which causes the shadow s a, and the shadow x a.

But if you uncover both the lights a b, then you get the two shadows n m both at once, and besides these, two other, simple shadows are produced at r o 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 PI. 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 lowly 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; c m and c n 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 n o. 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.