BOOK I

PREFACE

1. WHILE your divine intelligence and will, Imperator Caesar, were engaged in acquiring the right to command the world, and while your fellow citizens, when all their enemies had been laid low by your invincible valour, were glorying in your triumph and victory, — while all foreign nations were in subjection awaiting your beck and call, and the Roman people and senate, released from their alarm, were beginning to be guided by your most noble conceptions and policies, I hardly dared, in view of your serious employments, to publish my writings and long considered ideas on architecture, for fear of subjecting myself to your displeasure by an unseasonable interruption.

2. But when I saw that you were giving your attention not only to the welfare of society in general and to the establishment of public order, but also to the providing of public buildings intended for utilitarian purposes, so that not only should the State have been enriched with provinces by your means, but that the greatness of its power might likewise be attended with distinguished authority in its public buildings, I thought that I ought to take the first opportunity to lay before you my writings on this theme. For in the first place it was this subject which made me known to your father, to whom I was devoted on account of his great qualities. After the council of heaven gave him a place in the dwellings of immortal life and transferred your father's power to your hands, my devotion continuing unchanged as I remembered him inclined me to support you. And so with Marcus Aurelius, Publius Minidius, and Gnaeus Cornelius, I was ready to supply and repair ballistae, scorpiones, and other artillery, and I have received rewards for good service with them. After your first bestowal of these upon me, you continued to renew them on the recommendation of your sister.

3. Owing to this favour I need have no fear of want to the end of my life, and being thus laid under obligation I began to write this work for you, because I saw that you have built and are now building extensively, and that in future also you will take care that our public and private buildings shall be worthy to go down to posterity by the side of your other splendid achievements. I have drawn up definite rules to enable you, by observing them, to have personal knowledge of the quality both of existing buildings and of those which are yet to be constructed. For in the following books I have disclosed all the principles of the art.

CHAPTER I

THE EDUCATION OF THE ARCHITECT

1. The architect should be equipped with knowledge of many branches of study and varied kinds of learning, for it is by his judgement that all work done by the other arts is put to test. This knowledge is the child of practice and theory. Practice is the continuous and regular exercise of employment where manual work is done with any necessary material according to the design of a drawing. Theory, on the other hand, is the ability to demonstrate and explain the productions of dexterity on the principles of proportion.

2. It follows, therefore, that architects who have aimed at acquiring manual skill without scholarship have never been able to reach a position of authority to correspond to their pains, while those who relied only upon theories and scholarship were obviously hunting the shadow, not the substance. But those who have a thorough knowledge of both, like men armed at all points, have the sooner attained their object and carried authority with them.

3. In all matters, but particularly in architecture, there are these two points: — the thing signified, and that which gives it its significance. That which is signified is the subject of which we may be speaking; and that which gives significance is a demonstration on scientific principles. It appears, then, that one who professes himself an architect should be well versed in both directions. He ought, therefore, to be both naturally gifted and amenable to instruction. Neither natural ability without instruction nor instruction without natural ability can make the perfect artist. Let him be educated, skilful with the pencil, instructed in geometry, know much history, have followed the philosophers with attention, understand music, have some knowledge of medi-

cine, know the opinions of the jurists, and be acquainted with astronomy and the theory of the heavens.

4. The reasons for all this are as follows. An architect ought to be an educated man so as to leave a more lasting remembrance in his treatises. Secondly, he must have a knowledge of drawing so that he can readily make sketches to show the appearance of the work which he proposes. Geometry, also, is of much assistance in architecture, and in particular it teaches us the use of the rule and compasses, by which especially we acquire readiness in making plans for buildings in their grounds, and rightly apply the square, the level, and the plummet. By means of optics, again, the light in buildings can be drawn from fixed quarters of the sky. It is true that it is by arithmetic that the total cost of buildings is calculated and measurements are computed, but difficult questions involving symmetry are solved by means of geometrical theories and methods.

5. A wide knowledge of history is requisite because, among the ornamental parts of an architect's design for a work, there are many the underlying idea of whose employment he should be able to explain to inquirers. For instance, suppose him to set up the marble statues of women in long robes, called Caryatides, to take the place of columns, with the mutules and coronas placed directly above their heads, he will give the following explanation to his questioners. Caryae, a state in Peloponnesus, sided with the Persian enemies against Greece; later the Greeks, having gloriously won their freedom by victory in the war, made common cause and declared war against the people of Caryae. They took the town, killed the men, abandoned the State to desolation, and carried off their wives into slavery, without permitting them, however, to lay aside the long robes and other marks of their rank as married women, so that they might be obliged not only to march in the triumph but to appear forever after as a type of slavery, burdened with the weight of their shame and so making atonement for their State. Hence, the architects of the time designed for public buildings statues of these women, placed so as to

Photo H. B. Warren

CARYATIDES OF THE ERECHTHEUM AT ATHENS

CARYATIDES FROM THE TREASURY OF THE CNIDIANS AT DELPHI

Photo. Anderson

CARYATID NOW IN THE VILLA ALBANI AT ROME

carry a load, in order that the sin and the punishment of the people of Caryae might be known and handed down even to posterity.

6. Likewise the Lacedaemonians under the leadership of Pausanias, son of Agesipolis, after conquering the Persian

CARYATIDES
(From the edition of Vitruvius by Fra Giocondo, Venice, 1511)

armies, infinite in number, with a small force at the battle of Plataea, celebrated a glorious triumph with the spoils and booty, and with the money obtained from the sale thereof built the Persian Porch, to be a monument to the renown and valour of the people and a trophy of victory for posterity. And there they set effigies of the prisoners arrayed in barbarian costume and holding up the roof, their pride punished by this deserved affront, that enemies might tremble for fear of the effects of their courage, and that their own people, looking upon this ensample of their valour and encouraged by the glory of it, might be ready to defend their independence. So from that time on, many have put up statues of Persians supporting entablatures and their ornaments, and thus from that motive have greatly enriched the diversity of their works. There are other stories of the same kind which architects ought to know.

7. As for philosophy, it makes an architect high-minded and not self-assuming, but rather renders him courteous, just, and honest without avariciousness. This is very important, for no work can be rightly done without honesty and incorruptibility. Let him not be grasping nor have his mind preoccupied with the idea of receiving perquisites, but let him with dignity keep up his position by cherishing a good reputation. These are among the precepts of philosophy. Furthermore philosophy treats of physics (in Greek φυσιολογία) where a more careful knowledge is required because the problems which come under this head are numerous and of very different kinds; as, for example, in the case of the conducting of water. For at points of intake and at curves, and at places where it is raised to a level, currents of air naturally form in one way or another; and nobody who has not learned the fundamental principles of physics from philosophy will be able to provide against the damage which they do. So the reader of Ctesibius or Archimedes and the other writers of treatises of the same class will not be able to appreciate them unless he has been trained in these subjects by the philosophers.

8. Music, also, the architect ought to understand so that he may have knowledge of the canonical and mathematical theory, and besides be able to tune ballistae, catapultae, and scorpiones to the proper key. For to the right and left in the beams are the holes in the frames through which the strings of twisted sinew are stretched by means of windlasses and bars, and these strings must not be clamped and made fast until they give the same correct note to the ear of the skilled workman. For the arms thrust

through those stretched strings must, on being let go, strike their blow together at the same moment; but if they are not in unison, they will prevent the course of projectiles from being straight.

PERSIANS
(From the edition of Vitruvius by Fra Giocondo, Venice, 1511)

9. In theatres, likewise, there are the bronze vessels (in Greek ἠχεῖα) which are placed in niches under the seats in accordance with the musical intervals on mathematical principles. These vessels are arranged with a view to musical concords or harmony, and apportioned in the compass of the fourth, the fifth, and the octave, and so on up to the double octave, in such a way that when the voice of an actor falls in unison with any of them its power is increased, and it reaches the ears of the audience with

greater clearness and sweetness. Water organs, too, and the other instruments which resemble them cannot be made by one who is without the principles of music.

10. The architect should also have a knowledge of the study of medicine on account of the questions of climates (in Greek κλίματα), air, the healthiness and unhealthiness of sites, and the use of different waters. For without these considerations, the healthiness of a dwelling cannot be assured. And as for principles of law, he should know those which are necessary in the case of buildings having party walls, with regard to water dripping from the eaves, and also the laws about drains, windows, and water supply. And other things of this sort should be known to architects, so that, before they begin upon buildings, they may be careful not to leave disputed points for the householders to settle after the works are finished, and so that in drawing up contracts the interests of both employer and contractor may be wisely safe-guarded. For if a contract is skilfully drawn, each may obtain a release from the other without disadvantage. From astronomy we find the east, west, south, and north, as well as the theory of the heavens, the equinox, solstice, and courses of the stars. If one has no knowledge of these matters, he will not be able to have any comprehension of the theory of sundials.

11. Consequently, since this study is so vast in extent, embellished and enriched as it is with many different kinds of learning, I think that men have no right to profess themselves architects hastily, without having climbed from boyhood the steps of these studies and thus, nursed by the knowledge of many arts and sciences, having reached the heights of the holy ground of architecture.

12. But perhaps to the inexperienced it will seem a marvel that human nature can comprehend such a great number of studies and keep them in the memory. Still, the observation that all studies have a common bond of union and intercourse with one another, will lead to the belief that this can easily be realized. For a liberal education forms, as it were, a single body made up of

these members. Those, therefore, who from tender years receive instruction in the various forms of learning, recognize the same stamp on all the arts, and an intercourse between all studies, and so they more readily comprehend them all. This is what led one of the ancient architects, Pytheos, the celebrated builder of the temple of Minerva at Priene, to say in his Commentaries that an architect ought to be able to accomplish much more in all the arts and sciences than the men who, by their own particular kinds of work and the practice of it, have brought each a single subject to the highest perfection. But this is in point of fact not realized.

13. For an architect ought not to be and cannot be such a philologian as was Aristarchus, although not illiterate; nor a musician like Aristoxenus, though not absolutely ignorant of music; nor a painter like Apelles, though not unskilful in drawing; nor a sculptor such as was Myron or Polyclitus, though not unacquainted with the plastic art; nor again a physician like Hippocrates, though not ignorant of medicine; nor in the other sciences need he excel in each, though he should not be unskilful in them. For, in the midst of all this great variety of subjects, an individual cannot attain to perfection in each, because it is scarcely in his power to take in and comprehend the general theories of them.

14. Still, it is not architects alone that cannot in all matters reach perfection, but even men who individually practise specialties in the arts do not all attain to the highest point of merit. Therefore, if among artists working each in a single field not all, but only a few in an entire generation acquire fame, and that with difficulty, how can an architect, who has to be skilful in many arts, accomplish not merely the feat — in itself a great marvel — of being deficient in none of them, but also that of surpassing all those artists who have devoted themselves with unremitting industry to single fields?

15. It appears, then, that Pytheos made a mistake by not observing that the arts are each composed of two things, the actual work and the theory of it. One of these, the doing of the work, is

proper to men trained in the individual subject, while the other, the theory, is common to all scholars: for example, to physicians and musicians the rhythmical beat of the pulse and its metrical movement. But if there is a wound to be healed or a sick man to be saved from danger, the musician will not call, for the business will be appropriate to the physician. So in the case of a musical instrument, not the physician but the musician will be the man to tune it so that the ears may find their due pleasure in its strains.

16. Astronomers likewise have a common ground for discussion with musicians in the harmony of the stars and musical concords in tetrads and triads of the fourth and the fifth, and with geometricians in the subject of vision (in Greek λόγος ὀπτικός); and in all other sciences many points, perhaps all, are common so far as the discussion of them is concerned. But the actual undertaking of works which are brought to perfection by the hand and its manipulation is the function of those who have been specially trained to deal with a single art. It appears, therefore, that he has done enough and to spare who in each subject possesses a fairly good knowledge of those parts, with their principles, which are indispensable for architecture, so that if he is required to pass judgement and to express approval in the case of those things or arts, he may not be found wanting. As for men upon whom nature has bestowed so much ingenuity, acuteness, and memory that they are able to have a thorough knowledge of geometry, astronomy, music, and the other arts, they go beyond the functions of architects and become pure mathematicians. Hence they can readily take up positions against those arts because many are the artistic weapons with which they are armed. Such men, however, are rarely found, but there have been such at times; for example, Aristarchus of Samos, Philolaus and Archytas of Tarentum, Apollonius of Perga, Eratosthenes of Cyrene, and among Syracusans Archimedes and Scopinas, who through mathematics and natural philosophy discovered, expounded, and left to posterity many things in connexion with mechanics and with sundials.

