On casting medals.

Use a paste of emery mixed with acquavite (nitric acid) or iron filings and vinegar, or ashes of walnut leaves or finely ground straw ash.

To obtain the diamond powder crush it enclosed in lead, and pounded with a hammer; to avoid spilling the powder wrap the diamond in paper and double the folds several times so that the powder does not spill. Next melt the lead, and the powder will rise to the top of the molten lead. Then the powder should be rubbed between two steel plates, until it is finely pulverized. Lastly, wash it with nitric acid and the blackness of the iron will dissolve and leave only the diamond powder.

Large pieces of crystals must be broken into smaller flakes by putting them on a cloth folded many times and striking them sideways with a hammer; and then they are more easily crushed with a pestle. If the flakes are large and you put them on an anvil, you would never break them, being so hard.
Anyone who grinds enamel, should use this procedure: do it on plates of tempered steel with a steel grinder, and then put the enamel in nitric acid, which will separate any powdered steel that has been rubbed off and mixed with the enamel, making it black. It remains so purified that if you grind it on porphyry, the porphyry disintegrates and mixes with the enamel, and spoils it; and the nitric acid will never remove it, because it does not react with the porphyry.
If you wish to make a beautiful blue color, dissolve the enamel with tartar, and then remove the salt.

Vitrified brass makes a fine red.

De colori de polvere materiali

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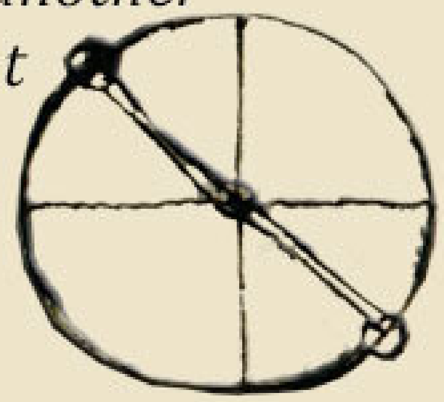
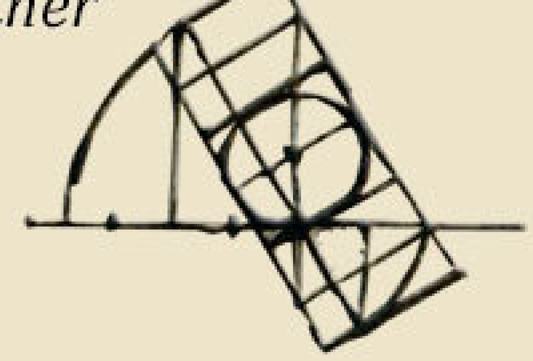
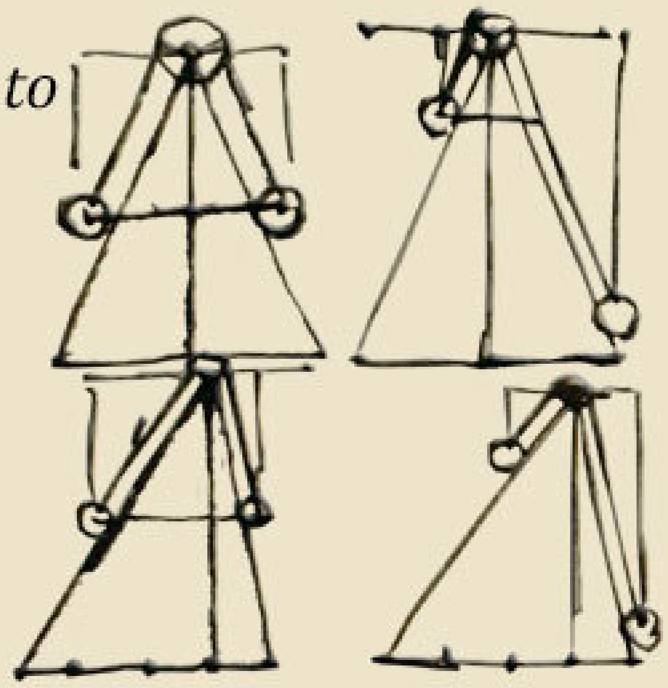
Folio 1 recto

Gravity occurs when one element is placed above another element that is lighter than itself.

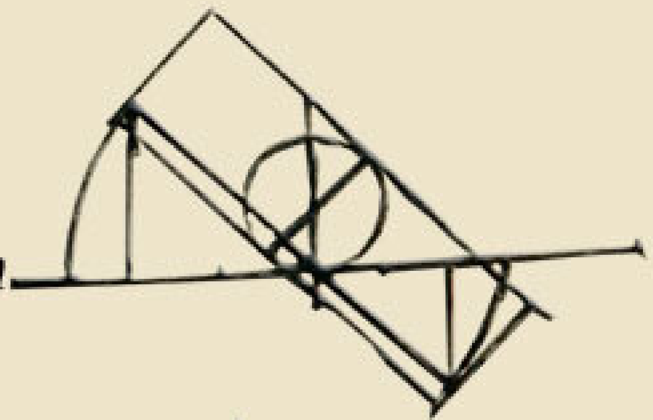


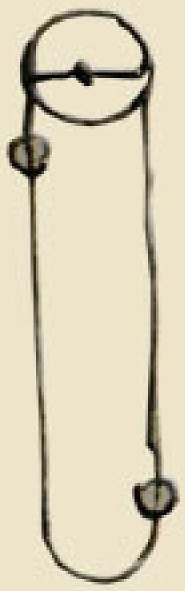
Gravity is caused by the attraction of one element to another

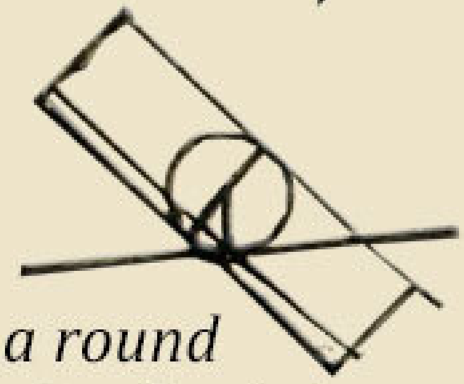




Adjust this scale in accordance with the fifth principle, check it and then compare it with the fifth scale shown below.







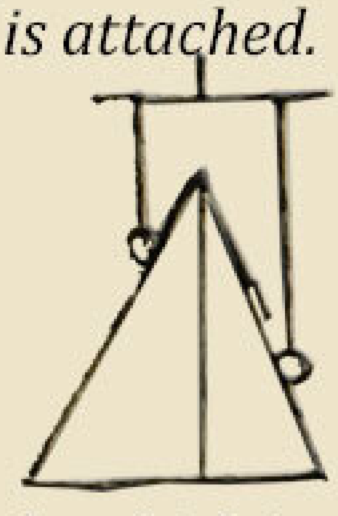
In a round or circular balance, oscillation does not occur because its parts always move equally around the fulcrum.

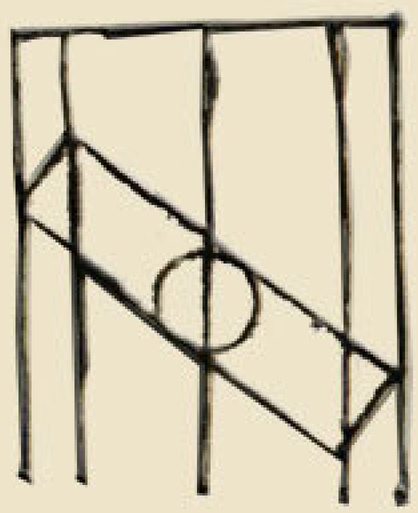
The shorter the arm of a balance, the less it will oscillate. The longer the arm of a balance, the smaller the angle of oscillation; in fact to achieve the same oscillating distance with a long cross-piece arm it will need a smaller oscillation angle than a balance with a short cross-piece.

A lighter object always remains above the heavier one, if both of them are free to move. When moving, the heavier part of a body guides the lighter parts.

When the center of gravity of a balance is the fulcrum, there are no oscillations.

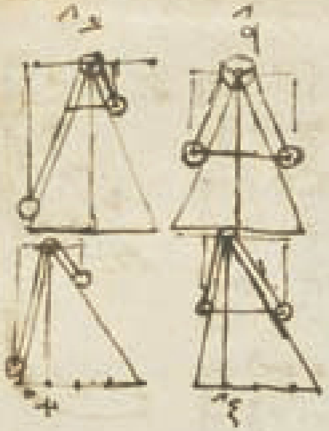
The vertical center of the balance must always be perpendicular, as must the point to which the pan is attached.





A body which is condensed becomes heavier; like air inside balloons. But if this is so, why does ice float on water, since it is denser than water? Because, for an equal weight, when it turns from the liquid to the solid state its volume increases.

This case shows that even though the perpendicular weights are equal, the oscillation of the balance is not caused by this--on the contrary, this would hinder its movement. Nor is it caused by the reasons illustrated in the fifth scale shown above , but by looking at the seventh scale, the cause proves to be physical movement.



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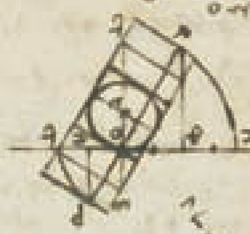

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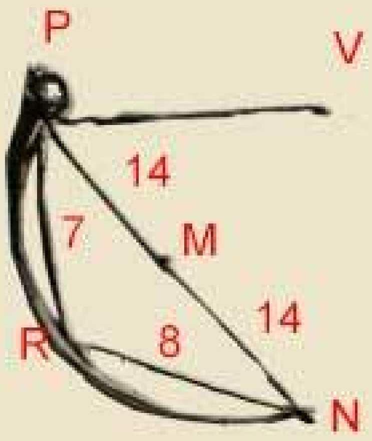
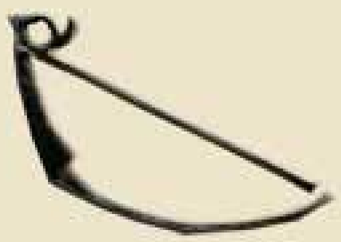
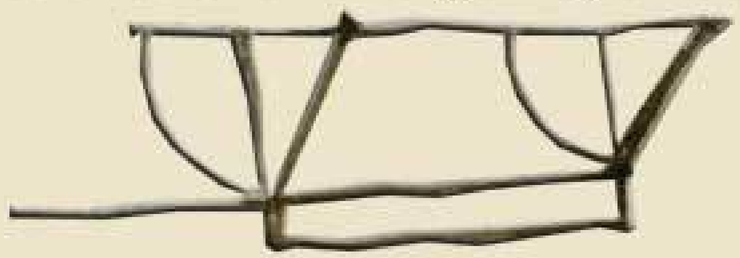
Folio 1 verso

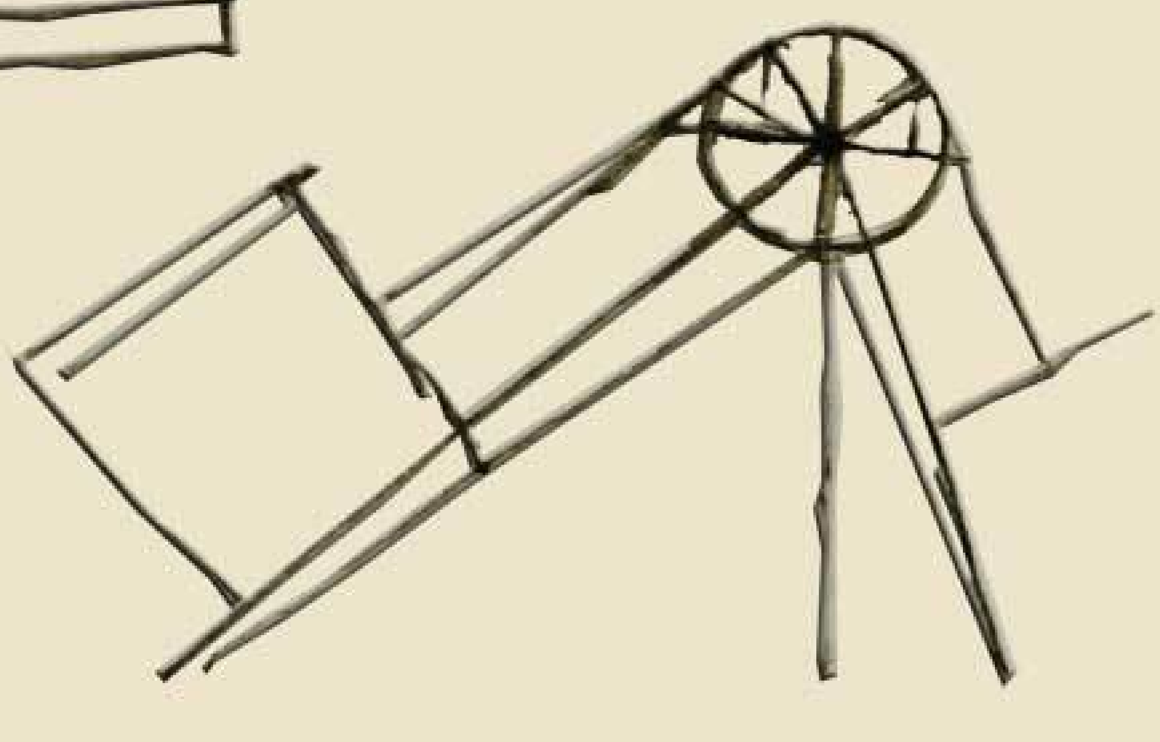


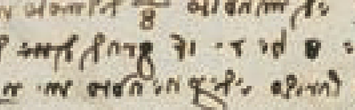


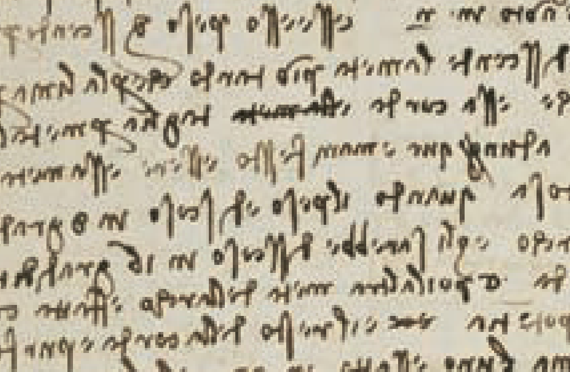
The longer the straight cord, the faster the weight P will descend the section of the arc. The reason is that the point is at the halfway position of the arc, because the weight drops from P to R, following the perpendicular, whereas the rest of the descent takes place through inertia at a speed equal to 7/8 of the initial velocity, as proved by the fifth principle.
However, if you let the weight descend the cord PN, this motion takes twice as long as the descent along the arc, that is 4/8 the speed. I have already said that the reflex motion RN has a speed of 7/8 the movement PR.
Suppose that the weight P, descending by PR, descends in 8 units of speed, and has traveled half of the arc PRN; on segment RN its speed is decreased by 1/8, which comes to be in total, 8 and 7, making a total of 15 units of time, in which P has passed the arc and reached N.
If this weight descends by cord PN, it falls at half the speed than by the perpendicular line PR, because the cord cuts the right angle RPV in half. Therefore it is clear that it is slower by half. Hence, when the weight has descended half the arc in 8 units of time, it would take 16 units of time to reach the halfway point of the cord; and then the other half of the arc is made with 7 units of time and the rest of the cord is made in 16. The conclusion is that it takes 15 time units to travel the arc and 32 to travel the length of the cord.



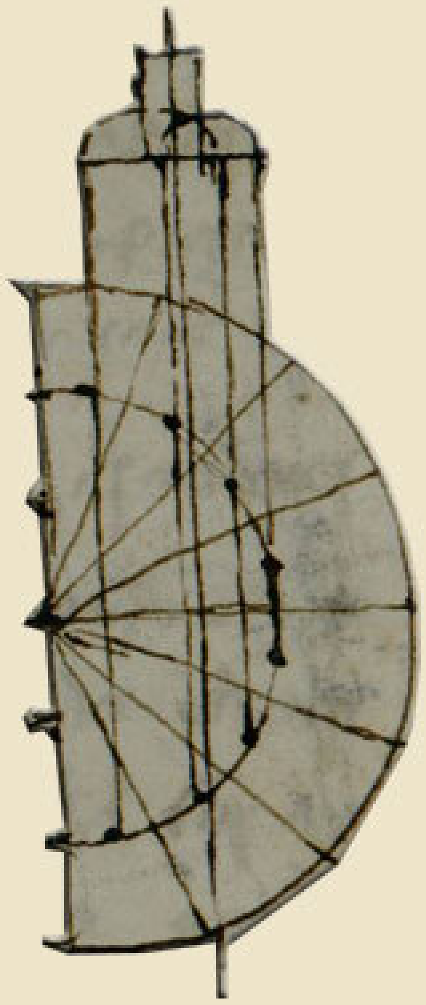
Velocity of the weight along the arc equals 8 plus 7 units of velocity. The velocity of the weight, descending along the cord, is slower by half, because the right angle RPV is cut in half, and therefore the weight has half the speed than by the perpendicular line PR. It is slower by half, and for this reason we say that the weight descends by the cord with a speed of 4 units of time for the first half and 4 for the second half and by the arc in 8 and 7 units of velocity, which makes 15 units of velocity by the arc and 8 by the cord. Thus it is faster by the arc than by the cord, with a speed of 15 to 8, that is an increase of 7. Therefore along the arc it is 7/8 faster.





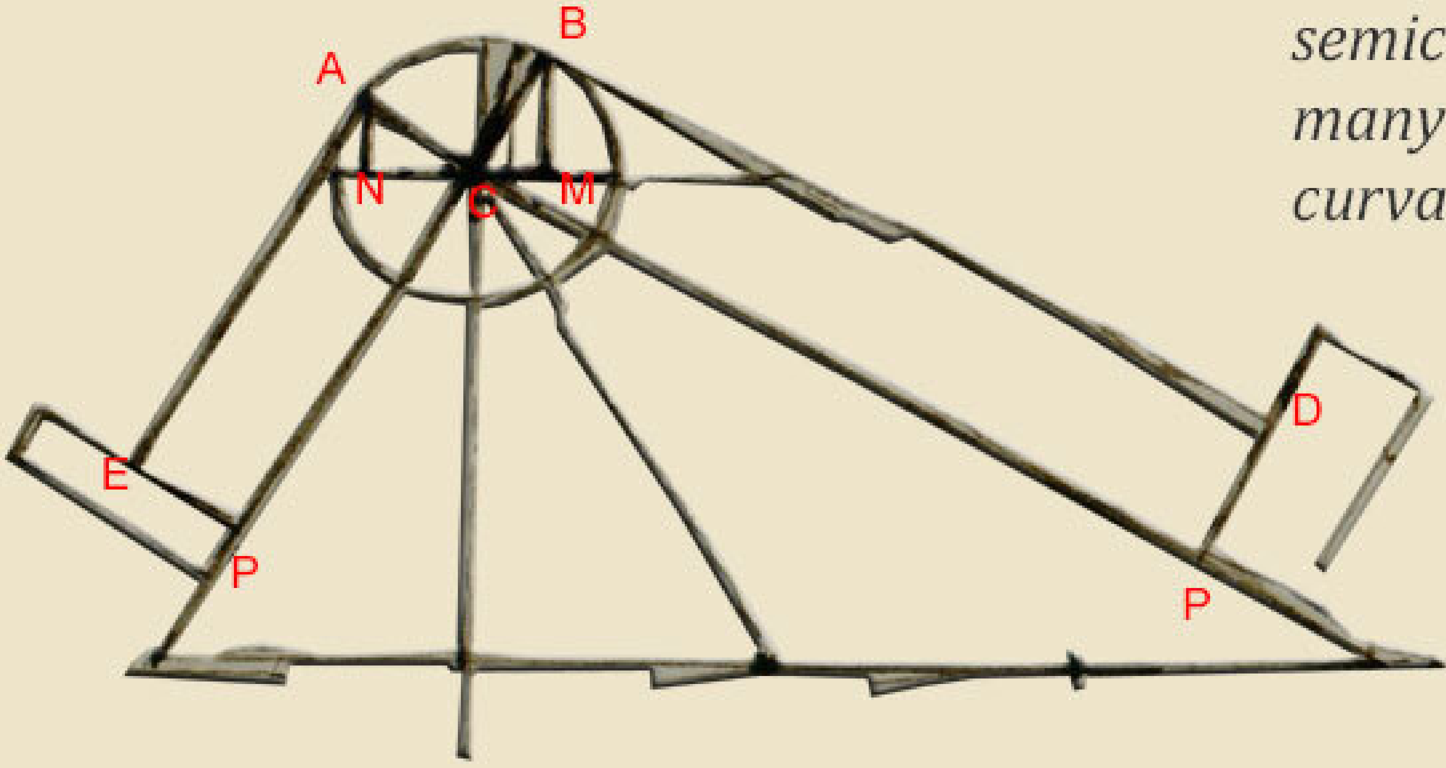


Gravity is caused by one element situated higher than another, and moves in an imaginary line toward the center of the other object. It isn't caused by its own movement, nor because the center attracts it to itself, but because the body cannot offer resistance.



