or 40 feet; and walls of such lengths and heights could hardly be deemed safe if not more than one brick thick. Consequently, a greater thickness has been prescribed as the least thickness of the walls of buildings of the sizes indicated. In the older Metropolitan Building Acts much greater thicknesses were prescribed for the walls likely to be the longer walls; whilst the only necessity for more than one brick rises from structural requisites, and not from any insufficiency of a wall of solid brickwork one brick thick as a means of preventing the spread of fire.

But the requisites of the structure would be as well fulfilled by one-brick walls upon the long sides as by 1½ brick walls, if the ordinary internal cross partition for dividing a house into front and back rooms were built of brickwork abutting upon, and at right angles to, the longer walls, and carried up coursed and bonded with them. That is to say, party-walls of one brick or 9 inches in thickness, connected at their ends by 1½-brick or 13-inch front and back walls, and at or about the middle of their length by other 9-inch cross walls, would be at the least as strong as 1½-brick party-walls, though connected in the same manner at the two ends, but without the abutting and connecting cross wall of brickwork. Instead, however, of such internal cross walls, hollow partitions of timber are commonly used in all stories above the basement story; and it is by these partitions, and by the light and highly inflammable wooden stairs, that fire extends itself rapidly throughout ordinary dwelling-houses; whilst the substitution of a brick wall for the cross timber partition would in most cases justify the abatement of a half brick of the thickness otherwise necessary to party-walls, and give an indestructible internal support to the floors, whereby also one of the means by which fire travels rapidly through a house would be removed. It is true that there must be openings as doorways, and fittings in them for doors, in such internal partition wall; but the wall could not carry fire up from floor to floor through its own heart, as the hollow wood-lathed quartering partition carries it. Doors and shutters, and door window linings, in and against brick or stone walls, may take fire and burn in any story of an ordinarily built dwelling-house, without carrying it beyond the story in which the fire occurs; for a plastered ceiling of the most common description will resist the action of flame upon its surface for a long time, and plastering of really good quality, though upon wood laths, will keep fire off from the joists by which it is held up, almost without danger, so long as the fire acts upon the face only of the plastering. If, however, fire reach the joists through the agency of hollow quartering partitions, the enemy has turned the flank of the plastering, and the floors and skirtings above and behind it taking fire, the building almost inevitably falls a prey to the flames. Any step, indeed, from the hollow quartering partition towards a solid wall is a step towards security. A brick wall is, perhaps, the best internal partition for all the purposes of strength and security from fire; and in small houses, which will not afford the expense of 9-inch walls, half-brick walls with 9-inch jambs at the doors, and short 9-inch piers on alternate sides of the partition, at intervals of 3 or 4 feet in length, will give sufficient strength; but even quartering partitions, if based upon brick walls, may be rendered nearly proof against fire by brick-nogging them, especially if care be taken to fill in with brickwork between the joists over the head of one partition and under the sill of another, as well as between the timbers of the partitions. Filling in between the joists, and up as high as the skirtings go, will do something, indeed, towards diminishing the dangerous tendency of even lathed and plastered timber partitions; whilst the adoption of the plan now commonly practised in Paris, in forming not only internal partitions, but the rearward external enclosures of buildings, would secure to the structure the structural efficiency of timber on end in carrying weight, and give the solid and incombustible character of a brick or stone wall to a partition or enclosure which is structurally of timber. The plan referred to is, to frame and brace with timber quarterings much in the manner practised in England, except that the timber used in Paris is commonly oak, and is generally seasoned previously. The framed structure being complete, strong oak batten-laths, from 2 to 3 inches wide, are nailed up to the quarterings horizontally, at 4, 6, or even 8 inches apart, according to the character of the work, throughout the whole height of the enclosure or partition; and the spaces between the quarterings, and behind the laths, are loosely built up with rough stone rubble, which the laths prevent from falling out until the next process has been effected. This is, to apply a strong mortar, which in Paris is mainly composed of plaster of Paris, which is there of excellent quality, laid on from both sides at the same time, and pressed through from the opposite sides so that the mortar meets and incorporates, embedding the stone rubble by filling up every interstice, and with so much body on the surfaces as to cover up and embed also the timber and the laths—in such a manner, indeed, as to render the concretion of stone and plaster, when thoroughly set, an independent body, and giving strength to rather than receiving support from the timber.

