W. Derby pinx.t Eng.d on Steel by J. Cochran

MR. PETER NICHOLSON,

the Practical Builder and Mathematician.

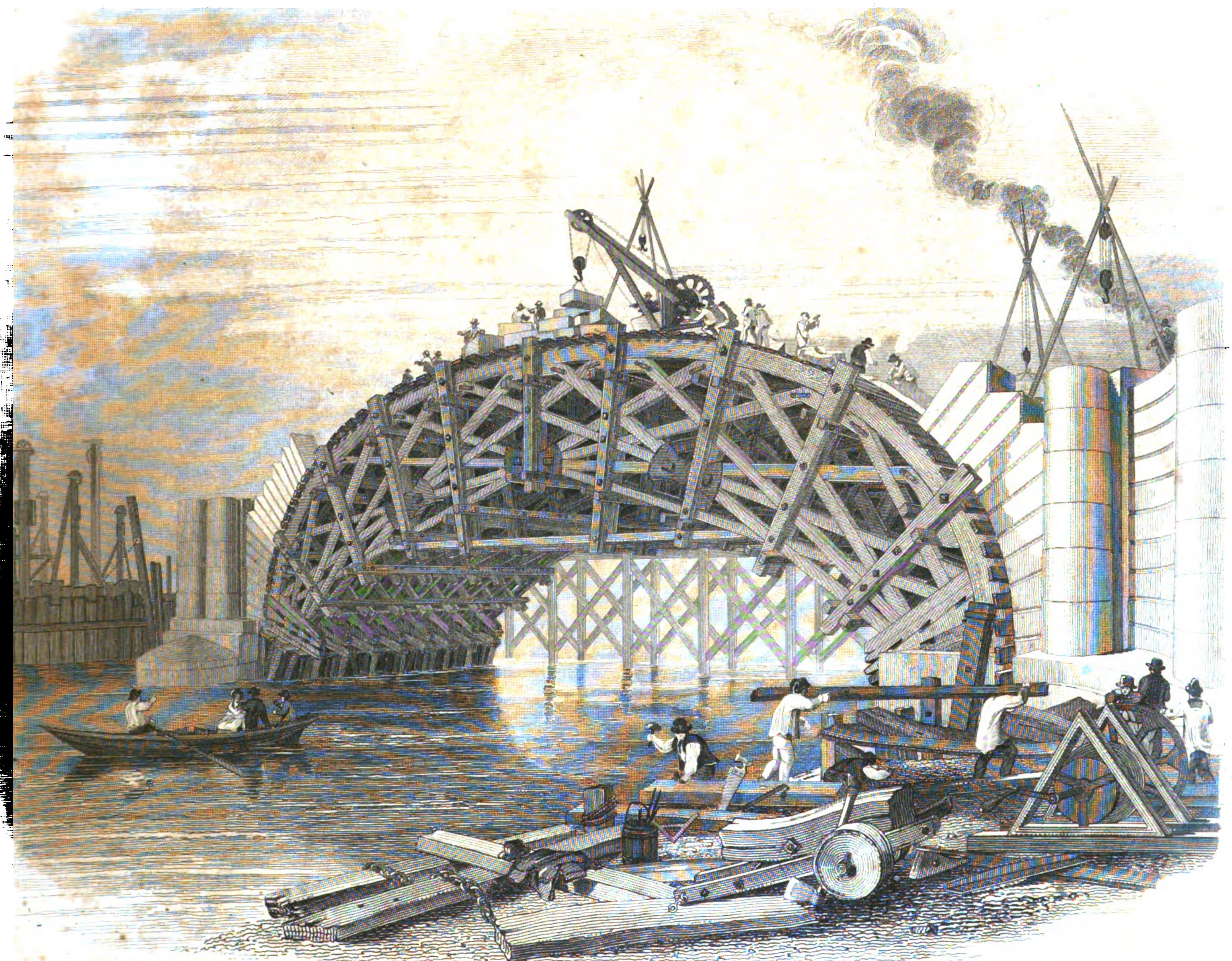
London, Published by T. Kelly, 17, Paternoster Row; Feb.y 10. 1837.

THE NEW AND IMPROVED

PRACTICAL BUILDER,

IN

Three Volumes.



E. Bloore del.t

A Perspective View of the Centering of Waterloo Bridge.

London.

Published by Thos. Kelly, 17, Paternoster Row, July 1st 1837.

THE

NEW AND IMPROVED PRACTICAL BUILDER.

CARPENTRY, JOINERY,

AND

CABINET-MAKING;

BEING

A NEW AND COMPLETE SYSTEM OF LINES

FOR THE

Use of Workmen;

FOUNDED ON ACCURATE GEOMETRICAL AND MECHANICAL PRINCIPLES,

WITH THEIR APPLICATION

IN CARPENTRY,—TO ROOFS, DOMES, CENTRING, &c.;

IN JOINERY,—TO STAIRS, HAND-RAILS, SOFFITS, NICHES, &c.;

AND

IN CABINET MAKING,—TO FURNITURE, BOTH PLAIN AND ORNAMENTAL;

FULLY AND CLEARLY EXPLAINED,

ILLUSTRATED BY NUMEROUS ENGRAVINGS BY ARTISTS OF THE FIRST TALENT.

VOL. I.

LONDON:

THOMAS KELLY, No. 17, PATERNOSTER ROW.

M.DCCC.XXXVII.

LONDON:
PRINTED BY J. RIDER, BARTHOLOMEW CLOSE.

PREFACE.

THIS Volume contains the science and present practice of the Arts of CARPENTRY, JOINERY, and CABINET-MAKING, explained in a simple and familiar manner; and for the advantage of readers not yet acquainted with abstruse scientific terms, no more of them have been employed than were absolutely necessary.

We have uniformly observed, that Carpenters, Joiners, and Cabinet-Makers, are alike distinguished for their superior knowledge in the scientific principles of their respective Arts; and, as it frequently happens that the whole of these arts are followed by a single individual, having considerable relation to each other, in consequence of being all more or less dependant on the same common principles, we have brought them together into one Work.

During the happy exertions still in progress for the education of the people, a result we expected has taken place: Carpenters, Joiners, and Cabinet-Makers, feeling a desire to hold their pre-eminence, have solicited for works of a superior character, both as regards elucidation of principles and ornamental embellishments. We have done our best endeavours to meet, if not exceed their wishes, and have had the assistance of talents of the highest rank in the respective departments; our illustrations being from the pencils and gravers of first-rate Artists; an appeal to the interior of our Work will, however, afford more conviction of its utility and value than we can possibly convey in the brief limits of a Preface.

The following is a short sketch of the contents:—This Volume is divided into three principal divisions, called Books. The first Book treats of CARPENTRY, with an Introduction, showing the principles and methods of describing Curves; the nature and methods of making Working-Drawings; the manner of Setting out Buildings, &c. &c. The Carpentry then commences with the Principles and Practice of Framing and Connecting Timbers; the Construction of Roofs, Floors, Partitions, Domes, Niches, Groins, Centres, and Wooden Bridges; with the principles and methods of finding the Lines for each of these species of work; concluding with a comprehensive view of the Qualities and Strength of Timber.

The Second Book treats of JOINERY; and, after a brief outline of its history and of the nature and mode of describing Mouldings, it proceeds to exhibit the methods of Framing, and Gluing-up, and Setting-out Work; the description of Raking-Mouldings; the Methods of Enlarging and Diminishing Mouldings; the Art of Hinging and forming Joints: the Construction of Doors, Windows, Window-Shutters, Circular Sashes, Skylights; the Mode of Bending Mouldings, of Diminishing and Fluting Columns and Pilasters; of forming Architraves, Surbases, and Bases, with specimens of Shop-Fronts; and a complete Treatise on the Theory and Construction of Stairs and Hand-rails; concluding with the Methods of fixing Joiners' Work, and laying both common and parquet Floors.

The Third Book is appropriated to CABINET-MAKING, or the principles of Designing, Constructing, and Selecting Furniture; and treats of the general principles of Design in respect to fitness, outline, relative proportion of Parts, selection of Ornaments, and combination of coloured Woods. The Grecian, Roman, and Gothic styles of Furnishing are next illustrated, and their distinguishing features shown; and the species of Furniture adapted to particular objects, and the modes of furnishing different kinds of rooms are described, and illustrated by original Designs. These are followed by the principles of Constructing Furniture, the methods of Veneering, Inlaying, Buhl-Work, Carving, moulding Ornaments in Wood and Composition, &c.; with the best methods of Cleaning-off, Stopping, Staining, common Polishing, French Polishing, Varnishing, and Cleaning Furniture, &c. &c.

Indices, with explanations of the peculiar *Technical Terms* of these Arts, are added; and the Index to the Cabinet-Making describes the celebrated French method of gilding, called *Or-moulu.*

In the CONSTRUCTIVE DEPARTMENT, the examples given in the PLATES are chiefly from works already *executed.* We have preferred selecting from the executed Buildings of RENNIE, SMIRKE, HARDWICK, &c. &c. to adding untried projects. But, in ORNAMENTAL WORKS, we have endeavoured to exhibit the reigning *Taste* of the period by means of *original Designs.* On the whole, it has been our object to combine *Theory* with *Practice,* and to illustrate both with taste, while we rendered the access to them easy and agreeable.

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THE NEW AND IMPROVED

PRACTICAL BUILDER,

AND

WORKMAN'S COMPANION:

EXHIBITING

A FULL DISPLAY AND ELUCIDATION OF THE MOST RECENT AND SKILFUL METHODS PURSUED BY ARCHITECTS AND ARTIFICERS,

IN ALL THE VARIOUS DEPARTMENTS OF BUILDING.

IN THREE VOLUMES.

VOL. I. CONTAINS

GEOMETRY, CARPENTRY, JOINERY, AND CABINET-MAKING.

VOL. II. CONTAINS

MASONRY, BRICKLAYING, PLASTERING, SLATING, PAINTING, GLAZING, & PLUMBING.

VOL. III. CONTAINS

THEORY AND PRACTICE OF THE FIVE ORDERS, GOTHIC ARCHITECTURE, PERSPECTIVE, PROJECTION, FRACTIONS, DECIMAL ARITHMETIC, &c.

COMPREHENDING

A SUMMARY OF THE ART OF BUILDING;

EXTENSIVE ACCOUNTS OF BUILDING MATERIALS, STRENGTH OF TIMBER, CEMENTS, &c. AND A GLOSSARY OF THE TECHNICAL TERMS PECULIAR TO EACH DEPARTMENT.

ILLUSTRATED BY NUMEROUS DIAGRAMS AND STEEL PLATES, ACCURATELY ENGRAVED BY MR. TURRELL AND OTHER EMINENT ARCHITECTURAL ARTISTS, FROM ORIGINAL DRAWINGS AND DESIGNS, AND WORKS EXECUTED BY

THE MOST DISTINGUISHED ARCHITECTS OF THIS COUNTRY,

VIZ.:

MESSRS. BRUNEL, BURTON, CLARKE, ELSAM, HARDWICK, INWOOD, JOHNSTONE, LAING, NASH, NICHOLSON, PERRONET, RENNIE, SHAW, SMIRKE, SOANE, TELFORD, TREDGOLD, WILKINS, WYATVILLE, &c. &c.

LONDON:
THOMAS KELLY, 17, PATERNOSTER ROW.

M.DCCC.XXXVII.

PRINTED BY J. RIDER, 14, BARTHOLOMEW CLOSE, LONDON.

PREFACE.

THE highly favorable reception and extensive sale of the former edition of "THE PRACTICAL BUILDER," induced the Proprietor, at a very considerable expense, to engage several eminent professional Gentlemen to improve and enlarge the Work, which he is now enabled to submit to the Public, arranged in Three Volumes, under their several Branches, and which he has no hesitation in stating, in conjunction with the impartial opinion of some of the most eminent and practical Architects of this country, will form the most complete and comprehensive Treatise on PRACTICAL BUILDING ever published.

This Work will be found to comprehend the PRESENT PRACTICE OF THE ART OF BUILDING, reduced to PURELY SCIENTIFIC and GEOMETRICAL PRINCIPLES, and yet explained in a manner so simple, as to be easily intelligible to every attentive Reader.

In order to facilitate this important object, the Work commences with a short Treatise on GEOMETRY, theoretical and practical, peculiarly adapted to the general object of the Work, and containing such theorems and problems only as are *absolutely necessary* to be understood by every person connected with the leading departments of the art.

And here the Conductors cannot refrain from adding a few words, with a view to impress upon the minds of STUDENTS, as well as WORKMEN engaged in the construction of buildings, whether CARPENTER, JOINER, MASON, or BRICKLAYER, the PARAMOUNT IMPORTANCE of obtaining a knowledge of the PRINCIPLES of GEOMETRY; since, of all the numerous classes, concerned in mechanical arts, THEY require the most intimate acquaintance with that primary science.

The execution of the design of the architect is generally left to the skill of the Workman; who is, of course, presumed to be fully competent to the performance of the task which he undertakes. Now, if he be not practically acquainted with the *geometrical* construction of the object to be executed, he is not only unfit for the undertaking, but, at every step that he takes, he will manifest his ignorance and inability, and eventually overwhelm himself with confusion and disgrace. While persons of this description draw down upon themselves such merited degradation, those who, by assiduous application, have made themselves masters of the principles of geometry, and have obtained a clear and comprehensive view of the practical application of these principles, will not fail to enjoy that intellectual satisfaction which results from a successful termination of efforts, conducted with scientific skill, and crowned with general approbation; and, at the same time, open for themselves a legitimate path to that reputation which directly and naturally leads to opulence and independence.

The articles on CARPENTRY, JOINERY, and CABINET-MAKING, are treated at great length, as their superior importance demand. Indeed, it has been the chief study of the Conductors to give to these branches the utmost degree of scientific connexion and development of which they are susceptible. It may be observed here, that there is no class of the mechanical arts so directly capable of receiving improvement from the researches of scientific men as those connected with building. Mr. PETER NICHOLSON laid the foundation of this useful and elaborate Work: he was the principal author of the former edition, and it is to him the public are indebted for the introduction of the scientific principles of practical Carpentry. He was the first to apply "*descriptive Geometry*" to the furnishing of actual measurements to "*finding the lines*," &c. The immense advantage attending such a method is apparent from the fact, that there is scarcely an intelligent carpenter or joiner in the kingdom who has not derived great benefit from his examples.

In MASONRY, the artist will find an ample detail of the methods of cutting stone, illustrated by several plates, (in which is exhibited a complete system of lines,) answering to most purposes which present themselves. And since the principles laid down in this Work are every where of a general tendency, the judgment of the workman will enable him to apply them wherever difficulties may occur. The various qualities of stones for building, the nature and composition of mortars, cements, and the principles of constructing walls, bridges, domes, tunnels, light-houses, &c. are fully considered and clearly explained.

The art of BRICKLAYING is but little connected with the study of geometrical lines; since the texture of bricks is such as will not admit of their being moulded to the different shapes which the ingenuity of the architect might devise. However, in order to render the present Work complete, and to obviate, as far as possible, every difficulty, several plates are introduced, illustrative of the various forms of arches, groins, niches, ovens, furnaces, &c.

The various other trades connected with building, as PLASTERING, both plain and ornamental, SLATING, PAINTING, GLAZING, PLUMBING, &c. will be found to be treated of in as complete a manner as was practicable, with a full description of the qualities of the various materials, and the most approved methods of preparing and applying them.

A theoretical and practical Treatise on the FIVE ORDERS is subjoined to the trades accessary to building: these Orders, with their appropriate embellishments, form the basis and superstructure of architectural decoration. The parts of the Orders are drawn on a scale which speaks to the eye, and renders all farther detail unnecessary. The parts are given in modules and minutes; this being the best mode of exhibiting their proportions, so as to be most readily and clearly comprehended by the student and workman. To which is added, an historical description of GOTHIC ARCHITECTURE, and its origin, exhibiting a comparison of the styles of England, Germany, France, Spain, and Italy: with the first, second, and third periods of the pointed arch, all of which is explained and elucidated by numerous examples and details, drawn from the best authorities.

In order to increase the utility of the Work, a select series of designs, in the modern style, accommodated to the various ranks of society, have been introduced; and, for the use of the ARCHITECTURAL STUDENT, that no accomplishment which might facilitate the operations of the draughtsman, or furnish the designer with more correct ideas, or more extensive views, may be wanting, the RULES OF PROJECTION, and the PRINCIPLES of PERSPECTIVE, together with Treatises on FRACTIONS, DECIMAL ARITHMETIC, &c. are presented; and in the most familiar and simple manner in which the subjects could be conceived. An architect, to design with propriety, must, to a good taste, unite a knowledge of perspective, an accurate idea of the effects to be produced by light and shadow, with an ample portion of practical knowledge.

Few things are more important than a clear idea of the mutual connexion of the various parts of a building. The authors have, therefore, introduced a section, in which they have endeavoured to show, from first principles only, the dependance which each part has upon some other; and in which the *fitness,* *proportion*, and *character*, of the various component parts of architectural structures are carefully investigated and compared, including rules for determining the proportions of apartments, and the most approved application of ornamental decoration, with critical remarks on the symmetry and beauty of buildings, the proper choice of situations and soils for country residences, &c.

Each portion of the Work will contain a copious GLOSSARY of the most useful terms employed by architects and builders.

On the whole, these volumes will be found to contain a much greater variety of subjects than any similar work; and, in the method of treating the various subjects, the studious reader will discover many things entirely new. And the examples which are given will be found of the greatest utility to the practical builder, in regulating his ideas with respect to any design under consideration, however much it may differ from any of the forms exhibited here.

The schemes or diagrams are proportioned in their size to their probable utility; and the strictest regard has been paid to giving to all the parts of each figure their respective and just proportions.

Finally, from the important information collected, the natural arrangement adopted, and the numerous and valuable illustrations exhibited in the course of this Work, the Conductors flatter themselves that they will be found to have rendered an important service to a numerous and highly meritorious class of their fellow-subjects; whilst even the most inattentive observer cannot but acknowledge that the Publisher has spared no expense to render the Work deserving of extensive patronage and general approbation. The grand principle of the undertaking is obvious: it is equally calculated to instruct the untaught, and to assist the intelligent; to promote a generous emulation, and at once to incite and satisfy inquiry into the elements and practice of those branches of science, than which no others are more conducive to the comfort and happiness of mankind.

The Illustrations and Examples are engraved in the best manner, on steel, by Mr. TURRELL and other eminent architectural artists, selected from the drawings, designs, and works executed by the most eminent architects of this country, amongst whom we make honorable mention of BRUNEL, BURTON, CLARKE, ELSAM, HARDWICK, INWOOD, JOHNSTONE, LAING, NASH, NICHOLSON, PERRONET, RENNIE, SHAW, SMIRKE, SOANE, TELFORD, TREDGOLD, WILKINS, WYATVILLE, &c. &c.

THE NEW AND IMPROVED

PRACTICAL BUILDER, &c.

INTRODUCTORY CHAPTER.

THE ELEMENTS OF GEOMETRY.

THE object of the science of Geometry is to consider the properties of lines and angles, as formed according to some certain law; as, also, the construction of all manner of figures, according to given *data*.

Geometry is divided into two branches; one of which considers the relations, positions, and properties, of lines, so as to render a proposition clear to the understanding without the aid of compasses or other instruments; being demonstrated, by a continued chain of reasoning, from certain principles previously established and laid down as axioms; so that the conclusions from one truth become part of the *data* for the proof of a succeeding proposition. This, which is called the Theory of Geometry, is fully explained by EUCLID, in his celebrated "ELEMENTS," which have served as the basis of all succeeding treatises on the subject: and so much of those Elements as may be required in the practice of Architecture will be found included in the present work.

The other branch of geometry is entirely *practical*, and may be acquired without the theory, according to the directions hereafter given; although with a knowledge of the reasons of the rules it will be more satisfactory. It is this practical branch that enables the architect to regulate his designs, and the artizan to construct his lines, so as to enable him to execute the work. Without the aid of this branch of knowledge, the workman will be unfit for any undertaking whatever; and, so long as he is ignorant of the methods of geometrical construction, he must remain under the control and direction of a superior in his own class.

The following definitions and problems are calculated to instruct the student, and will qualify him for proceeding to the remaining parts of this treatise, wherein it will be found that the application of this branch of science is absolutely necessary.

The uses of Geometry are not confined to Carpentry and Architecture: Astronomy, Navigation, Perspective, and numerous other branches, are entirely dependent upon it. "It conducts the soldier in the field, and the seaman on the ocean; it gives strength to the fortress, and elegance to the palace." In short, there is no mechanical profession that does not derive considerable advantage from it. One artizan is superior to another, in proportion to his knowledge of the subject we are now commenting upon, and which we are about to explain.

The Terms are here as clearly defined as the nature of the subject will admit, and the Problems are put in a regular succession; so that nothing is introduced, in any problem, as taken for granted, but what has been explained in some problem previously given. This selection, though not very numerous, is sufficient to enable the student to proceed with the remaining parts of the work, to which it is specially adapted: and every attention has been paid to divest the diagrams of superfluous lines, without rendering them less intelligible.

DEFINITIONS OF TERMS IN PLANE GEOMETRY.

1. A Point.—Abstractedly considered, a *point* is said to have position without magnitude; and it is, therefore, represented to the eye by the smallest visible mark; that is, simply, by a *dot.*

2. A Line is considered as *length* only, without dimension of breadth or thickness: it is therefore represented by the motion of a visible point.

3. A Right Line is the shortest that can be drawn between two given points; it being what is commonly called a *Straight* Line.

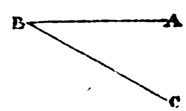
A Curve or *Curved Line* is any other than a right line, from which it differs by inflexion, either regular or irregular.

4. A Superficies, or Surface, is considered as an extension of length and breadth, without depth.

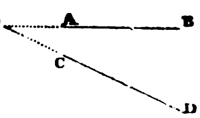
5. A Plane Superficies is a flat surface, which will coincide, in every point, with a right line.

6. A Plane Figure, Scheme, or Diagram, is the lineal representation of any object on a plane surface. If the lines forming the figure be straight, the figure is said to be *rectilineal;* being composed of right lines.

7. An Angle is the space or corner between two lines meeting in a point. It is expressed by three letters, as ABC; and the middle letter, as B, always denotes the *vertex*, or angular point. The figure in the margin represents a *plane rectilineal angle*, it being formed by two right lines, meeting in a point (B)



8. Converging Lines are right lines so inclined to each other as to meet, if continued, or *produced*, to a certain point. Thus, AB and CD, *converge* to each other; because, if produced, or continued, they meet in the angle O.



9. Right and Oblique Angles.—If one right line stands upon another, so as to make the angles on each side *equal*, each angle is called a Right Angle, and the line which stands upon the base, or lower line, is called a *perpendicular*.

Thus, in *fig.* 1, annexed, if the line CD stand upon AB, and make the angles on both sides of CD equal, each of these angles is a *right angle*. In *fig.* 2, the line CD does not make the angles on each side of it equal to each other; and therefore CD is said to stand at *oblique angles* to AB; while in *fig.* 1, CD is at *right angles* to AB.

Fig. 1.

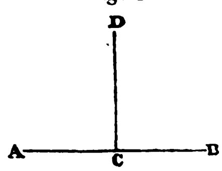
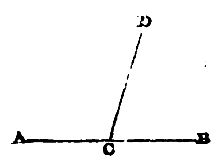


Fig. 2.

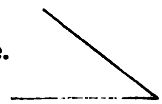


10. An Acute Angle is *less* than a right angle.

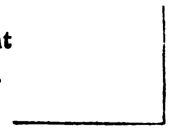
11. An Obtuse Angle is *greater* than a right angle.

In *fig.* 2, above, the line CD makes the angles on each side of it unequal; and, therefore, one must be greater than the other: the greater is, of course, an *obtuse angle*, and the lesser an *acute angle:* for it is clear, by inspection, that, whatever be the position of the line CD, relative to AB, what the one angle has in excess, more than a right angle, the other must want, in order to be equal to the same.

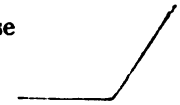
EXAMPLES: An Acute Angle.

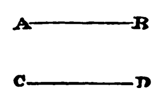


A Right Angle.



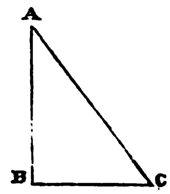
An Obtuse Angle.





12. A PLANE TRIANGLE is a space inclosed by three right lines, as ABC.

13. A RIGHT-ANGLED TRIANGLE is that which has one right angle, as ABC.



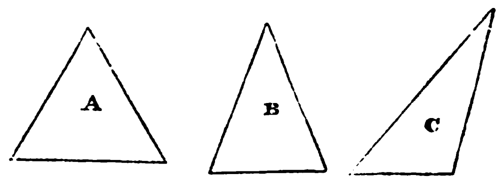
14. An ACUTE-ANGLED TRIANGLE is a triangle which has all its angles *acute;* as *figures* A and B.

15. An OBTUSE-ANGLED TRIANGLE is a triangle having one *obtuse* angle; as *figure* C.

16. An EQUILATERAL TRIANGLE is a triangle having all its sides equal; as *figure* A.

17. An ISOSCELES TRIANGLE is a triangle having two equal sides; as *figure* B.

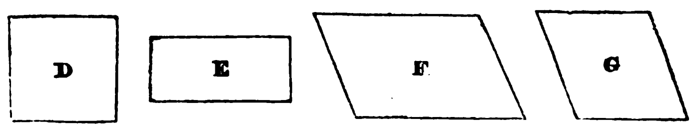
18. A SCALENE TRIANGLE is a triangle having no two of its sides equal; as *figure* C.



19. PARALLEL LINES are lines equally distant from each other in all parts, and which, though produced or continued ever so far, could never meet. Such are the lines AB and CD.

20. A PARALLELOGRAM is a figure of which the opposite sides are *parallels.*

Thus, the *figures* D, E, F, G, are *parallelograms.*



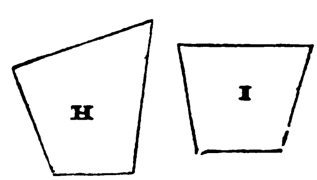
21. When the parallelogram has a right angle, it is called a RECTANGLE. Thus the *figures* D and E are *rectangles.*

22. If the sides of the rectangle be equal, it is called a SQUARE. Hence, *figure* D is a *square.*

23. If the two adjacent sides be unequal, the rectangle is termed an OBLONG; as the *figure* E.

24. If only two opposite angles of a parallelogram be equal, the figure is called a RHOMBUS; as *figures* F and G.

25. If two adjacent sides of a rhombus be equal, the figure is called a RHOM-BO-ID; as *figure* G.



26. Every figure, inclosed by four right lines, is called a QUADRANGLE, or QUADRILATERAL. Thus, *figures* D, E, F, G, H, and I, are *quadrangles* or *quadrilaterals.*

27. When all the sides of a quadrilateral are unequal, it is called a TRAPEZIUM.

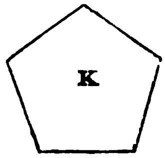
28. If two sides of a trapezium be parallel, it is called a TRA-PE-ZO-ID; as *figure* I.

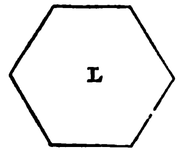
29. Figures having equal sides and equal angles, or equilateral and equiangular figures, formed by more than four right lines, are called REGULAR POLYGONS.

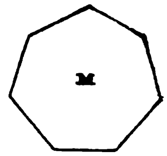
30. A regular polygon of *five* sides is called a PENTAGON; as *figure* K.

31. A regular polygon of *six* sides is called a HEXAGON; as *figure* L.

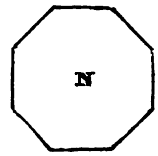
32. A regular polygon of *seven* sides is called a HEPTAGON; as *figure* M.





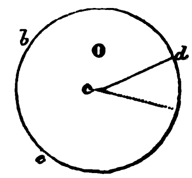


33. A regular polygon of *eight* sides is called an OCTAGON; as *fig.* N. Of nine sides, an *eneagon* or *nonagon;* of ten sides, a *decagon;* of eleven sides, a *undecagon;* of twelve sides, a *duodecagon;* of fifteen sides, a *quindecagon:* but polygons having more than twelve sides are commonly expressed as such, with the number of sides.



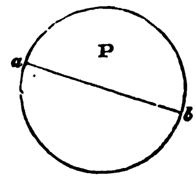
34. A CIRCLE is a plane figure formed by one uniform curved line only, which is called its *circumference.* (*Fig.* O.)

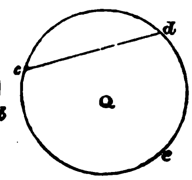
35. The CENTRE of a circle is the point in the middle of it, as *c* in *fig.* O; and the line *cd,* drawn from the centre to the circumference, is the *radius* of the circle; all lines, *radii,* thus drawn, are equal.



36. The DIAMETER of a circle is a right line, drawn through the centre, and terminated on both sides by the circumference; as *a b, figure* P.

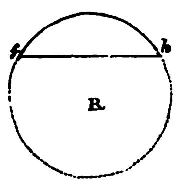
37. A CHORD of a circle is a right line, drawn from one point of a circle to another, and dividing it into unequal or equal parts, or *segments.* In the latter case, the chord is also the diameter. Thus, *c d, fig.* Q, is a *chord,* as well as *a b, fig* P.

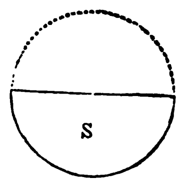




38. A SEMICIRCLE is one-half of a circle, as divided into two equal parts by the diameter.

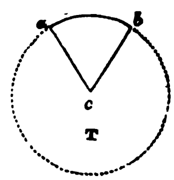
39. A SEGMENT of a circle is that portion which is cut off by a chord. Thus, in *figures* Q and R, *cde* and *fgh* are *segments;* and *fig.* S, though a semi-circle, is still a segment, terminated by the diameter.

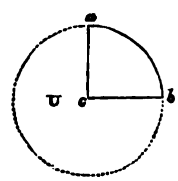




40. A SECTOR is the portion of a circle formed by two radii and the intercepted part of the circumference; as *a bc, fig.* T.

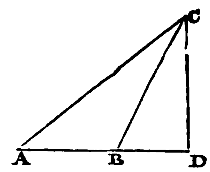
41. A QUADRANT is the fourth part or quarter of a circle; or, in other words, a sector contained by two radii, forming a right angle at the centre, and the intercepted part of the circumference; as *acb, fig.* U.





42. An ARC or ARCH is any portion of the circumference of a circle.

43. The ALTITUDE of a figure is a right line drawn from the top or vertical angle perpendicular to the base or opposite side, or to the base *produced* or continued. Thus CD, in the annexed figure, is the altitude of the triangle ABC.



44. NOTATION.—It has been already shown (*Art.* 7) that an angle is generally expressed by three letters, as ABC, of which the middle one denotes the *vertex,* or angular point. As the signs used in Algebraic Notation will necessarily occur in this Treatise, it is proper here to notice that, + (*plus*) signifies *more,* or one quantity or thing added to another: The sign — (*minus*) signifies *less,* or one quantity subtracted from another: = means is, or are.

equal to: × denotes *multiplication*, as A × B, that is, A multiplied into B, or as $4 \times 5 = 20$: ÷ is the sign of *division*, as $36 \div 3$ or $\frac{36}{3} = 12$. : :: : denotes equality of *proportion;* thus, $a : b :: c : d$, signifies that a bears the same proportion to b as c to d; or, as 6 to 9 :: 2 : 3. ∠ signifies an *angle:* ∠s, *angles:* △ a triangle: ⊥ a perpendicular.

45. GENERAL TERMS USED IN GEOMETRY.—An AXIOM is a truth so evident as to require no demonstration. A THEOREM is a truth or proposition to be demonstrated by a process of reasoning. A PROBLEM is something proposed to be done. A LEMMA is a truth premised, in order to facilitate a following demonstration or solution: this term is rejected by some Geometricians as unnecessary. A PROPOSITION is a common term for a Theorem or Problem. A COROLLARY is a truth or deduction which arises from a preceding demonstration. A SCHOLIUM is a remark explanatory of some deduction from a preceding proposition. An HYPOTHESIS is something supposed or premised in a proposition, and from which some certain consequence is deduced.

46. AXIOMS.—The AXIOMS are as follow: 1. Things that are equal to the same thing, or to equal things, are equal to one another. 2. If equal things be added to equals, the sums or wholes will be equal. 3. If equal things be taken from equals, the remainders will be equal. 4. If equal things be added to unequals, the sums or wholes will be unequal. 5. The halves of equal things are equal, and the doubles of equal things are equal. 6. Magnitudes that mutually agree, or fill equal spaces, are equal to one another. 7. The whole is greater than a part, and equal to all its parts. 8. Only one right line can be drawn from one point to another. 9. Two right lines cannot be drawn through the same point parallel to another right line, without coinciding with each other. 10. All right angles are equal to each other. 11. Equal circles have equal semi-diameters.

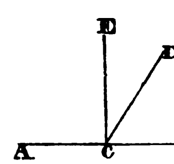
47. POSTULATES.—A POSTULATE signifies something which may be assumed as granted. Hence it may be granted, 1st, That a right line may be drawn from any one point to any other point: 2dly, That a line may be *produced*, that is, continued or lengthened at pleasure: 3dly, That a circle may be described from any centre, at any distance therefrom, or with any radius.

THEOREMS.

THEOREM 1.

48. If one right line, as CD, touch or cut another right line, AB, at any point between its two ends, it makes two adjacent angles, BCD, ACD, which, together, are equal to two right angles.

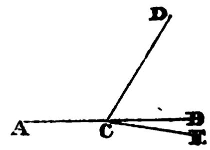
DEMONSTRATION.—If CD were perpendicular to AB, each of the angles, DCB and DCA, would be a right angle; but, as ECD is the excess of DCA above a right angle, and DCB is less than a right angle by the same quantity, the angles DCB and DCA must be equal to two right angles.



49. COROLLARY.—If one of the angles be a right angle, the other also must be a right angle. Again, whatever number of right lines stand thus on one point C, on the same side of a right line AB, the sum of all the angles are equal to two right angles; and all the angles formed about the same point, by any number of lines, are altogether equal to four right angles.

THEOREM 2.

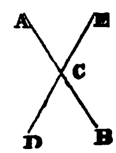
50. If the sum of two adjacent angles ACD, DBC, be equal to two right angles, the exterior or outer sides, ACB, will form one right line.



For, if CB be not the continuation of AC, assume CE as its continuation. In this case the sum of the angles ACD, DCE, (by *theorem* 1,) must be equal to two right angles; but, by hypothesis, the sum of ACD, DCB, is equal to two right angles; therefore the angles ACD, DCE, are equal to the two angles ACD, DCB (*Ax.* 1, *page* xi.); and, taking from each of these equal angles the angle ACD, there will remain the angle DCE, equal to DCB, or a part equal to the whole, which is impossible.

THEOREM 3

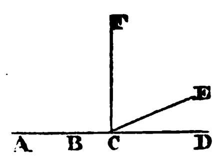
51. When two straight lines, AB, DE, cut each other, the opposite angles are equal.



For, since DE is a straight line, the sum of the two angles ACD, ACE, is equal to two right angles (*theorem* 1); and, because AB is a straight line. the sum of the angles ACE, ECB, is equal to two right angles (*theorem* 1); therefore the sum of the angles ACD, ACE, is equal to the sum of the angles ACE, ECB; and, taking away from each the common angle ACE, there will remain the angle ACD, equal to the vertical opposite angle ECB.

THEOREM 4.

52. Two straight lines, which have two common points, coincide entirely throughout their whole extent.

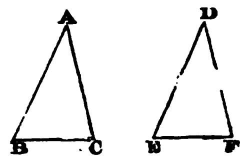


Let A and B be the two common points; in the first place, the two lines can make but one from A to B, (*Ax.* 10, *p.* xi.). If it were possible that they could separate, let C be the point of separation, and let us suppose that one of them takes the direction CD, and the other CE.

At the point C suppose CF to be drawn, perpendicular to AC; then, because ACD is, by hypothesis, a straight line, the angle FCD is a right angle; (*Def. art.* 9;) in like manner, because ACE is supposed to be a straight line, the angle FCE is a right angle; therefore the angles FCD, FCE, are equal; but this is impossible (*Ax.* 9, *page* xi.); therefore the two straight lines, which have two common points, A and B, cannot separate, but must form one continued line.

THEOREM 5.

53. Two triangles are equal when, in the one, an angle and the two sides which contain it are equal, in the other, to an angle and the two sides which contain it.



Let the angle A be equal to the angle D, the side AB equal to DE, and the side AC equal to DF; then the triangles ABC, DEF, shall be equal.

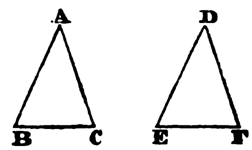
Suppose the triangle ABC to be placed upon the triangle DEF, so that AB may be upon DE; then, because the angles A and D are equal, AC will fall upon DF; and, because AB is equal to DE, and AC equal to DF, the point B

will coincide with E, and C with F: therefore, the base BC will coincide with the base EF (*theorem* 4); and, since the sides of the triangles coincide, the other two angles must also coincide; that is, they must be equal to each other.

THEOREM 6.

54. Two triangles are equal when a side and two adjacent angles of the one are respectively equal to a side and two adjacent angles of the other.

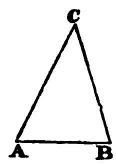
Let the side BC be equal to the side EF, the angle B equal to the angle E, and the angle C equal to the angle F, the triangles shall be equal.



For, suppose the triangle ABC to be placed upon the triangle DEF, so that their bases, BC and EF, may coincide; then, because the angles B and E are equal, the straight line BA will fall upon ED; and, because the angles C and F are equal, the straight line CA will fall upon FD: therefore, the three sides of one triangle will coincide with the three sides of the other; and, consequently, the triangles themselves will be equal: and, since therefore the sides of the triangles coincide, the corresponding angles will be equal.

THEOREM 7.

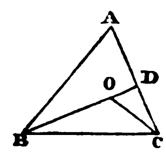
55. Any two sides of a triangle are together equal to more than a third side.



For, in the triangle, ABC, the straight line BC is the shortest line that can be drawn from B to C; therefore the sum of the two sides, BA, AC, is greater than BC.

THEOREM 8.

56. If from any point, as O, within a triangle, ABC, there be drawn two straight lines, OB, OC, one to each extremity of any side, as BC, their sum is less than the sum of the other two sides of the triangle.



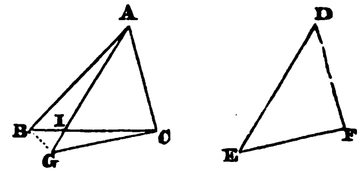
Produce BO till it meet AC in D; the line OC is less than the sum of the two lines OD, DC (*theorem* 7); and, adding to these unequals the line BO, the sum of the two lines, BO, OC, is less than the sum of the three lines BO, OD, DC (*ax.* 4, *p.* xi.); that is, the sum of the two lines BO, OC, is less than the sum of the two lines BD, DC.

In like manner, BD is less than the sum of the two lines BA, AD; and, adding DC to these unequals, the sum of the two straight lines, BD, DC, is less than the sum of the three straight lines BA, AD, DC; that is, the two straight lines BD, DC, are less than the two straight lines BA, AC; but the two straight lines BO, OC, have been shown to be less than the two straight lines BD, DC; and, therefore, much less is the sum of the two straight lines BO, OC, than that of the two sides BA, AC, of the triangle ABC.

THEOREM 9.

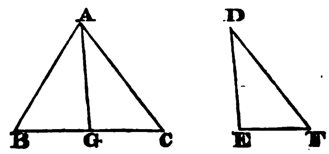
57. If any two sides AB, AC, of a triangle, ABC, are equal to two sides DE, DF, of another triangle, DEF, each to each, and if the angle BAC, contained by the sides, AB, AC, be greater than the angle EDF, contained by the sides ED, DF, the base BC of the triangle which has the greater angle shall be greater than the base EF of the other triangle.

Make the angle CAG equal to D, take AG equal to DE or AB, and join CG; and because the two triangles CAG, DEF, have an angle of the one equal to an angle of the other, and the sides which contain these angles are equal, CG shall be equal to EF (*theorem* 5). Now there may be three cases, according as the point G falls without the triangle ABC, or on the side BC, or within the triangle.

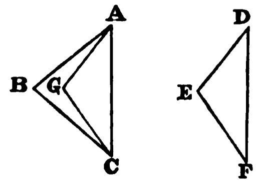


Case 1.—Because GC is less than the sum of the two straight lines GI, IC; and AB less than the sum of the two straight lines AI, IB: therefore, the sum of the two straight lines GC, AB, is less than the sum of the four straight lines GI, IC, AI, IB; that is, the sum of the two straight lines GC, AB, is less than the sum of the two straight lines AG, BC; but AG is equal to AB, therefore GC is less than BC; but GC=EF, therefore EF is less than BC.

Case 2.—If the point G fall on BC, it is evident that GC, or its equal EF, is less than BC.



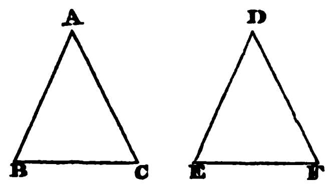
Case 3.—Lastly, if the point G fall within the triangle ABC, by *theorem* 8, we have the sum of the two straight lines AG, GC, less than the sum of the two straight lines AB, BC; but since AB is equal to AG, we shall have GC less than BC; and, consequently, EF less than BC.



THEOREM 10.

58. One triangle is equal to another, when the three sides of the first are respectively equal to the three sides of the second.

Let the side AB be equal to DE, AC equal to DF, and BC equal to EF; then shall the angle A be equal to the angle D, the angle B equal to the angle E, and the angle C equal to the angle F. For, if the angle A were greater than D, then, as the two sides AB, AC, are equal to the two sides DE, DF, each to each, it would follow (*theorem* 9) that the side BC would be greater than EF; and, if the angle A were *less* than the angle D, BC would be less than EF; therefore, the angle A can neither be greater nor less than the angle D; the angle A must therefore be equal to the angle D. In like manner, it may be proved that the angle B is equal to E, and C equal to F.

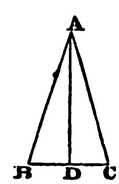


59. Corollary.—Whence it appears that, in two equal triangles the equal angles are opposite to the equal sides; for the equal angles A and D are opposite to the equal sides BC and EF.

THEOREM 11.

60. The angles opposite to the equal sides of an isosceles triangle are equal.

Let the side AB be equal to AC; then shall the angle C equal the angle B. For, suppose AD to be drawn from the vertex A to the middle point D, of the base BC; then the two triangles ADB, ADC, will have the two sides AB, BD, of the one equal to the two sides AC, CD, of the other, each to each; and AD is common to both: therefore the angle B shall be equal to the angle C.

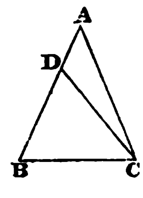


61. Corollary 1.—Hence every equilateral triangle is also equiangular.

62. Corollary 2.—A straight line drawn from the vertex of an isosceles triangle to the middle of the base will bisect the vertical angle, and be perpendicular to the base.

THEOREM 12.

63. If two angles of a triangle be equal, the opposite sides shall be equal, and the triangle shall be isosceles.

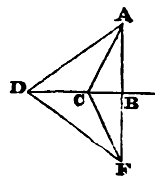


Let the angle ABC be equal to ACB, the side AC shall be equal to the side AB.

For, if the two sides AB, AC, are not equal, let AB be greater than AC, and from BA cut off BD, equal to CA, and join CD; the angle DBC is, by hypothesis, equal to the angle ACB, and the two sides DB, BC, are equal to the two sides AC, CB; therefore the triangle DBC is equal to the triangle ACB, the less to the greater, which is impossible (*ax.* 9, *p.* xi.); therefore AB cannot be unequal to AC, but must be equal to it.

THEOREM 13.

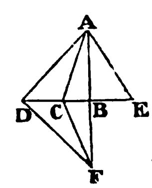
64. From a point A, without a straight line DE, only one perpendicular can be drawn to that line.



For, suppose it were possible to draw AB, AC, perpendicular from the same point A, upon the straight line DE; produce one of them, AB, to F, so that BF may be equal to AB, and join FC; and, because AB is equal to BF, and BC is common to the two triangles ABC, FBC, and the angles ABC and FBC are equal; the angle ACB is equal to FCB (*theorem* 5); therefore AC and CF must be a continued line (*theorem* 2); and so, through the two points A, F, two straight lines, AF and ACF, may be drawn, that do not coincide; which is impossible: and, therefore, it is equally impossible that two perpendiculars can be drawn from the same point to the same straight line.

THEOREM 14.

65. Of all the lines that can be drawn from a given point A, to a given straight line DE, the perpendicular is the shortest: and of the other lines, that which is nearer the perpendicular is less than that which is more remote; and those two lines, on opposite sides, and at equal distances, from the perpendicular, are equal.



Produce the perpendicular, so that BF may be equal to AB, and draw the straight lines AC, AD, and AE, to meet DE in C, D, and E, and join FC, FD, &c.

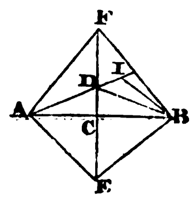
The triangles BCF and BCA are equal (*theorem* 5); for BF is equal to BA, and BC common; therefore CF is equal to CA. Now AF is less than AC+CF (*theorem* 7); therefore, taking the halves, AB is less than AC; that is, the perpendicular is the shortest line that can be drawn from A to DE.

Next, suppose BE equal to BC; then the triangles ABE and ABC will be equal (*theorem* 5), for they have BA common, and the angles ABE and ABC equal; therefore AE is equal to AC; that is, two oblique lines equally distant from the perpendicular, on opposite sides, are equal.

In the triangle ADF, the sum of AC and CF is less than the sum of AD and DF (*theorem* 8); therefore AC, the half of AC+CF, is less than AD, the half of AD+DF; that is, the oblique line, which is farther from the perpendicular, is greater than that which is nearer to it.

THEOREM 15.

66. If through the point C, the middle of the straight line AB, a perpendicular be drawn to that line, every point in the perpendicular is equally distant from the extremities of the line AB, and every point out of the perpendicular is unequally distant from these extremities.

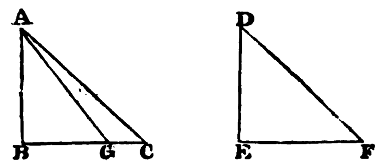


Because AC is equal to BC, the two oblique lines AD, BD, which are equally distant from the perpendicular, are equal (*theorem* 14). The same is also true of the two oblique lines AE, EB, and of the two oblique lines AF, FB, &c. Therefore, every point in the perpendicular is equally distant from the ends of the line.

Let I be a point out of the perpendicular. If IA, IB, be joined, one of them will cut the perpendicular in D; therefore, drawing DB, we have DB equal to DA: but IB is less than ID+DB, and ID+DB is equal to ID+DA equal to IA; therefore IB is less than IA: that is, any point out of the perpendicular is unequally distant from the extremities A and B.

THEOREM 16.

67. Two right-angled triangles are equal if the hypothenuse and a side of the one be equal to the hypothenuse and a side of the other.

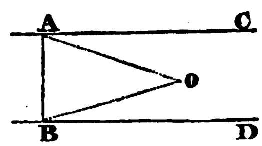


Let the hypothenuse (or longest side) AC be equal to the hypothenuse DF, and the side AB equal to the side DE, and the right-angled triangle ABC shall be equal to the right-angled triangle DEF.

The proposition will be evidently true if it can be proved that BC is equal to EF (*theorem* 10). Let us suppose, if it be possible, that these sides are unequal, and that BC is the greater. Take BG equal to EF, and join AG. The triangles ABG and DEF, having AB equal to DE, and BG equal to EF, by hypothesis, and also having the angle ABG equal to DEF, they will be equal (*theorem* 5): therefore AG is equal to DF; but DF is equal to AC; therefore AG is equal to AC: that is, two oblique lines, one more remote from the perpendicular than the other, are equal; which is impossible (*theorem* 15): therefore, BC is not unequal to EF, and hence the triangle ABC is equal to the triangle DEF.

THEOREM 17.

68. Two straight lines perpendicular to a third are parallel.

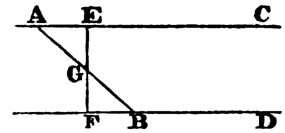


For, if the straight lines AC, BD, be not parallel, they will meet on one side or the other of the line AB; let them meet in O; then AC and OB are both perpendicular to AB, from the same point O; which is impossible (*theorem* 13).

THEOREM 18.

69. If two straight lines, AC and BD, make, with a third, AB, the sum of the two interior angles CAB, ABD, equal to two right angles, these two straight lines are parallel.

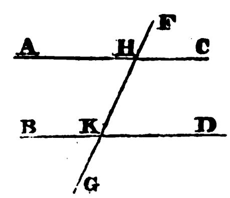
From G, the middle of AB, draw EGF, perpendicular to AC: then, since the sum of the angles ABD, ABF, is equal to two right angles (*theorem* 1), and, by hypothesis, the sum of the two angles ABD, BAC, is also equal to two right angles; therefore the two angles ABD, ABF, are together equal to the sum of the two angles ABD, BAC; and, taking away the common angle ABD, there remains the angle ABF=BAC; that is, GBF equal to GAE. But the angles BGF and AGE are also equal (*theorem* 3); and, since BG is equal to GA, therefore the triangles BGF and AGE, having a side and two adjacent angles of the one equal to a side and two adjacent angles of the other, are equal (*theorem* 6), and the angle BFG is equal to AEG; but AEG is, by construction, a right angle; therefore, BFG is also a right angle; and, since GEC is a right angle, the straight lines EC and FD are perpendicular to EF, and are, therefore, parallel to each other (*theorem* 17).



THEOREM 19.

70. If two straight lines, AC, BD, make with a third, HK, the alternate angles, AHK and HKD, equal, the two lines are parallel.

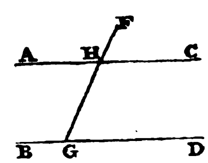
For, adding KHC to each of the angles AHK, HKD, the sum of the angles AHK, KHC, is equal to the sum of the angles HKD, KHC; but the angles AHK, KHC, are together equal to two right angles; therefore, also, the angles HKD, KHC, are also equal to two right angles; and, consequently, AC is parallel to BD (*theorem* 18).



THEOREM 20.

71. If two straight lines, AC, BD, are cut by a third, FG, so as to make the exterior angle, FHC, equal to the interior and opposite angle, HGD, on the same side, the two lines are parallel.

