: Ser Giuliano, da Vinci the painter's brother, had been commissioned, with some others, to order and to execute the garments of the Allegorical figures for the Carnival at Florence in 1515--16; VASARI however is incorrect in saying of the Florentine Carnival of 1513: "\_equelli che feciono ed ordinarono gli abiti delle figure furono Ser Piero da Vinci, padre di Lonardo, e Bernardino di Giordano, bellissimi ingegni\_" (See MILANESI'S ed. Voi. VI, pg. 251.)]

705.

Snow taken from the high peaks of mountains might be carried to hot places and let to fall at festivals in open places at summer time.

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