338.

A man when he lies down is reduced to 1/9 of his height.

339.

The opening of the ear, the joint of the shoulder, that of the hip and the ancle are in perpendicular lines; a n is equal to m o.

[Footnote: See Pl. XVI, No. 2, the upper sketch.]

340.

From the chin to the roots of the hair is 1/10 of the whole figure. From the joint of the palm of the hand to the tip of the longest finger is 1/10. From the chin to the top of the head 1/8; and from the pit of the stomach to the top of the breast is 1/6, and from the pit below the breast bone to the top of the head 1/4. From the chin to the nostrils 1/3 Part of the face, the same from the nostrils to the brow and from the brow to the roots of the hair, and the foot is 1/6, the elbow 1/4, the width of the shoulders 1/4.

341.

The width of the shoulders is 1/4 of the whole. From the joint of the shoulder to the hand is 1/3, from the parting of the lips to

below the shoulder-blade is one foot.

The greatest thickness of a man from the breast to the spine is one 8th of his height and is equal to the space between the bottom of the chin and the top of the head.

The greatest width is at the shoulders and goes 4.

The torso from the front and back.

342.

The width of a man under the arms is the same as at the hips.

A man's width across the hips is equal to the distance from the top of the hip to the bottom of the buttock, when a man stands equally balanced on both feet; and there is the same distance from the top of the hip to the armpit. The waist, or narrower part above the hips will be half way between the arm pits and the bottom of the buttock.

[Footnote: The lower sketch Pl. XVI, No. 2, is drawn by the side of line 1.]

Vitruvius' scheme of proportions.

343.

Vitruvius, the architect, says in his work on architecture that the measurements of the human body are distributed by Nature as follows: that is that 4 fingers make 1 palm, and 4 palms make 1 foot, 6 palms make 1 cubit; 4 cubits make a man's height. And 4 cubits make one pace and 24 palms make a man; and these measures he used in his buildings. If you open your legs so much as to decrease your height 1/14 and spread and raise your arms till your middle fingers touch the level of the top of your head you must know that the centre of the outspread limbs will be in the navel and the space between the legs will be an equilateral triangle.

The length of a man's outspread arms is equal to his height.

From the roots of the hair to the bottom of the chin is the tenth of a man's height; from the bottom of the chin to the top of his head is one eighth of his height; from the top of the breast to the top of his head will be one sixth of a man. From the top of the breast to the roots of the hair will be the seventh part of the whole man. From the nipples to the top of the head will be the fourth part of a man. The greatest width of the shoulders contains in itself the fourth part of the man. From the elbow to the tip of the hand will be the fifth part of a man; and from the elbow to the angle of the armpit will be the eighth part of the man. The whole hand will be the tenth part of the man; the beginning of the genitals marks the middle of the man. The foot is the seventh part of the man. From the

sole of the foot to below the knee will be the fourth part of the man. From below the knee to the beginning of the genitals will be the fourth part of the man. The distance from the bottom of the chin to the nose and from the roots of the hair to the eyebrows is, in each case the same, and like the ear, a third of the face.

[Footnote: See Pl. XVIII. The original leaf is 21 centimetres wide and 33 1/2 long. At the ends of the scale below the figure are written the words diti (fingers) and palmi (palms). The passage quoted from Vitruvius is Book III, Cap. 1, and Leonardo's drawing is given in the editions of Vitruvius by FRA GIOCONDO (Venezia 1511, fol., Firenze 1513, 8vo.) and by CESARIANO (Como 1521).]

The arm and head.

344.

From b to a is one head, as well as from c to a and this happens when the elbow forms a right angle.

[Footnote: See Pl. XLI, No. 1.]

Proportions of the arm (345-349).

345.

From the tip of the longest finger of the hand to the shoulder joint is four hands or, if you will, four faces.

a b c are equal and each interval is 2 heads.

[Footnote: Lines 1-3 are given on Pl. XV below the front view of the leg; lines 4 and 5 are below again, on the left side. The lettering refers to the bent arm near the text.]

346.

The hand from the longest finger to the wrist joint goes 4 times from the tip of the longest finger to the shoulder joint.

347.

a b c are equal to each other and to the foot and to the space between the nipple and the navel d e will be the third part of the whole man.

f g is the fourth part of a man and is equal to g h and measures a cubit.

[Footnote: See Pl. XIX, No. 1. 1. mamolino (=bambino, little child) may mean here the navel.]

348.

a b goes 4 times into a c and 9 into a m. The greatest thickness of the arm between the elbow and the hand goes 6 times into a m and is equal to r f. The greatest thickness of the arm between the shoulder and the elbow goes 4 times into c m, and is equal to h n g. The smallest thickness of the arm above the elbow x y is not the base of a square, but is equal to half the space h 3 which is found between the inner joint of the arm and the wrist joint.

[11]The width of the wrist goes 12 times into the whole arm; that is from the tip of the fingers to the shoulder joint; that is 3 times into the hand and 9 into the arm.

The arm when bent is 4 heads.

The arm from the shoulder to the elbow in bending increases in length, that is in the length from the shoulder to the elbow, and this increase is equal to the thickness of the arm at the wrist when seen in profile. And the space between the bottom of the chin and the parting of the lips, is equal to the thickness of the 2 middle fingers, and to the width of the mouth and to the space between the roots of the hair on the forehead and the top of the head [Footnote: Queste cose. This passage seems to have been written on purpose to rectify the foregoing lines. The error is explained by the

accompanying sketch of the bones of the arm.]. All these distances are equal to each other, but they are not equal to the above-mentioned increase in the arm.