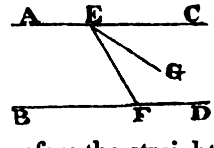
For, since the angle FHC is equal to the angle AHG, and since, when AC is parallel to BD, the angle AHG is equal to HGD (*theorem* 19), therefore the angle FHC is equal to HGD.



THEOREM 21.

72. If a straight line, EF, meet two parallel straight lines, AC, BD, the sum of the inward angles CEF, EFD, on the same side, will be equal to two right angles.

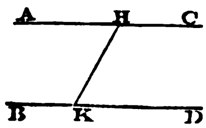
For, if not, suppose EG to be drawn through E, so that the sum of the angles GEF and EFD may be two right angles; then EG will be parallel to BD (*theorem* 18); and thus, through the same point E, two straight lines, EG, EC, are drawn, each parallel to BD; which is impossible (*ax.* 11, *p.* xi.); therefore no straight line that does not coincide with AC, is parallel to BD; wherefore the straight line AC is parallel to BD.



73. COROLLARY.—If a straight line is perpendicular to one of two parallel straight lines, it is also perpendicular to the other.

THEOREM 22.

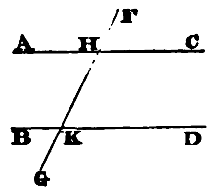
74. If a straight line, HK, meet two parallel straight lines, AC, BD, the alternate angles, AHK, HKD, shall be equal.



For, the sum of the angles CHK, HKD, is equal to two right angles; and the sum of the angles BKH, AHK, is also equal to two right angles; therefore the angle HKD must be equal to AHK.

THEOREM 23.

75. If a straight line FG, cut two parallel straight lines, AC, BD, the exterior angle, FHC, is equal to the interior and opposite angle HKD.

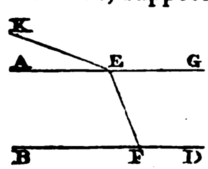


For, since the angle FHC is equal to the angle AHK (*theorem* 3), and the angle AHK equal to the angle HKD; therefore the angle FHC is equal to the angle HKD.

THEOREM 24.

76. If a straight line, EF, meet two other straight lines, EG, FD, and make the two interior angles, EFD, FEG, on the same side, less than two right angles, the lines EG, FD, meet, if produced, on the side of EF, on which the angles are less than two right angles.

For, if they do not meet on that side, they are either parallel, or else they meet on the other side. Now they cannot be parallel, for then the two interior angles would be equal to two right angles, instead of being less. Again, to show that they cannot meet on the other side, suppose EA to be parallel to DFB; then, because the sum of the angles EFD, FEG, is, by hypothesis, less than two right angles, that is, less than the sum of the two angles, FEK, FEG (*theorem* 1), and EFD is equal to FEA (*theorem* 20); therefore the sum of the two angles FEA, FEG, is less than the sum of the two angles FEK, FEG; and, taking FEG from both, FEA is less than FEK: hence, FB and EK must be on opposite sides of EA; and, therefore, can never meet.

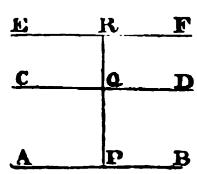


The truth of this proposition is assumed as an axiom in the Elements of Euclid, and made the foundation of parallel lines.

THEOREM 25.

77. Two straight lines, AB, CD, parallel to a third, EF, are parallel to one another.

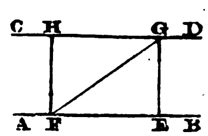
Draw the straight line PQR, perpendicular to EF. Because AB is parallel to EF, the line PR shall be perpendicular to AB; and, because CD is parallel to EF, the line PR is also perpendicular to CD: therefore AB and CD are perpendicular to the same straight line PQ; hence they are parallel (*theorem* 17).



THEOREM 26.

78. Two parallel straight lines are every where equally distant.

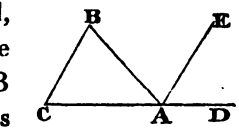
Let AB, CD, be two parallel straight lines. From any points, E and F, in one of them, suppose perpendiculars EG, FH, to be drawn; these, when produced, will meet the others at right angles, in H and G. Join FG· then,



because FH and EG are both perpendicular to AB, they are parallel (*theorem* 17); therefore, the alternate angles, HFG, FGE, which they make with FG are equal (*theorem* 22): and, because AB is parallel to CD, the alternate angles, GFE, FGH, are also equal; therefore the two triangles GEF, HFG, have two angles of the one equal to two angles of the other, each to each; and the side FG, adjacent to the equal angles, common; the triangles are therefore equal (*theorem* 6); and FH is equal to EG; that is, any two points, F, E, on the one of the lines, are equdistant from the other line.

THEOREM 27.

79. In any triangle, if one of the sides be *produced*, the exterior angle is equal to both the interior and opposite angles; and the three interior angles are equal to two right angles.



Let ABC be a triangle; produce any one of its sides, AC towards D; and, from the point A, let AE be drawn, parallel to BC; and, because of the parallels CB and AE, and the angle EAD=C, and the angle EAB=B (*theorems* 22, 23); therefore the sum of the two angles, EAD, EAB, is equal to the sum of the two angles C and B; that is, since the angle BAD is equal to the sum of the two angles BAE, EAD, the angle BAD is equal to the sum of the angles B, C. Hence the outward angle is equal to the sum of the inward opposite angles.

Again, because the angle BAD is equal to the sum of the angles B and C, add to each the angle BAC, and the sum of the two angles BAC, BAD, will be equal to the sum of the three angles BAC, B, C, or the three angles of the triangle; but the sum of the two angles BAC, BAD, is equal to two right angles (*theorem* 1); therefore the sum of the three angles of a triangle is equal to two right angles.

80. Corollary 1.—If two angles of one triangle be equal to two angles of another triangle, each to each, the third angle of the one shall be equal to the third angle of the other, and the triangles shall be equi-angular.

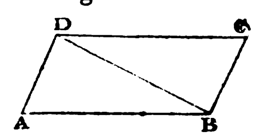
81. Corollary 2.—A triangle can have only one right angle.

82. Corollary 3.—In any right-angled triangle the sum of the two acute angles is equal to a right angle.

83. Corollary 4.—In an equilateral triangle, each of the angles is one-third of two right angles.

THEOREM 28.

84. The opposite sides of a parallelogram are equal, as well as the opposite angles.



Draw the diagonal BD. The triangles ADB, DBC, have the common side DB; also, because of the parallels, AB, CD, the angle ABD is equal to CDB (*theorem* 22); and, because of the parallels AD, BC, the angle ADB is equal to DBC; therefore the triangles (*theorem* 6) and the sides AB, DC, which are opposite the equal angles, are equal. In like manner AD and BC are equal; therefore the opposite sides of the parallelogram are equal.

Again, from the equality of the triangles, it follows, that the angle A is equal to the angle C; and it has been shown that the angles ADB, BDC, are respectively equal to the angles CBD, DBA; therefore the whole angle ADC is equal to the whole angle ABC, and thus the opposite angles are equal.

85. Corollary.—Two parallels, AB, CD, comprehended between two other parallels, AD, BC, are equal.

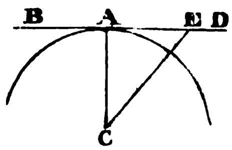
THEOREM 29.

86. If the opposite sides of a quadrilateral be equal, the figure is a parallelogram.

For, drawing the diagonal BD, (as before,) the triangles ABD, BDC, have the three sides equal, each to each; therefore the angle ADB, opposite to the side AB, is equal to the angle CBD, opposite to the side CD (*theorem* 10); hence the side AD is parallel to BC (*theorem* 19). For the like reason AB is parallel to CD: therefore the quadrilateral, ABCD, is a parallelogram.

THEOREM 30.

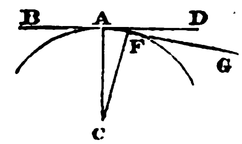
87. A straight line, BD, drawn perpendicular to the extremity of a radius, CA, is a *tangent* to the circumference.



For every oblique line, CE, is longer than the perpendicular CA (*theorem* 15); therefore the point E must be without the circle; and since this is true of every point in the line BD, except the point A, the line BD is a *tangent* (*def.* 9, *p.* viii).

THEOREM 31.

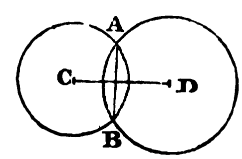
88. Only one tangent can be drawn from a point, A, in the circumference of a circle.



Let BD be a tangent at A, in the circumference, described with the radius CA; and let AG be another tangent, if possible; then, as CA would not be perpendicular to AG, another line, CF, would be perpendicular to AG, and so CF would be less than CA (*theorem* 14); therefore F would fall within the circle, and AF, if produced, would cut the circumference.

THEOREM 32.

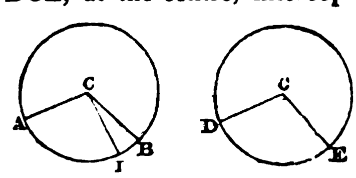
89. If two circumferences cut each other, the straight line which passes through their centres shall be perpendicular to the chord which joins the points of intersection, and shall divide it into two equal parts.



For the line AB, which joins the points of intersection, being a common chord to the two circles; if, through the middle of this chord, a perpendicular be drawn, it will pass through the points C, D, the centres of the two circles. But only one line can be drawn through two given points; therefore the straight line which passes through the centres is a perpendicular to the middle of the common chord.

THEOREM 33.

90. In the same circle, or in equal circles, equal angles ACB, DCE, at the centre, intercept equal arcs, AB, DE, on the circumference; and conversely, if the arcs AB, DE, be equal, the angles ACB and DCE are also equal.



If the angle ACB be equal to DCE, these two angles may be placed on each other; and, as their sides are equal, the point A will fall on D, and the point B on E; but then the arc AB must also fall on DE; for, if the two arcs did not coincide, there would be, in one or the other, points unequally distant from the centre; therefore the arc AB is equal to DE.

Next, if the arc AB be equal to DE, the angle ACB shall be equal to DCE; for, if they are not equal, let ACB be the greater, and take ACI equal to DCE; then, by what has been demonstrated, AI is equal to DE; but, by hypothesis, the arc AB is equal to DE; therefore the arc AI is equal to AB, which is impossible: therefore the angle ACB is equal to DCE.

THEOREM 34.

91. An angle, ACB, at the centre of a circle, is double of the angle at the circumference, upon the same arc, AB.

Fig. 1.

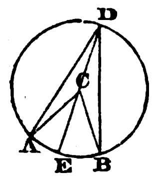
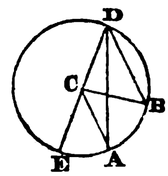


Fig. 2.



Draw DC, (*fig.* 1,) and produce it to E. First, let the angle at the centre be within the angle at the circumference, then the angle ACE is equal to the sum of the angles CAD, CDA (*theorem* 27); but, because CA is equal to CD, the angle CAD is equal to CDA (*theorem* 11); therefore the angle ACE is equal to twice the angle CDA. By the same reason the angle BCE is equal to twice the angle CDB; therefore the whole angle ACB is double the whole angle ADB.

Next, let the angle at the centre (*fig.* 2) be without the angle at the circumference. It may be demonstrated, as in the first case, that the angle ECB is equal to twice the angle EDB, and that the angle ECA, a part of the first, is equal to twice EDA, a part of the second; therefore, the remainder, ACB, is double the remainder ADB.

THEOREM 35.

92. The angles, ADB, AEB, in the same segment, AEB, of a circle, are equal to one another.

Fig. 1.

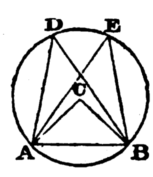
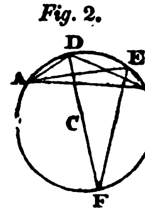


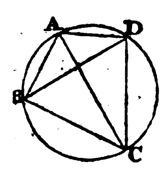
Fig. 2.



Let C (*fig.* 1) be the centre of the circle; and, first, let the segment AEB be greater than a semi-circle. Draw CA, CB, to the ends of the base of the segment; then each of the angles, ADB, AEB, will be half of the angle ACB (*theorem* 34); therefore the angles ADB and AEB are equal.

Next, let the segment AEB (*fig.* 2) be less than a semi-circle; draw the diameter DCF, and join EF; and, because the segment ADEF is greater than a semi-circle, by the first case, the angle ADF is equal to AEF. In like manner, because the segment BEDF is greater than a semi-circle, the angle BDF is equal to the angle BEF; therefore the whole angle ADB is equal to the whole angle AEB.

THEOREM 36.

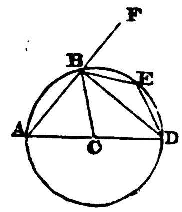


93. The sum of the opposite angles of any quadrilateral, ABCD, inscribed in a circle, is equal to two right angles.

Draw the diagonals AC, BD. In the segment ABCD, the angle ABD is equal to ACD; and, in the segment CBAD, the angle CBD is equal to CAD (*theorem* 35); therefore the whole angle ABC is equal to the sum of the two angles ACD, CAD; and, adding ADC, the sum of the two angles, ABC, ADC, is equal to the sum of the three angles. Now these three angles are the angles of the triangle ADC, and therefore equal to two right angles (*theorem* 27): therefore the sum of the two angles ABC, ADC, is equal to two right angles. In the same manner it may be demonstrated that the sum of the two angles BAD, BCD, is equal to two right angles.

THEOREM 37.

94. An angle ABD, in a semi-circle, is a right angle; an angle BAD, in a segment greater than a semi-circle, is less than a right angle; and an angle, BED, in a segment less than a semi-circle, is greater than a right angle.

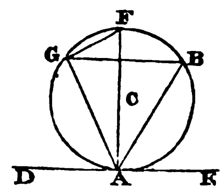


Produce AB to F, draw BC to the centre, and, because CA is equal to CB, the angle CBA is equal to CAB (*theorem* 11). In like manner, because CD is equal to CB, the angle CBD is equal to CDB; therefore the sum of the two angles CBA, CBD, is equal to the sum of the two angles CAB, CDB; that is, the angle ABD is equal to the sum of the two angles CAB, CDB; but this last sum is equal to the angle DBF (*theorem* 27); therefore the angle ABD is equal to the angle DBF: but, when the angles are equal on each side of a straight line which meets another, each of these angles is a right angle; therefore each of the angles ABD and DBF is a right angle; and, consequently, the angle ABD in a semi-circle is a right angle.

Again, because in the triangle ABD, the angle ABD is a right angle; therefore BAD, which is manifestly in a segment less than a semi-circle is less than a right angle: and, lastly, because ABED is a quadrilateral in a circle, the sum of the two angles A, E, is equal to two right angles; but the angle A is less than a right angle; therefore E, which is in a segment less than a semi-circle, is greater than a right angle.

THEOREM 38.

95. The angle BAE, contained by a tangent AE to a circle, and a chord AB, drawn from the point of contact, is equal to the angle AGB in the alternate segment.



Let the diameter ACF be drawn, and GF be joined; and, because the angles FGA, FAE, are right angles (*theorems* 37, 30), and of these FGB, a part of the one, is equal to FAB, a part of the other, (*theorem* 35,) the remainders BAE, BAG, are equal.

The geometric definitions, &c. having been given generally, and explained in the preceding pages, it now becomes necessary to add the following elucidations:—

96. EQUIVALENT FIGURES are such as have equal surfaces, without regard to their form.

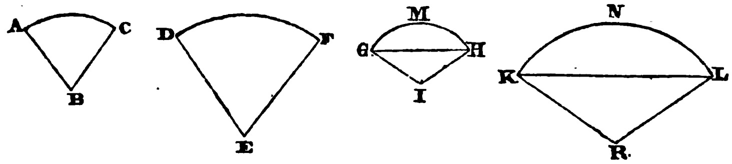
97. IDENTICAL FIGURES are such as would entirely coincide, if the one be applied to the other.

98. In EQUIANGULAR FIGURES, the sides which contain the equal angles, and which adjoin equal angles, are *homologous*.

99. Two figures are *similar*, when the angles of the one are equal to the angles of the other, each to each, and the homologous sides are proportionals.

100. In two CIRCLES, similar sectors, similar arcs, or similar segments, are those which have equal angles at the centre.

Thus, if the sector ABC be similar to the sector DEF, then the angle ABC will be equal to the angle DEF; or, if the arc AC be similar to the arc DF, then the angle at B will be equal to the angle at E. Also, if the segment GMH be similar to the segment KNL, the angle I will be equal to the angle R.



101. The AREA of a figure is the quantity of surface, containing a certain number of units of any given scale; as of inches, feet, yards, &c.

THEOREM 39.

102. Parallelograms which have equal bases and equal altitudes are equal.

Take the two parallelograms, ABCD, and ABEF, upon the same base, AB, and between the same parallels, AB and DE; these parallelograms are equal.

Fig. 1.

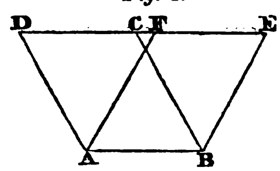
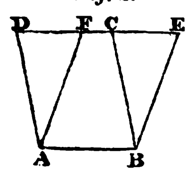


Fig. 2.

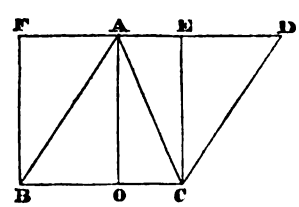


For, in the parallelogram ABCD (*fig.* 1), the opposite sides CD and AB are equal; and in the parallelogram ABEF, the opposite sides EF and AB are equal; therefore EF is equal to CD (84).* Again, in the parallelogram ABCD (*fig.* 2), the side CD is equal to AB; and, in the parallelogram ABEF, the side FE is equal to AB; therefore EF is equal to CD. Now, in *fig.* 1, since CD is equal to EF, add CF to both; then will DF be equal to CE. In *fig.* 2, take away the common part CF, and there will remain DF equal to CE. Therefore, in each of these figures, the three straight lines AD, DF, FA, are respectively equal to the three straight lines BC, CE, EB; and, consequently, the triangle ADF is equal to the triangle BCE: therefore, from the quadrilateral ABED take away the triangle BCE, there will remain the parallelogram ABCD; and, from the same quadrilateral, take away the equal triangle ADF, and there will remain the parallelogram ABEF: therefore the parallelogram ABCD is equal to the parallelogram ABEF.

103. COROLLARY.—Every parallelogram is equal to a rectangle, of the same base and altitude.

THEOREM 40.

104. Any triangle is equal to half a parallelogram of the same base and altitude.



For the triangle ABC is equal to the triangle ACD, and the parallelogram ABCD is equal to the sum of both triangles; and consequently, double to one of them.

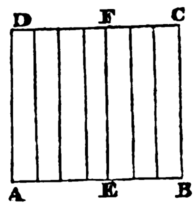
105. COROLLARY 1.—Hence every triangle is half a rectangle, having the same base and altitude.

106. COROLLARY 2.—Triangles which have equal bases and equal altitudes are equal.

* The figures thus inserted in a parenthesis refer to a preceding or a following paragraph; as in this instance, to 84, on page xix.

THEOREM 41.

107. Rectangles, of the same altitude, are to one another as their bases.'

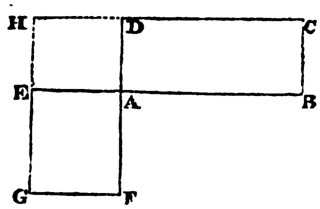


Let ABCD, AEFD, be two rectangles, which have a common altitude AD; they are to one another as their bases AB, AE.

For, suppose that the base AB contains seven equal parts, and that the base AE contains four similar parts; then, if AB be divided into seven equal parts, AE will contain four of them. At each point of division draw a perpendicular to the base, and these will divide the figure ABCD into seven equal rectangles (102); and, as AB contains seven such parts as AE contains four, the rectangle ABCD will also contain seven such parts as the rectangle AEFD contains four; therefore the bases AB, AE, have the same ratio that the rectangles ABCD, AEFD, have.

THEOREM 42.

108. Rectangles are to one another as the products of the numbers which express their bases and altitudes.



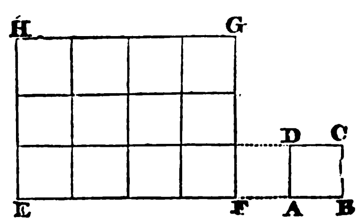
Let ABCD, AEGF, be two rectangles, and let some line taken, as a unit, be contained m times in AB, the base of the one, and n times in AD, its altitude; also p times in AE, the base of the other, and q times in AF, its altitude; the rectangle ABCD shall be to the rectangle AEGF, as the product mn is to the product pq.

Let the rectangles be so placed that their bases AB, AE, may be in a straight line; then their altitudes AD, AF, shall also form a straight line (48). Complete the rectangle EADH; and, because this rectangle has the same altitude as the rectangle ABCD, when EA and AB are taken as their bases; and the same altitude as the rectangle AEGF, when AD, AF, are taken as their bases; we have

the rectangle ABCD : ADHE :: AB : AE :: $m : p$ .... (107)
But........ $m : p :: mn : pn$
therefore, ABCD : ADHE :: $mn : pn$.
In like manner, ADHE : AEGF :: $pn : pq$

But, placing the terms of these two sets of proportionals alternately, we have,

ADHE : pn :: ABCD : mn
and .... ADHE : pn :: AEGF : pq
therefore, by equality, ABCD : mn :: AEGF : pq
therefore, alternately, ABCD : AEGF :: $mn : pq$.



109. Observation.—If ABCD, one of the rectangles, be a square, having the measuring unit for its side; this square may be taken as the measuring unit of its surfaces; because the linear unit, AB, is contained p times in EF, and q times in EH, by the proposition.

$1 \times 1 : pq$ :: ABCD : EFGH.

Hence the rectangle EFGH will contain the superficial unit ABCD, as often as the numeral product pq contains unity.

Consequently, the product pq will express the area of the rectangle, or will indicate how often it contains the unit of its surfaces.

Thus, if EF contains the linear unit AB four times, and EH contains it three times, the area EFGH will be $3\times4=12$: that is, equal to twelve times a square whose side AB is $=1$.

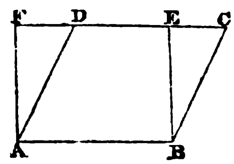
In consequence of the surface of the rectangle EFGH being expressed by the product of its sides, the rectangle, or its area, may be denoted by the symbol $EF\times FG$, in conformity to the manner of expressing a product in arithmetic.

However, instead of expressing the area of a square, made on a line AB, thus, $AB\times AB$; it is thus expressed AB^2.

110. NOTE.—A rectangle is said to be contained by two of its sides, about any one of its angles.

THEOREM 43.

111. The area of a parallelogram is equal to the product of its base and altitude.



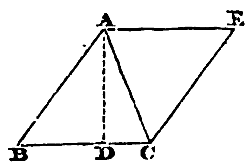
For the parallelogram ABCD is equal to the rectangle ABEF, which has the same base AB, and the same altitude (102), and this last is measured by $AB\times BE$, or by $AB\times AF$; that is, the product of the base of the parallelogram and its altitude.

112. COROLLARY.—Parallelograms of the same base are to one another as their altitudes; and parallelograms of the same altitudes are to one another as their bases.

For, in the former case, put B for their common base, and A, a, for their altitudes; then we have $B\times A : B\times a :: A : a$. And, in the latter case, put A for their common altitude, and B, b, for their bases; then $B\times A : b\times A :: B : b$.

THEOREM 44.

113. The area of a triangle is equal to the product of the base by half its altitude.

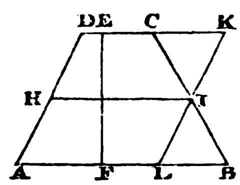


For the triangle ABC is half the parallelogram ABCE, which has the same base, BC, and the same altitude AD (104); but the area of the parallelogram is $BC\times AD$ (111), therefore, the area of the triangle is $\frac{1}{2}BC\times AD$, or $BC\times\frac{1}{2}AD$.

114. COROLLARY.—Two triangles of the same base are to one another as their altitudes; and two triangles, of the same altitude, are to one another as their bases.

THEOREM 45.

115. The area of every trapezoid, ABCD, is equal to the product of half the sum of its parallel sides, AB, DC, by its altitude, EF.



Through I, the middle of the side BC, draw KL, parallel to the opposite side AD, and produce DC until it meet KL in K. In the triangles IBL, ICK, the side IB is equal to IC, and the angle B equal to C (74), the angle BIL equal to CIK; therefore the triangles are equal (54), and the side CK equal to BL. Now the parallelogram ALKD is the sum of the polygon ALICD; and the triangle CIK, and the trapezoid ABCD, is the sum of the same polygon and the triangle BIL; therefore, the trapezoid ABCD is equal to the parallelogram

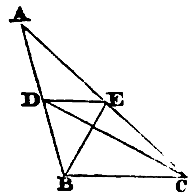
ALKD, and has, for its measure, AL × EF. Now AL is equal to DK, and BL equal to CK: and CD = DK − CK; but DK is equal to AL, and CK equal to BL;

$$\text{Therefore } CD = AL - BL.$$
$$\text{But} \ldots\ldots AB = AL + BL,$$
$$\text{Therefore, } AB + CD = 2AL$$
$$\text{Consequently } \tfrac{1}{2}(AB + CD) = AL.$$
$$\text{It follows that} \ldots AL \times EF = \tfrac{1}{2}(AB + CD) \times EF.$$

THEOREM 46.

116. A straight line, DE, drawn parallel to the side of a triangle ABC, divides the other sides AB, AC, proportionally, or so that AD : DB :: AE : EC.

Join BE and DC: the two triangles BDE, CDE, have the same base, DE, and they have also the same altitude, because BC is parallel to DE; and, consequently, the triangles DBE and DCE are equal. Since the triangles BED and AED have the same altitude, they are to one another as their bases; and since the triangles CED and AED have the same altitude, they are to one another as their bases.



Therefore, the triangle BDE : ADE :: BD : DA. But since the triangle BDE is equal to the triangle CED, therefore the triangle CED : ADE :: BD : DA.

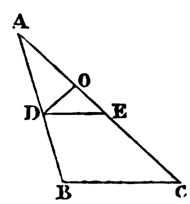
But the triangle CED : ADE :: CE : EA.

It follows that, BD : DA :: CE : EA.

THEOREM 47.

117. If the two sides, AB, AC, of a triangle be cut proportionally by the line DE, so that AD : DB :: AE : EC, the line DE shall be parallel to the remaining side of the triangle.

For, if DE be not parallel to BC, some other line, DO, will be parallel to BC; then, by the preceding proposition,



AD : DB :: AO : OC.

And, by hypothesis, AD : DB :: AE : EC.

Therefore,........ AO : OC :: AE : EC.

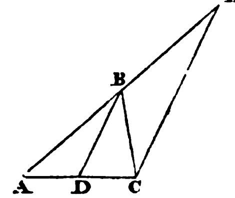
And, by addition, AC : OC :: AC : EC.

And hence OC must be equal to EC; which is impossible, unless the point O coincide with E; therefore no line besides DE can be parallel to BC.

THEOREM 48.

118. A line, BD, which bisects any angle, ABC, of a triangle, will divide the opposite side AC into two segments, AD, DC, which shall have the same ratio as the other two sides, AB, BC, of the triangle.

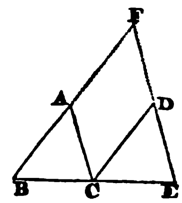
From C, one extremity of the base, draw CE, parallel to BD, meeting AB produced in E. Then the angle ABD is equal to the angle BEC (75), and the angle CBD equal to BCE (74); but, by hypothesis, the angle ABD is equal to CBD; therefore the angle BEC is equal to BCE: hence the side BC is equal to BE (63). Now, because ACE is a triangle, and BD is drawn parallel to one of its sides, AD : DC :: AB : BE (116); but, since BE is equal to BC; therefore AD : DC :: AB : BC.



THEOREM 49.

119. Two equiangular triangles have their sides proportional, and are similar to each other.

Let ABC, DCE, be two triangles, which have their angles equal, each to each; viz. BAC equal to CDE, ABC equal to DCE, and ACB equal to DEC; the homologous sides, or the sides adjacent to the equal angles, shall be proportionals; that is, BC : CE :: BA : CD, and BA : CD :: AC : DE.



Place the homologous sides BC, CE, in a straight line; and, because the angles B and E are together less than two right angles, the lines BA and ED shall meet, if produced (76): let them meet in F. Then, since BCE is a straight line, and the angle BCA equal to E, AC is parallel to EF. In like manner, because the angle DCE is equal to B, the straight line CD is parallel to BF; therefore ACDF is a parallelogram.

120. In the triangle BFE, the straight line AC is parallel to FE; wherefore BC : CE :: BA : AF (116). Again, in the same triangle, BFE, CD is parallel to BF; therefore BC : CE :: FD : DE; but, by substituting CD for its equal AF, in the first set of proportionals, and AC for its equal FD in the second set,

we have............BC : CE :: BA : CD by the first,
and ....BC : CE :: AC : DE by the second,
therefore, by equality, BA : CD :: AC : DE;

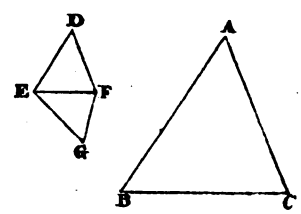
therefore the homologous sides are proportionals; and, because the triangles are equiangular, they are similar.

SCHOLIUM.—It may be remarked that the homologous sides are opposite to the equal angles.

THEOREM 50.

121. Two triangles, which have their homologous sides proportionals, are equiangular and similar.

Suppose that BC : EF :: AB : DE
and that.... AB : DE :: AC : DF



the triangles ABC, DEF, have their angles equal: viz. A equal to D, B equal to E, and C equal to F. At the point E make the angle FEG equal to B, and at the point F make the angle EFG equal to C, then G shall be equal to A (80), and the triangles GEF, ABC, shall be equiangular; therefore,

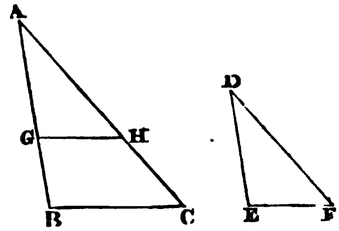
by the preceding prop. BC : EF :: AB : EG
and, by hypothesis, .. BC : EF :: AB : DE; therefore EG is equal to DE.
In like manner....... BC : EF :: AC : FG
and, by hypothesis,... BC : EF :: AC : DF; therefore FG is equal to DF.

Thus, it appears that, the triangles DEF, GEF, have their three sides equal, each to each, therefore they are equal (58). But, by construction, the triangle GEF is equiangular to the triangle ABC; therefore, also, the triangles DEF, ABC, are equiangular and similar.

THEOREM 51.

122. Two triangles which have an angle of the one equal to an angle of the other, and the sides about them proportionals, are similar.

Let the angle A equal D, and suppose that AB : DE :: AC : DF, the triangle ABC is similar to DEF.



Take AG equal to DE, and draw GH parallel to BC, the angle AGH shall be equal to ABC (75), and the triangle AGH equiangular to the triangle ABC; therefore AB : AG :: AC : AH; but AG is equal to DE;

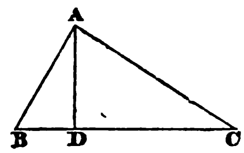
therefore........AB : DE :: AC : AH,

but, by hypothesis AB : DE :: AC : DF; therefore AH is equal to DF.

The two triangles AGH, DEF, have therefore an angle of the one equal to an angle of the other, and the sides containing these angles equal; therefore they are equal (53); but the triangle AGH is similar to ABC.

THEOREM 52.

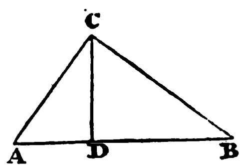
123. A perpendicular, AD, drawn from the right angle, A, of a right-angled triangle, upon the hypothenuse, or longest side, BC, will divide that triangle into two others, which will be similar to each other, and to the whole.



The triangles BAD and BAC have the common angle B; and, besides, the right angle BDA is equal to the right angle BAC; therefore, the third angle BAD of the one is equal to the third angle C of the other (80); therefore the two triangles are equiangular and similar. In like manner it may be demonstrated that the triangle DAC is equiangular and similar to the triangle BAC; therefore the three triangles are equiangular and similar to one another.

THEOREM 53.

124. The square described upon the hypothenuse, or longest side, is equal to the squares described upon the other two sides.



From the right angle C draw CD, perpendicular to the hypothenuse AB; then the triangle ABC is divided into two triangles, ADC, CDB, which are similar to one another, and to the whole triangle ABC (123);

therefore, by the similar triangles, ABC, CBD,..AB : BC :: BC : BD;

again, by the similar triangles, BAC, CAD,.... AB : AC :: AC : AD;

therefore, reducing the first to an equation,.... $AB \times BD = BC^2$

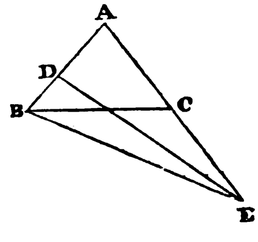
and, reducing the second analogy to an equation, $AB \times AD = AC$

then, adding these two equations ...... $AB \times (AD+BD) = AC^2 + BC$

but, since AB is equal to the sum of the two lines AD, DB, therefore $AB^2 = AC^2 + BC$.

THEOREM 54.

125. Two triangles, which have an angle of the one equal to an angle of the other, are to each other as the rectangle of the sides about the equal angles.



Suppose the two triangles joined, so as to have a common angle, and let the two triangles be ABC, ADE. Draw the straight line BE.

Now the triangle ABE : tria. ADE :: AB : AD;

Therefore the triangle ABE : tria. ADE :: AB $\times$ AE : AD $\times$ AE.

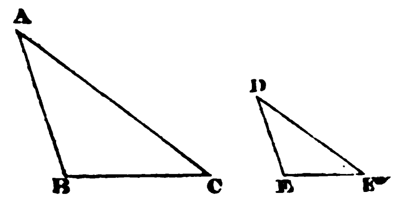
Or, alternately, the triangle ABE : AB $\times$ AE :: the triangle ADE : AD $\times$ AE.

In like manner, the triangle ABE : AB $\times$ AE :: the triangle ABC : AB $\times$ AC.

Therefore, by equality, the tria. ABC : tria. ADE :: AB $\times$ AC : AD $\times$ AE.

THEOREM 55.

126. Similar triangles are to one another as the squares of their homologous sides.



Let the angle A be equal to the angle D, and the angle B equal to E.

Then AB : DE :: AC : DF (119)

and AB : DE :: BC : EF

therefore, by multiplying the corresponding terms, we have $AB^2 : DE^2$ :: AC $\times$ AB : DF $\times$ DE.

But the triangle BAC : triangle EDF :: AC $\times$ AB : DF $\times$ DE (126).

Therefore the triangle ABC : triangle DEF :: $AB^2 : DE^2$.

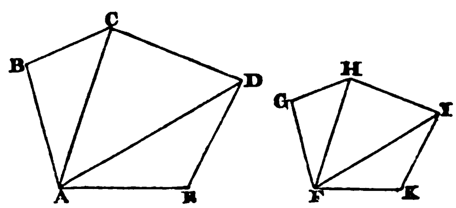
Or thus, let $\triangle$ signify a triangle; then (126)—

$$\triangle ABC : \triangle DEF :: AB \times AC : DE \times DF.$$
$$\triangle ABC : \triangle DEF :: AB \times BC : DE \times EF.$$
$$AC \times BC : DF \times EF :: \triangle ABC : \triangle DEF.$$

Therefore, by multiplication, $\triangle ABC : \triangle DEF :: AB^2 : DE^2$.

THEOREM 56.

127. Similar polygons are composed of the same number of triangles, which are similar, and similarly situated.



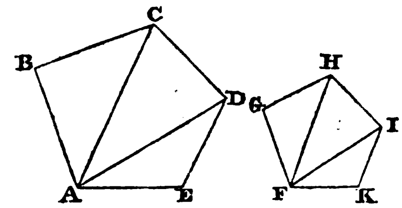
In the polygon ABCDE, draw from any angle A, the diagonals AC, AD; and, in the other polygon, FGHIK, draw, in like manner, from the angle F, which is homologous to A, the diagonals FH, FI.

Since the polygons are similar, the angle B is equal to its homologous angle G; and, besides, AB : BC :: FG : GH; therefore, the triangles ABC and FGH are similar (122), and the angle BCA is equal to GHF; these equal angles being taken from the equal angles BCD, GHI, the remainders ACD, FHI, are equal: but, since the triangles ABC and FGH are similar, we have AC : FH :: BC : GH; and, because of the similitude of the polygons, we have BC : GH :: CD : HI; therefore, AC : FH :: CD : HI. Now it has been shown that the angle ACD is equal to FHI; therefore the triangles ACD, FHI, are similar (122).

In like manner, it may be demonstrated that, the remaining triangles of the two polygons are similar; therefore the polygons are composed of the same number of similar triangles, similarly situated.

THEOREM 57.

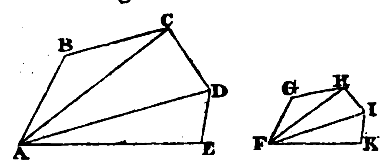
128. The perimeters of similar polygons are to one another as their homologous sides.



AB : FG :: BC : GH.
BC : GH :: CD : HI.
Therefore, AB : FG :: AB+BC+CD : FG + GH + HI (95); wherefore AB is to FG as the perimeter of the polygon ABCD is to the perimeter of the polygon FGHIK.

THEOREM 58.

129. The areas of similar polygons are as the squares of their homologous sides.



Let the polygons be ABCDE and FGHIK; from any angle, A, draw the diagonals AC, AD; and, from the homologous angle F, draw the diagonals FH, FI; then the triangles ABC, ACD, ADE, are respectively equal and similar to the triangles FGH, FHI, FIK.

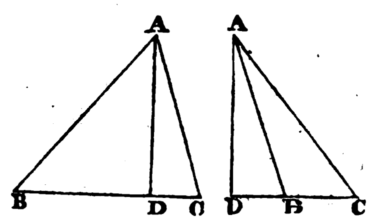
Therefore the triangle ABC : triangle FGH :: AC^2 : FH^2
And .... the triangle ACD : triangle FHI :: AC^2 : FH^2.
Therefore the triangle ABC : triangle FGH :: ACD : FHI.

In the same manner it may be demonstrated that the triangle ACD : triangle FHI :: ADE : FIK, and so on, if the polygons consist of more triangles. Hence (95) the triangle ABC is to the triangle FGH as the sum of the triangles ABC, ACD, ADE, to the sum of the triangles FGH, FHI, FIK; but the sum of the triangles ABC, ACD, ADE, compose the whole polygon ABCDE, and the sum of the triangles FGH, FHI, FIK, compose the polygon FGHIK; wherefore the triangle ABC is to the triangle FGH as the polygon ABCDE is to the polygon FGHIK; but the triangle ABC is to the triangle FGH as AB^2 is to FG^2; therefore the similar polygons are as the squares of their homologous sides.

130. Corollary.—If three similar figures have their homologous sides equal to the three sides of a right-angled triangle, the figure made on the side opposite to the right angle shall be equal to the other two.

THEOREM 59.

131. In any triangle, ABC, the square of AB, opposite to one of the acute angles, is equal to the difference between the sum of the squares of the other two sides, and twice the rectangle BD × DC, made by the perpendicular AD, to the side BC.



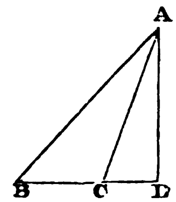
There are two cases, according as the perpendicular falls within or without the triangle. In the first case, BD = BC — CD; and, in the second case, BD = CD — BC.

In either case .... $BD^2 = BC^2 + CD^2 - 2BC \times CD$.
But (124) .... $AB^2 = AD^2 + BD^2$
and (124) .... $AD^2 + CD^2 = AC^2$.
Therefore, by addition, ... $AB^2 = AC^2 + BC - 2B \times CD$.

THEOREM 60.

132. In any obtuse-angled triangle, the square of the side opposite to the obtuse angle is equal to the sum of the squares of the other two sides, and twice the rectangle, $BC \times CD$, made by the perpendicular, AD, upon the side BC.

For .... $BD = BC + CD$;
Therefore, ... $BD^2 = BC^2 + CD^2 + 2BC \times CD$;
But, (124) .... $AB^2 = AD^2 + BD^2$
and (124) .. $AD^2 + CD^2 = AC^2$

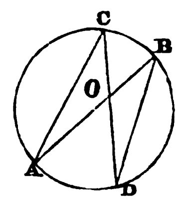


Therefore, by adding these three equations together,

$$AB^2 = AC^2 + BC^2 + 2BC \times CD.$$

THEOREM 61.

133. If any two chords, in a circle, cut each other, the rectangle of the segments of the one is equal to the rectangle of the segments of the other.



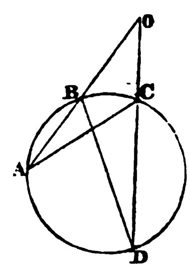
Let AB and CD cut each other in O; then $OA \times OB = OD \times OC$.

For, join AC and BD: then, in the triangles AOC, BOD, the vertical angles at O are equal; also the angle $A = D$ and $C = B$ (92), consequently the triangles AOC and DOB are similar, and their homologous sides proportional.

Whence $AO : OC :: DO : OB$
Wherefore $AO \times OB = OD \times CO$.

THEOREM 62.

134. If any two chords, in a circle, be produced to meet each other, the rectangle of the two distances, from the point of intersection, to each extremity of the one chord, is equal to the rectangle of the two distances from the point of intersection to each extremity of the other chord.



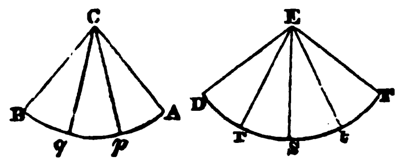
Let AB and CD be two chords, and let them be produced to meet in O; $OA \times OB = OD \times OC$.

For, join AC and BD; then, in the triangles AOC and DOB the angle at O is common, and the angle $A = D$ (92); therefore the third angle, ACB, of the one triangle is equal to the third angle, DBO, of the other; consequently the triangles AOC and DOB are similar, and their homologous sides proportional.

Whence $AO : OC :: DO : OB$
Wherefore, $AO \times OB = OD \times OC$.

THEOREM 63.

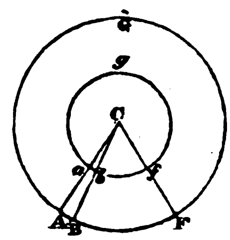
135. In the same circle, or in equal circles, any angles, ACB, DEF, at the centres, are to each other as the arcs AB, DF, of the circles intercepted between the lines which contain the angles.



Let us suppose that the arc AB contains three of such parts as DF contains four. Let A*p*, *pq*, *q*B, be the equal parts in AB, and D*r*, *rs*, &c. the equal parts in DF: draw the lines C*p*, C*q*, E*r*, E*s*, &c.; the angles AC*p*, *p*C*q*, *q*CB, DE*r*, &c. all are equal; therefore, as the arc AB contains $\frac{1}{4}$th part of the arc DF three times, the angle ACB will evidently contain $\frac{1}{4}$ of the angle DEF also three times; and, in general, whatever number of times the arc AB contains some part of the arc DF, the same number of times will the angle ACB contain a like part of the angle DEF.

THEOREM 64.

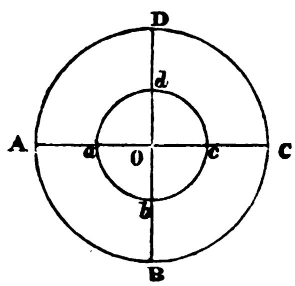
136. In two different circles, similar arcs are as the radii of the circles.



Let the circles AFG, *afg*, be each described from the centre C. Draw the radii CA, CF, then the arcs A*f* and *af* are similar. Draw CB, indefinitely, near CA, and the sectors C*ab*, CAB, will approach very nearly to isosceles triangles, which are similar to each other; therefore, C*a* : CA :: *ab* : AB; let BF be divided into small arcs, each equal to AB, and draw the radii from each point of division; then *bf* will contain as many arcs, each equal to *ab*, as the arc BF contains arcs equal to AB; therefore *af* is the same multiple of *ab* that AF is of AB; whence C*a* : CA :: *af* : AF.

THEOREM 65.

137. The circumference of circles are to one another as their diameters.



For, let the circumferences ABCD, *abcd*, be divided into quadrants by the radii O*a*B, O*b*B, O*c*C, O*d*D, then the quadrants AB, *ab*, will be similar arcs;

therefore, OA : O*a* :: AB : *ab*
wherefore, OA : O*a* :: 4AB : 4*ab*.

PRACTICAL GEOMETRY.

PROBLEM 1.

138. To make an angle at a given point E, *fig.* 1, in a straight line, DE, equal to a given angle ABC, *fig.* 2.

From the centre B, with any radius, describe an arc *gh*, cutting BA at *g*, and BC at *h*; from the point E, with the same radius, describe an arc, *ik*, cutting ED at *i*; make *ik* equal to *gh*, and through the point *k* draw EF: then the angle DEF will be equal to the given angle ABC.

Fig. 1.

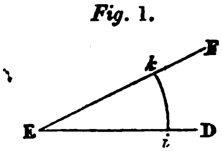
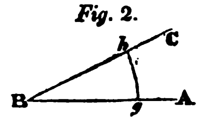
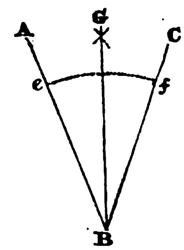


Fig. 2.



PROBLEM 2.

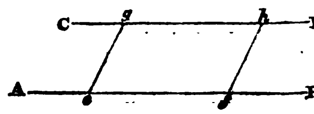


139. To bisect a given angle ABC.

From BA and BC cut off B*e* and B*f*, equal to each other; from the points *e* and *f*, as centres, with any radius greater than the distance *ef*, describe arcs, cutting each other at G, and join BG, which will bisect the angle ABC, as required.

PROBLEM 3.

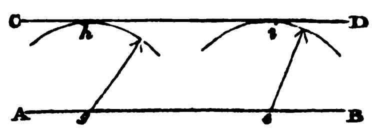
140. Through a given point, *g*, to draw a straight line parallel to a given straight line, AB.



From *g*, draw *ge*, to cut AB at any angle in the point *e*: in AB take any other point *f*; make the angle B*fh* equal to *feg*, and make *fh* equal to *eg*, and through the points *g* and *h* draw the line CD; then CD will pass through *g* parallel to AB, as required.

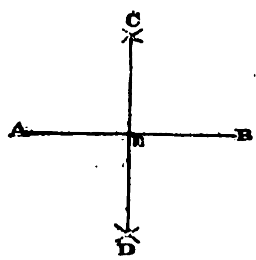
PROBLEM 4.

141. At a given distance, parallel to a given straight line, AB, to draw a straight line, CD.



In the given straight line AB, take any two points, *g* and *e*; and, from the centres *g* and *e*, with the given distance, describe arcs at *h* and *i*; draw the line CD to touch the arcs *h* and *i*; then CD will be parallel to AB, at the distance required.

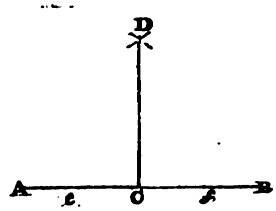
PROBLEM 5.



142. To bisect a given straight line, AB, by a perpendicular.

From the points A and B, with any distance greater than the half of AB, describe arcs cutting each other in C and D; join CD, and this line will bisect AB perpendicularly.

PROBLEM 6.



143. From a given point, C, in a given straight line, AB, to erect a perpendicular.

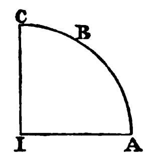
In the straight line, AB, take any two points *e* and *f*, equally distant from C: from the points *e* and *f*, with any equal radius, greater than the half of *ef*, describe arcs, cutting each other at D, and draw CD, which will be perpendicular to AB.

For further elucidation and examples refer to the Introductory Chapter to Practical Carpentry.

PLANE TRIGONOMETRY.

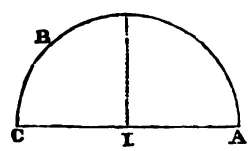
DEFINITIONS OF TERMS IN TRIGONOMETRY.*

144. The COMPLEMENT OF AN ARC is the difference between that arc and a quadrant or quarter of a circle.



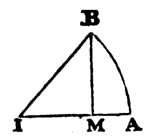
Thus, the arc BC, which is the difference between AC and AB, is the complement of AB; and AB is, in like manner, the complement of BC.

145. THE SUPPLEMENT OF AN ARC is the remainder between that arc and a semi-circle.

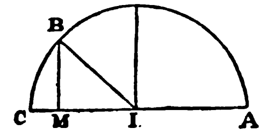


Thus, the arc given being AB, its supplement is BC.

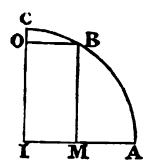
146. The SINE OF AN ARC is a straight line, drawn from one extremity of the arc, upon and perpendicular to a radius or diameter.



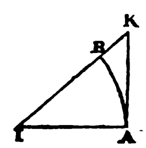
Thus, BM is the *sine* of the arc AB; and here it is evident that an arc and its supplement have the same sine.



147. The CO-SINE OF AN ARC is the sine of the complement of that arc. Hence, BO or IM is the co-sine of the arc AB; and, therefore, the sine of the complement BC.

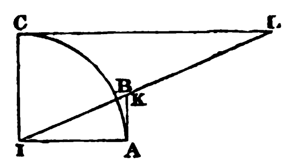


148. The TANGENT OF AN ARC is a straight line drawn from one extremity of the arc, where it touches it, to meet the prolongation of the radius through the other extremity.



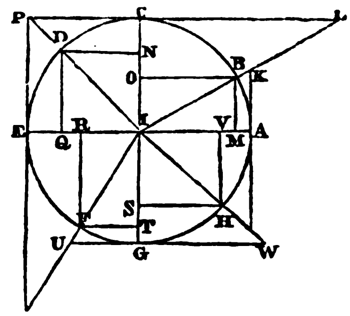
The line AK, touching the arc at A, and extended to meet the radius IB produced, is the tangent of the arc AB.

149. The CO-TANGENT OF AN ARC is the tangent of the complement of that arc.



Thus, CL is the co-tangent of the arc AB, or the tangent of the arc BC.

* Trigonometry is that branch of Geometry which treats exclusively on the properties, relations, and measurement, of triangles.