If an ounce of powder requires a one-ounce ball, or if a one-ounce ball requires an ounce of powder, how many are needed for a two-ounce ball? The quantity of powder increases according to the diameter of the ball, the proportion is their diameters multiplied by themselves. This means that the quantity of powder is directly proportional to the square of the diameter. For example, if we give the value of 1 to one diameter, then 1 x 1 is equal to 1 unit of powder.
If we give the value of 2, then 2 x 2 makes 4. So the ball...

The center of gravity of pyramids of two equidistant sides lies in the third point along of its length toward the base. And if you wished to find the exact center of gravity of the semicircle, divide it into so many triangles so that the curvature of their bases almost seems a straight line, and then you have the example illustrated here above, and you will find the position of the center almost pefectly.



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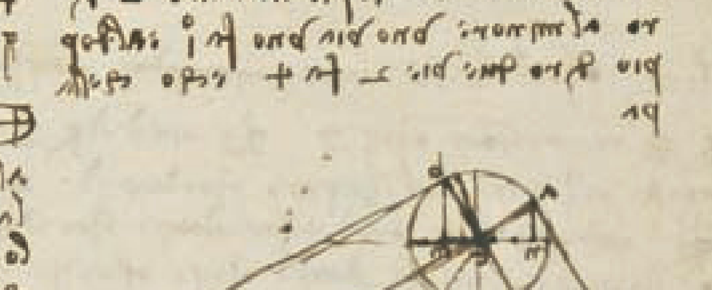
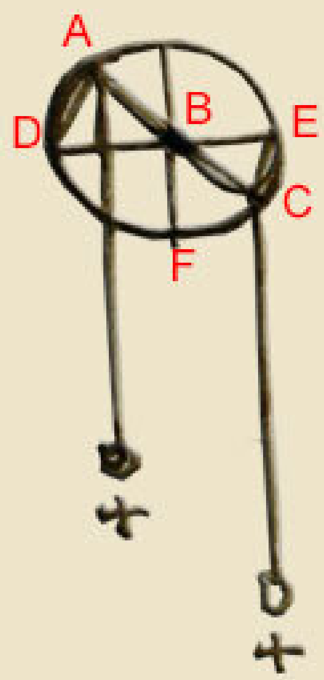


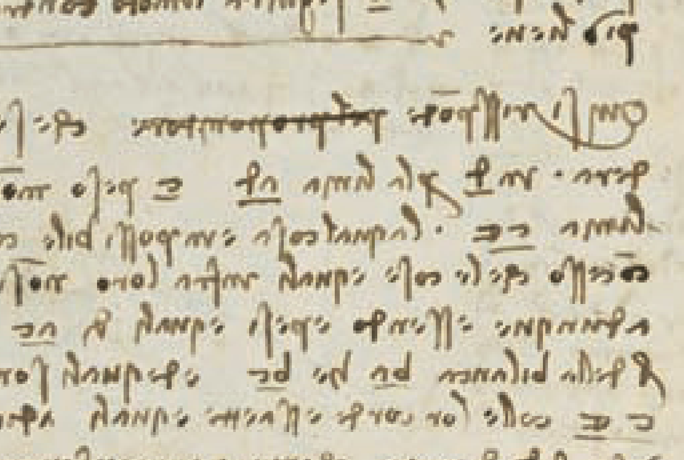


If it were possible to suspend the balance in the center of its gravity, it would stay still and never oscillate, in whatever slanted position it was situated, as is seen in a round balance.

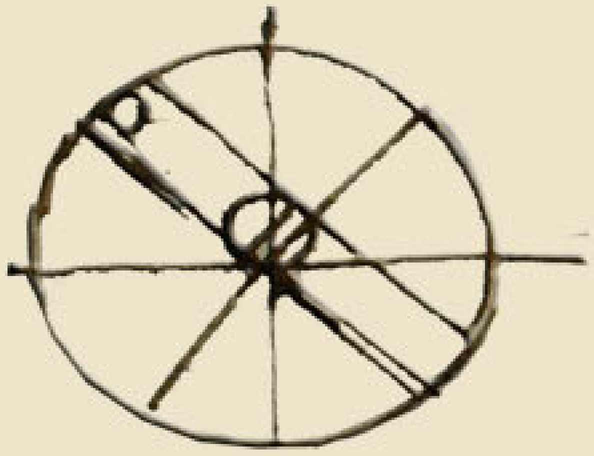
If two equal weights are placed to the ends of the diameter of a round balance and the weights are then moved, they will never return to their original position of equilibrium unaided.

Let us examine the opposite case. I say that each of the weights A and C wishes to descend, but it is the one with the straightest line of descent that will fall rather than the one with the more oblique motion. Thus, AD being a motion closer to a vertical line than the motion CF, the weight will descend as a heavier body, and C will follow it with the opposite motion as if it were a lighter body.

Here it will be argued that, if the weight A descends to D along the line AD, weight C will rise to E by line CE. Such a thing is impossible, since it is already established that things equal between themselves do not counteract each other. Hence, since the weights A and C being equal, and the arms of the balance BA and BC are equal, and the arcs of the motions AD and CE with their equal cords, thus there is no cause for motion, as is already confirmed by experience.

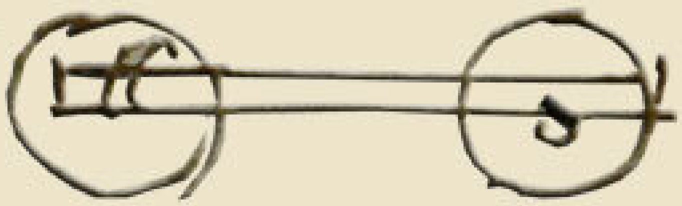


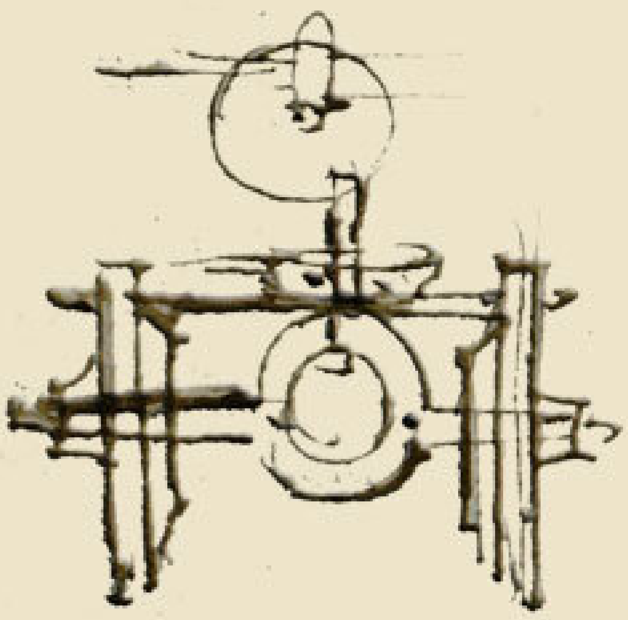
Folio 3 recto

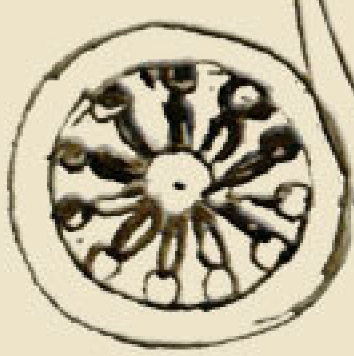


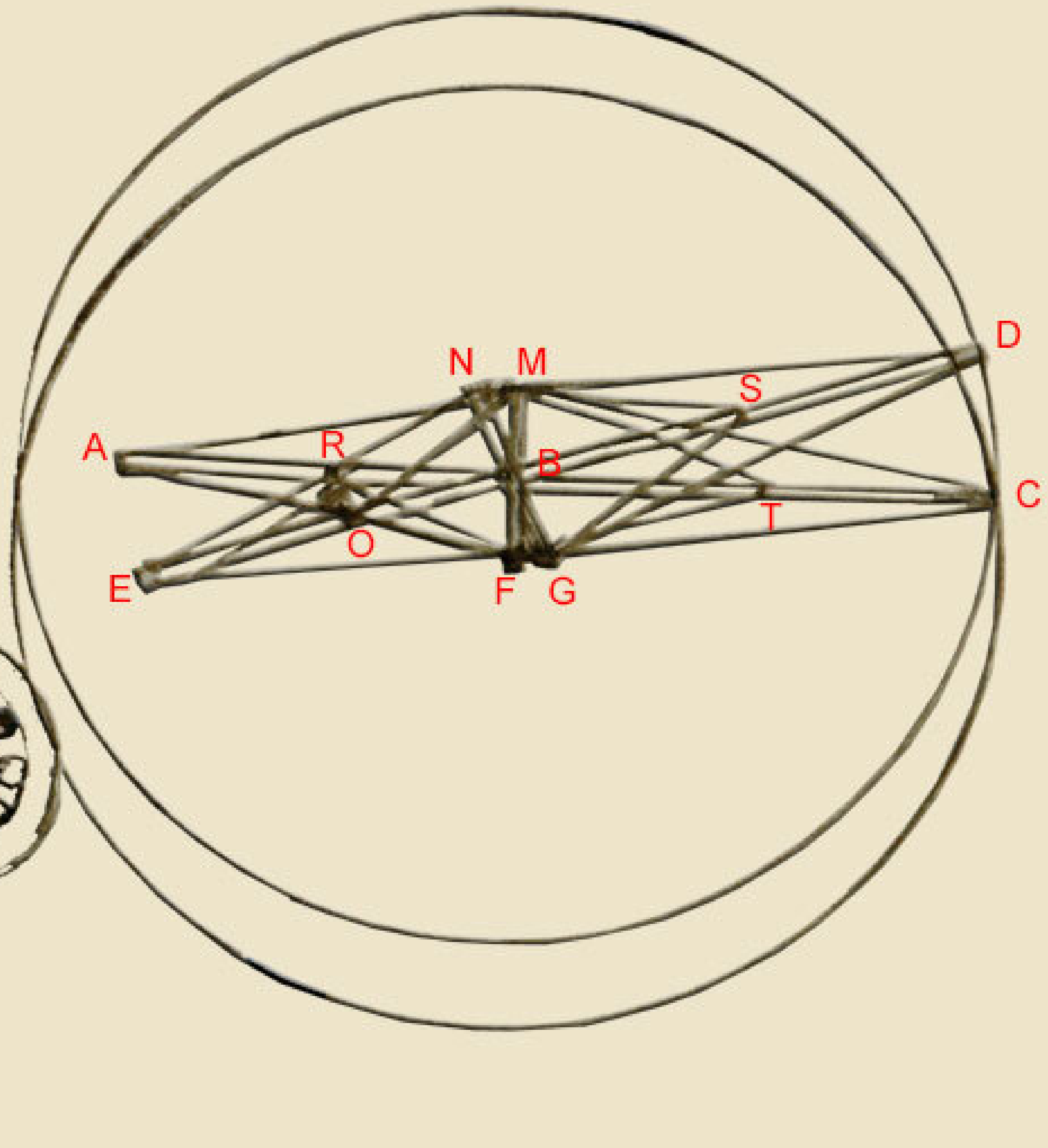
The science of instruments, or rather machines, is very noble and the most useful above all others, since by means of it all animated bodies, which have motion, follow the rules of this science. This is also true for movements generated by their center of gravity, for objects of unequal weights, for bodies moved by muscles or for bodies moved because they cannot offer resistance or which are moved by sufficient impulse, and also movement caused by one lever against another.

Here the balance ABC has more space from B to A than from B to C and it would seem that with weights attached to its ends it would have to stop after several oscillations in its initial equilibrium position.









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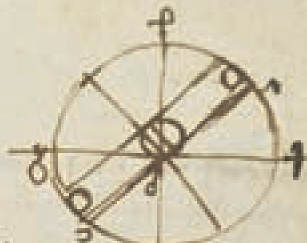

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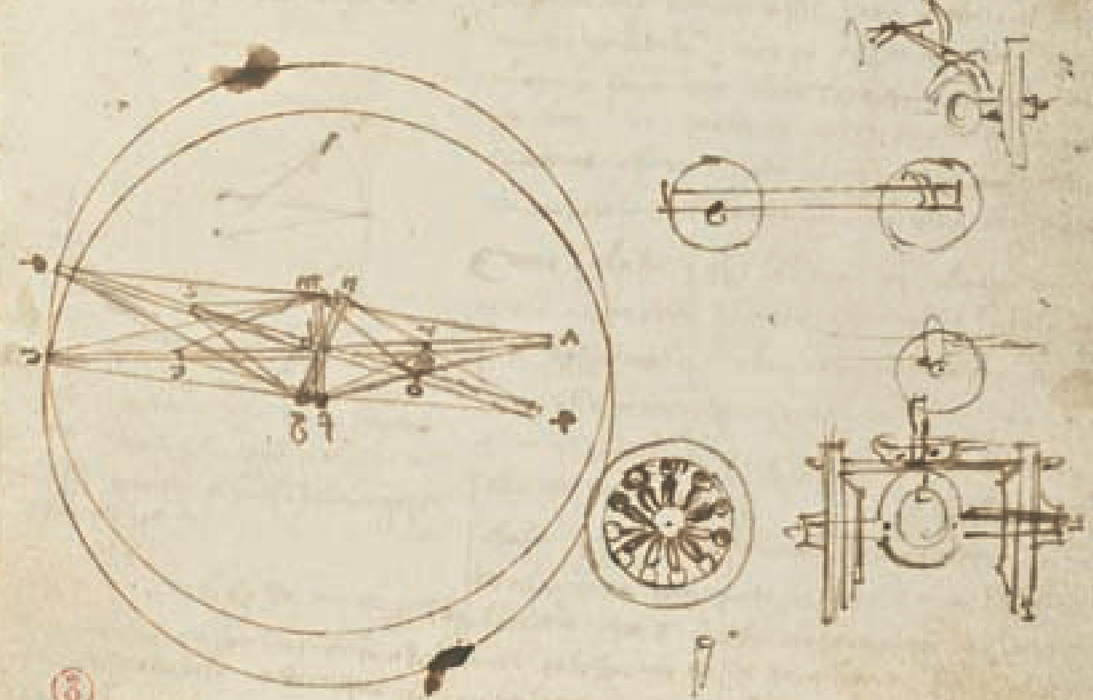
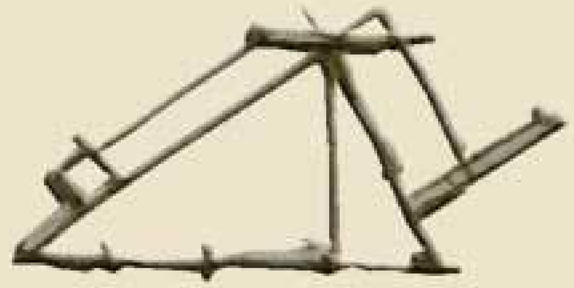
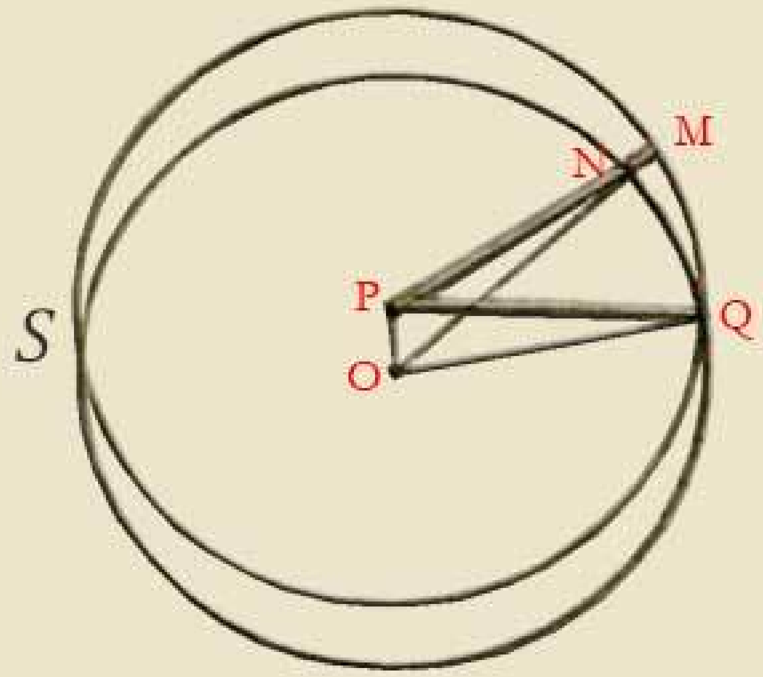


Folio 3 verso

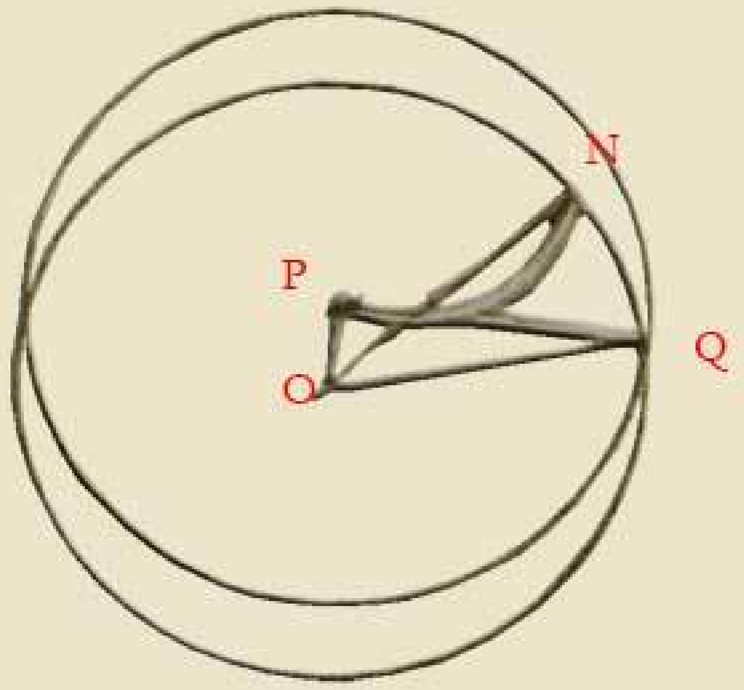


Different shapes placed on different slopes produce different degrees of energy.

If the rods are connected at their ends .... circumference .... at the opposite end.
At the ends of the rods, circular motion with the opposite end as its center is prevented.
At this end will be connected a straight cord: attach the same cord to the opposite end, below the center of the circumference.
At this end of the rods, circular motion is prevented with the opposite end as its center is obstructed, which will be tied with a straight cord. With this rope stretched from the end A of the lever to a fixed point under the center of the circumference, join together the ends of the rods.
Define a line PQ. At the end of this line circular motion QM is prevented, as it is also at the fixed end Q below the center of circumference OQ, by means of a straight cord. I believe that the end of rod Q will never reach M, if the cord does not break.



Anyone who contradicts this theory asserts that the rod PM will curve so that its end arrive at point O and N



In that case, the cord will have to be made as long as the rods, or else the rods must be shorted to the length of the cord.

This can be proved as follows. If end Q of rod PQ has to move to M, it will trace the arc QM, because that rod is half the diameter of the circle QMA; and the stretched cord OQ that is pulled during this displacement cannot follow that end of the rod from point Q to point M, unless it is lengthened the entire part NM, because it too is half the diameter of its circle QNS. Thus it is true that point Q cannot move.