The arm between the elbow and wrist never increases by being bent or extended.

The arm, from the shoulder to the inner joint when extended.

When the arm is extended, p n is equal to n a. And when it is bent n a diminishes 1/6 of its length and p n does the same. The outer elbow joint increases 1/7 when bent; and thus by being bent it increases to the length of 2 heads. And on the inner side, by bending, it is found that whereas the arm from where it joins the side to the wrist, was 2 heads and a half, in bending it loses the half head and measures only two: one from the [shoulder] joint to the end [by the elbow], and the other to the hand.

The arm when folded will measure 2 faces up to the shoulder from the elbow and 2 from the elbow to the insertion of the four fingers on the palm of the hand. The length from the base of the fingers to the elbow never alters in any position of the arm.

If the arm is extended it decreases by 1/3 of the length between b and h; and if--being extended--it is bent, it will increase the half of o e. [Footnote 59-61: The figure sketched in the margin is

however drawn to different proportions.] The length from the shoulder to the elbow is the same as from the base of the thumb, inside, to the elbow a b c.

[Footnote 62-64: The arm sketch on the margin of the MS. is identically the same as that given below on Pl. XX which may therefore be referred to in this place. In line 62 we read therefore z c for m n.] The smallest thickness of the arm in profile z c goes 6 times between the knuckles of the hand and the dimple of the elbow when extended and 14 times in the whole arm and 42 in the whole man [64]. The greatest thickness of the arm in profile is equal to the greatest thickness of the arm in front; but the first is placed at a third of the arm from the shoulder joint to the elbow and the other at a third from the elbow towards the hand.

[Footnote: Compare Pl. XVII. Lines 1-10 and 11-15 are written in two columns below the extended arm, and at the tips of the fingers we find the words: fine d'unghie (ends of the nails). Part of the text--lines 22 to 25--is visible by the side of the sketches on Pl. XXXV, No. 1.]

349.

From the top of the shoulder to the point of the elbow is as far as from that point to the joints of the four fingers with the palm of the hand, and each is 2 faces.

[5]a e is equal to the palm of the hand, r f and o g are equal to half a head and each goes 4 times into a b and b c. From c to m is 1/2 a head; m n is 1/3 of a head and goes 6 times into c b and into b a; a b loses 1/7 of its length when the arm is extended; c b never alters; o will always be the middle point between a and s.

y l is the fleshy part of the arm and measures one head; and when the arm is bent this shrinks 2/5 of its length; o a in bending loses 1/6 and so does o r.

a b is 1/7 of r c. f s will be 1/8 of r c, and each of those 2 measurements is the largest of the arm; k h is the thinnest part between the shoulder and the elbow and it is 1/8 of the whole arm r c; o p is 1/5 of r l; c z goes 13 times into r c.

[Footnote: See Pl. XX where the text is also seen from lines 5-23.]

The movement of the arm (350-354).

350.

In the innermost bend of the joints of every limb the reliefs are converted into a hollow, and likewise every hollow of the innermost bends becomes a convexity when the limb is straightened to the

utmost. And in this very great mistakes are often made by those who have insufficient knowledge and trust to their own invention and do not have recourse to the imitation of nature; and these variations occur more in the middle of the sides than in front, and more at the back than at the sides.

351.

When the arm is bent at an angle at the elbow, it will produce some angle; the more acute the angle is, the more will the muscles within the bend be shortened; while the muscles outside will become of greater length than before. As is shown in the example; d c e will shrink considerably; and b n will be much extended.

[Footnote: See Pl. XIX, No. 2.]

352.

OF PAINTING.

The arm, as it turns, thrusts back its shoulder towards the middle of the back.

353.

The principal movements of the hand are 10; that is forwards,

backwards, to right and to left, in a circular motion, up or down, to close and to open, and to spread the fingers or to press them together.

354.

OF THE MOTIONS OF THE FINGERS.

The movements of the fingers principally consist in extending and bending them. This extension and bending vary in manner; that is, sometimes they bend altogether at the first joint; sometimes they bend, or extend, half way, at the 2nd joint; and sometimes they bend in their whole length and in all the three joints at once. If the 2 first joints are hindered from bending, then the 3rd joint can be bent with greater ease than before; it can never bend of itself, if the other joints are free, unless all three joints are bent. Besides all these movements there are 4 other principal motions of which 2 are up and down, the two others from side to side; and each of these is effected by a single tendon. From these there follow an infinite number of other movements always effected by two tendons; one tendon ceasing to act, the other takes up the movement. The tendons are made thick inside the fingers and thin outside; and the tendons inside are attached to every joint but outside they are not.

[Footnote 26: This head line has, in the original, no text to follow.] Of the strength [and effect] of the 3 tendons inside the

fingers at the 3 joints.

The movement of the torso (355-361).

355.

Observe the altered position of the shoulder in all the movements of the arm, going up and down, inwards and outwards, to the back and to the front, and also in circular movements and any others.

And do the same with reference to the neck, hands and feet and the breast above the lips &c.

356.

Three are the principal muscles of the shoulder, that is b c d, and two are the lateral muscles which move it forward and backward, that is a o; a moves it forward, and o pulls it back; and bed raises it; a b c moves it upwards and forwards, and c d o upwards and backwards. Its own weight almost suffices to move it downwards.

The muscle d acts with the muscle c when the arm moves forward; and in moving backward the muscle b acts with the muscle c.

[Footnote: See Pl. XXI. In the original the lettering has been

written in ink upon the red chalk drawing and the outlines of the figures have in most places been inked over.]

357.

OF THE LOINS, WHEN BENT.

The loins or backbone being bent. The breasts are are always lower than the shoulderblades of the back.