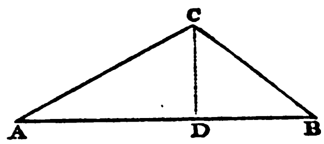
In the annexed diagram let AB, AC, AD, AE, AF, AG, AH, to A, be the several portions of the circumference, by supposing the point B to revolve round the circumference from A to B, C, D, E, F, G, H, the sine of any arc, in the first quadrant, increases from A to C, where it is the greatest possible, and then decreases to E, where it becomes zero; the sine will, therefore, be positive for the first semi-circumference, and in the other half it will be negative.

The *co-sine* will be positive in the first quarter, negative in the second and third, and again positive in the fourth.

The *tangent* will be positive in the first quarter, negative in the second, positive in the third, and negative in the fourth.

TRIGONOMETRY.—THEOREM 1.

150. If a perpendicular be drawn from an angle of a triangle, to the opposite side, which is the base; then, as the base is to the sum of the two sides, so is the difference of the sides to the difference of the segments of the base.



For, (*theorem* 53, *page* xxviii.)..$AC^2 - CD^2 = AD^2$

and again, (*theorem* 53,) ...... $BC^2 - CD^2 = BD^2$.

Subtract the second equation from the first, and the result is.............................. $AC^2 - BC^2 = AD^2 - BD^2$:

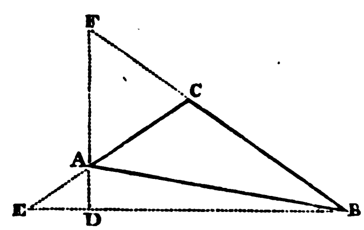
but, since the difference of the squares of any two quantities is equal to a rectangle contained by their sum and difference;

therefore .... $(AC + BC)(AC - BC) = (AD + BD)(AD - BD)$

Whence,................ $AD + BD : AC + BC :: AC - BC : AD - BD$.

TRIGONOMETRY.—THEOREM 2.

151. The sum of the two sides of a triangle is to their difference as the tangent of half the sum of the angles at the base is to the tangent of half their difference.



Let ABC be a triangle; then, of the two sides, CA and CB, let CB be the greater. Produce CA to E, and make $CE = CB$, and join BE. Produce BC to F; and, through A, draw FD, perpendicular to EB, meeting it in D; then FBD will be half the sum of the angles at the base, and ABD half their difference. Likewise, DF is the tangent of the angle FBD, and AD the tangent of the angle ABD: moreover BF is the sum of the two sides BC, CA, and AE is their difference.

Then, by similar triangles, BFD, EAD,....$BF \times AD = FD \times EA$. Wherefore $BF : AE :: FD : AD$; which is the proposition to be demonstrated.

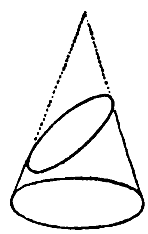
DEFINITIONS OF CONIC SECTIONS.

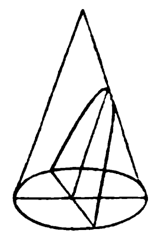
152. A Cone is a solid body, terminating in a point, called its vertex, and having a circle for its base, connected to the vertex by a curved surface, which every where coincides with a straight line passing through its vertex, and through any point in the circumference of the base. If a cone be cut by an imaginary plane, the figure of the section so formed acquires its name according to the inclination or direction of the cutting plane.

153. A plane passing through the vertex of a cone, and meeting the plane of the base, is called a *directing plane;* and the line of common section is called a *directing line.*

154. If a cone be cut by a plane parallel to the directing plane, the section is denominated a *conic section.*

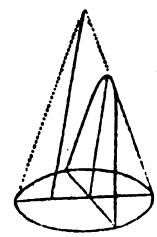
155. If the directing line fall without the base of the cone, the section is called an *ellipse.*





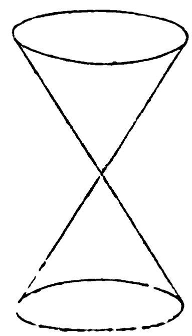
156. If the directing line touch the circumference of the base, the section is called a *parabola.*

157. If the directing line fall within the base, the section is called an *hyperbola.*



158. Equal opposite cones are those which have their axes in the same straight line; and, if cut by a plane through their common line of axis, the sides of the section will be two straight lines cutting each other.

Hence the two equal and opposite cones join each other at their vertices, and have their vertical angles equal.

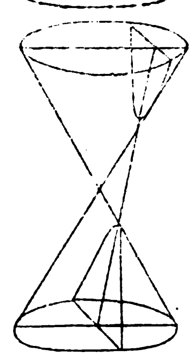


159. If the plane which produces the section of an hyperbola be extended so as to cut the opposite cone, the two sections are denominated *opposite hyperbolas.*

160. If the plane of a conic section be cut perpendicularly by another plane, which passes through the axis of the cone, the line of common section, in the plane of the figure, is called the *primary line.*

161. A point where the primary line cuts a conic section is called a *vertex* of that conic section.

Hence the ellipse has two vertices; opposite hyperbolas have each one, and the parabola has one.



PRACTICAL

CARPENTRY, JOINERY, &c.

BOOK I.

CARPENTRY

CHAPTER I.

INTRODUCTION.

1. In the Art of Building, a design of the full size of the object to be executed is termed a *working drawing;* and a working drawing ought to exhibit every detail of the form and construction of the piece of work it represents.

It will, therefore, be obvious how important it is that both the designer and the workman should understand the principles of making such drawings. Our object, in this part of our Work, is, to explain those principles, and their application in practice.

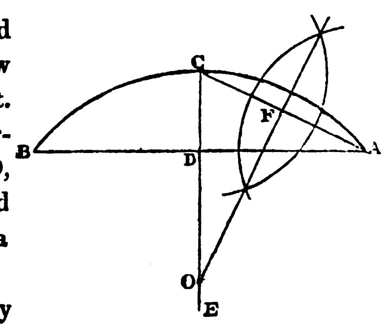
We will suppose the art of drawing lines parallel, or perpendicular, to one another to have been acquired; leaving it to the reader's choice whether he will use a tee-square and drawing-board, or a parallel-ruler and set-square; but we recommend the latter method.

The methods of drawing the curved lines which sometimes occur in drawings, and the methods of setting out work on a large scale, being less generally known, we will, in the first place, explain these for the use of learners.

To describe a Portion of a Circle.

2. When the chord-line AB, and the height CD, are given.

First Method.—Let AB, the chord-line, be drawn; and through the point D, in the middle of the line AB, draw CE perpendicular to AB, and set off DC equal to the height. Join AC, and through its middle point, F, draw a line perpendicular to AC, which will cut the line CE in a point, O, which is the centre of the circle. With the radius OC, and centre O, describe the arc ACB, which is the portion of a circle required.



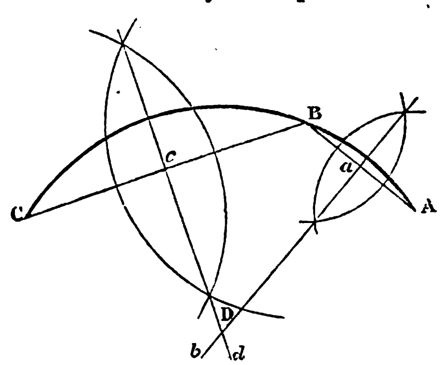
3. *Second Method.*—When the distance of the centre is very great, a portion of a circle may be described by means of an angle.

Let AC (*pl. I, fig.* 1,) be the length or chord-line, and DB the height. Join AB and BC, and take two pieces of wood, with straight sides, and fasten them together, so that the outward edges may form the angle ABC; then fix another slip, GH, across, as a brace, to keep them correctly to the same angle. To describe the curve, begin with the angular point B, at A; and move the triangle, so that the side BE may always be against the point A, and the side BF against the point C; then a pencil held at the angular point B, will describe an arc of a circle, ABC. The legs BE, BF, should be a little longer than the chord-line, AC.

4. Or, an arc of equal extent may be drawn by a smaller instrument, thus: Let AC, (*fig. 2, pl. I,*) be the chord-line, and BD the height of the arch. Join AB, and draw BE parallel to AC. Form a triangular piece of wood ABE; and to describe the arc AB, let the side AB of the triangle move against the point A, and the side BE move against the point B; then, if during the motion a pencil be held at the angular point B, it will describe the arc AB. By causing the same triangle to move against the points B, C, the arc BC may be described, which will complete the arch ABC.

5. *Third Method.*—A flat circular arch is easily drawn, by an instrument which was first proposed by Dr. Young. It consists of a straight bar, AB, (*fig. 3, pl. I,*) of any convenient length, with an elastic bar, CD, which is bent to any required degree of curvature by the screw E. The ends of the elastic bar, CD, move against two small rollers, which are fixed to the bar, AB, by thin brass plates. In order that the elastic bar may form a circle, when bent, its depth at the ends should be half the depth at the middle; and it should be adjusted till the outside be a true circular arc when bent to its greatest extent. When any three points in the curve are known, turn the screw till the outside of the elastic bar, CD, coincides with the given points, and draw the curve.

6. *Fourth Method.*—To describe an arc of a circle through any three given points, A, B, and C, which are not in a straight line.



Join AB and BC; and from *a*, the middle of the line AB, draw *ab* perpendicular to AB; and from *c*, the middle of the line BC, draw *cd* perpendicular to BC. Then the point D, where the perpendiculars meet, is the centre of the circle from whence the arc may be described.

To describe an Ellipsis, of any Length and Breadth.

7. *First Method.*—Draw AC, (*fig. 4, pl. I,*) equal to the length of the ellipsis, and divide it into two equal parts AE, EC; through E draw a line perpendicular to AC, and make EB, ED each equal to half the breadth.

To find a point, as *g*, in the curve, take A*a*, the difference between ED and EA, as a radius; and from any point, *f*, in EB, describe an arc, cutting EC in *h*. Draw *fh*, and produce it to *g*, and make *hg* equal to EB, then *g* is a point in the ellipsis.

8. The trammel is an application of the same principle. (See *fig. 5, pl. I.*) It is set by making *hg* equal to EB, or half the breadth; and *fh* equal the difference between half the length and half the breadth. The point *h* moves in the groove in one arm of the cross, and the point *f* in the groove in the other arm, while the point *g* traces the curve.

9. When an ellipsis is to be described round a given rectangle, QRSG, (*fig. 6, pl. I,*) it may be effected by making HK equal to IE; and draw GH, producing it to meet EB in F. Then, FH is the difference between half the length and half the breadth of the ellipsis, and HG is half its breadth. The curve may, therefore, be described by the method above.

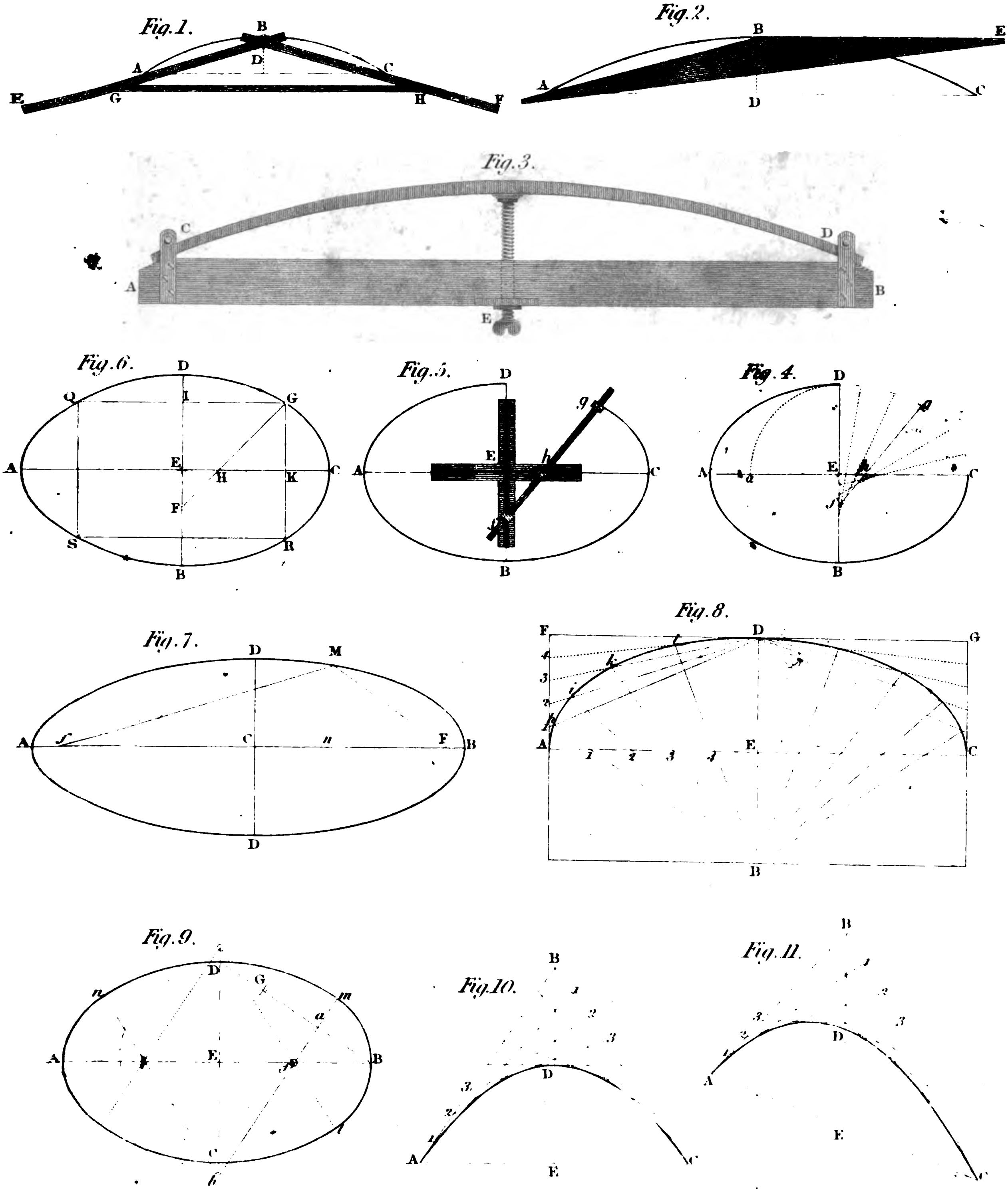


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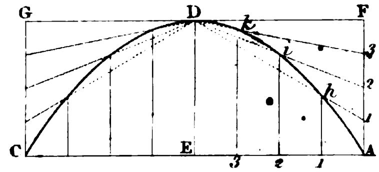
Fig. 1.



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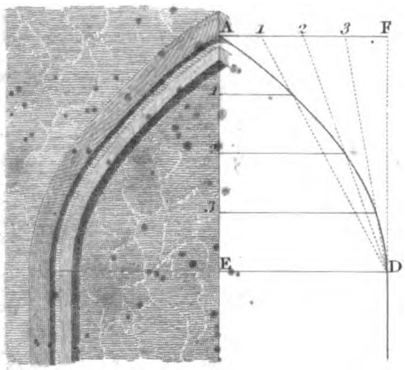

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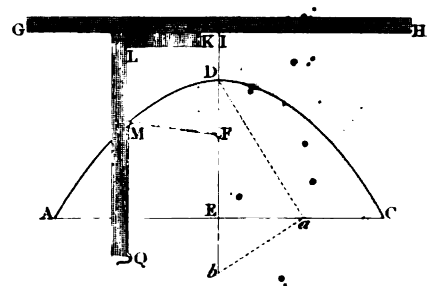

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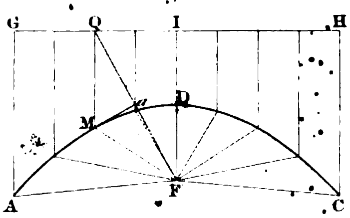

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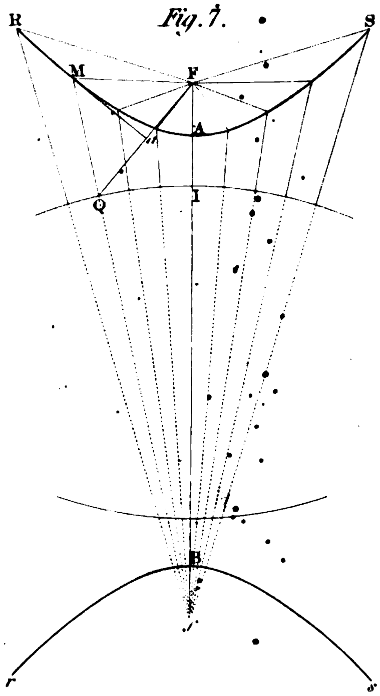
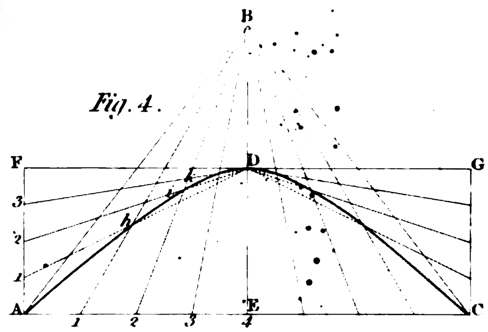


Fig. 4.



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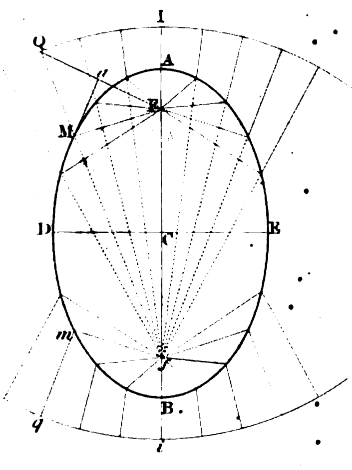

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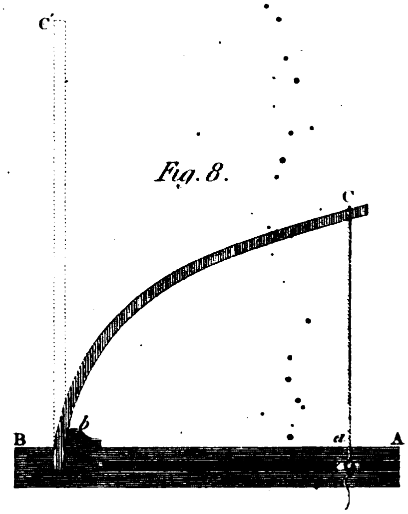
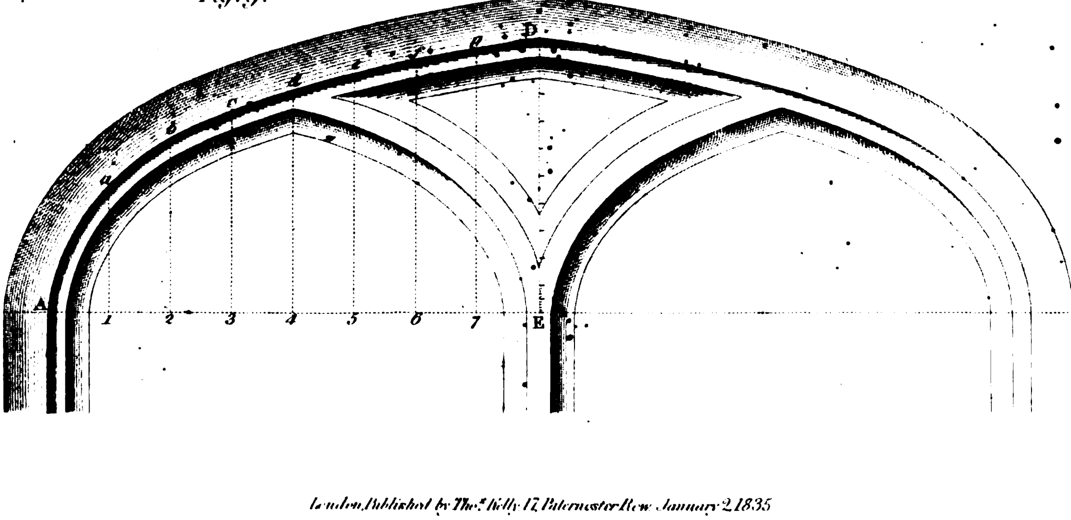


Fig. 9.



London, Published by Thos. Kelly 17, Paternoster Row January 2, 1835

Engraved by E. Turrell.

10. *Second Method.*—Let AB (*fig.* 7, *pl. I,*) be the length, and DD the breadth, of the ellipsis, and C the centre.

With the radius AC, and centre D, describe arcs, cutting AB in F, *f*. The points F, *f*, are called the *foci* of an ellipsis. Take any point, *n*, in the length AB, and with the radii, *n*A and *n*B, and centres F, *f*, describe arcs, intersecting one another in M, then M is a point in the curve.

11. Hence, if a thread of the same length as the ellipsis have its ends fastened to two pins in the foci, F, *f*, and it be stretched to M, by moving a pencil round within the thread, so as to keep it uniformly stretched, the curve may be described.

12. *Third Method.*—To describe an ellipsis by finding points in the curve. Divide AE and AF, (*fig.* 8,) each into the same number of equal parts, as five for example. Through the points of division, 1, 2, 3, &c., in AE, draw the lines B*h*, B*i*, B*k*, &c.; and through the points of division, 1, 2, 3, &c., in AF, draw the lines 1 D, 2 D, 3 D, &c., intersecting the former lines in the points *h*, *i*, *k*, &c. Through the points A*hikl*D, draw the curve, and it is one quarter of the ellipsis required. In the same manner the other parts may be described.

To describe the False Ellipsis, or an Elliptical Figure, by means of Circular Arcs.

13. Let AB be the length, and CD the breadth, (*fig.* 9, *pl. I.*) Join BD, and make GD equal to the difference between DE and AE. Through the middle of the line BG draw *ab* perpendicular to BG, intersecting EB in *f*, and EC produced in *b*. From the centres *f* and *b* describe the arcs *l*B*m*, and *m*D*n*; and complete the curve in the same manner.

This curve is frequently used for bridges. Blackfriars' bridge has arches nearly of the same figure as would be obtained by this method.

When the length is not above one-third greater than the breadth, the circles meet one another without the change of curvature being strongly marked; but when the length exceeds this proportion, a greater number of centres should be employed. The arch of the bridge of Neuilly was drawn from eleven centres; but it becomes more troublesome to draw a curve of good form by arcs of circles, than to draw it of the true elliptical figure, which is decidedly more beautiful. The arches of the Waterloo-bridge are ellipses.

To describe a Parabola.

14. *First Method, by Tangents.*—Let AC (*fig.* 10 or 11,) be the base, and ED the height. Produce ED to B, and make DB equal to DE. Join AB and BC; and divide AB into any even number of equal parts, numbering them from A to B; also divide BC into the same number of equal parts, numbering the parts from B to C. Join 1, 1; 2, 2; 3, 3; &c., and the lines so drawn will be tangents to the parabola; and a curve, ADC, drawn to touch these tangents is the parabola required.

This curve is adapted for arches in some cases: and this method of drawing it is much used for rounding off angles, as will be shown in other parts of this Work.

15. *Second Method, by Ordinates.*—Let AC, (*fig.* 1, *pl. II,*) be the width, and ED the height of the arch. Make EC equal to EA, and complete the rectangle AFGC, so that the side FG may pass through D. Divide AE and AF each into the same number of equal parts; and join 1 D, 2 D, 3 D, &c. from the divisions on AF. And from the divisions 1, 2, 3, &c., on AE, draw lines parallel to ED, meeting the former lines in the points *h*, *i*, *k*, &c., which are points in the curve.

The parabola answers very well for a Gothic arch when the line ED is made the springing line. An example is shown of its application to the head of a window, in *fig.* 2; the mode of describing the curve is the same as in *fig.* 1, and the figures of reference the same; but any of the other methods of describing the parabola will apply to the same purpose.

16. *Third Method, by continued Motion.*—Let GH (*fig.* 3,) be the edge of a straight ruler, and KLQ the internal angle of a square, of which the edge is parallel to KL, and coincides with the straight edge, GH. Then, if one end of a string be fastened at F, and the other end to the point Q of the square, and the side of the square be moved along GH, while the parts QM, FM, of the string are kept uniformly stretched by a pencil at M, the pencil will be moved and describe a parabola.

If AC be the breadth, and DE the height of the curve, the point F may be found by drawing a line from D to *a*, the middle of AE: and make *ab* perpendicular to *a*D, intersecting DE produced in *b*, then make DF equal to E*b*. The length of the string must not be less than the line D*b*; and GH should be parallel to AC, and at any convenient distance from D.

To describe a Hyperbola.

17. In this figure (see *fig.* 4, *pl. II,*) the degree of curvature is not fixed by the height and width of the arch, but is capable of every degree of variation between the curvature of the parabola and the straight lines of a triangle. This variation depends on the position of the point B; for the nearer that point is to D, the nearer the figure will be to a triangle; and the more distant the point B is from D, the nearer the curve will be to a parabola.

To draw the curve, divide AF and AE, each into the same number of equal parts; and from the points of division 1, 2, 3, &c. on AF, draw lines to D. Also, from the points of division 1, 2, 3, &c. on AE, draw lines to the point B, cutting the former lines in the points *h*, *i*, *k*, &c. Through the points A, *h*, *i*, *k*, &c. draw a curve, and it will be the hyperbola required.

To describe the Sections of a Cone by a general Method.

18. The ellipsis, parabola, and hyperbola, are curves formed by cutting a cone in different directions in respect to its sides; hence they are sometimes called conic sections; but as these figures are formed by various operations both of nature and art, it seems improper to name them from any particular ones.

Let FI (*figs.* 5, 6, or 7,) be a line drawn through the foci of the curve, and A the vertex or top of the curve. Make AI equal to FA; and when the curve has two foci, as in the hyperbola, *fig.* 7, and the ellipsis, *fig.* 6, from the focus *f*, as a centre, with the radius *f*I, describe an arc QI.

To find any point, M, in the curve, draw *f*QM, and join QF; also from *a*, the middle of QF, draw *a*M perpendicular to QF, and it will meet *f*QM in the point M, a point in the curve.

In the parabola, (*fig.* 5,) as there is only one focus, draw QI perpendicular to IF; and to find any point M in the curve, draw QM parallel to IF; join FQ, and *a*M being drawn perpendicular to QF, it will meet QM in M, a point in the curve; and any other point may be found in the same manner.*

In all the cases FM is equal to MQ, and M*a* is a tangent to the curve at the point M; also, a line drawn perpendicular to M*a* would be the proper direction for a joint at M, in a brick or stone arch, of any of these forms.

* This method of drawing the sections of a cone was ascribed to Mr. Gibson; but his was not complete, and only differed in want of completeness from methods described in *Emerson's Conics.*

Fig. 1.

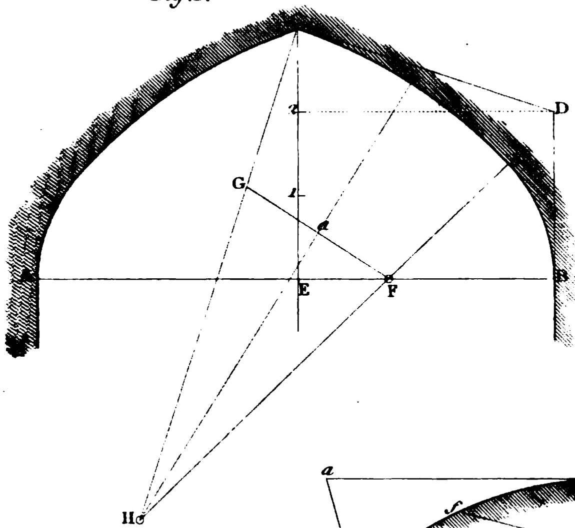
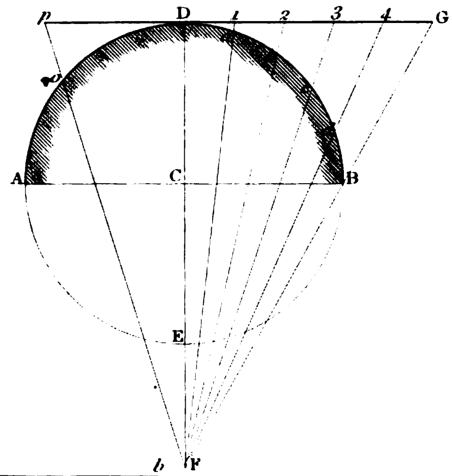


Fig. 2.



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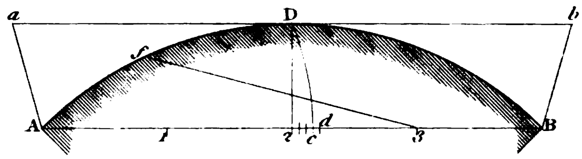
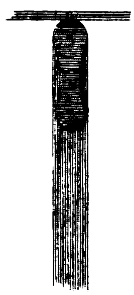


Fig. 5.



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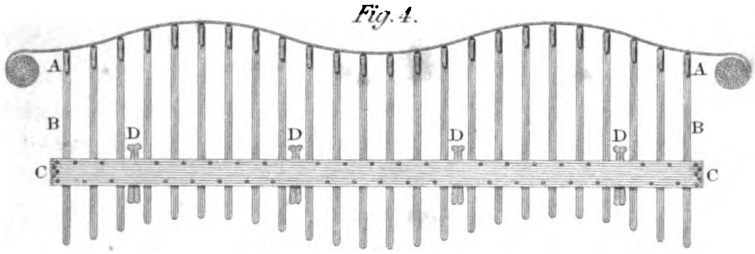


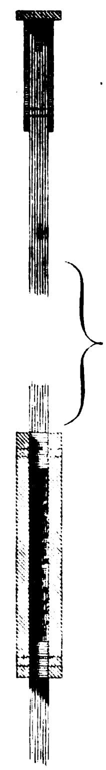


Fig. 6.

Fig. 7.

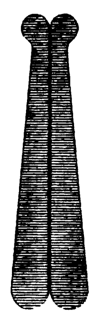
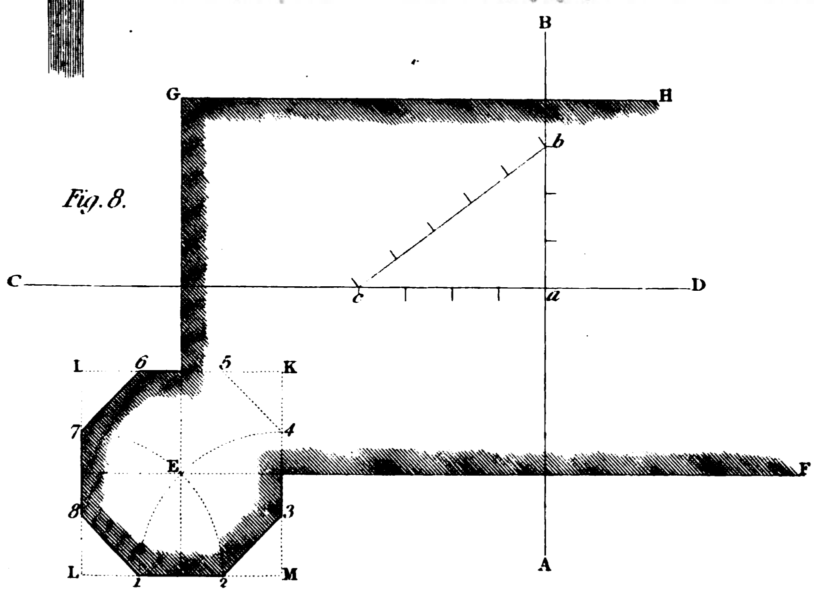


Fig. 8.



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London, Published by Thos. Kelly, 17 Paternoster Row, January 1 1835.

To describe Gothic Arches.

19. A Gothic arch is generally composed of a curve, which has different degrees of curvature at different points; and a graceful curve of this kind cannot be produced by circular arcs; neither is it easy to describe them for the flat parts of the arch. To avoid this difficulty, we have used the following simple instrument for several years.

CB (*fig.* 8, *pl. II.*) is a bar of wood of equal breadth and thickness, which is straight, as shown by the dotted lines C′B, when the string, C*a*, is loose. The bar CB is fixed at one end into a strong piece, AB, of equal thickness to the breadth of the bar CB. The piece AB is provided with a groove on each side to receive a button, *a*, with a flat head to fix the string to when the bar CB is to be retained at any degree of curvature. The part *b* is added to prevent the bar curving below the line AB.

To use the instrument, set the line AB to the springing-line of the arch, with the point B adjusted to the line of the jamb, and bend the bar CD by the string till some point on its upper edge coincides with the height of the arch, and the string should be adjusted so as to be perpendicular to the line AB, by means of the sliding button; then, the upper edge is of the proper form for the arch; and by turning over the instrument, the other half of the arch may be described.

20. A Gothic arch may also be described by points in this manner: divide the base AE into eight equal parts, (see *fig.* 9,) and on each point of division draw a perpendicular. Then, divide ED, the height, into 100 equal parts, and make 7*g* equal to 96 of these parts; 6*f* equal 91 parts; 5*e* equal 86 parts; 4*d* equal 79 parts; 3*c* equal 72 parts; 2*b* equal 63 parts; and 1*a* equal 50 parts. Through the points A*abcdefg*D draw the curve.

The example shows the head of a Gothic window, the arches of which may be described either by this method or the preceding one.

21. *To describe a Gothic Arch by Arcs of Circles.*—Let AB (*fig.* 1, *pl. III.*) be the springing-line, and EC the height of the arch. Draw BD perpendicular to AB, and make it equal to two-thirds of the height EC. Join DC, and from C draw CH perpendicular to CD. Make BF and CG each equal to BD. Join FG; and from the middle of FG, draw *a*H perpendicular to FG, meeting CH in H. Then, F and H are the centres for describing the curve, and the two arcs will meet in the line HF*b*, which passes through their centres.

When a line drawn from A to C is equal to the width AB, the point H coincides with the point A, and the arch is drawn from one centre in A. Also, when the height is in any proportion greater than that which makes the line AC equal to AB, the arch may be described from one centre in the line AB continued.

If this rule be compared with the remains of the best examples of Gothic architecture in this country, it will be found to nearly agree with them.

TRANSFERRING CURVES.

22. It often happens in making drawings, that a complex curve is to be transferred from one drawing to another. A very convenient instrument for making such transfers, has lately been invented by Mr. Warcup.* *Figs.* 4, 5, 6, and 7, (*pl. III,*) represent this instrument and its parts. AA, (*fig.* 4,) is a plain slip of whalebone, forming the ruler; BB, a series of graduated

* "*Transactions of the Society of Arts.*" Vol. XXXV, p. 109.

rods at right angles to a beam, CC, which is formed of two pieces of wood or whalebone with slips of cork, or other elastic matter, between the rods.

Figure 6 is a section of the beam, showing also the mode of connecting the rods to the ruler, by small joints of brass; and *fig.* 5 shows another view of the same connection.

The wedges, marked DD, of wood or ivory, are for tightening or releasing the rods in setting or altering the curve; they tighten the rods by pressing against the elastic slios of cork. *Fig.* 7 shows the wedges, D, D, on a larger scale.

SETTING-OUT BUILDINGS.

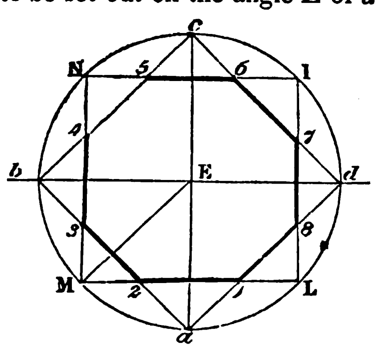
23. To set out a building to a plan, and build it with accuracy, is a branch of the building-art which few can perform with satisfaction to themselves, or to their employers, and chiefly from want of method. The great principle of setting-out well consists in providing the means of correcting the work as it proceeds; and for this purpose, there should be two or more principal lines laid down in such situations that they can be restored at any time, during the progress of the building. Hence, it is obvious that they should be distinct from the walls: but it will be desirable to make the principal or longest line parallel to the longest wall; and the position of the lines should be drawn on the plan.

In an ordinary-sized and simple building, two lines, at right angles to one another, through the central part of the building, will be sufficient; as AB, CD, *fig.* 8. The points A, B, C, D, being chosen so that they will not be disturbed during the progress of the building, and that lines can be stretched from point to point at any time.

To prove whether the lines AB, BC be at right angles or not, set off 40 feet on *a*C, and 30 feet on *a*B, and then *bc* should be 50 feet, if the lines be square to one another. The same thing may be tried by rods, making it 4, 3, and 5 feet, instead of 40, 30, and 50; or 8, 6, and 10 feet.* The distance and parallelism of the walls from these lines are easily tried at any time.

24. In setting-out any door, window, or other part, the distance of its centre from each wall should be measured, and half the width set off on each side of that centre; otherwise. from want of accurate workmanship, it may be found much out of its place, if measured from one wall only.

25. In setting-out any complex figure, that mode of doing it should be chosen which depends least on the accuracy of performing the operation. We will give the usual mode of describing an octagon as an example. Suppose a square, IKML, (*fig.* 8,) to be set out on the angle E of a building, to find the sides of the octagon, it is common to make M 1, M4, L2, L7, and so on, each equal to ME; then 1, 2, 3, 4, 5, 6, 7, and 8, are the angles of the octagon.



26. *Better thus.*—Construct the square IKLM, and make E*a*, E*d*, E*c*, and E*b*, each equal to EM; then, if a line be stretched from *a* to *d*, from *d* to *c*, from *c* to *b*, and from *b* to *a*, they will cut the sides of the square in the angles of the octagon.

If the figure has been truly set-out, *abcd* will be an exact square, and which is easily tried.

* If a triangle be drawn, so that its sides be any equi-multiple of the numbers 3, 4, and 5, one of its angles will be a right angle. Thus, if 2 be the multiplier, then the numbers will be 6, 8, and 10; if 3 be the multiplier, then they will be 9, 12, and 15, and so on.

WORKING DRAWINGS.

27. It has already been stated how much depends on a sound knowledge of the formation of working drawings. We now propose to exhibit the principles of forming them in detail, with occasional examples of application to render the object we treat on more clear, and to relieve the tediousness of the bare contemplation of lines and figures.

28. A Working Drawing is a representation of the whole or of some part of an object on a level plane; and is either a plan, an elevation, a section of the object, or its development.

29. The form of an object on the ground, or on some plane parallel to the ground, is called the *Plan;* as, for example, the plan of a house, the plan of the chamber-floor of a house, and the like.

30. The form of an object, as it would be seen if the eye could regard it every where, in a direction perpendicular to the plane it is drawn upon, is called an *elevation.* Therefore, in an elevation, those sides of an object which are parallel to the plane of the drawing, are the only ones which are represented of their real size; and the sole difficulty of representing an object in elevation, consists in finding the form of the parts which are oblique to the plane of the drawing.

31. If an object be supposed to be cut by a plane, the form its parts would have, at the place where it is cut, is called a *Section.* It is by means of sections that the construction and internal forms and arrangements of objects are shown.

32. As an elevation does not show the exact form of any thing which is oblique to the plane of the drawing, it is sometimes an advantage to consider the whole surface of the body to be spread out flat upon the plane of the drawing; a surface spread out in this manner is called the *development* of the object.

The forms which occur in working drawings are chiefly portions of solids, sometimes of regular solids, and not unfrequently of irregular ones. Therefore, to give an example of each solid which occurs would be an endless task; and we must confine ourselves to a few of the most usual forms, and show methods which are applicable to any form of solid whatever.

33. The principles of drawing an elevation and a section are the same, and therefore we need not repeat them for both cases, but at once proceed to finding the sections of bodies, showing the application to elevations when they are likely to occur of the same form.

34. The solids usually forming the parts of building are prisms, pyramids, cones, cylinders, spheres, and rings.

A Prism is a solid, bounded by plane surfaces, of which two are opposite, equal, and parallel.

A Pyramid is a solid, bounded by plane surfaces, all but one of which meet in one point.

A Right Cone is a solid, described by the revolution of a right-angled triangle about one of its legs. The leg, or the line round which the triangle revolves, is called the *axis* of the cone; and the *base* of a cone is the circle described by the other leg of the triangle.

A Cylinder is a solid, described by the revolution of a right-angled parallelogram about one of its sides. The side round which the parallelogram revolves is called the *axis* of the cylinder; and the circles described by the ends of the parallelogram are called the ends of the cylinder.

A Sphere, or Globe, is a solid formed by the revolution of a semi-circle about its diameter as an axis.

A Ring is a solid described by a circle revolving round a point without the circle, and in a direction perpendicular to the plane of the circle.

A species of wedge-formed figure is also sometimes used, and a variety of forms which are generated by Gothic curves.

35. When the body to be represented consists of only part of a known regular solid, it will generally be most convenient to complete the solid to obtain the representation.

Sections of Solids.

36. To find the section of a cone, ABC, through a line given in position, and passing through the axis.

Let ABC, (*figures* 1, 2, and 3, *pl. IV,*) be the elevation of the cone, and let DE be the line of section. Through the apex or top of the cone, C, draw CF, parallel to the base-line AB, and produce ED to meet AB in D, as in *figure* 2 and 3, or to meet AB produced in G, as in *fig.* 1, as also to meet CF in F. On AB describe a semi-circle, which will be equal to half the base of the cone. In the semi-circle take any number of points, *a, b, c,* &c. Draw D*d,* in *figure* 2 and 3, and G*d* in *fig.* 1, perpendicular to AB; and G*d′*, in *fig.* 1, perpendicular to GF; as, also, D*d′*, *figure* 2 and 3, perpendicular to DF. From the points *a, b, c,* &c. draw lines *ae, bf, cg,* &c., cutting G*d* (*figure* 1) and D*d* (*figure* 2 and 3) in the points *e, f, g,* &c. In *figure* 1, make in G*e′*, G*f′*, G*g′*, &c. equal to G*e*, G*f*, G*g*, &c.; and in D*d′*, (*figure* 2 and 3,) make D*e′*, D*f′*, D*g′*, &c. equal to D*e*, D*f*, D*g*, &c. Through the points *e′*, *f′*, *g′*, &c. draw lines to F. From the points *a, b, c,* &c. draw lines perpendicular to AB; and from the points where these perpendiculars meet AB, draw lines to the vertex, C, of the cone, cutting the line of section, DE, in *l, m, n,* &c. Through the points *l, m, n,* &c., draw *lh, mi nk,* &c. perpendicular to DE; and through the points D, *h, i, k,* &c., in *figure* 1, or *d′*, *h, i, k,* &c. *figure* 2 and 3, draw a curve, which will be the section required of the cone ABC.

37. *Remarks.*—In the first of these figures, the line of section cuts both sides of the cone; in this case, the curve D*hik* and E is an *Ellipsis.* In *fig.* 2, the line of section DE is parallel to the side AC of the cone; in this case, the curve *d′hik*E is a *Parabola.* In *fig.* 3, the line of section, DE, is not parallel to any side of the cone; but when both it and the sides of the cone are produced, if it meet one of these sides, as at B′, then the curve *d′hik*E is a *Hyperbola.*

And it may also be remarked, that the line of section, DE, in *fig.* 3, is the same as that which has before (in *Art.* 17,) been called the *height;* the part EB′, contained between the two sides of the section, is called the *major axis;* and the line D*d,* perpendicular to DE, the *base.*

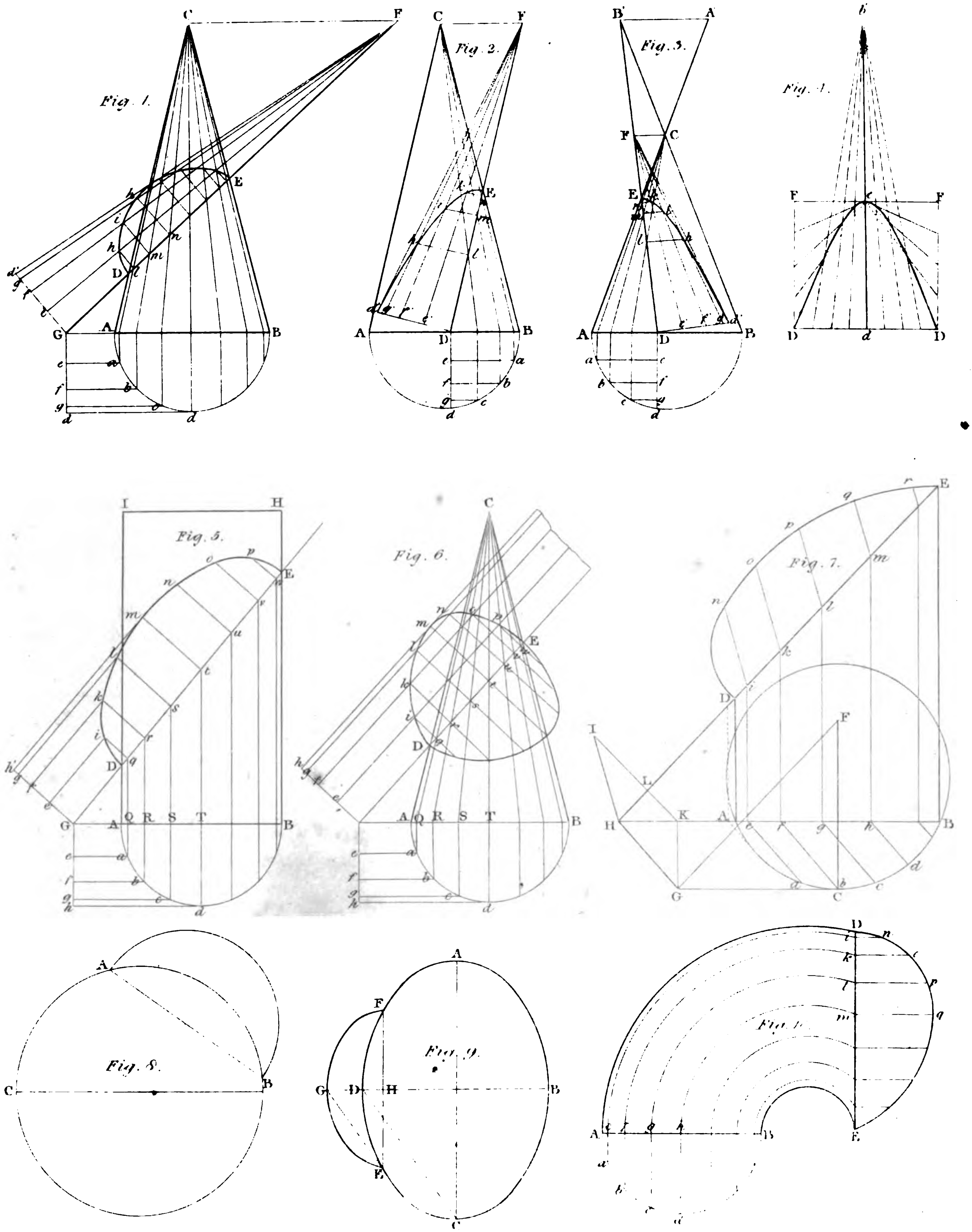
Hence the same section may be found by the method already shown in *Art.* 17; viz. by drawing any straight line *deb′*, *fig.* 4: make *de* equal to DE, *fig.* 3, and *eb′*, *fig.* 4, equal to EB′, *fig.* 3. Through *d, fig.* 4, draw the straight line DD at right angles to *db′*: make *d*D equal to D*d′*, *fig.* 3; then, with the major axis *b′e,* the height *ed,* and the base *d*D, on each side describe the curve of the hyperbola, which will be of the same species as that shown in *fig.* 3.

38. To describe the section of a cylinder, through a line given in position, upon the elevation, (*fig.* 5, *pl. IV.*)

This might be considered a particular case of the last problem. For a cone, having its apex at an infinite distance from its base; or, practically, at an immense distance from its base, approaches to a cylinder; and all the lines, for a short distance, would differ insensibly from parallel lines. This is the construction shown at *fig.* 5. But as the section of a cylinder frequently occurs, a more practical description of it is desirable.

Let ABHI (*fig.* 5) be the elevation of a right cylinder; AB being the base, and let DE be the line of section. On AB describe a semi-circle; and, in the arc A*d,* take any number of

SECTIONS OF SOLIDS.



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points, *a, b, c,* &c., from which draw lines perpendicular to the diameter, AB, cutting it in Q, R, S, &c.: and the line of section, DE, in the points, *q, r, s,* &c.: from the points *q, r, s,* &c. draw the lines *qi, rk, sl,* &c. perpendicular to the line of section, DE. Make the ordinates *qi, rk, sl,* &c. each respectively equal to the ordinates Q*a*, R*b*, S*c*, &c.; and through the points D, *i, k, l,* &c. to E, draw a curve, which will evidently be the section of the cylinder, as required.

The curve is an ellipsis; hence the same may be done in this manner, viz.—Bisect the line of section DE in the point *t*. Draw *tm* perpendicular to DE. Make *tm* equal to the radius of the circle which forms the end of the cylinder; then, with the length DE, and the breadth, *tm*, by any of the methods in *Art.* 7, and those following it, describe an ellipsis which will be the section of the cylinder required.

39. Given the position of three points, in the circumference of a cylinder, and the heights of the perpendiculars, let fall from these points to the base, to find the section of the cylinder passing through these three points.

Let ABC be the feet of the perpendiculars from the three points, (*fig.* 7, *pl. IV,*) in the circumference of the base. Join the two points, A and B, and draw AD, CF, and BE, perpendicular to AB. Make AD equal to the height of the point above the base at A, BE equal to the height at B, and CF equal to the height at C. Produce BA and ED to meet each other in H: draw CG parallel to BH, and FG parallel to EH. Join GH. In GH take any point, G, and draw GK perpendicular to CG, cutting BH in K: from the point K draw KI, perpendicular to EH, cutting EH in L. From H, with the radius HG, describe an arc, cutting KI at I. Join HI. In the circumference of the base ACB, take any number of points *a, b, c,* &c., at pleasure, and draw *ae, bf, cg,* &c. parallel to GH, cutting AB at *e, f, g,* &c. Through the points *e, f, g,* &c., draw lines *ei, fk, gl,* &c., parallel to GK, or AD, or BE, cutting DE at *i, k, l,* &c.; from the points, *i, k, l,* &c., draw the lines *in, ko, lp,* &c., parallel to HI. Make the ordinates *in, ko, lp,* &c. equal to *ea, fb, gc,* &c.; then, through the points D, *n, o, p,* &c. draw the curve D*nop*, &c. to E, and it will be the section cut by the plane, as required.