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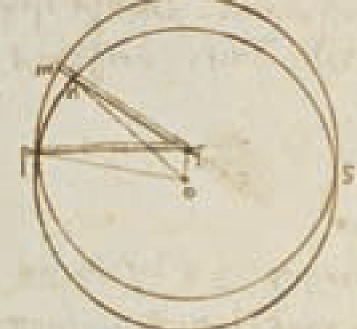

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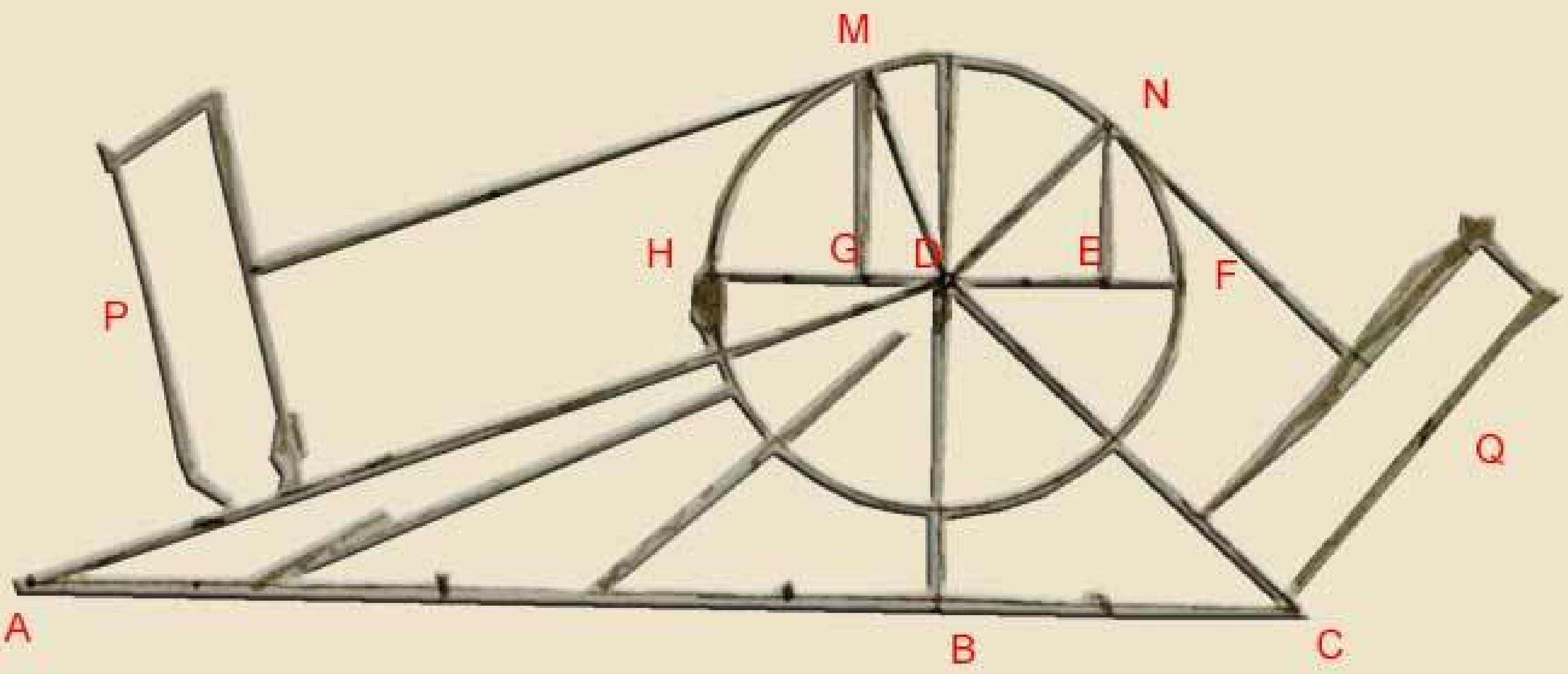
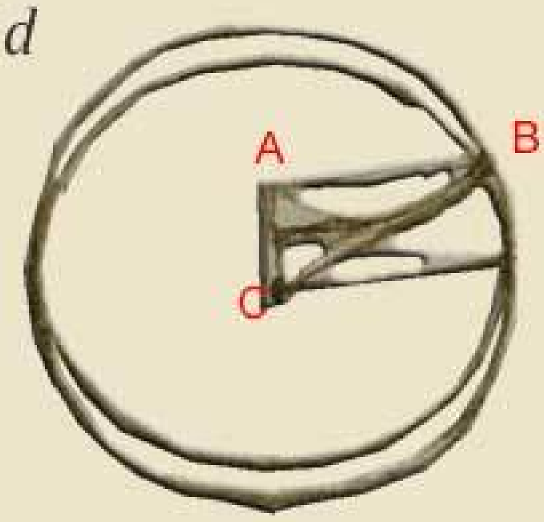


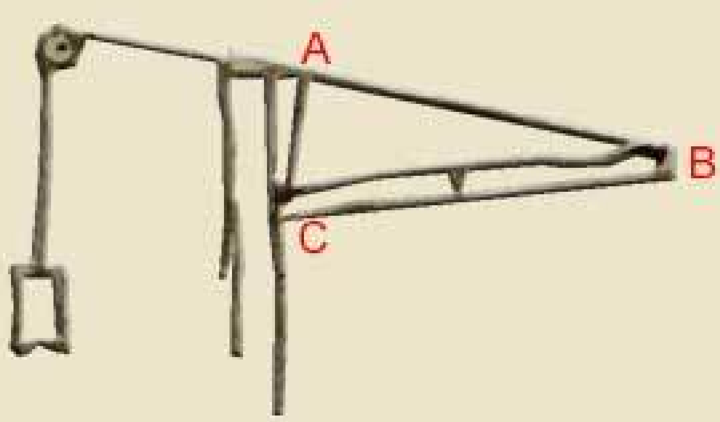
Weight Q, because of the right angle N above DF at point E, weighs 2/3 of its initial weight, which was 3 pounds. Its force therefore remains 2 pounds. Weight P, also 3 pounds, has a potential force of one pound because of the right angle M located at point G on line HD. Therefore we have here one pound against 2 pounds.

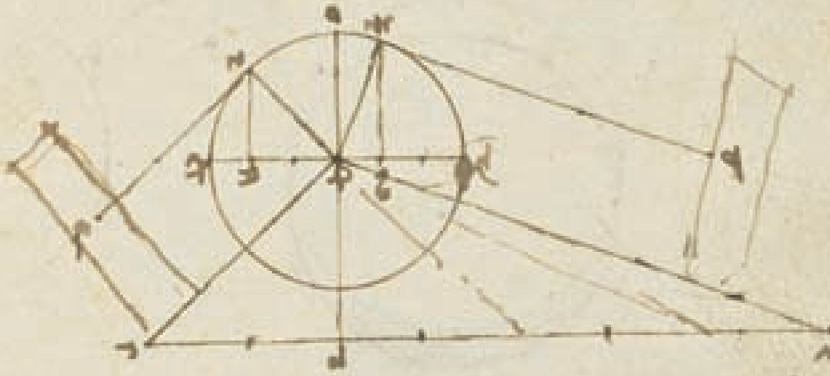
Because the slopes DA and DC, where the weights rest, have different gradients in proportion to their weights, that is one is twice the other, their gravities change in value. Slope DA exceeds the slope DC, and exercises a force of 2.5 on the plane DC, as shown by the proportion between AB and BC. The ratio between the slopes remains in a ratio of 5 to 2 whereas the ratio between the weights was double in proportion. Hence the difference between the greater slope and the lesser is 1 ½. If, for example, the weights were, let us say, 3 pounds on each side, they would rest on DA.

C is the pole or center of the circumference, and because AC depends on lever CB, a weight of one pound at C gives a force of 2 pounds at A and of 2 pounds in C because A is also the center of the second circumference.

Therefore for one pound placed at point B will correspond to two at A and this produces a pressure of two at C, making four pounds in all.







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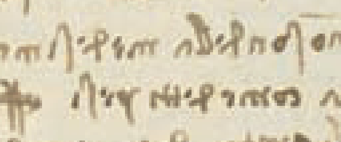

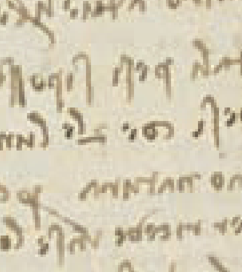

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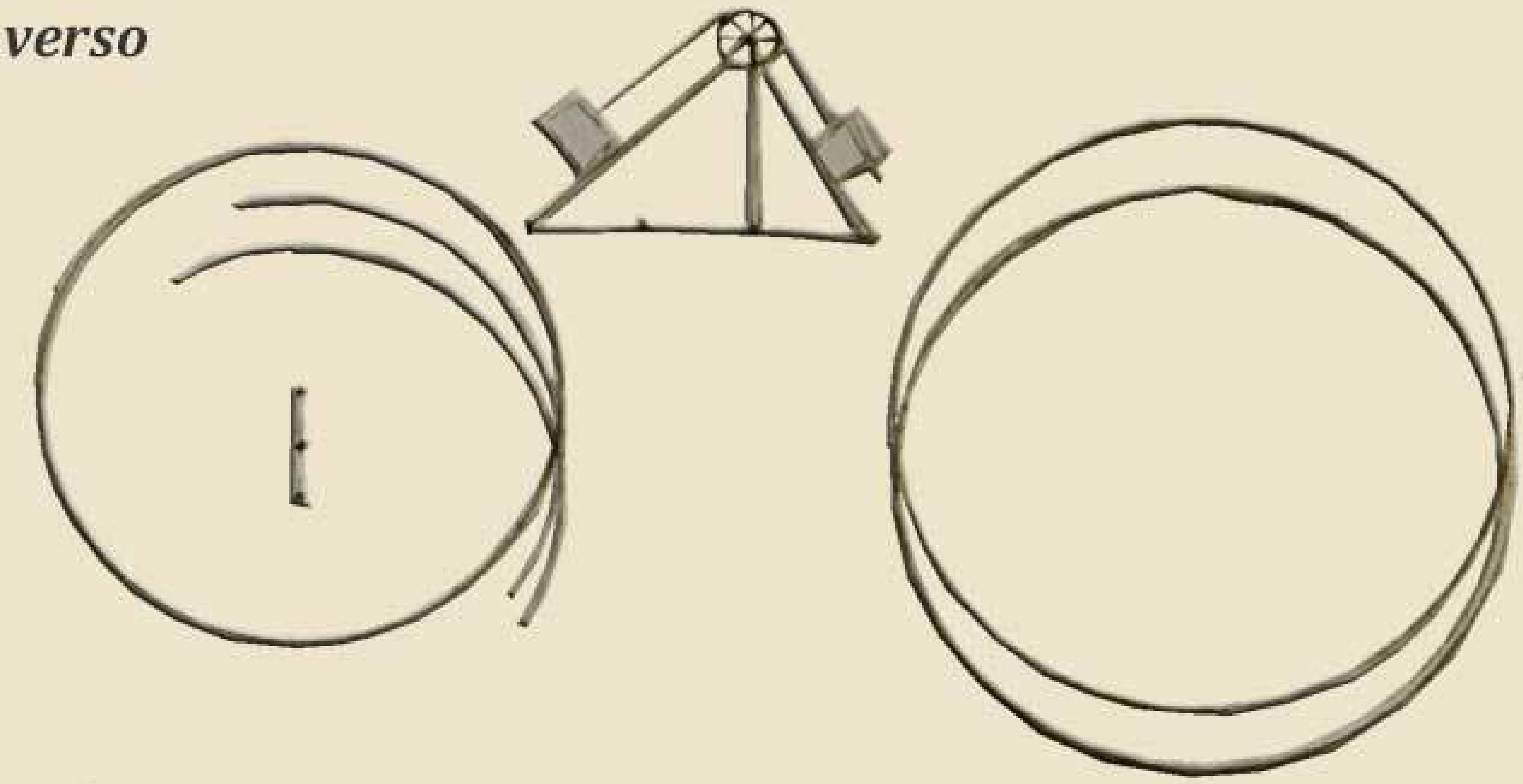
Folio 4 verso

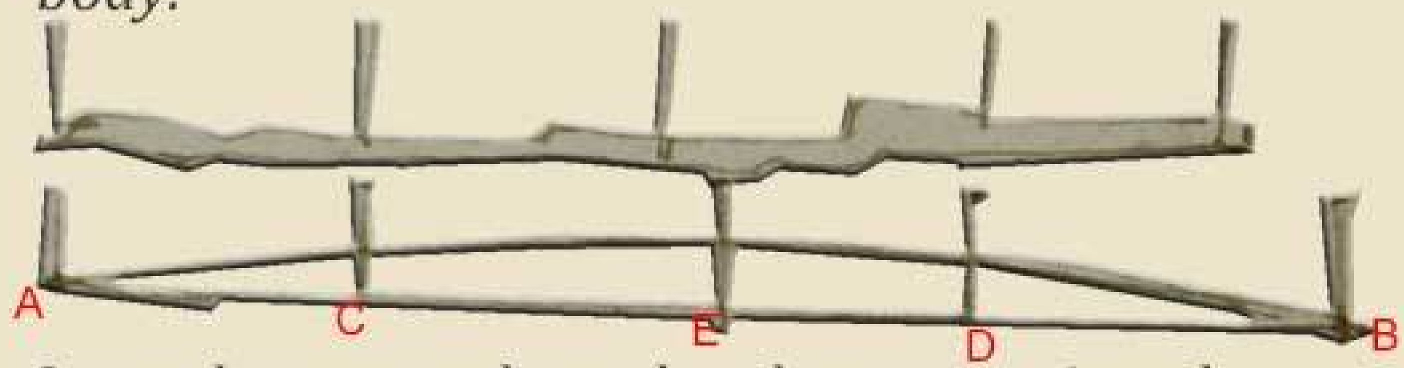


Those feathers that are farthest from their roots can bend the most. Thus the tips of the feathers of the wings will always be higher than their roots. So we can reasonably assume that the bones in the wings will always be lower than any part of the wing when the wings are lowered, and in raising these bones of the wings they will be higher than any other part of that wing.

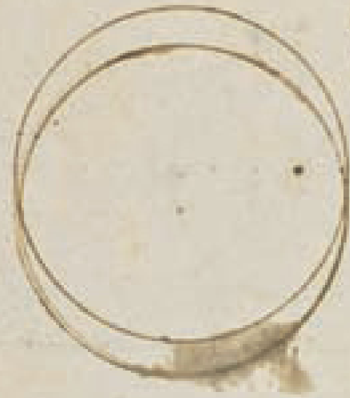
Because the heaviest part of a body always guides the movement. But if the body in question could bend under the action of other bodies with different sizes and weights, even if the center of gravity corresponds to the geometric center, then only the support nearest the center of gravity would remain. Or in the case where the center of gravity and the geometric center do not correspond, the weight will make the lighter parts of the body bend most.

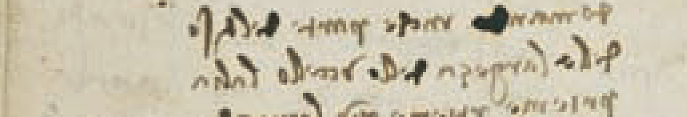
I wonder at what point in the lower part of the wing of the bird the air exerts greatest pressure on the entire width of the wing.

All bodies that do not bend under the pressure of objects of different sizes and weights will distribute their weight evenly on all their supporting points that are equidistant from the center of gravity of the object, this being the center of gravity centered in the dimensions of such a body.

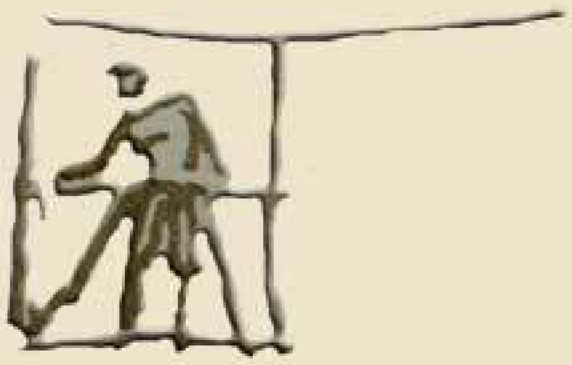


It can be proven how the above-mentioned weight transfers an equal pressure on its supports. Supposing that it is 4 pounds and that it is sustained by the support AB. I believe that the body not being impeded in its descent except by the two supports AB, that these supports will sustain equal parts of this weight, that is to say 2 pounds each. The two supports C and D would do the same thing if the other three supports were not there; and if only C, the middle one, remained, it would sustain all of the weight.

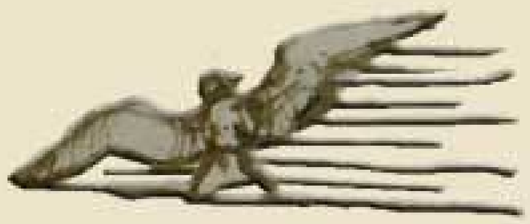


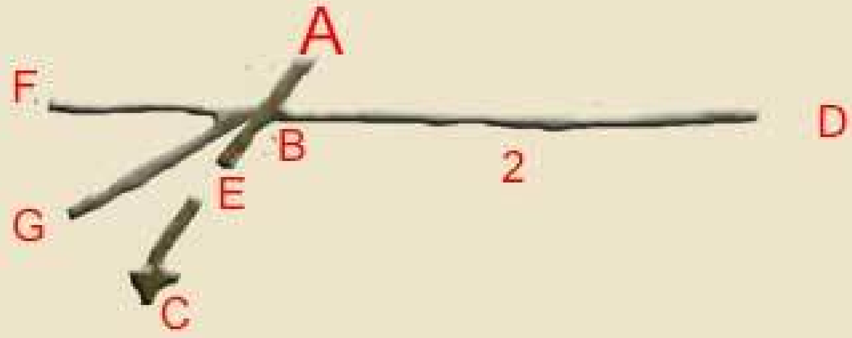


Folio 5 recto

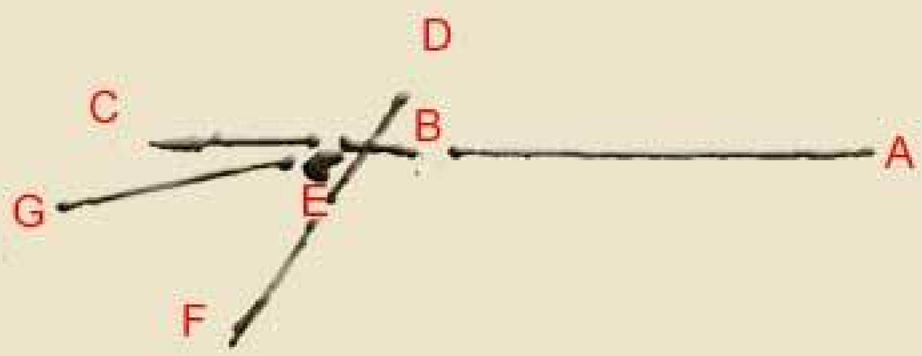


A man in a flying machine must be free from the waist up in order to be able to balance himself, as he does in a boat, so that his center of gravity and that of the machine can balance and change as necessity demands, according to shifts in the center of resistance.





When a bird is descending the line of its open wings with a speed of 4 units, and the wind, which strikes it from below, with a power of 2, it flies in a straight line. So we will say then that the descent of such a bird will be by a median line between the straightness of the course of the wind and the gradient on which the bird was already flying at a speed of 4. For example: let the gradient of such a bird be the line ADC and the wind be BA. So, if the bird ABC had a speed of 4, and the wind BA had a power of 2, the bird would not cross either the final point of the wind F, nor by its own gradient G, but will fall by the median line AE. This can be proved in this way.



And if the bird's oblique descent has a power of 4, and the wind that meets it has a power of 8....

When the bird wants to turn to the right or to the left by beating its wings, then it will beat lower the wing on the side to which it wants to turn. In this way, the bird will change its movement by following the wing which has moved downward most.

When the bird beats its wings and wants to gain height, it raises the shoulders and beats the tips of the wings towards itself, thus condensing the air that stands between the tips of his wings and its chest. This makes the bird rise upward.

The Kite and other birds do not flap their wings very much, but seek the current of the wind. When the wind is strong in the sky, then you always see them flying at great heights, but when the wind is light they are low.

When the wind is not blowing, the Kite flaps its wings in such a way as to fly upward freely. Then it begins to descend losing lots of altitude but gaining speed, flying without flapping its wings. And when it has dropped down, it does the same thing again, and so continues successively. Gliding without flapping its wings allows the bird to rest in the air, after the effort of beating the wings in order to gain altitude.