17. Since, therefore, the possession of such talents due to natural capacity is not vouchsafed at random to entire nations, but only to a few great men; since, moreover, the function of the architect requires a training in all the departments of learning; and finally, since reason, on account of the wide extent of the subject, concedes that he may possess not the highest but not even necessarily a moderate knowledge of the subjects of study, I request, Caesar, both of you and of those who may read the said books, that if anything is set forth with too little regard for grammatical rule, it may be pardoned. For it is not as a very great philosopher, nor as an eloquent rhetorician, nor as a grammarian trained in the highest principles of his art, that I have striven to write this work, but as an architect who has had only a dip into those studies. Still, as regards the efficacy of the art and the theories of it, I promise and expect that in these volumes I shall undoubtedly show myself of very considerable importance not only to builders but also to all scholars.

CHAPTER II

THE FUNDAMENTAL PRINCIPLES OF ARCHITECTURE

1. ARCHITECTURE depends on Order (in Greek *τάξις*), Arrangement (in Greek *διάθεσις*), Eurythmy, Symmetry, Propriety, and Economy (in Greek *οἰκονομία*).

2. Order gives due measure to the members of a work considered separately, and symmetrical agreement to the proportions of the whole. It is an adjustment according to quantity (in Greek *ποσότης*). By this I mean the selection of modules from the members of the work itself and, starting from these individual parts of members, constructing the whole work to correspond. Arrangement includes the putting of things in their proper places and the elegance of effect which is due to adjustments appropriate to the character of the work. Its forms of expression (in Greek *ἰδέαι*) are these: groundplan, elevation, and perspec-

tive. A groundplan is made by the proper successive use of compasses and rule, through which we get outlines for the plane surfaces of buildings. An elevation is a picture of the front of a building, set upright and properly drawn in the proportions of the contemplated work. Perspective is the method of sketching a front with the sides withdrawing into the background, the lines all meeting in the centre of a circle. All three come of reflexion and invention. Reflexion is careful and laborious thought, and watchful attention directed to the agreeable effect of one's plan. Invention, on the other hand, is the solving of intricate problems and the discovery of new principles by means of brilliancy and versatility. These are the departments belonging under Arrangement.

3. Eurythmy is beauty and fitness in the adjustments of the members. This is found when the members of a work are of a height suited to their breadth, of a breadth suited to their length, and, in a word, when they all correspond symmetrically.

4. Symmetry is a proper agreement between the members of the work itself, and relation between the different parts and the whole general scheme, in accordance with a certain part selected as standard. Thus in the human body there is a kind of symmetrical harmony between forearm, foot, palm, finger, and other small parts; and so it is with perfect buildings. In the case of temples, symmetry may be calculated from the thickness of a column, from a triglyph, or even from a module; in the ballista, from the hole or from what the Greeks call the περίτρητος; in a ship, from the space between the tholepins (διάπηγμα); and in other things, from various members.

5. Propriety is that perfection of style which comes when a work is authoritatively constructed on approved principles. It arises from prescription (Greek θεματισμῷ), from usage, or from nature. From prescription, in the case of hypaethral edifices, open to the sky, in honour of Jupiter Lightning, the Heaven, the Sun, or the Moon: for these are gods whose semblances and manifestations we behold before our very eyes in the sky when it

is cloudless and bright. The temples of Minerva, Mars, and Hercules, will be Doric, since the virile strength of these gods makes daintiness entirely inappropriate to their houses. In temples to Venus, Flora, Proserpine, Spring-Water, and the Nymphs, the Corinthian order will be found to have peculiar significance, because these are delicate divinities and so its rather slender outlines, its flowers, leaves, and ornamental volutes will lend propriety where it is due. The construction of temples of the Ionic order to Juno, Diana, Father Bacchus, and the other gods of that kind, will be in keeping with the middle position which they hold; for the building of such will be an appropriate combination of the severity of the Doric and the delicacy of the Corinthian.

6. Propriety arises from usage when buildings having magnificent interiors are provided with elegant entrance-courts to correspond; for there will be no propriety in the spectacle of an elegant interior approached by a low, mean entrance. Or, if dentils be carved in the cornice of the Doric entablature or triglyphs represented in the Ionic entablature over the cushion-shaped capitals of the columns, the effect will be spoilt by the transfer of the peculiarities of the one order of building to the other, the usage in each class having been fixed long ago.

7. Finally, propriety will be due to natural causes if, for example, in the case of all sacred precincts we select very healthy neighbourhoods with suitable springs of water in the places where the fanes are to be built, particularly in the case of those to Aesculapius and to Health, gods by whose healing powers great numbers of the sick are apparently cured. For when their diseased bodies are transferred from an unhealthy to a healthy spot, and treated with waters from health-giving springs, they will the more speedily grow well. The result will be that the divinity will stand in higher esteem and find his dignity increased, all owing to the nature of his site. There will also be natural propriety in using an eastern light for bedrooms and libraries, a western light in winter for baths and winter apartments, and a northern light for picture galleries and other places in which a steady light is

needed; for that quarter of the sky grows neither light nor dark with the course of the sun, but remains steady and unshifting all day long.

8. Economy denotes the proper management of materials and of site, as well as a thrifty balancing of cost and common sense in the construction of works. This will be observed if, in the first place, the architect does not demand things which cannot be found or made ready without great expense. For example: it is not everywhere that there is plenty of pitsand, rubble, fir, clear fir, and marble, since they are produced in different places and to assemble them is difficult and costly. Where there is no pitsand, we must use the kinds washed up by rivers or by the sea; the lack of fir and clear fir may be evaded by using cypress, poplar, elm, or pine; and other problems we must solve in similar ways.

9. A second stage in Economy is reached when we have to plan the different kinds of dwellings suitable for ordinary householders, for great wealth, or for the high position of the statesman. A house in town obviously calls for one form of construction; that into which stream the products of country estates requires another; this will not be the same in the case of money-lenders and still different for the opulent and luxurious; for the powers under whose deliberations the commonwealth is guided dwellings are to be provided according to their special needs: and, in a word, the proper form of economy must be observed in building houses for each and every class.

CHAPTER III

THE DEPARTMENTS OF ARCHITECTURE

1. There are three departments of architecture: the art of building, the making of time-pieces, and the construction of machinery. Building is, in its turn, divided into two parts, of which the first is the construction of fortified towns and of works for general use in public places, and the second is the putting up of structures for private individuals. There are three classes of pub-

lic buildings: the first for defensive, the second for religious, and the third for utilitarian purposes. Under defence comes the planning of walls, towers, and gates, permanent devices for resistance against hostile attacks; under religion, the erection of fanes and temples to the immortal gods; under utility, the provision of meeting places for public use, such as harbours, markets, colonnades, baths, theatres, promenades, and all other similar arrangements in public places.

2. All these must be built with due reference to durability, convenience, and beauty. Durability will be assured when foundations are carried down to the solid ground and materials wisely and liberally selected; convenience, when the arrangement of the apartments is faultless and presents no hindrance to use, and when each class of building is assigned to its suitable and appropriate exposure; and beauty, when the appearance of the work is pleasing and in good taste, and when its members are in due proportion according to correct principles of symmetry.

CHAPTER IV

THE SITE OF A CITY

1. FOR fortified towns the following general principles are to be observed. First comes the choice of a very healthy site. Such a site will be high, neither misty nor frosty, and in a climate neither hot nor cold, but temperate; further, without marshes in the neighbourhood. For when the morning breezes blow toward the town at sunrise, if they bring with them mists from marshes and, mingled with the mist, the poisonous breath of the creatures of the marshes to be wafted into the bodies of the inhabitants, they will make the site unhealthy. Again, if the town is on the coast with a southern or western exposure, it will not be healthy, because in summer the southern sky grows hot at sunrise and is fiery at noon, while a western exposure grows warm after sunrise, is hot at noon, and at evening all aglow.

2. These variations in heat and the subsequent cooling off are harmful to the people living on such sites. The same conclusion may be reached in the case of inanimate things. For instance, nobody draws the light for covered wine rooms from the south or west, but rather from the north, since that quarter is never subject to change but is always constant and unshifting. So it is with granaries: grain exposed to the sun's course soon loses its good quality, and provisions and fruit, unless stored in a place unexposed to the sun's course, do not keep long.

3. For heat is a universal solvent, melting out of things their power of resistance, and sucking away and removing their natural strength with its fiery exhalations so that they grow soft, and hence weak, under its glow. We see this in the case of iron which, however hard it may naturally be, yet when heated thoroughly in a furnace fire can be easily worked into any kind of shape, and still, if cooled while it is soft and white hot, it hardens again with a mere dip into cold water and takes on its former quality.

4. We may also recognize the truth of this from the fact that in summer the heat makes everybody weak, not only in unhealthy but even in healthy places, and that in winter even the most unhealthy districts are much healthier because they are given a solidity by the cooling off. Similarly, persons removed from cold countries to hot cannot endure it but waste away; whereas those who pass from hot places to the cold regions of the north, not only do not suffer in health from the change of residence but even gain by it.

5. It appears, then, that in founding towns we must beware of districts from which hot winds can spread abroad over the inhabitants. For while all bodies are composed of the four elements (in Greek *στοιχεῖα*), that is, of heat, moisture, the earthy, and air, yet there are mixtures according to natural temperament which make up the natures of all the different animals of the world, each after its kind.

6. Therefore, if one of these elements, heat, becomes predominant in any body whatsoever, it destroys and dissolves all the

others with its violence. This defect may be due to violent heat from certain quarters of the sky, pouring into the open pores in too great proportion to admit of a mixture suited to the natural temperament of the body in question. Again, if too much moisture enters the channels of a body, and thus introduces disproportion, the other elements, adulterated by the liquid, are impaired, and the virtues of the mixture dissolved. This defect, in turn, may arise from the cooling properties of moist winds and breezes blowing upon the body. In the same way, increase or diminution of the proportion of air or of the earthy which is natural to the body may enfeeble the other elements; the predominance of the earthy being due to overmuch food, that of air to a heavy atmosphere.

7. If one wishes a more accurate understanding of all this, he need only consider and observe the natures of birds, fishes, and land animals, and he will thus come to reflect upon distinctions of temperament. One form of mixture is proper to birds, another to fishes, and a far different form to land animals. Winged creatures have less of the earthy, less moisture, heat in moderation, air in large amount. Being made up, therefore, of the lighter elements, they can more readily soar away into the air. Fish, with their aquatic nature, being moderately supplied with heat and made up in great part of air and the earthy, with as little of moisture as possible, can more easily exist in moisture for the very reason that they have less of it than of the other elements in their bodies; and so, when they are drawn to land, they leave life and water at the same moment. Similarly, the land animals, being moderately supplied with the elements of air and heat, and having less of the earthy and a great deal of moisture, cannot long continue alive in the water, because their portion of moisture is already abundant.

8. Therefore, if all this is as we have explained, our reason showing us that the bodies of animals are made up of the elements, and these bodies, as we believe, giving way and breaking up as a result of excess or deficiency in this or that element, we cannot but believe that we must take great care to select a very

temperate climate for the site of our city, since healthfulness is, as we have said, the first requisite.

9. I cannot too strongly insist upon the need of a return to the method of old times. Our ancestors, when about to build a town or an army post, sacrificed some of the cattle that were wont to feed on the site proposed and examined their livers. If the livers of the first victims were dark-coloured or abnormal, they sacrificed others, to see whether the fault was due to disease or their food. They never began to build defensive works in a place until after they had made many such trials and satisfied themselves that good water and food had made the liver sound and firm. If they continued to find it abnormal, they argued from this that the food and water supply found in such a place would be just as unhealthy for man, and so they moved away and changed to another neighbourhood, healthfulness being their chief object.