The most useful application of this case is to find the moulds for hand-rails of staircases; this application will be shown in treating of that part of our subject.

40. A wedge-formed solid is one ending in a straight line, in which, if any point be taken, a line from that point may be made to coincide with the surface: the end of the figure may be of any form whatever.

The forms which occur in architecture have a semi-circular, a Gothic arched, or a semi-elliptical end, parallel to the straight line from which the line is applied. The base is generally a triangle.

To find the section of a wedge-formed solid, with a semi-circular end, the given *data* being a plan, perpendicular to the vertex, or sharp end, and the line of section.

Let ABC, (*fig.* 6, *pl. IV,*) be the plan, perpendicular to the sharp edge, and let DE be the line of section.

This construction is similar to that of finding the section of a cone, excepting that, instead of drawing lines to a point, they are, in this figure, drawn parallel to the line of section DE: the ordinates Q*a*, R*b*, S*c*, &c., being transferred respectively to *qi, rk, sl,* &c.; and the curve D, *i, k, l,* &c. to E, drawn through the points, D, *i, k, l,* &c., by hand.

41. It must be obvious that, in any of these cases, if the curve D*ikl*E be given, the end A*d*B may be found by reversing the process.

This example applies to drawing the interior elevation of a window or door when the jambs are splayed at the sides, and level at the crown. The interior face of the wall, AB, is commonly parallel to the exterior one DE; but the figure is drawn with the walls oblique to one another to show the general nature of the construction.

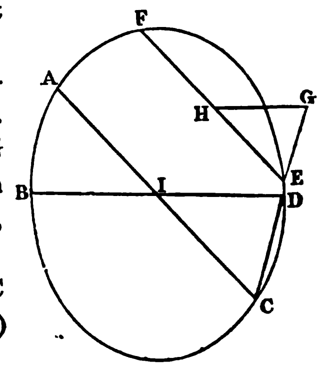
Fig. 1, *pl. IV,* applies in like manner to the case where a window or door is splayed equally all round.

The construction is not confined to particular curves in any of these examples; that is, whatever form is given to the original curves, the other will be found by the preceding processes to correspond to them.

42. Given the plan of a sphere, and the line of a section at right angles to that plan, to find the form of the section.

Let ABC (*fig.* 8, *pl. IV,*) be the plan, and AB the line of section.

On AB, as a diameter, describe a semi-circle, which will be half of the section required: since all the sections of a sphere, or globe, are circles.



43. Given the plan of a spheroid,* and the line of section, at right angles to the plan, to find the form of the section through that line.

Let ABCD be the plan, DB the breadth, and EF the line of section. Through the centre of the spheroid draw AC parallel to EF. Bisect EF in H. Join CD; and draw EG parallel to CD, and HG parallel to DB; then HG is half the breadth, and EF the length of the section; and with this length and breadth describe an ellipsis, by *Art.* 7, or any of those methods already described.

When EF, the line of section, is perpendicular to DB, then AC becomes equal to the length of the plan, and EGF (*fig.* 9, *pl. IV,*) represents half the section.

44. To find the section of a ring, the plan and line of section being given.

Let ABED (*fig.* 10, *pl. IV,*) be part of the plan of a ring; AB a straight line, which, if produced would pass through F, the centre of the ring; and DE the line of section.

On AB describe a semi-circle, and take any number of points, *a, b, c, d,* &c. in its circumference; then draw the ordinates *ae, bf, gc,* &c. perpendicular to AB. From the points *e, f, g,* &c. and centre F, describe arcs of circles, cutting the line of section DE in *i, k, l, m,* &c.; and from each of these points draw lines perpendicular to DE. Make *in* equal to *ea*; *ko* equal to *fb*, &c.; and through the points D, *n, o, p,* &c. draw a curve, which is the boundary of the section required.

Many other examples of sections will be found in different parts of the Work.

Developement of Surfaces.

45. We have already explained that the developement of the surface of any body is the same as describing a flat surface that would cover the body, (*Art.* 32.) In most works which are bounded by curved surfaces, this mode of drawing is extremely useful; as, for example, in covering domed roofs, centres, and the like, in finding the moulds for arches, in forming the moulds for hand-rails, and the soffits of stairs; and in finding the forms for veneers, and moulds for soffits of windows, arches, and the like.

* A spheroid is a figure generated by the revolution of a semi ellipsis round one of its principal diameters.

The developement of a curved surface might be obtained, in many instances, by the surface being rolled on a plane, so that all its parts should be successively in contact with the plane.

46. To find the developement of the curved surface of a right cylinder.

The surface is evidently of the same length as the cylinder, and of the same breadth as the circumference of the cylinder. And as the circumference of a circle $3\frac{1}{7}$th times the diameter, the breadth of the developement will be $3\frac{1}{7}$th times the diameter of the cylinder, and its length the length of the cylinder.

If only a portion of the circumference of a cylinder is to be developed, as, for example, the portion D*o*, (*fig.* 2, *pl. III.*) Draw the line DF through the centre C of the circle, divide the radius DC into four equal parts; and make EF equal to three of these parts. Draw D*p* perpendicular to DF; and from the point F, and through the point *o*, draw F*p*; then D*p* is equal to the arc D*o*, very nearly.

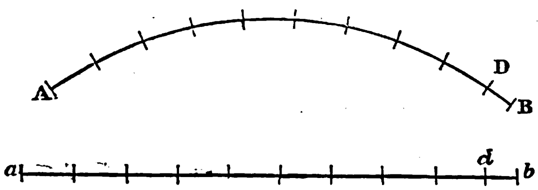
In the same manner D1 is the length of the arc D*a*; D2 of the arc D*b*, &c. to DG, which is equal the quadrant DB. And if the length, D4, of any arc, as D*d*, be found, and it is required to divide that arc into any number of equal parts, we have only to divide D4 into the proposed number of parts, and from the points of division to draw lines to F, and these lines will divide the arc into the same number of equal parts.

47. When a portion of a cylinder is to be developed, and its diameter is so great as to render the preceding method troublesome, it may be done in this manner. Let ADB (*fig.* 3, *pl. III,*) be the portion of the plan of the cylinder. Join AB, and divide it into four equal parts; set off A*f* equal to one of these parts, and from the third division draw the line 3*f*. Then the line 3*f* is very nearly equal to half the length of the arc AB.

Otherwise.—Draw D2 perpendicular to the middle of AB; and with the radius AD, and centre A, describe the arc D*c*. Divide 2*c* into three equal parts, and make *cd* equal to one of these parts; then A*d* is equal to half the length of the arc ADB.

Hence if *a*D*b* be made equal to either, twice A*d*, or twice 3*f*, it will be the developement of the arc ADB.

48. If it be required to develope a curve which is not a circle, it may be done by the operation called stepping. A pair of compasses must be set to such an opening, that a portion of the quickest part of the curve, included between their points, may not sensibly differ from a straight line. Then, beginning at one end, A, step with the points of the compasses along the curve AB, and suppose the last step to be at D, set off an equal number of steps on a straight line, and make *db* equal to DB; then *ab* will be very nearly equal to the length of the curve AB.



This mode of finding the length of a curve requires much care in practice, to render it accurate enough for use.

49. To find the developement of the curved surface of a cone.

Let AFB (*fig.* 1, *pl. V,*) be the plan of the cone, and AEB a plan of half its base. With the radius AF, and F as a centre, describe the arc A*eb*. Divide the arc AE of the plan of the base into any number of equal parts, and set off the same number of these parts from A to *e*; and make *be* equal to A*e*. Join F*b*, and FA*eb* is the developement of half the surface of the cone.

Otherwise.—Multiply half the diameter of the base in inches by 360; and divide the product by the length AF in inches, and the quotient will express the degrees, and parts of a degree, contained in the angle AFb; therefore, if AFb be made equal to that angle, it will be the boundary of half the developement. Thus, if half AB be 12 inches, and AF be 42 inches, then $\frac{360 \times 12}{42}=102$ degrees 51 minutes, for the angle AFb.

When only part of a conic surface is to be developed, and ABCD represents the plan of the part, then proceed as before; and the covering for the whole cone being found, with a radius FD, and centre F, describe the arc Dc, and ADcb will be the developement of the part ABCD of the cone.

If ABCD be the plan of the walls of a semi-circular headed window, which is splayed equally all round the head, then ADcb is the lining of the soffit, which is lightly tinted to show it more distinctly.

50. To find the lining of a soffit formed by a circular aperture in a circular wall, when splayed equally all round.

Let ABCD be the plan of the aperture, (*fig.* 2, *pl. V.*) Produce the lines AD and BC to meet in F; also, join AB, and describe the arch AEB. With the radius AE, and centre F, describe the arc Ab; and make its length equal to that of the arch AEB, as in the preceding example, marking the points of division on both arcs, as at 1, 2, 3, &c. From the points 1, 2, 3, &c. in Ab, draw lines to F; and from the points of division in AE, draw lines perpendicular to AB; also, from the points in which these perpendiculars cut the line AB, draw lines to F; and from the points where the lines to F cut the plan of the wall, draw lines parallel to AB to meet the line AD, then from the points of meeting, and centre F, describe arcs of circles, each circle to meet its corresponding line 1F, 2F, 3F, &c. which will determine the form of the edge of the lining of the soffit. The whole lining is shown by the lightly tinted part, ADcb.

The problem stated in general terms, is to find the developement of the interior surface of the aperture, formed by piercing a conical hole through a hollow cylinder.

51. To develope the soffit of a circular arch, which cuts obliquely through a straight wall.

Let ABCD be the plan of the wall. (*fig.* 3, *pl. V.*) From the point C, draw CGc perpendicular to CB, and produce AD to G. On CG describe a semicircle CFG, which is the curvature of the arch. Divide the semicircle GFC into any number of equal parts, so small in practice that the distance between two points on the arc may be considered a straight line, and extend the same number of parts along from G to c. From each point, both in the arch and in the line Gc, draw a line parallel to GA; and from each point, where the parallels from the divisions in the arc cut the line AB of the wall, draw a line parallel to Cc, which will meet the corresponding parallel of the developement in the edge of the soffit; and the line Aeb being drawn through the points thus found, will be the form of the edge corresponding to the side AB. The breadth of the soffit measured on the parallels will be every where the same, and equal to AD, or BC; therefore, setting off this breadth on each parallel will give the other edge, and completes the soffit ADcbe.

If AGCH had been the plan of the opening, then AGch would have been the lining of the soffit, as it would in that case have been half a cylinder.

52. To develope the soffit of a circular arch, which cuts obliquely through a circular wall.

Let ABCD, (*fig.* 4, *pl. V.*) be the plan of the wall. Draw Dd perpendicular to DA, and produce BC to meet Dd in G. On DG, as a base, describe the arch DFG, and divide it into equal parts; and extend those parts on the line Gd, so that Gd may be equal to the length of the curve DFG. From each point of division draw a line parallel to GB; and from the points where the parallels, from the divisions in the arch, cut the lines of the wall in the plan,

DEVELOPEMENT OF SOFFITS.

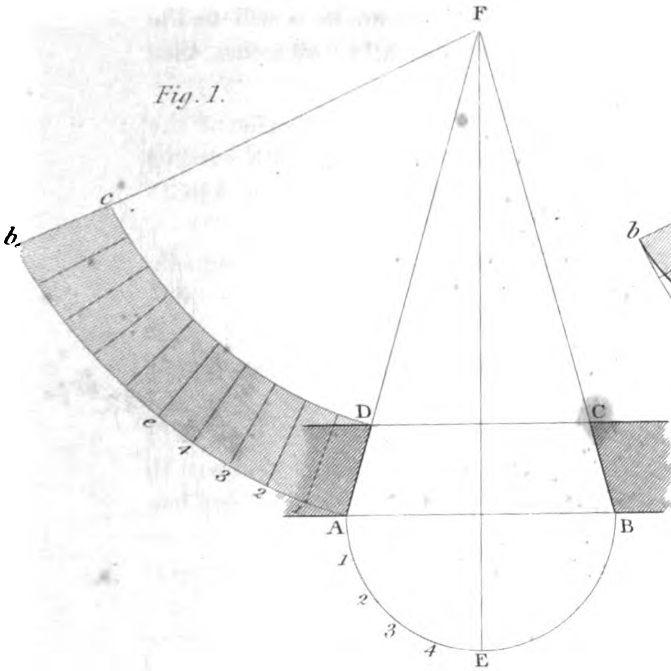


Fig. 1.

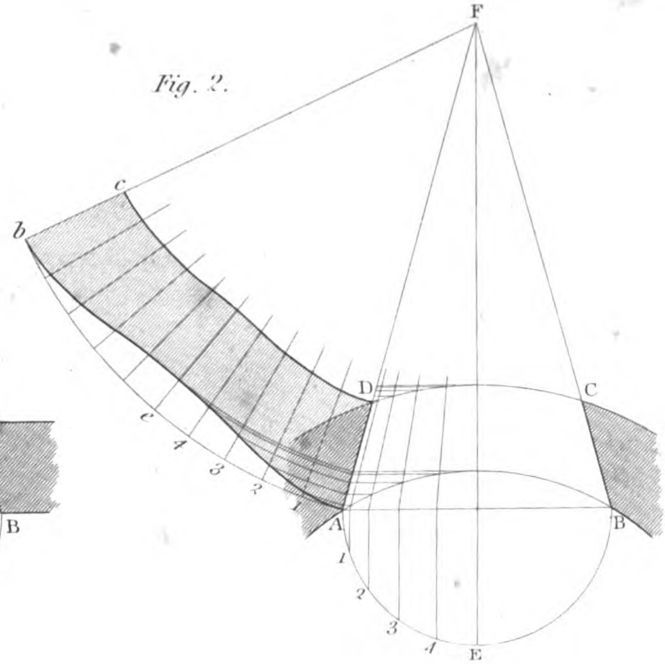


Fig. 2.

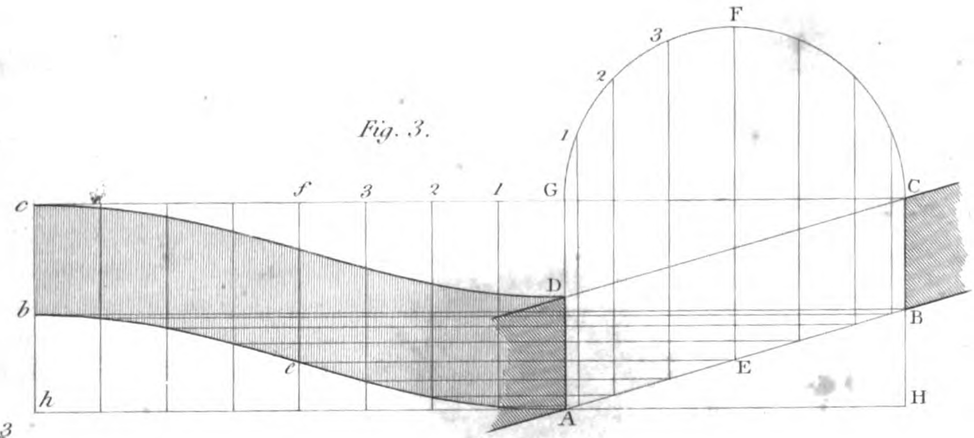


Fig. 3.

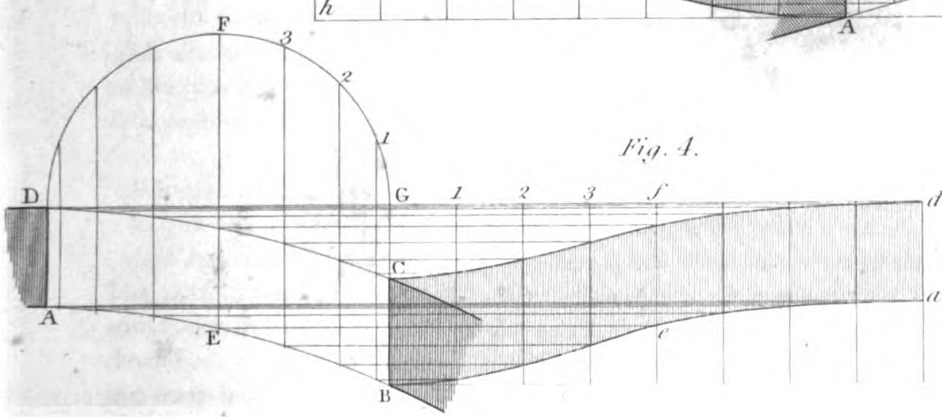


Fig. 4.

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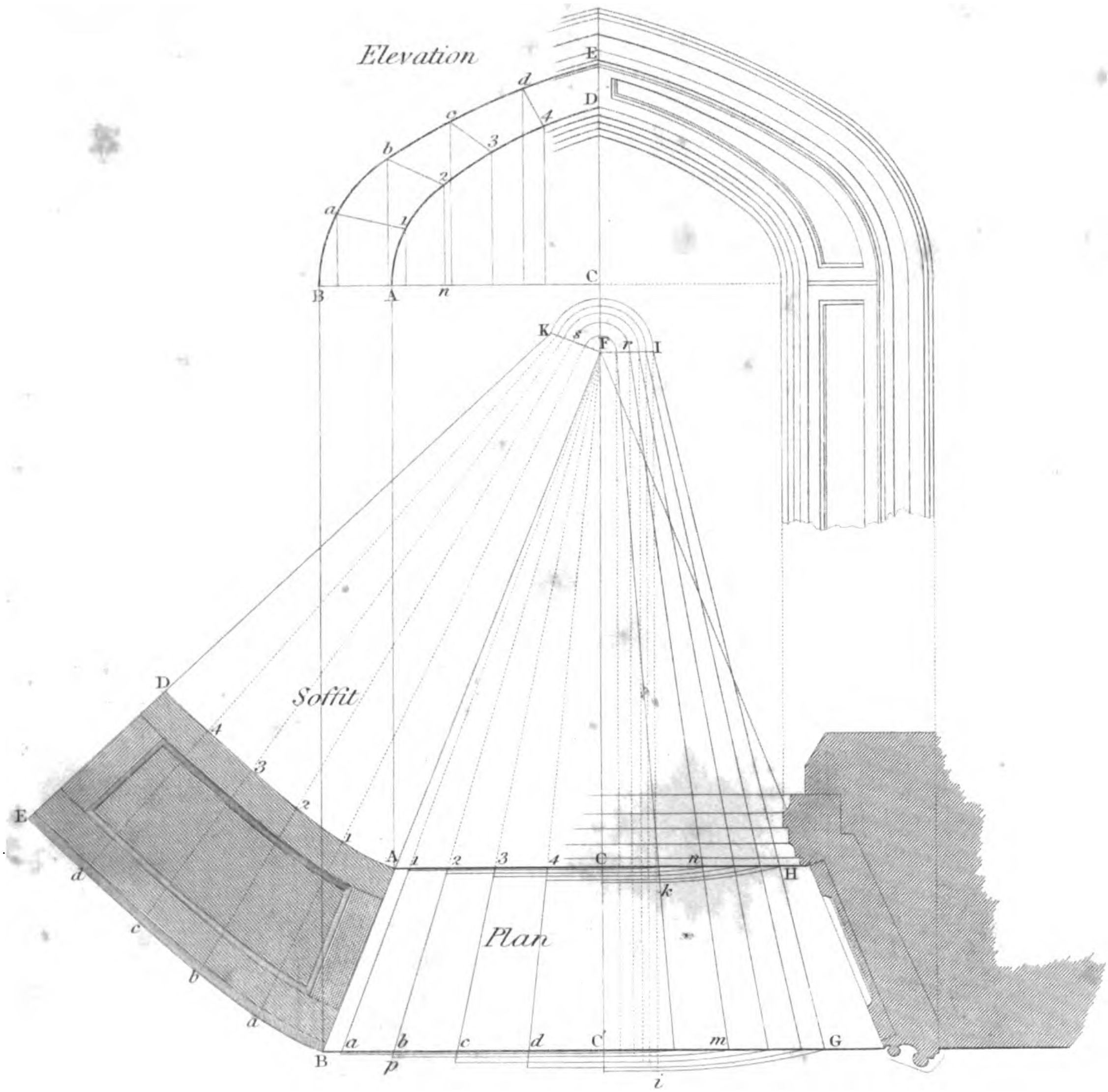
SOFFITS.



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draw lines parallel to D*d*; and these lines will meet the parallels from the divisions in G*d*, in the edges of the soffit CB*a d*, which is distinguished by a light tint in the figure.

53. To develope the soffit of a Gothic arch, when the splay at the top is less than at the jambs.

The plan, the elevation, and the developement of the soffit, is shown in *plate VI.* Let AD, on the elevation, be the arch of the window, and BE the arch formed by the inner line of the architrave. Divide the arch AD into any number of equal parts; and from each point of division let fall a perpendicular to AC on the plan, which gives the points 1, 2, 3, &c. Produce BA to meet the middle line C′C in F; and from F draw the lines F1, F2, &c. to cut the line BC′ in *a, b, c,* &c. Transfer the points *a, b, c,* &c. from BC′ on the plan to BC on the elevation, and from each point draw a perpendicular to BC, meeting the arch BE in the points *a, b, c,* &c.

Make FI on the plan perpendicular to FC, and FK perpendicular to FA. Then, to find any point, as 2 for example, in the developement, make C′*m* and C*n* on the plan, respectively equal to *b m* and 2*n* on the elevation; and through the points *m, n,* in the plan, draw a line to meet FI in *r,* and transfer the distances *rn, rm* to the line FC; and from the points thus found in FC, draw lines parallel to AC to meet F*b* in *o* and *p*. Make F*s* equal F*r*; and from the point *s*, with the radius F*o*, describe an arc at 2 in the developement. In the same manner describe arcs for each of the points 1, 2, 3, &c. in the developement. Then, with a radius equal to one of the divisions A1, on the arch AD in the elevation, and the point A on the plan, as a centre, cross the arc at 1, which determines the point 1 in the developement; and from the point 1, with the same opening, cross the arc at 2; and from the point of crossing at 2, cross the next arc at 3, and so on, till the whole of the points A, 1, 2, 3, &c. in the edge AD of the developement, be found.

To find any point, *b*, in the other edge, through the points *s*, 2, draw the line *sb*, and make 2*b* equal to *op*; and so of other points. Lines drawn through the points will give the form of the soffit, ABED, as shown by the figure.

The same method applies to the case where the soffit is level at the crown. And it is drawn for a Gothic arch in the figure, but it is equally applicable to any other kind of arch.

54. As no line can be formed on the edge of a single piece of timber, so as to arrange with a given surface, nor in the intersection of two surfaces, (by workmen called a *groin,*) without a complete understanding of both the sections and coverings of solids, the reader is required not to pass them until the operations are perfectly familiar to him; and for the more effectually rivetting the principles upon his mind, it is requested that he will *model* them as he proceeds, and apply the sections and coverings found on the paper to the real sections and surfaces of his models, by bending them around the solid.

CHAPTER II.

CARPENTRY.

55. CARPENTRY is the art of applying timber in the construction of buildings.

To CUT TIMBERS, and adapt them to their various situations, so that one of the sides of every timber may be arranged according to some given surface, as indicated in the designs of the architect, is one department of Carpentry which requires profound skill in geometrical construction. The other department consists in the art of applying and joining rough timbers, so as to give the greatest degree of strength.

For these purposes, it is necessary to be expert in the common problems we have given, with a thorough knowledge of the sections of solids and their coverings, and the various methods of connecting timbers. Of these subjects, the first has already been explained in the introduction to this Work, and we are now about to treat of the other; that is, the METHODS of CONNECTING and FRAMING TIMBERS.

Since a thorough knowledge of Carpentry can be obtained only by considering both departments in the construction of each piece of work, the principles of framing and connecting timber being carefully studied, we may then proceed to consider each subject, or smaller division, of the art with reference to both the departments.

56. When the distance of two walls is not much more than fourteen or fifteen feet, a floor may be formed over the space between them, of sufficient strength by a series of joists, or a roof may be formed by a series of rafters; but when we want to cover an area of forty or fifty feet square, no single piece of timber would be of that strength which is necessary to render a floor or a roof firm and secure.

Hence, it is necessary to combine pieces of timber for such purposes, and to combine them so that they may have the greatest possible degree of strength and firmness. The art of combining pieces of timber to increase their strength and firmness is called *Framing*.

PRINCIPLES OF FRAMING.

57. The form of a frame should be designed according to the nature of the load it is to carry; for it is clear that the framing which would be best adapted for supporting a load at the middle, would not be equally fit to carry a load at any other point of its length. In carpentry the load is usually distributed over the whole length of the framing; but it is generally supported from point to point by short beams or joists. We will first consider the case where the load is col-

PRINCIPLES OF FRAMING.

Fig. 1.

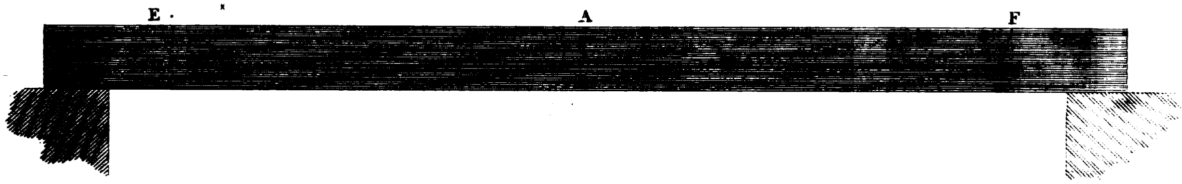


Fig. 2.

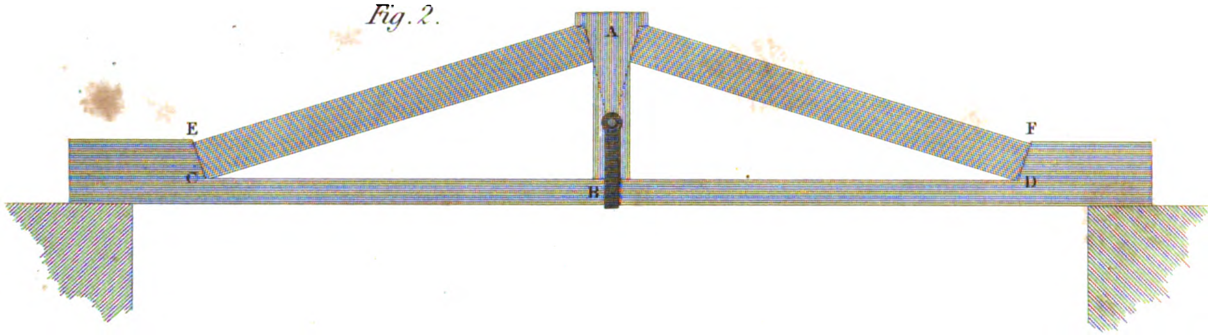


Fig. 3.

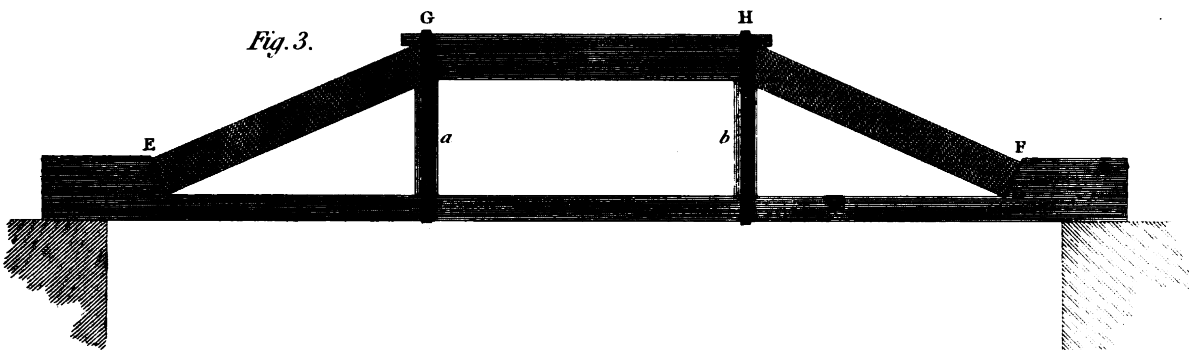


Fig. 4.

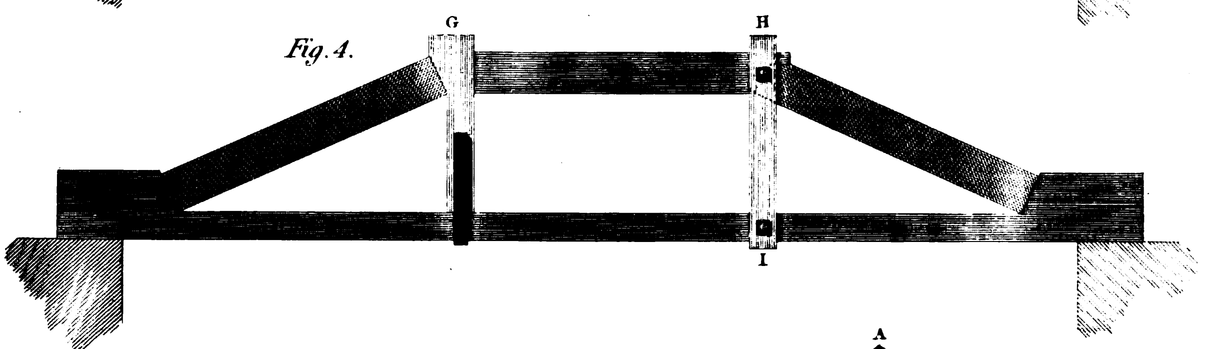


Fig. 6.

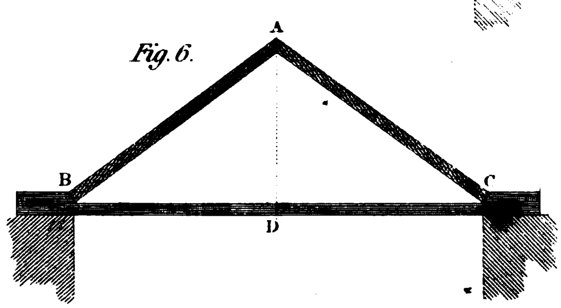
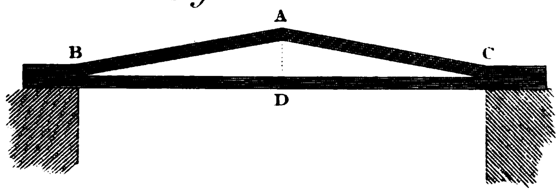


Fig. 5.



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lected to one point of the length of the frame. And, in order that the advantage of framing may be more obvious, we will suppose its parts to be cut out of a single beam, which in a solid mass would have been too weak for the purpose.*

58. Let *fig.* 1, *plate VII,* be a piece of timber, and make the saw-cuts in it which are shown by the dotted lines, and in the same proportions, and remove the triangular pieces E, F. Then raise the pieces AE and AF till they form close joints at E and F, and insert a piece of hard wood at A, cut so as to fit the ends. The piece of timber will then form a frame or truss, as represented in *fig. 2,* if a slight strap in the middle be added to sustain the lower part B to the piece A. If the depth of the frame at the middle be double the depth of the beam, the strength of the frame will be a little more than three times the strength of the beam, and its firmness will be very nearly eight times as great as that of the beam. If the depth of the frame be made three times the depth of the beam, as represented in *fig. 2,* it will be about six times as strong as the beam, and about eighteen times as firm or stiff; that is, it would bend only an eighteenth part of what the beam would bend by the same weight. When the depth of the frame is increased in the middle to more than three times the depth of the beam, the truss ceases to be equally strong in all its parts, and has the greatest strength in the middle, but is weak near to the joints at C and D.

59. To render the strength more equal, and to obtain two points of support instead of one, the piece A may be made longer, and joined, as in *fig. 3.* But, in this case, if a greater weight were to be supported at G than at H, there would be a tendency to spring outwards at H, and inwards at G. This may be effectually prevented by inserting the short struts *a, b,* and the iron straps shown in the figure.

Frames or trusses constructed in this manner are exceedingly strong, and easily made, and the learner will gain much instruction by trying them in model. The abutments at C and D are stronger than any that can be formed by mortises and tenons, and a small part of the wood being left whole at the angles C, D, renders tenons unnecessary. The parts are kept together at G and H by the straps. The wood is abutted end to end, and therefore its shrinkage cannot affect this truss.

Figure 4 shows two different modes of obtaining the same kind of effect. In one of these a short piece, G, is inserted, and connected to the tie, B, by a strap. In the other, the construction is the same as *fig.* 3, excepting that a piece, HI, is notched on each side at the joint, and the two pieces bolted together.

60. We have now to show why the strength of a piece of timber is increased by forming it into a truss; and to have a clear conception of this subject is one of the most important in the science of Carpentry.

Let ABC (*fig.* 5, *pl. VII,*) be a truss, to support a pressure to be applied at A; the action of the pressure will tend to spread the abutments B and C apart; and the nearer we make the angle BAC to a straight line, the greater pressure will be exerted on the abutments B and C by the same load at A. On the contrary, if the height be increased, as in *fig.* 6, the stress tending to spread the abutments will be less.

But when the height, AD, is very small, as in *fig.* 5, the stress on the abutments is very great, and the parts BA and AC must be also much compressed, and likely to fail through the excess of strain on them; while there is an immense strain, tending to thrust the piece BC asunder in the

* This idea was suggested by the bow-and-string rafter of Mr. SMART, described in the *Transactions of the Society of Arts,* Vol. XXXVII

direction of its length. If AD were to be no deeper than the solid beam, there is no framing nor disposition of the parts that would render the piece stronger than the solid beam, unless some stronger matter than timber were to be employed. A beam may be stiffened a little by tight wedging on the upper side, but the increase of stiffness is very small, and it does not retain it for more than a few months in a place where the truss is exposed to vibration, as in floors of houses.

The idea that a truss could be made to strengthen a beam, without increasing its depth, was very general a few years ago. It was attempted to a considerable extent about the time Nicholson wrote his *Carpenters' Guide;* he gave the best method then in use; and it was not till many architects found the floors they constructed settle and shake, so as to threaten them with serious discredit, that a better mode was earnestly sought after; and it was effected by using a complete truss of iron, placed between the parts of a wooden beam, as we will describe when we treat of floors.

61. To find the pressure on oblique supports, or parts of trusses, frames, &c.

Having shown how important it is to attend to the strength of a truss, and how much it depends on knowing what degree of strain there will be on each of its parts, we will next proceed to show how the strain on any part may be measured. Let AB (*fig.* 1, *pl. VIII.*) be a heavy beam, and let it be supported by two posts, AC and BD, placed at equal distances from E, the middle of the beam. The pressure on each post will obviously be equal to half the weight of the beam. But if the posts be placed obliquely, as in *fig.* 2, the pressure on each post will be increased exactly in the same proportion as its length is increased, the height AC being the same as before: that is, when AF is double AC, the pressure on the post, in the direction of its length, is double the half weight of the beam AB; when AF is three times AC, the pressure in the direction of the post is three times the half weight of the beam, and so on. Hence, it is very easy to find the pressure in the direction of any inclined strut, for it is as many times half the weight supported as AC is contained in AF; therefore, if the depth AC of a truss, to support a weight of two tons, be only one foot, and AF be ten feet, the pressure in the direction AF will be ten tons.

62. It will be observed, that, when the beam is supported by oblique posts, as in *fig.* 2, these posts would slide out at the bottom, and slide together at the top, if not prevented by proper abutments. The force with which the foot F tends to slide out, is, to half the weight of the beam AB, as FC is to AC; therefore, when FC is equal to AC, the tendency to slide out is equal to half the weight supported; and if FC were ten times AC, the tendency to spread out would be ten times half the weight supported. Hence, it will be evident, that a flat truss requires a tie of immense strength to keep it from spreading; and if a flat truss does produce any degree of stretching in the tie, the truss must obviously settle, and by settling it becomes flatter, and therefore exerts a greater strain. Consequently, in a very flat truss, too much caution cannot be employed in fitting the joints, and choosing good materials.

63. It is necessary that the lines drawn in the directions of the supports should meet in a point, in the vertical line drawn through E, the centre of the weight; for, when this condition is not attended to, the frame will have a tendency to spring out at the joint, where the direction of the support cuts the vertical line E at the highest point, and the other angle will have a tendency to spring inwards. In *fig.* 3, the angle B would go outwards, and A inwards, and the beam fall. But in *fig.* 2, the directions meet one another at the same point in the line E, and the parts balance one another.

Fig 2

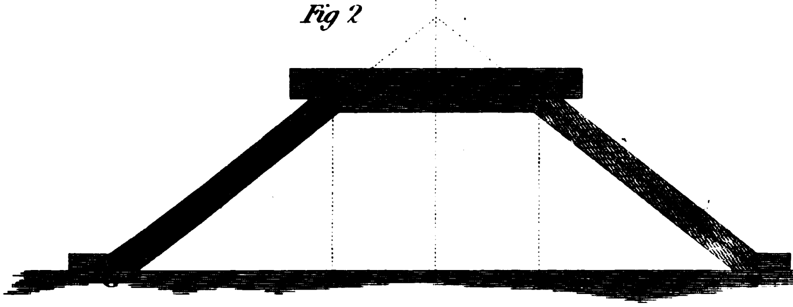
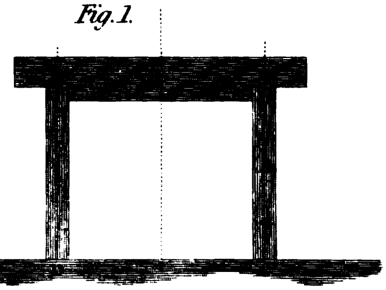


Fig. 1.



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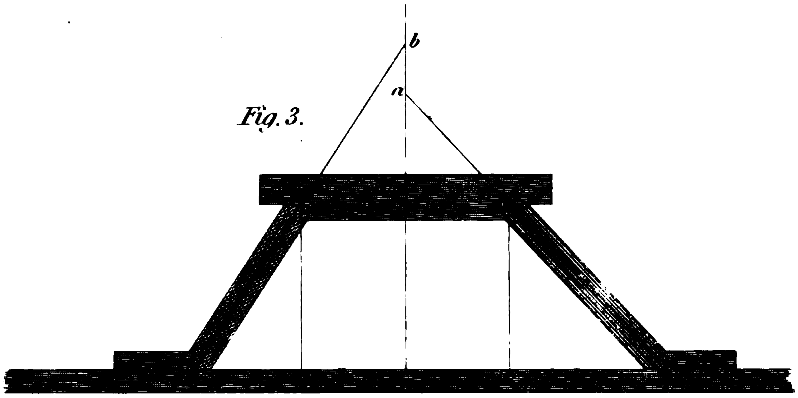

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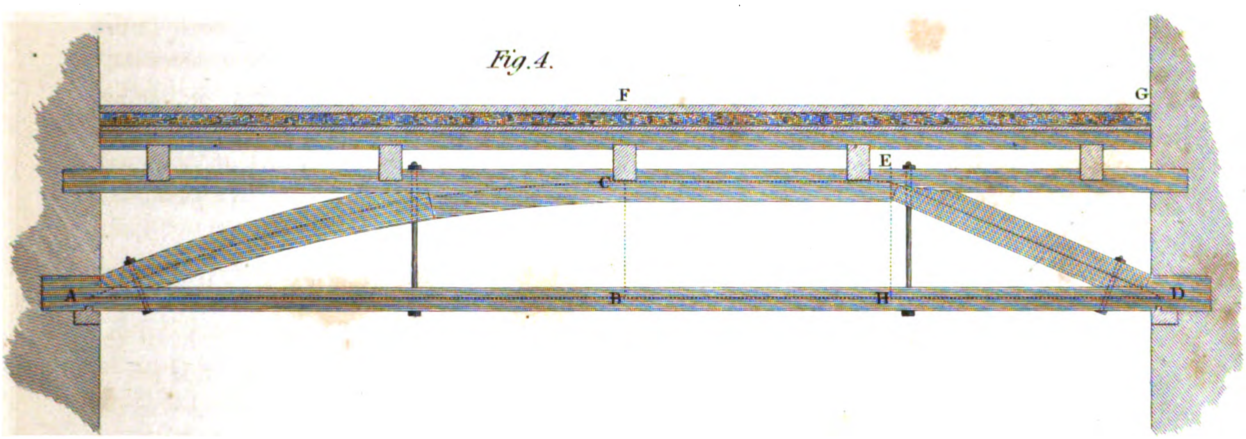

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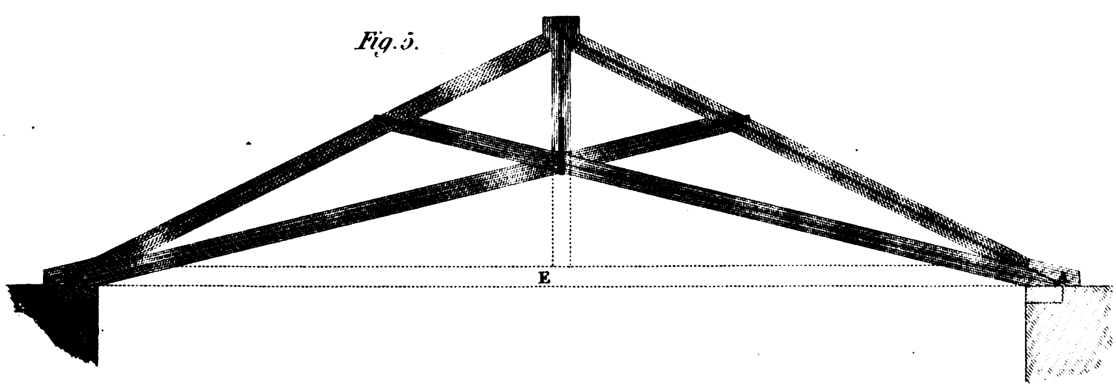

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In most of the cases which occur in practice, the weight to be supported is not regularly the same, it being sometimes more on one side, and sometimes on another; therefore a line drawn through its centre of action is not always exactly in the same place. Thus, in a roof, the wind acts sometimes on one side and sometimes on another; and, consequently, its strength must not depend altogether on a balance of its parts, as many mere theorists have imagined; but it must be provided to resist every variation of pressure by braces, disposed so as to resist any change of figure: examples of the application of braces will be given in treating of partitions and roofs.

64. There are cases where the strains do not depend on the position of the parts of the frame, and these it is important to explain, because they have sometimes been misunderstood, and have led to very inaccurate notions respecting the strength of framing. For example, if a heavy lead flat be supported by a truss, of which the depth at the middle point is CB, (*fig.* 4, *pl. VIII,*) then, the weight being uniformly distributed over the length, the centre of the weight, resting on half the truss FG, will be at E. This part of the weight is to be supported from the points C and D; and the direction EC cannot be varied; therefore ED must be the direction of the stress on the point D, whether the strut be in that direction or not. The best place for the strut is the direction ED, as shown in the figure, unless the framing be contrived so that a parabolic curve, AC, can be described through the centre of its depth, as shown in the side, AC, of the figure.

It should also be observed, that the strains at C and B are not altered by any arrangement of the framing, not even if all the other parts could be made solid masses, without addition to their weight. So that to render the truss stronger the bulk of the timber must be increased at B and C, or the truss made so much deeper.

65. When the spreading of a frame is to be counteracted, it is most effectively done by a straight tie-beam, connecting the points together; but sometimes a carpenter is so limited for space, to form a truss in, that he cannot obtain a straight tie, and then it is desirable to know the strain on such a tie as can be procured.

Let ACD (*fig.* 5, *pl. VIII,*) be a truss to which a straight tie, AED, cannot be applied without interfering with the architect's design. In this case, let AB and BD be the ties; and draw the lines in the middle of the pieces, forming a triangle, ACB. Then, as CB is to AB, so is half the load at C to the strain it produces on the tie AB. And the strength of the frame ABCD is to the strength of a frame of the same quantity of material, having a straight tie AED, as CB is to CE. In the example we have drawn, the frame would have only half the strength of one with a straight tie.

It is also a serious defect in this species of framing, that its settlement, however small it may be, tends to spread out its supports, A and D, while an equal settlement of a frame, with a straight tie, has scarcely a sensible effect; and the tendency of what effect it has, is, to draw the supports nearer together, instead of spreading them asunder.

ON SCARFING AND LENGTHENING BEAMS.

66. When timber cannot be procured of sufficient length to answer a required purpose, it becomes necessary to join two or more pieces together, in order to obtain the extent required, and the mode of uniting the pieces is called *Scarfing.*

SCARFING is, therefore, the art of connecting two pieces of timber together, in such manner as to appear like one piece, and possess sufficient strength to answer the purpose which renders this connection necessary.

In scarfing timber it is not requisite to pay particular attention to the form of the joint, as that can be altered at pleasure, to meet the views of the mechanic.

In each piece of timber to be joined, the parts of the joints that come in contact are called *scarfs*.

Scarfs are formed either by a slanting joint, or by notching the two parts together; and, sometimes, by a third short piece, which has a mutual connection with the two.

The projecting parts of a scarf are called *tables*.

When the scarfs are put together, they are usually firmly secured in that position by bolts passing through the joints.

Some of the most useful methods of scarfing beams will be understood by a reference to the *plate IX*.

67. *Figure* 1, on this plate, shows the method of lengthening beams, without shortening the pieces, by applying an intermediate piece, and connecting the three by means of *steps;* the joint being secured by iron plates with bolts.

68. *Fig.* 2 represents another method of joining beams by steps, where the timber is shortened as much as the length of the scarf.

69. *Fig.* 3 is a method of building beams, by uniting smaller ones together; where the different lengths meet, they are connected by tabling, as at A, if the timbers be of sufficient length, or as at B, if they be short. A person of judgment will always choose that method which makes the smallest number of joints; and hence will prefer the joining at A, to that at B. The joint A may be tightened by wedges, if an accurate and neat joint be required.

70. Another method of joining by tables is shown by *fig.* 4, the parts being locked together by a pair of wedges, or keys. No. 2 is a perspective sketch of the scarf and tables.

71. *Fig.* 5 shows a method of joining two pieces of timber by an oblique scarf; the mode of forming the parts is shown by the perspective sketch, No. 2. The ends may either be cut square across, or as shown in No. 2; the latter mode of cutting makes it less difficult to keep the pieces fair and even at the joinings.

72. But timbers may be lengthened in various ways, besides those we have already noticed, either by making the piece of timber in two or more thicknesses; or, by securing one piece to another, with a piece on each side, over the joint, and then spiking or bolting each piece on both sides of the joint. Sometimes the pieces that are applied on the sides are made of wood, in this case it is called *fishing the beam*. Such modes are used in ships, when their masts, beams, or yards, are broken, in order to mend them. Other modes of continuing the length of timbers or beams, are by splicing them with a long bevel-joint, ending in a sharp edge at the end of each piece. Sometimes the sharp edge of the end of each piece is cut off, so as to form an obtuse angle at the top. Sometimes the splice is so formed that the two surfaces which come into contact are indented into each other, which adds greatly to their security, when firmly bolted together. Every kind of scarf for *strength* should have a strong iron-strap upon each opposite side, extending in length considerably beyond each joint. Timbers that are scarfed and strapped ought to be so applied that the sides which are strapped should be the horizontal sides; for, if otherwise applied, they will be liable to split at the places where they are bolted.

But if the surfaces having the abutting joints be placed in a vertical position, there ought to be two straps at the top, and two at the bottom; each strap being brought close to the hori-

SCARFING OF TIMBER.

Fig. 1.

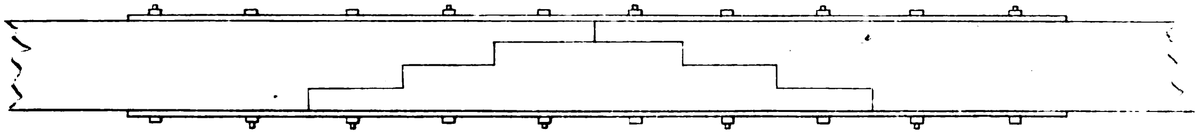


Fig. 2.

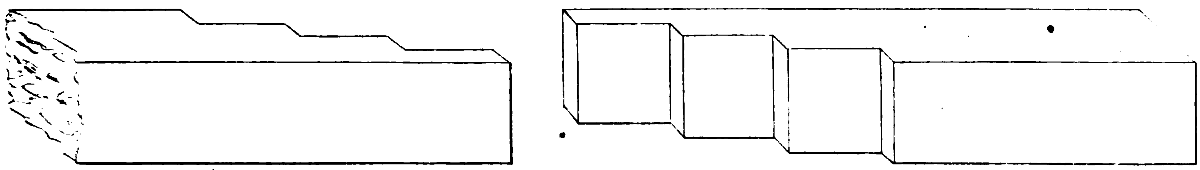


Fig. 3.

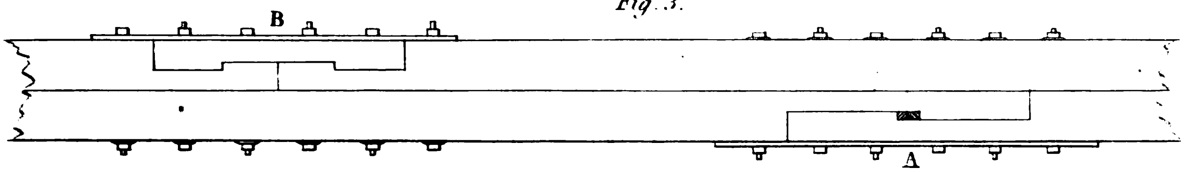


Fig. 4.

