

der than those that man has used his strength and skill to force together and fuse. And the blocks on either side must be equal, so that the right balances the left in appearance, size, weight, and so on. With a series of arches springing from columns, as with the openings of a portico, the wedge from which two or more arches may spring together should not be divided into twin blocks, or whatever the number of the arches, but it should consist of one and the same block, quite undivided, so that it contains the base of the arches on all sides. If the second pair of wedges, set on top of the first wedge, are extremely large blocks of stone, make sure that they are linked, their backs meeting along a straight line. The third layer, set over the second pair, should be laid level, following the principles of good walling, with even joints on either side, so that it serves both arches to which it is joined and holds in their wedges. Make sure that throughout the arch the lines of contact and the joints point toward the center of the arch. Those with experience would always use a single, integral, large block of stone for the keystone; but if the wall is so thick that it is impossible to use a whole wedge of this kind, then it is no longer an arch; rather it is becoming a vault, which we shall call the barrel vault. ♦

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There are several different types of vaulting. We must inquire in what way they differ, and of what lines they are composed. To make myself as clear and straightforward as possible, which I have endeavored to be throughout this book, it will be necessary for me to invent new names. It has not escaped my notice that the poet Ennius refers to “the vast vault of the heavens,”⁵¹ and that Servius calls every vault made in the manner of a ship’s keel “a cavern.”⁵² But I ask this one favor, that in this book at any rate we consider acceptable Latin anything that is both accurate and easy to understand.

These are the various types of vaulting: the barrel, the camerated, and the perfectly spherical,⁵³ as well as any others consisting of a certain part of these three.⁵⁴ Of these the spherical by its very nature can be set only on walls that arise from a circular plan; the camerated requires a square plan, whereas the barrel covers any rectangular *area*, short or long, as may be seen in crypto-porticoes. Any vault constructed like a hole bored through a mountain shall be called a tunnel vault or barrel vault, because of the similarity of its name.⁵⁵ The barrel vault, then, is like a series of arches added one to the other, or like a curved beam stretched laterally, and hence it may be compared to a wall bent over our heads for protection. However, if a vault such as this, running from north to south, were completely transversed by another vault, running from east to west, it would create a vault resembling curved horns running out into the corners, which is therefore called “camerated.”⁵⁶ But if the apexes of many identical arches were to

meet at a point in the center, a vault would be created that is like the heavens; this then we prefer to call the perfectly spherical.

The vaults formed out of those parts mentioned are these: If nature had divided the hemisphere of the heavens into two parts by a straight vertical section running from east to west, she would produce two vaults fitting a semicircular niche. However, if nature had bounded the hemisphere of the heavens with lines running from the eastern corner to the southern one, from the southern to the western, from that to the northern, then from the northern to the original eastern corner by the same method, and then cropped them away, the vault left in the middle would resemble a billowing sail, and we would therefore call it a sail vault. Any vault that consists of several sections of barrel vaulting meeting together, such as may be seen spanning hexagonal or octagonal *areae*, we shall call an angular spherical vault.

The same method of construction should be followed for the vaults as is used for the walls. In fact, the bones⁵⁷ within the wall continue unbroken right up to the top of the vault; they are constructed in the same way and are set a correspondingly similar distance apart. The ligaments stretch from bone to bone, and the section between is filled in with paneling. But there is this one difference: in a wall the individual stones and courses are set and laid together in straight lines along the horizontal and vertical, but in a vault the courses are laid along a curved line, with the joints of all the stones pointing toward the centers of their respective arches. For the bones the ancients would almost always use baked bricks, generally two feet in length. It is advisable to complete the infill paneling with an extremely light stone, to prevent any eccentric loading putting a strain on the wall. I notice, however, that the bones were not made continuously solid by some architects; instead they would be interspersed here and there with bricks standing on edge, their ends fitting into one another like the teeth of a comb, as though someone were interlocking the fingertips of his right hand with those of his left. The middle they would fill in with aggregate, often of pumice, commonly regarded as the most suitable infill material for vaults.

For the construction of arches and vaults it is necessary to make use of centering. This is a form of temporary, rough wooden framework shaped like a curved line, with wickerwork, reeds, or any other cheap material laid down as a covering or skin; its function is to support the vaulting during construction, until it has hardened. The perfect sphere, however, is the one vault that does not require centering, being composed not only of arches but also of rings.⁵⁸ It is impossible to describe or even conceive in the mind the countless lines of mutual support, intersecting at equal and unequal angles, that these two provide. Consequently, wherever you insert a block within a vault of this kind, you realize that you are positioning a wedge for several arches and rings. And as you lay ring over ring, and arch beside

arch, can you imagine the work ever being liable to give way, and if so, from which point, especially when all the wedges are inclined toward the center with equal force and pressure? Many of the architects of antiquity exploited the inherent strength of this structure, and would lay only a simple earthenware cornice every few feet, then fill in the remainder of the vault somewhat hastily, by just pouring in a cement mix. I would much rather that care be taken during the construction of the vault to ensure that the rings are not too infrequent and that they are connected one above the other, and so too the arches, side by side, with the same technique that is used to bond stones together in the wall, especially if quarry sand is in short supply and the work is exposed to sea breezes or Auster.⁵⁹

The angular spherical vault may also be raised without centering, provided a perfectly spherical vault is inserted within its thickness, although it is particularly important that you use fixings to bind the weaker parts of the main vault to the stronger parts of the inner one tightly. It will be useful nonetheless, once one or two stone rings have been laid and have set firm, to fix below them some light thongs and eyes to which to attach sufficient centering to support a few feet of rings above, until they have dried. Then, once these also have hardened, the centering should be moved up a certain number of rows to construct the section above, until the work is complete.⁶⁰

Cross vaults and likewise barrel vaults both require the support of centering. But I would prefer the first few courses and the feet of the arches to have a solid base. I do not approve of the practice whereby the entire wall is raised, leaving consoles as the only eventual support for the vault: it is far too weak and unreliable. If you want my advice, you should construct the arch and the wall to which it is fastened together, row by row, so that the work is tied by several connections of the strongest possible kind. The space left between the curving vault and the wall to which it is attached, which the workmen know as the hip, should be filled not with earth and dry stone fragments, but with ordinary solid stonework to keep it continually bonded with the wall. Also, I am impressed by the attempt to reduce weight by placing in the hips empty earthenware water vessels, which are cracked and turned upside down to prevent them from collecting water and gaining weight; over these is then poured a light but nonetheless strong stone aggregate.

In short, with every type of vault, we should imitate Nature throughout, that is, bind together the bones and interweave flesh with nerves running along every possible section: in length, breadth, and depth, and also obliquely across. When laying the stones to the vault, we should, in my opinion, copy the ingenuity of Nature.

Having completed the vault it remains to cover it, one of the most important elements in the whole building process, and one that is as vital as it is