10. That pasturage and food may indicate the healthful qualities of a site is a fact which can be observed and investigated in the case of certain pastures in Crete, on each side of the river Pothereus, which separates the two Cretan states of Gnosus and Gortyna. There are cattle at pasture on the right and left banks of that river, but while the cattle that feed near Gnosus have the usual spleen, those on the other side near Gortyna have no perceptible spleen. On investigating the subject, physicians discovered on this side a kind of herb which the cattle chew and thus make their spleen small. The herb is therefore gathered and used as a medicine for the cure of splenetic people. The Cretans call it *ἄσπληνον*. From food and water, then, we may learn whether sites are naturally unhealthy or healthy.

11. If the walled town is built among the marshes themselves, provided they are by the sea, with a northern or north-eastern exposure, and are above the level of the seashore, the site will be reasonable enough. For ditches can be dug to let out the water to the shore, and also in times of storms the sea swells and comes backing up into the marshes, where its bitter blend prevents the reproductions of the usual marsh creatures, while any that swim

down from the higher levels to the shore are killed at once by the saltness to which they are unused. An instance of this may be found in the Gallic marshes surrounding Altino, Ravenna, Aquileia, and other towns in places of the kind, close by marshes. They are marvellously healthy, for the reasons which I have given.

12. But marshes that are stagnant and have no outlets either by rivers or ditches, like the Pomptine marshes, merely putrefy as they stand, emitting heavy, unhealthy vapours. A case of a town built in such a spot was Old Salpia in Apulia, founded by Diomede on his way back from Troy, or, according to some writers, by Elpias of Rhodes. Year after year there was sickness, until finally the suffering inhabitants came with a public petition to Marcus Hostilius and got him to agree to seek and find them a proper place to which to remove their city. Without delay he made the most skilful investigations, and at once purchased an estate near the sea in a healthy place, and asked the Senate and Roman people for permission to remove the town. He constructed the walls and laid out the house lots, granting one to each citizen for a mere trifle. This done, he cut an opening from a lake into the sea, and thus made of the lake a harbour for the town. The result is that now the people of Salpia live on a healthy site and at a distance of only four miles from the old town.

CHAPTER V

THE CITY WALLS

1. AFTER insuring on these principles the healthfulness of the future city, and selecting a neighbourhood that can supply plenty of food stuffs to maintain the community, with good roads or else convenient rivers or seaports affording easy means of transport to the city, the next thing to do is to lay the foundations for the towers and walls. Dig down to solid bottom, if it can be found, and lay them therein, going as deep as the magnitude of the proposed work seems to require. They should be much thicker than

the part of the walls that will appear above ground, and their structure should be as solid as it can possibly be laid.

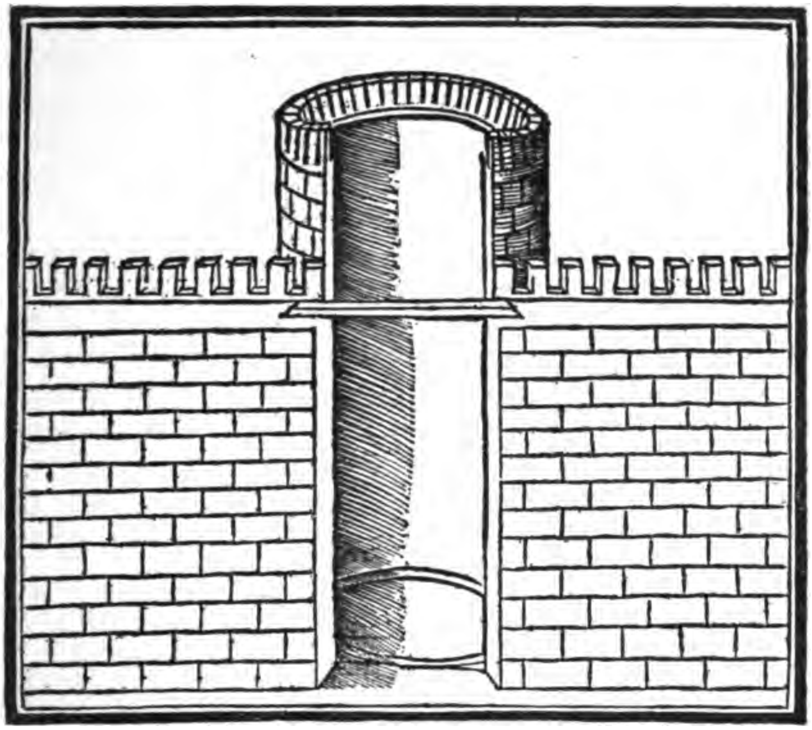
2. The towers must be projected beyond the line of wall, so that an enemy wishing to approach the wall to carry it by assault may be exposed to the fire of missiles on his open flank from the towers on his right and left. Special pains should be taken that there be no easy avenue by which to storm the wall. The roads should be encompassed at steep points, and planned so as to approach the gates, not in a straight line, but from the right to the left; for as a result of this, the right hand side of the assailants, unprotected by their shields, will be next the wall. Towns should be laid out not as an exact square nor with salient angles, but in circular form, to give a view of the enemy from many points. Defence is difficult where there are salient angles, because the angle protects the enemy rather than the inhabitants.

3. The thickness of the wall should, in my opinion, be such that armed men meeting on top of it may pass one another without interference. In the thickness there should be set a very close succession of ties made of charred olive wood, binding the two faces of the wall together like pins, to give it lasting endurance. For that is a material which neither decay, nor the weather, nor time can harm, but even though buried in the earth or set in the water it keeps sound and useful forever. And so not only city walls but substructures in general and all walls that require a thickness like that of a city wall, will be long in falling to decay if tied in this manner.

4. The towers should be set at intervals of not more than a bowshot apart, so that in case of an assault upon any one of them, the enemy may be repulsed with scorpiones and other means of hurling missiles from the towers to the right and left. Opposite the inner side of every tower the wall should be interrupted for a space the width of the tower, and have only a wooden flooring across, leading to the interior of the tower but not firmly nailed. This is to be cut away by the defenders in case the enemy gets possession of any portion of the wall; and if the work is quickly

done, the enemy will not be able to make his way to the other towers and the rest of the wall unless he is ready to face a fall.

5. The towers themselves must be either round or polygonal. Square towers are sooner shattered by military engines, for the



CONSTRUCTION OF CITY WALLS
(From the edition of Vitruvius by Fra Giocondo, Venice, 1511)

battering rams pound their angles to pieces; but in the case of round towers they can do no harm, being engaged, as it were, in driving wedges to their centre. The system of fortification by wall and towers may be made safest by the addition of earthen ramparts, for neither rams, nor mining, nor other engineering devices can do them any harm.

6. The rampart form of defence, however, is not required in all places, but only where outside the wall there is high ground from

which an assault on the fortifications may be made over a level space lying between. In places of this kind we must first make very wide, deep ditches; next sink foundations for a wall in the bed of the ditch and build them thick enough to support an earthwork with ease.

7. Then within this substructure lay a second foundation, far enough inside the first to leave ample room for cohorts in line of battle to take position on the broad top of the rampart for its defence. Having laid these two foundations at this distance from one another, build cross walls between them, uniting the outer and inner foundation, in a comb-like arrangement, set like the teeth of a saw. With this form of construction, the enormous burden of earth will be distributed into small bodies, and will not lie with all its weight in one crushing mass so as to thrust out the substructures.

8. With regard to the material of which the actual wall should be constructed or finished, there can be no definite prescription, because we cannot obtain in all places the supplies that we desire. Dimension stone, flint, rubble, burnt or unburnt brick, — use them as you find them. For it is not every neighbourhood or particular locality that can have a wall built of burnt brick like that at Babylon, where there was plenty of asphalt to take the place of lime and sand, and yet possibly each may be provided with materials of equal usefulness so that out of them a faultless wall may be built to last forever.

CHAPTER VI

THE DIRECTIONS OF THE STREETS; WITH REMARKS ON THE WINDS

1. The town being fortified, the next step is the apportionment of house lots within the wall and the laying out of streets and alleys with regard to climatic conditions. They will be properly laid out if foresight is employed to exclude the winds from the alleys. Cold winds are disagreeable, hot winds enervating, moist

winds unhealthy. We must, therefore, avoid mistakes in this matter and beware of the common experience of many communities. For example, Mytilene in the island of Lesbos is a town built with magnificence and good taste, but its position shows a lack of foresight. In that community when the wind is south, the people fall ill; when it is northwest, it sets them coughing; with a north wind they do indeed recover but cannot stand about in the alleys and streets, owing to the severe cold.

2. Wind is a flowing wave of air, moving hither and thither indefinitely. It is produced when heat meets moisture, the rush of heat generating a mighty current of air. That this is the fact we may learn from bronze eolipiles, and thus by means of a scientific invention discover a divine truth lurking in the laws of the heavens. Eolipiles are hollow bronze balls, with a very small opening through which water is poured into them. Set before a fire, not a breath issues from them before they get warm; but as soon as they begin to boil, out comes a strong blast due to the fire. Thus from this slight and very short experiment we may understand and judge of the mighty and wonderful laws of the heavens and the nature of winds.

3. By shutting out the winds from our dwellings, therefore, we shall not only make the place healthful for people who are well, but also in the case of diseases due perhaps to unfavourable situations elsewhere, the patients, who in other healthy places might be cured by a different form of treatment, will here be more quickly cured by the mildness that comes from the shutting out of the winds. The diseases which are hard to cure in neighbourhoods such as those to which I have referred above are catarrh, hoarseness, coughs, pleurisy, consumption, spitting of blood, and all others that are cured not by lowering the system but by building it up. They are hard to cure, first, because they are originally due to chills; secondly, because the patient's system being already exhausted by disease, the air there, which is in constant agitation owing to winds and therefore deteriorated, takes all the sap of life out of their diseased bodies and leaves them more

meagre every day. On the other hand, a mild, thick air, without draughts and not constantly blowing back and forth, builds up their frames by its unwavering steadiness, and so strengthens and restores people who are afflicted with these diseases.

4. Some have held that there are only four winds: Solanus from due east; Auster from the south; Favonius from due west; Septentrio from the north. But more careful investigators tell us that there are eight. Chief among such was Andronicus of Cyrrhus who in proof built the marble octagonal tower in Athens. On the several sides of the octagon he executed reliefs representing the several winds, each facing the point from which it blows; and on top of the tower he set a conical shaped piece of marble and on this a bronze Triton with a rod outstretched in its right hand. It was so contrived as to go round with the wind, always stopping to face the breeze and holding its rod as a pointer directly over the representation of the wind that was blowing.

5. Thus Eurus is placed to the southeast between Solanus and Auster: Africus to the southwest between Auster and Favonius; Caurus, or, as many call it, Corus, between Favonius and Septentrio; and Aquilo between Septentrio and Solanus. Such, then, appears to have been his device, including the numbers and names of the wind and indicating the directions from which particular winds blow. These facts being thus determined, to find the directions and quarters of the winds your method of procedure should be as follows.

6. In the middle of the city place a marble amussium, laying it true by the level, or else let the spot be made so true by means of rule and level that no amussium is necessary. In the very centre of that spot set up a bronze gnomon or "shadow tracker" (in Greek σκιαθήρας). At about the fifth hour in the morning, take the end of the shadow cast by this gnomon, and mark it with a point. Then, opening your compasses to this point which marks the length of the gnomon's shadow, describe a circle from the centre. In the afternoon watch the shadow of your gnomon as it lengthens, and when it once more touches the circumference of this

THE TOWER OF THE WINDS AT ATHENS

circle and the shadow in the afternoon is equal in length to that of the morning, mark it with a point.