If the breast bone is arched the breasts are higher than the shoulderblades.

If the loins are upright the breast will always be found at the same level as the shoulderblades.

[Footnote: See Pl. XXII, No. 1.]

358.

a b the tendon and ankle in raising the heel approach each other by a finger's breadth; in lowering it they separate by a finger's breadth.

[Footnote: See Pl. XXII, No. 2. Compare this facsimile and text with Pl. III, No. 2, and p. 152 of MANZI'S edition. Also with No. 274 of

LUDWIG'S edition of the Vatican Copy.]

359.

Just so much as the part d a of the nude figure decreases in this position so much does the opposite part increase; that is: in proportion as the length of the part d a diminishes the normal size so does the opposite upper part increase beyond its [normal] size. The navel does not change its position to the male organ; and this shrinking arises because when a figure stands on one foot, that foot becomes the centre [of gravity] of the superimposed weight. This being so, the middle between the shoulders is thrust above it out of it perpendicular line, and this line, which forms the central line of the external parts of the body, becomes bent at its upper extremity [so as to be] above the foot which supports the body; and the transverse lines are forced into such angles that their ends are lower on the side which is supported. As is shown at a b c.

[Footnote: See Pl. XXII, No. 3.]

360.

OF PAINTING.

Note in the motions and attitudes of figures how the limbs vary, and their feeling, for the shoulderblades in the motions of the arms and

shoulders vary the [line of the] back bone very much. And you will find all the causes of this in my book of Anatomy.

361.

OF [CHANGE OF] ATTITUDE.

The pit of the throat is over the feet, and by throwing one arm forward the pit of the throat is thrown off that foot. And if the leg is thrown forward the pit of the throat is thrown forward; and. so it varies in every attitude.

362.

OF PAINTING.

Indicate which are the muscles, and which the tendons, which become prominent or retreat in the different movements of each limb; or which do neither [but are passive]. And remember that these indications of action are of the first importance and necessity in any painter or sculptor who professes to be a master &c.

And indicate the same in a child, and from birth to decrepitude at every stage of its life; as infancy, childhood, boyhood, youth &c.

And in each express the alterations in the limbs and joints, which

swell and which grow thinner.

363.

O Anatomical Painter! beware lest the too strong indication of the bones, sinews and muscles, be the cause of your becoming wooden in your painting by your wish to make your nude figures display all their feeling. Therefore, in endeavouring to remedy this, look in what manner the muscles clothe or cover their bones in old or lean persons; and besides this, observe the rule as to how these same muscles fill up the spaces of the surface that extend between them, which are the muscles which never lose their prominence in any amount of fatness; and which too are the muscles of which the attachments are lost to sight in the very least plumpness. And in many cases several muscles look like one single muscle in the increase of fat; and in many cases, in growing lean or old, one single muscle divides into several muscles. And in this treatise, each in its place, all their peculiarities will be explained--and particularly as to the spaces between the joints of each limb &c. Again, do not fail [to observe] the variations in the forms of the above mentioned muscles, round and about the joints of the limbs of any animal, as caused by the diversity of the motions of each limb; for on some side of those joints the prominence of these muscles is wholly lost in the increase or diminution of the flesh of which these muscles are composed, &c.

[Footnote: DE ROSSI remarks on this chapter, in the Roman edition of the Trattato, p. 504: "Non in questo luogo solo, ma in altri ancora osserverà il lettore, che Lionardo va fungendo quelli che fanno abuso della loro dottrina anatomica, e sicuramente con ciò ha in mira il suo rivale Bonarroti, che di anatomia facea tanta pompa." Note, that Leonardo wrote this passage in Rome, probably under the immediate impression of MICHAELANGELO'S paintings in the Sistine Chapel and of RAPHAEL'S Isaiah in Sant' Agostino.]

364.

OF THE DIFFERENT MEASUREMENTS OF BOYS AND MEN.

There is a great difference in the length between the joints in men and boys for, in man, from the top of the shoulder [by the neck] to the elbow, and from the elbow to the tip of the thumb and from one shoulder to the other, is in each instance two heads, while in a boy it is but one because Nature constructs in us the mass which is the home of the intellect, before forming that which contains the vital elements.

365.

OF PAINTING.

Which are the muscles which subdivide in old age or in youth, when

becoming lean? Which are the parts of the limbs of the human frame where no amount of fat makes the flesh thicker, nor any degree of leanness ever diminishes it?

The thing sought for in this question will be found in all the external joints of the bones, as the shoulder, elbow, wrists, finger-joints, hips, knees, ankle-bone and toes and the like; all of which shall be told in its place. The greatest thickness acquired by any limb is at the part of the muscles which is farthest from its attachments.

Flesh never increases on those portions of the limb where the bones are near to the surface.

At b r d a c e f the increase or diminution of the flesh never makes any considerable difference. Nature has placed in front of man all those parts which feel most pain under a blow; and these are the shin of the leg, the forehead, and the nose. And this was done for the preservation of man, since, if such pain were not felt in these parts, the number of blows to which they would be exposed must be the cause of their destruction.

Describe why the bones of the arm and leg are double near the hand and foot [respectively].

And where the flesh is thicker or thinner in the bending of the

limbs.

366.

OF PAINTING.

Every part of the whole must be in proportion to the whole. Thus, if a man is of a stout short figure he will be the same in all his parts: that is with short and thick arms, wide thick hands, with short fingers with their joints of the same character, and so on with the rest. I would have the same thing understood as applying to all animals and plants; in diminishing, [the various parts] do so in due proportion to the size, as also in enlarging.

367.

