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 braccia 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.

Heigh 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 c 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. Yhe 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 dirivative 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 1/2 [Footnote 31: passa per 6 1/2 (passes through 6 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.

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 e f and m e, is a simple shadow pfoduced as at e h and m g, while no such simple shadow is produced at the other two intersections c d made by the very same compound shadows?

ANSWER.

Compound shadow 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 a b; 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 x b, and the shadow s b, but the intersection m is produced by the light a