7. From these two points describe with your compasses intersecting arcs, and through their intersection and the centre let a line be drawn to the circumference of the circle to give us the quarters of south and north. Then, using a sixteenth part of the entire circumference of the circle as a diameter, describe a circle with its centre on the line to the south, at the point where it crosses the circumference, and put points to the right and left on the circumference on the south side, repeating the process on the north side. From the four points thus obtained draw lines intersecting the centre from one side of the circumference to the other. Thus we shall have an eighth part of the circumference set out for Auster and another for Septentrio. The rest of the entire circumference is then to be divided into three equal parts on each side, and thus we have designed a figure equally apportioned among the eight winds. Then let the directions of your streets and alleys be laid down on the lines of division between the quarters of two winds.

8. On this principle of arrangement the disagreeable force of the winds will be shut out from dwellings and lines of houses. For if the streets run full in the face of the winds, their constant blasts rushing in from the open country, and then confined by narrow alleys, will sweep through them with great violence. The lines of houses must therefore be directed away from the quarters from which the winds blow, so that as they come in they may strike against the angles of the blocks and their force thus be broken and dispersed.

9. Those who know names for very many winds will perhaps be surprised at our setting forth that there are only eight. Remembering, however, that Eratosthenes of Cyrene, employing mathematical theories and geometrical methods, discovered from the course of the sun, the shadows cast by an equinoctial gnomon, and the inclination of the heaven that the circumference of the earth is two hundred and fifty-two thousand stadia, that is, thirty-

one million five hundred thousand paces, and observing that an eighth part of this, occupied by a wind, is three million nine hundred and thirty-seven thousand five hundred paces, they should not be surprised to find that a single wind, ranging over so wide a field, is subject to shifts this way and that, leading to a variety of breezes.

10. So we often have Leuconotus and Altanus blowing respectively to the right and left of Auster; Libonotus and Subvesperus to the right and left of Africus; Argestes, and at certain periods the Etesiae, on either side of Favonius; Circias and Corus on the sides of Caurus; Thracias and Gallicus on either side of Septentrio; Supernas and Caecias to the right and left of Aquilo; Carbas, and at a certain period the Ornithiae, on either side of Solanus; while Eurocircias and Volturnus blow on the flanks of Eurus which is between them. There are also many other names for winds derived from localities or from the squalls which sweep from rivers or down mountains.

11. Then, too, there are the breezes of early morning; for the sun on emerging from beneath the earth strikes humid air as he returns, and as he goes climbing up the sky he spreads it out before him, extracting breezes from the vapour that was there before the dawn. Those that still blow on after sunrise are classed with Eurus, and hence appears to come the Greek name *εὖρος* as the child of the breezes, and the word for "to-morrow," *αὔριον*, named from the early morning breezes. Some people do indeed say that Eratosthenes could not have inferred the true measure of the earth. Whether true or untrue, it cannot affect the truth of what I have written on the fixing of the quarters from which the different winds blow.

12. If he was wrong, the only result will be that the individual winds may blow, not with the scope expected from his measurement, but with powers either more or less widely extended. For the readier understanding of these topics, since I have treated them with brevity, it has seemed best to me to give two figures, or, as the Greeks say, *σχήματα*, at the end of this book: one de-

signed to show the precise quarters from which the winds arise; the other, how by turning the directions of the rows of houses and the streets away from their full force, we may avoid unhealthy blasts. Let A be the centre of a plane surface, and B the point to

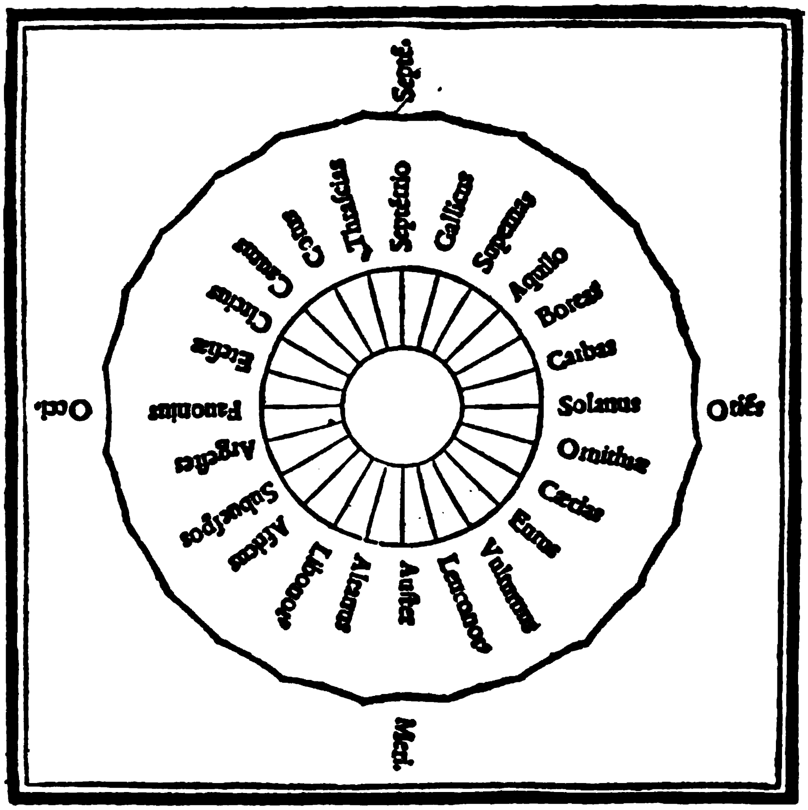
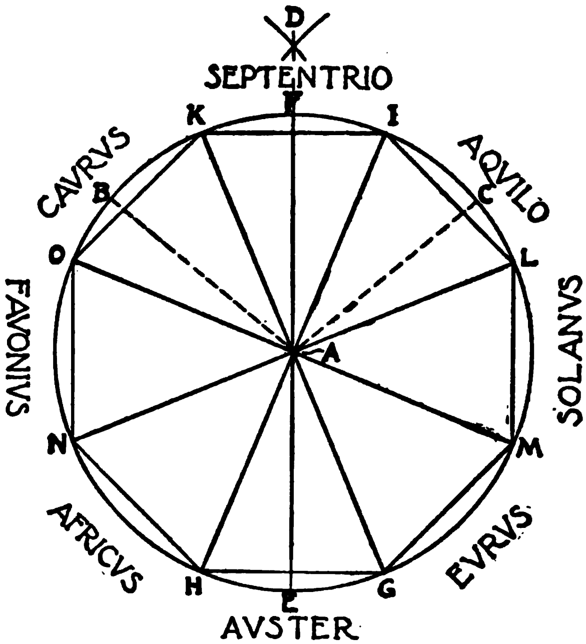


DIAGRAM OF THE WINDS
(From the edition of Vitruvius by Fra Giocondo, Venice, 1511)

which the shadow of the gnomon reaches in the morning. Taking A as the centre, open the compasses to the point B, which marks the shadow, and describe a circle. Put the gnomon back where it was before and wait for the shadow to lessen and grow again until in the afternoon it is equal to its length in the morning, touching the circumference at the point C. Then from the points B and C describe with the compasses two arcs intersecting at D. Next draw a line from the point of intersection D through the centre of the circle to the circumference and call it E F. This line will show where the south and north lie.

13. Then find with the compasses a sixteenth part of the entire circumference; then centre the compasses on the point E where



the line to the south touches the circumference, and set off the points G and H to the right and left of E. Likewise on the north side, centre the compasses on the circumference at the point F on the line to the north, and set off the points I and K to the right and left; then draw lines through the centre from G to K and from H to I. Thus the space from G to H will belong to Auster and the south, and the space from I to K will be that of Septentrio. The rest of the circumference is to be divided equally into three parts on the right and three on the left, those to the east at the points L and M, those to the west at the points N and O.

Finally, intersecting lines are to be drawn from M to O and from L to N. Thus we shall have the circumference divided into eight equal spaces for the winds. The figure being finished, we shall have at the eight different divisions, beginning at the south, the letter G between Eurus and Auster, H between Auster and Africus, N between Africus and Favonius, O between Favonius and Caurus, K between Caurus and Septentrio, I between Septentrio and Aquilo, L between Aquilo and Solanus, and M between Solanus and Eurus. This done, apply a gnomon to these eight divisions and thus fix the directions of the different alleys.

CHAPTER VII

THE SITES FOR PUBLIC BUILDINGS

1. HAVING laid out the alleys and determined the streets, we have next to treat of the choice of building sites for temples, the forum, and all other public places, with a view to general convenience and utility. If the city is on the sea, we should choose ground close to the harbour as the place where the forum is to be built; but if inland, in the middle of the town. For the temples, the sites for those of the gods under whose particular protection the state is thought to rest and for Jupiter, Juno, and Minerva, should be on the very highest point commanding a view of the greater part of the city. Mercury should be in the forum, or, like Isis and Serapis, in the emporium: Apollo and Father Bacchus near the theatre: Hercules at the circus in communities which have no gymnasia nor amphitheatres; Mars outside the city but at the training ground, and so Venus, but at the harbour. It is moreover shown by the Etruscan diviners in treatises on their science that the fanes of Venus, Vulcan, and Mars should be situated outside the walls, in order that the young men and married women may not become habituated in the city to the temptations incident to the worship of Venus, and that buildings may be free from the terror of fires through the religious rites and sacrifices which

call the power of Vulcan beyond the walls. As for Mars, when that divinity is enshrined outside the walls, the citizens will never take up arms against each other, and he will defend the city from its enemies and save it from danger in war.

2. Ceres also should be outside the city in a place to which people need never go except for the purpose of sacrifice. That place should be under the protection of religion, purity, and good morals. Proper sites should be set apart for the precincts of the other gods according to the nature of the sacrifices offered to them.

The principle governing the actual construction of temples and their symmetry I shall explain in my third and fourth books. In the second I have thought it best to give an account of the materials used in buildings with their good qualities and advantages, and then in the succeeding books to describe and explain the proportions of buildings, their arrangements, and the different forms of symmetry.

BOOK II

BOOK II

INTRODUCTION

1. DINOCRATES, an architect who was full of confidence in his own ideas and skill, set out from Macedonia, in the reign of Alexander, to go to the army, being eager to win the approbation of the king. He took with him from his country letters from relatives and friends to the principal military men and officers of the court, in order to gain access to them more readily. Being politely received by them, he asked to be presented to Alexander as soon as possible. They promised, but were rather slow, waiting for a suitable opportunity. So Dinocrates, thinking that they were playing with him, had recourse to his own efforts. He was of very lofty stature and pleasing countenance, finely formed, and extremely dignified. Trusting, therefore, to these natural gifts, he undressed himself in his inn, anointed his body with oil, set a chaplet of poplar leaves on his head, draped his left shoulder with a lion's skin, and holding a club in his right hand stalked forth to a place in front of the tribunal where the king was administering justice.

2. His strange appearance made the people turn round, and this led Alexander to look at him. In astonishment he gave orders to make way for him to draw near, and asked who he was. "Dinocrates," quoth he, "a Macedonian architect, who brings thee ideas and designs worthy of thy renown. I have made a design for the shaping of Mount Athos into the statue of a man, in whose left hand I have represented a very spacious fortified city, and in his right a bowl to receive the water of all the streams which are in that mountain, so that it may pour from the bowl into the sea."

3. Alexander, delighted with the idea of his design, immediately inquired whether there were any fields in the neighbour-

hood that could maintain the city in corn. On finding that this was impossible without transport from beyond the sea, "Dinocrates," quoth he, "I appreciate your design as excellent in composition, and I am delighted with it, but I apprehend that anybody who should found a city in that spot would be censured for bad judgement. For as a newborn babe cannot be nourished without the nurse's milk, nor conducted to the approaches that lead to growth in life, so a city cannot thrive without fields and the fruits thereof pouring into its walls, nor have a large population without plenty of food, nor maintain its population without a supply of it. Therefore, while thinking that your design is commendable, I consider the site as not commendable; but I would have you stay with me, because I mean to make use of your services."