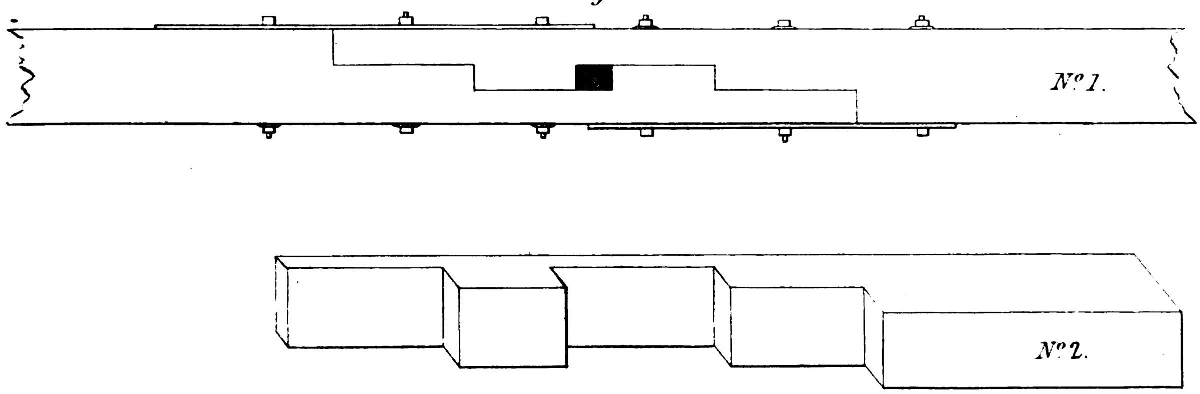
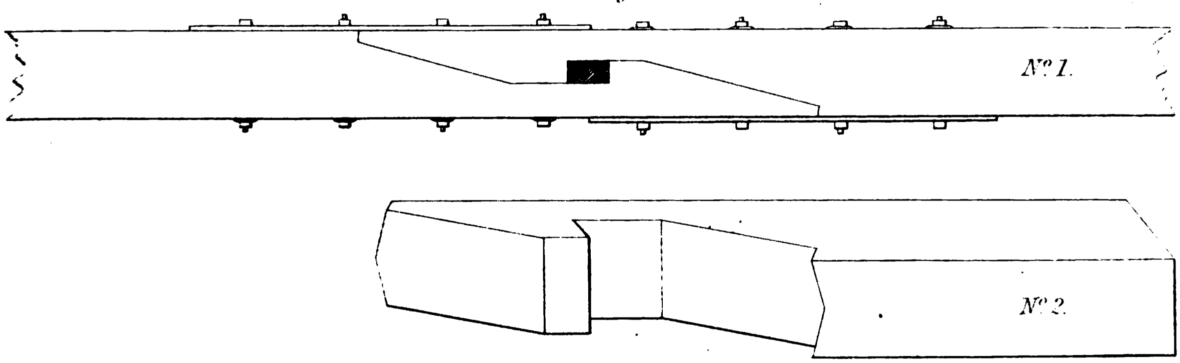


Fig. 5.



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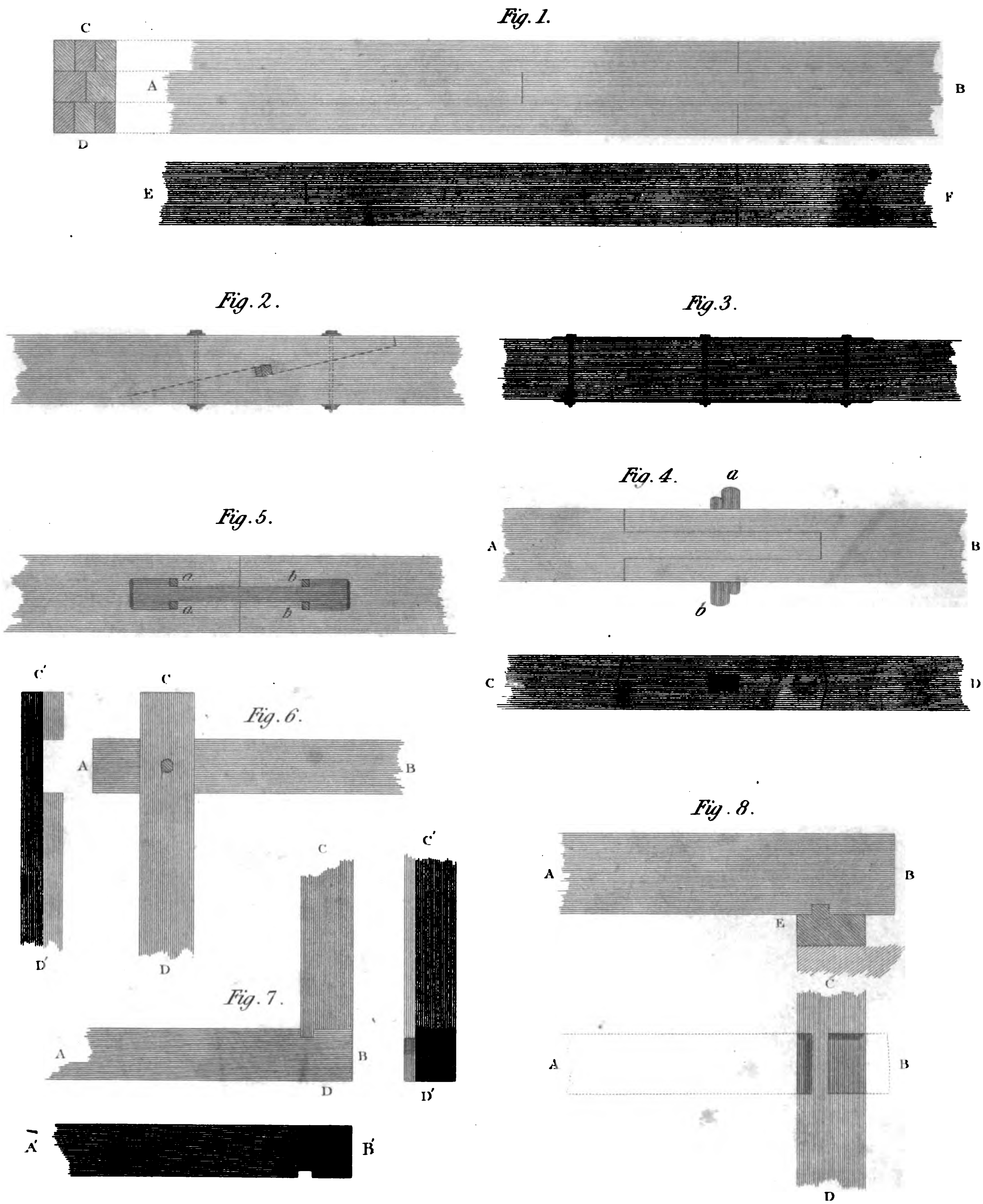
Edmd. Turrell, sc.

Connecting Timbers,

Pl. X.



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zontal face. By this method the scarf will be much stronger than when set in the other position, or with the joint of the scarf horizontal.

73. *Fig.* 1, *plate X*, shows a method of building a beam for any purpose for which one piece of timber would not be of sufficient strength. The pieces should be put together so that the joints may be as far distant from each other as possible. In this instance the section of the beam is supposed to be in eight pieces. The reason for preferring small parts, is, that the beam may not be rendered weak at particular points by the abutting joints of large pieces. AB is the side, CD the section, and FE the plan of the upper surface of the compound beam.

74. *Fig.* 2 shows a scarf, with indents, and wedges, to draw the joints close. It is a very good and simple species of scarf.

Fig. 3 is a plainer kind, but its connection depends entirely on bolts and straps.

Fig. 4 is a good kind of joining for cases where bolts are not used, and much strength is not required. AB is the side and BC the upper surface. The joint to be tightened by the wedges, *ab*.

When the parts are not long enough to allow of being joined by the preceding method, a key may be employed, as shown by *fig.* 5; the parts being forced together by wedges, as at *a* and *b*.

Connecting Horizontal Timbers at Right Angles.

75. The connection of many kinds of horizontal timbers is effected by notching. In wall-plates the joints are formed as *fig.* 6, where C′D′ is the side of the piece CD. The addition of a pin through the joint is a common and a useful practice.

Fig. 7 shows a joint for the case where the ends have to be cut fair, as in external wall-plates, the wall-plates of hot-houses, and the like; C′D′ shows the plate CD when the other is removed, and A′B′ is the plate AB turned upside down.

76. When the timbers are not in the same plane, but yet so that the upper can be notched into the lower ones, as in *fig.* 8; then this figure shows the most effective form for the joint. CD is a wall-plate, and AB may be a tie-beam, a binding-joist, a diagonal tie, or any other timber which it is important should be firmly connected to the wall-plate. Giving the timber a short bearing at E adds much to its strength for bearing purposes. The figure is drawn about in the proportions usual in practice.

77. The principle of notching, with square abutting joints, has always been much adhered to by the best carpenters; but its advantages over the dove-tail joint, in not admitting the joint to draw when the timbers shrink, was, we believe, first noticed in Tredgold's Carpentry. (*Sect.* IX, p. 146.) He has shown that all dovetail-joints will draw, when the timber shrinks, and that the oblique surface of the dove-tail acts as a wedge to force the timber apart.

78. Where the timbers are in the same plane, and not sustained by walls, except at the ends, as in the case of joists and other floor-timbers, the joints ought to be formed so as to have the best possible bearing without weakening either the supporting or the supported joist. The joint of a binding-joist framed into a girder, is shown by *fig.* 1, *plate XI*; and it is one of the most perfect joints of this kind that we have seen. A is the section of the girder through the joint; B, a binding-joint in its place; C, one drawn out to show more distinctly the form of the joint. In fitting it, the lower bearing, *a*, should take the pressure equally with the tenon, or rather more than less of it. The sloping tusk, *b*, it will be observed, extends further on to the tenon than the lower bearing, so as to strengthen it. The joints are held together by pins, draw-bored a little to bring the parts in contact.

79. When timbers are not in the same plane, and continue across one another, it is usual to notch them; but, in so doing, the timber should not be cut away more than is absolutely necessary. Where the timber has to be notched down not more than one-fourth of its depth, it may be done as in *fig.* 2; but when the quantity to be notched down is more than one-fourth of the depth, *fig.* 3 shows the mode usually adopted.

Connection of Horizontal to Vertical Timbers.

80. If a horizontal timber to support a considerable weight has to be framed into a vertical post, it should have a degree of insertion in proportion to the strain upon it (see *fig.* 4, *plate XI.*); and if the breadth of the timber be greater than 6 inches, a double tenon will be better than a single one. There is no objection to double tenons for bearing purposes, where the tenon is vertical, but they have been very justly objected to for horizontal bearing timbers, on account of the difficulty of making each tenon bear alike. To prevent the joint being drawn out beyond the insertion, it should be secured by a pin for ordinary purposes, or by a strap where the strain is great.

Abutting-Joints for Oblique Timbers.

81. The proper formation of a joint, when the surfaces are oblique to one another, is one of the most difficult tasks in the whole art of framing. We hope, however, to be of considerable assistance to the practical Carpenter in this matter, and we will take for illustration the familiar case of the joint between the foot of a principal-rafter and a tie-beam.

In the first place, when the truss settles, from its own weight being increased by the addition of the covering, the settlement tends to throw the pressure on the internal angle of this joint: hence it is desirable that the chief abutment should be as near to that angle as possible. This is also attended by the advantage of removing the abutment further from the end, and, consequently, further from a risk of decay. Perhaps these properties are attained in the greatest degree by the joint, *fig.* 5. The dotted line shows the tenon. The extreme end receives the strap, indicated also by dotted lines.

Fig. 6 is a more common form, but certainly not so good when the above reasoning is considered.

Fig. 7 is a better form than *fig.* 6; its greatest defect consists in the difficulty of fitting two abutments, and particularly where they are likely to change their position by the settlement of a roof.

Fig. 8 is of an intermediate kind between these varieties; it is a very simple and effective joint.

82. When the timbers will allow of being cut for the purpose, a *joggle-joint* is the best. In king-posts and partitions the joints are generally done in this manner. *Fig.* 9 is an example of the head of a king-post with a joggle-joint.

At the side, marked A, the joggle is cut so as to receive the whole of the end of the rafter; but we prefer that a part should abut against the side of the king-post, as at B: first, because there is less width of wood to shrink; and, secondly, when the abutment is made to bear most on the angle *a*, the joint is less affected by any change of position. In fact, it then resembles the circular joints so strongly recommended by Professor Robison and Mr. Tredgold.

83. The thickness of the tenon for any of these kinds of joints is generally made one-fourth of the thickness of the timber; and the tenons are made short in modern works, the joints being bound together by straps of iron.

Having treated of the principles of framing, and the construction of joints, we now proceed to examples of their application.

CONNECTING TIMBERS,

Fig. 1.

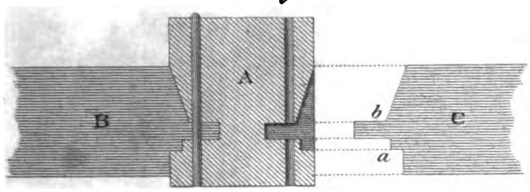
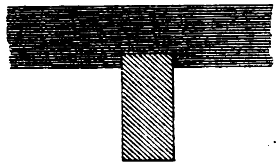


Fig. 2.



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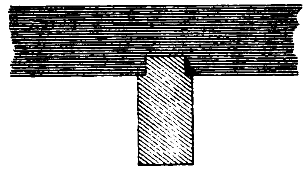

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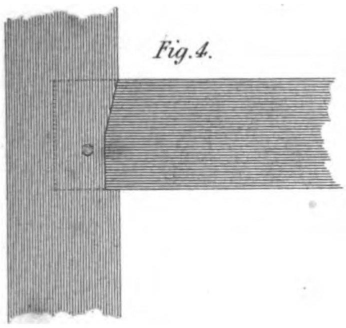

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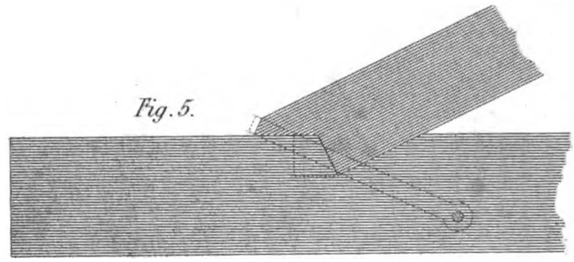

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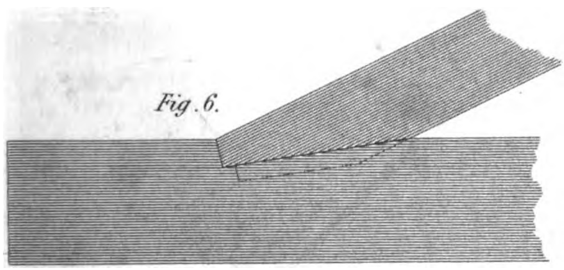


Fig. 7.

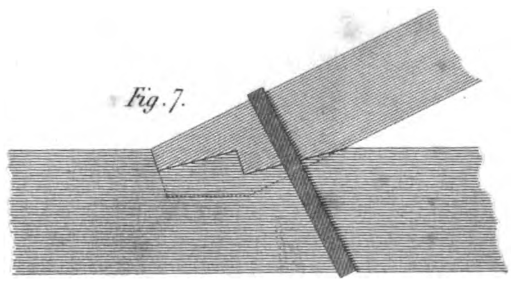


Fig. 8.

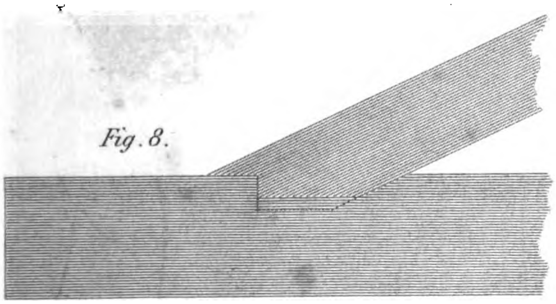
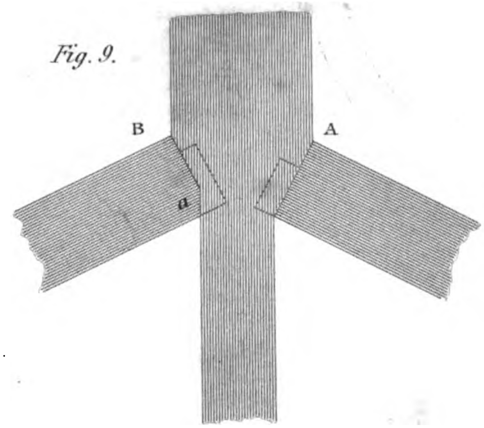


Fig. 9.



E. Turrell Sculp.t

London, Published by Thos. Kelly 17, Paternoster Row, January 2. 1835

DESIGNS FOR PARTITIONS.

Fig. 1.

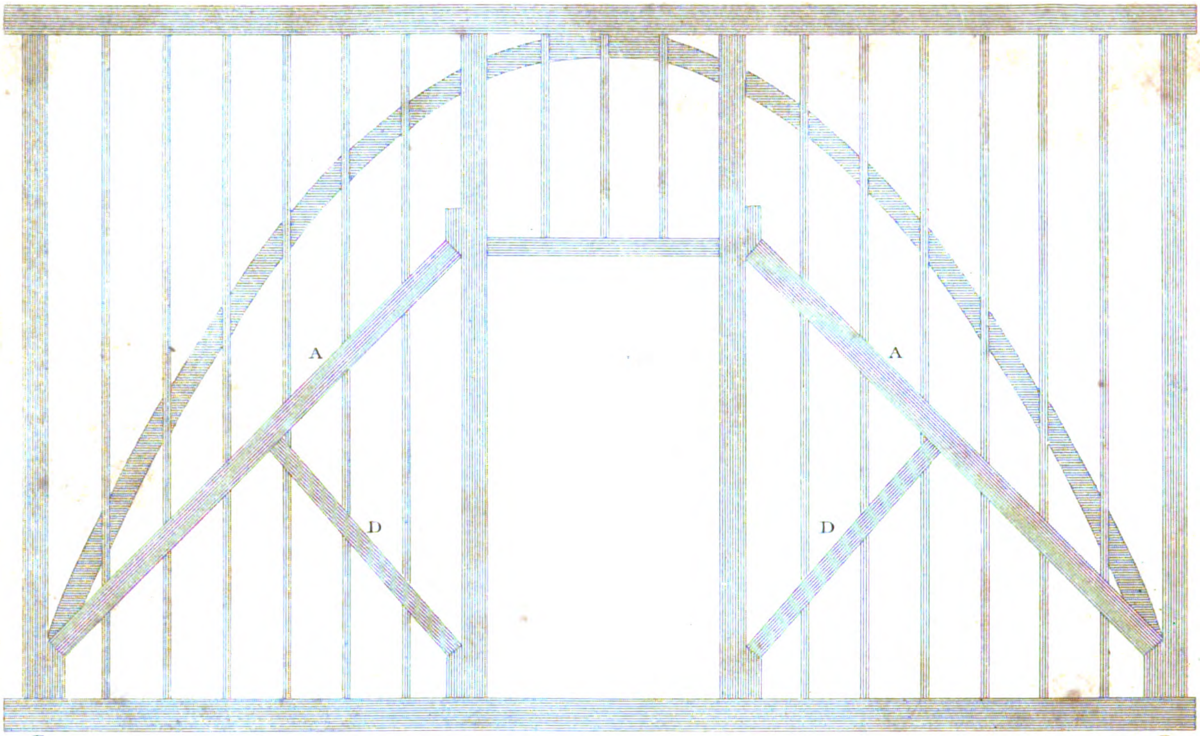
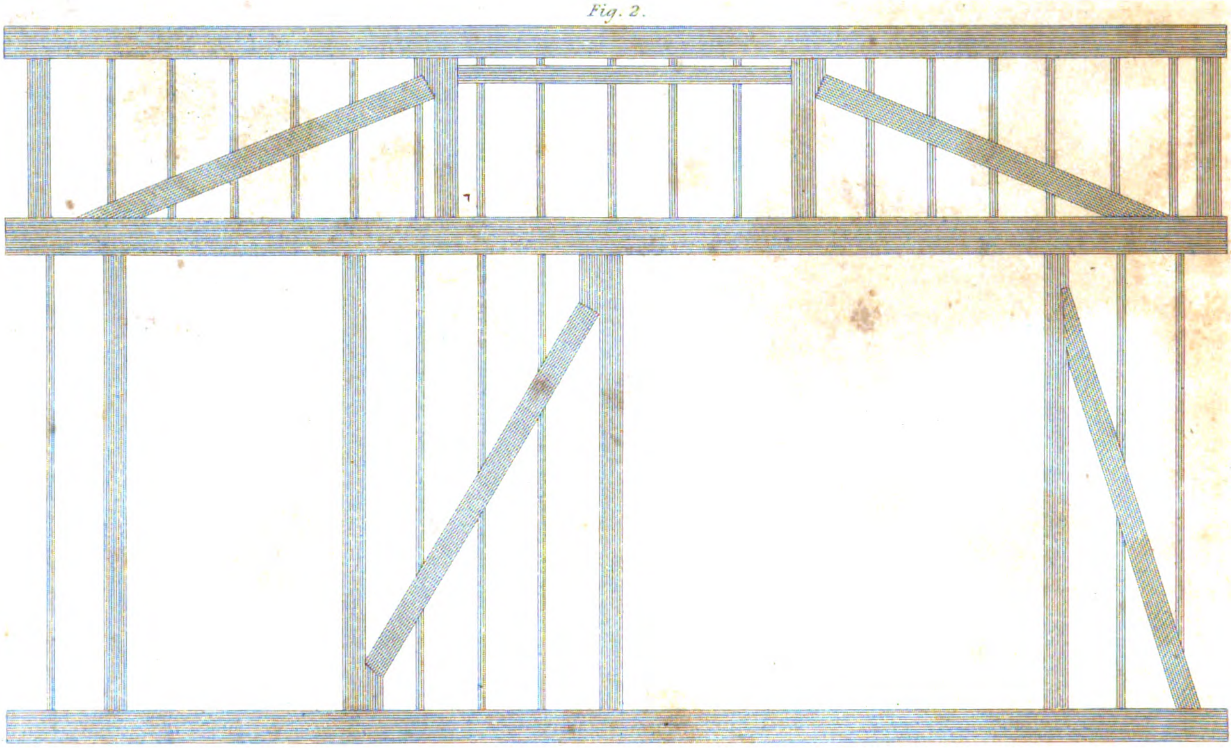


Fig. 2.



H. Adlard Sculp.

London Published by Thos. Kelly, 17, Paternoster Row, Jan. 2 1837.

TIMBER PARTITIONS.

84. PARTITIONS, in Carpentry, are framed divisions between rooms, filled with ribs of timber for sustaining the laths and plaster.

It is evident that long pieces of timber, when supported only at each extremity, will descend more and more towards the middle, and will take a curvature; but, if supported by trusses or braces from any fixed points, the braces will prevent that deflexion from the straight line.

85. *Figure* 1, *pl. XII*, is a design for a TRUSSED PARTITION, with a door in the middle. In order to keep the timbers from descending, two braces, A, A, are introduced, one on each side of the door-way, and the weight is supported at each extremity of the sill. The two struts, D, D, which support the middle of these braces, are sustained at the lower extremities by the bottom of the door-posts. Now the door-posts cannot descend without pressing down the braces, and the braces cannot descend without forcing down the extreme posts; but, as each end of the foot-beam, or sill, is supported by the wall, the extreme posts cannot descend; therefore the two braces cannot descend, and the posts on each side of the door-way cannot descend; consequently, the timbers will keep straight. But the weight of the quarters may still have a slight tendency to bend the braces: in order to prevent this effectually, the parabolic arch may be introduced, as shown in the figure.

86. *Figure* 2 is a design for a partition with two door-ways, one of them being a folding-door. Here the braces on each side of the large opening not being each supported at each extremity of the sill, and as the upper part of the space is not interrupted by openings, a complete truss is introduced above the two apertures, particularly as there is sufficient height for a truss of proper strength. The middle door-posts should be connected to the tie of the truss by iron straps. A reference to *Art.* 58, and the following ones, will assist in giving the right proportion of strength to trusses of this kind.

87. In framing partitions the object to be kept in view is to render them firm, and capable of sustaining their own weight. If it be found that from the situation of door-ways, and want of height over them, that a partition cannot be framed so as to support its own weight, then, an adequate support should be placed under it.

If a partition be intended to prevent sound passing from one room to another, it should be made double, and a coat of lath and plaster between the two parts.

In cases where it is desirable to intercept the passage of sound through partitions in old houses, we have succeeded by battening upon the old partition, and lathing and plastering upon the battening. We have found the same expedient useful on a ceiling below a nursery; and not only lessened the noise, but also obtained a very perfect ceiling.

NAKED FLOORING.

88. FLOORS are those parts in houses that divide one story from another.

Floors are executed in various ways: some are supported by single pieces of timber, upon which the boards for walking upon are nailed. Floors of this simple construction are called *single-joisted floors,* or *single floors;* the pieces of timber, which support the boards, being called *joists.* It is, howevei customary to call every piece of timber, under the boarding of a floor, used either for supporting the boards or the ceiling, by the name of *joists,* excepting large beams of timber, into which the smaller timbers are framed.

When the supporting timbers of a floor are formed by one row laid upon another, the joists of the upper row are called *bridging-joists,* and those of the lower row are called *binding-joists.* Sometimes a row of timbers is fixed into the binding-joists, either by mortises and tenons, or by placing them underneath, and nailing them to the binding-joists: these timbers are called *ceiling-joists,* and are used for the purpose of lathing upon, in order to sustain the plaster-ceiling.

In forming the naked flooring, over rooms of very large dimensions, it is found necessary to introduce large strong timbers, in order to shorten the bearing of the binding-joists: such strong timbers are called *girders,* and are made with mortises, in order to receive the tenons at the ends of the binding-joists, which, by this means, are greatly stiffened, the timbers being much shorter.

The bridging-joists are frequently notched down on the binding-joists, in order to rendei the whole work more steady.

89. *Figure* 1, *pl. XIII,* is the plan of a naked floor: *b, b, b,* &c., are the binding-joists; *a, a, a,* &c. are the bridging-joists; *d,* a timber close upon the stair-case. This piece of timber is called a *trimmer:* its use is to receive and secure the ends of the joists, *e, e, e,* &c. upon the landing.

C, C, C, &c. are wall-plates, upon which the ends of the binding-joists rest. The other ends are sustained by a cross partition.

In the construction of floors, great care must be taken that no timber be at a less distance than nine inches from any flue or chimney; hence the ends of the timbers, as shown in this plan, have no connection with the fire-places, nor with the flues.

The flues, in the plans, are indicated by their being shadowed darker than the other parts.

90. *Figure* 2, *pl. XIII,* is a plan of naked flooring with a girder. In this case the joists are simply framed into a girder, A, of the same depth, in order to shorten and stiffen the joists. To prevent the too-frequent insertion of the joists in the wall, their ends are framed into the *trimmers, d, d, d,* &c.; and the ends of the pairs of joists, which enter the wall, are generally supported on short plates, called *templates.* The joists into which the trimmers are framed are called *trimming-joists.* The construction of this floor is not good; but, on account of the regulations of the Building-Act, it is often adopted in London. For a girder should not be supported by a wooden partition in any case where it can be avoided; and the cutting a girder with so many mortises weakens it. Partly from want of strength in the partitions, and partly from the weight of the floor being thrown on the partitions by girders, or by misplacing the joists, there are very few old houses in London that have not sunk from one to three inches in the middle. If the girder were taken out of the plan, *fig.* 2, and the joists made stronger, with cross-stays between them, at two places in the length, the floor would be much improved

91. *Figure* 3 represents the mode of fitting down the bridging-joists, A, to the binding-joists, B. And the ceiling-joists, C, are now almost always notched and nailed up, as shown in this figure.

92. *Figure* 4 shows the connection when there is binding-joists, bridging-joists, and ceiling-joists; as, also, the manner of fixing the binding-joists upon the wall-plates; this manner is called *cocking,* or *cogging.* The long dark parts represent the mortises, into each of which one end of each ceiling-joist is fixed. These long mortises are called pully-mortises, or chase-mortises. The end of each ceiling-joist is introduced into the common mortise, and the other end of it is put into the long mortise obliquely, and slides along until it be perpendicular.

NAKED FLOORING.

Fig. 1.

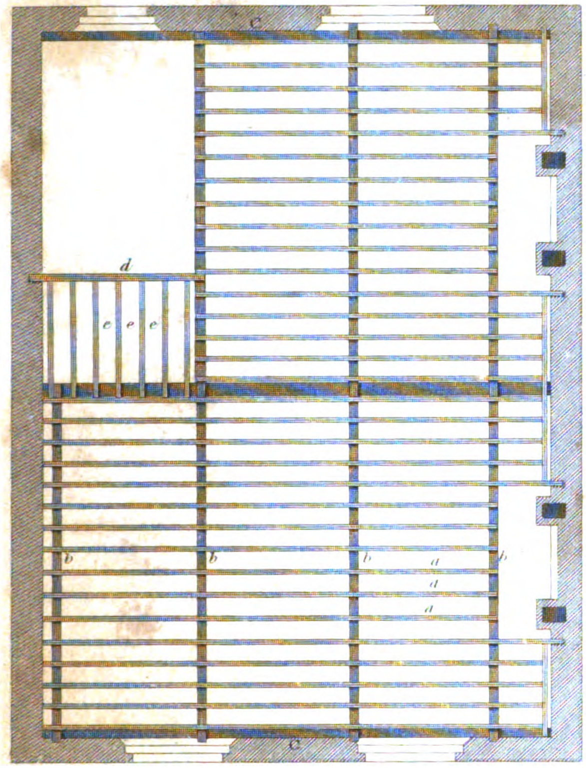


Fig. 2.

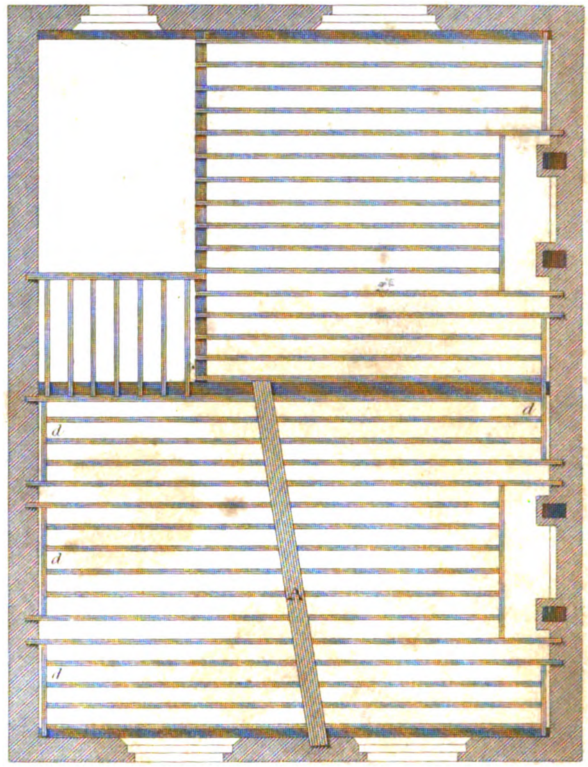


Fig. 3.

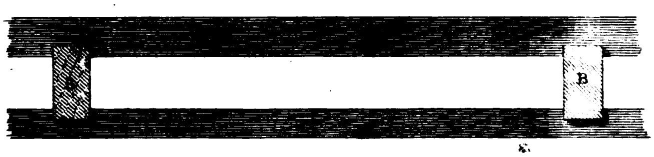


Fig. 4.

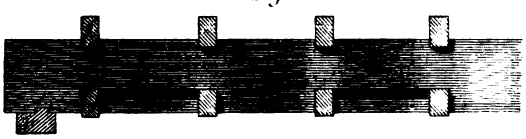


Fig. 5.

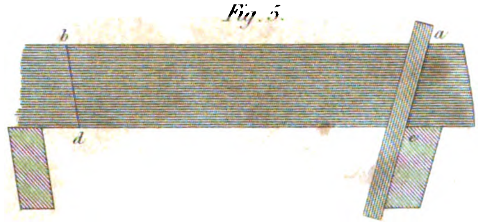


Fig. 6.

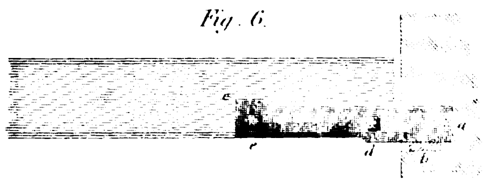


Fig. 7.

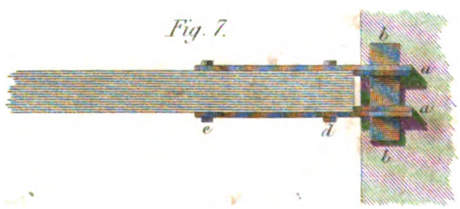
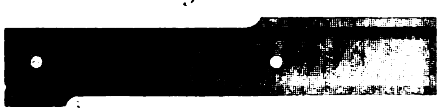


Fig. 8.



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Engraved by E. Turr

PLANS OF FLOORS TO A FIRST RATE HOUSE.

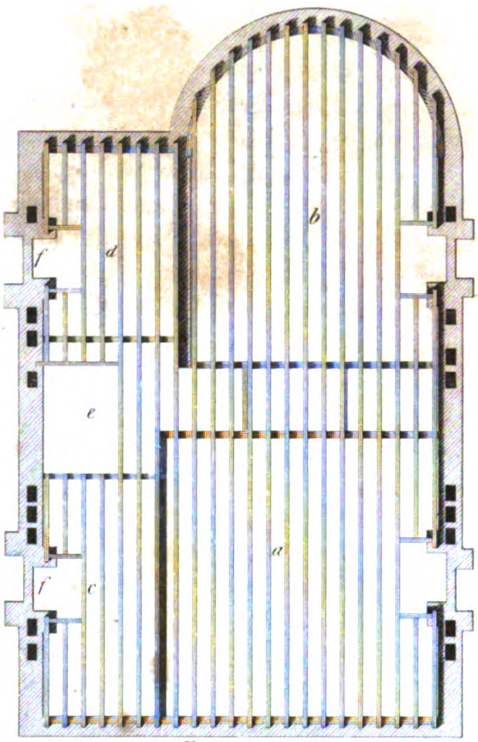

Fig. 3.

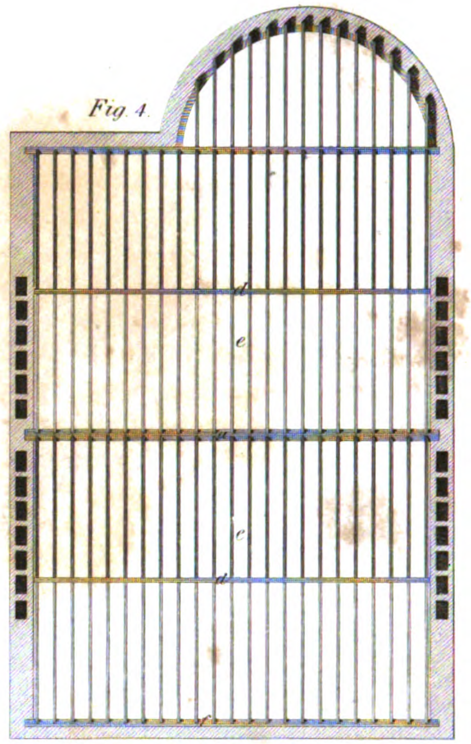

Fig. 4.

10 20 30 feet

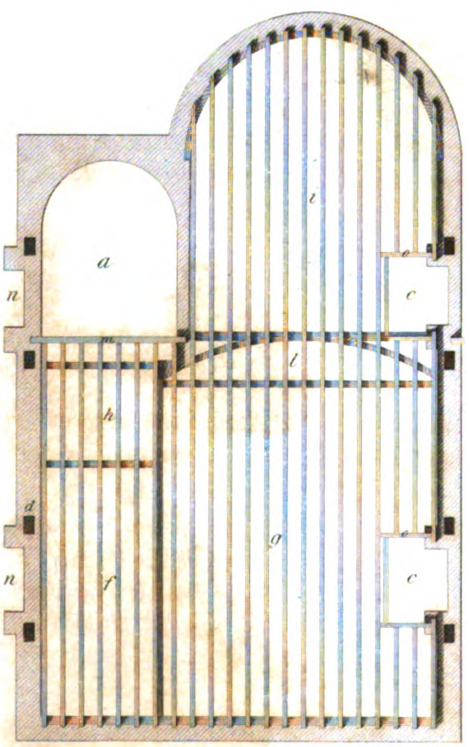

Fig. 1.

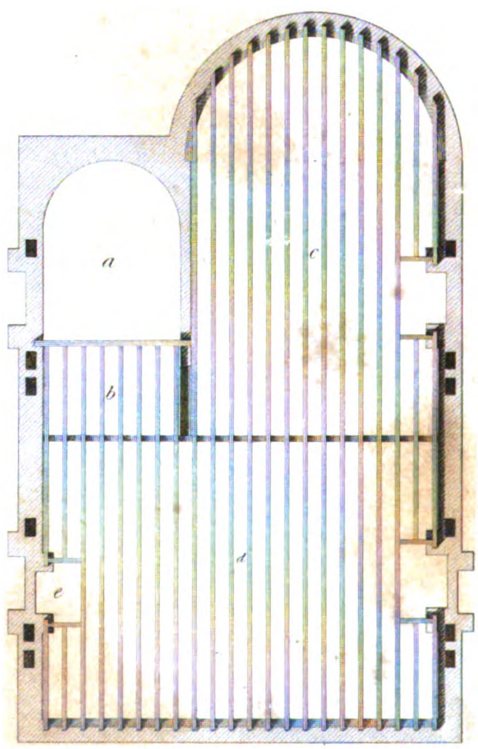

Fig. 2.

Designed by M. A. Nicholson

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93. TUMBLING in a joist, is to frame a joist between two timbers, of which the sides, which ought to be vertical or square to the upper edges, are oblique to these edges.

Figure 5 shows the method of fitting-in a joist between the sloping sides of two others. The first thing done, is, to turn the upper edge of the joist upon the top of the two pieces into which it is to be fitted, and brought over its proper place. The next thing is to turn the joist on its under edge, so as to lie over its place; then apply a rule, or straight edge, *ac*, upon the side of the one piece where the shoulder of the joist is intended to come; then slide the joist until the line, previously drawn on the upper edge, come to the straight edge of the rule so applied; then draw a line by the edge of the rule. Do the same at the other end, and the two lines thus drawn will mark the bevel of the shoulder of the tenon at each end.

94. It frequently happens, in modern houses, that the flues are so numerous as not to leave space for the insertion of binding or trimming-joists, without either placing them too far apart, or too near to the flues. To avoid this difficulty, we have generally put iron ends to the joists, as shown in *figs.* 6 and 7, *plate XIII. Fig.* 7 shows the plan of a joist with the iron plates bolted to it, one on each side; the iron ends, *aa*, resting upon a short iron plate, *bb*, inserted in the wall. The wooden joist is cut off so as not to touch the wall. A mortise is made in the joist on each side at *c*, *fig.* 6, and each plate is cast with a nob upon it, to insert in these mortises. *Fig.* 8 shows the inner side of one of the plates. The reasons for placing the bolts, and forming the plate, as shown in the figures, will be understood by considering that the bolt, *d*, and the ledges bear the whole weight; and that the bolt *d* being in its place, the one at *e* is to prevent the plates descending, or turning round on the bolt *d*: hence, the nearer the bolt *d* is to the end of the beam the better, and there should be as much distance between the bolts as the nature of the case will allow of.

The same method is sometimes applied to secure the decayed ends of girders, and renders the expensive process of renewing large girders unnecessary.

95. The plans of the floor-timbers for a house, which is called a first-rate house, according to the dimensions specified in the London Building-Act, are shown in *plate XIV. Fig.* 1 is the plan of the ground-floor, *a* is the space for the staircase, *cc* the spaces trimmed for the hearths; the joists, *fgh* and *i*, are supported by the partitions and the front and back walls. *Fig.* 2 is the plan of the first floor, *fig.* 3 the plan of the bed-room floor, and *fig.* 4 the plan of the attic floor. These plans will afford the Carpenter a tolerable idea of the slight and cheap system of constructing floors adopted for the London houses.

Trussed Girders.

96. It has been shown, in *Art.* 60, that to render a girder effective without increasing its depth, it must be trussed with a stronger material than wood; and, in *plate XV.* we show various methods of trussing girders with iron.

Fig. 1, *No.* 1, shows the arrangement of a truss, consisting of two truss-pieces, a king-bolt, and a tie. The truss-pieces should not be fitted too tightly into the parts of the beam. *No.* 2 is the plan of a girder trussed in this manner. The sides should be firmly bolted together.

Fig. 2 shows a girder trussed with queen-bolts, the truss being in three parts. When the span exceeds 23 or 24 feet, this species of truss is much to be preferred to the preceding. No. 2 shows the plan.

In all trusses of this kind the tie should be of wrought iron, and the extremities of the truss should extend on to the wall-plates, as shown in these figures; then the floor will remain firm, though the ends of the girder be partially decayed.

Figure 3 is a section of either of the preceding girders at the abutments to a large scale, with one of the bolts. *Fig.* 4 shows the abutment-bolt, with part of the tie, and of the truss-pieces. *Fig.* 5 is the king-bolt and part of the truss-pieces to *fig.* 1.

97. Where there is depth for the purpose a light truss may be framed, as in *fig.* 6, connected by bolts. The principles of framing trusses have been explained in *Art.* 63, and *plates VII.* and *VIII.*

98. In order further to illustrate this interesting subject, we have procured a drawing of the girders used for the large room over the Riding-School of the Horse Bazaar, King Street, Portman Square; the span being esteemed the largest in Britain. *Fig.* 1, *plate XVI*, shows the arrangement of this truss; and its parts, to a larger scale, are shown by the other figures. The span is 46 feet, and the floor is supported by eight of these girders, and the roof, with its three large lanthorn lights, is supported by girders of the same kind. They were designed expressly for the purpose, by Mr. Tredgold, and, according to his recommendation, each girder was proved before it was fixed in its place; the first one was proved by a load of six tons distributed over the middle part of the girder.

The tie TT is a double bar of wrought iron, each part 3 inches by 1 inch, and thicker where it is bent round the foot of the abutments; see *fig.* 5. For convenience, it was formed in lengths, and joined by gibs and wedges, as shown in *fig.* 6.

The truss-pieces B, B, are of cast iron, 3 inches in thickness, and 6 inches deep in the middle, and 4½ inches deep at the ends.

The middle stretcher, A, is also of cast iron, 3 inches in breadth, 9 inches deep in the middle, and 6 inches deep at the ends, its section in the middle resembling the letter I, and is shown in *fig.* 4. The straps, E, *fig.* 3, are of wrought iron, 5 inches by ½ an inch, and bent round the joints, as shown in *fig.* 4. The wooden beams, DD, rest on the edges of the ties, and are firmly bolted together. On these the binding-joists, CC, are notched; and the bridging and ceiling-joists, as shown in *fig.* 4. The enlarged parts are drawn to a scale of half an inch to a foot.

99. The framing to support the galleries of churches and chapels should be strong and secure, as they are frequently much crowded with people. In order to illustrate this part of our subject, we give the framing of the galleries of Camden-Town Chapel, near London, as executed by Messrs. Inwood, Architects. The following detail of the scantlings of the timbers, with references to them by letters, will render them still more useful to the reader, as it rarely happens that such minute detail can be procured.

Figure 1, *plate XVII*, the Truss to the Gallery at the west end, bearing on the Tower wall. Its scantlings are:—

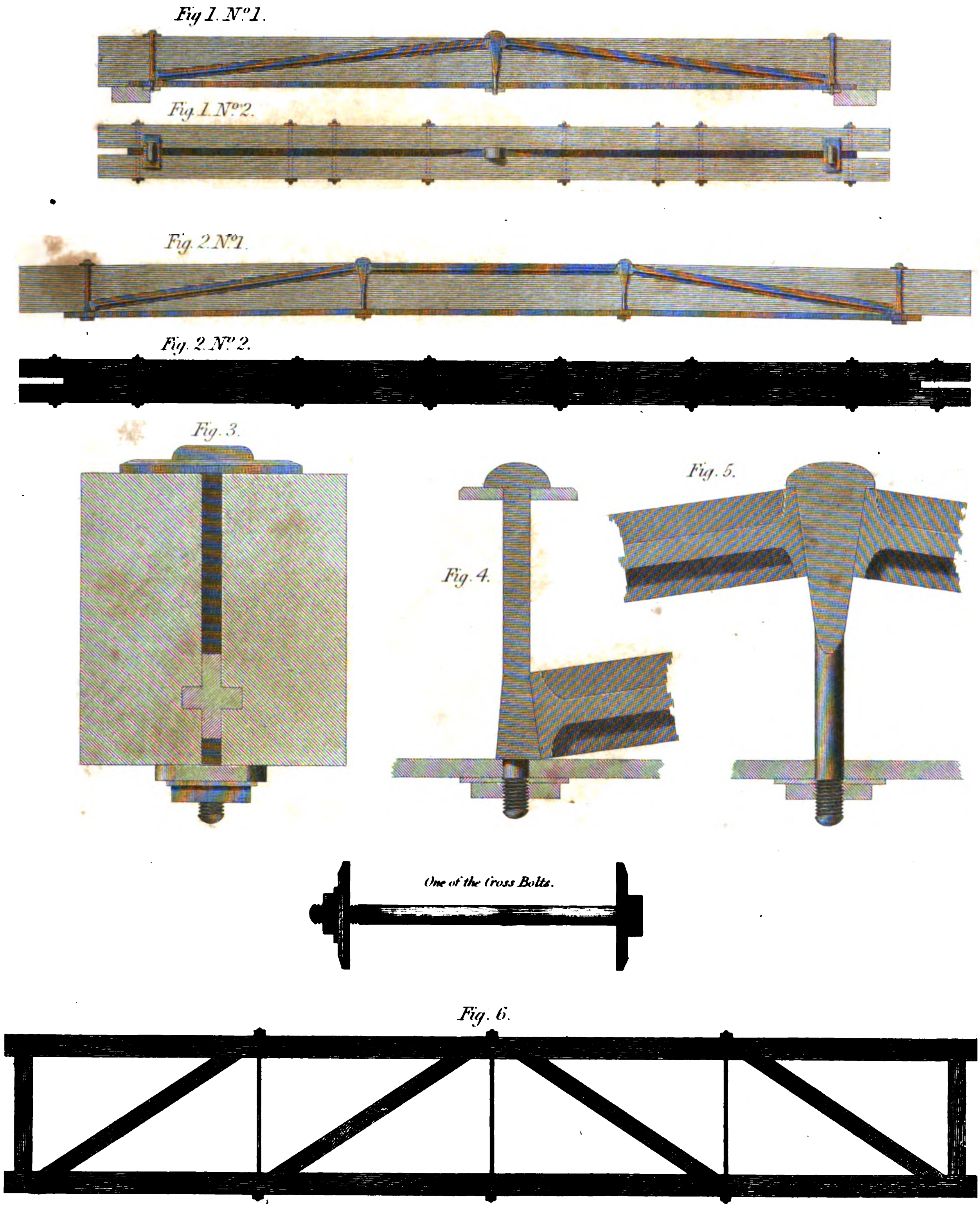
H, Strut, 8 inches by 6 inches.
J, Trimmer, 9 in. by 6 in.
K, Small Strut, 5 in. by 4 in.

Figure 2, the Trusses of the Side Galleries.

A, Bressumer, 10 inches by 8 inches.
B, Girder, 10 in. by 8 in.
C, Binder, 13 in. by 3½ in.
D, Bridging-joints, 4½ in. by 3 in.
E, Truss, 6 in. by 4 in.
F, Carriage, 8 in. by 4 in.

G, King-post (oak), 4 inches by 4 inches.
H, Binders to ceiling-joists, 7 in. by 5 in.
J, Ceiling-joists, 3 in. by 2½ in.
K, Plate, 8 in. by 5 in.
L, Wall-plate, 12 in. by 6 in.

TRUSS GIRDERS.



London. Published by Thos. Kelly, 17 Paternoster Row, January 2d 1835.

E. Turrell, sculp.

GIRDERS TRUSSED WITH IRON.

as executed in 1823.

Fig. 1.

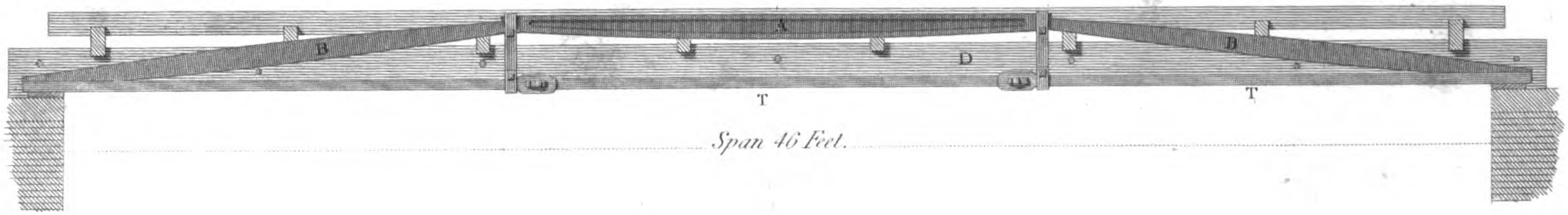


Fig. 4.

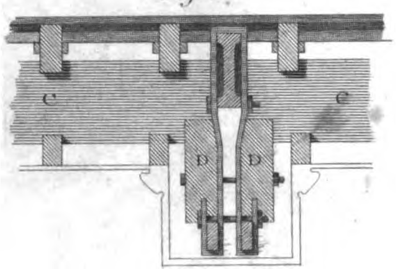


Fig. 3.

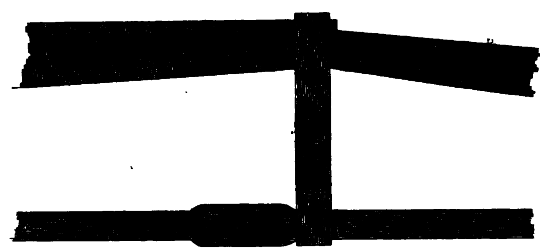


Fig. 2.

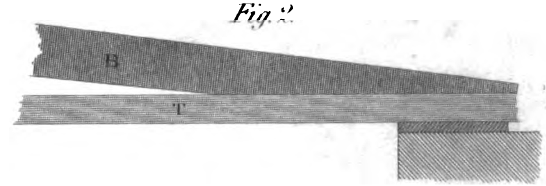


Fig. 6.