Partitions as formed in England.

The English brick-nogged partition is, in point of structure, nothing without the aid of timber. The plastering is merely spread upon the surfaces of brick and wood, and is fragile in the extreme, and always liable to crack and drop off. This lathed and plastered partition is composed of the hollow framework of the timber quarters, with two slight thicknesses of mortar; as plastering, hung upon slighter laths, over and between which the flaccid mortar forms a key for itself; but all necessarily depends upon the timber, and fails with it wherever decay or fire may destroy it.

Stairs.

Only second in importance to the internal partition as a source of danger, or as a means of safety, are the stairs; and the stairs are second in importance only when the partitions are made to carry the floors of the several stories. In England, and in London particularly, even when the steps and intermediate landings are of stone, it is but too common to find the passage from the street door to the foot of the stairs, and the floors which connect flight with flight at the several landings, either wholly of wood or of slight stone paving laid upon wooden joists or bearers. Any stone paving upon wooden joists will certainly retard the action of fire upon the joists, especially if assisted by a well-plastered ceiling; but in this, again, if the floors be not formed of wholly incombustible materials, the French practice as to floors would be better than ours.

In Paris stone stairs are far less common in modern houses than they are in London in houses of corresponding character and date; but wooden staircases in Paris are rendered almost as safe as common stone staircases are in England, by a process similar in character to that applied to partitions and enclosures. The result is an almost incombustible structure. Wooden staircases formed between brick or stone walls, or between partitions of the kind above described as commonly made in modern buildings in Paris (that is, filled with a solid mass of concreted rubble), may perhaps be set on fire, but they can hardly burn.

It has been remarked that a mere plastered ceiling will resist the action of fire for a long time, although the plastering be upon wooden laths, and the laths nailed to joists of timber; and as fire does not readily act downwards, flooring boards may take fire from above without any immediately serious consequence to the joists under them,

so long as there is no access of air from below. But the English indoor plastering upon laths is commonly of the most fragile kind, and the slightest weight falling upon the back of a ceiling will make a breach through it, whilst the floors are commonly of deal laid upon fir joists, and are exposed to the action of fire from below directly the lathed and plastered ceiling has failed; if, indeed, the fire have not found its way to the joists under the flooring boards by the hollow lathed and plastered quartering partitions. In the timber enclosures and partitions, which economy induces the Paris builder to introduce as substitutes for walls, the timber is so embedded in and made part of a solid concrete, as to be protected from almost every casualty of which it is susceptible. But the French render their floors also so nearly incombustible as to leave but little to desire in that respect, and in a manner attainable with single joists, as well, at the least, as with joists framed into girders. According to their practice, the ceiling *must* be formed before the upper surface or floor is laid, as the ceiling is formed from above instead of from below. The carpenters' work being complete, strong batten-laths are nailed up to the under sides of the joists, as laths are in England; but they are much thicker and wider than our laths, and are placed so far apart that not more, perhaps, than one-half of the space is occupied by the laths. The laths being affixed—and they must be soundly nailed, as they have a heavy weight to carry—a platform, made of rough boards, is strutted up from below parallel to the plane formed by the laths, and at about an inch below them. Mortar is then laid in from above over the platform and between and over the laths, to a thickness of from 2½ inches to 3 inches, and is forced in under the laths, and under the joists and girders. The mortar, being gauged, as plasterers term it, or rather, in great part composed of plaster of Paris, soon sets sufficiently to allow the platform to be removed onwards to another compartment, until the whole ceiling is formed. The plaster ceiling thus produced is, in fact, a strong slab or table, in the body of which the batten-laths which hold it up are incorporated, and in the back of which the joists, from which the mass is suspended, are embedded. The finishing coat of plastering is then laid on. Such a ceiling will resist any fire that can act upon it from below, under ordinary circumstances; and it would be difficult for fire to take such a hold from above as to destroy the joists to which a ceiling so composed is attached, the laths and the under side of the joists being alike out of its reach; and consequently such a ceiling alone would diminish the danger from fire, although the floor above the joists were laid with deal boards.