4. From that time, Dinocrates did not leave the king, but followed him into Egypt. There Alexander, observing a harbour rendered safe by nature, an excellent centre for trade, cornfields throughout all Egypt, and the great usefulness of the mighty river Nile, ordered him to build the city of Alexandria, named after the king. This was how Dinocrates, recommended only by his good looks and dignified carriage, came to be so famous. But as for me, Emperor, nature has not given me stature, age has marred my face, and my strength is impaired by ill health. Therefore, since these advantages fail me, I shall win your approval, as I hope, by the help of my knowledge and my writings.

5. In my first book, I have said what I had to say about the functions of architecture and the scope of the art, as well as about fortified towns and the apportionment of building sites within the fortifications. Although it would next be in order to explain the proper proportions and symmetry of temples and public buildings, as well as of private houses, I thought best to postpone this until after I had treated the practical merits of the materials out of which, when they are brought together, buildings are constructed with due regard to the proper kind of material for each part, and until I had shown of what natural elements those materials are composed. But before beginning to explain their

natural properties, I will prefix the motives which originally gave rise to buildings and the development of inventions in this field, following in the steps of early nature and of those writers who have devoted treatises to the origins of civilization and the investigation of inventions. My exposition will, therefore, follow the instruction which I have received from them.

CHAPTER I

THE ORIGIN OF THE DWELLING HOUSE

1. THE men of old were born like the wild beasts, in woods, caves, and groves, and lived on savage fare. As time went on, the thickly crowded trees in a certain place, tossed by storms and winds, and rubbing their branches against one another, caught fire, and so the inhabitants of the place were put to flight, being terrified by the furious flame. After it subsided, they drew near, and observing that they were very comfortable standing before the warm fire, they put on logs and, while thus keeping it alive, brought up other people to it, showing them by signs how much comfort they got from it. In that gathering of men, at a time when utterance of sound was purely individual, from daily habits they fixed upon articulate words just as these had happened to come; then, from indicating by name things in common use, the result was that in this chance way they began to talk, and thus originated conversation with one another.

2. Therefore it was the discovery of fire that originally gave rise to the coming together of men, to the deliberative assembly, and to social intercourse. And so, as they kept coming together in greater numbers into one place, finding themselves naturally gifted beyond the other animals in not being obliged to walk with faces to the ground, but upright and gazing upon the splendour of the starry firmament, and also in being able to do with ease whatever they chose with their hands and fingers, they began in that first assembly to construct shelters. Some made them of green boughs, others dug caves on mountain sides, and some, in imitation of the nests of swallows and the way they built, made places of refuge out of mud and twigs. Next, by observing the shelters of others and adding new details to their own incep-

tions, they constructed better and better kinds of huts as time went on.

3. And since they were of an imitative and teachable nature, they would daily point out to each other the results of their building, boasting of the novelties in it; and thus, with their natural gifts sharpened by emulation, their standards improved daily. At first they set up forked stakes connected by twigs and covered these walls with mud. Others made walls of lumps of dried mud, covering them with reeds and leaves to keep out the rain and the heat. Finding that such roofs could not stand the rain during the storms of winter, they built them with peaks daubed with mud, the roofs sloping and projecting so as to carry off the rain water.

4. That houses originated as I have written above, we can see for ourselves from the buildings that are to this day constructed of like materials by foreign tribes: for instance, in Gaul, Spain, Portugal, and Aquitaine, roofed with oak shingles or thatched. Among the Colchians in Pontus, where there are forests in plenty, they lay down entire trees flat on the ground to the right and the left, leaving between them a space to suit the length of the trees, and then place above these another pair of trees, resting on the ends of the former and at right angles with them. These four trees enclose the space for the dwelling. Then upon these they place sticks of timber, one after the other on the four sides, crossing each other at the angles, and so, proceeding with their walls of trees laid perpendicularly above the lowest, they build up high towers. The interstices, which are left on account of the thickness of the building material, are stopped up with chips and mud. As for the roofs, by cutting away the ends of the crossbeams and making them converge gradually as they lay them across, they bring them up to the top from the four sides in the shape of a pyramid. They cover it with leaves and mud, and thus construct the roofs of their towers in a rude form of the "tortoise" style.

5. On the other hand, the Phrygians, who live in an open coun-

try, have no forests and consequently lack timber. They therefore select a natural hillock, run a trench through the middle of it, dig passages, and extend the interior space as widely as the site admits. Over it they build a pyramidal roof of logs fastened together, and this they cover with reeds and brushwood, heaping up very high mounds of earth above their dwellings. Thus their fashion in houses makes their winters very warm and their summers very cool. Some construct hovels with roofs of rushes from the swamps. Among other nations, also, in some places there are huts of the same or a similar method of construction. Likewise at Marseilles we can see roofs without tiles, made of earth mixed with straw. In Athens on the Areopagus there is to this day a relic of antiquity with a mud roof. The hut of Romulus on the Capitol is a significant reminder of the fashions of old times, and likewise the thatched roofs of temples on the Citadel.

6. From such specimens we can draw our inferences with regard to the devices used in the buildings of antiquity, and conclude that they were similar.

Furthermore, as men made progress by becoming daily more expert in building, and as their ingenuity was increased by their dexterity so that from habit they attained to considerable skill, their intelligence was enlarged by their industry until the more proficient adopted the trade of carpenters. From these early beginnings, and from the fact that nature had not only endowed the human race with senses like the rest of the animals, but had also equipped their minds with the powers of thought and understanding, thus putting all other animals under their sway, they next gradually advanced from the construction of buildings to the other arts and sciences, and so passed from a rude and barbarous mode of life to civilization and refinement.

7. Then, taking courage and looking forward from the standpoint of higher ideas born of the multiplication of the arts, they gave up huts and began to build houses with foundations, having

brick or stone walls, and roofs of timber and tiles; next, observation and application led them from fluctuating and indefinite conceptions to definite rules of symmetry. Perceiving that nature had been lavish in the bestowal of timber and bountiful in stores of building material, they treated this like careful nurses, and thus developing the refinements of life, embellished them with luxuries. Therefore I shall now treat, to the best of my ability, of the things which are suitable to be used in buildings, showing their qualities and their excellencies.

8. Some persons, however, may find fault with the position of this book, thinking that it should have been placed first. I will therefore explain the matter, lest it be thought that I have made a mistake. Being engaged in writing a complete treatise on architecture, I resolved to set forth in the first book the branches of learning and studies of which it consists, to define its departments, and to show of what it is composed. Hence I have there declared what the qualities of an architect should be. In the first book, therefore, I have spoken of the function of the art, but in this I shall discuss the use of the building materials which nature provides. For this book does not show of what architecture is composed, but treats of the origin of the building art, how it was fostered, and how it made progress, step by step, until it reached its present perfection.

9. This book is, therefore, in its proper order and place.

I will now return to my subject, and with regard to the materials suited to the construction of buildings will consider their natural formation and in what proportions their elementary constituents were combined, making it all clear and not obscure to my readers. For there is no kind of material, no body, and no thing that can be produced or conceived of, which is not made up of elementary particles; and nature does not admit of a truthful exploration in accordance with the doctrines of the physicists without an accurate demonstration of the primary causes of things, showing how and why they are as they are.

CHAPTER II

ON THE PRIMORDIAL SUBSTANCE ACCORDING TO THE PHYSICISTS

1. First of all Thales thought that water was the primordial substance of all things. Heraclitus of Ephesus, surnamed by the Greeks σκοτεινὸς on account of the obscurity of his writings, thought that it was fire. Democritus and his follower Epicurus thought that it was the atoms, termed by our writers "bodies that cannot be cut up," or, by some, "indivisibles." The school of the Pythagoreans added air and the earthy to the water and fire. Hence, although Democritus did not in a strict sense name them, but spoke only of indivisible bodies, yet he seems to have meant these same elements, because when taken by themselves they cannot be harmed, nor are they susceptible of dissolution, nor can they be cut up into parts, but throughout time eternal they forever retain an infinite solidity.

2. All things therefore appear to be made up and produced by the coming together of these elements, so that they have been distributed by nature among an infinite number of kinds of things. Hence I believed it right to treat of the diversity and practical peculiarities of these things as well as of the qualities which they exhibit in buildings, so that persons who are intending to build may understand them and so make no mistake, but may gather materials which are suitable to use in their buildings.

CHAPTER III

BRICK

1. Beginning with bricks, I shall state of what kind of clay they ought to be made. They should not be made of sandy or pebbly clay, or of fine gravel, because when made of these kinds they are in the first place heavy; and, secondly, when washed by

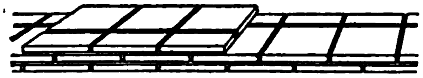
the rain as they stand in walls, they go to pieces and break up, and the straw in them does not hold together on account of the roughness of the material. They should rather be made of white and chalky or of red clay, or even of a coarse grained gravelly clay. These materials are smooth and therefore durable; they are not heavy to work with, and are readily laid.

2. Bricks should be made in Spring or Autumn, so that they may dry uniformly. Those made in Summer are defective, because the fierce heat of the sun bakes their surface and makes the brick seem dry while inside it is not dry. And so the shrinking, which follows as they dry, causes cracks in the parts which were dried before, and these cracks make the bricks weak. Bricks will be most serviceable if made two years before using; for they cannot dry thoroughly in less time. When fresh undried bricks are used in a wall, the stucco covering stiffens and hardens into a permanent mass, but the bricks settle and cannot keep the same height as the stucco; the motion caused by their shrinking prevents them from adhering to it, and they are separated from their union with it. Hence the stucco, no longer joined to the core of the wall, cannot stand by itself because it is so thin; it breaks off, and the walls themselves may perhaps be ruined by their settling. This is so true that at Utica in constructing walls they use brick only if it is dry and made five years previously, and approved as such by the authority of a magistrate.

3. There are three kinds of bricks. First, the kind called in Greek Lydian, being that which our people use, a foot and a half long and one foot wide. The other two kinds are used by the Greeks in their buildings. Of these, one is called *πεντάδωρον*, the other *τετράδωρον*. *Δῶρον* is the Greek for "palm," for in Greek *δῶρον* means the giving of gifts, and the gift is always presented in the palm of the hand. A brick five palms square is called "pentadoron"; one four palms square "tetradoron." Public buildings are constructed of *πεντάδωρα*, private of *τετράδωρα*.

4. With these bricks there are also half-bricks. When these are used in a wall, a course of bricks is laid on one face and a course

of half-bricks on the other, and they are bedded to the line on each face. The walls are bonded by alternate courses of the two different kinds, and as the bricks are always laid so as to break joints, this lends strength and a not unattractive appearance to both sides of such walls.



VITRUVIUS' BRICK-BOND ACCORDING TO REBER

In the states of Maxilua and Callet, in Further Spain, as well as in Pitane in Asia Minor, there are bricks which, when finished and dried, will float on being thrown into water. The reason why they can float seems to be that the clay of which they are made is like pumice-stone. So it is light, and also it does not, after being hardened by exposure to the air, take up or absorb liquid. So these bricks, being of this light and porous quality, and admitting no moisture into their texture, must by the laws of nature float in water, like pumice, no matter what their weight may be. They have therefore great advantages; for they are not heavy to use in building and, once made, they are not spoiled by bad weather.

CHAPTER IV

SAND

1. In walls of masonry the first question must be with regard to the sand, in order that it may be fit to mix into mortar and have no dirt in it. The kinds of pitsand are these: black, gray, red, and carbuncular. Of these the best will be found to be that which crackles when rubbed in the hand, while that which has much dirt in it will not be sharp enough. Again: throw some sand upon a white garment and then shake it out; if the garment is not soiled and no dirt adheres to it, the sand is suitable.

2. But if there are no sandpits from which it can be dug, then we must sift it out from river beds or from gravel or even from the sea beach. This kind, however, has these defects when used in

masonry: it dries slowly; the wall cannot be built up without interruption but from time to time there must be pauses in the work; and such a wall cannot carry vaultings. Furthermore, when sea-sand is used in walls and these are coated with stucco, a salty efflorescence is given out which spoils the surface.

