**Source: The Ten Books on Architecture
by Vitruvius
(Translated by Morris Hicky Morgan 1914)**

# BOOK X

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## INTRODUCTION

1. In the famous and important Greek city of Ephesus there is said to be an ancient ancestral law, the terms of which are severe, but its justice is not inequitable. When an architect accepts the charge of a public work, he has to promise what the cost of it will be. His estimate is handed to the magistrate, and his property is pledged as security until the work is done. When it is finished, if the outlay agrees with his statement, he is complimented by decrees and marks of honour. If no more than a fourth has to be added to his estimate, it is furnished by the treasury and no penalty is inflicted. But when more than one fourth has to be spent in addition on the work, the money required to finish it is taken from his property.

2. Would to God that this were also a law of the Roman people, not merely for public, but also for private buildings. For the ignorant would no longer run riot with impunity, but men who are well qualified by an exact scientific training would unquestionably adopt the profession of architecture. Gentlemen would not be misled into limitless and prodigal expenditure, even to ejectments from their estates, and the architects themselves could be forced, by fear of the penalty, to be more careful in calculating and stating the limit of expense, so that gentlemen would procure their buildings for that which they had expected, or by adding only a little more. It is true that men who can afford to devote four hundred thousand to a work may hold on, if they have to add another hundred thousand, from the pleasure which the hope of finishing it gives them; but if they are loaded with a fifty per cent increase, or with an even greater expense, they lose hope, sacrifice what they have already spent, and are compelled to leave off, broken in fortune and in spirit.

3. This fault appears not only in the matter of buildings, but also in the shows given by magistrates, whether of gladiators in the forum or of plays on the stage. Here neither delay nor postponement is permissible, but the necessities of the case require that everything should be ready at a fixed time, — the seats for the audience, the awning drawn over them, and whatever, in accordance with the customs of the stage, is provided by machinery to please the eye of the people. These matters require careful thought and planning by a well trained intellect; for none of them can be accomplished without machinery, and without hard study skilfully applied in various ways.

4. Therefore, since such are our traditions and established practices, it is obviously fitting that the plans should be worked out carefully, and with the greatest attention, before the structures are begun. Consequently, as we have no law or customary practice to compel this, and as every year both praetors and aediles have to provide machinery for the festivals, I have thought it not out of place, Emperor, since I have treated of buildings in the earlier books, to set forth and teach in this, which forms the final conclusion of my treatise, the principles which govern machines.

# CHAPTER I

## MACHINES AND IMPLEMENTS

1. A MACHINE is a combination of timbers fastened together, chiefly efficacious in moving great weights. Such a machine is set in motion on scientific principles in circular rounds, which the Greeks call *κυκλικὴ κίνησις*. There is, however, a class intended for climbing, termed in Greek *ἀκροβατικόν*, another worked by air, which with them is called *πνευματικόν*, and a third for hoisting; this the Greeks named *βαρουλκός*. In the climbing class are machines so disposed that one can safely climb up high, by means of timbers set up on end and connected by crossbeams, in order to view operations. In the pneumatic class, air is forced by pressure to produce sounds and tones as in an *ὄργανον*.

2. In the hoisting class, heavy weights are removed by machines which raise them up and set them in position. The climbing machine displays no scientific principle, but merely a spirit of daring. It is held together by dowels and crossbeams and twisted lashings and supporting props. A machine that gets its motive power by pneumatic pressure will produce pretty effects by scientific refinements. But the hoisting machine has opportunities for usefulness which are greater and full of grandeur, and it is of the highest efficacy when used with intelligence.

3. Some of these act on the principle of the *μηχανή*, others on that of the *ὄργανον*. The difference between "machines" and "engines" is obviously this, that machines need more workmen and greater power to make them take effect, as for instance ballistae and the beams of presses. Engines, on the other hand, accomplish their purpose at the intelligent touch of a single workman, as the scorpio or anisocycli when they are turned. Therefore engines, as well as machines, are, in principle, practical necessities, without which nothing can be unattended with difficulties.

4. All machinery is derived from nature, and is founded on the teaching and instruction of the revolution of the firmament. Let us but consider the connected revolutions of the sun, the moon, and the five planets, without the revolution of which, due to mechanism, we should not have had the alternation of day and night, nor the ripening of fruits. Thus, when our ancestors had seen that this was so, they took their models from nature, and by imitating them were led on by divine facts, until they perfected the contrivances which are so serviceable in our life. Some things, with a view to greater convenience, they worked out by means of machines and their revolutions, others by means of engines, and so, whatever they found to be useful for investigations, for the arts, and for established practices, they took care to improve step by step on scientific principles.