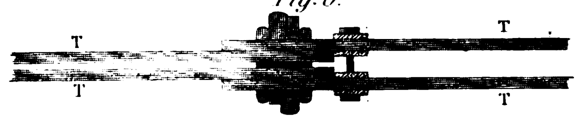
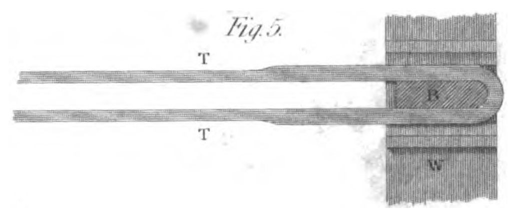
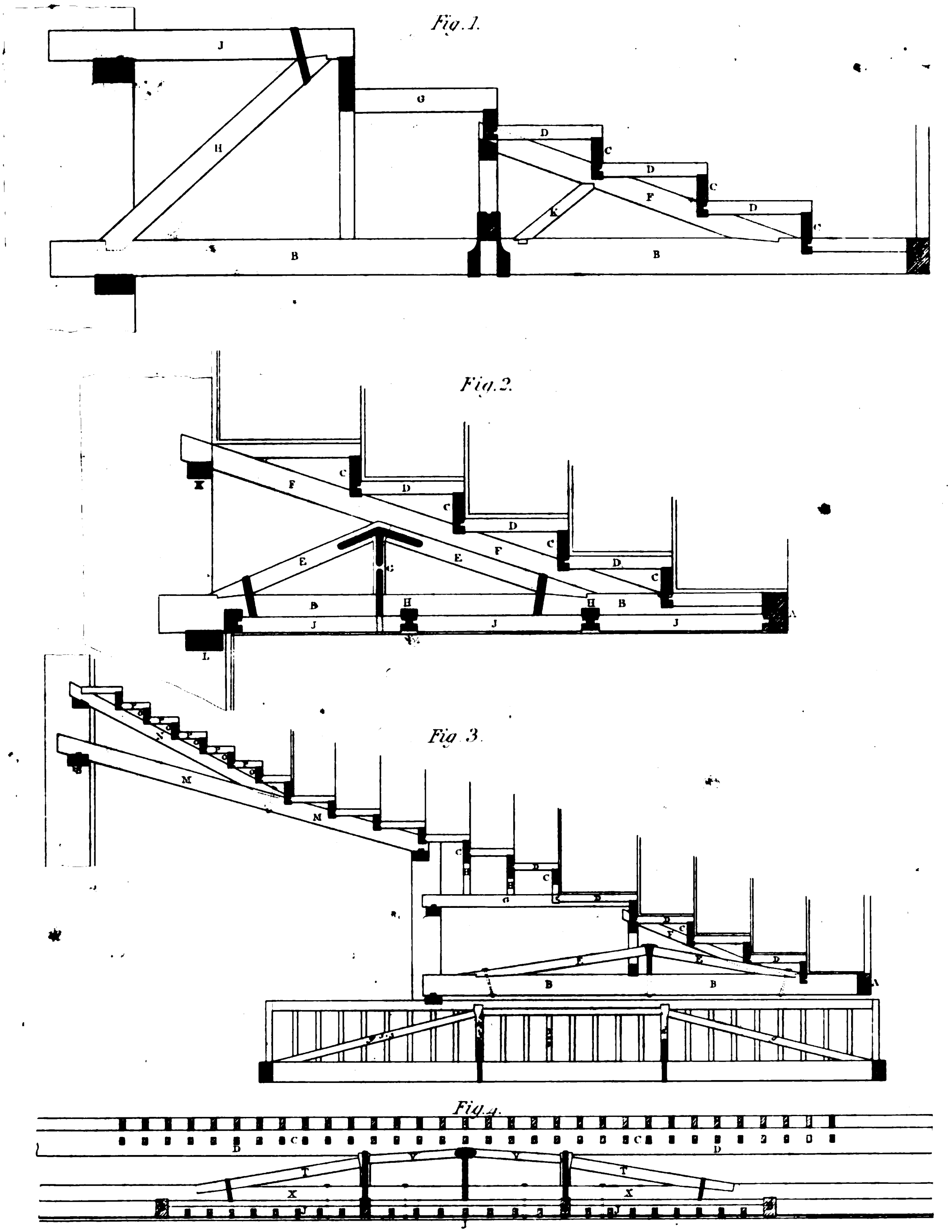


Fig. 5.



TRUSSES EXECUTED IN CAMDEN CHAPEL.



Drawn by M. A. Nicholson

Engraved by [illegible]

London, Published by Thos Kelly 17 Paternoster Row Jan 2. 1834.

Figure 3, the construction of the End Gallery and Children's Gallery

A, Bressummer, 10 inches by 8 inches.
B, Girders, 10 in. by 8 in.
C, Binders, 13 in. by 3 in.
D, Bridging-joists, 4 in. by 3 in.
E, Truss, 6 in. by 4 in.
F, Carriage, 8 in. by 5 in.
G, Bearer, 7 in. by 4 in.
H, Puncheons, 3½ in. by 3 in.
J, Binders to Ceiling-joists, 7 in. by 5 in.
K, Ceiling-joists, 3½ inches by 2½ inches.
L, Plates, 9 in. by 6 in.
M, Oblique Girder, 12 in. by 8 in.
N, Carriage, 8 in. by 6 in.
O, Binder, 10 in. by 3 in.
P, Bridging-joint, 4 in. by 3 in.
Q, Binder to Ceiling-joists, 7 in. by 5 in.
R, Ceiling-joist, 3½ in. by 2½ in.
S, Plate, 12 in. by 8 in.

Figure 4, the longitudinal Trusses of the West-end Gallery.

T, Trusses, 6 in. by 4½ inches.
V, Strainers, 5 in. by 4½ in.
X, Abutment-piece, { at each end, 9 in. by 6 in. / in the middle, 7½ in. by 6 in. }

ROOFING.

100. The Roof is that part of a building which is raised upon the walls, and extends over all the parts of the interior, in order to protect its contents from depredation, and from the severities and changes of the weather.

The Roof, in Carpentry, consists of the timber-work which is found necessary for the support of the external covering.

The most simple form for a roof is that consisting of a level plane; but this description of roof is adapted only to short bearings, and is not at all calculated to resist or prevent the torrents of rain or moisture from penetrating into the interior.

The next simple form is that which consists of an inclined plane; and, though well calculated to resist the injuries of the weather, and to afford greater strength than a level disposition of the timbers would supply, it is far from admitting of the utmost strength that a given quantity of timber is capable of affording; and it occasions an inequality, and a want of uniformity and correspondence in the proportions of the fabric, and an unnecessary and unpleasant height of walling. The best figure for a roof is that which consists of two equal sides equally inclined to the horizon, terminating in the summit, over the middle of the edifice, in a horizontal line, called the *ridge* of the roof; so that the section made by a plane, perpendicular to the ridge, is every where an isosceles triangle, the vertical angle of which is the top of the roof. This form is very advantageous, as it regards saving of timber; for it may be executed with the same scantlings, to span double the distance that the simple sloping roof admits; or, in buildings of the same dimensions, the scantlings of the timbers will be very much diminished.

101. The antient Egyptians, and other eastern nations of the remotest antiquity, constructed their roofs flat, as do likewise the present inhabitants of these countries. The antient Greeks, though favoured with a mild climate, yet sometimes liable to rain, found the inconvenience of a platform covering for their houses; and, accordingly, raised the roof in the middle, declining

towards each side of the building, by a gentle inclination to the horizon, forming an angle of from 13 to 15 degrees, or the perpendicular height of the roof from one-eighth to one-ninth of the span.

In Italy, where the climate is still more liable to rain, the antient Romans constructed their roofs with a rise of from one-fifth to two-ninth parts of the span.

In Germany, where the severities of the climate are still more intense than in Italy, the antient inhabitants, as we are informed by *Vitruvius*, made their roofs of a very high pitch.

When the pointed style of architecture was introduced into Europe, high pitched roofs were thought consonant with its principles; and they therefore formed, externally, one of the most striking characteristics of the Gothic style.

In the usual proportions of the Gothic roof, the length of the rafters was equal to the breadth or span of the roof, or the rafters were the sides of an equilateral triangle, of which the spanning line was the base. During the middle ages this form prevailed, with little variation, not only in public but in private buildings, from the most stately and sumptuous mansion, down to the humble cottage of the common labourer; and this equilateral triangular roof continued to be used till the pointed style began to decline, and Italian architecture, in a great measure, superseded it.

The celebrated INIGO JONES was chiefly instrumental in introducing Italian architecture; then a change in the proportions of the roof took place, and the rafters were made three-quarters of the breadth of the building; and this proportion, which was called *true pitch*, still prevails in some parts of the country, where plain tiles are used; subsequently, however, the square, or angle of 45 degrees, seems to have been considered as the *true pitch:* but, in large mansions, constructed in the Italian style, roofs of the same inclination as the pediment, called a *pediment pitch*, were introduced, and covered with lead.

At the present time, where good slates are to be obtained in abundance, roofs may be covered with them of any pitch, from the pyramidal Gothic down to the gently-inclined Greek pediment.

Therefore, with regard to the present practice, the proportion of the roof for slates depends on the style of the architecture of the edifice; the usual height varying from one-third to one-fourth part of the span.

There are, doubtless, some advantages in high-pitched roofs, as they discharge the rain with greater rapidity; the snow does not lodge so long on their surface; also, they may be covered with smaller slates, and even with less care, and are not so liable to be stripped by high winds as the low roofs are: but the low roofs have less pressure and stress on the walls, and are considerably cheaper, since they require shorter timbers, and, of course, smaller scantlings.

The roof is one of the principal ties to a building, when executed with judgment; as it connects the exterior walls, and binds them together as one mass; and, besides the protection it affords the inhabitant within, it preserves the whole work from a state of decay, which would soon inevitably ensue, from the effects of rain or frost, as moisture would operate in rotting the timbers, and frost in destroying the connexion of the walls, and the whole would ultimately fall to ruin.

102. The several timbers of a roof are termed *principal rafters*, *tie-beams*, *king-posts*, *queen-posts*, *struts*, *collar-beams*, *straining-sills*, *pole-plates*, *purlins*, *ridge-piece*, *common-rafters*, and *camber-beams*. The uses of these will appear from the description of them; but, in the first place, we must describe the nature of the roof itself.

The usual EXTERNAL FORM of a ROOF has two surfaces, which generally rise from opposite walls, with the same angle of inclination; and, as the walls are most commonly built parallel to each other, the section of the roof made by a plane perpendicular to the horizon, and to one of the walls, is a triangle with two equal sides; the base being the extension from the one wall-head to the other. This extension is called the *span of the roof.*

To FRAME the TIMBERS of a ROOF, so that their external surfaces shall keep this position, is the business of the Carpenter; and ingenuity is displayed in making the strongest roof with a given quantity of timber.

All long beams, or pieces of timber, from their weight, when supported at the two ends only, become concave on the upper side; and this concavity is the greater as the distance between the props is the greater. It is, therefore, the grand object to prevent this bending as much as possible. The curvature will take place, whether the position of beams be horizontal or inclined; but the same beam will have less curvature the more upright it is, or as the angle, to which it is inclined to the horizon, is greater. For, it is evident that, when a beam is laid level, and supported at its extremities, its curvature will be greater than when inclined at any angle, however small; and, again, if it stand perpendicular to the horizon, its curvature will be nothing; that is to say, its curvature will be nothing when the angle of inclination is the greatest.

The curvature which timber obtains by bending is called *sagging*. To prevent timber from sagging, as much as is possible, it must be supported at a certain number of intermediate points or places, besides the two extreme ends. Now these supports must themselves be supported from some base or other; but, if the resting points or places be upon the surface or surfaces of other timbers, the greatest care must be taken that they do not fall between the extremities of the supporting timbers intended to support the other: that is to say, the lower end of every piece of timber, used as a prop, must rest upon some supported point; or, otherwise, the propping piece of timber must be so disposed that the pressing forces at each end must be equal to each other.

These are the general principles upon which the strength of roofs depend.

The supported points, in Carpentry, are those points or places where there are walls, or columns from the ground, or two timbers meet together in an angle; and no roof or piece of framing is good where the end of one piece, used as a prop to another, presses upon a third piece of timber, between its supported extremities. The pressing end of every prop ought to rest upon some *supported point.*

103. PRINCIPAL RAFTERS are the two pieces of timber, in the truss of a framed roof, that form the two equal sides under the covering.

It is evident that the greater the opening is, the more supports each principal rafter will require.

A piece of timber may be supported either from some supported point above it, or some supported point below it: if the support be above the piece to be supported, then it is evident that the connecting piece will act as a string; but, if below the piece to be supported, it is evident that the prop must be an inflexible beam or piece of timber.

Therefore, as from the nature of a roof the principal rafters cannot be supported from above, they must be supported from below, by walls, piers, or posts, made of some fit material, as stone, brick, iron, or timber, of sufficient thickness; and, because the pressure occasioned by the weight of the covering is uniformly distributed over the principal rafters, these principal rafters must be supported at a certain number of equidistant points, which will depend upon the distance of the walls.

104. A TIE-BEAM is a piece of timber for connecting the feet of the principal rafters, in order to prevent them from spreading, by the weight of the covering. The *tie-beam* is therefore used as a tie, and, in respect to the strain from the pressure of the rafters, is in a state of tension.

In order to prevent the sagging of the tie-beam, in very wide houses, it must be supported in one or more places in its length; and if it cannot be supported from the ground, it must be supported from some other *supported point* or points in the roof itself. Such a point we have where the two principal rafters meet each other; and this one point will furnish as many supports to the tie-beam as we please: while, from each of these supported points in the tie-beam, the middle parts of the principal rafters may be supported. For, when once a frame is formed, the timbers may be made to strengthen one another, so as to form a strong and perfect whole.

It is not easy to give a direct rule for the disposition and position of supporting timbers: but we ought to prefer such a disposition as will keep the bearing timbers within a proper limit as to length, and the angles should be as direct as possible. Oblique or acute angles occasion very great strains at the joints, and should therefore be avoided. One grand principle is, in every frame or roof, to resolve the whole frame into the least number of triangles, affording direct connections between all the points of support, which must be considered as the elements of the framing. Four-sided figures must be avoided, if possible; and this may be done by introducing diagonals, which will form them into triangles; for, without this, a four-sided figure will be moveable round its angles, and has no stiffness except what depends on the strength of its joints. Sometimes it may be necessary to divide a quadrangular piece of framing into *four* triangles, by means of two diagonal pieces, particularly when this figure occurs in the middle of a roof. Our *plate XXI, fig.* 2, shows a beautiful specimen of this arrangement, designed by Mr. Smirke, whose high reputation as an architect is well known.

The principles of framing being once understood, a little practice in designing will soon enable the Carpenter to judge of the proper disposition of timbers, so as to produce a good design, if not the best possible.

105. A King-Post, or principal Post, is a vertical piece of timber, extending from the place where the two principal rafters meet to the tie-beam, for the purpose of supporting the tie-beam in the middle.

The King-Post is, therefore, in a state of tension; and, consequently, it may be a slender bar of wrought iron, or any tenacious material that will not be liable to extension when stretched or drawn in length.

The principal rafters are frequently supported from one or more points in the king-post: but it is evident that both the rafters must be supported exactly in the same manner when the supporting points in the king-post are between its two extremities; so that the principal rafters may produce equal and opposite pressures on each side of the king-post.

Each of the principal rafters may be supported in many points, either from one point in the king-post, or from as many points as the number of points to be supported; or, as has been said before, either from one supported point, or from as many supported points, in the tie-beam, as the number of points to be supported; and, in short, the principal rafters may be supported from any supported point whatever, from the king-post, or tie-beam, or from both. This very circumstance points out the vast variety there may be in designs for roofs.

106. Queen-Posts are two pieces of timber, equidistant from the middle of the truss; the one suspended from the head of one of the principal rafters, and the other from the head of the other, with a level piece of timber, called a straining-beam, between them.

The Queen-posts, therefore, divide the internal space of the frame into three compartments, of which the two extreme ones are right-angled triangles, and the middle one a rectangle.

The use of the queen-posts is similar to that of the king-posts; *viz.* for furnishing a general support for the principal rafters, at different points between the ends, by connecting timbers, but their chief object is supporting the tie-beam at more places between its extremities.

107. STRUTS are those props which support the principal rafters, in one or more points, so as to divide them into equidistant parts.

Struts are generally disposed in pairs, equally inclined to the vertical line, which divides the truss into two equal and similar parts; and which, therefore, divides the two beams into two equal lengths. Struts are necessary in roofs where the span is great; and the greater the span or distance of the walls, the greater the number of struts will be required; for, in this case, more points in the principal rafters will have to be supported.

108. A COLLAR-BEAM is the piece of timber framed between two principal rafters, and usually employed where there are no king-posts.

109. A STRAINING-BEAM is the piece of timber framed between the heads of the queen-posts; and is necessary where the roof is to have a platform, or flat for walking upon, or wherever rooms are required in the roof.

110. A STRAINING-SILL is a horizontal piece of timber, disposed between the feet of the queen-posts, to counteract the efforts of the struts, in pushing these feet nearer to each other, when, on account of rooms, the space cannot be filled with diagonal braces.

Having thus noticed the several parts of a truss, it may be proper to observe that all king-posts, queen-posts, and tie-beams are *ties;* and may be formed by an iron tie incapable of farther extension than is sufficient to bring it to a straight line. A chain, or a slender bar of iron, will therefore answer the same purpose, in some of these cases, as a piece of timber, or other such inflexible material. It is also to be remarked, that all collar-beams, principal rafters, and struts, are to resist compression; and are, therefore, necessarily constructed of an inflexible material, such as wood, or a stiff piece of iron. It may be further observed that, in complex frames, such as the centring to large arches or bridges, the same timbers, in different stages of the work, sometimes perform the office of ties, and sometimes that of struts; and, in the transition from one office to the other, must be sometimes in a neutral state. The material employed in such situations must, necessarily, be inflexible. This is to be recommended not only here, but in every doubtful case, or where it is uncertain whether the part of the truss requires to be a tie or a strut.

111. A POLE-PLATE is a beam over each opposite wall, supported upon the ends of the tie-beam, or upon the feet of the principal rafters, to receive the ends of the common rafters.

112. PURLINS are horizontal pieces of timber, supported by the principal rafters. Their office is to support the common rafters in the middle parts of their length.

113. A RIDGE-PIECE is a beam at the apex of a roof, supported by the king-posts, or by the heads of the principal rafters, and supports the upper ends of the common rafters.

COMMON RAFTERS are inclined pieces of timber, parallel to the principal rafters, supported by the pole-plates, the purlins, and the ridge-piece. They support the covering, the material of which is sometimes large slates, extended from rafter to rafter, but more commonly either boards, or laths, are nailed upon the common rafters, and the slates, tiles, &c. fastened on with nails or pins.

114. JOGGLES are the joints at the meeting of struts, king-posts, queen-posts, and principal rafters; where there is a piece left to form the abutment. The usual form for the joggles is that which is at right angles to the lengths of the struts or rafters, or at right angles to the tenoned piece: but this position cannot, at all times, be obtained, from the want of sufficient substance of timber: in that case, the joint is made either oblique, or the upper part in a line with the side of the piece which has the mortise, and the lower part perpendicular to the sides of the

tenoned piece; or the joint is sometimes made partly parallel, and partly perpendicular, to the mortised piece. When the joint is oblique, the force of the tenoned piece, in the direction of its length, causes the end to slide upon the abutment, towards the side which contains the obtuse angle: but this is, in some degree, counteracted by the resistance of the tenon on the lower end of the mortise. With regard to the stress of the timbers in a frame, the direction of the abutting-joint is of little importance; but it ought to be the best for the strength of the joint itself. *M. Perronet*, the celebrated French engineer, formed the abutments in the arcs of circles, making the centre at the other extremity of the piece. In *Art.* 82, we have alluded to joints of this kind, but with the arcs described by a radius not much exceeding half the breadth of the timber; otherwise circular arcs have no advantage.

115. CAMBER-BEAMS are those timbers which support the purlins or joists over the collar-beams, and the boarding for a leaden platform; for this purpose they have an equal declivity from the middle, in order to cause the rain or snow-water to descend equally on each side of the roof.

116. COCKING, or COGGING, is the form of the joints, which the tie-beams and wall-plates make with each other; and here, as in every other case of jointing, the parts must be reciprocally indented into each other, so that the protuberant part or parts of the one are indented parts of the other. The parts which come in contact are plane surfaces; those which form the bottom or bottoms of the recess or recesses are parallel to, and those which form the sides perpendicular to the surfaces, from which the joints are made. The best method is, by cutting a groove, across the fibres, in the beam to be let down, to correspond to a rising in the plate formed by recessing the plate, on each side of the rising. (See *plate X, fig.* 8.) Another method is by an external and internal dovetail: but this method is almost entirely abandoned.

Observations on the Forms of Roofs.

117. GABLE-ENDED ROOFS, unless properly connected by ties, have the same tendency to thrust out the walls as other roofs, and particularly when the walls are very thin, or the distance between them very great.

118. A HIPPED ROOF, over a rectangular plan, when the common rafters are well secured to the principals, produces very little lateral pressure on the walls. In a hipped roof, upon a square plan, the lateral pressure upon the walls may be prevented without using cross-ties, by making the wall-plates act as ties to the feet of the four hip-rafters; but, with regard to roofs executed upon regular polygonal plans of the same area, that plan which has the greater number of sides produces less lateral pressure on the walls than that which has fewer sides; and, when the number of sides are very many, the polygon may be considered as a circle; and, consequently a circular roof will give less lateral pressure upon the walls than a polygonal one of any number of sides, however great.

In the execution of all these, however, it will be necessary that a wall-plate should be formed to the plan, and well connected, not only between each of the angular points, but also at the angular points themselves; for, when the building is carried up on a polygonal plan, every two adjacent hips will act in the same manner as the two principals in a framed roof; and, therefore, every side of the wall-plate will be a tie; and, consequently, if not properly joined, the walls will be liable to be rent.

ROOFING.

Fig. 1.

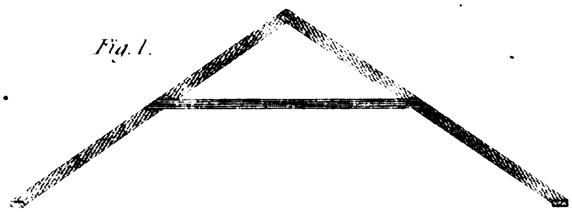


Fig. 2.

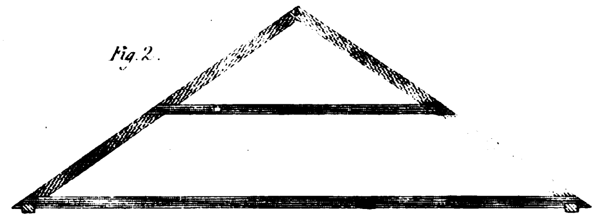


Fig. 4.

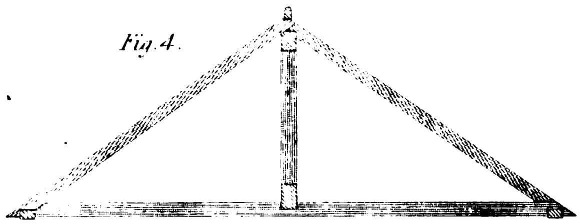


Fig. 3.

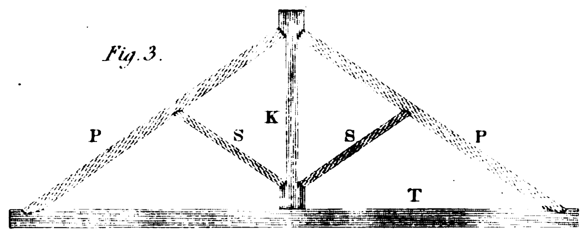


Fig. 5.

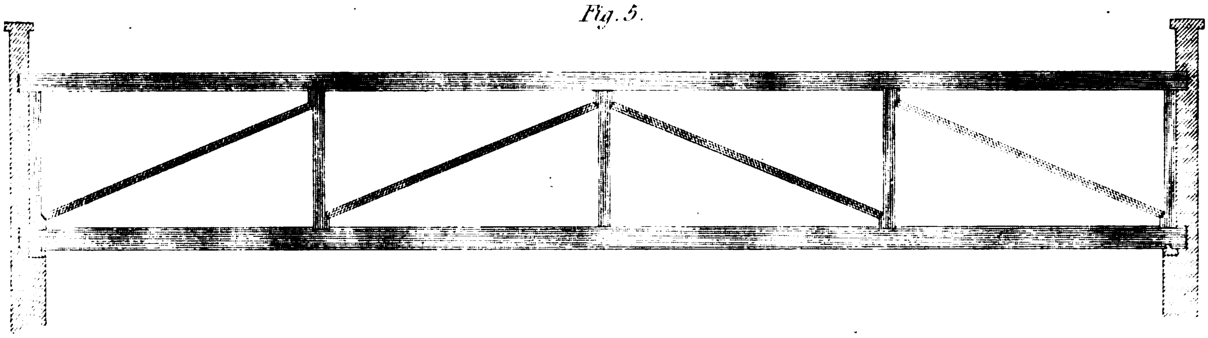
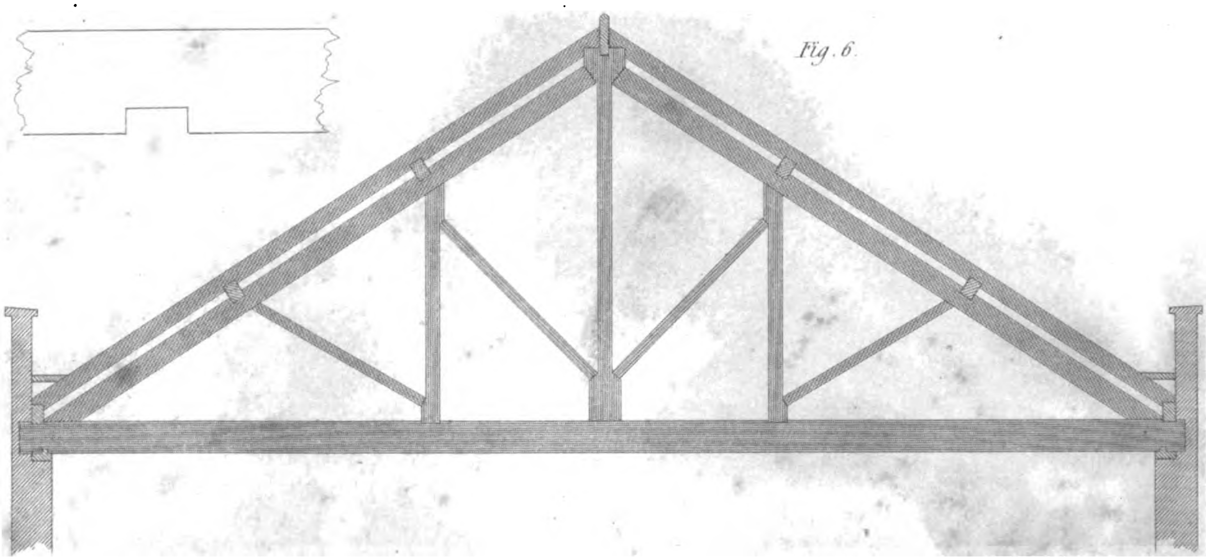


Fig. 7.

Fig. 6.



London. Published by Thos Kelly, 17 Paternoster Row, January 2nd 1835

E. Turrell sc.

CURB ROOFS.

Fig. 1

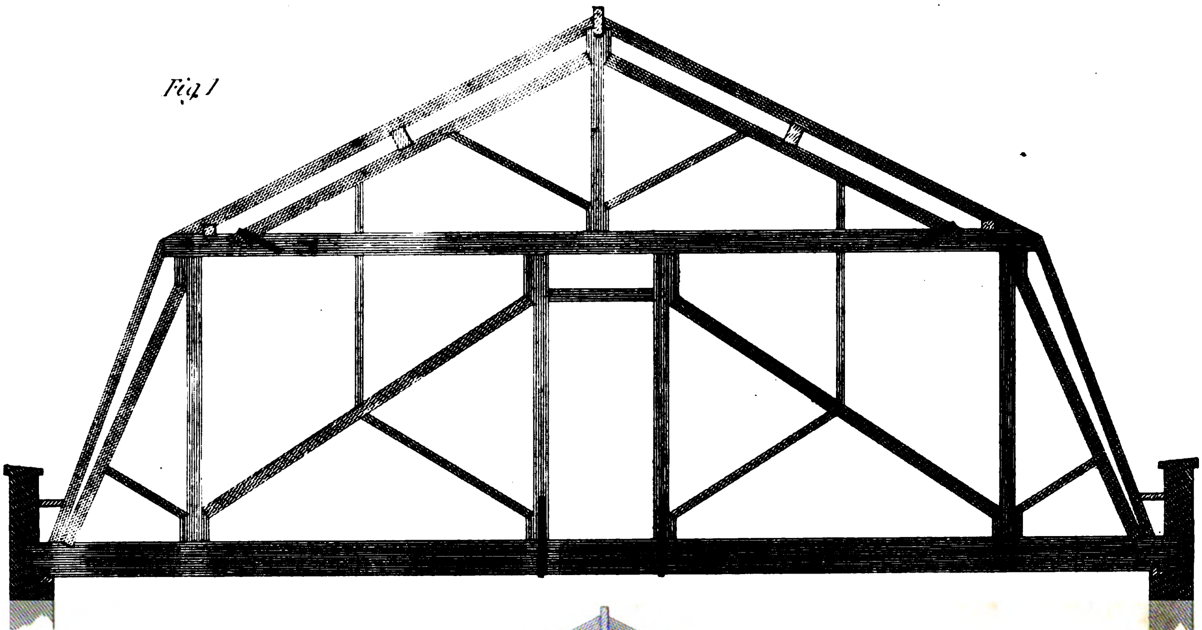


Fig. 2

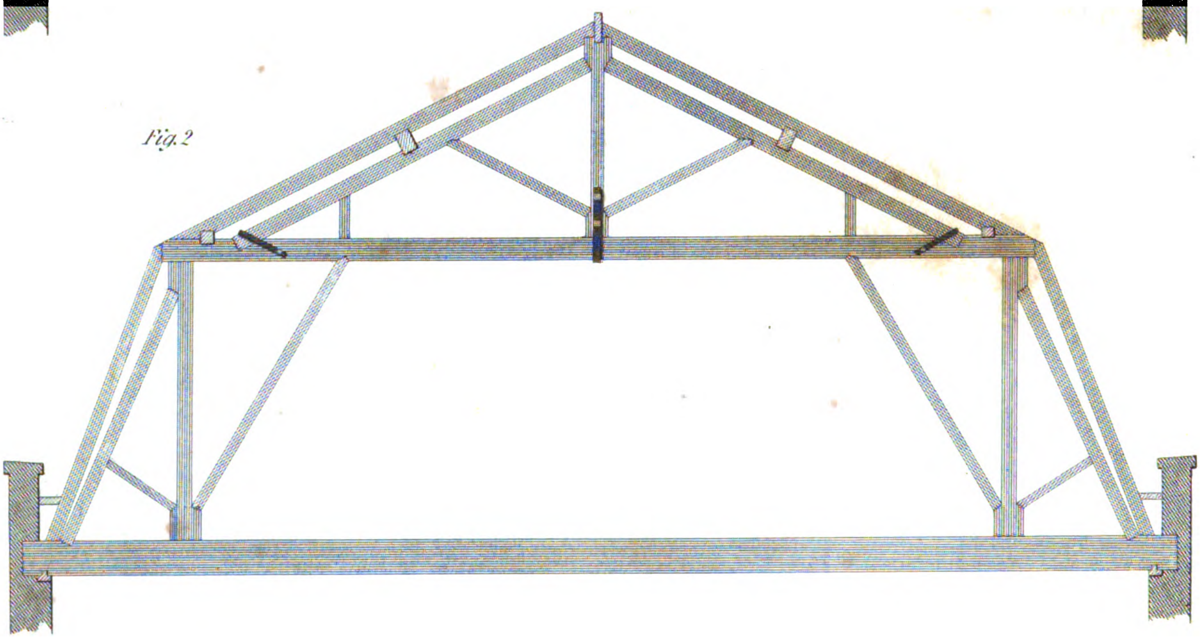
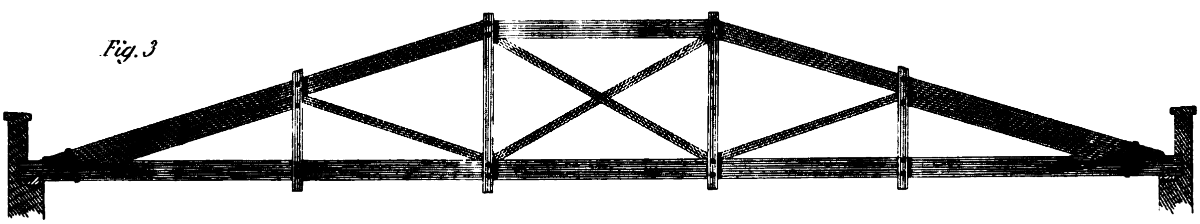


Fig. 3



London, Published by Thos. Kelly, 17 Paternoster Row, January 2d 1836.

E. Turrell, sculp.

CONSTRUCTION OF ROOFS.

119. *Figure* 1, *plate XVIII*, is a roof, for a very narrow span, having only one collar-beam, without a tie at the bottom. In this example the collar-beam acts as a tie, but with very little effect; and this arrangement ought not to be employed over a space exceeding fifteen or twenty feet wide with stout walls.

120. *Figure* 2 is a roof with a tie-beam at the foot, and a collar-beam. Here the strain on the collar-beam is different; since the tie-beam is in a state of tension; the collar-beam is merely employed to keep the rafters straight, and is, therefore, in a state of compression. This truss may be employed where the span is from twenty to twenty-eight feet in width. This truss without additional timbers, does not afford any support to the tie-beam.

121. *Figure* 3 is a truss free from these inconveniences; the tie-beam being supported by the king-post K, and the rafters being supported by two struts, *s s*.

122. *Figure* 4, *pl. XVIII*, represents the side of a truss, with the ends of a longitudinal frame for supporting the tops of the rafters, which are here exhibited. *Fig.* 5 exhibits the frame as seen in the length of the roof, and is divided into several compartments, by means of a middle and two side posts. The ends of this longitudinal truss are fixed in the gables or cross-walls. In wider spans, two or more such trusses may be inserted.

123. *Figure* 6 is a principal truss, with a king-post and two queen-posts. Here the manner in which the tie-beam is supported upon the wall-plates is shown. The sections of the pole-plates and purlins are also exhibited. *Fig.* 7 shows the manner of notching down the small rafter upon the purlins, and the manner of notching the purlins upon the principals. Respecting the mode of joining the feet of the principal rafters and the tie-beam. (See *Art.* 81-83, and *plate XI.*)

This roof is adapted for a span of 55 or 60 feet. The supports are all directed to the points where the purlins rest on the principal rafters, which of course are loaded with the common rafters and covering, and the whole affords an example of the principles of mutual support and connection, which we endeavoured to explain in *Art.* 102 and 104.

124. In towns it is very common to form the roof of a house with two inclinations, so as to procure a space of sufficient height for a room over the tie-beams. Roofs of this kind are called *Curb-roofs*.

When it is convenient to divide the rooms, so that the principals of the roof may form the partition, it is a considerable advantage in strength as well as cheapness.

Figure 1, *plate XIX*, is an example of a truss for a Curb-roof of this kind, with the door-way in the middle.

Fig. 2 is another example, where it is supposed that the space is to be left as clear of framing as possible, owing to the truss not being in a place adapted for a partition.

125. When a roof is to be covered with lead, it is generally also required to be nearly flat; and therefore the depth of framing being small, it must be made very strong; a reference to *Art.* 60, and those immediately following it, will illustrate this subject.

Fig. 3, *plate XIX*, shows a flat-roof for a 50 feet span, with the least rise it would be prudent to adopt for such a purpose, unless the covering and ceiling be exceedingly light.

126. *Fig.* 1, *plate XX*, shows a truss for a flat roof, as executed for the roof of St. Mary's Church, Mary-le-bone, designed by R. Smirke, Esq., Architect. The middle part of the roof is supported by iron pillars, F, so that it exerts only a very small degree of pressure on the external walls. The trusses are 6 feet 3 inches apart, and the timbers of the following scantlings:

A, Principal rafters, 8 inches by 6 inches.
B, Tie-beam, 9 in. by 6 in.
C, King-post, 8 in. by 6 in.
Queen-posts, 6 in. by 5 in.
Braces, 6 in. by 6 in.
Purlin at the foot of braces, 8 in. by 8 in.
D and E, Longitudinal beams, 12 inches by 12 inches.
G, Beams, 8½ in. by 8 in.
H, Tie-beams, 6 in. by 6 in.
King-posts of side roofs, 6 in. by 5 in.
Braces of do., 6 in. by 4½ in.

A longitudinal frame is continued over each range of columns, with posts, 12 inches by 10 inches, under each truss, and diagonal braces 12 inches by 8 inches.

127. On the same plate, *fig.* 2, we have given the roof of Whitehall-Chapel; it has stood many years, but not without showing symptoms of weakness, though it contains abundance of timber. The weakness, therefore, is occasioned by the mode of construction; and we have selected this example for the purpose of pointing it out. The points of stress are the places of the purlins, and these are none of them at supported points. The principal braces, D, do not meet the queen-posts, so as to get the advantage of the triangle's unchangeable figure; and this defect is very imperfectly compensated for by the introduction of two iron rods from the heads of the rafters to the tie-beam. The bulk of the head of the king-post would render the settlement from shrinkage considerable, and a like reason would cause settlements in other parts of the roof, as will be evident from the size of the timbers.

A, Principal rafters, $\begin{cases}\text{18½ inches by 13 inches at the bottom,}\\ \text{12 in. by 12 in. at the top.}\end{cases}$
B, Tie-beam, 15 in. by 15 in.
C, King-post, $\begin{cases}\text{13 in. by 10 in. middle,}\\ \text{13 in. by 14 in. head and foot.}\end{cases}$
D, Braces, 12½ in. by 11 in.
E, Queen-posts, 9½ in. by 9½ in.
F, Braces, 8 in. by 9 in.
Purlins, 12 in. by 8½ in.; Wall-plate, 14 in. by 7 in.
Principals 14 feet apart, which is much too great a distance.

128. The next example is from the new church of Saint Mary-le-bone, London, designed by P. Hardwick, Esq., Architect, *plate XXI, fig.* 1. The construction of this roof is very judicious, and adapted to give space in the roof without a sacrifice of strength.

T, Tie-beam, 12 in. by 12 in.
P, Principal rafters, 8 in. by 7 in.
S, Straining-beam, 10 in. by 8 in.
Q, Queen-posts, 8 in. by 7 in.
P, Auxiliary rafters, 8 in. by 7 in.
B, Braces, 6 in. by 5 in.
K, King-post, in two pieces, each 8½ in. by 5 in.
Purlins, 8 inches by 6 inches.
Common rafters, 5 in. by 3 in.
Pole-plate, 6 in. by 6 in.
Wall-plates, 12 in. by 8 in.
Binding-joists to carry ceiling, 9 in. by 5½ in.
Ceiling-joists, 4 in. by 2¼ in.
Trusses, 12 ft. 10 in. apart.

ROOFS AS EXECUTED.

Fig. 1.

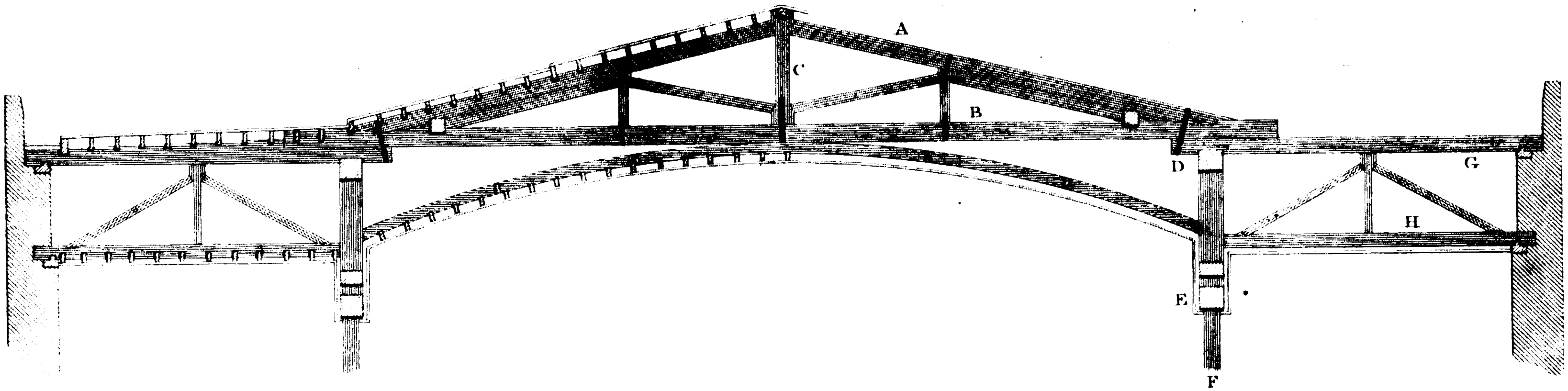
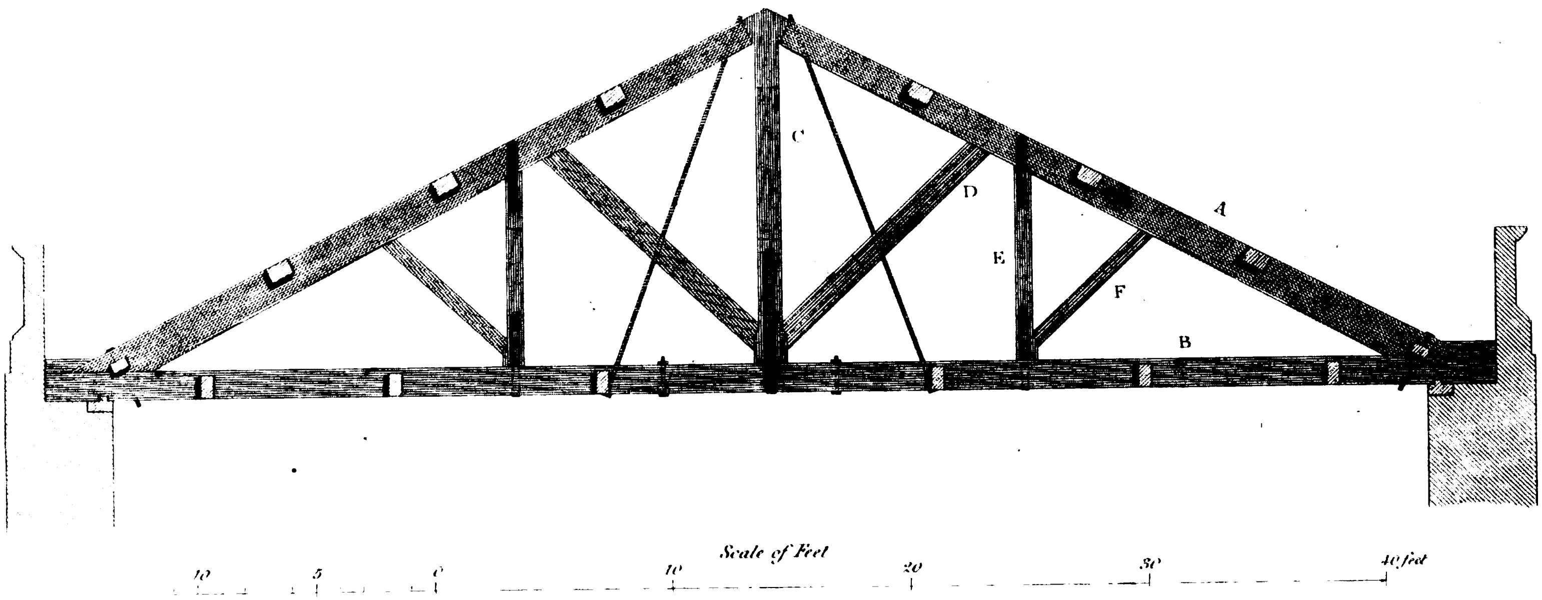


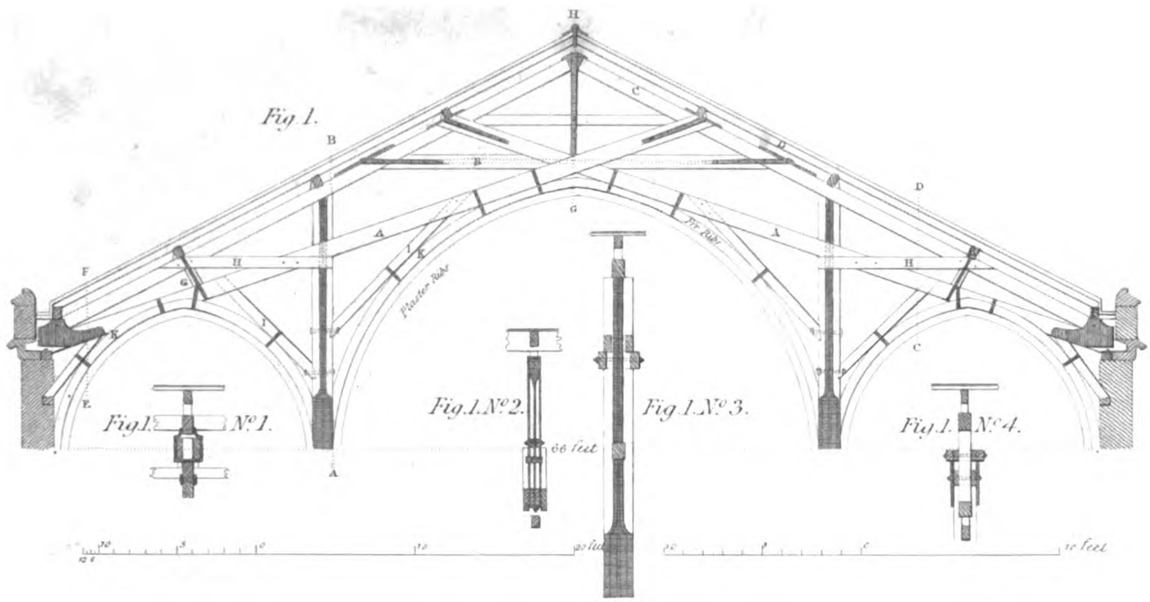
Fig. 2.



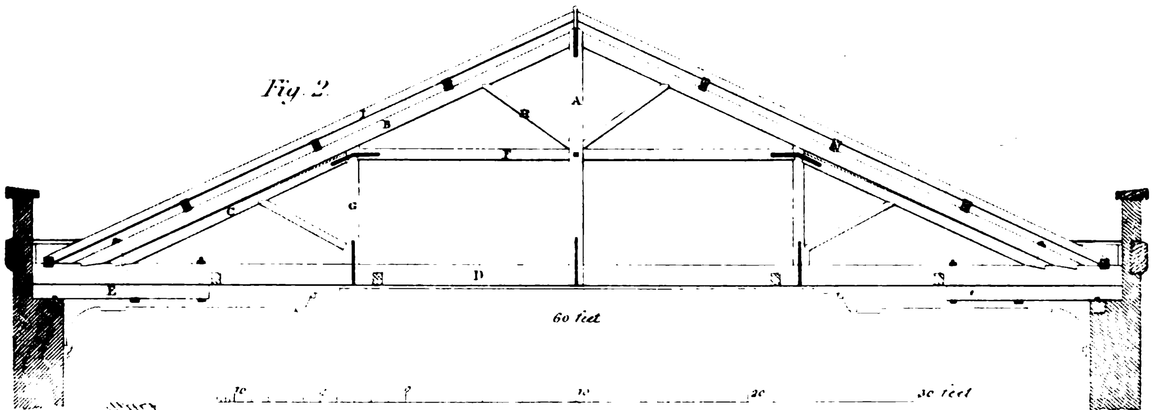
Engraved by E. Turrell

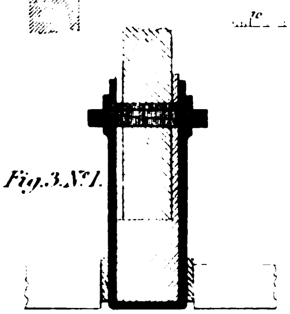
ROOF OF St. PANCRAS CHAPEL, SOMERS TOWN.

As executed by W. & H. W. Inwood, Esqrs Architects.



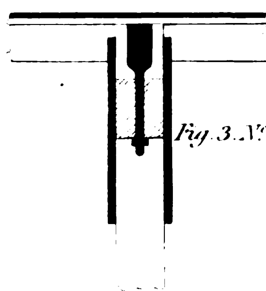
ROOF OF St. LUKES CHURCH, OLD STREET.

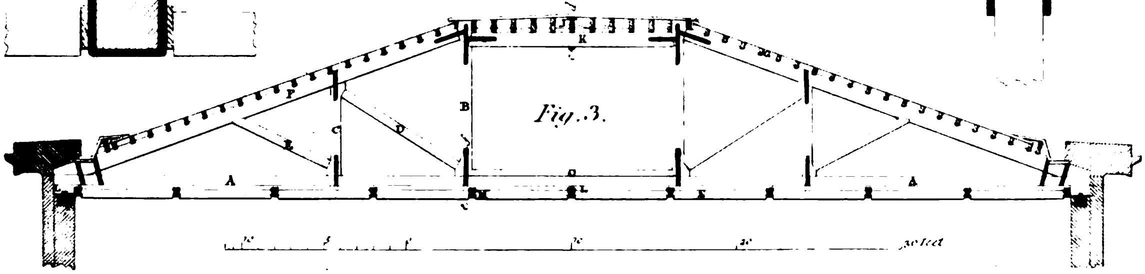




ROOF OF CAMDEN CHAPEL.

As executed by W. & H. W. Inwood, Esqrs Architects.





Drawn by M. A. Nicholson.

Engraved by [illegible]

London, Published by Thos. Kelly, 17 Paternoster Row, Jany 2 1835.

Fig. 1.