3. But pitsand used in masonry dries quickly, the stucco coating is permanent, and the walls can support vaultings. I am speaking of sand fresh from the sandpits. For if it lies unused too long after being taken out, it is disintegrated by exposure to sun, moon, or hoar frost, and becomes earthy. So when mixed in masonry, it has no binding power on the rubble, which consequently settles and down comes the load which the walls can no longer support. Fresh pitsand, however, in spite of all its excellence in concrete structures, is not equally useful in stucco, the richness of which, when the lime and straw are mixed with such sand, will cause it to crack as it dries on account of the great strength of the mixture. But river sand, though useless in "signinum" on account of its thinness, becomes perfectly solid in stucco when thoroughly worked by means of polishing instruments.

CHAPTER V

LIME

1. SAND and its sources having been thus treated, next with regard to lime we must be careful that it is burned from a stone which, whether soft or hard, is in any case white. Lime made of close-grained stone of the harder sort will be good in structural parts; lime of porous stone, in stucco. After slaking it, mix your mortar, if using pitsand, in the proportions of three parts of sand to one of lime; if using river or sea-sand, mix two parts of sand with one of lime. These will be the right proportions for the composition of the mixture. Further, in using river or sea-sand, the addition of a third part composed of burnt brick, pounded up and sifted, will make your mortar of a better composition to use.

2. The reason why lime makes a solid structure on being combined with water and sand seems to be this: that rocks, like all other bodies, are composed of the four elements. Those which contain a larger proportion of air, are soft; of water, are tough from the moisture; of earth, hard; and of fire, more brittle. Therefore, if limestone, without being burned, is merely pounded up small and then mixed with sand and so put into the work, the mass does not solidify nor can it hold together. But if the stone is first thrown into the kiln, it loses its former property of solidity by exposure to the great heat of the fire, and so with its strength burnt out and exhausted it is left with its pores open and empty. Hence, the moisture and air in the body of the stone being burned out and set free, and only a residuum of heat being left lying in it, if the stone is then immersed in water, the moisture, before the water can feel the influence of the fire, makes its way into the open pores; then the stone begins to get hot, and finally, after it cools off, the heat is rejected from the body of the lime.

3. Consequently, limestone when taken out of the kiln cannot be as heavy as when it was thrown in, but on being weighed, though its bulk remains the same as before, it is found to have lost about a third of its weight owing to the boiling out of the water. Therefore, its pores being thus opened and its texture rendered loose, it readily mixes with sand, and hence the two materials cohere as they dry, unite with the rubble, and make a solid structure.

CHAPTER VI

POZZOLANA

1. There is also a kind of powder which from natural causes produces astonishing results. It is found in the neighbourhood of Baiae and in the country belonging to the towns round about Mt. Vesuvius. This substance, when mixed with lime and rub-

ble, not only lends strength to buildings of other kinds, but even when piers of it are constructed in the sea, they set hard under water. The reason for this seems to be that the soil on the slopes of the mountains in these neighbourhoods is hot and full of hot springs. This would not be so unless the mountains had beneath them huge fires of burning sulphur or alum or asphalt. So the fire and the heat of the flames, coming up hot from far within through the fissures, make the soil there light, and the tufa found there is spongy and free from moisture. Hence, when the three substances, all formed on a similar principle by the force of fire, are mixed together, the water suddenly taken in makes them cohere, and the moisture quickly hardens them so that they set into a mass which neither the waves nor the force of the water can dissolve.

2. That there is burning heat in these regions may be proved by the further fact that in the mountains near Baiae, which belongs to the Cumaeans, there are places excavated to serve as sweating-baths, where the intense heat that comes from far below bores its way through the earth, owing to the force of the fire, and passing up appears in these regions, thus making remarkably good sweating-baths. Likewise also it is related that in ancient times the tides of heat, swelling and overflowing from under Mt. Vesuvius, vomited forth fire from the mountain upon the neighbouring country. Hence, what is called "sponge-stone" or "Pompeian pumice" appears to have been reduced by burning from another kind of stone to the condition of the kind which we see.

3. The kind of sponge-stone taken from this region is not produced everywhere else, but only about Aetna and among the hills of Mysia which the Greeks call the "Burnt District," and in other places of the same peculiar nature. Seeing that in such places there are found hot springs and warm vapour in excavations on the mountains, and that the ancients tell us that there were once fires spreading over the fields in those very regions, it seems to be certain that moisture has been extracted from the

tufa and earth, by the force of fire, just as it is from limestone in kilns.

4. Therefore, when different and unlike things have been subjected to the action of fire and thus reduced to the same condition, if after this, while in a warm, dry state, they are suddenly saturated with water, there is an effervescence of the heat latent in the bodies of them all, and this makes them firmly unite and quickly assume the property of one solid mass.

There will still be the question why Tuscany, although it abounds in hot springs, does not furnish a powder out of which, on the same principle, a wall can be made which will set fast under water. I have therefore thought best to explain how this seems to be, before the question should be raised.

5. The same kinds of soil are not found in all places and countries alike, nor is stone found everywhere. Some soils are earthy; others gravelly, and again pebbly; in other places the material is sandy; in a word, the properties of the soil are as different and unlike as are the various countries. In particular, it may be observed that sandpits are hardly ever lacking in any place within the districts of Italy and Tuscany which are bounded by the Apennines; whereas across the Apennines toward the Adriatic none are found, and in Achaea and Asia Minor or, in short, across the sea, the very term is unknown. Hence it is not in all the places where boiling springs of hot water abound, that there is the same combination of favourable circumstances which has been described above. For things are produced in accordance with the will of nature; not to suit man's pleasure, but as it were by a chance distribution.

6. Therefore, where the mountains are not earthy but consist of soft stone, the force of the fire, passing through the fissures in the stone, sets it afire. The soft and delicate part is burned out, while the hard part is left. Consequently, while in Campania the burning of the earth makes ashes, in Tuscany the combustion of the stone makes carbuncular sand. Both are excellent in walls, but one is better to use for buildings on land, the other for piers

TRAVERTINE QUARRIES ON THE ROMAN CAMPAGNA

1. 2. Ancient quarries. 3. A similar modern quarry.

The top of the rock shows the original ground level. The present ground level shows the depth to which the rock has been removed.

under salt water. The Tuscan stone is softer in quality than tufa but harder than earth, and being thoroughly kindled by the violent heat from below, the result is the production in some places of the kind of sand called carbuncular.

CHAPTER VII

STONE

1. I HAVE now spoken of lime and sand, with their varieties and points of excellence. Next comes the consideration of stone-quarries from which dimension stone and supplies of rubble to be used in building are taken and brought together. The stone in quarries is found to be of different and unlike qualities. In some it is soft: for example, in the environs of the city at the quarries of Grotta Rossa, Palla, Fidenae, and of the Alban hills; in others, it is medium, as at Tivoli, at Amiternum, or Mt. Soracte, and in quarries of this sort; in still others it is hard, as in lava quarries. There are also numerous other kinds: for instance, in Campania, red and black tufas; in Umbria, Picenum, and Venetia, white tufa which can be cut with a toothed saw, like wood.

2. All these soft kinds have the advantage that they can be easily worked as soon as they have been taken from the quarries. Under cover they play their part well; but in open and exposed situations the frost and rime make them crumble, and they go to pieces. On the seacoast, too, the salt eats away and dissolves them, nor can they stand great heat either. But travertine and all stone of that class can stand injury whether from a heavy load laid upon it or from the weather; exposure to fire, however, it cannot bear, but splits and cracks to pieces at once. This is because in its natural composition there is but little moisture and not much of the earthy, but a great deal of air and of fire. Therefore, it is not only without the earthy and watery elements, but when fire, expelling the air from it by the operation and force of heat, penetrates into its inmost parts and occupies the empty spaces of the

fissures, there comes a great glow and the stone is made to burn as fiercely as do the particles of fire itself.

3. There are also several quarries called Anician in the territory of Tarquinii, the stone being of the colour of peperino. The principal workshops lie round the lake of Bolsena and in the prefecture of Statonia. This stone has innumerable good qualities. Neither the season of frost nor exposure to fire can harm it, but it remains solid and lasts to a great age, because there is only a little air and fire in its natural composition, a moderate amount of moisture, and a great deal of the earthy. Hence its structure is of close texture and solid, and so it cannot be injured by the weather or by the force of fire.

4. This may best be seen from monuments in the neighbourhood of the town of Ferento which are made of stone from these quarries. Among them are large statues exceedingly well made, images of smaller size, and flowers and acanthus leaves gracefully carved. Old as these are, they look as fresh as if they were only just finished. Bronze workers, also, make moulds for the casting of bronze out of stone from these quarries, and find it very useful in bronze-founding. If the quarries were only near Rome, all our buildings might well be constructed from the products of these workshops.

5. But since, on account of the proximity of the stone-quarries of Grotta Rossa, Palla, and the others that are nearest to the city, necessity drives us to make use of their products, we must proceed as follows, if we wish our work to be finished without flaws. Let the stone be taken from the quarry two years before building is to begin, and not in winter but in summer. Then let it lie exposed in an open place. Such stone as has been damaged by the two years of exposure should be used in the foundations. The rest, which remains unhurt, has passed the test of nature and will endure in those parts of the building which are above ground. This precaution should be observed, not only with dimension stone, but also with the rubble which is to be used in walls.

Photo Moscioni

EXAMPLE OF OPUS INCERTUM, THE CIRCULAR TEMPLE AT TIVOLI

CHAPTER VIII

METHODS OF BUILDING WALLS

1. THERE are two styles of walls: "opus reticulatum," now used by everybody, and the ancient style called "opus incertum." Of these, the reticulatum looks better, but its construction makes it likely to crack, because its beds and builds spread out in every direction. On the other hand, in the opus incertum, the rubble, lying in courses and imbricated, makes a wall which, though not beautiful, is stronger than the reticulatum.

2. Both kinds should be constructed of the smallest stones, so that the walls, being thoroughly puddled with the mortar, which is made of lime and sand, may hold together longer. Since the stones used are soft and porous, they are apt to suck the moisture out of the mortar and so to dry it up. But when there is abundance of lime and sand, the wall, containing more moisture, will not soon lose its strength, for they will hold it together. But as soon as the moisture is sucked out of the mortar by the porous rubble, and the lime and sand separate and disunite, the rubble can no longer adhere to them and the wall will in time become a ruin.

3. This we may learn from several monuments in the environs of the city, which are built of marble or dimension stone, but on the inside packed with masonry between the outer walls. In the course of time, the mortar has lost its strength, which has been sucked out of it by the porousness of the rubble; and so the monuments are tumbling down and going to pieces, with their joints loosened by the settling of the material that bound them together.

4. He who wishes to avoid such a disaster should leave a cavity behind the facings, and on the inside build walls two feet thick, made of red dimension stone or burnt brick or lava in courses, and then bind them to the fronts by means of iron clamps and lead. For thus his work, being no mere heap of material but regularly laid in courses, will be strong enough to last forever

without a flaw, because the beds and builds, all settling equally and bonded at the joints, will not let the work bulge out, nor allow the fall of the face walls which have been tightly fastened together.

5. Consequently, the method of construction employed by the Greeks is not to be despised. They do not use a structure of soft rubble polished on the outside, but whenever they forsake dimension stone, they lay courses of lava or of some hard stone, and, as though building with brick, they bind the upright joints by interchanging the direction of the stones as they lie in the courses. Thus they attain to a perfection that will endure to eternity. These structures are of two kinds. One of them is called "isodomum," the other "pseudisodomum."

6. A wall is called isodomum when all the courses are of equal height; pseudisodomum, when the rows of courses do not match but run unequally. Both kinds are strong: first, because the rubble itself is of close texture and solid, unable to suck the moisture out of the mortar, but keeping it in its moist condition for a very long period; secondly, because the beds of the stones, being laid smooth and level to begin with, keep the mortar from falling, and, as they are bonded throughout the entire thickness of the wall, they hold together for a very long period.