Flooring materials.

A boarded floor, however, in Paris is a luxury not to be found in the dwellings of the labouring classes, nor, indeed, are boarded floors to be found in any dwelling-houses but those of the more costly description. Whether the proposed surface is to be boarded or not, however, the flooring joists are covered by a table of plaster above, as completely as they are covered by a plaster ceiling below. Rough battens, generally split and in short lengths stout enough to bear the weight of a man without bending, are laid with ends abutting upon every joist, and as close together as they will lie without having been shot or planed on their edges. Upon this rough loose floor, mortar of nearly similar consistence to that used for the ceilings is spread to a thickness of about three inches; and as it is made to fill in the voids at the ends and sides of the floor-laths upon the joists, the laths become bedded upon the joists, whilst they are to some extent also incorporated with the plaster. The result is a firm floor, upon which, in ordinary buildings, paving-tiles are laid, bedded in a tenacious cement. It must be clear that the timbers of a floor so encased could hardly be made to burn even if fire were let in between the floor and ceiling. But it has been already stated that the practice of making these incombustible floors is connected with the use of walls which have no timber laid in them bedwise, and that the timber enclosures employed instead of walls, and the internal partitions, are rendered practically incombustible, whilst the wooden staircase which economy dictates to the Parisian builders—the freestone which is used in building walls being altogether too soft for the purpose—is also rendered, in the manner already shown, almost unassailable by fire.

It may be remarked with reference to the employment of any substance such as cinder, being of the nature of pozzuolana, or volcanic scoria, in mortar, to form a floor in the manner above described (about 3 inches thick), that as all such mortars expand in setting, the walls of buildings may be forced out by the expansion of the plaster floors, if the whole surface of the floor in any story be at once covered with the mortar. A margin of 4 or 5 inches on every side should be left void until the expansion has taken place, when the floor may be completed with an assurance of close joints, and without injury to reasonably stable walls.

When a boarded floor is required, as the surfaces of the true joists lie under the mortar, a base for the boards is formed of what English carpenters would call stout fillets of wood, about 2½ inches square, ranged as joists, and strutted apart to keep them in their places, over the mortar table, to which they are sometimes scribed down, and that to these fillets, or false joists, the flooring boards are secured by nails; so that in truth the boarded floor is not at all connected with the structure of the floor, but is formed upon its upper coat of plaster. The wooden floor thus becomes a mere fitting in an apartment, and not extending beyond the room the floor might burn without communicating fire to the stairs, even if the stairs were readily ignitible.

Floors with iron joists.

The practice now in Paris, in respect of floors, is to form the structure of wrought iron joists rolled to the form known with us as I, T, and ⌶ iron, and to fill in with the same strong plaster between, below, and above the iron, and so to form a slab of plaster from 6 to 8 inches thick, according to the bearing and the depth of the iron bars—the bars being enveloped in the plaster; and the ceiling is formed as before described by laths resting on the lower flanges. In order to lighten the weight of the solid plaster, earthen pots have been placed between the joists, and the spaces filled up with the mortar.

Upper partitions.

The necessity which arises with us of dividing the upper stories of houses into more rooms, as bed-rooms, than are commonly required in the lower stories, will be made an objection to any process that would render the partitions heavier; but it is not in the upper stories that the lathed and plastered partition is most dangerous in respect of fire. Generally the stairs may be enclosed by solid partitions throughout almost the whole height of an ordinary dwelling-house without occasioning any inconvenience as regards the greater weight of such a partition; and generally, too, the partition which divides the front from the back rooms of such houses may be carried up throughout the whole height of a house without removing the bearing, if the house be judiciously disposed. But even if a partition rest upon a beam or girder, a very slight addition to the scantling of the timber will make up for the additional weight which the filling in of the partition would involve, if the materials of the core be well chosen; and it is well known that a piece of timber placed over a void as a bressummer, and carrying a wall, resists the action of fire for a long time, and the longer if it be of oak or other hard wood. It is not necessary, however, that the timber employed in parti-

tions and enclosures should be of oak; though it is desirable that main bearing timbers, in situations which render them most liable to be exposed to the action of fire in the event of casualty, should be of such timber rather than of fir; but the quarterings, or partition timbers, which the plaster concrete wholly encases, may be of fir as safely almost as of oak.