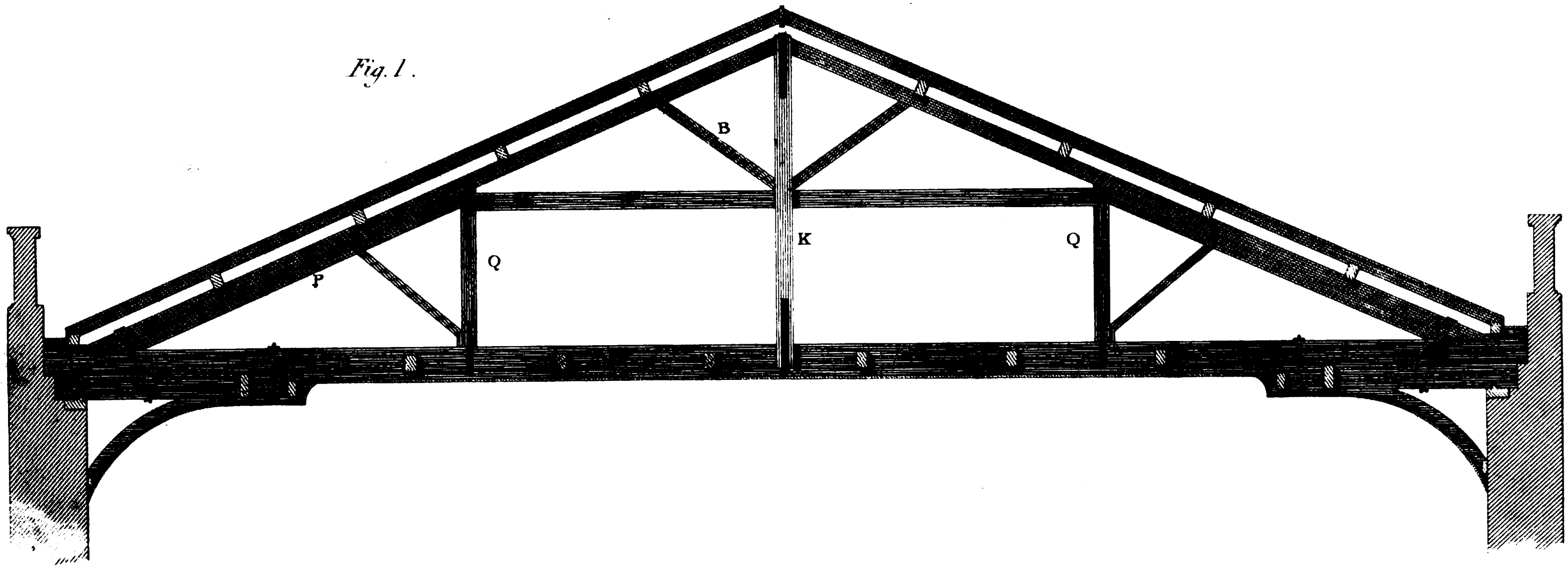
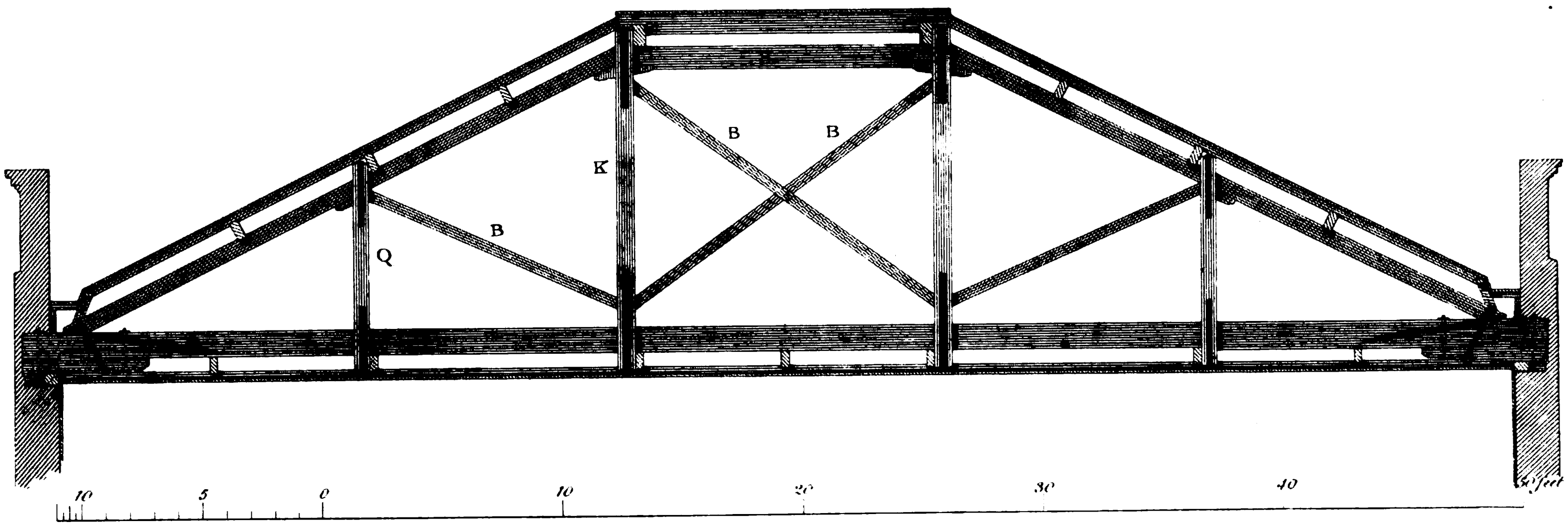


Fig. 2.



Engraved by E. Turrell.

London, Published by Thos. Kelly, 17, Paternoster Row, January 2, 1835.

129. A very neat and simple roof is exhibited in *plate XXI, fig. 2,* executed for Belgrave Chapel, and designed by R. Smirke, Esq. To lessen the elevation of the roof, a part of the top is a lead-flat. The principal rafters and straining-beam abut end to end, and the queen-posts are each in two pieces, notched on, one on each side, and strapped and bolted together.

T, Tie-beam, 12 inches by 7 inches.
P, Principal rafters, 10 in. by 6 in.
S, Straining-beam, 10 in. by 6 in.
B, Braces, 7 in. by 6 in.
K, Queen-post, in two pieces, 9 in. by 5 in.
Q, Second Queen-posts, in two pieces, 8 in. by 5 in.
Purlins, 8 in. by 4 in.
Common rafters, 5 in. by 2 in.
Binding-joists for ceiling, 8 in. by 3 in.
Ceiling-joists, 3 in. by 2 in.

Trusses about 10 feet 6 inches apart.

130. Three more examples of roofs as executed, are given in *plate XXII.* Of these, *fig.* 1 is a complicated and rather an expensive mode of gaining height for the middle aisle of the chapel. *Fig.* 2 is similar to that of the New Church, Mary-le-bone; and *fig.* 3 is another very good specimen of a roof, with a portion of the top flat. The scantlings of the timbers of these roofs we will now proceed to describe.

Figure 1, the Roof of the new Gothic Chapel, of St. Pancras, Somers' Town, near London.

Scantlings of the Timbers.

A, Oblique tie-beam, { at the bottom, 11 inches by 7 inches. / at the top, 10 in. by 7 in. }
B, Collar-beam, 10 in. by 7 in.
C, Principal rafter,-- { at the bottom, 10 in. by 7 in. / at the top, 9 in. 7 in. }
D, Common rafters, 5 in. by 2½ in.
E, Purlins, 6 in. by 7 in.
F, Pole-plates, 5½ in. by 8½ in.
G, Struts, 6 in. by 7 in.
H, Braces, 8 in. by 7 in.
I, Oblique braces, 6 in. by 7 in.
K, Ribs to ceiling, 7 in. by 5 in.

Figure 1, *No.* 1, Section through at EF, to a larger scale.
Figure 1, *No.* 2, Section through at GH, to a larger scale.
Figure 1, *No.* 3, Section through at AB, to a larger scale.
Figure 1, *No.* 4, Section through at CD, to a larger scale.

Figure 2.—The Roof of St. Luke's Church, Old-Street, London.

Scantlings of the Timbers.

A, Double king-post of oak, 9 inches by 5 inches.
B, Principal rafters, { at the bottom, 8 in. by 7 in. / at the top, 6 in. by 7 in. }
C, Auxiliary rafters, 6 in. by 7 in.
D, Tie-beams, 14 in. by 12 in.
E, Hammer-beams, 12 in. by 12 in.

F, Stretching-beams, 10 in. by 8 in.
G, Queen-posts of oak, 10 in. by 7 in.
H, Struts, 5 in. by 6 in.
I, Common-rafters, 5 in. by 3 in.
K, Purlins, 8 in. by 6 in.
L, Wall-plates, 12 in. by 8 in.
M, Pole-plates, 6 in. by 6 in.
Ridge-boards, 12 in. by $2\frac{1}{2}$ in.
Hips, 12 in. by $2\frac{1}{2}$ in.

Figure 3.—Roof of Camden Chapel, Camden Town, near London.

Figure 3, *No.* 1, Section through at *ef* to a larger scale.
Figure 3, *No.* 2, Section through at *cd* to a larger scale.

Scantlings of the Timbers.

A, Tie-beam, 14 inches by 9 inches.
B, Queen-posts of oak, 8 in. by 7 in.
C, Small posts of oak, 7 in. by 7 in.
D, Struts, 7 in. by 7 in.
E, Small struts, 6 in. by 6 in.
F, Principal rafter, $\begin{cases}\text{at the top, 9 in. by 7 in.}\\ \text{at the bottom, 11 in. by 7 in.}\end{cases}$
G, Common rafters, 6 in. by $2\frac{1}{2}$ in.
Horizontal rafters to flat, increased in depth to produce a proper current, 8 in. by 5 in.
H, Wall-plate, 9 in. by 6 in.
J, Truss to stretching-beam, 5 in. by 3 in.
K, Stretching-beam, 10 in. by 7 in.
L, Pieces spiked to the sides of the tie-beam, 8 in. by 2 in.
M, Binders, 8 in. by 5 in.
N, Ceiling-joists, $3\frac{1}{2}$ in. by $2\frac{1}{2}$ in.
O, Abutment-piece, 5 in. by 5 in.

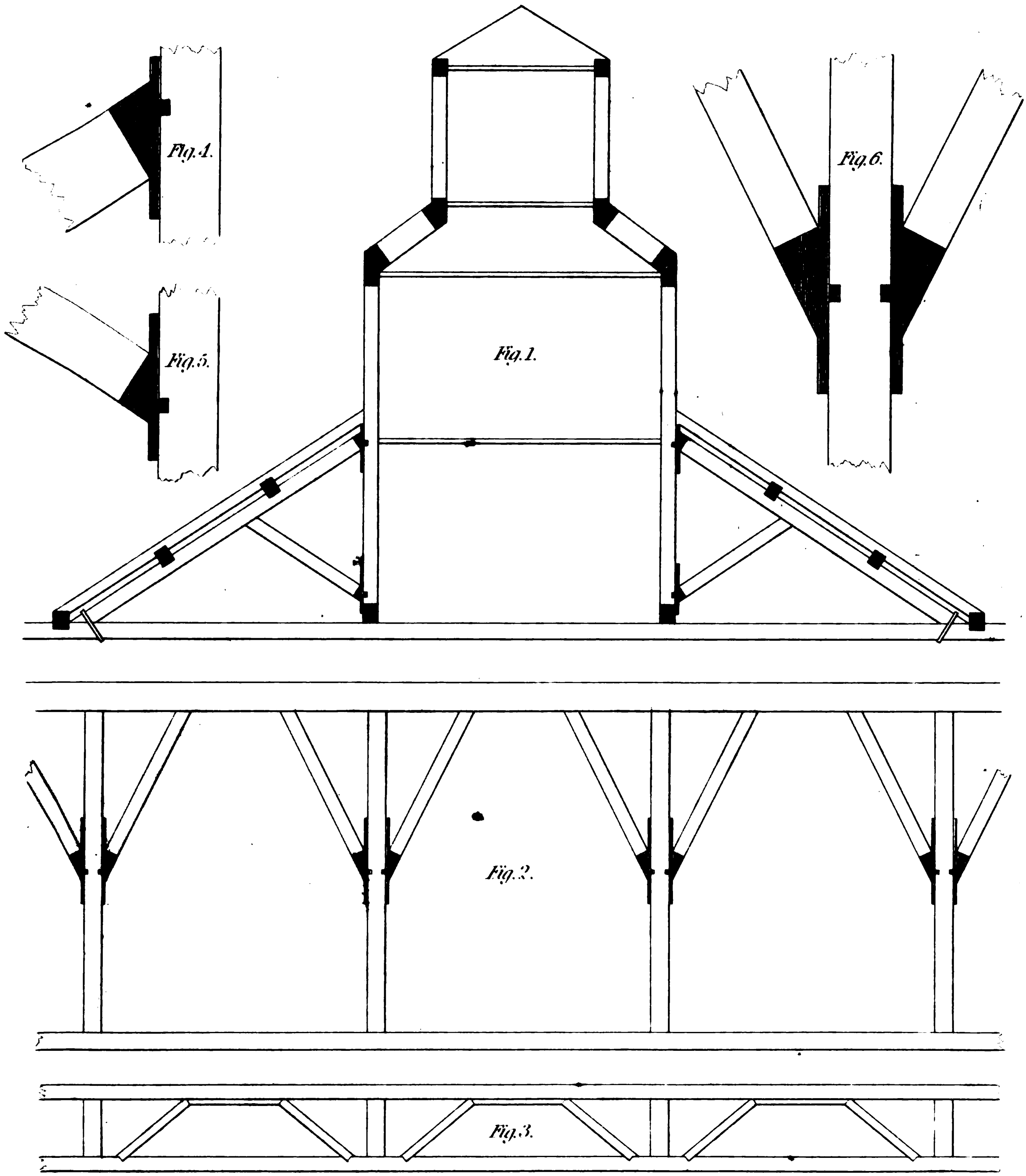
131. *Figure* 1, *plate XXIII*, is a design for a roof in several stages, adapted for a warehouse. The parts are arranged in the following manner. *Fig.* 2 is the side of the two longitudinal trusses which rest upon the main tie-beams, and which support the oblique parts on which the upper stage is sustained. The mode of trussing the oblique portions is shown by *fig.* 3. The abutting-joints, of cast-iron, are shown by *figs.* 4 and 5; and *fig.* 6 shows the cast-iron abutments for braces in the truss, *fig.* 2.

GEOMETRICAL LINES FOR ROOFS.

132. To find the bevels for cutting the various timbers in a hipped roof, and the backing of the hips (*pl. XXIV*, *figures* 1, 2, 3).

Let ABCD, *figures* 1, 2, and 3, be the outlines of the wall-plates, AF, DF, and BE, CE, the plan-lines of the hips, and EF the plan-line of the ridge-piece.

DESIGNS FOR ROOFS.



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GEOMETRICAL LINES,

FOR ROOFS.

Fig. 1.

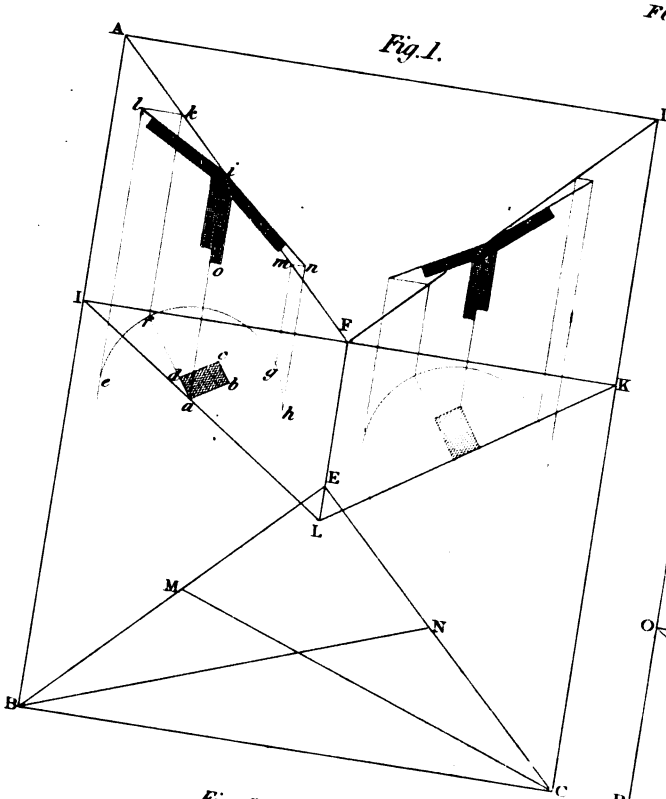


Fig. 2.

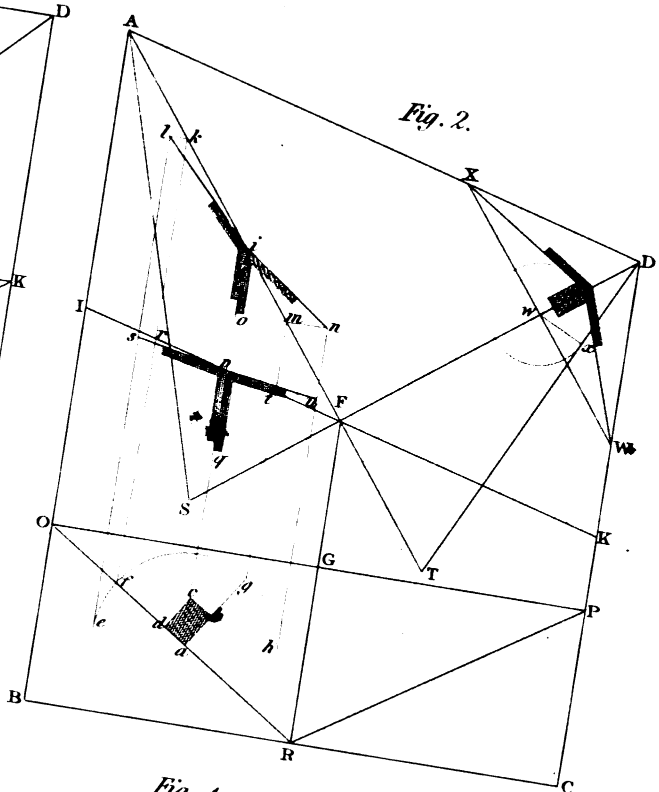


Fig. 3.

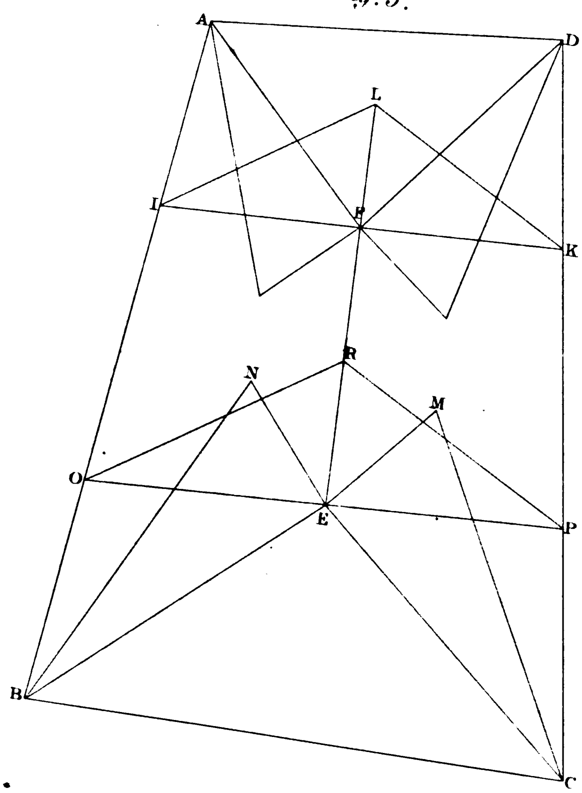
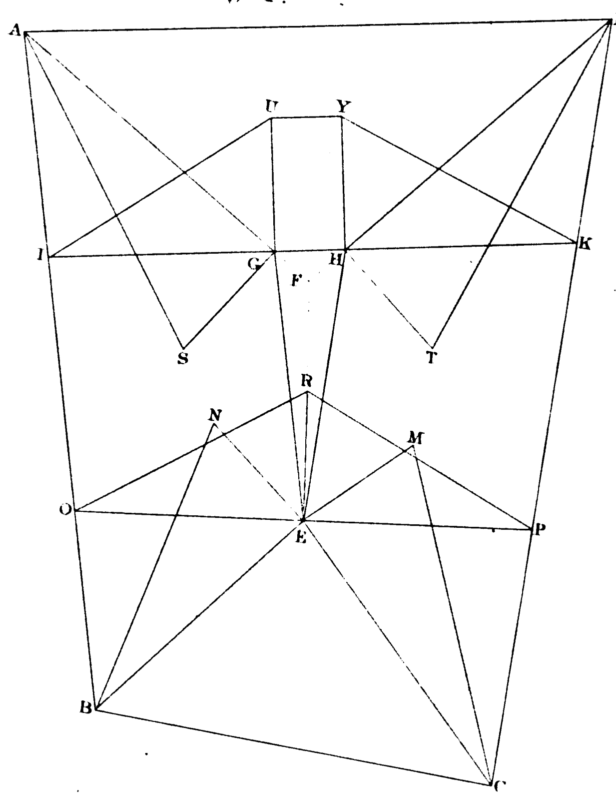


Fig. 4.



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Engraved by E. Turrell

To find the length of any rafter, draw a line from the one extremity of the plan-line of that rafter, perpendicular to that line, and make the height of the perpendicular equal to the height of the roof; join the point of height and the other extremity of the plan-line, and the line thus joined is the length of the rafter as required.

Example 1; *fig.* 1.—To find the length of the common rafters standing upon IK; divide IK into two equal parts in the point F: draw FL perpendicular to IK; make FL equal to the height of the roof, and join IL or KL; then IL or KL is the length of each rafter.

Example 2; *fig.* 2.—To find the length of the hip-rafter standing upon AF. Draw FS, perpendicular to AF: make FS equal to the height of the roof; join AS, and AS is the length of the hip.

Example 3.—To find the bevels of the back of the hip-rafters. Let FD, *fig.* 2, be the plan of a rafter; and draw XW perpendicular to FD, to meet the lines of the wall-plates in X and W, and intersect FD in *w*. From the point *w*, as a centre, describe a circle to touch the elevation of the rafter DT; and from the point where the circle cuts the line FD, draw lines to X and W, then will the angle formed by these lines be the proper bevel for the back of the hip-rafter.

133. To find the bevels of a purlin against a hip-rafter, when the plan-line of a common rafter, that of the hip-rafter, and the angle which the common rafter makes with its plan are known.

Place the section of the purlin in its real position with respect to the common rafter. Produce that side of the section of the purlin, of which the bevel is required upon the hip, toward the plan of the rafter; from one extremity of the line thus produced, and, with the length of the said line as a radius, describe a circle. Draw three lines, parallel to the wall-plate, to meet the hipped line: viz. one from the centre of the circle, one from the point where the line meets the circle, and the third to touch or be a tangent to the circle. From the point in the plan of the hip-rafter, where the middle line meets the said plan, draw a line perpendicular to that middle line to meet the tangent; join the point, where this perpendicular meets the tangent, to the point where the line drawn from the centre meets the plan of the hip-rafter, and the angle formed by the line thus joining, and the line drawn from the centre of the circle, will be the bevel of the purlin.

Example; plate XXIV, fig. 1.—Let AF be the plan of a hip-rafter, IF that of a common-rafter, and FIL the angle which the common-rafter makes with its plan, and *abcd* the section of the purlin.

Now suppose it were required to find the bevel of that side of the purlin represented by *ad*.

Produce *ad* to any point, *f*; and from *a*, with the radius *af*, describe a circle, *efgh*. Parallel to the line of the wall-plate, AB, draw two lines to cut the plan, AF, of the hip; viz., from the centre, *a*, draw *ai*; and from the point *f*, where *af* meets the circle, draw *fk*, the former cutting AF in *i*, and the latter in *k*; also draw *el* to touch the circle. Draw *kl* perpendicular to *fk*, cutting *el* in *l*; and join *il*; then the angle *lia* is the bevel required.

In the same manner, by producing *ab*, we may find the angle formed upon the end of the side, of which the section is *ab*.

134. In order that the different inclined planes, which form the sides of a roof, may have an equal inclination to the horizon, the plan-lines of the hip-rafters ought to bisect the angles formed by the wall-plates.

When a roof is wider at one end than at the other, as in *fig.* 3, in order to prevent its winding, let IK and OP be the plans of the two common rafters, passing through each extremity of the ridge-piece, and let the rafters IL and KL be found as before; divide OP into two equal parts, in E; draw ER perpendicular to OP. Make the angle EPR equal to the angle FKL; then ER will be the height of the roof at the point E.

If this should be objected to, because it makes the ridge higher at one end than at the other, let E, *fig.* 4, be the end of the ridge next to the narrow end of the roof.

Bisect all the four angles of the roof by the straight lines AF, BE, CE, DF; and, through E, draw EG, parallel to AB, cutting AF in G; and draw EH, parallel to CD, cutting DF in H; and join GH: then GH will be parallel to AD. This is true, because, since all the angles are bisected, if we imagine perpendiculars drawn from E to the three sides, the three straight lines thus drawn will be equal: and because EG is parallel to AB, the perpendiculars drawn from the points E and G, to the straight line AB, are equal; from the same reason, because EH is parallel to CD, the perpendiculars drawn from the points E and H, to the straight line CD, are equal; therefore the perpendicular drawn from the point G, to the straight line AB, is equal to the perpendicular drawn from H to the straight line CD. And, since the angles BAD and CDA are bisected by the straight lines AG and DH, the two perpendiculars, drawn from G, to the sides AB and AD, are equal; as also the two perpendiculars from the point H to the sides DA and DC: but the perpendicular drawn from G, to the side AB, is equal to the perpendicular drawn from H to the side CD; therefore the perpendiculars, drawn from the points G and H, to the straight line AD, are equal to each other; but when the perpendiculars drawn between two straight lines are equal, these two straight lines are parallel: therefore the straight line GH is parallel to AD.

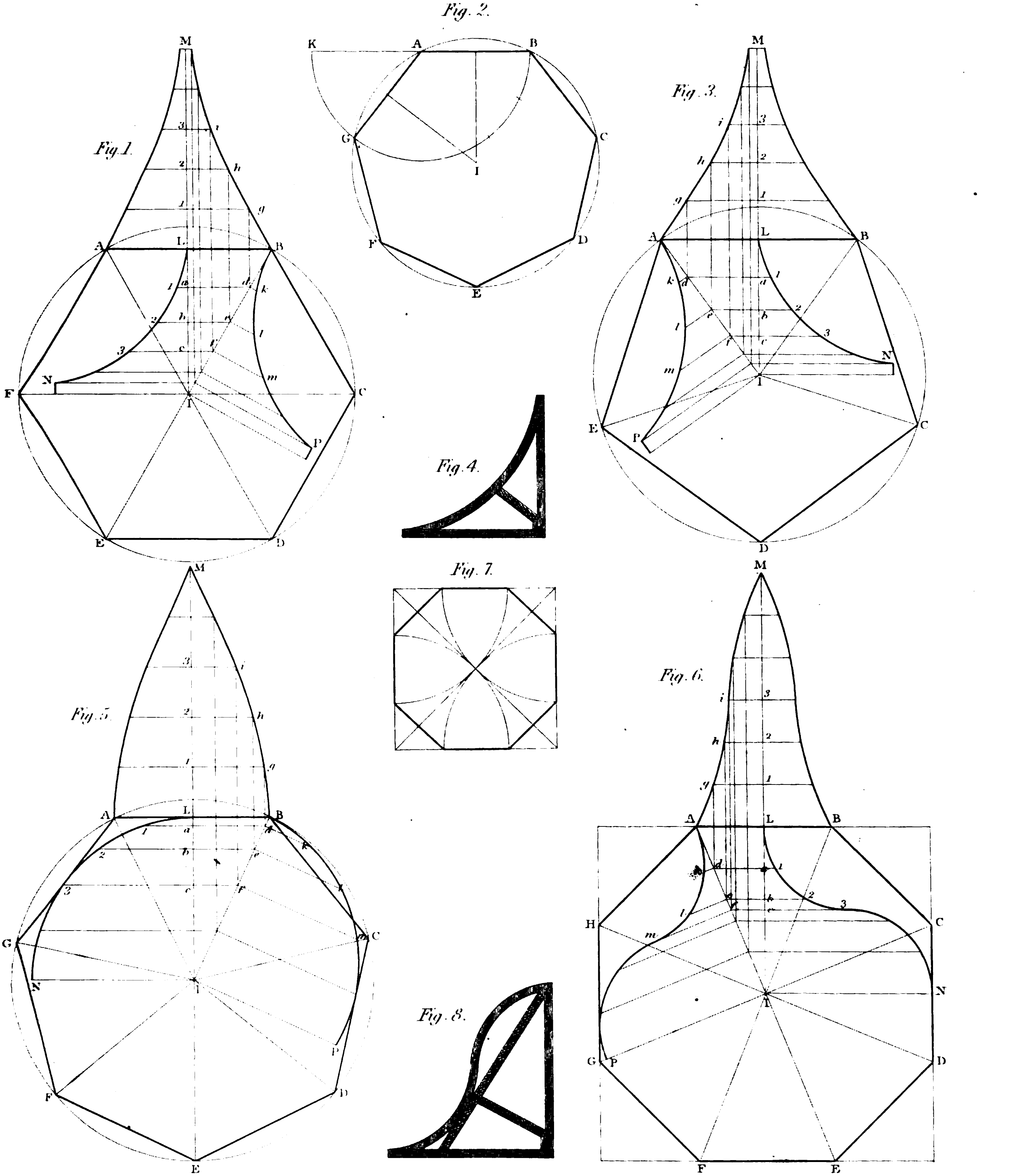
Whence, if all the angles of a roof be bisected, and if any point be taken in any one of the bisecting lines, and if a line be drawn through the point thus assumed, parallel to one of the adjacent sides, to meet the next bisecting line, and so on from one to another, till only one line remains to be drawn; then, if the point assumed be joined to the point where the parallel meets the last bisecting line, the line thus joining will be parallel.

GEOMETRICAL LINES FOR POLYGONAL ROOFS.

135. THE plans of these roofs are supposed to be regular polygons, and all the sections of the same roof, parallel to the plan, to be similar to the plan, and therefore all the parallel sections similar to one another. They may be conceived to be formed of a series of triangular prisms whose joining planes meet in the same point, and their exterior surfaces cut to the form of the roof.

136. In *pl. XXV, fig.* 1, the plan of the roof is denoted by the letters ABCDEFA. Then the centre of the polygon being the point I, draw the lines AI, BI, CI, &c. Bisect any of the sides, as AB, in the point L, and draw LI; then LI is perpendicular to AB.

Produce the line IL to M, and let ILN be the section applied upon IL. In the curve LN take any number of points, 1, 2, 3, at equal distances, and transfer these distances to the line LM, so that LM may be equal to the arc LN. Through the points 1, 2, 3, &c. in LM, draw lines 1*g*, 2*h*, 3*i*, &c. parallel to AB; and from the points 1, 2, 3, &c., in the arc LN, draw lines 1*d*, 2*e*, 3*f*, &c., parallel to AB, cutting LI at the points *a*, *b*, *c*, &c., and BI at the points *d*, *e*, *f*, &c.: Make 1*g* equal to *ad*, 2*h* equal to *be*, 3*i* equal to *cf*, &c. Through the points *g*, *h*, *i*, &c., draw a curve, which will be the edge of the covering which corresponds to the joint over the mitre IB.



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E. Turrell, sculp.

To find the angle-rib, through the points *d, e, f,* &c., draw *dk, el, fm,* &c. perpendicular to BI. Make *dk, el, fm,* &c., respectively equal to *a* 1, *b* 2, *c* 3, &c. Through the points *k, l, m,* &c., draw a curve, which will be the edge of the angle-rib, as required.

137. *Figure* 2 shows the manner of describing a polygon, to any given number of sides. Thus suppose, upon the side AB, it were required to describe a polygon of seven sides, called a *heptagon.* Produce BA to K, and, with the radius AB, describe a semi-circle BGK, of which the diameter is BK; divide the arc BK into seven equal parts, and through the second division, G, draw AG; then BA and AG are two adjacent sides of the heptagon. Bisect each of the sides AG and AB by a perpendicular, meeting each other at I. Then I is the centre of a circle that will contain either of the sides AB or AG seven times. The equal chords, being inscribed in the remaining part of the circle, will complete the polygon as required. In this manner we may describe a polygon of any given number of sides whatever; by producing the given side, and describing a semi-circle on that side, and the part produced, and dividing the arc into as many equal parts as the polygon is to contain sides; then, drawing a line from the centre, through the second point of division, will form two adjacent sides of that polygon. The remaining part of the process is to be completed as before.

138. *Figure* 3, *pl. XXV,* shows the manner of finding the covering of a roof, when the plan is a regular pentagon.

Figure 4, exhibits the method of framing the ribs for such sorts of roofs.

Figure 5, shows the manner of describing the covering and ribs of a domical roof.

Figure 6, shows the manner of describing the covering and ribs of a roof whose vertical section is a figure of contrary curvature.

Figure 7, shows the method of describing a regular octagon from a given square. Thus, draw the diagonals; then, with half the diagonal, as a radius, and from each of the four angular points of the square, describe a quadrant or arc; join the two adjacent points of intersection, in each two adjacent sides of the square, and you have the octagon required.

Figure 8, exhibits the manner of forming one of the ribs for the ogee roof, or that of contrary curvature.

The method of finding the coverings and ribs of *figures* 3, 5, and 6, is the very same as that described in *figure* 1; and the same letters of reference being used, the description applies to all these figures.

Such forms of roofs most frequently occur in temples or garden-buildings.

Polygonal Roofs and Circular Domes are of the same nature; as a dome cannot be covered upon any other principle than by supposing it either a polygon, having a great number of sides; or to be composed of frustums of cones.

COVERING OF CIRCULAR ROOFS.

139. Circular Roofs may be covered upon two different principles; one is, by supposing the axal section to be divided into a number of small equal parts, and the roof cut by planes through the points of division, parallel to the base; and, by considering the frustums of the solid as so many frustums of cones, the covering of each respective part will be found. The other principle is by dividing the circumference of the base into a number of small equal parts, and

supposing axal sections to be made through the points of division; then, by considering the surface of each axal portion as the surface of a cylinder, the covering will be found. The distance between the points of division, in the former case, must be less than the breadth of the boards which are to form the envelopes of the covering, in order to make the convex edge of the board: this distance must, therefore, be less, as the length of the boards is greater. In the latter case, the distances between the points of division may be exactly equal to the breadth of the boards. It is true that the surface of each part is spherical or convex, and therefore can neither be considered as the frustum of a cone, nor that of a cylinder: but, if the distance between the divisions be small, the surfaces will be almost straight in all the axal sections: so that there will be no practical difference, even though the widest boards be used in moderate-sized works. The boards which thus form the envelopes must be thin, in order that they may bend easily to the surface of the circular roof to be covered. It is here proper to notice that, when boards are bent, so as to form a surface either concave or convex, they are much stronger than if the surface were a plane, even though the ribs were at the same distance in both: but, in order to make the boards bend regularly and truly, the ribs ought to be disposed at a nearer distance, even at the widest place, which is at the bottom, than the rafters of a common roof. When the ribs are disposed in axal planes, they will come in contact with each other at the top, unless they terminate upon a circular kirb, of a diameter sufficient to prevent their doing so; but as the intervals at the top are always much less than at the bottom, the ribs are sometimes discontinued, in order to reduce the intervals nearer to an equality of breadth throughout the length of each: the execution in this way will save the timber-work, and, consequently, lessen the expense. Sometimes the ribbing of circular roofs consists of only several principal axal ribs, and the intervals filled in with jack-ribs; which, if the surface to be covered be spherical, are portions of less circles of the sphere, and are disposed in parallel vertical planes.

Purlins and Ribs for Circular Roofs.

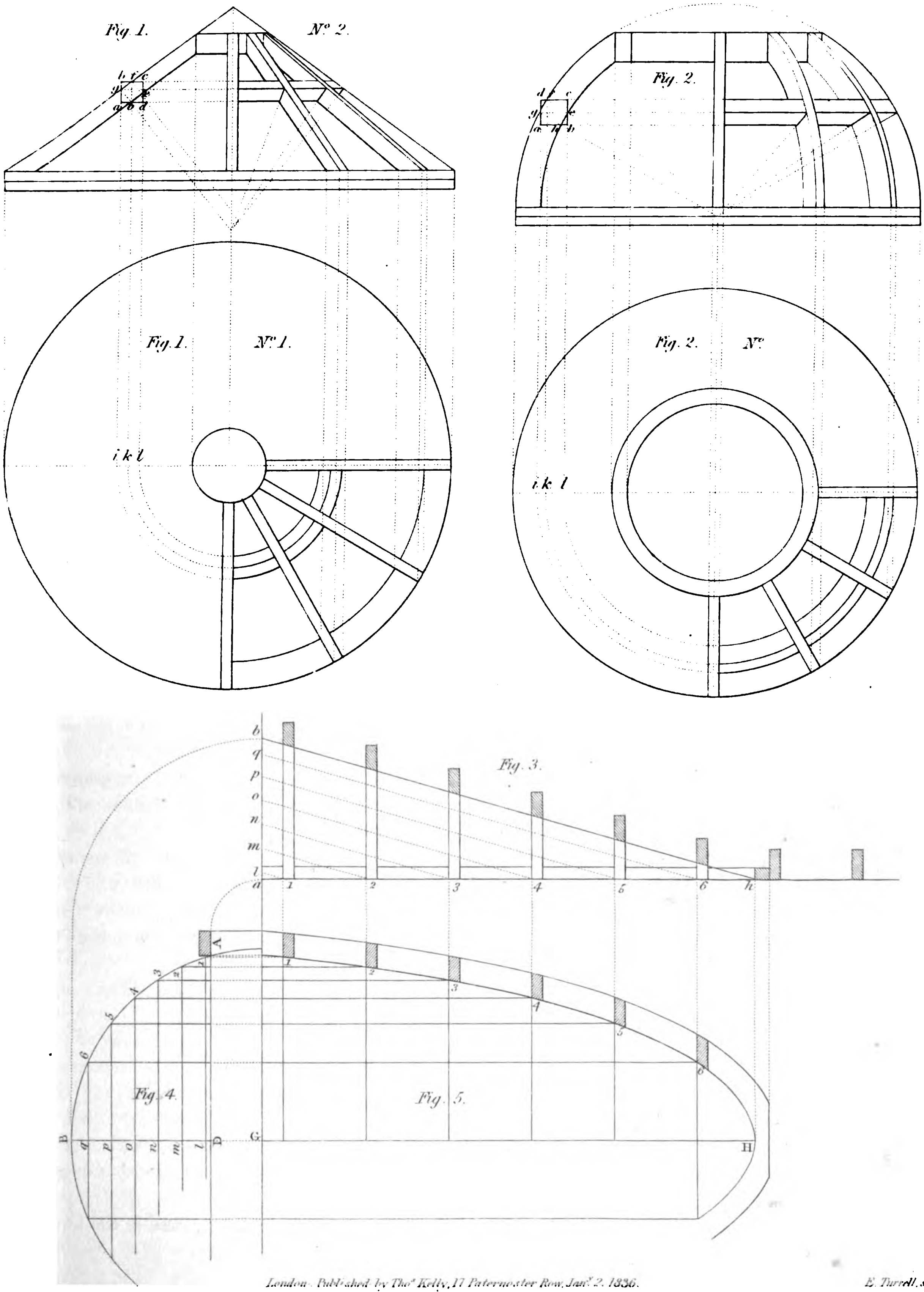
140. In *plate XXVI, figures* 1 and 2, show the plan and elevation of a conical and domical roof; No. 1 in each figure being the plan, and No. 2 the elevation, to determine the size of the timber for the purlins.

The first thing to be done is, to draw the contour both of the plan and elevation. In the one extreme rafter let *gfeh* be the section of the purlin. Round the angular points *g, f, e, h,* describe the square *abcd*: then will *fb, fc, bg, ce, ag, de, ha, hd,* be the parts that are to be gauged off, after having been squared to the circular plan. The same description applies to both figures.

141. *Figure* 1, *pl. XXVII,* is a design for an ellipsoidal dome, the plan being elliptic, and one of the vertical sections circular. The ribs are constructed without trusses. In order to divide them as equally as possible, a purlin is introduced, to support the upper ends of the jack-ribs. As this dome is supposed to rise from an elliptic well-hole, the timbers are carried below the base, from *a, b, c, d, e, f.* No. 1 is the elevation; and No. 2 the plan, showing the upper face of the wall-plate, purlin, and curb. Nos. 3, 5, 7, are the entire ribs, to be placed upon A, C, E, in the plan; and 4, 6, 8, are the jack-ribs, to be placed upon B, D, F, on the plan. The upper ends of all the ribs terminate upon the curb, or upon the purlin, with a *bird's mouth,* which is the usual method of fitting them.

142. *Figure* 2, *plate XXVII,* is a design for an hemispherical dome, constructed in the same manner as the elliptic dome, *fig.* 1. Nos. 3 and 4 show the ribs.

PURLINS IN CIRCULAR ROOFS &c.



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E. Turrell, sculp.

DOMES.

Fig. 1. No. 1.

Fig. 2. No. 1.

Fig. 1. No. 2.

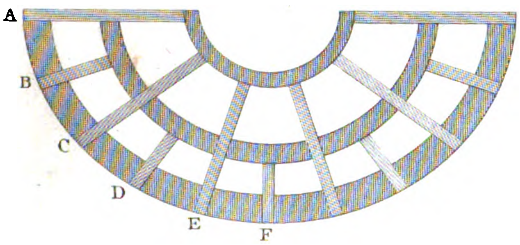
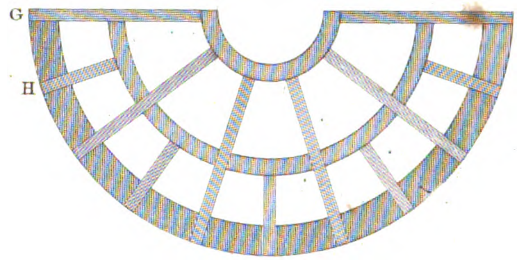
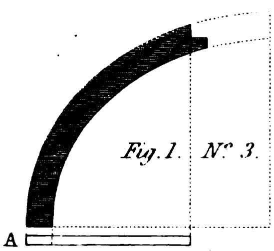


Fig. 2. No. 2.





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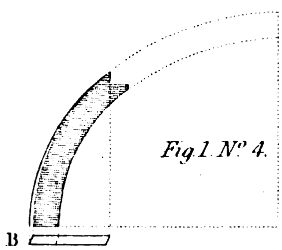


Fig. 1. No. 4.

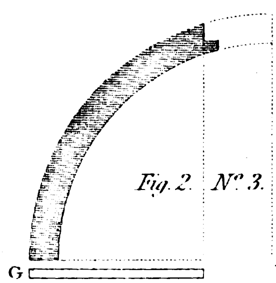
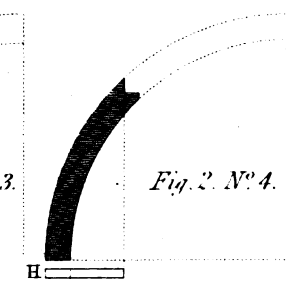


Fig. 2. No. 3.



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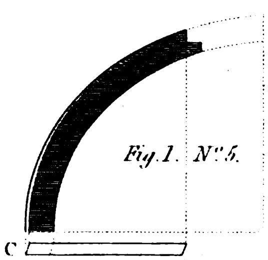

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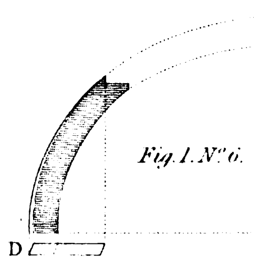


Fig. 1. No. 6.

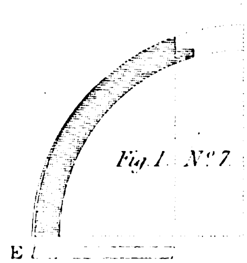


Fig. 1. No. 7.

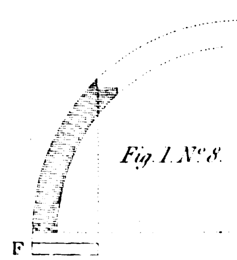


Fig. 1. No. 8.

Drawn by M. A. Nicholson. *London, Published by Thos. Kelly, 17 Paternoster Row, Jany. 2. 1835.* *Engraved by E. Turrell.*

DOMICAL ROOFS.

Fig. 3.

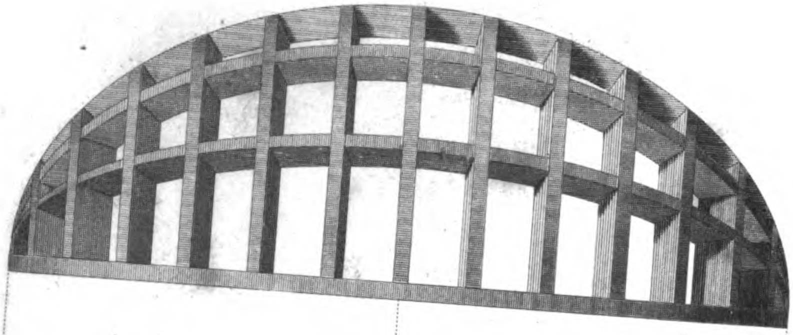


Fig. 1.

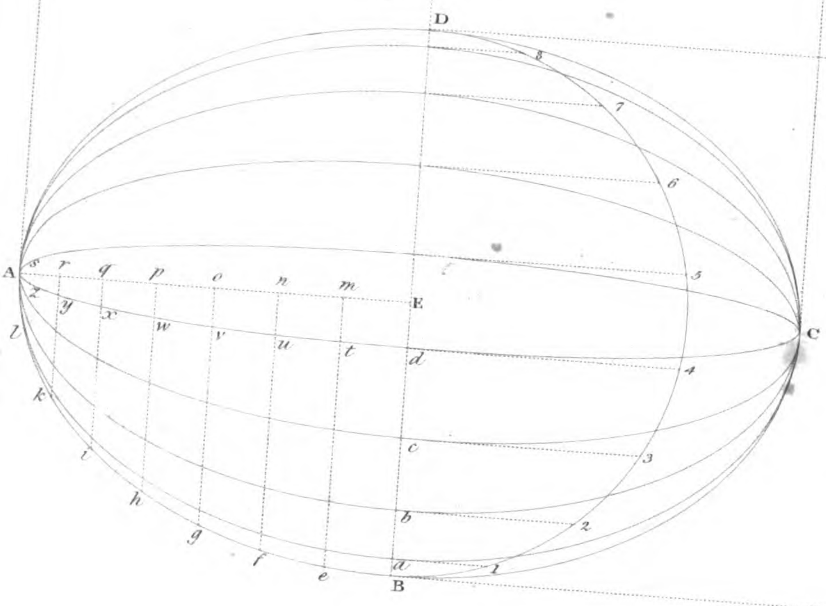


Fig. 4.

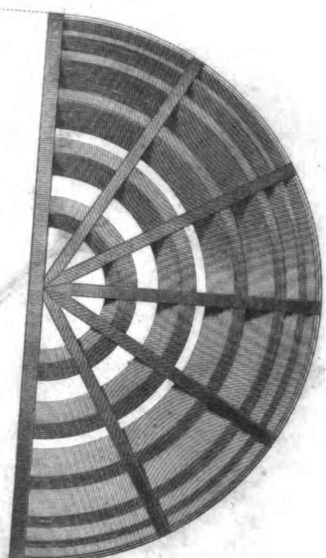
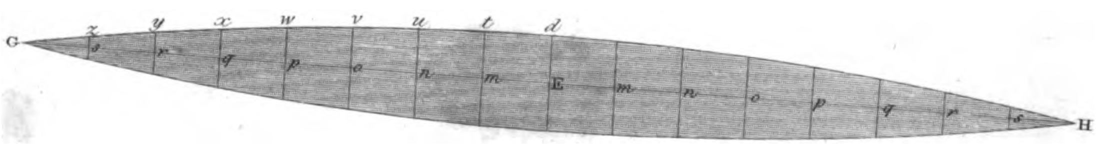


Fig. 2.



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E. Turrell sc.

In large roofs, constructed of a domic form, without trussing, the ribs may be made in two or more thicknesses, in such a manner that the common abutment of every two pieces, in the same ring, may fall as distant as possible from the abutment of any other two pieces, in a different ring. The number of purlins must depend upon the diameter of the dome.

Boarding for Circular Roofs.

143. To find the form of the boards for an ellipsoidal dome, the plan being an ellipsis, and the vertical section upon the least diameter a semi-circle; so that the joints of the boards may be in planes passing through the greatest diameter of the plan.

Let ABCD, *fig.* 1, *pl. XXVIII,* be the plan of the dome, AC the greater diameter, and DB the less; E the centre. From E, with the distance ED, or EB, describe the semi-circle BFD. Divide the arc into such a number of equal parts, that one of them may be equal to the breadth of a board, and let the points of division be at 1, 2, 3, 4, &c. Draw the lines 1*a*, 2*b*, 3*c*, 4*d*, perpendicular to BD, cutting BD at the points *a, b, c, d.* Then, upon AC, as the length, and upon E*a*, E*b*, E*c*, E*d*, as so many breadths, describe the semi-ellipses, A*a*C, A*b*C, A*c*C, A*d*C, which will represent the joints of the boards upon one side of the dome. Now, since all the sections of this dome, through the line AC, are identical figures, the vertical section, upon the line AC, will be identical to the half plan ABC, or ADC. Divide, therefore, BA into any number of equal parts, by the points of division *e, f, g, h, i, k, l*; the more the truer the operation. Draw the straight lines *em, fn, go, hp, iq, kr, ls,* perpendicular to AC, cutting AC at the points *m, n, o, p, q, r, s,* and the semi-ellipsis A*d*C, in the points *t, u, v, w, x, y, z.* On the straight line, GH, *fig.* 2, set off the equal parts, E*m*, *mn*, *no*, &c., from each side of the centre E, each equal to one of the equal parts B*e*, *ef*, *fg*, &c., in the semi-elliptic curve, ABC, in the plan *fig.* 1. Through the points *m, n, o, p,* &c., *fig.* 2, draw lines perpendicular to GH. Make *mt* equal to *mt* in the plan, *fig.* 1; and *nu*, *fig.* 2, equal to *nu* in the plan, *fig.* 1; then, through all the points *t, u, v,* &c., draw a curve, and the same curve repeated on each side of the line GEH will give the form of the board to reach from A to C, and each curve will be the edge of a board, and all the boards of the same figure.

Figure 3 shows the longitudinal elevation; *viz.* on the line AC of the plan.

Figure 4 exhibits the transverse elevation, the contour being identical to that of the section on the line DB.

144. In *figures* 2, 3, 4, (*plate XXIX,*) No. 1 is the plan, and No. 2 the elevation; the contour of the latter being a vertical section passing through the axis. *Figure* 2 represents a dome, whose contour is a semi-circle; *figure* 3 represents a segmental dome; *figure* 4 represents a round body, of which the vertical section is an *ogee,* or curve of contrary flexure.