Even the birds that rise up with a non-continuous beating of the wings glide when they rest, because in descending they do not beat their wings.

[illegible]

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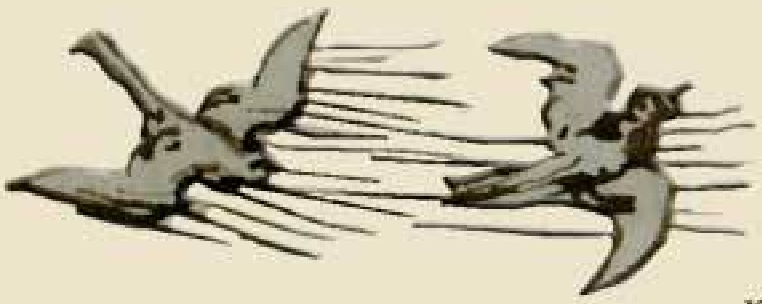
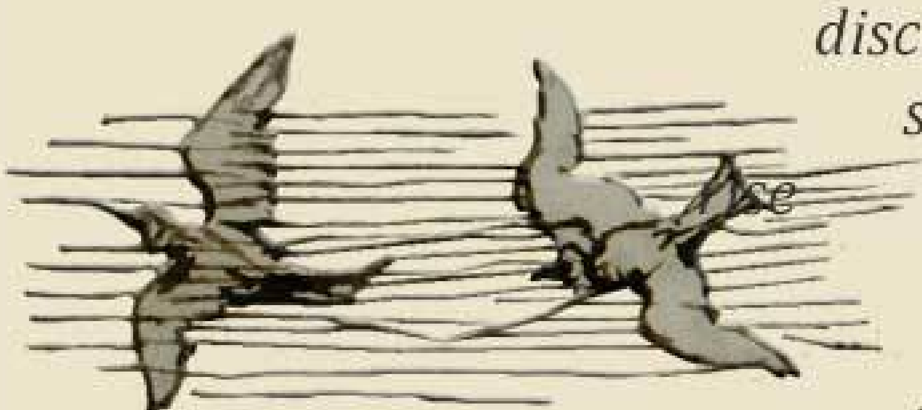
Folio 6 recto

The four downward and upward motions made by birds according to various types of wind.
The descent of birds, if it is done with headwind, will always be made under the wind, with the wind on their backs, and as they ascend the wind will be on the belly of the bird, that is they fly above the wind.

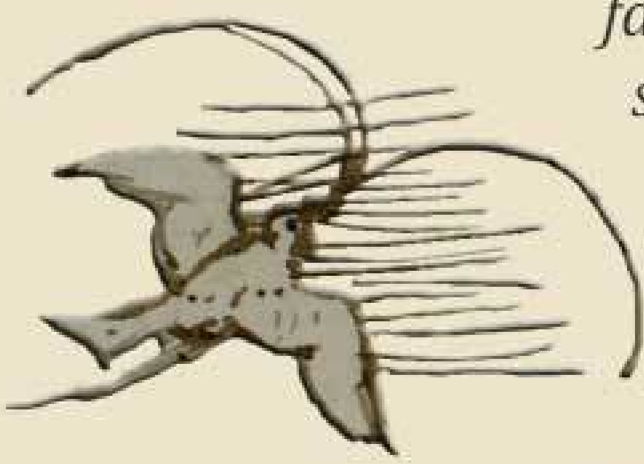


But if the descent is made toward the east, with the wind blowing from the north, then the wing facing north will stay under the wind, and then during an ascent will follow suit, so that at the highest point, it will find itself heading north.

And if the bird descends toward the south, with the wind blowing from the north, it will make that descent above the wind, and it will rise flying beneath the wind. But on the subject of this point there is a debate, which will be discussed in its proper place, because it seems that in such circumstances the bird would not be able to rise again.



When the bird rises in the opposite direction to and above the wind, then it gains height much faster than it should from its natural impetus, since it is favored by the wind, which, entering beneath it, acts as a wedge. But when the bird reaches the end of its ascent, it will have used up its impetus and there will remain only the support of the wind, which striking the belly, it would overturn but for the fact that by lowering the right wing or left, it would manage to turn to the right or to the left, traveling along a semicircular path and rising beneath the wind, in the opposite direction.



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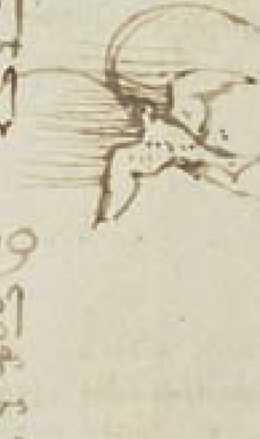
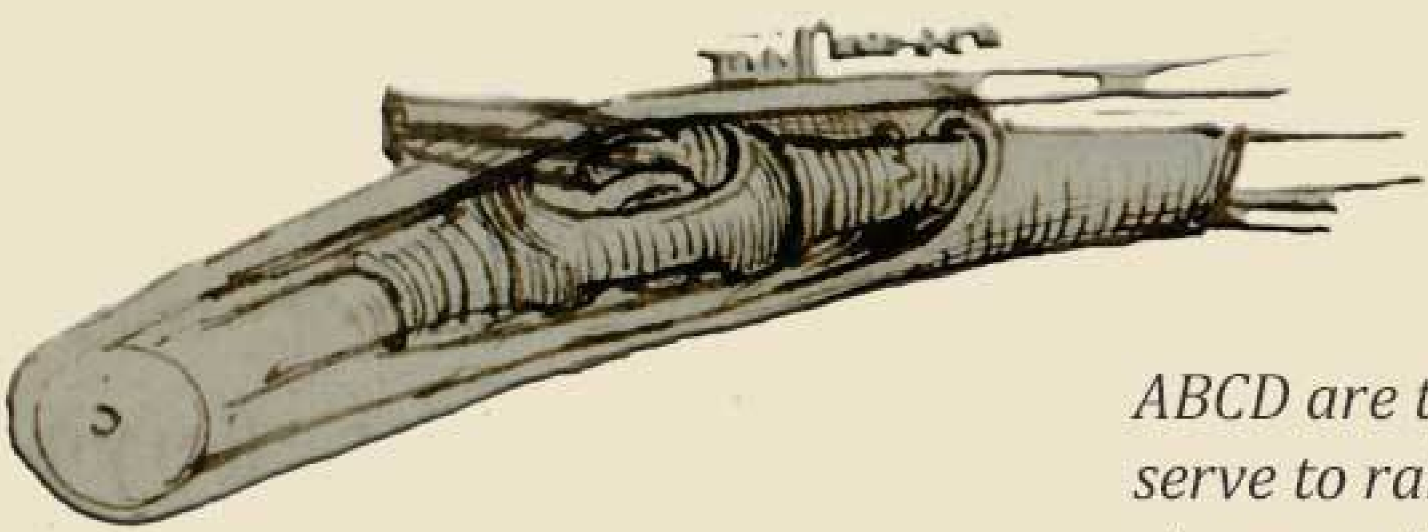
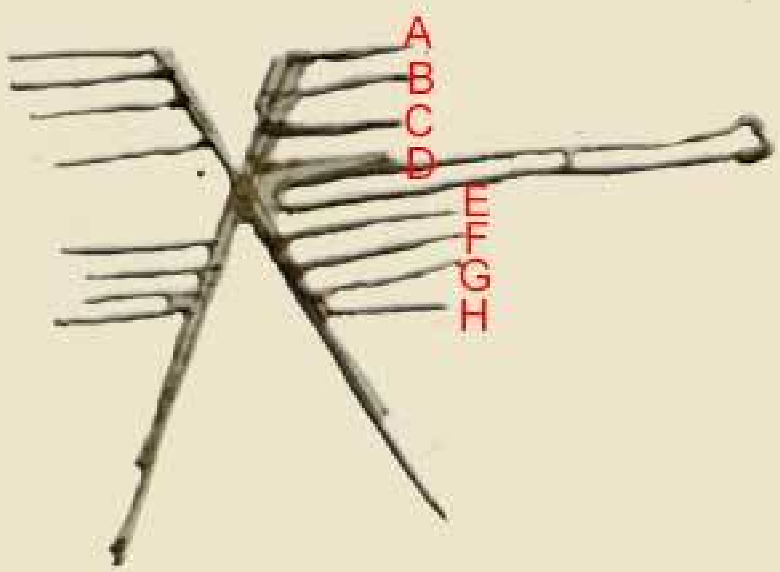


[illegible]

The movement of the bird should always be above the clouds, so that the wing does not get wet, to discover more countries during the flight and to escape the danger of the circular movements of the winds present in the mountainous areas, which are always full of gusts and eddies. In addition, if the bird turned upside down, it would have plenty of time to right itself by following the instructions already mentioned before falling to the ground.

If the tip of the wing is stuck by the wind, and this wind enters below that tip, then the bird will be in the situation of being overturned when not using one of two remedies: fall immediately with the wingtip downwind, or lowering the opposite wing to below halfway.





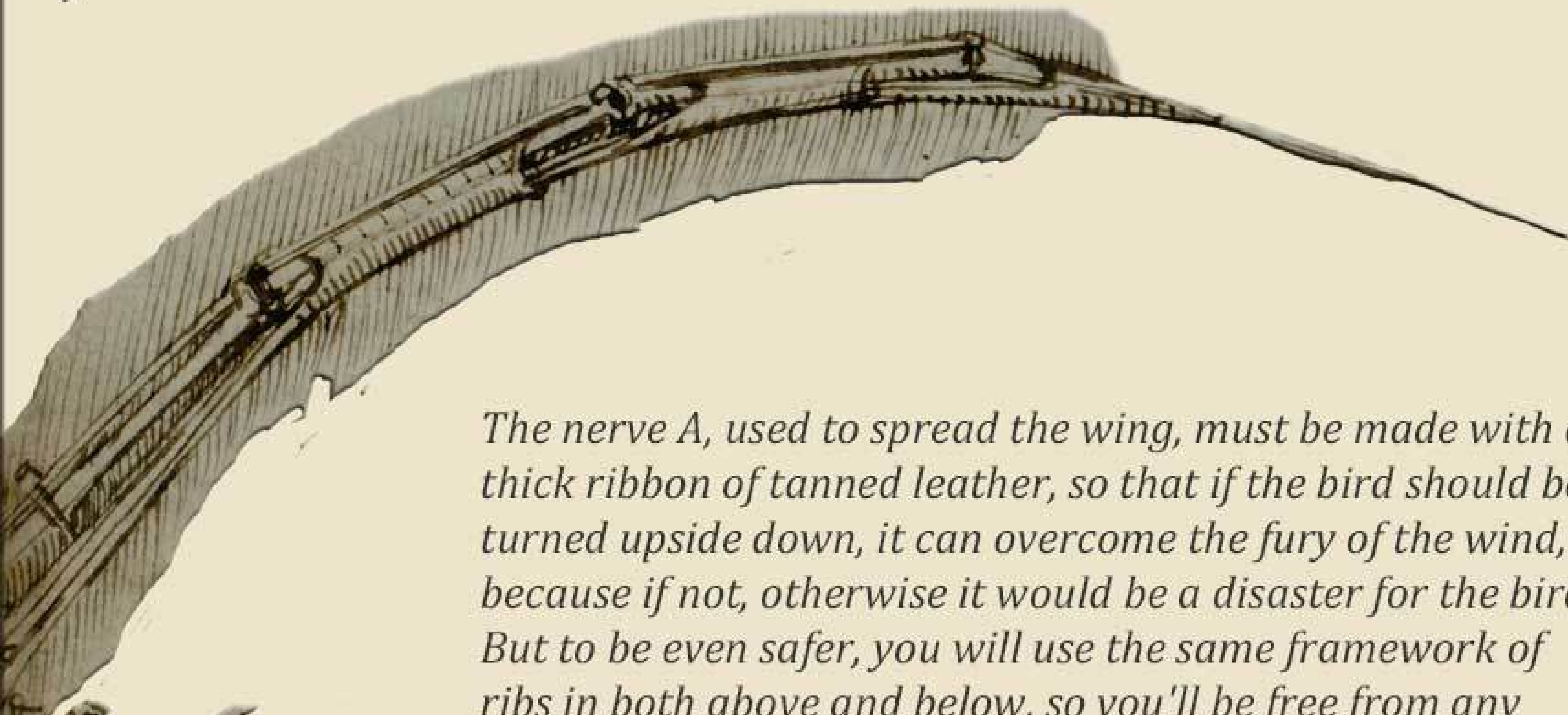
ABCD are the four upper ribs that serve to raise the wing and are as strong as the ribs below EFGH. In the event of the overturning of the bird, both the upper and lower ribs will be of use, even though a single, thick, wide rib of treated leather might be enough. To check what I have said we will make some more practical tests.

[illegible]

[illegible]

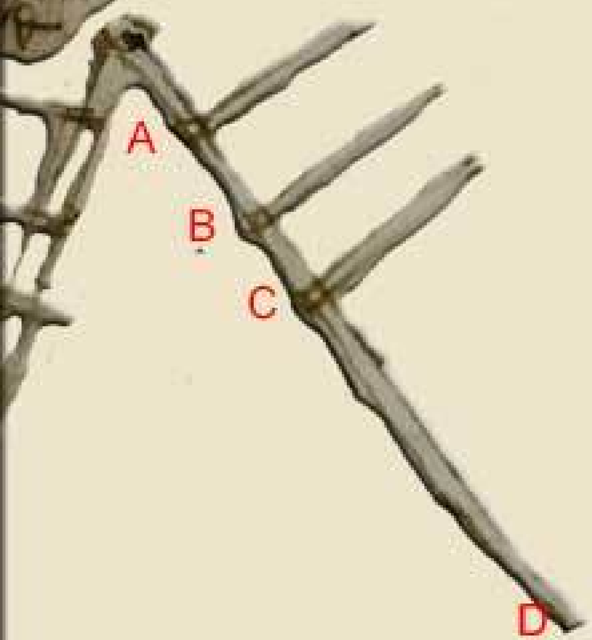
[illegible]

The bird I mentioned must, with the help of the wind, rise to a great height, and this will be a safety factor because, in case of overturned, it would have time to return to a stable position, provided the framework were very resistant, its the joints constructed with strong leather laces and its ribs of very strong raw silk, so that they can withstand the stresses and the speed of descent, with the actions already mentioned, and is not used in its construction any piece of metal, because this material breaks or wears away under stress, which is why there is no reason to complicate the job.



The nerve A, used to spread the wing, must be made with a thick ribbon of tanned leather, so that if the bird should be turned upside down, it can overcome the fury of the wind, because if not, otherwise it would be a disaster for the bird. But to be even safer, you will use the same framework of ribs in both above and below, so you'll be free from any danger.

ABC are the points where the ribs of the three joints of the fingers of the wing are attached. D is the point where the lever AD moves the whole wing.



Folio 7 verso

When the profile of the wingtip is turned toward the wind I have to put this wing immediately below or above the wind and the same operation must be carried out with the sides of the tail and similarly with the rudders of the wing's humerus.

The bird will always descend on the side nearest center of gravity.

When the bird drops in altitude, the heavier part will always be ahead of the geometric center.

3a. When the bird is in the air without beating its wings in a position of equilibrium without the benefit of the wind it means the geometric center and the center of gravity correspond.

4a. When the bird falls with the head facing downwards, the heaviest part of the bird will never be higher than, nor even at the same height, of the lighter part.
If the bird will fall with the tail down, by rotating the tail backward it will return to a state of balance, and if it rotates the tail forward it will overturn.

1a. When the bird in its stable position throws the center of the resistance of the wing behind the center of gravity, then it will descend with its head down.

2a. The bird which is in its position of equilibrium, and moves the center of resistance of its wings ahead of its center of gravity, will fall with the tail pointing towards the ground.

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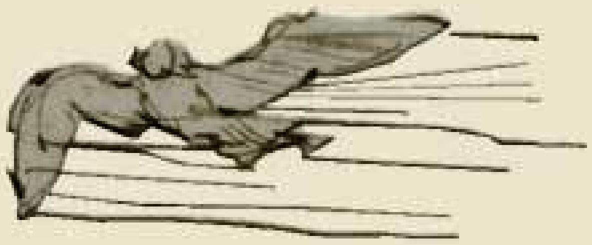
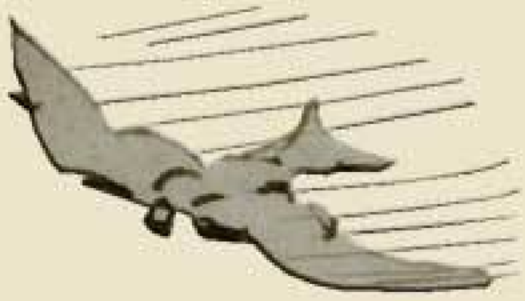
Folio 8 recto

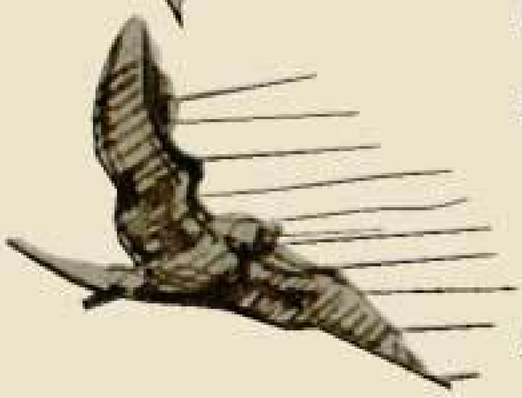


If the wing and the belly are too far above the wind, then you must lower the opposite wing to allow the wind to strike and push upward, thus righting yourself.

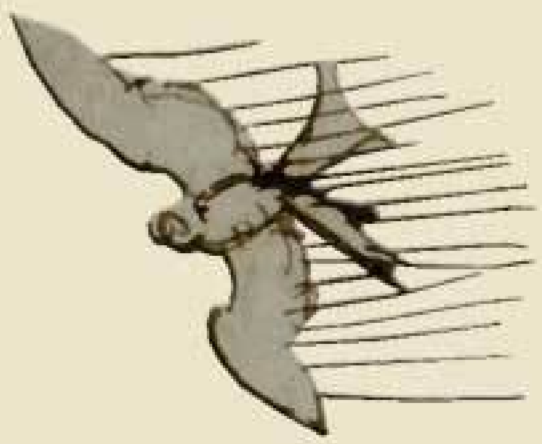


If the wing and the tail are beneath the wind, lift the opposite wing and you will right yourself, as long as the wing you lift is less slanted than the one opposite it.

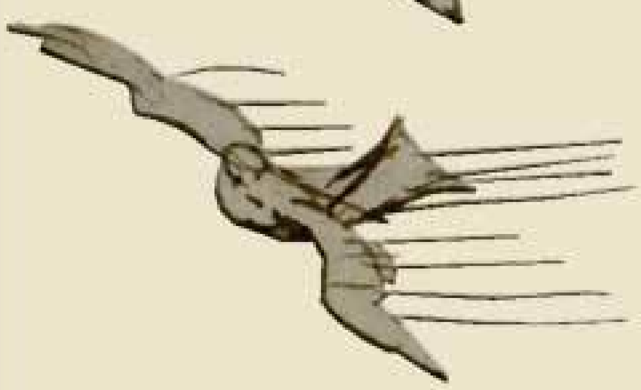
But if the wing and the breast will be under the wind, then you will need to lift the opposite wing and show it in favor of the wind so that the bird will straighten.



But if the wing and the back are beneath the wind, then you will need to lift the opposite wing and shelter it from the wind so that the bird will right itself.



But if the bird has its back to the wind, then the tail must be placed beneath the wind to counterbalance the forces.



But if the bird has its back beneath the wind, it must put the tail above the wind to straighten it.