OF THE AGREEMENT OF THE PROPORTION OF THE LIMBS.

And again, remember to be very careful in giving your figures limbs, that they must appear to agree with the size of the body and likewise to the age. Thus a youth has limbs that are not very muscular not strongly veined, and the surface is delicate and round, and tender in colour. In man the limbs are sinewy and muscular, while in old men the surface is wrinkled, rugged and knotty, and the sinews very prominent.

HOW YOUNG BOYS HAVE THEIR JOINTS JUST THE REVERSE OF THOSE OF MEN,

AS TO SIZE.

Little children have all the joints slender and the portions between them are thick; and this happens because nothing but the skin covers the joints without any other flesh and has the character of sinew, connecting the bones like a ligature. And the fat fleshiness is laid on between one joint and the next, and between the skin and the bones. But, since the bones are thicker at the joints than between them, as a mass grows up the flesh ceases to have that superfluity which it had, between the skin and the bones; whence the skin clings more closely to the bone and the limbs grow more slender. But since there is nothing over the joints but the cartilaginous and sinewy skin this cannot dry up, and, not drying up, cannot shrink. Thus, and for this reason, children are slender at the joints and fat between the joints; as may be seen in the joints of the fingers, arms, and shoulders, which are slender and dimpled, while in man on the contrary all the joints of the fingers, arms, and legs are thick; and wherever children have hollows men have prominences.

The movement of the human figure (368-375).

368.

Of the manner of representing the 18 actions of man. Repose,

movement, running, standing, supported, sitting, leaning, kneeling, lying down, suspended. Carrying or being carried, thrusting, pulling, striking, being struck, pressing down and lifting up.

[As to how a figure should stand with a weight in its hand [Footnote 8: The original text ends here.] Remember].

369.

A sitting man cannot raise himself if that part of his body which is front of his axis [centre of gravity] does not weigh more than that which is behind that axis [or centre] without using his arms.

A man who is mounting any slope finds that he must involuntarily throw the most weight forward, on the higher foot, rather than behind--that is in front of the axis and not behind it. Hence a man will always, involuntarily, throw the greater weight towards the point whither he desires to move than in any other direction.

The faster a man runs, the more he leans forward towards the point he runs to and throws more weight in front of his axis than behind. A man who runs down hill throws the axis onto his heels, and one who runs up hill throws it into the points of his feet; and a man running on level ground throws it first on his heels and then on the points of his feet.

This man cannot carry his own weight unless, by drawing his body back he balances the weight in front, in such a way as that the foot on which he stands is the centre of gravity.

[Footnote: See Pl. XXII, No. 4.]

370.

How a man proceeds to raise himself to his feet, when he is sitting on level ground.

371.

A man when walking has his head in advance of his feet.

A man when walking across a long level plain first leans [rather] backwards and then as much forwards.

[Footnote 3-6: He strides forward with the air of a man going down hill; when weary, on the contrary he walks like a man going up hill.]

372.

A man when running throws less weight on his legs than when standing still. And in the same way a horse which is running feels less the

weight of the man he carries. Hence many persons think it wonderful that, in running, the horse can rest on one single foot. From this it may be stated that when a weight is in progressive motion the more rapid it is the less is the perpendicular weight towards the centre.

373.

If a man, in taking a jump from firm ground, can leap 3 braccia, and when he was taking his leap it were to recede 1/3 of a braccio, that would be taken off his former leap; and so if it were thrust forward 1/3 of a braccio, by how much would his leap be increased?

374.

OF DRAWING.

When a man who is running wants to neutralise the impetus that carries him on he prepares a contrary impetus which is generated by his hanging backwards. This can be proved, since, if the impetus carries a moving body with a momentum equal to 4 and the moving body wants to turn and fall back with a momentum of 4, then one momentum neutralises the other contrary one, and the impetus is neutralised.

Of walking up and down (375-379)

375.

When a man wants to stop running and check the impetus he is forced to hang back and take short quick steps. [Footnote: Lines 5-31 refer to the two upper figures, and the lower figure to the right is explained by the last part of the chapter.] The centre of gravity of a man who lifts one of his feet from the ground always rests on the centre of the sole of the foot [he stands on].

A man, in going up stairs involuntarily throws so much weight forward and on the side of the upper foot as to be a counterpoise to the lower leg, so that the labour of this lower leg is limited to moving itself.

The first thing a man does in mounting steps is to relieve the leg he is about to lift of the weight of the body which was resting on that leg; and besides this, he gives to the opposite leg all the rest of the bulk of the whole man, including [the weight of] the other leg; he then raises the other leg and sets the foot upon the step to which he wishes to raise himself. Having done this he restores to the upper foot all the weight of the body and of the leg itself, and places his hand on his thigh and throws his head forward and repeats the movement towards the point of the upper foot, quickly lifting the heel of the lower one; and with this impetus he lifts himself up and at the same time extends the arm which rested on his knee; and this extension of the arm carries up the body and

the head, and so straightens the spine which was curved.

[32] The higher the step is which a man has to mount, the farther forward will he place his head in advance of his upper foot, so as to weigh more on a than on b; this man will not be on the step m. As is shown by the line g f.

[Footnote: See Pl. XXIII, No. 1. The lower sketch to the left belongs to the four first lines.]

376.

I ask the weight [pressure] of this man at every degree of motion on these steps, what weight he gives to b and to c.

[Footnote 8: These lines are, in the original, written in ink]
Observe the perpendicular line below the centre of gravity of the man.

[Footnote: See Pl. XXIII, No. 2.]

377.

In going up stairs if you place your hands on your knees all the labour taken by the arms is removed from the sinews at the back of the knees.