The core used in Paris consists for the most part of chips and spalls arising in the process of dressing the soft free-stone which is the main constituent of the walls of most buildings in that city. Almost any hard material, however, will furnish rubble fit for the purpose, which must be angular and irregular in form, so as to allow the mortar to pass freely through the rubble, and embed it all. Rubble of brick material, as broken burrs, or even of old bricks freshly broken, will answer very well; but if brickbats or shreds of plain tiles be used, care must be taken in packing not to bring flat beds together, or the mortar will not pass through and make a perfect concrete. Rubble of almost any kind may be used; but the kinds of stone which are themselves concretions, and present rough surfaces upon the fracture, are the best, while schistose or scaling slaty stones are the worst for the purpose. But there is no better substance for coring partitions upon the plan described than clay burnt into a kind of brick rubble.

Use of timber.

The same process applied to external enclosures will justify the use of timber in their structure in situations and under circumstances in which it may be properly prohibited when the timber is merely lathed and plastered, or even brick-nogged, for brick-nogging adds nothing, as already remarked, to the strength of a partition or an enclosure, but rather takes from it, being itself a source of infirmity. But chimneys and their flues, with their congeners, stoves and furnaces, ought not, under any circumstances, to be formed in an enclosure in which timber is employed as a part of the structure.

Under some circumstances, again,—that is to say, when any street of a town is so wide and the buildings to be built fronting it are to be of such small elevation, as to make the communication of fire from one side to the opposite side practically impossible, if the buildings adjoining laterally are effectually separated from one another by sufficient walls, party or otherwise, and these project before the outside faces of the front and back enclosures so as effectually to prevent fire from passing round them,—the temperature of dwelling-houses may be much more easily maintained and regulated if the outside surface be boarded. Weather-boarding is a safe and economical, as well as a neat, wholesome, and equable outside casing for the fronts of a dwelling-house, if the boarding be backed up solidly, and the timber quarterings necessary to secure it be properly filled in between and behind with brick or stone work, or with rubble and concrete in the manner already described. Brickwork builds up badly with the raking braces of timber-framed enclosures, and the concrete described would not be so perfect with weather-boarding on one side as if the mortar were thrown in from both sides; but raking braces are less essential to enclosures which are filled in and backed with a heavy body of brick-work or concrete, than when mere lathing or even brick-nogging is to be employed on the inside. A 9-inch brick wall may, indeed, be very well built up with framed quarterings without raking braces, if the work be built between and around the quarterings, carrying, that is to say, the inner half-brick before the inside faces of the quartering, and so as to show on the inside a plain brick wall.

Building Trades.—The artificers whose trades properly belong to the builder's business are the digger or excavator, bricklayer, mason, sawyer, carpenter, joiner, cabinetmaker, slater, plumber, plasterer, modeller. carver, glazier, smith, founder, ironmonger, gasfitter, painter, and decorator. In this order the works of the trades will be described, and we now proceed to the ordinary routine of the practice of building. The two publications which should be noticed here as comprising more detailed references to these trades are Gwilt's *Encyclopædia of Architecture*, 8vo, 1869, edited by Wyatt Papworth; and Cresy's *Encyclopædia of Civil Engineering*, 8vo, 1861,—these will not, therefore, be noticed in the list at the end of each trade.