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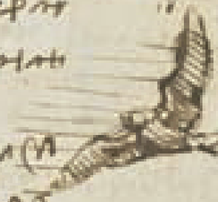

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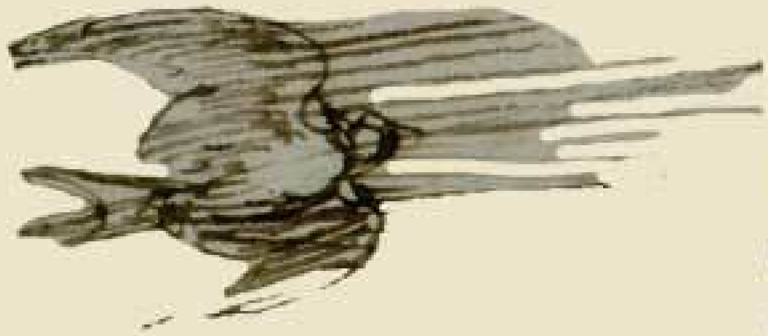
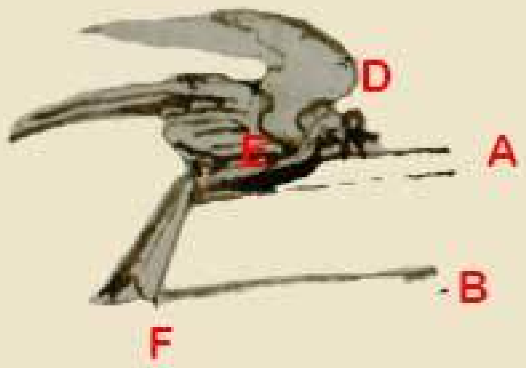
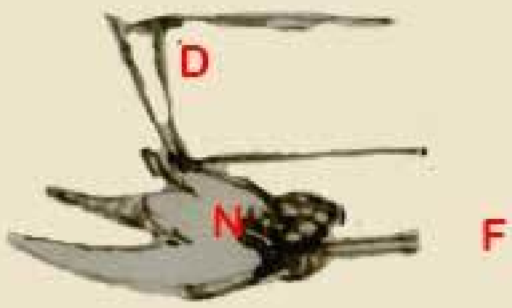
Folio 8 verso



When the bird is above the wind and turning its beak and breast into the wind, then the bird could be over-turned by such a wind, unless it lowers its tail so that not much wind strikes it; and in so doing, it is impossible to be overturned. This can be proved by the first principle of the "Elements of Machinery", which demonstrates how things in balance, which are struck beyond the center of their gravity, tilt down their opposite parts below that center of gravity.



For example: if we suppose a bird placed at position DF, the center of its revolution is E, and that the wind striking it is ABD and BCEF. I believe that a greater amount of wind strikes along the line EF, the tail of the bird, beyond the center of its revolution and that the wind does not strike along the line DE. For this reason the bird cannot overturn, and especially while holding its wings open and cutting into the wind.



If this bird put the whole length of its body beneath the wind, then the wind will overturn it, if it does not imme-diately raise itself with its tail up. Try for example to suppose that the length of the bird is DNF, where N is the center of its circumference. I argue that DN receives more wind than NF and for this reason DN will obey the course of the wind and moves downward, moving the bird from its equilibrium position.

The whole expanse of the wing is not used in compress-ing the air when the wings are beating.

To prove that this is true, look at the spaces between the primary feathers: they are much wider than the feather themselves; therefore you, who study flight, use the whole size of the wing in your calculation and look carefully at the different types of bird wings.

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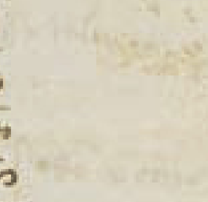

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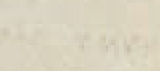

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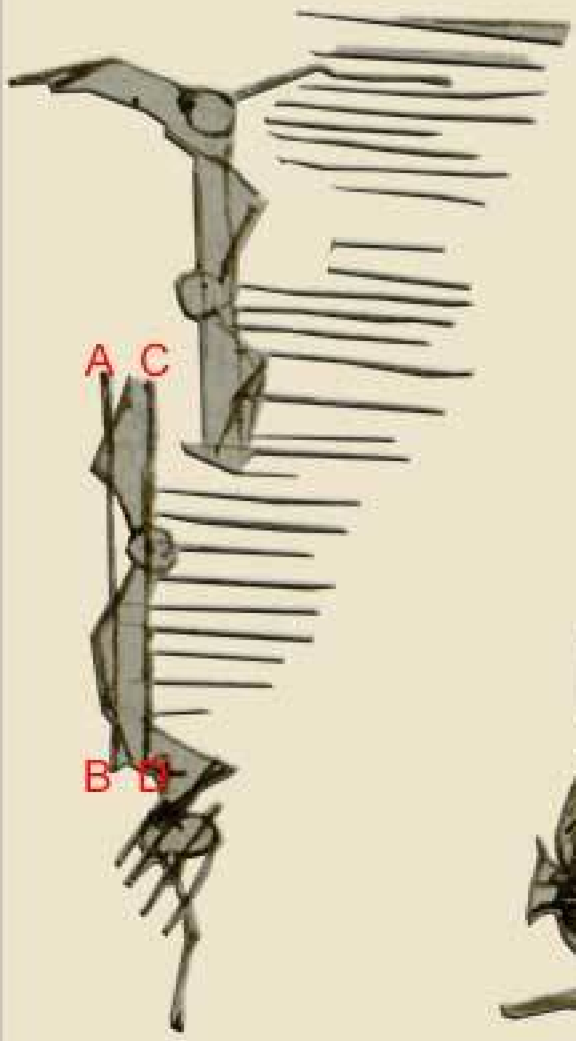
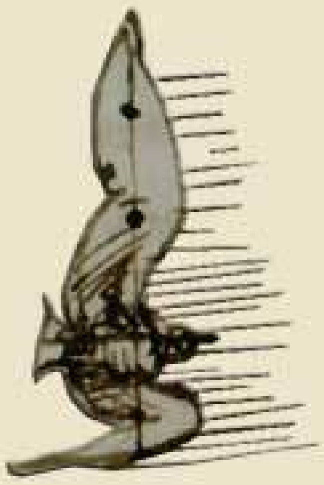
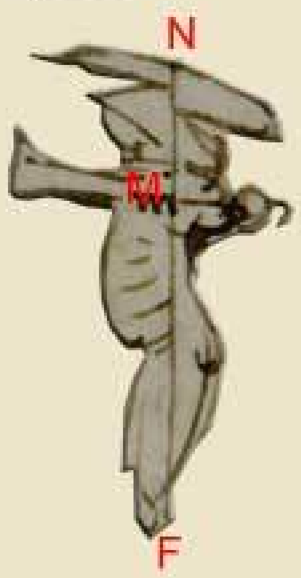




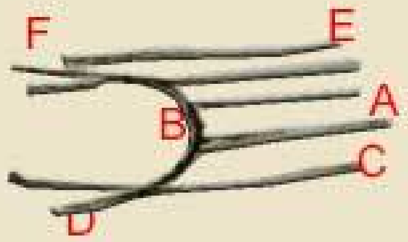
When the wind strikes the bird from the bottom upwards, with the center of gravity to the wind, the bird will turn its back to the wind. And when the wind is stronger below than above, then the bird could turn upside down unless it immediately pulls in the wing which is lower and stretches out the upper wing. In this way, it straightens and returns its equilibrium position.

Try the following: Let AC be the closed wing of the bird and BC the wing that is stretched. I say that the wind will have the same speed in proportion to the parts of the two wings it strikes by the wind and in proportion to their wingspans AB and AC. It's true that C is wider than B, but it is so close to the center of gravity of the bird that it offers little resistance compared to the spread wing B.



But when the bird is struck by the wind beneath of one of the wings, then it could overturn it, unless the bird immediately turns its breast to the wind and extends the opposite wing toward the earth and closing the wing struck by the wind, which remains higher and thus will return to a state of balance. This is proved by the fourth rule of the third principle, which states "that the object is more overcome when it is opposed by a greater force." Also by the fifth rule of the third principle, which states "that the weakest support is located farthest from its point of attachment." Finally, again in the fourth rule of the third principle, it is stated "between winds of equal force, the one of greatest area will have the greatest force, and the one which strikes the greatest amount of area will meet with the greatest resistance. Therefore, as MF is longer than MN, MF will obey the wind.

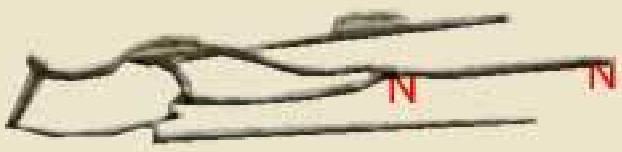
Folio 9 verso



(continued from folio 10R) ...on its upper surface, the force of the wind, which strikes from above, is not at its full force, because part of the wind, like a wedge, strikes the underside of the wing. The wind divides at the bottom near the middle point of the edge of the humerus, raising the wing up almost with the same force as the wind that strikes the upper surface of the wing and pushes it downward.

This is proved as follows. Let the humerus of the wing be FBD, and EFCD is the total amount of wind that strikes the humerus of the wing, of which half is ABCD, which strikes from the top of the humerus B as far as D. Since the line of the humerus BD is oblique, this wind ABCD forms a wedge at the contact point BD and lifts it up. Instead, the wind ABEF, which strikes the upper surface of the wing and the edge BF, pushes the wing down.

Therefore, these two opposing forces do not allow the humerus to be placed beneath or above the wind according to the course the bird requires. This necessity has been met by putting a rudder on top of this round humerus, which should act as a shield and immediately cut into the wind in such a way as the bird requires, as shown in MN.



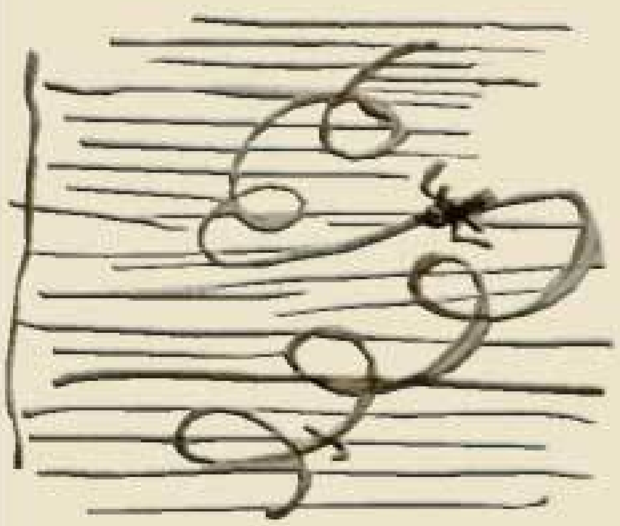
But if the wind strikes the bird on the left or right wing, then it is necessary that the bird enter beneath or above the wind, at an angle to the wind. The maneuver is made possible by the wind that strikes in a different way the wingtip; the amplitude of these movements is proportional to the size of the tips of the wings. If this is done beneath the wind, the bird turns with its beak to the wind; if however, it is above the wind, the bird turns with its tail toward the same wind. And here arises the danger of the bird overturning with its body upside down, if nature had not provided for the heaviest part of the bird to be below the point where its wings are attached, as will be shown hereafter.

Folio 10 recto

The wings and tail of a bird have the same functions as the arms and legs of a swimmer in the water.
If man swims with his arms in the same way toward the east, and continues ahead in that direction, the final movement will be eastward. But if the northern arm makes a longer stroke than the southern arm, then the movement of his length will be northeasterly. And if the right arm makes a longer movement than the left arm, the swimmer will move toward the southeast.

If only one wing is turned sideways toward the tail it causes the bird to immediately make a circular motion, following the impetus of the aforesaid wing.

When the bird rises in circles above the wind without beating its wings, using the ascending currents, it will be carried far from the area to which it wishes to return, even without ever beating its wings. Then it will turn its head in favor of wind, coming in with an inclination to the wind, losing lots of height, until it arrives above the place where it wants to return.



*The cutting edge A placed along the femur in the wing, that is the big finger of the bird's hand BA, is what allows it to quickly move the humerus below or above the wind. And if this humerus were not sharp, with a thin, strong edge, the wing would not be able to enter quickly below or above the wind, when it became necessary to do so. In fact, if the edge were rounded, and if the wing is suddenly hit by a gust of wind F ...**(continued on folio 9 verso).*

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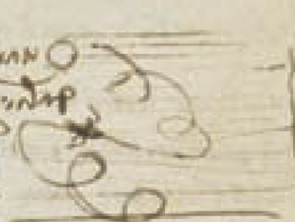

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If the bird wishes to turn quickly on one of its sides to continue its circular flight, it will beat the wing two times on that side, thrusting the wing back, while the other wing remains still, or else with a single beat versus two of the opposite wing.

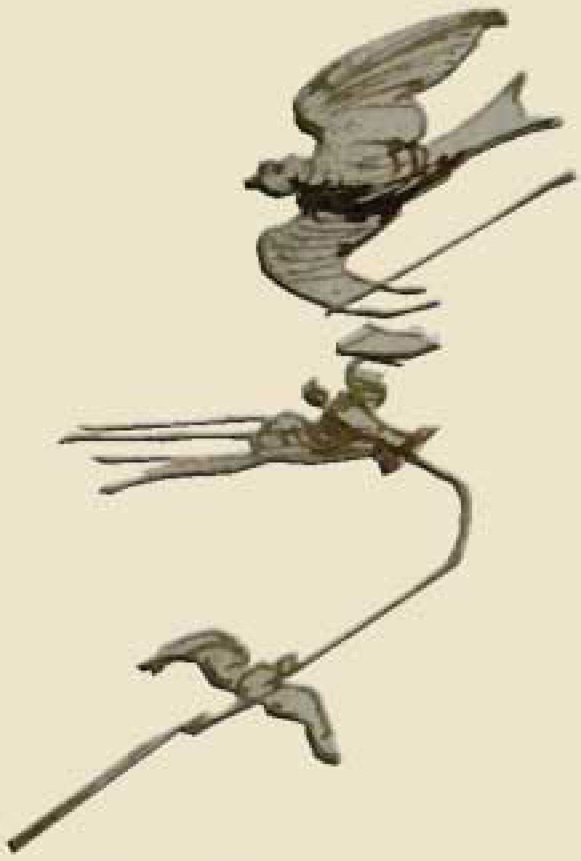
Since the wings compress the air faster than the air can escape from under the wings, this air becomes heavier and resists the movement of the wings themselves. The "engine" of these wings, that is the bird's body, overcomes the resistance of the air and advances with a movement contrary to that of the wings themselves.

The bird that will descend fastest is the one with a steeper angle of descent. At the same speed, the angle of descent of that bird will be smaller if the wingtips and the humerus are pulled in close to the body.

The lines of the movements made by birds ascending are of two kinds, of which one is always curved like a screw, and the other straight or in an arc.

The bird which gains height in a circular motion similar to a screw will fly against the force of the wind and to escape that wind will turn either to the left or to the right.

Similarly, when you feel the force of the northern wind above the air current and in the opposite direction, you will go against the wind; when in your straight ascent that wind is disposed to overturn you, then you are free to bend your right or left wing and with the inner wing lowered you will begin a curved motion by using the tail as well. So, you will curve toward the lower wing, always descending and curving around the lower wing, until you regain height into the wind by following the current of the wind. And when you are about to turn over, the same lowered wing will make you turn around, and you will again turn into and below the wind, until you have acquired speed. And then it raises you above the wind, toward its direction; then, because of the speed you have gained, your upward movement will be greater than the downward movement.



The bird that is rising always keeps its wings still and above

the wind, and always moves in a circle.

If you want to go to the west without beating your wings, by making use of the north wind, descend in a straight line beneath the wind, moving toward the west, or go upwind in the direction of the north wind.

[illegible]

[illegible]

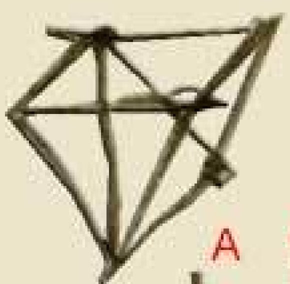
[illegible]

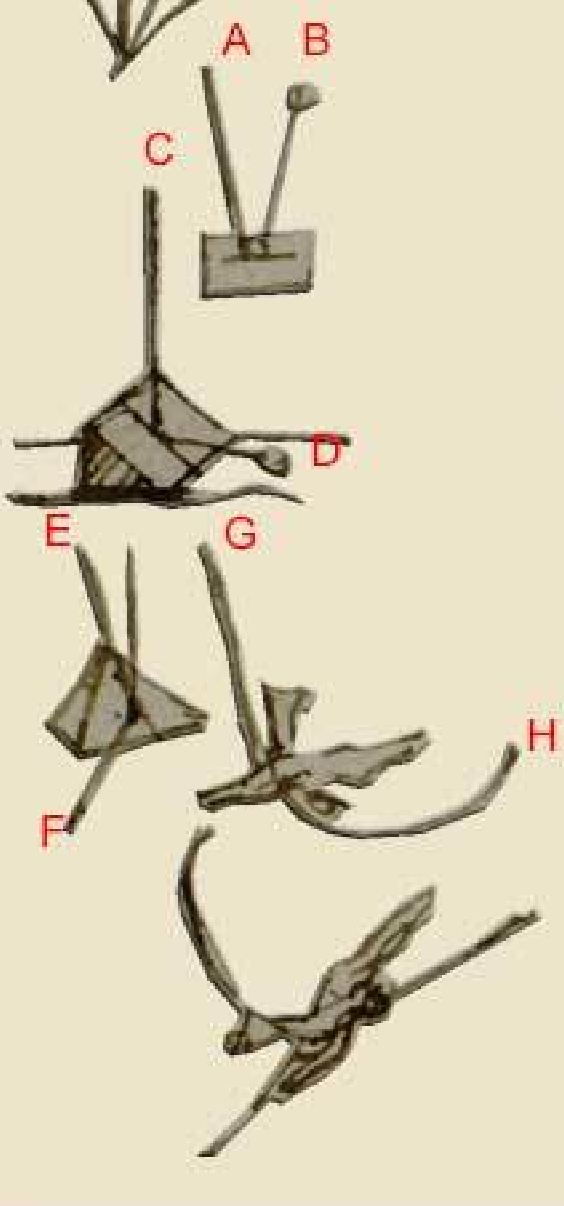
Folio 11 recto

And falsehood is so despicable, that if it said even great things of God, it would cast a bad light on his nature; and truth is so excellent that even small things are ennobled when praised by truth.

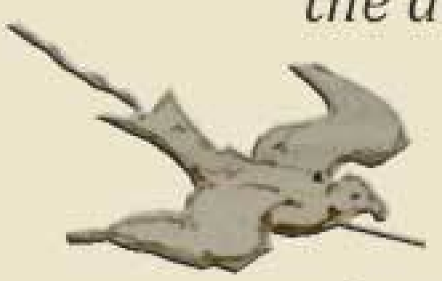
But you who live in dreams—are you better pleased by the false reasoning and cheating that goes on when great and uncertain things are discussed than by things which are sure and natural and not so far beyond our grasp?

No doubt between the truth and falsehood is the same difference between light and darkness. Truth is in itself so excellent that even if it is applied to humble and lowly matters, without comparison it exceeds the uncertainties and lies applied to great and lofty subjects. Because in our minds even if lying is part of human nature, it is still a fact that the truth of the things is a great nourishment of refined intellects as well as wandering wits.