[Footnote: See Pl. XXIII, No. 3.]

378.

The sinew which guides the leg, and which is connected with the patella of the knee, feels it a greater labour to carry the man upwards, in proportion as the leg is more bent; and the muscle which acts upon the angle made by the thigh where it joins the body has less difficulty and has a less weight to lift, because it has not the [additional] weight of the thigh itself. And besides this it has stronger muscles, being those which form the buttock.

379.

A man coming down hill takes little steps, because the weight rests upon the hinder foot, while a man mounting takes wide steps, because his weight rests on the foremost foot.

[Footnote: See Pl. XXIII, No. 4.]

On the human body in action (380-388).

380.

OF THE HUMAN BODY IN ACTION.

When you want to represent a man as moving some weight consider what the movements are that are to be represented by different lines; that is to say either from below upwards, with a simple movement, as a man does who stoops forward to take up a weight which he will lift as he straightens himself. Or as a man does who wants to squash something backwards, or to force it forwards or to pull it downwards with ropes passed through pullies [Footnote 10: Compare the sketch on page 198 and on 201 (S. K. M. II.1 86b).]. And here remember that the weight of a man pulls in proportion as his centre of gravity is distant from his fulcrum, and to this is added the force given by his legs and bent back as he raises himself.

381.

Again, a man has even a greater store of strength in his legs than he needs for his own weight; and to see if this is true, make a man stand on the shore-sand and then put another man on his back, and you will see how much he will sink in. Then take the man from off his back and make him jump straight up as high as he can, and you will find that the print of his feet will be made deeper by the jump than from having the man on his back. Hence, here, by 2 methods it is proved that a man has double the strength he requires to support his own body.

382.

OF PAINTING.

If you have to draw a man who is in motion, or lifting or pulling, or carrying a weight equal to his own, in what way must you set on his legs below his body?

[Footnote: In the MS. this question remains unanswered.]

383.

OF THE STRENGTH OF MAN.

A man pulling a [dead] weight balanced against himself cannot pull more than his own weight. And if he has to raise it he will [be able to] raise as much more than his weight as his strength may be more than that of other men. [Footnote 7: The stroke at the end of this line finishes in the original in a sort of loop or flourish, and a similar flourish occurs at the end of the previous passage written on the same page. M. RAVAISSON regards these as numbers (compare the photograph of page 30b in his edition of MS. A). He remarks: "Ce chiffre 8 et, a la fin de l'alinea precedent, le chiffre 7 sont, dans le manuscrit, des renvois."] The greatest force a man can apply, with equal velocity and impetus, will be when he sets his feet on one end of the balance [or lever] and then presses his shoulders against some stable body. This will raise a weight at the

other end of the balance [lever], equal to his own weight and [added to that] as much weight as he can carry on his shoulders.

384.

No animal can simply move [by its dead weight] a greater weight than the sum of its own weight outside the centre of his fulcrum.

385.

A man who wants to send an arrow very far from the bow must be standing entirely on one foot and raising the other so far from the foot he stands on as to afford the requisite counterpoise to his body which is thrown on the front foot. And he must not hold his arm fully extended, and in order that he may be more able to bear the strain he must hold a piece of wood which there is in all crossbows, extending from the hand to the breast, and when he wishes to shoot he suddenly leaps forward at the same instant and extends his arm with the bow and releases the string. And if he dexterously does every thing at once it will go a very long way.

386.

When two men are at the opposite ends of a plank that is balanced, and if they are of equal weight, and if one of them wants to make a leap into the air, then his leap will be made down from his end of

the plank and the man will never go up again but must remain in his place till the man at the other end dashes up the board.

[Footnote: See Pl. XXIV, No. 3.]

387.

Of delivering a blow to the right or left.

[Footnote: Four sketches on Pl. XXIV, No. 1 belong to this passage. The rest of the sketches and notes on that page are of a miscellaneous nature.]

388.

Why an impetus is not spent at once [but diminishes] gradually in some one direction? [Footnote 1: The paper has been damaged at the end of line 1.] The impetus acquired in the line a b c d is spent in the line d e but not so completely but that some of its force remains in it and to this force is added the momentum in the line d e with the force of the motive power, and it must follow than the impetus multiplied by the blow is greater that the simple impetus produced by the momentum d e.

[Footnote 8: The sketch No. 2 on Pl. XXIV stands, in the original, between lines 7 and 8. Compare also the sketches on Pl. LIV.] A man

who has to deal a great blow with his weapon prepares himself with all his force on the opposite side to that where the spot is which he is to hit; and this is because a body as it gains in velocity gains in force against the object which impedes its motion.

On hair falling down in curls.

389.

Observe the motion of the surface of the water which resembles that of hair, and has two motions, of which one goes on with the flow of the surface, the other forms the lines of the eddies; thus the water forms eddying whirlpools one part of which are due to the impetus of the principal current and the other to the incidental motion and return flow.

[Footnote: See Pl. XXV. Where also the text of this passage is given in facsimile.]

On draperies (390--392).

390.

OF THE NATURE OF THE FOLDS IN DRAPERY.

That part of a fold which is farthest from the ends where it is

confined will fall most nearly in its natural form.

Every thing by nature tends to remain at rest. Drapery, being of equal density and thickness on its wrong side and on its right, has a tendency to lie flat; therefore when you give it a fold or plait forcing it out of its flatness note well the result of the constraint in the part where it is most confined; and the part which is farthest from this constraint you will see relapses most into the natural state; that is to say lies free and flowing.

EXAMPLE.