Foundation.—The architect having furnished the specification and working-drawings of his design, the first step is to prepare the foundation; and as this relates to the bricklayer as well as to the mason, we say what is necessary respecting it here. Much in this particular, it is evident, must depend on localities. It is not of so much importance that the ground be hard, or even rocky, as that it be compact, and of similar consistence throughout; that it be so constituted as to resist entirely and throughout, or yield equally to the superincumbent weight. But in the ordinary processes of building little requires to be said of the artificial preparation of foundations beyond the notice of it already given. When a good, hard soil is easily accessible, as solid gravel, chalk, or rock, we have nothing to do but to remove the surface mould, dig to the sound bottom, and at once to put in the footings. On softer ground it was usual to employ footings at least double the width of the wall, and frequently more; but since the invention, or rather revival, of the use of concrete, this is seldom or never done. In this case, or when the ground is a deep clay, be the material used what it may, it should at least go so deep as not to be affected by change of temperature, or the rising and falling of springs, as the alternate shrinking and swelling of the ground must affect the building. Frost seldom penetrates a foot into the ground in this country; but in clay soils, fissures, the consequences of drought, are found 3 feet and more in depth. The basis should, therefore, be below this point in such a stratum. If the ground be springy, it should be drained, if possible; if not, a foundation should be made with concrete as low as the lowest level of the water; or if very deep or boggy, piles must be used. The plan of building on sleepers and planking, so common some years ago, is very bad, as they rot after a time, and the building settles in all directions, as the greater weights crush the decayed timbers sooner than do the lighter portions of the building. Where ground is alternately wet and dry, the best timber soon decays; even piles should always be kept in the water. The use of concrete, except in very peculiar cases, has entirely superseded every other artificial foundation. It may be defined as a sort of rough masonry, composed of broken pieces of stone or gravel, cemented together with lime prepared in various ways, and thoroughly mixed with it, and not laid by hand but thrown at random into the trenches, to form the depth required.

Planking.

Concrete.

Any hard substance, broken into small pieces, will make good concrete. That most used is gravel, or ballast. This should not be too fine, as the sand which may be in it will mix with the lime and form a sort of mortar, assisting to cement the stones together. If broken stones or masons' chips are used, it is desirable to add some sharp sand with them. The general rule is, that no piece of stone should exceed a hen's egg in size. In this country the lime is generally ground, which is bad, as the core or unburnt portion is ground up with the good lime. About one-sixth part of lime is generally used; chalk lime should not be used in a damp situation. It is mixed with the ballast by scattering it among the stones, and turning it all over with a shovel, water being at the same time thrown upon the mass. It is then, while hot, filled into the trenches, sometimes by shooting from stages

erected for the purpose 6 or 8 feet above the work; but this process has been very justly censured as uncertain by eminent engineers, who prefer to put it in layers of not more than one foot in thickness, and to level each course, ramming it down thoroughly. When the lime is too hastily put into the trenches, and has not had time to be thoroughly slaked, the process will continue, and the mass will puff or swell and sometimes cause considerable mischief. Wing walls of bridges have been thrust out by this means. To make a solid concrete all the interstices of the gravel should be filled with the sand, and the lime and the water will be absorbed without any increase of bulk. In France the lime is first made into a paste, and the mixture is then called *béton*, not concrete; this is a more scientific process for obtaining a sound substance. In some experiments made by the Architectural Publication Society, where the materials were carefully mixed, no change took place in the bulk; but some experimentalists, practical men, and writers differ on this point, and assert there is a loss of one-seventh in bulk when set. The lime, if it can be procured, should be hydraulic; and concrete is much improved by the addition of the volcanic sands. French authors recommend, as good proportions, one-fifth hydraulic lime, one-fourth pozzuolana, one-eighth sharp sand, and the rest broken stone or gravel; or 20 per cent. hydraulic lime, the same of trass, the same of sharp sand, 15 per cent. of gravel, and 25 per cent. of broken stone. Perhaps the very best concrete is made of a simple mixture of gravel, sand, and Portland cement. It is unnecessary to enter into the details of foundations in water, as this but seldom comes within the ordinary builder's province.

Digger or Excavator.—The digger works with a pick-axe and a spade or shovel. With the pick-axe he breaks down the soil if it be hard or very stiff, and throws it out with the shovel; but compacted sand and alluvial soil are spitted and thrown out with the spade alone, without previous breaking down. When rock occurs in a foundation, the assistance of the quarryman is requisite to cut through or blast it, as the occasion may require. The digger should be required to produce a perfect level in every direction, and especially in trenches for walls; nor may this be done by replacing loose matter, but the level must be produced on the solid or undisturbed bed. A good excavator will dig and throw out, of common soil, into a basket or wheelbarrow, 8 or 10 yards per diem; but of stiff clay or firm gravel not more than 6 yards.