7. Another method is that which they call ἔμπλεκτον, used also among us in the country. In this the facings are finished, but the other stones left in their natural state and then laid with alternate bonding stones. But our workmen, in their hurry to finish, devote themselves only to the facings of the walls, setting them upright but filling the space between with a lot of broken stones and mortar thrown in anyhow. This makes three different sections in the same structure; two consisting of facing and one of filling between them. The Greeks, however, do not build so; but laying their stones level and building every other stone lengthwise into the thickness, they do not fill the space between, but construct the thickness of their walls in one solid and unbroken mass from the facings to the interior. Further, at intervals they

Photo. Moscioni

OPUS RETICULATUM FROM THE THERMAE OF HADRIAN'S VILLA AT TIVOLI

Photo Moscioni

EXAMPLE OF OPUS RETICULATUM FROM THE DOORWAY OF THE STOA POECILE. VILLA OF HADRIAN AT TIVOLI

lay single stones which run through the entire thickness of the wall. These stones, which show at each end, are called διάτονοι, and by their bonding powers they add very greatly to the solidity of the walls.

8. One who in accordance with these notes will take pains in selecting his method of construction, may count upon having something that will last. No walls made of rubble and finished with delicate beauty — no such walls can escape ruin as time goes on. Hence, when arbitrators are chosen to set a valuation on party walls, they do not value them at what they cost to build, but look up the written contract in each case and then, after deducting from the cost one eightieth for each year that the wall has been standing, decide that the remainder is the sum to be paid. They thus in effect pronounce that such walls cannot last more than eighty years.

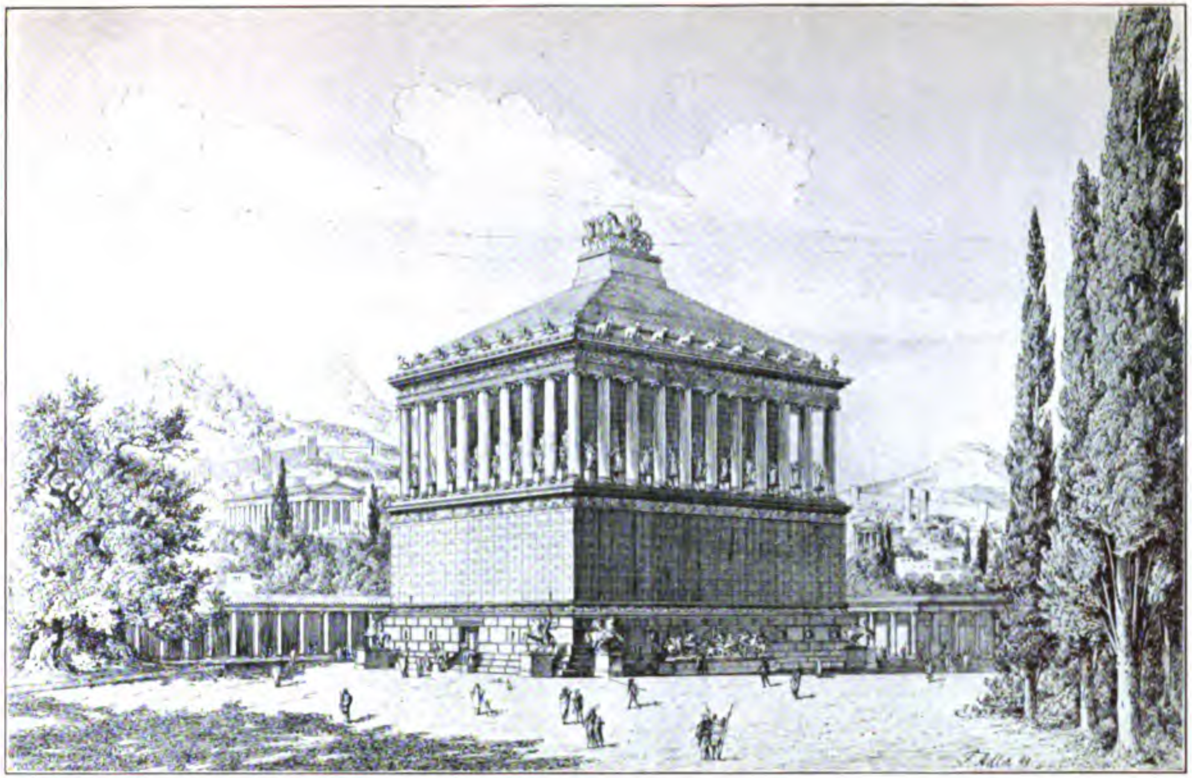
9. In the case of brick walls, however, no deduction is made provided that they are still standing plumb, but they are always valued at what they cost to build. Hence in some states we may see public buildings and private houses, as well as those of kings, built of brick: in Athens, for example, the part of the wall which faces Mt. Hymettus and Pentelicus; at Patras, the cellae of the temple of Jupiter and Hercules, which are brick, although on the outside the entablature and columns of the temple are of stone; in Italy, at Arezzo, an ancient wall excellently built; at Tralles, the house built for the kings of the dynasty of Attalus, which is now always granted to the man who holds the state priesthood. In Sparta, paintings have been taken out of certain walls by cutting through the bricks, then have been placed in wooden frames, and so brought to the Comitium to adorn the aedileship of Varro and Murena.

10. Then there is the house of Croesus which the people of Sardis have set apart as a place of repose for their fellow-citizens in the retirement of age, — a "Gerousia" for the guild of the elder men. At Halicarnassus, the house of that most potent king Mausolus, though decorated throughout with Proconnesian mar-

ble, has walls built of brick which are to this day of extraordinary strength, and are covered with stucco so highly polished that they seem to be as glistening as glass. That king did not use brick from poverty; for he was choke-full of revenues, being ruler of all Caria.

11. As for his skill and ingenuity as a builder, they may be seen from what follows. He was born at Melassa, but recognizing the natural advantages of Halicarnassus as a fortress, and seeing that it was suitable as a trading centre and that it had a good harbour, he fixed his residence there. The place had a curvature like that of the seats in a theatre. On the lowest tier, along the harbour, was built the forum. About half-way up the curving slope, at the point where the curved cross-aisle is in a theatre, a broad wide street was laid out, in the middle of which was built the Mausoleum, a work so remarkable that it is classed among the Seven Wonders of the World. At the top of the hill, in the centre, is the fane of Mars, containing a colossal acrolithic statue by the famous hand of Leochares. That is, some think that this statue is by Leochares, others by Timotheus. At the extreme right of the summit is the fane of Venus and Mercury, close to the spring of Salmacis.

12. There is a mistaken idea that this spring infects those who drink of it with an unnatural lewdness. It will not be out of place to explain how this idea came to spread throughout the world from a mistake in the telling of the tale. It cannot be that the water makes men effeminate and unchaste, as it is said to do; for the spring is of remarkable clearness and excellent in flavour. The fact is that when Melas and Arevanias came there from Argos and Troezen and founded a colony together, they drove out the Carians and Lelegans who were barbarians. These took refuge in the mountains, and, uniting there, used to make raids, plundering the Greeks and laying their country waste in a cruel manner. Later, one of the colonists, to make money, set up a well-stocked shop, near the spring because the water was so good, and the way in which he carried it on attracted the barbarians. So



THE MAUSOLEUM AT HALICARNASSUS AS RESTORED BY FRIEDRICH ADLER

they began to come down, one at a time, and to meet with society, and thus they were brought back of their own accord, giving up their rough and savage ways for the delights of Greek customs. Hence this water acquired its peculiar reputation, not because it really induced unchastity, but because those barbarians were softened by the charm of civilization.

13. But since I have been tempted into giving a description of this fortified place, it remains to finish my account of it. Corresponding to the fane of Venus and the spring described above, which are on the right, we have on the extreme left the royal palace which king Mausolus built there in accordance with a plan all his own. To the right it commands a view of the forum, the harbour, and the entire line of fortifications, while just below it, to the left, there is a concealed harbour, hidden under the walls in such a way that nobody could see or know what was going on in it. Only the king himself could, in case of need, give orders from his own palace to the oarsmen and soldiers, without the knowledge of anybody else.

14. After the death of Mausolus, his wife Artemisia became queen, and the Rhodians, regarding it as an outrage that a woman should be ruler of the states of all Caria, fitted out a fleet and sallied forth to seize upon the kingdom. When news of this reached Artemisia, she gave orders that her fleet should be hidden away in that harbour with oarsmen and marines mustered and concealed, but that the rest of the citizens should take their places on the city wall. After the Rhodians had landed at the larger harbour with their well-equipped fleet, she ordered the people on the wall to cheer them and to promise that they would deliver up the town. Then, when they had passed inside the wall, leaving their fleet empty, Artemisia suddenly made a canal which led to the sea, brought her fleet thus out of the smaller harbour, and so sailed into the larger. Disembarking her soldiers, she towed the empty fleet of the Rhodians out to sea. So the Rhodians were surrounded without means of retreat, and were slain in the very forum.

15. So Artemisia embarked her own soldiers and oarsmen in the ships of the Rhodians and set forth for Rhodes. The Rhodians, beholding their own ships approaching wreathed with laurel, supposed that their fellow-citizens were returning victorious, and admitted the enemy. Then Artemisia, after taking Rhodes and killing its leading men, put up in the city of Rhodes a trophy of her victory, including two bronze statues, one representing the state of the Rhodians, the other herself. Herself she fashioned in the act of branding the state of the Rhodians. In later times the Rhodians, labouring under the religious scruple which makes it a sin to remove trophies once they are dedicated, constructed a building to surround the place, and thus by the erection of the "Grecian Station" covered it so that nobody could see it, and ordered that the building be called "*ἄβατον*."

16. Since such very powerful kings have not disdained walls built of brick, although with their revenues and from booty they might often have had them not only of masonry or dimension stone but even of marble, I think that one ought not to reject buildings made of brick-work, provided that they are properly "topped." But I shall explain why this kind of structure should not be used by the Roman people within the city, not omitting the reasons and the grounds for them.

17. The laws of the state forbid that walls abutting on public property should be more than a foot and a half thick. The other walls are built of the same thickness in order to save space. Now brick walls, unless two or three bricks thick, cannot support more than one story; certainly not if they are only a foot and a half in thickness. But with the present importance of the city and the unlimited numbers of its population, it is necessary to increase the number of dwelling-places indefinitely. Consequently, as the ground floors could not admit of so great a number living in the city, the nature of the case has made it necessary to find relief by making the buildings high. In these tall piles reared with piers of stone, walls of burnt brick, and partitions of rubble work, and provided with floor after floor, the upper stories can be par-

titioned off into rooms to very great advantage. The accommodations within the city walls being thus multiplied as a result of the many floors high in the air, the Roman people easily find excellent places in which to live.

18. It has now been explained how limitations of building space necessarily forbid the employment of brick walls within the city. When it becomes necessary to use them outside the city, they should be constructed as follows in order to be perfect and durable. On the top of the wall lay a structure of burnt brick, about a foot and a half in height, under the tiles and projecting like a coping. Thus the defects usual in these walls can be avoided. For when the tiles on the roof are broken or thrown down by the wind so that rain-water can leak through, this burnt brick coating will prevent the crude brick from being damaged, and the cornice-like projection will throw off the drops beyond the vertical face, and thus the walls, though of crude brick structure, will be preserved intact.

19. With regard to burnt brick, nobody can tell offhand whether it is of the best or unfit to use in a wall, because its strength can be tested only after it has been used on a roof and exposed to bad weather and time — then, if it is good it is accepted. If not made of good clay or if not baked sufficiently, it shows itself defective there when exposed to frosts and rime. Brick that will not stand exposure on roofs can never be strong enough to carry its load in a wall. Hence the strongest burnt brick walls are those which are constructed out of old roofing tiles.