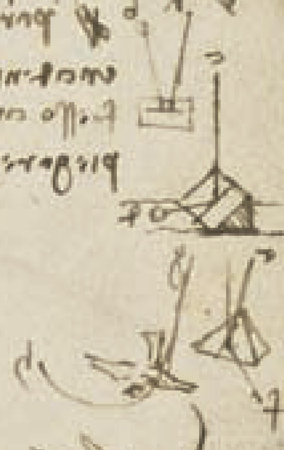




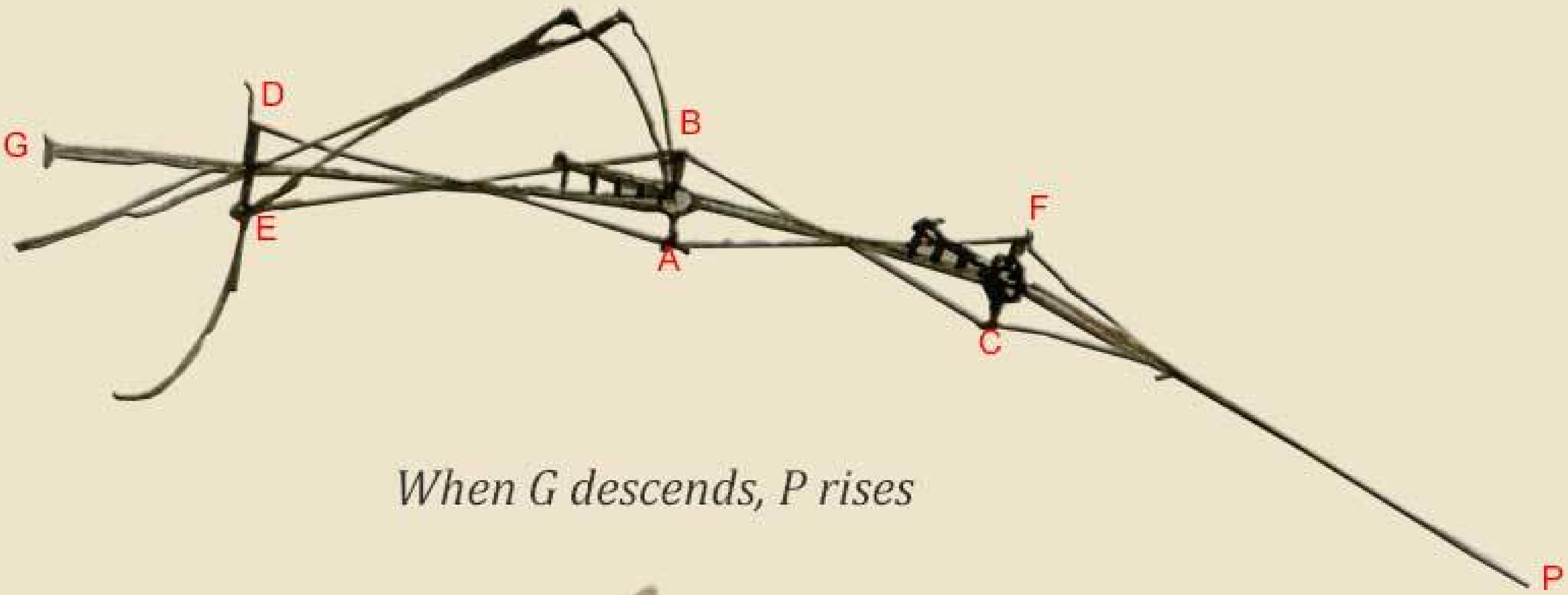
Upward movements, with their associated downward movements, are of four kinds: in the first the movement is upward, downward and straight forward, having lines of equal gradient; in the second it is also straight forward, but the gradients are different; in the third the upward movement is straight forward and the downward curved; in the fourth the upward movement is curved and the downward straight forward.
These straight and curving lines are divided into two parts: in the first, the straight forward upward movement can take place entirely along the cord of the arc, while the second can follow along its entire route a curved line; the downward movement can also bend to the right or left in relation to the upward movement.



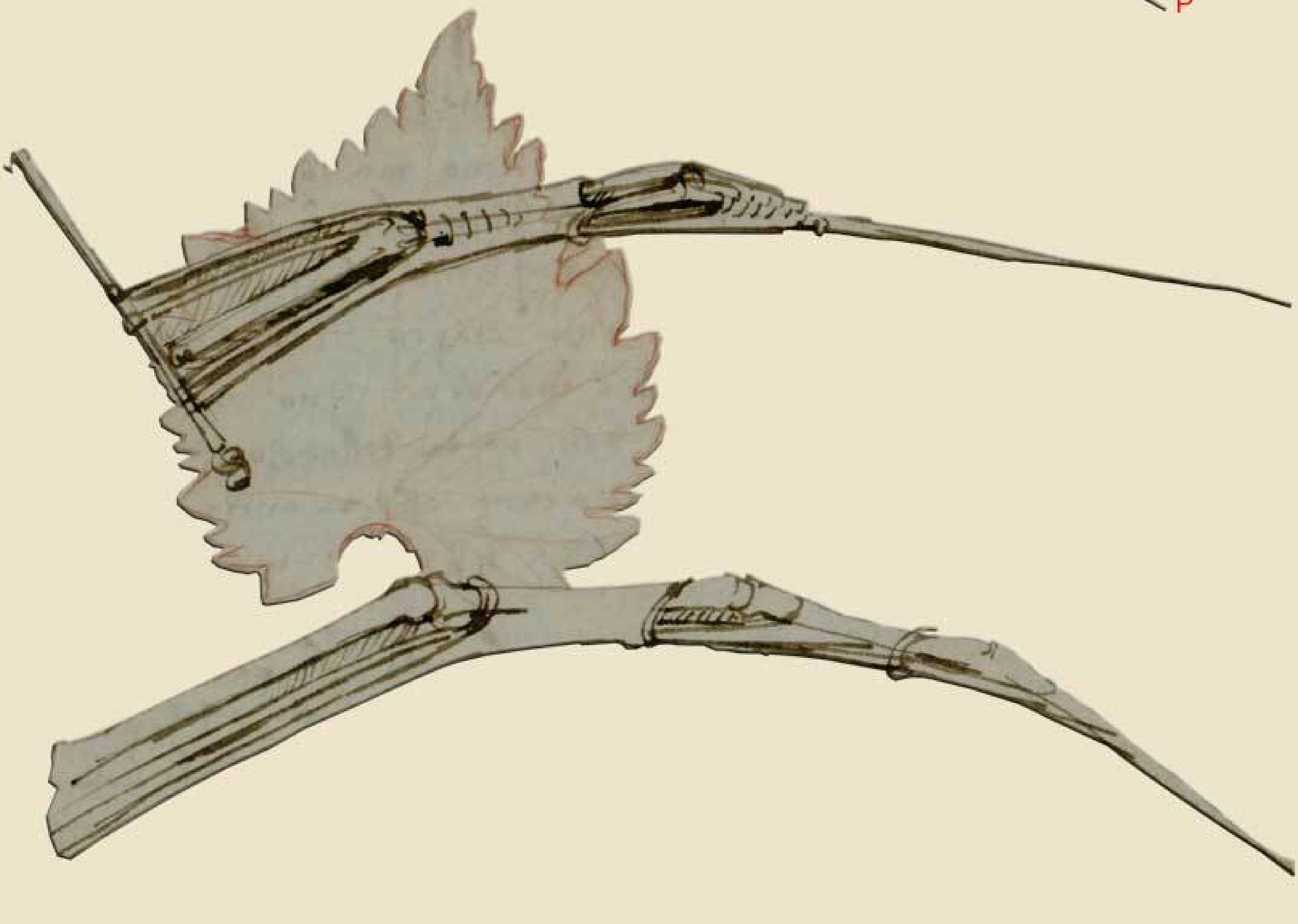
When the bird flies by beating its wings, it does not spread the wings entirely, because the tips of the wings would be too far from the leverage point of the wings and from the ribs that move them. If during the descent of the bird, it rows backward with its wings, the bird is faster, and this happens because the wings push the air behind the bird, filling the empty air space where the bird was before.

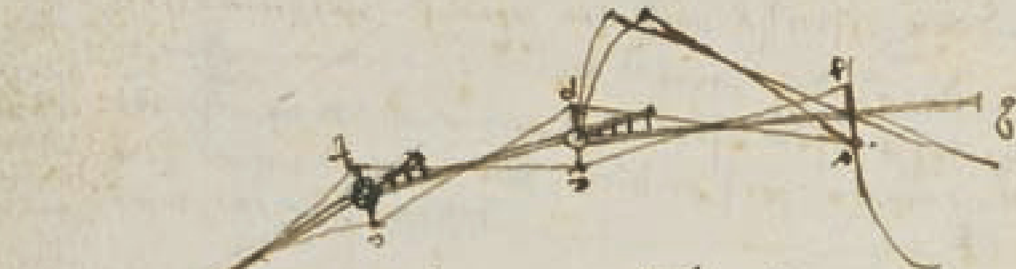


Folio 11 verso



When G descends, P rises





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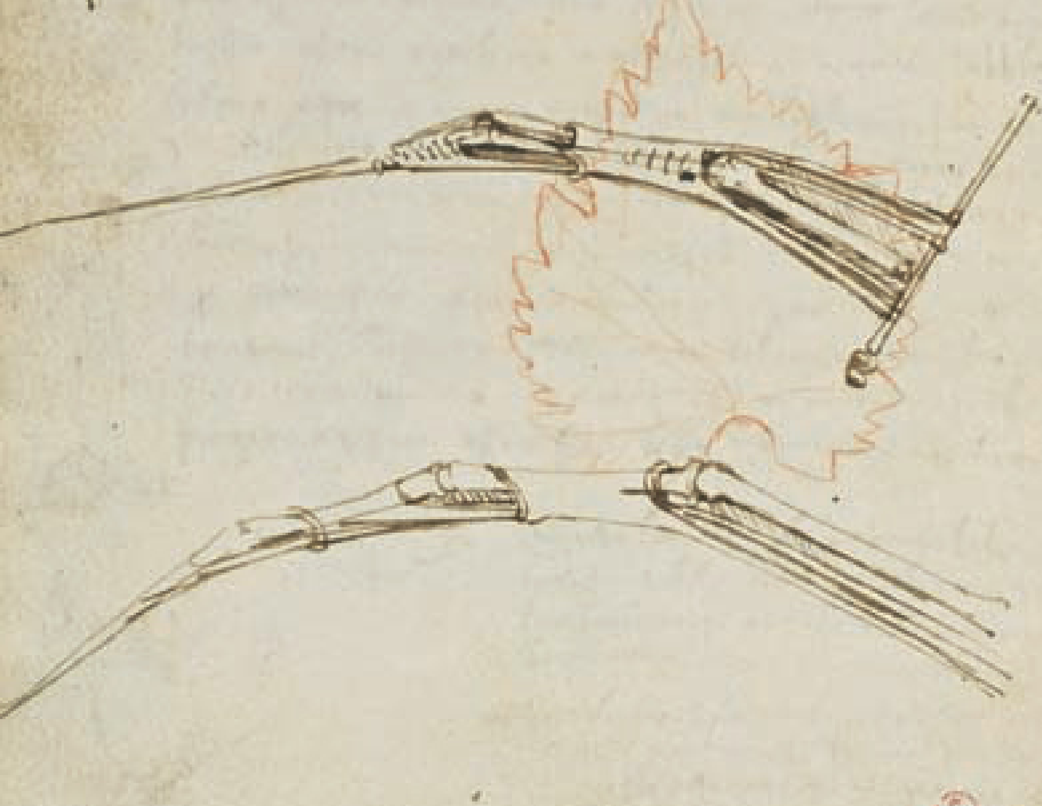
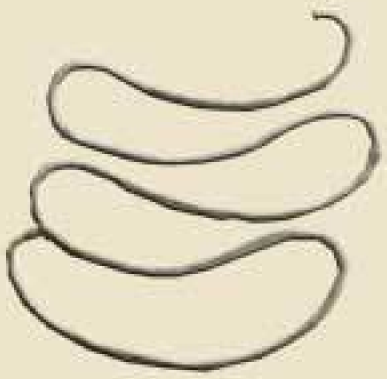


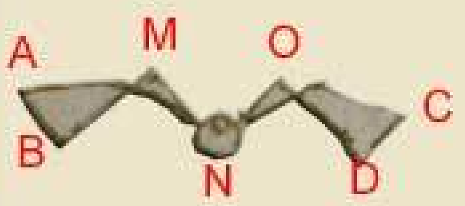
(continued from 12V) *curving until it has made a semicircle, then at the end of the climb the bird will find itself with its beak pointing towards the point where it began the reflex movement that, if it made against the direction of the wind, will take the bird to much higher altitude than the one which had started earlier in the downward motion.*



This is the way in which the bird rises high, without the need to beat their wings and making circular trajectories. The remaining part of this circle is completed with the thrust of the wind, by upward movement, always with one of the wings lowered and one side of the tail lowered as well; and it then makes a reflex movement in the direction of the wind and in the end remains with its beak turned in the direction of the wind before incidental movement again takes over, and then reflex, always circling.

When the bird wants to change direction rapidly, it quickly pushes the tip of the wing on that side toward its tail. Every movement tends to maintain its own direction, or rather every moving object continues to move as long as its own drive has enough power. Therefore the movement of this wing will be driven forcefully in the direction of the tail and will retain part of this energy almost till the end; not being able by itself to follow the already started movement, it moves the whole bird with it until the speed caused by the movement of the air is entirely used up.

When the surface of the tail pushes against the wind it makes the bird move quickly in the opposite direction.



When the bird is in the position ANC, and rises in altitude, it will lift its shoulders MO. Thus it will find itself in the position shown by the points BMNOD, and will press the air between the sides and the tip of the wings, so that it will be condensed and produces an upward movement. This generates air speed and, because of its compression, this speed will push the bird upward.

[illegible]

[illegible]

[illegible]

[illegible]

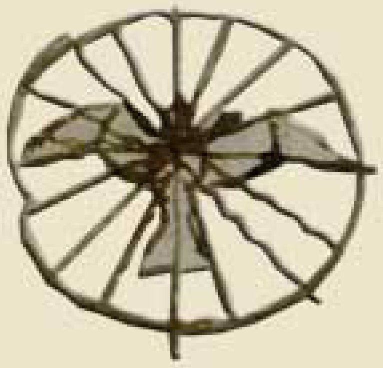
[illegible]

Folio 12 verso

To escape the danger of destruction

These machines can fall for two reasons: the first is a breakage, while the second is when the machine turns edgewise or near that edge; this second situation is dangerous because the bird should always descend along a very steep gradient, which almost matches its center of balance.

To prevent the machine from breaking, you will build it strong enough to resist any inclination and whatever line it may be able to turn itself; that is either by the edge, falling either with the head or the tail first, or else with the tip of the right or left wing, or by the halves or quarters of the aforesaid lines, as the drawing shows.



Regarding the possibility to turn sideways in any direction, the solution should be foreseen and the machine should be manufactured in such a way that during the descent, in whatever position it may be in, it can come out of the situation as quickly as possible. And this will be done by placing the center of gravity above the center of the weight being carried by it and by keeping these centers far from each other. For example, in a flying machine with a width of 30 arm's length these centers must be of four arms (old measure) away from each other and, as already said, one beneath the other with heaviest on the bottom, because during the descent the heaviest part guides the movement of the lighter one. Beyond this if the bird is about to fall with its head down at such a gradient that would cause it to overturn, this could not happen, because the lighter part would be below the heavier one and the light one would descend before the heavy one, something that cannot occur during a descent, as set out in the Fourth principle of the mechanical elements.

And if the bird falls at such an angle, head first, to direct the body toward the ground, then the lower edges of the wings must turn so as to be parallel to the ground, the tail must lift towards the kidneys and the head, the part below the jaw, that is- should also be turned toward the ground. In this way the bird will begin a downward movement which will push it back toward the sky. In this situation and at the end of the downward flight, the bird could fall backwards, unless, as it was ascending again, it lowered somewhat one of the wings ...
(continues on 12 recto)

[illegible]

[illegible]

Folio 13 recto

Here the large fingers of the wings are those that allow a bird to stay still in the air despite the wind; when the wind blows over a bird that supports itself without beating its wings, and the bird does not change its place. The reason is that the bird holds its wings at an angle so that the wind, striking it from below, does not act as a wedge that can lift the bird, but lifts it only as much as its weight would cause it to fall. That is, if the bird wants to get down with a power of two and, at the same time, the wind exerts an opposing upwards pressure equal to two trying to lift it, since the two forces are the same the bird remains where it is without rising or descending. In my opinion, if it remains in this situation it will go neither forward nor back, and this happens if the wind tries to push the bird out of its equilibrium position with a power of 4, and with the same force the bird, taking the angle mentioned above, goes against the wind. I repeat that these forces must be equal if the bird will not move forward or backward. But because the movements and forces are variable and the angles of the wings must not change, when the wind increases its force the bird will change the inclinations of its wings, in order not to be pushed upwards by the wind ...

(consideration of Leonardo) In summer you can bring snow to warm places by collecting it from the high peaks of the mountains, and letting it fall on the streets during the summer festivals.

In the cases mentioned above the wind does not behave like a wedge under the inclined wings, but touches the wing only along the edge that the bird is trying to lower against the wind.

The wind strikes sideways on the wing in the area of the humerus, which acts as a shield to the entire wing; in this situation there would be no resistance to the wing being lowered if it were not for the fact that the large finger "A", acts as a shield, taking the entire force of the wind in full, or almost in full, according to the greater or lesser force of the wind.

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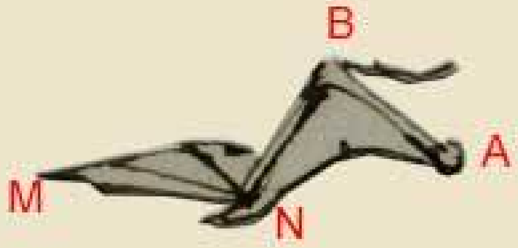
Folio 13 verso

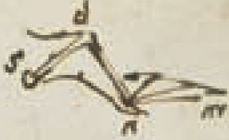


Note (4)
But if the tail is at an angle when struck by the wind on its upper surface, the bird will turn toward the side faced by the upper surface of the tail.

The large finger N of the hand MN is that which, when the hand is lowered, comes to be lowered more than the rest of the hand, so that it closes and prevents the escape of the air compressed by the lowering of the hand; by lowering and closing the hand the air in this area is compressed and opposes resistance to movement of the wing itself. For this reason, nature has provided birds a large finger fitted with a very strong bone, to which are joined very strong ribs and short feathers which have greater resistance than all others. In fact, the bird rests on this part of the wing, above the air it has compressed, by exerting all its power and strength of its wings, because this is what allows the bird to move forward, in the same way as a cat uses its claws to climb trees.

But when the wing is able to produce new force, once it has been raised and turned forward, then the big finger of the wing places itself in a straight line with the other fingers and so, with the "side" of its hand, cut through the air as if it were a rudder, and move in any direction the bird chooses to go, either upward or downward.

The second rudder, that is to say the tail, is at the opposite end, beyond the center of gravity of the bird, which is why, if struck by the wind underneath, the bird will be tipped forward. However, if the wind strikes the upper surface of the tail the bird will be tipped backward. If the tail twists somewhat, so that the surface is angled toward the right wing, the forward part of the bird turns toward the right. But if it turns the underside of the tail toward the left wing, it will turn the forward part of the bird to the left. The bird will descend during both these movements.


d
s
n
m

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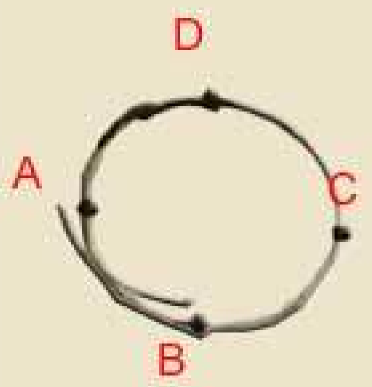
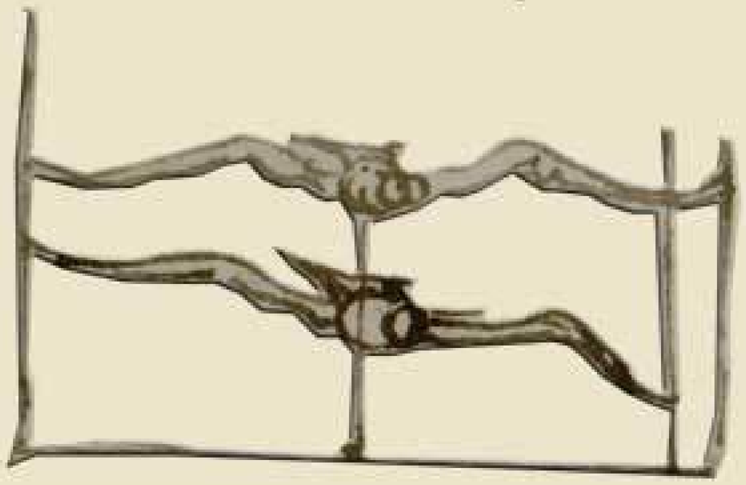
The centerpiece of the shoulder of the bird is the part turned by pectoral and dorsal muscles. These muscles control whether the elbow is raised or lowered, according to the will and needs of the animal that is moving.



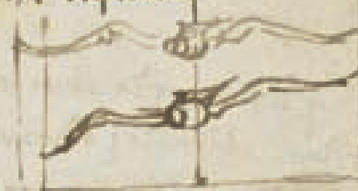
I conclude by saying that when the birds fly high without beating their wings they can only do so if they fly in circles using wind currents; which movement, when it originates from the direction of the wind, is gradually decreasing to the point where the downward movement is created. Once it reaches this point, still continuing with a circular movement, after making semi-circle in the air, the bird reaches its maximum height with the aid of the wind; then it will continue its downward movement above the wind, always circling, until it reaches its greatest height with the help of the wind; it remains in the air with a light wind. From this great height, again in a circular motion, it will come back down with upward movement, that is spiraling, keeping its right wing to the wind. As shown in the drawing, when the wind blows from point A to point C, the bird moves from A and descends along the stretch ABC and at C takes the downward movement along the path CDA, and by favor of the wind finds itself much higher at the end of the downward movement than at the beginning of the upward movement.