[Footnote 13: a c sia. In the original text b is written instead of c--an evident slip of the pen.] Let a b c be the fold of the drapery spoken of above, a c will be the places where this folded drapery is held fast. I maintain that the part of the drapery which is farthest from the plaited ends will revert most to its natural form.

Therefore, b being farthest from a and c in the fold a b c it will be wider there than anywhere else.

[Footnote: See Pl. XXVIII, No. 6, and compare the drawing from Windsor Pl. XXX for farther illustration of what is here stated.]

391.

OF SMALL FOLDS IN DRAPERIES.

How figures dressed in a cloak should not show the shape so much as that the cloak looks as if it were next the flesh; since you surely cannot wish the cloak to be next the flesh, for you must suppose that between the flesh and the cloak there are other garments which prevent the forms of the limbs appearing distinctly through the cloak. And those limbs which you allow to be seen you must make thicker so that the other garments may appear to be under the cloak. But only give something of the true thickness of the limbs to a nymph [Footnote 9: Una nifa. Compare the beautiful drawing of a Nymph, in black chalk from the Windsor collection, Pl. XXVI.] or an angel, which are represented in thin draperies, pressed and clinging to the limbs of the figures by the action of the wind.

392.

You ought not to give to drapery a great confusion of many folds, but rather only introduce them where they are held by the hands or the arms; the rest you may let fall simply where it is its nature to flow; and do not let the nude forms be broken by too many details and interrupted folds. How draperies should be drawn from nature: that is to say if youwant to represent woollen cloth draw the folds from that; and if it is to be silk, or fine cloth or coarse, or of linen or of crape, vary the folds in each and do not represent

dresses, as many do, from models covered with paper or thin leather which will deceive you greatly.

[Footnote: The little pen and ink drawing from Windsor (W. 102), given on Pl. XXVIII, No. 7, clearly illustrates the statement made at the beginning of this passage; the writing of the cipher 19 on the same page is in Leonardo's hand; the cipher 21 is certainly not.]

VIII.

Botany for Painters and Elements of Landscape Painting.

The chapters composing this portion of the work consist of observations on Form, Light and Shade in Plants, and particularly in Trees summed up in certain general rules by which the author intends to guide the artist in the pictorial representation of landscape.

With these the first principles of a Theory of Landscape painting are laid down--a theory as profoundly thought out in its main lines as it is lucidly worked out in its details. In reading these chapters the conviction is irresistible that such a Botany for painters is or ought to be of similar importance in the practice of painting as the principles of the Proportions and Movements of the human figure i. e. Anatomy for painters.

There can be no doubt that Leonardo, in laying down these rules, did not intend to write on Botany in the proper scientific sense--his own researches on that subject have no place here; it need only be observed that they are easily distinguished by their character and contents from those which are here collected and arranged under the title 'Botany for painters'. In some cases where this division might appear doubtful,--as for instance in No. 402--the Painter is directly addressed and enjoined to take the rule to heart as of special importance in his art.

The original materials are principally derived from MS. G, in which we often find this subject treated on several pages in succession without any of that intermixture of other matters, which is so frequent in Leonardo's writings. This MS., too, is one of the latest; when it was written, the great painter was already more than sixty years of age, so we can scarcely doubt that he regarded all he wrote as his final views on the subject. And the same remark applies to the chapters from MSS. E and M which were also written between 1513--15.

For the sake of clearness, however, it has been desirable to sacrifice--with few exceptions--the original order of the passages as written, though it was with much reluctance and only after long hesitation that I resigned myself to this necessity. Nor do I mean to impugn the logical connection of the author's ideas in his MS.; but it will be easily understood that the sequence of disconnected

notes, as they occurred to Leonardo and were written down from time to time, might be hardly satisfactory as a systematic arrangement of his principles. The reader will find in the Appendix an exact account of the order of the chapters in the original MS. and from the data there given can restore them at will. As the materials are here arranged, the structure of the tree as regards the growth of the branches comes first (394-411) and then the insertion of the leaves on the stems (412-419). Then follow the laws of Light and Shade as applied, first, to the leaves (420-434), and, secondly, to the whole tree and to groups of trees (435-457). After the remarks on the Light and Shade in landscapes generally (458-464), we find special observations on that of views of towns and buildings (465-469). To the theory of Landscape Painting belong also the passages on the effect of Wind on Trees (470-473) and on the Light and Shade of Clouds (474-477), since we find in these certain comparisons with the effect of Light and Shade on Trees (e. g.: in No. 476, 4. 5; and No. 477, 9. 12). The chapters given in the Appendix Nos. 478 and 481 have hardly any connection with the subjects previously treated.

Classification of trees.

393.

TREES.

Small, lofty, straggling, thick, that is as to foliage, dark, light, russet, branched at the top; some directed towards the eye, some downwards; with white stems; this transparent in the air, that not; some standing close together, some scattered.

The relative thickness of the branches to the trunk (393--396).

394.

All the branches of a tree at every stage of its height when put together are equal in thickness to the trunk [below them].

All the branches of a water [course] at every stage of its course, if they are of equal rapidity, are equal to the body of the main stream.

395.

Every year when the boughs of a plant [or tree] have made an end of maturing their growth, they will have made, when put together, a thickness equal to that of the main stem; and at every stage of its ramification you will find the thickness of the said main stem; as: i k, g h, e f, c d, a b, will always be equal to each other; unless the tree is pollard--if so the rule does not hold good.

All the branches have a direction which tends to the centre of the tree m.

[Footnote: The two sketches of leafless trees one above another on the left hand side of Pl. XXVII, No. 1, belong to this passage.]

396.