20. As for "wattle and daub" I could wish that it had never been invented. The more it saves in time and gains in space, the greater and the more general is the disaster that it may cause; for it is made to catch fire, like torches. It seems better, therefore, to spend on walls of burnt brick, and be at expense, than to save with "wattle and daub," and be in danger. And, in the stucco covering, too, it makes cracks from the inside by the arrangement of its studs and girts. For these swell with moisture as they are daubed, and then contract as they dry, and, by their shrinking, cause the

solid stucco to split. But since some are obliged to use it either to save time or money, or for partitions on an unsupported span, the proper method of construction is as follows. Give it a high foundation so that it may nowhere come in contact with the broken stone-work composing the floor; for if it is sunk in this, it rots in course of time, then settles and sags forward, and so breaks through the surface of the stucco covering.

I have now explained to the best of my ability the subject of walls, and the preparation of the different kinds of material employed, with their advantages and disadvantages. Next, following the guidance of Nature, I shall treat of the frame-work and the kinds of wood used in it, showing how they may be procured of a sort that will not give way as time goes on.

CHAPTER IX

TIMBER

1. Timber should be felled between early Autumn and the time when Favonius begins to blow. For in Spring all trees become pregnant, and they are all employing their natural vigour in the production of leaves and of the fruits that return every year. The requirements of that season render them empty and swollen, and so they are weak and feeble because of their looseness of texture. This is also the case with women who have conceived. Their bodies are not considered perfectly healthy until the child is born; hence, pregnant slaves, when offered for sale, are not warranted sound, because the fetus as it grows within the body takes to itself as nourishment all the best qualities of the mother's food, and so the stronger it becomes as the full time for birth approaches, the less compact it allows that body to be from which it is produced. After the birth of the child, what was heretofore taken to promote the growth of another creature is now set free by the delivery of the newborn, and the channels being now empty and open, the body will take it in by lapping up its juices, and thus

becomes compact and returns to the natural strength which it had before.

2. On the same principle, with the ripening of the fruits in Autumn the leaves begin to wither and the trees, taking up their sap from the earth through the roots, recover themselves and are restored to their former solid texture. But the strong air of winter compresses and solidifies them during the time above mentioned. Consequently, if the timber is felled on the principle and at the time above mentioned, it will be felled at the proper season.

3. In felling a tree we should cut into the trunk of it to the very heart, and then leave it standing so that the sap may drain out drop by drop throughout the whole of it. In this way the useless liquid which is within will run out through the sapwood instead of having to die in a mass of decay, thus spoiling the quality of the timber. Then and not till then, the tree being drained dry and the sap no longer dripping, let it be felled and it will be in the highest state of usefulness.

4. That this is so may be seen in the case of fruit trees. When these are tapped at the base and pruned, each at the proper time, they pour out from the heart through the tapholes all the superfluous and corrupting fluid which they contain, and thus the draining process makes them durable. But when the juices of trees have no means of escape, they clot and rot in them, making the trees hollow and good for nothing. Therefore, if the draining process does not exhaust them while they are still alive, there is no doubt that, if the same principle is followed in felling them for timber, they will last a long time and be very useful in buildings.

5. Trees vary and are unlike one another in their qualities. Thus it is with the oak, elm, poplar, cypress, fir, and the others which are most suitable to use in buildings. The oak, for instance, has not the efficacy of the fir, nor the cypress that of the elm. Nor in the case of other trees, is it natural that they should be alike; but the individual kinds are effective in building, some in one way, some in another, owing to the different properties of their elements.

6. To begin with fir: it contains a great deal of air and fire with very little moisture and the earthy, so that, as its natural properties are of the lighter class, it is not heavy. Hence, its consistence being naturally stiff, it does not easily bend under the load, and keeps its straightness when used in the framework. But it contains so much heat that it generates and encourages decay, which spoils it; and it also kindles fire quickly because of the air in its body, which is so open that it takes in fire and so gives out a great flame.

7. The part which is nearest to the earth before the tree is cut down takes up moisture through the roots from the immediate neighbourhood and hence is without knots and is "clear." But the upper part, on account of the great heat in it, throws up branches into the air through the knots; and this, when it is cut off about twenty feet from the ground and then hewn, is called "knotwood" because of its hardness and knottiness. The lowest part, after the tree is cut down and the sapwood of the same thrown away, is split up into four pieces and prepared for joiner's work, and so is called "clearstock."

8. Oak, on the other hand, having enough and to spare of the earthy among its elements, and containing but little moisture, air, and fire, lasts for an unlimited period when buried in underground structures. It follows that when exposed to moisture, as its texture is not loose and porous, it cannot take in liquid on account of its compactness, but, withdrawing from the moisture, it resists it and warps, thus making cracks in the structures in which it is used.

9. The winter oak, being composed of a moderate amount of all the elements, is very useful in buildings, but when in a moist place, it takes in water to its centre through its pores, its air and fire being expelled by the influence of the moisture, and so it rots. The Turkey oak and the beech, both containing a mixture of moisture, fire, and the earthy, with a great deal of air, through this loose texture take in moisture to their centre and soon decay. White and black poplar, as well as willow, linden, and the agnus

castus, containing an abundance of fire and air, a moderate amount of moisture, and only a small amount of the earthy, are composed of a mixture which is proportionately rather light, and so they are of great service from their stiffness. Although on account of the mixture of the earthy in them they are not hard, yet their loose texture makes them gleaming white, and they are a convenient material to use in carving.

10. The alder, which is produced close by river banks, and which seems to be altogether useless as building material, has really excellent qualities. It is composed of a very large proportion of air and fire, not much of the earthy, and only a little moisture. Hence, in swampy places, alder piles driven close together beneath the foundations of buildings take in the water which their own consistence lacks and remain imperishable forever, supporting structures of enormous weight and keeping them from decay. Thus a material which cannot last even a little while above ground, endures for a long time when covered with moisture.

11. One can see this at its best in Ravenna; for there all the buildings, both public and private, have piles of this sort beneath their foundations. The elm and the ash contain a very great amount of moisture, a minimum of air and fire, and a moderate mixture of the earthy in their composition. When put in shape for use in buildings they are tough and, having no stiffness on account of the weight of moisture in them, soon bend. But when they become dry with age, or are allowed to lose their sap and die standing in the open, they get harder, and from their toughness supply a strong material for dowels to be used in joints and other articulations.

12. The hornbeam, which has a very small amount of fire and of the earthy in its composition, but a very great proportion of air and moisture, is not a wood that breaks easily, and is very convenient to handle. Hence, the Greeks call it "zygia," because they make of it yokes for their draught-animals, and their word for yoke is ζυγά. Cypress and pine are also just as admirable; for although they contain an abundance of moisture mixed with

an equivalent composed of all the other elements, and so are apt to warp when used in buildings on account of this superfluity of moisture, yet they can be kept to a great age without rotting, because the liquid contained within their substances has a bitter taste which by its pungency prevents the entrance of decay or of those little creatures which are destructive. Hence, buildings made of these kinds of wood last for an unending period of time.

13. The cedar and the juniper tree have the same uses and good qualities, but, while the cypress and pine yield resin, from the cedar is produced an oil called cedar-oil. Books as well as other things smeared with this are not hurt by worms or decay. The foliage of this tree is like that of the cypress but the grain of the wood is straight. The statue of Diana in the temple at Ephesus is made of it, and so are the coffered ceilings both there and in all other famous fanes, because that wood is everlasting. The tree grows chiefly in Crete, Africa, and in some districts of Syria.

14. The larch, known only to the people of the towns on the banks of the river Po and the shores of the Adriatic, is not only preserved from decay and the worm by the great bitterness of its sap, but also it cannot be kindled with fire nor ignite of itself, unless like stone in a limekiln it is burned with other wood. And even then it does not take fire nor produce burning coals, but after a long time it slowly consumes away. This is because there is a very small proportion of the elements of fire and air in its composition, which is a dense and solid mass of moisture and the earthy, so that it has no open pores through which fire can find its way; but it repels the force of fire and does not let itself be harmed by it quickly. Further, its weight will not let it float in water, so that when transported it is loaded on shipboard or on rafts made of fir.

15. It is worth while to know how this wood was discovered. The divine Caesar, being with his army in the neighbourhood of the Alps, and having ordered the towns to furnish supplies, the inhabitants of a fortified stronghold there, called Larignum, trusting in the natural strength of their defences, refused to obey his command. So the general ordered his forces to the assault.

In front of the gate of this stronghold there was a tower, made of beams of this wood laid in alternating directions at right angles to each other, like a funeral pyre, and built high, so that they could drive off an attacking party by throwing stakes and stones from the top. When it was observed that they had no other missiles than stakes, and that these could not be hurled very far from the wall on account of the weight, orders were given to approach and to throw bundles of brushwood and lighted torches at this outwork. These the soldiers soon got together.

16. The flames soon kindled the brushwood which lay about that wooden structure and, rising towards heaven, made everybody think that the whole pile had fallen. But when the fire had burned itself out and subsided, and the tower appeared to view entirely uninjured, Caesar in amazement gave orders that they should be surrounded with a palisade, built beyond the range of missiles. So the townspeople were frightened into surrendering, and were then asked where that wood came from which was not harmed by fire. They pointed to trees of the kind under discussion, of which there are very great numbers in that vicinity. And so, as that stronghold was called Larignum, the wood was called larch. It is transported by way of the Po to Ravenna, and is to be had in Fano, Pesaro, Ancona, and the other towns in that neighbourhood. If there were only a ready method of carrying this material to Rome, it would be of the greatest use in buildings; if not for general purposes, yet at least if the boards used in the eaves running round blocks of houses were made of it, the buildings would be free from the danger of fire spreading across to them, because such boards can neither take fire from flames or from burning coals, nor ignite spontaneously.

17. The leaves of these trees are like those of the pine; timber from them comes in long lengths, is as easily wrought in joiner's work as is the clearwood of fir, and contains a liquid resin, of the colour of Attic honey, which is good for consumptives.

With regard to the different kinds of timber, I have now explained of what natural properties they appear to be composed, and how they were produced. It remains to consider the question why the highland fir, as it is called in Rome, is inferior, while the lowland fir is extremely useful in buildings so far as durability is concerned; and further to explain how it is that their bad or good qualities seem to be due to the peculiarities of their neighbourhood, so that this subject may be clearer to those who examine it.

CHAPTER X

HIGHLAND AND LOWLAND FIR

1. The first spurs of the Apennines arise from the Tuscan sea between the Alps and the most distant borders of Tuscany. The mountain range itself bends round and, almost touching the shores of the Adriatic in the middle of the curve, completes its circuit by extending to the strait on the other shore. Hence, this side of the curve, sloping towards the districts of Tuscany and Campania, lies basking in the sun, being constantly exposed to the full force of its rays all day. But the further side, sloping towards the Upper Sea and having a northern exposure, is constantly shrouded in shadowy darkness. Hence the trees which grow on that side, being nourished by the moisture, not only themselves attain to a very large size, but their fibre too, filled full of moisture, is swollen and distended with abundance of liquid. When they lose their vitality after being felled and hewn, the fibre retains its stiffness, and the trees as they dry become hollow and frail on account of their porosity, and hence cannot last when used in buildings.

2. But trees which grow in places facing the course of the sun are not of porous fibre but are solid, being drained by the dryness; for the sun absorbs moisture and draws it out of trees as well as out of the earth. The trees in sunny neighbourhoods, therefore, being solidified by the compact texture of their fibre, and not being porous from moisture, are very useful, so far as durability goes, when they are hewn into timber. Hence the lowland firs,

being conveyed from sunny places, are better than those highland firs, which are brought here from shady places.

3. To the best of my mature consideration, I have now treated the materials which are necessary in the construction of buildings, the proportionate amount of the elements which are seen to be contained in their natural composition, and the points of excellence and defects of each kind, so that they may be not unknown to those who are engaged in building. Thus those who can follow the directions contained in this treatise will be better informed in advance, and able to select, among the different kinds, those which will be of use in their works. Therefore, since the preliminaries have been explained, the buildings themselves will be treated in the remaining books; and first, as due order requires, I shall in the next book write of the temples of the immortal gods and their symmetrical proportions.