The downward movement comes to an end at a point perpendicularly above the starting point of the upward movement.

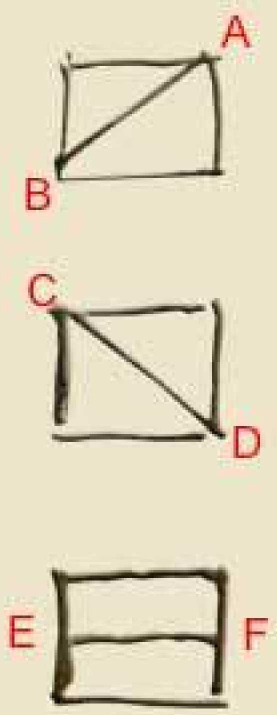
When both wings have the same resistance, then the distance of the wingtips is also the same and is arranged so as to be equidistant from the center of gravity of the bird.

But when one of the wingtips moves nearer to the center of gravity of the bird than the other, then the bird descends on that side.



Folio 14 verso

The "hand" is the part of the wing that produces speed. Once the wing has moved downward, the elbow is placed sideways to not hinder the movement that creates speed, that is to say, the flapping. When the bird has gained speed the elbow is lowered and tilted, while air enters the wing and behaves like a wedge, opening the wing upwards. If this did not occur, when the wing was moved forward again the bird would slow down and exhaust its speed. In fact, the bird does not lose height because when there is not enough speed for this kind of movement, the elbow moves rapidly, flapping the wings, and thus resists falling and propels the bird upward again.



Let's suppose that the bird's speed and weight are each equal to 6 and that halfway along its path its speed is reduced to 3, but its weight remains at 6. Then the bird would have to lose height along a diagonal path, but the wing, angled in the opposite direction to that diagonal, would not allow the weight to descend, yet neither would the bird's weight allow it to rise, so it would end up moving straight forward. It's as if to say that at the halfway point of its flight the bird would take line AB and, because its wings are angled in the opposite direction, it would rise along line DC. Therefore, for the reasons given above, the bird moves along the middle line of balance EF.

The animal's elbows are not completely lowered immediately because, given that they produce the necessary speed, the bird would bounce upward repeatedly. The wings are lowered just enough for the bird to resist falling as much as it wants to. When the bird wants to rise quickly, it drops its elbows immediately so as to produce the desired speed.
But if it wants to descend, once it has enough speed, it keeps its elbows up and holds them still.

Remember that your bird must only copy the bat because the membranes act as a framework, connecting the major articulations of the wings.

If you wanted to copy the wings of feathered birds, they have stronger bones and quills because they are permeable: the feathers are divided and the air passes through them. On the other hand, the bat is held up by its membranes, which connect everything together and are not permeable.

How to balance

The heaviest part of an object always guides the movement of the whole object.
Then, when the bird is in position AB, as A is lighter than the place where the "engine" B is located, the lighter point A will always be above the heavier point B, so it will never happen that A is in front of B, except in case of accidents and for a very short time.

The bird that wants to fly higher without beating its wings, bends into the opposing wind, opening its wings and its elbows to the wind, placing its center of gravity more toward the wind than toward the center of the wings. Thus if the bird puts itself at an angle that makes it descend at a speed of 2, while the force of the striking wind is 3, the bird's movement will obey the greater force 3 of the wind and it will continue to rise.

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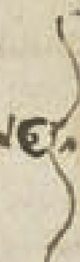

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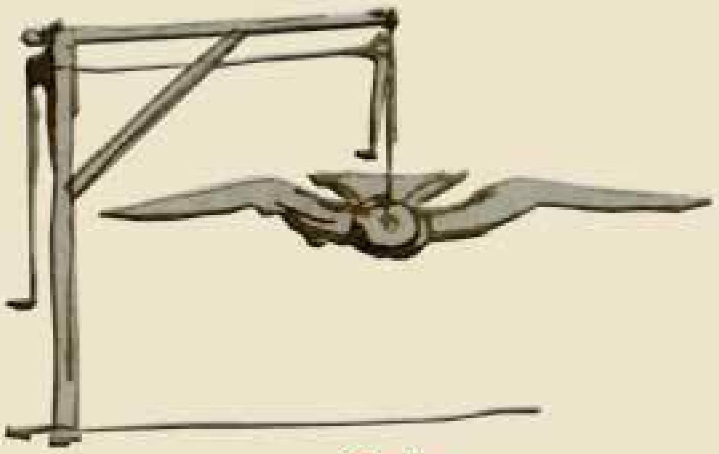
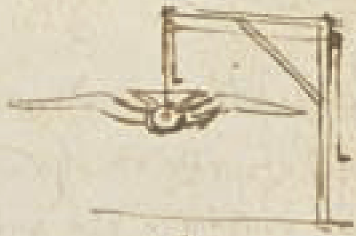
Folio 15 verso



This is done to find the bird's center of gravity; without this equipment the bird as built would be of little use.
When the bird descends, then its center of gravity is different from its center of resistance; as if the center of gravity corresponded with line AB and the center of resistance were near line CD.

When the bird wants to rise, its center of gravity remains behind its center of resistance.
As if the center of gravity just cited was situated at FG and the center of resistance at EH.

The bird can stay in the air without necessarily keeping its wings balanced, because as its center of gravity does not always correspond to its midpoint, as the scales do, it is not necessarily forced to keep its wings at the same height, unlike scales. But if these wings are positioned beyond the stable position, then the bird will descend along the angle of the wings; and if the angle is complex, that is if the parts of the body point in two different directions, for example the wings pointing south and the head and tail east, then the bird will descend toward the southeast. If the angle of the bird is double that of the wings alone, the bird will descend halfway between southeast and east, and the angle of its flight will be along the two angles.



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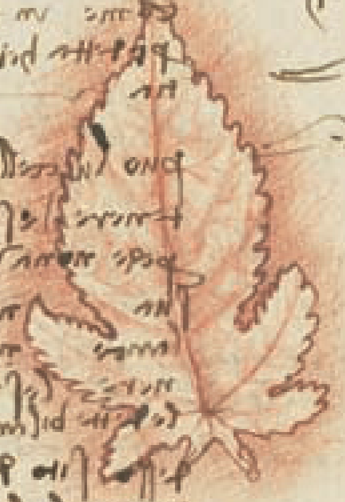

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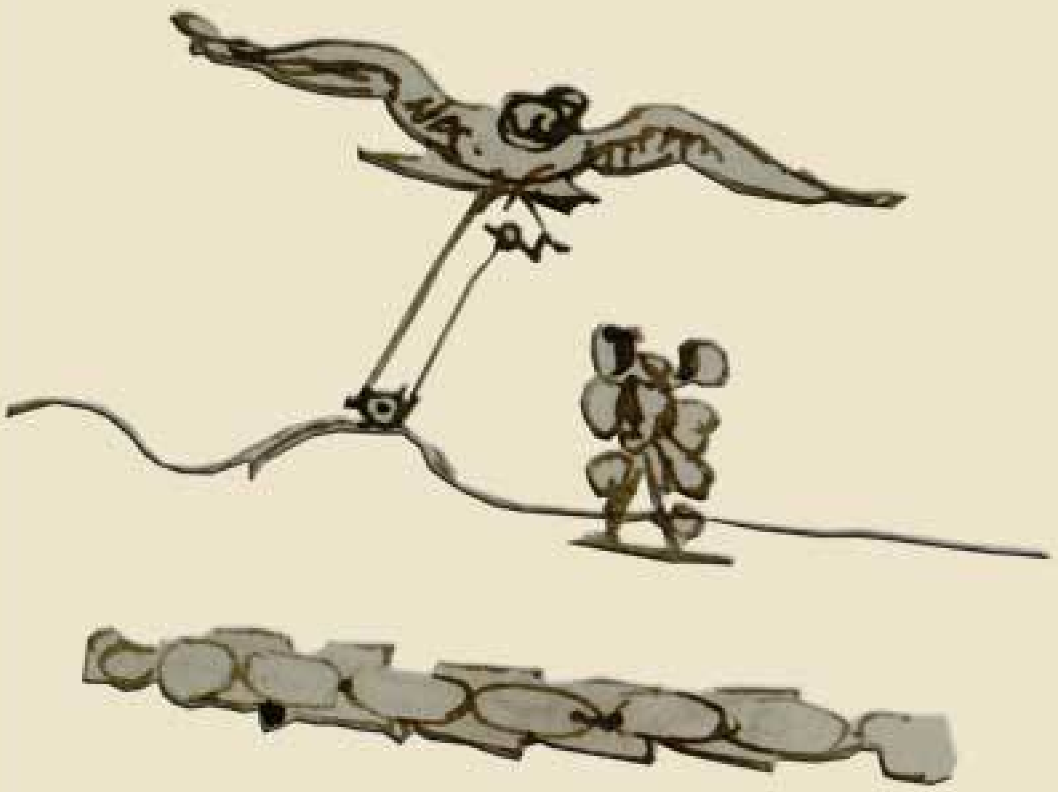


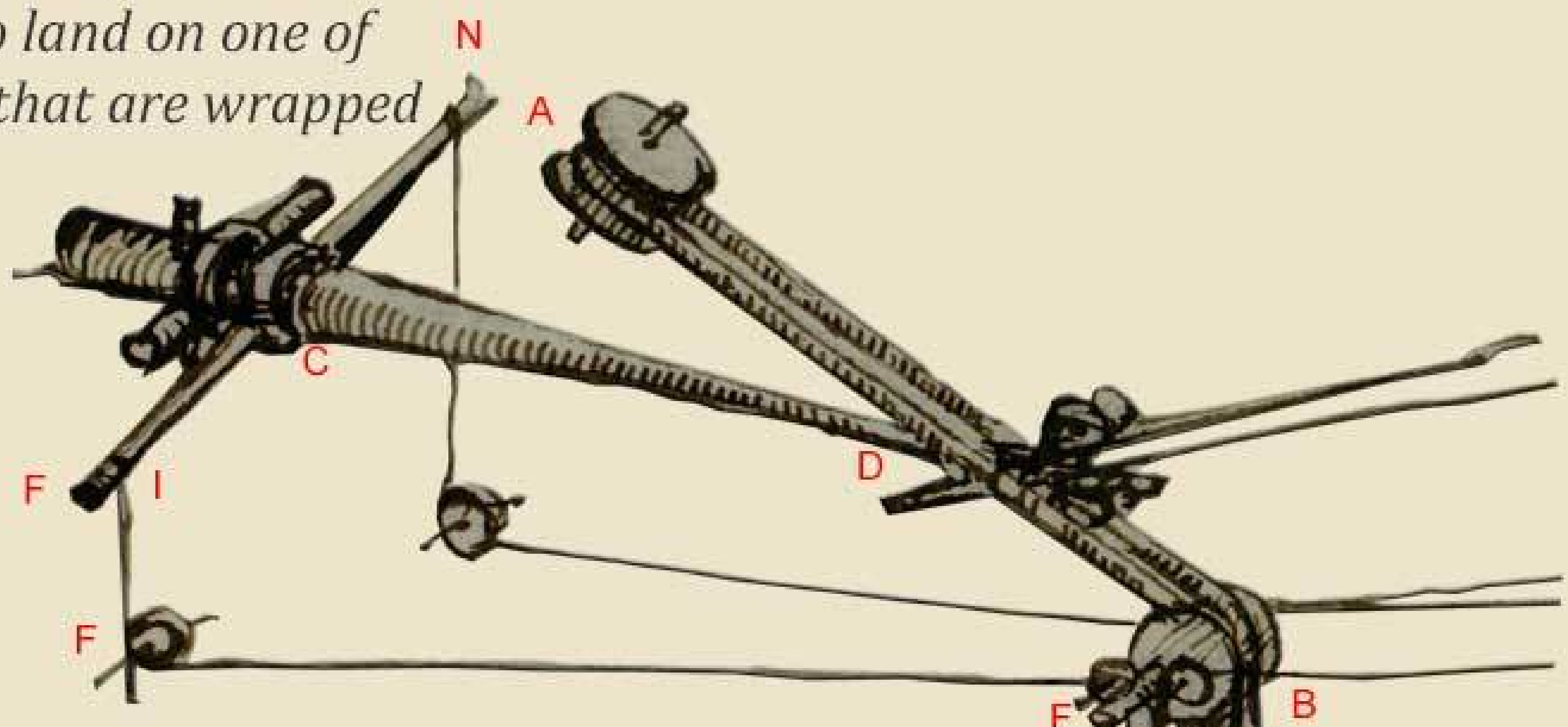
Leather bags by which a man falling from a height of 6 arm's length may avoid hurting himself, falling into water or onto the ground. These bags are to be wrapped around him and tied on.

Man too has excess energy that is not needed to support his own weight on his legs. To demonstrate that this is true, place a man on fine sand and observe the depth of his footprints. Then, put another man on his back and you will see how much his feet will sink into the sand. Get the second man down, then make the first one jump as high as he can; you will see that his footprints are deeper than when he had the other man on his back. Therefore it is proved in two different ways that man has twice the strength he needs to support himself.

Persuading objectors to this bold enterprise.

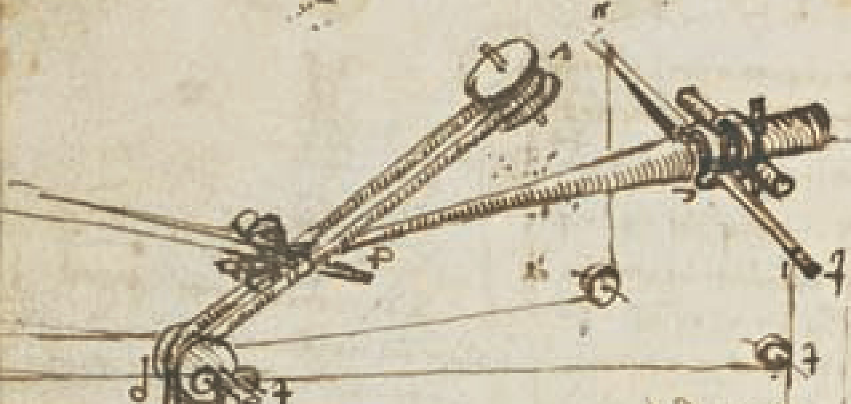
If you say the power of the bird's quills and muscles cannot be compared with those of a man, and that the whole mass or so many muscles and of the breast are for the benefit of accelerating the movement of the wings together with the single, extremely strong, one-piece bone in the breast and the fabric of large strong quills connected by cartilage and very strong skin with various muscles, my answer is that so much power is available not only to keep the bird in the air by means of the wings in the ordinary way, but also to escape predators or catch its own prey with double or triple energy. For these reasons the bird needs to double or triple its own strength. There are some cases where we can see how this extra energy is used: for example, to carry weights which may be as heavy as the bird itself, grasping them in its claws as it flies, like a falcon carrying a duck or an eagle catching a hare. So, little strength is necessary to hold up its own weight and maintain its balance on its wings, sailing on the air currents and adjusting the rudder to follow them. Little movement of the wings is required: the larger the bird, the less it will need to flap its wings.

If you fall off the double leather bag you have under your backside, arrange to land on one of the other bags that are wrapped around you.

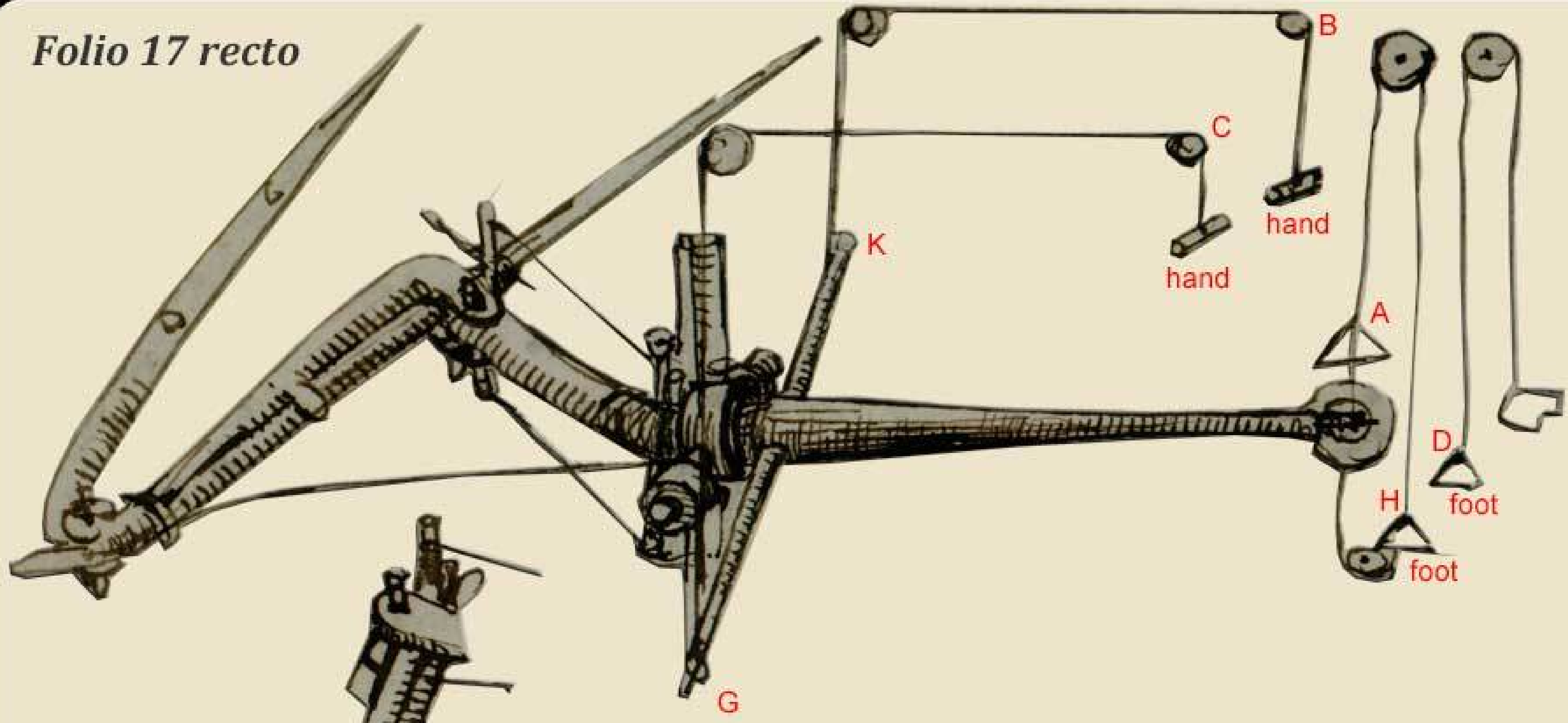


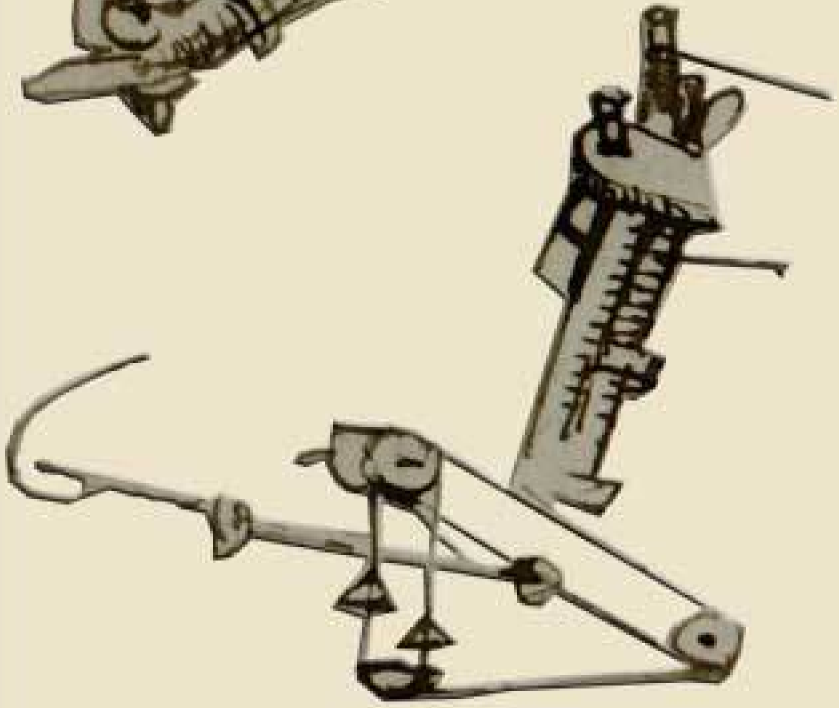
Because the wings must be rowed down and back at the same time to keep the machine flying, and going forward, the movement of the lever CD follows an oblique line, guided by the belt AB.