If the plant n grows to the thickness shown at m, its branches will correspond [in thickness] to the junction a b in consequence of the growth inside as well as outside.

The branches of trees or plants have a twist wherever a minor branch is given off; and this giving off the branch forms a fork; this said fork occurs between two angles of which the largest will be that which is on the side of the larger branch, and in proportion, unless accident has spoilt it.

[Footnote: The sketches illustrating this are on the right hand side of PI. XXVII, No. I, and the text is also given there in facsimile.]

397.

There is no boss on branches which has not been produced by some branch which has failed.

The lower shoots on the branches of trees grow more than the upper ones and this occurs only because the sap that nourishes them, being heavy, tends downwards more than upwards; and again, because those [branches] which grow downwards turn away from the shade which exists towards the centre of the plant. The older the branches are, the greater is the difference between their upper and their lower shoots and in those dating from the same year or epoch.

[Footnote: The sketch accompanying this in the MS. is so effaced that an exact reproduction was impossible.]

398.

OF THE SCARS ON TREES.

The scars on trees grow to a greater thickness than is required by the sap of the limb which nourishes them.

399.

The plant which gives out the smallest ramifications will preserve the straightest line in the course of its growth.

[Footnote: This passage is illustrated by two partly effaced sketches. One of these closely resembles the lower one given under No. 408, the other also represents short closely set boughs on an

upright trunk.]

400.

OF THE RAMIFICATION.

The beginning of the ramification [the shoot] always has the central line [axis] of its thickness directed to the central line [axis] of the plant itself.

401.

In starting from the main stem the branches always form a base with a prominence as is shown at a b c d.

402.

WHY, VERY FREQUENTLY, TIMBER HAS VEINS THAT ARE NOT STRAIGHT.

When the branches which grow the second year above the branch of the preceding year, are not of equal thickness above the antecedent branches, but are on one side, then the vigour of the lower branch is diverted to nourish the one above it, although it may be somewhat on one side.

But if the ramifications are equal in their growth, the veins of the

main stem will be straight [parallel] and equidistant at every degree of the height of the plant.

Wherefore, O Painter! you, who do not know these laws! in order to escape the blame of those who understand them, it will be well that you should represent every thing from nature, and not despise such study as those do who work [only] for money.

The direction of growth (403-407).

403.

OF THE RAMIFICATIONS OF PLANTS.

The plants which spread very much have the angles of the spaces which divide their branches more obtuse in proportion as their point of origin is lower down; that is nearer to the thickest and oldest portion of the tree. Therefore in the youngest portions of the tree the angles of ramification are more acute. [Footnote: Compare the sketches on the lower portion of Pl. XXVII, No. 2.]

404.

The tips of the boughs of plants [and trees], unless they are borne down by the weight of their fruits, turn towards the sky as much as possible.

The upper side of their leaves is turned towards the sky that it may receive the nourishment of the dew which falls at night.

The sun gives spirit and life to plants and the earth nourishes them with moisture. [9] With regard to this I made the experiment of leaving only one small root on a gourd and this I kept nourished with water, and the gourd brought to perfection all the fruits it could produce, which were about 60 gourds of the long kind, andi set my mind diligently [to consider] this vitality and perceived that the dews of night were what supplied it abundantly with moisture through the insertion of its large leaves and gave nourishment to the plant and its offspring--or the seeds which its offspring had to produce--[21].

The rule of the leaves produced on the last shoot of the year will be that they will grow in a contrary direction on the twin branches; that is, that the insertion of the leaves turns round each branch in such a way, as that the sixth leaf above is produced over the sixth leaf below, and the way they turn is that if one turns towards its companion to the right, the other turns to the left, the leaf serving as the nourishing breast for the shoot or fruit which grows the following year.

[Footnote: A French translation of lines 9-12 was given by M. RAVAISSON in the Gazette des Beaux Arts, Oct. 1877; his paper also

contains some valuable information as to botanical science in the ancient classical writers and at the time of the Renaissance.]

405.

The lowest branches of those trees which have large leaves and heavy fruits, such as nut-trees, fig-trees and the like, always droop towards the ground.

The branches always originate above [in the axis of] the leaves.

406.

The upper shoots of the lateral branches of plants lie closer to the parent branch than the lower ones.

407.

The lowest branches, after they have formed the angle of their separation from the parent stem, always bend downwards so as not to crowd against the other branches which follow them on the same stem and to be better able to take the air which nourishes them. As is shown by the angle b a c; the branch a c after it has made the corner of the angle a c bends downwards to c d and the lesser shoot c dries up, being too thin.

The main branch always goes below, as is shown by the branch f n m, which does not go to f n o.

The forms of trees (408--411).

408.

The elm always gives a greater length to the last branches of the year's growth than to the lower ones; and Nature does this because the highest branches are those which have to add to the size of the tree; and those at the bottom must get dry because they grow in the shade and their growth would be an impediment to the entrance of the solar rays and the air among the main branches of the tree.

The main branches of the lower part bend down more than those above, so as to be more oblique than those upper ones, and also because they are larger and older.

409.

In general almost all the upright portions of trees curve somewhat turning the convexity towards the South; and their branches are longer and thicker and more abundant towards the South than towards the North. And this occurs because the sun draws the sap towards that surface of the tree which is nearest to it.

And this may be observed if the sun is not screened off by other plants.

410.

The cherry-tree is of the character of the fir tree as regards its ramification placed in stages round its main stem; and its branches spring, 4 or five or 6 [together] opposite each other; and the tips of the topmost shoots form a pyramid from the middle upwards; and the walnut and oak form a hemisphere from the middle upwards.

411.