5. Let us take first a necessary invention, such as clothing, and see how the combination of warp and woof on the loom, which does its work on the principle of an engine, not only protects the body by covering it, but also gives it honourable apparel. We should not have had food in abundance unless yokes and ploughs for oxen, and for all draught animals, had been invented. If there had been no provision of windlasses, pressbeams, and levers for presses, we could not have had the shining oil, nor the fruit of the vine to give us pleasure, and these things could not be transported on land without the invention of the mechanism of carts or waggons, nor on the sea without that of ships.

6. The discovery of the method of testing weights by steelyards and balances saves us from fraud, by introducing honest practices into life. There are also innumerable ways of employing machinery about which it seems unnecessary to speak, since they are at hand every day; such as mills, blacksmiths' bellows, carriages, gigs, turning lathes, and other things which are habitually used as general conveniences. Hence, we shall begin by explaining those that rarely come to hand, so that they may be understood.

## CHAPTER II

### HOISTING MACHINES

1. FIRST we shall treat of those machines which are of necessity made ready when temples and public buildings are to be constructed. Two timbers are provided, strong enough for the weight of the load. They are fastened together at the upper end by a bolt, then spread apart at the bottom, and so set up, being kept upright by ropes attached at the upper ends and fixed at intervals all round. At the top is fastened a block, which some call a "rechamus." In the block two sheaves are enclosed, turning on axles. The traction rope is carried over the sheave at the top, then let fall and passed round a sheave in a block below. Then it is brought back to a sheave at the bottom of the upper block, and so it goes down to the lower block, where it is fastened through a hole in that block. The other end of the rope is brought back and down between the legs of the machine.

2. Socket-pieces are nailed to the hinder faces of the squared timbers at the point where they are spread apart, and the ends of the windlass are inserted into them so that the axles may turn freely. Close to each end of the windlass are two holes, so adjusted that handspikes can be fitted into them. To the bottom of the lower block are fastened shears made of iron, whose prongs are brought to bear upon the stones, which have holes bored in them. When one end of the rope is fastened to the windlass, and the latter is turned round by working the handspikes, the rope winds round the windlass, gets taut, and thus it raises the load to the proper height and to its place in the work.

3. This kind of machinery, revolving with three sheaves, is called a trispast. When there are two sheaves turning in the block beneath and three in the upper, the machine is termed a pentaspast. But if we have to furnish machines for heavier loads, we must use timbers of greater length and thickness, providing them with correspondingly large bolts at the top, and windlasses

turning at the bottom. When these are ready, let forestays be attached and left lying slack in front; let the backstays be carried over the shoulders of the machine to some distance, and, if there is nothing to which they can be fastened, sloping piles should be driven, the ground rammed down all round to fix them firmly, and the ropes made fast to them.

4. A block should then be attached by a stout cord to the top of the machine, and from that point a rope should be carried to a pile, and to a block tied to the pile. Let the rope be put in round the sheave of this block, and brought back to the block that is fastened at the top of the machine. Round its sheave the rope should be passed, and then should go down from the top, and back to the windlass, which is at the bottom of the machine, and there be fastened. The windlass is now to be turned by means of the handspikes, and it will raise the machine of itself without danger. Thus, a machine of the larger kind will be set in position, with its ropes in their places about it, and its stays attached to the piles. Its blocks and traction ropes are arranged as described above.

5. But if the loads of material for the work are still more colossal in size and weight, we shall not entrust them to a windlass, but set in an axle-tree, held by sockets as the windlass was, and carrying on its centre a large drum, which some term a wheel, but the Greeks call it *ἀμφίεσις* or *περιθήκιον*.

6. And the blocks in such machines are not arranged in the same, but in a different manner; for the rows of sheaves in them are doubled, both at the bottom and at the top. The traction rope is passed through a hole in the lower block, in such a way that the two ends of the rope are of equal length when it is stretched out, and both portions are held there at the lower block by a cord which is passed round them and lashed so that they cannot come out either to the right or the left. Then the ends of the rope are brought up into the block at the top from the outside, and passed down over its lower sheaves, and so return to the bottom, and are passed from the inside to the sheaves in the lowest block, and

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