I could make the foot that presses stirrup G be the same one that, as well as its ordinary job, pulls down lever F. But that's no use in our case, because the lever F has to be raised and lowered first, and the stirrup G has to move along its path. In this way, the wing can go forward and upward, because the bird has already reached a speed that enables it to fly without the wings being flapped and they can be positioned edgeways. If that did not happen, the upper surface of the wings would strike the wind in the wrong direction, which would hinder the mechanical bird's movement, not letting it advance or increase its speed.



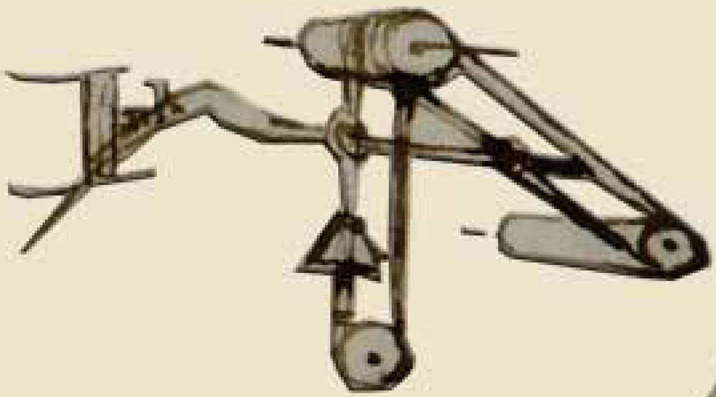
Folio 17 recto

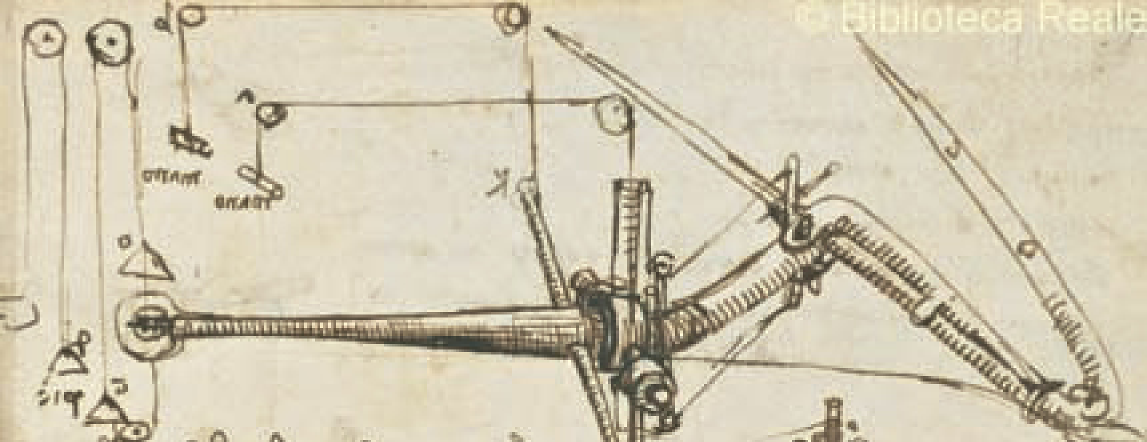




Page 19 [really 18 recto] shows the purpose of this.

While the feet lower wing H, the hand B, going down will raise the lever K and H will row backwards.
When the feet lift the wing, and you quicky bring the wing to H, pulling the lever G upward with the hand A, then the wing will remain sideways on, so that it does not hinder the movement of the bird against the air.





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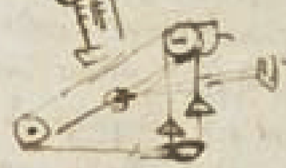
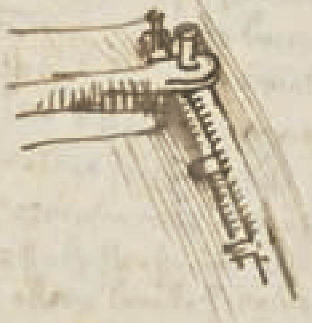
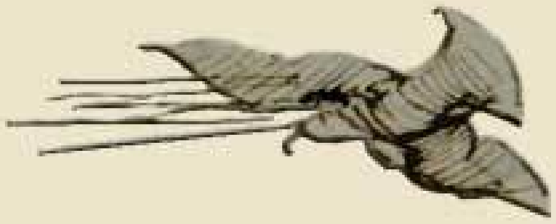
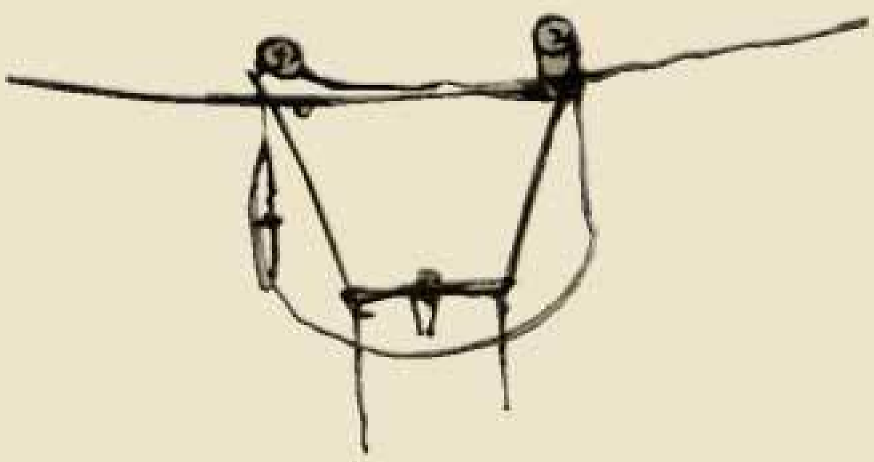




Folio 17 verso





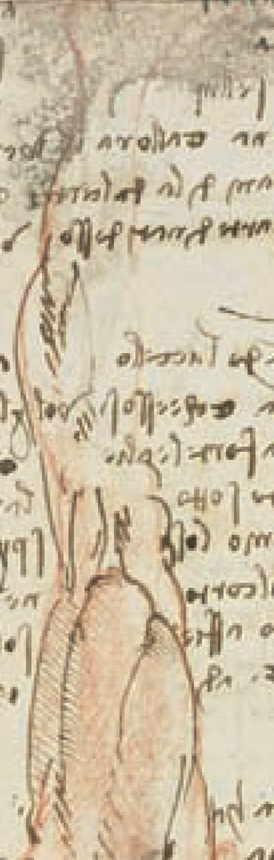
If the bird descends eastward with its right wing above the south wind there is no doubt that it will be turned upside down, unless it turns its beak rapidly to the west. Then the wind will strike the "palms of its hands" beyond the center of gravity and lift up the front part of the bird.

When a bird with a wide wingspan and a short tail wants to take off, it will lift its wings with force and turn them to receive the wind beneath them. The wind, forming a wedge, will quickly propel it up high like the Greek partridge, a raptor I saw on my way to Fiesole, above the Barbiga estates, on 14 March 1505.

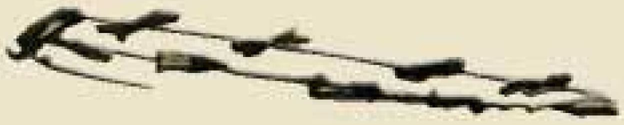
The tail makes a number of movements: sometimes it's flat, when the bird is flying in a stable position; at other times the ends are low and even, when the bird is ascending.

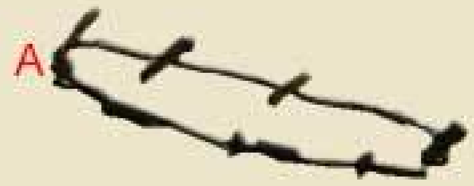
Sometimes, during the descent, the ends are raised upward to the same height. But when the tail is down and the left side is lower than the right, then the bird will circle upward toward the right. It can be proven, but not here. When the right end of the tail is lower than the left side, then the bird will turn toward the left.

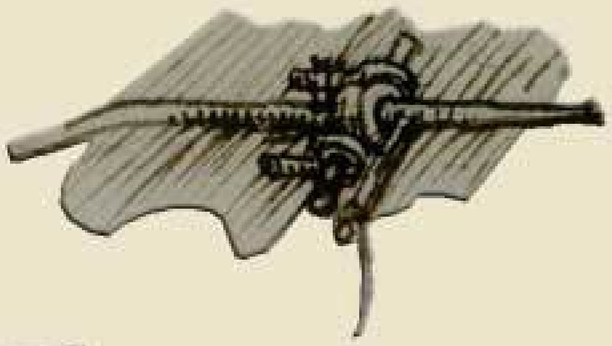
And if the ends of the tail are high and the left higher than the right, the bird will turn with its head toward the right; if the ends of the tail are high and the right is higher than the left, the bird will turn toward the left.

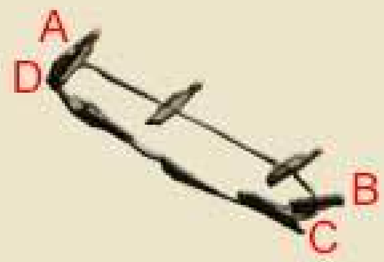


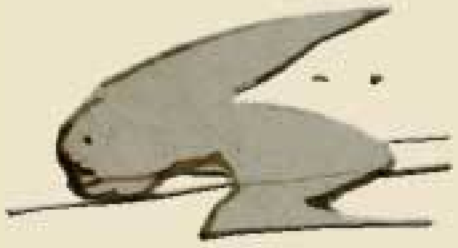
Folio 18 recto

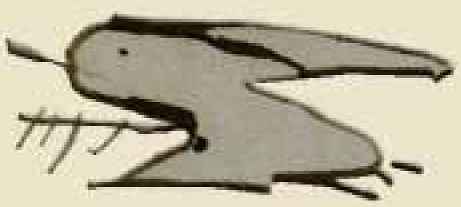












Always in the raising of the hand the elbow is lowered and presses the air down, whereas in the descent of the hand the elbow is raised and remains sideways on in order not to impede the movement in the air compressed within the wing.

The lowering of the elbows, at the time that the bird thrusts the edge of its wings forward when it is above the wind and propeled by the speed it has already acquired, causes the wind to strike under this elbow and to form a wedge which the bird manages to fly over, using the speed it has acquired but without beating its wings. If the bird weighs 3 pounds, and if its breast is a third the size of its wingspan, the wings will not feel but two thirds of the weight of such a bird.

The hand feels great stress toward the big finger, the wing's true rudder, because this is the part that strikes the air.

The palm of the hand goes from point A to point B, always at the same angle, descending and putting pressure on the air. When it reaches point B, it immediately flattens and turns back, following the line CD, and having arrived at D, it quickly turns around and goes descending by the line AB, and in turning always turns around the center of its width.

The backward turn using the flat hand will be done with great speed, whereas pushing backward with the surface that is pushing the air will be done with whatever speed the engine may require at various times.

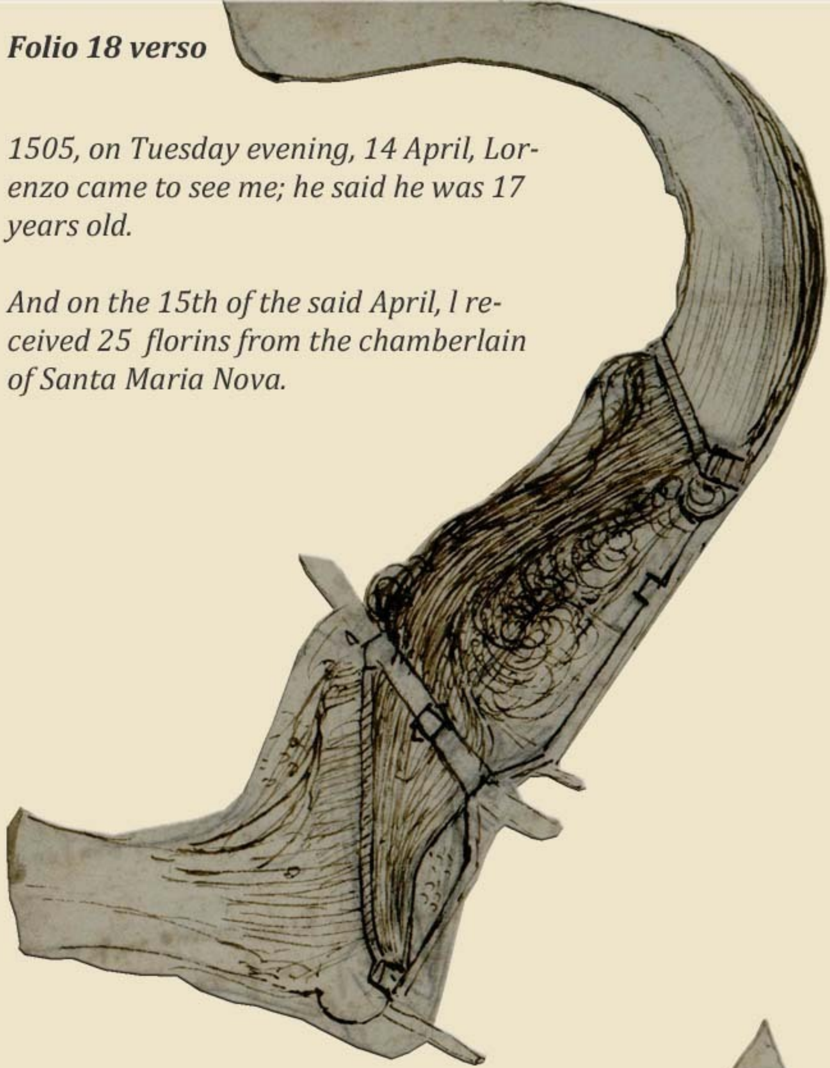
The path taken by the end of the finger is different on the outward and return journeys; it is higher on the way back. The shape of both the higher and lower trajectories is a very elongated oval.

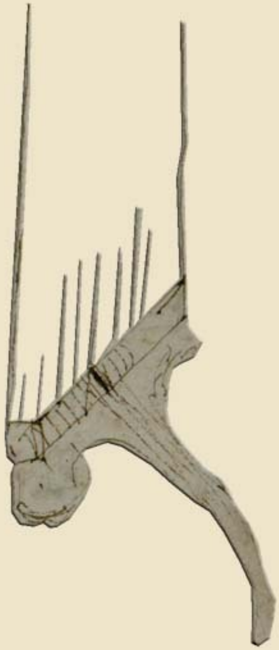
Folio 18 verso

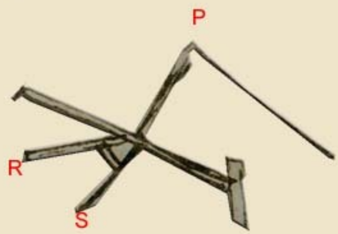
1505, on Tuesday evening, 14 April, Lorenzo came to see me; he said he was 17 years old.

And on the 15th of the said April, I received 25 florins from the chamberlain of Santa Maria Nova.

It is from the mountain called after the great bird that the famous bird whose fame will ring around the world will take flight.

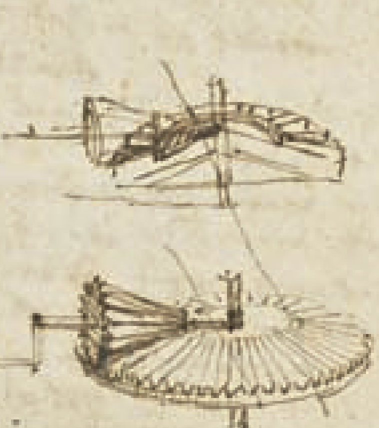






To raise a tree to point P, while R and S support it.

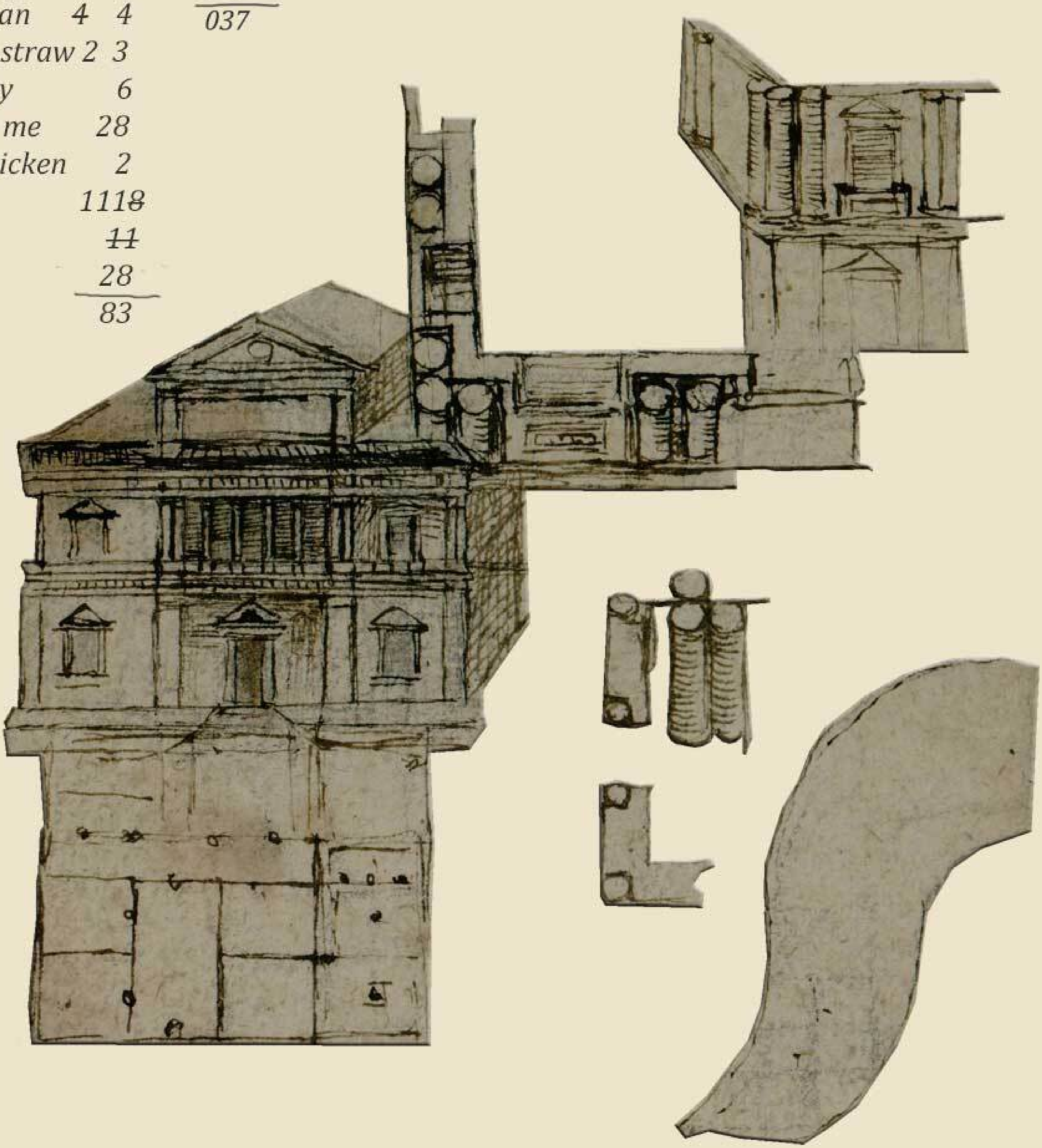
1509



lady		48
bran	4	4
in straw	2	3
key		6
to me		28
chicken		2

111~~8~~
~~11~~
28
83

148
111
037



It will make the first flight, being launched from the peak of Mount Cecero, this great bird, filling the universe with awe, filling all writings with its fame, and eternal glory to the nest where it was born.