The bough of the walnut which is only hit and beaten when it has brought to perfection...

[Footnote: The end of the text and the sketch in red chalk belonging to it, are entirely effaced.]

The insertion of the leaves (412--419).

412.

OF THE INSERTION OF THE BRANCHES ON PLANTS.

Such as the growth of the ramification of plants is on their

principal branches, so is that of the leaves on the shoots of the same plant. These leaves have [Footnote 6: Quattro modi (four modes). Only three are described in the text, the fourth is only suggested by a sketch.

This passage occurs in MANZI'S edition of the Trattato, p. 399, but without the sketches and the text is mutilated in an important part. The whole passage has been commented on, from MANZI'S version, in Part I of the Nuovo Giornale Botanico Italiano, by Prof. G. UZIELLI (Florence 1869, Vol. I). He remarks as to the 'four modes': "Leonardo, come si vede nelle linie sententi da solo tre esempli. Questa ed altre inessattezze fanno desiderare, sia esaminato di nuovo il manoscritto Vaticano". This has since been done by D. KNAPP of Tubingen, and his accurate copy has been published by H. LUDWIG, the painter. The passage in question occurs in his edition as No. 833; and there also the drawings are wanting. The space for them has been left vacant, but in the Vatican copy 'niente' has been written on the margin; and in it, as well as in LUDWIG'S and MANZI'S edition, the text is mutilated.] four modes of growing one above another. The first, which is the most general, is that the sixth always originates over the sixth below [Footnote 8: la sesta di sotto. "Disposizione 2/5 o 1/5. Leonardo osservo probabilmente soltanto la prima" (UZIELLl).]; the second is that two third ones above are over the two third ones below [Footnote 10: terze di sotto: "Intende qui senza dubbio parlare di foglie decussate, in cui il terzo verticello e nel piano del primo" (UZIELLI).]; and the

third way is that the third above is over the third below [Footnote 11: 3a di sotto: "Disposizione 1/2" (UZIELLI).].

[Footnote: See the four sketches on the upper portion of the page reproduced as fig. 2 on P1. XXVII.]

413.

A DESCRIPTION OF THE ELM.

The ramification of the elm has the largest branch at the top. The first and the last but one are smaller, when the main trunk is straight.

The space between the insertion of one leaf to the rest is half the extreme length of the leaf or somewhat less, for the leaves are at an interval which is about the 3rd of the width of the leaf.

The elm has more leaves near the top of the boughs than at the base; and the broad [surface] of the leaves varies little as to [angle and] aspect.

[Footnote: See Pl. XXVII, No. 3. Above the sketch and close under the number of the page is the word 'olmo' (elm).]

414.

In the walnut tree the leaves which are distributed on the shoots of this year are further apart from each other and more numerous in proportion as the branch from which this shoot springs is a young one. And they are inserted more closely and less in number when the shoot that bears them springs from an old branch. Its fruits are borne at the ends of the shoots. And its largest boughs are the lowest on the boughs they spring from. And this arises from the weight of its sap which is more apt to descend than to rise, and consequently the branches which spring from them and rise towards the sky are small and slender [20]; and when the shoot turns towards the sky its leaves spread out from it [at an angle] with an equal distribution of their tips; and if the shoot turns to the horizon the leaves lie flat; and this arises from the fact that leaves without exception, turn their underside to the earth [29].

The shoots are smaller in proportion as they spring nearer to the base of the bough they spring from.

[Footnote: See the two sketches on Pl XXVII, No. 4. The second refers to the passage lines 20-30.]

415.

OF THE INSERTION OF THE LEAVES ON THE BRANCHES.

The thickness of a branch never diminishes within the space between one leaf and the next excepting by so much as the thickness of the bud which is above the leaf and this thickness is taken off from the branch above [the node] as far as the next leaf.

Nature has so placed the leaves of the latest shoots of many plants that the sixth leaf is always above the first, and so on in succession, if the rule is not [accidentally] interfered with; and this occurs for two useful ends in the plant: First that as the shoot and the fruit of the following year spring from the bud or eye which lies above and in close contact with the insertion of the leaf [in the axil], the water which falls upon the shoot can run down to nourish the bud, by the drop being caught in the hollow [axil] at the insertion of the leaf. And the second advantage is, that as these shoots develop in the following year one will not cover the next below, since the 5 come forth on five different sides; and the sixth which is above the first is at some distance.

416.

OF THE RAMIFICATIONS OF TREES AND THEIR FOLIAGE.

The ramifications of any tree, such as the elm, are wide and slender after the manner of a hand with spread fingers, foreshortened. And these are seen in the distribution [thus]: the lower portions are seen from above; and those that are above are seen from below; and

those in the middle, some from below and some from above. The upper part is the extreme [top] of this ramification and the middle portion is more foreshortened than any other of those which are turned with their tips towards you. And of those parts of the middle of the height of the tree, the longest will be towards the top of the tree and will produce a ramification like the foliage of the common willow, which grows on the banks of rivers.

Other ramifications are spherical, as those of such trees as put forth their shoots and leaves in the order of the sixth being placed above the first. Others are thin and light like the willow and others.

417.

You will see in the lower branches of the elder, which puts forth leaves two and two placed crosswise [at right angles] one above another, that if the stem rises straight up towards the sky this order never fails; and its largest leaves are on the thickest part of the stem and the smallest on the slenderest part, that is towards the top. But, to return to the lower branches, I say that the leaves on these are placed on them crosswise like [those on] the upper branches; and as, by the law of all leaves, they are compelled to turn their upper surface towards the sky to catch the dew at night, it is necessary that those so placed should twist round and no longer form a cross.