When the excavation has to be dug to a depth about the height of a man it will be necessary to strut the ground to prevent its falling in, especially if it be of a sandy, loose, or watery nature. This is done by placing on each side of the cutting upright planks against the soil, which may be either open or close, according to the quality of the soil, and against these one or more horizontal waling pieces secured by horizontal cross pieces or struts, and wedging up as necessary. On these struts are formed the landings or stages on which the lowest workman throws the soil he digs up, which is then again thrown up by a second man to another stage or to the surface, according to the depth. Sometimes the soil is hoisted in baskets or tubs raised by a windlass worked by hand, or by a horse-run. When the work has been executed for which the excavation was prepared, the digger has to fill in over and around it, carefully ramming the soil to prevent inequalities on the surface by the soil sinking, and to prevent water soaking in which might affect the foundations.

Brickwork.

The tools and implements employed by the bricklayer are the trowel. plumb-rule, rod, level, square, bevel, line-pins and lines, raker, jointer, crow-bar, pick-axe, and rammer, together with a hod and spade for his labourer. Besides these there are sundry others, as an axe, saw, and rubstone, used in cutting and gauging bricks, and some which are peculiar to tiling and paving. A pug-mill and screens for mixing and tempering mortar, and tubs and pails for water. are also auxiliaries of great importance.

In ordinary practice the bricklayer's scaffolds are carried up with the walls, and are made to rest on them. Having built up the walls as high as he can reach from the ground, he plants a row of poles, which vary in height from 30 to 40 and even 50 feet, parallel to and at a distance of about 4 feet 6 inches from the walls, and from 10 to 12 feet apart. To these, which are called standards, are attached by means of cords other poles called ledgers, horizontally and on the inside, with their upper surface on a level with the highest course of the wall yet laid; and on the ledgers and wall short transverse poles, called putlogs or putlocks, are laid as joists to carry the floor of scaffold boards. These putlocks are placed from 4 to 6 feet apart, according to the length and strength of the scaffold boards; and the ends which rest on the walls are carefully laid on the middle of a stretcher, so as to occupy the place of a header brick, which is inserted when the scaffolds are struck after the work is finished. On the floor of the scaffold thus formed the bricklayer stands, and the materials are brought up ladders to him by labourers in hods from the ground below; or they are hoisted up in baskets and buckets by means of a pulley-wheel and fall; or by the horse-run, which is more generally used, formed of a level pathway in which the horse moves, drawing up the load by the intervention of snatch blocks and guide wheels; or by the now usual hoisting-machine, worked by men, horses, or steam-power. The mortar is placed on ledged boards about 3 feet square, at convenient distances; and the bricks are strewn on the scaffold between the mortar boards, leaving a clear way against the wall for the bricklayers to move along unobstructedly. The workman then recommences the operation of bricklaying, beginning at the extreme left of his course, and advancing to the right until he reaches the angle or quoin in that direction, or the place where his fellow-workman on the same side may have begun. Thus he goes on with course after course until the wall is as high as he can conveniently reach from that scaffold, when another ledger is tied to the poles, another row of putlocks laid, and the boards are removed up to the new level. The ledger and most of the putlocks, however, remain to give steadiness to the temporary structure, and so on to the full height of the wall, the poles being pieced out by additional lengths as may be required. If a scaffold be very much exposed, and run to a great height, it must be braced. This is done by tying poles diagonally across on the outside to the standards and ledgers, and it may be further secured by tying the ends of some of the putlocks to the ledgers; but an outside scaffold should never be attached in any way to the building about which it stands. A scaffold should never be loaded heavily, as well or account of the work as of the scaffold itself; for the putlocks resting, as they do, on single bricks, in a green wall, they exert an injurious influence on it, which every additional pound weight on the scaffold must necessarily increase, and the putlocks themselves are liable to be bent or broken. A constant and steady supply of bricks and mortar on the part of the labourers, without overloading the scaffold at any one time, should be strictly required.

The suspended scaffold is a very ingenious contrivance, by which pointing and other external repairs of a house can be performed at a comparatively small cost, and without interference with the thoroughfare. The front can also be painted by the same means. Although known at least