Through the centre of the plan, G, draw the diameter, AC; and the diameter BD, at right angles to AC; and produce BD to E. Let BD, *figures* 2 and 3, be the base of a semi-section of the dome: on BD apply the semi-section BFD; and as the dome, represented by *figure* 2, is semi-circular, the point F will coincide with the point A in the circumference of the plan. In *figures* 2 and 3 divide the curve FD, of the rib, into any number of equal parts, and extend the curve DF upon the straight line DE, from D to E; that is, make the straight line DE equal in length to the curve DF. Through the points of division, in the curve DF, draw lines perpendicular to DG, cutting it at the points *a, b, c*: then, extending the parts of the arc between the points of division upon the line DE, from D to 1, from 1 to 2, from 2 to 3, &c.: make D1 equal to half the breadth of a board, and join 1G; produce the lines 1*a*, 2*b*, 3*c*, &c.,

drawn through the curve DF, to meet the line 1 G, in the points *d, e, f,* &c. Through the points 1, 2, 3, &c., in DE, draw perpendiculars $1g$, $2h$, $3i$, &c.: make $1g$, $2h$, $3i$, &c., respectively equal to ad, be, cf, &c.; and, through the points *d, g, h, i,* &c., E, draw a curve, which will form one edge of the board. The other edge, being similar, we have only to describe a curve equal and similar, so as to have all its ordinates respectively equal from the same straight line DE.

In *fig.* 4, the form of the mould for the boards is found in a similar manner, except that the curve DF is one side of the elevation, No. 2: Lines are drawn from the points of division in DF perpendicular to the diameter AC, which is parallel to the base of No. 2; and the points of division are transferred from the radius GC, to the radius GD, which is the base of the section. The remaining part of the process is the same as in *figures* 1 and 2.

In *figure* 2, the curved edge of the board is a symmetrical figure of sines; the curve of the mould, *fig.* 3, is a smaller portion of the figure of the same curve: and, in *fig.* 4, the mould is a curve of contrary flexure; and if the curve DE be composed of two arcs of circles, the curve of the edges of the mould for the boards will still be compounded of the figure of sines set on contrary sides; and, if the curve DE be compounded of two elliptic segments, the edges of the mould for the formation of the boards will still be of the same species of curve: *viz.* the figure of sines.

This figure occurs very frequently in the geometry of building.

145. The method we have described may be called the *vertical method* of covering a dome, and we now proceed to give the *horizontal method.*

In *fig.* 1, *pl. XXX,* let ABC be a vertical section of a circular dome, through its axis; and let it be required to cover this dome horizontally; bisect the base, AC, in the point H, and draw HI perpendicular to AC, cutting the semi-circumference in B. Divide the arc BC into such a number of equal parts that each part may be less than the breadth of a board; that is to say, allowing the boards to be of a certain length, each part may be of the proper width, allowing for waste. Then if, between the points of division, we suppose the small arcs to be straight lines, as they will differ very little from them, and if horizontal lines be drawn through the points of division, to meet the opposite side of the circumference, the trapezoids will be the sections of so many frustums of cones, and the straight line HI will be the common axis for every one of these frustums.

Now, therefore, to describe any board, which shall correspond to the surface of which one of the parts, ab, is the section, produce ab to meet HI in c; then, with the radii cb, ca, describe two arcs; then radiating the end to the centre, the lines thus drawn will form the board required.

In the same manner any other board may be found; as is evident from the principle described.

146. To find the forms of the boards for covering an ANNULAR VAULT (*pl. XXX, fig.* 2).

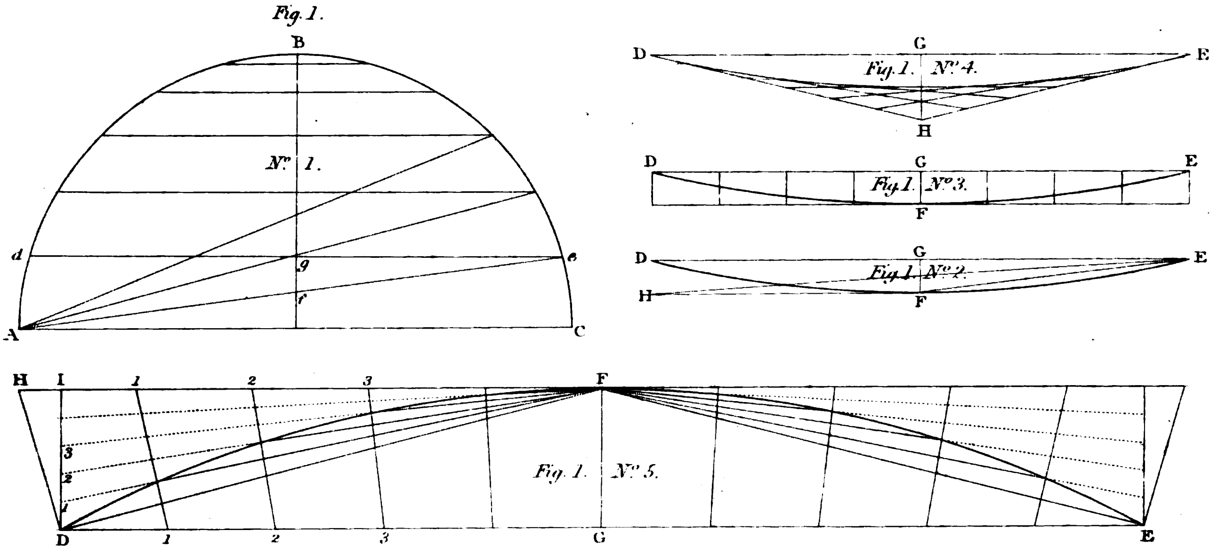
Let AD be the outer diameter of the annulus, CG the inner, E the centre, and AC the the breadth of the vault.

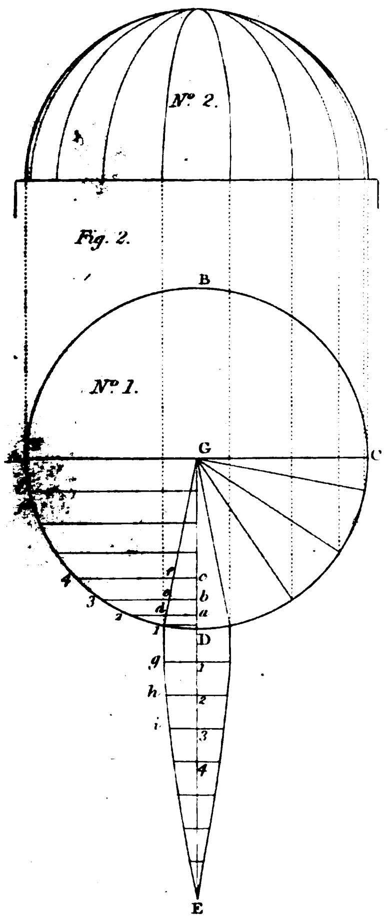
On AC describe the semi-circle ABC: then, if ABC be supposed to be set or turned perpendicular to the plane of the paper, it will represent the section of the vault. From E, with the radius EA, describe the semi-circle AFD; and, from the same centre, E, with the radius EC, describe the semi-circle CHG; then AFD is the outer circumference, and CHG the inner circumference; and, consequently, AFDGHC is the plan of the vault, perpendicular to the fixed axis; and the section ABC of the vault is perpendicular to the plan AFDGHC.

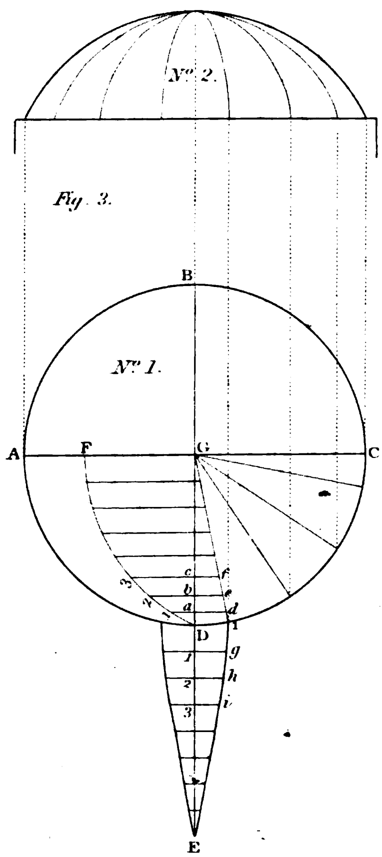
To find the form of any board; divide the circumference of the semi-circle, ABC, into such a number of equal parts as the boards or planks out of which they are to be cut will admit.

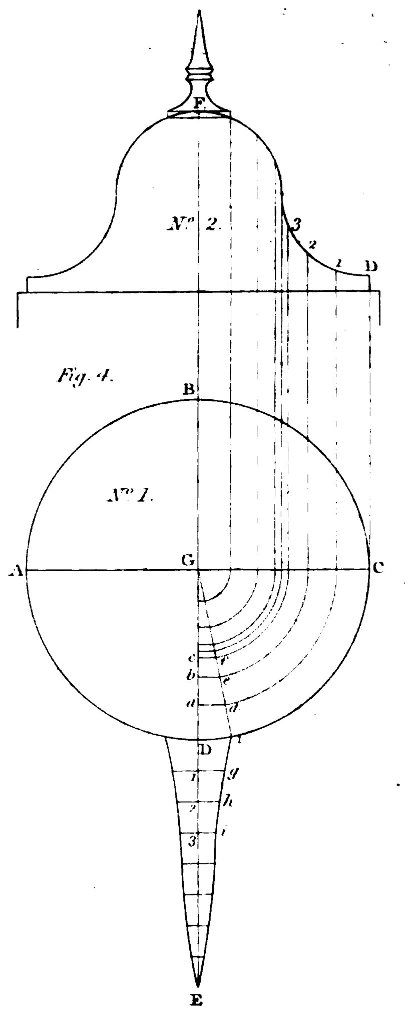
Let ab be one of the divisions or the distance between two adjacent points; through the centre E draw HI, perpendicular to AD; and through the points a and b, draw the straight

COVERINGS OF CIRCULAR ROOFS.









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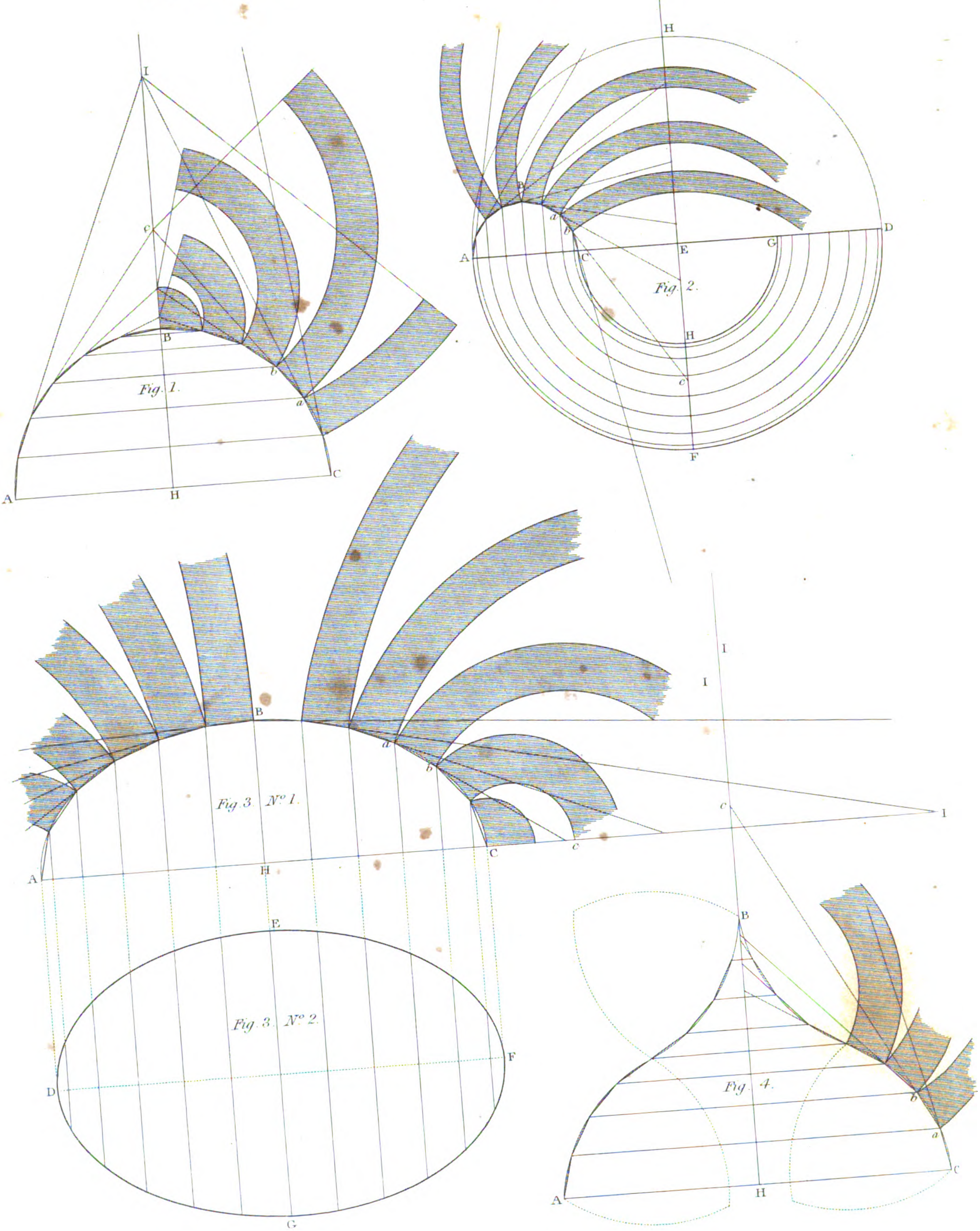
METHODS FOR COVERING CIRCULAR ROOFS.



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line *ac*, meeting HI in the point *c*: from *c*, with the radius *ca*, describe an arc; and from the same centre, *c*, with the radius *cb*, describe another arc, and enclose the space by a radiating line at each end; and the figure bounded by the two arcs, and the radiating lines, will be the form of the board required.

In the same manner the form of every remaining board may be found.

It is obvious that, as common boards are not more than from nine or eleven inches in breadth, the boards formed for the covering cannot be very long; or otherwise they must be very narrow, which will produce much waste

147. To cover an ELLIPSOIDAL DOME, the length of the generating ellipse being the fixed axis, (*pl. XXX, fig.* 3.)

Let ABC be the section through the fixed axis, or generating ellipse, which will also be the vertical section of such a solid.

Produce the fixed axis AC to I, and divide the curve ABC into such a number of equal parts that each may be equal to the proper width for a board. Then, as before, draw a straight line through two adjacent points, as *a* and *b*, to meet the line AI in *c*; then, with the radii *ca* and *cb*, describe arcs, and terminate the board at its proper length.

No. 2, (*fig.* 3,) is a horizontal section or plan of the dome, exhibiting the plan of the boarding.

148. *Figure* 4 is a section of an ogee roof circular on the plan. The principle of covering it with boards bent horizontally, is exactly the same as in the preceding examples.

It is now necessary only to explain *one general principle*, which extends to the whole of these round solids. The planes which contain the conic frustums are all perpendicular to the fixed axis, which is represented by HI, in all the figures. Produce *ab*, to meet the fixed axis HI in *c*; then, with the radius *ca*, describe an arc; and, with the radius *cb*, describe another arc, which two arcs will form the edges of the boards; the ends are formed by lines radiating from the centre *c*. Now, whichever figure is inspected, it will be found that this rule applies to it.

As the boards approach nearer to the part of the roof which is of the greatest diameter, they may be made either wider or longer; but, as the boards approach nearer to the axis HI, the waste of stuff will be greater, and, consequently, the boards must be shorter.

149. When the boards come very near to the bottom of the dome, the centres for describing the edges of the boards will be too distant for the length of a rod to be used as a radius. In this case we must have recourse to the following method. Let ABC, (*fig.* 1, *pl. XXIX,*) be the section of the dome, as before, and let *e* be the point in the middle of the breadth of a board: draw *ed* parallel to AC, the base of the section, cutting the axis of the dome in *g*, and join A*e*, cutting the axis in *f*. Then, by *Art.* 6, describe the segment of a circle, through the three points *d*, *f*, *e*, and this will give the curve of the edge of the board, as required.

Figure 1, No. 2, exhibits the manner of applying the instrument we have described in *Art.* 4, to this purpose. Thus, suppose we make DE equal to *de* in No. 1: Bisect DE in G, and draw GF, perpendicular to DE, and make GF equal to *gf*, in No. 1. Draw FH parallel to DE, and make FH equal to FE, and join EH; then cut a piece of board into the form of the triangle HFE: then let HFE be that triangle; then move the vertex F from F to E, keeping the leg FE upon the point E; and the leg F, and the angular point F of the piece, so cut, will describe the curve, or perhaps as much of it as may be wanted.

It must be here observed that the line described is the middle of the board; but, if the breadth of the board is properly set off at each end, on each side of the middle, we shall be able to describe the arc with the same triangle; or, if the concave edge of the board be hollowed out, the convex edge will be found by gauging the board off to its breadth.

As all the conic sections approach nearer and nearer to circles, as they are taken nearer to the vertex; a parabola, whose abscissa is small, compared to its double ordinate, will have its curvature nearly uniform, and will, consequently, coincide very nearly with the segment of a circle; and, as this curve is easily described, we may employ it instead of a circular arc, as in Nos. 3 and 4.

Draw the chord DE, as before, and bisect it in G. Draw GF perpendicular to DE, and make GF equal to *gf*, in No. 1: so far the construction of the diagrams, Nos. 3 and 4, are the same; and then describe No. 3 by *Art.* 14, and No. 4 by *Art.* 15.

The arc of a circle may, however, be accurately drawn through points, by the following method:

Let DE, (*fig.* 1, No. 5,) be the chord of the segment, and GF the height. Through F draw HF, parallel to DE; join DF, and draw DH perpendicular to DF. Divide DG and HF each into the same number of equal parts, as five, in this example; draw DI perpendicular to DG, meeting HF in I; and divide DI into the same number of parts as DG: *viz.* five. Join the points of division in DG to those in HF, and also through the points of division in DI draw straight lines to the point F, cutting the former straight lines, drawn through the points of division in the lines DG and HF: then trace a curve from the point D, and through the points of intersection to F, and we shall have one half of the circular arc. The other half is found in the same manner, as is obvious from inspection of the figure. But the method described in *Art.* 5 is the most easy in practice for a case where every board is of a different curvature.

The last method of covering round solids requires all the boards to be of different curvatures, and continually quicker as they approach nearer to the crown; but, by the first method of covering a dome, with the joints in vertical planes, when the form of one of the moulds is obtained, this form will serve for moulding the whole solid. The waste of stuff is, however, the same in both methods, and the horizontal method admits of the ribs being disposed so as to give greater strength with less material.

OF NICHES.

150. Niches are recesses formed in walls, in order to contain some ornament, as a statue, or an elegant vase. They are also adapted to receive figures bearing lights in halls, galleries, and staircases. Sometimes niches are made in thick walls to save materials.

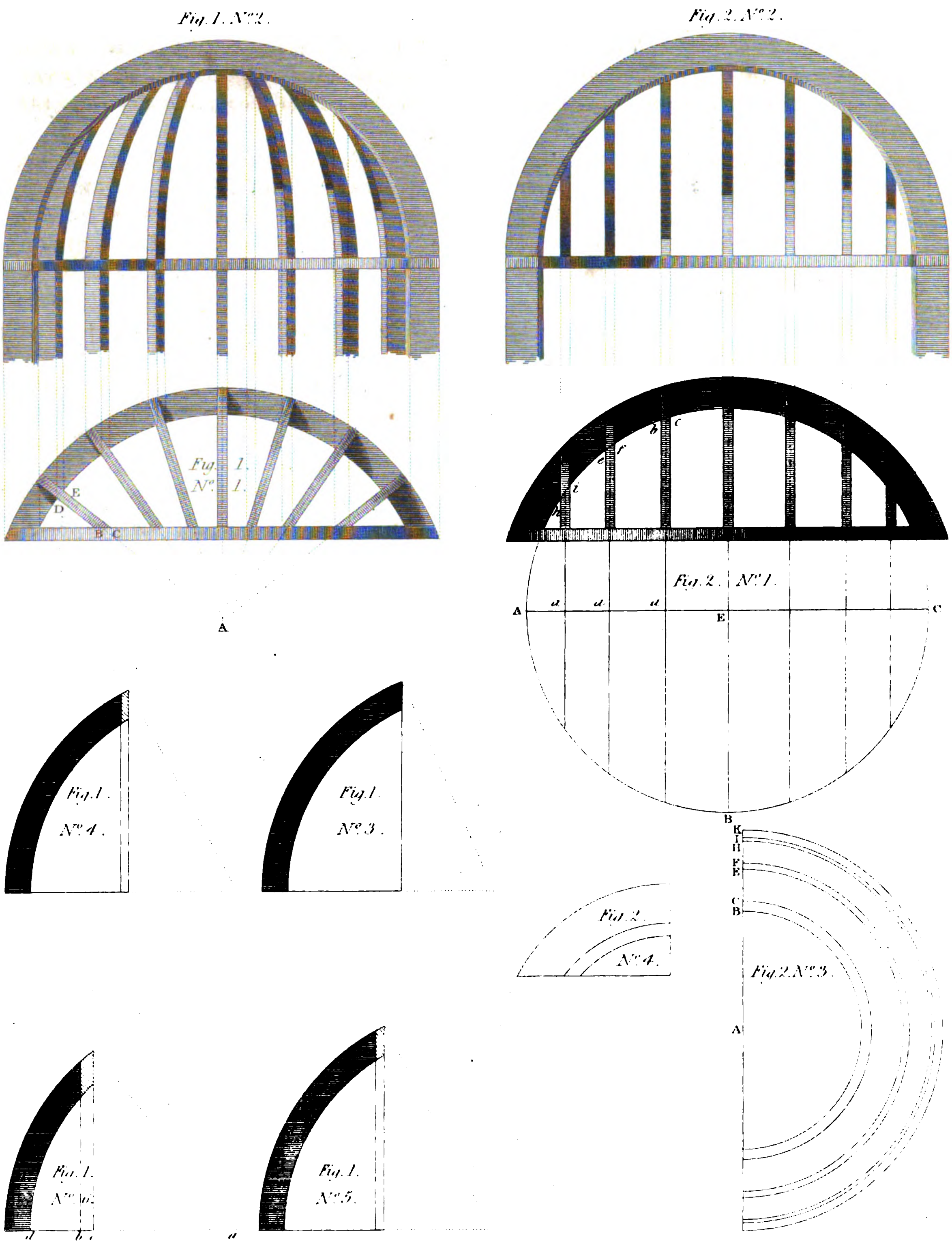
Niches for the interior parts of buildings are generally constructed of ribs of timber, and lathed and coated over with plaster, which forms the apparent surface.

The plan or base of a niche is always some symmetrical figure; as a rectangle, a segment of a circle, or of an ellipsis.

All the sections of a niche, parallel to the base, are similar figures; and all the sections parallel to the base, to a certain height are equal. Niches sometimes terminate upwards in a plain surface, and sometimes in a spheroidal surface; but most frequently in the portion of a spherical surface; so that, as the faces of walls are generally perpendicular to the horizon, the aperture in the face is either a rectangle, or a rectangle terminating in the segment of a circle, or in the segment of an ellipsis. Two of the sides of the rectangular part being perpendicular to the horizon.

Niches are always constructed in a symmetrical form; *viz.* if a vertical plane be supposed to

NICHES.



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E. Turrell sc.

pass through the middle point of the breadth, perpendicular to the surface of the wall, it will divide the niche into two equal and similar parts; or, if any two points be taken in the breadth, equi-distant from the sides of the niche, and if two vertical planes be supposed to pass through these points, perpendicular to the surface of the wall, the sections of the niche will be equal and similar.

Niches are placed either equi-distantly, in a straight wall, or round a cylindrical wall, dividing the circumference into equal parts: sometimes they are placed in an elliptic wall. In the latter case, however, they ought not to divide the circumference into equal parts, but to be at an equal distance from each extremity of the principal axis of the ellipsis. Niches are frequently constructed in polygonal rooms; a niche being placed in the middle of each side of the prismatic cavity. The opposite sides of such rooms are always equal and similar rectangles. The plans are either hexagonal or octagonal; but, most frequently, of the latter form.

151. The principles of forming the ribs, for the heads of spherical niches, are drawn from the following considerations:

All the sections of a sphere, made by a plane, are circles; therefore the edges of the ribs to be lathed ought to be portions of circles.

The ribs of niches may be placed either in vertical planes, or in horizontal planes; and, indeed, in any manner, so as to form the spherical surface as required: it will be most convenient, however, to dispose the ribs either in vertical planes, or in planes parallel to the horizon, as the case may require.

One of the most easy considerations for the ribs of a niche, when they are placed in vertical planes, is to suppose them to pass through a common line of intersection; and, if this line passes through the axis of the sphere, the ribs will be all equal portions of the circumference of a great circle of the sphere: and will, in consequence, be very easily executed. In this case, the square edges of the ribs will range, or form the surface of the niche. This position of the ribs is therefore very convenient for forming them, as not only less time, but much less wood will be required to execute them.

There is another position of vertical ribs, which is frequently convenient; that is, by placing the ribs in equi-distant planes, perpendicular to the surface of the wall; and, consequently, when the surface of the wall is a plane, the planes of the ribs will be all parallel.

152. *Figure* 1, in *pl. XXXI*, exhibits the plan and elevation of a niche; the ribs are disposed in vertical planes, which intersect in the axis of the sphere. The plan, No. 1, is the segment of a circle; and, in consequence of this, the back ribs are of different lengths, and will therefore meet the front rib in different places, as shown in the elevation, No. 2. But, if the plan had been a semi-circle, all the back ribs would have necessarily met the front rib in the middle of its circumference. Numbers 3, 4, 5, 6, (*fig.* 1,) exhibit the ribs as cut to their proper lengths, according to the plan, No. 1. Thus, let it be required to find the rib standing upon the plan BCED, of which the sides BD and CE are equi-distant from the line that passes through the centre A. In No. 6 draw the straight line ad, in which make ac, ab, ad, equal to AC, AB, AD, No. 1: in No. 6, from the point a, as a centre, describe an arc of a circle; from the points b, c, draw two straight lines, perpendicular to ad, cutting the arc; then the portion of the arc, intercepted between the point d and the perpendicular drawn from the point b, is the *arris line* next to the front, and the part intercepted between the point d and the perpendicular from c is the arc forming the arris line next to the back; so that the extremities of the perpendiculars drawn from b and c, give the extremities of the joint against or upon the front rib.

As to the form of the back edges of the ribs, they may be curved or formed in straight portions. In this manner all the other ribs may be formed; as is evident from the preceding explanation.

153. *Figure 2, pl. XXXI*, exhibits the plan and elevation of a niche, with the method of describing the ribs when they are disposed in parallel planes. No. 1 is the *plan*, No. 2 the *elevation*, and Nos. 3 and 4 the method of *drawing the ribs*. The lengths of the bases of the ribs, in Nos. 3 and 4, are taken from the plan, No. 1; as AK, AI, AH, AF, AE, AC, AB, are respectively equal to ED, *ac, ab, af, ae, ai, ah*, in the base No. 1. The two distances which approach near to each other show the quantity of bevelling. With these distances, from the centre A, No. 3, describe as many semi-circles as there are points; then the double lines will represent the quantity of bevelling, or the distance from the square edge. No. 4 shows one of the ribs alone by itself.

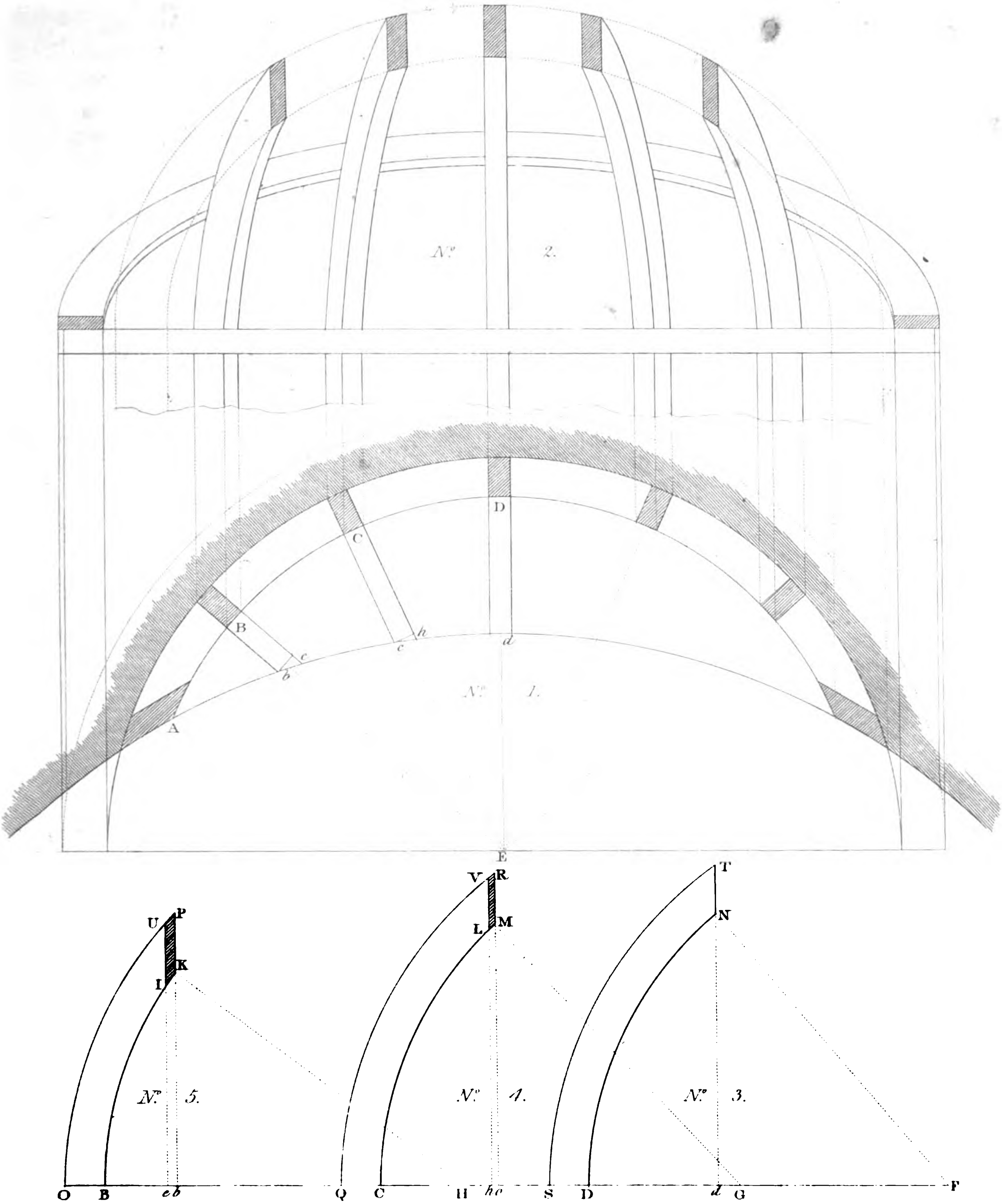
154. To draw the ribs of a spherical niche, in a circular wall. *Plate XXXII*, Nos. 1, 2, 3, 4, 5.

Let No. 1 be the plan of the niche, and that of the wall A*bcd*, &c. that being the base line of the circular wall; and ABCD the base line of the spherical niche; and A, B, C, D, &c. the bases of the ribs, of which the sides are all supposed to stand in a vertical plane. A plane, passing through the middle of the thickness of each rib, parallel to the sides of that rib, is supposed to pass through the centre of the sphere; and, therefore, the bases of these planes will pass through the point E, which is the projection of the centre of the sphere, on the horizontal plane, where the cylindrical and spherical surfaces meet each other; and this we may suppose to be the plane of the paper.

Now, since all sections of the sphere are circles, all the edges of the ribs of the niche will be circular; but, because all the circles pass through the centre of the sphere, the edges of the ribs of the niche must be all segments of great circles of the sphere; and, therefore, they must all be described with one radius, which is equal to that of the arc A, B, C, D, &c., and, consequently, with the radius EA, EB, EC, ED, &c., as at No. 3, No. 4, No. 5, &c.; therefore, from F, G, H, as centres, with the radius EA, describe the arcs DN, CM, BK; and draw FD, GC, HB. Produce FD to S, GC to Q, and HB to O. In the radius FD, No. 3, make F*d* equal to E*d*, No. 1, and draw *d*T perpendicular to FD, cutting the arc DN at N: then DN will be the under edge of the rib which stands upon *d*D, its plan. In No. 4, upon the radius the CG, make C*h*, C*e*, equal to the plan of each side of the rib which stands upon C, No. 1; and, in No. 4, draw the perpendicular *c*R, *h*V, cutting the arc CM at L and M.

In like manner, in No. 5, make B*e*, B*b*, each equal to the side of the rib B, in the plan, No. 1; and, in No. 4, draw *b*P, *e*U, perpendicular to BH, cutting the arc BK in I and K. Then the backs of these ribs may either be the arcs ST, QR, OP, or may have any outline whatever; but, for the convenience of what will be presently shown, in the fixing of the ribs, it will be proper to make them all circular arcs of one radius, which will make them sufficiently strong. Then IPKU is the representation of the top of the rib, which top coincides with the face of the wall, and, consequently, the distance between the lines LV, MR, is the quantity which this rib, now under description, must be bevelled. In like manner, IKPU is the representation of the upper end of the rib which stands upon its plan B, and where it falls in the surface of the wall.

The back of the ribs being made circular, and of one radius, they will all coincide with another spherical surface: if, therefore, the back ribs are fixed at their bases, the inner edges will be brought to the spherical surface, by fixing a rib, at the back of these ribs to attach them to, whose inner concavity has the same radius as the backs of the ribs, and the plane, passing



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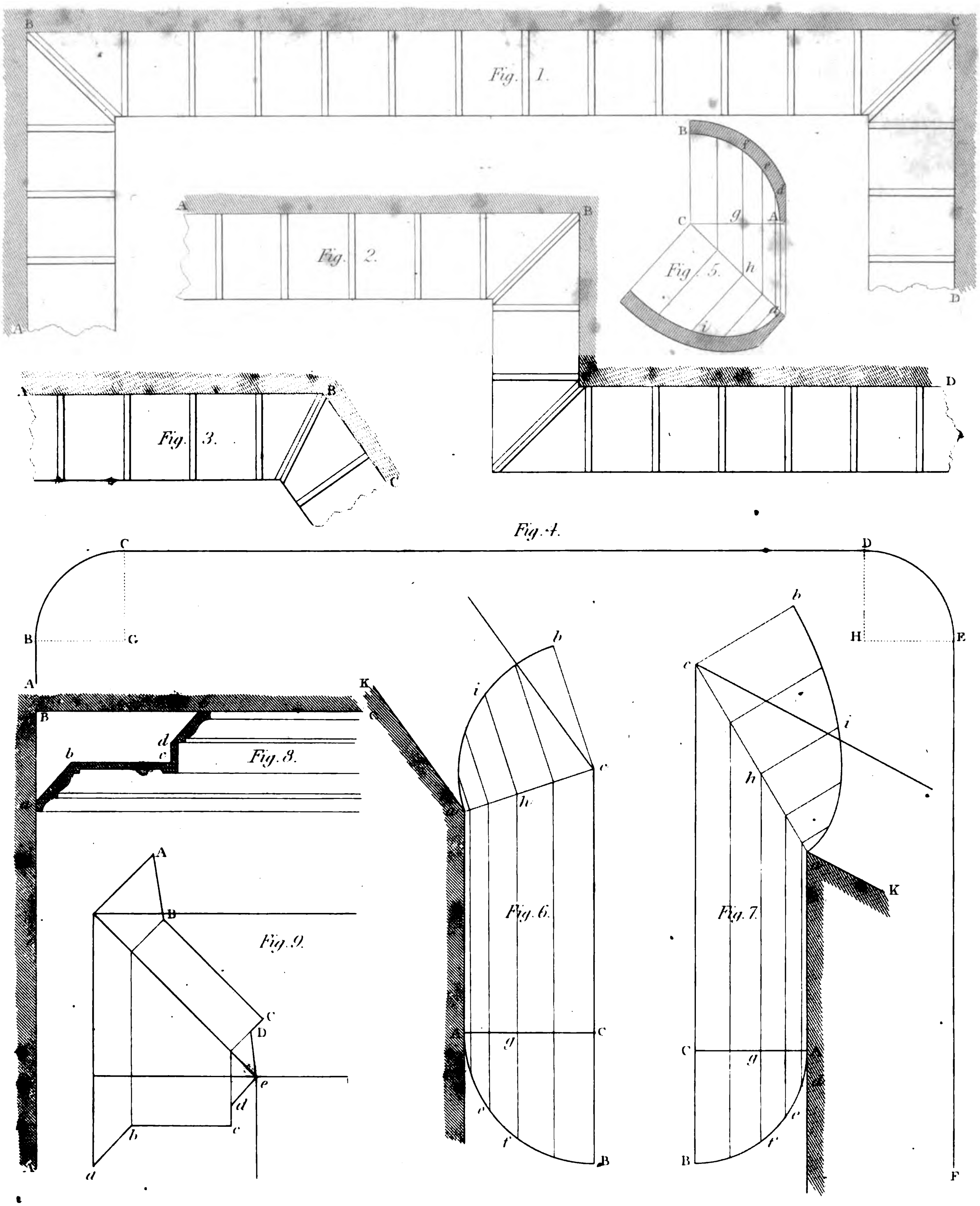
E. Turrell sc.

BRACKETING FOR CORNICES AND COVES.



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Ed. Turrell, sc.

through the middle of its thickness, parallel to its sides, must pass through the centre of the sphere. In other respects, the plane of this fixing rib may have any other position whatever, besides what has now been described.

Where niches are to be lined with boards, it may be done by the same methods as are employed for covering domes, see Art. 143 and 144.

BRACKETING FOR COVES AND CORNICES.

155. Cove-bracketing is a method of forming the angle between the ceiling and walls of a room for the cornice, the middle part of which consists, generally, of the concave surface of a cylinder; though its curvature may be, occasionally, elliptical or of other compound curves; and the surfaces produced by using the latter kind of curves will have the appearance of greater ease and propriety than the surface of a cylinder.

All the vertical sections of coved ceilings, perpendicular to the wall, are equal and similar figures, alike situated to the surface of the wall, and equi-distant from the floor.

The cornice of a room has the same properties; that is, its vertical sections, perpendicular to the surface of the wall, are equal and similar figures; and their corresponding parts are equi-distant from the wall, and also from the floor.

As the coves and cornices of rooms are generally executed in plaster, when they are large, in order to save the materials, the plaster is supported upon lath, which is fastened to wooden brackets, and these again to the bond timbers, or to plugs in the wall: and for this purpose the brackets are equi-distantly placed, at from three-quarters of an inch to an inch within the line of the cornice; and, in order to support the lath at the mitres, brackets are also fixed in the angles.

156. In *fig.* 1, *pl.* XXXIII, ABCD is part of the plan of the faces of the walls of a room. The plan of the bracketing is here disposed internally, and the angle brackets are placed at B and C.

In *fig.* 2, ABCD is the plan of part of one side and the chimney-breast; and here, on account of the projection, we have one internal angle and one external angle. We may here observe, that the angle bracket of the external angle is parallel to that of the internal angle.

Figure 3 exhibits a bracket upon an obtuse angle.

In *fig.* 4, ABCDEF is part of the section of a room; CD is the ceiling line; CB and DE are the sections of the coves; BA and EF are portions of the wall-lines.

Figure 5 shows the construction of a cove-bracket at a right angle. Let AC be the projection of the cove, and let A*a* be part of the wall-line: make A*a* equal to AC, and join *a*C; on the base AC describe the bracket AB, which is here the quadrant of a circle, but may be of any figure. In the arc AB take any number of points, *d*, *e*, *f*, &c., and from these points draw lines parallel to A*a*; that is, perpendicular to AC, cutting both AC and *a*C in as many points; from the points of section in *a*C draw lines perpendicular to *a*C, and make the lengths of the perpendiculars respectively equal to those contained between the base AC and the curve AB; and, through the points thus found, draw a curve; and the curve, thus drawn, will be the angle-rib to form the cove in the angle, as required to be done.

Figure 6 exhibits the construction of a bracket for an external obtuse angle, A*a*K being the wall-line.

Figure 7 exhibits the construction of a bracket for an external acute angle.

Figure 8 exhibits the section of a large cornice, where the lines within the mouldings form the bracket required.

Figure 9 shows the construction of the angle-bracket for a cornice in a right-angle.

To form the bracket in the obtuse or acute angle, take any point f (*figures* 6 and 7,) in the given cove, and draw Fh parallel to Aa, cutting the base AC of the given bracket in g, and the base ac of the angle-bracket in h: draw hi perpendicular to ac, and make hi equal to gf; then will i be a point in the curve. In the same manner we may obtain as many points as we please.

This description also applies to the construction of an angle-bracket of a cornice; the only thing to observe with regard to this is, to make all the constructive lines pass through the angular points in the edge of the common bracket.

In the construction of angle-brackets, it will be the best method to get them out in two halves, and so range each half to its correspondino side of the room; and, when they are ranged, nail the halves together.

PENDENTIVE BRACKETING.

157. PENDENTIVE BRACKETING occurs when certain portions of a concave surface are introduced between the walls of a rectangular or polygonal room and the level ceiling, so as to reduce the outline of the ceiling to a regular figure of a different form from the plan of the room. The parts thus introduced are called PENDENTIVES.

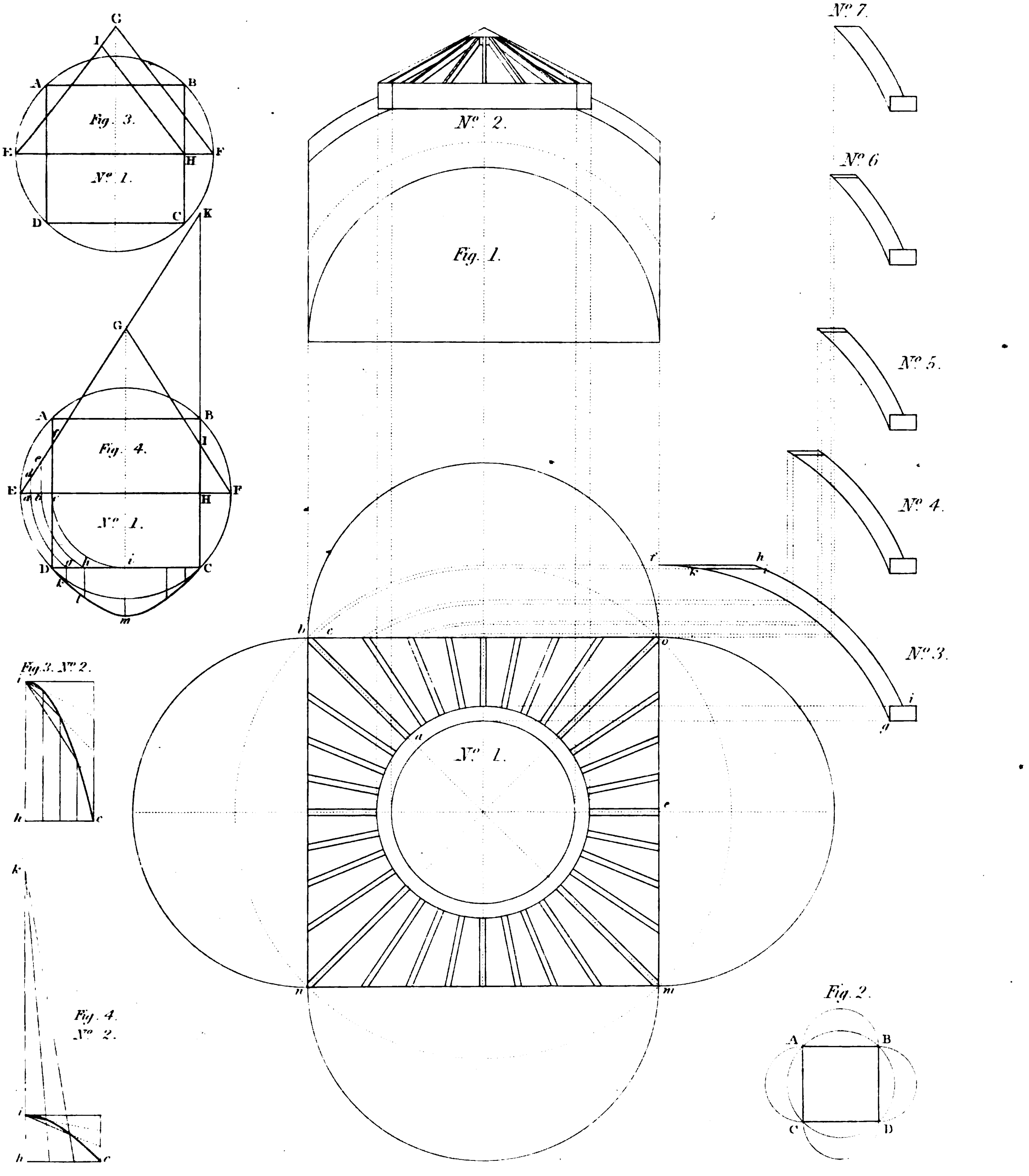
Pendentives are either portions of cones, spheres, or spheroids, and the figures they form, by their intersection with the walls from whence they spring, are dependant on the following principles.

158. It is well known that, if a sphere be cut by a plane, the section will be a *circle;* and, if a hemisphere be cut by a plane perpendicular to its base, the section will be a *semi-circle.* If a right cone be cut by a plane, perpendicular to its base, the section will be a *hyperbola;* and, generally, if any conoid, formed by the revolution of a conic section about its axis, be cut by a plane perpendicular to its base, the section will always be similar to the section of the solid passing through the axis; and every two sections of a conoid, cut by a plane perpendicular to the base, at an equal distance from the axis, are equal and similar figures. Therefore if, on the base of a hemisphere, we inscribe a square within the containing circle, and cut the solid by planes perpendicular to the base, through each of the four sides of the square, the four sections will represent the four portions of each wall, and the arcs will represent the springing lines for the spherical surfaces.

159. On *pl.* XXXIV, *fig.* 1, No. 1 is the plan of a room, with the ribs which form the pendentive ceiling; the semi-circles on the sides are supposed to turn up perpendicular to the plan $bnmo$, which will form the terminations of the four walls; No. 2 is the elevation.

Numbers 3, 4, 5, 6, and 7, exhibit the ribs for one-eighth part of the whole; and, as these ribs are all in planes passing through the axis, they are all great circles of a sphere, of which the diagonal of the square is a diameter; therefore, though the ribs are shorter in the middle of each side, and increased towards the angles, they are all described with the same radius, which is half the diagonal of that square. The whole of the scheme may be formed in paste-board. Thus, in *figure* 2, let ABCD be the plan; on each of the sides, AB, BC, CD, DA, describe a semi-circle; then let each semi-circle be turned round its respective diameter until its plane becomes perpendicular to the plane ABCD; then the sides, thus turned up, will represent the

PENDENTIVE BRACKETING.



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PENDENTIVES.

Fig. 1.

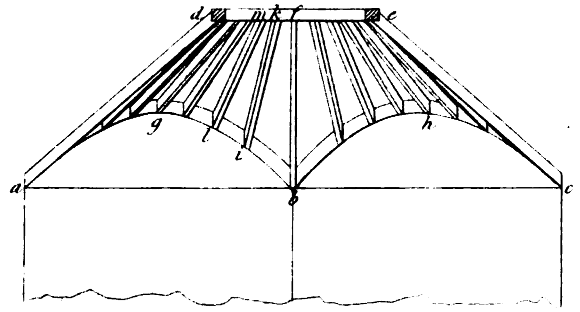


Fig. 2.

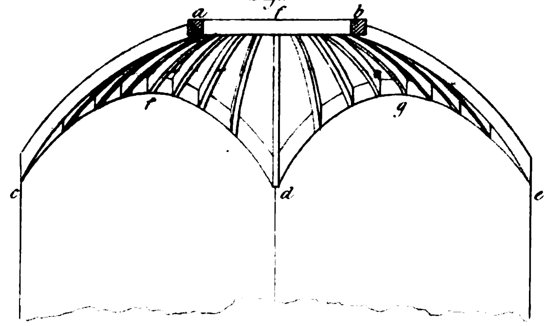


Fig. 1. No. 1.

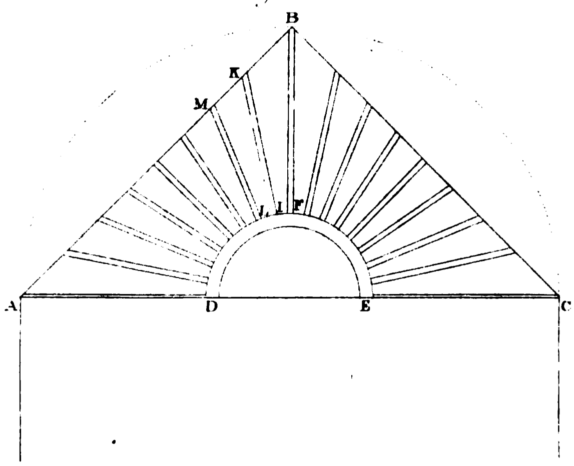


Fig. 2. No. 1.

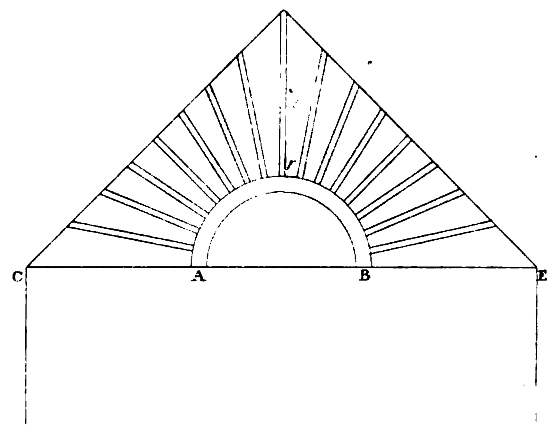


Fig. 4.

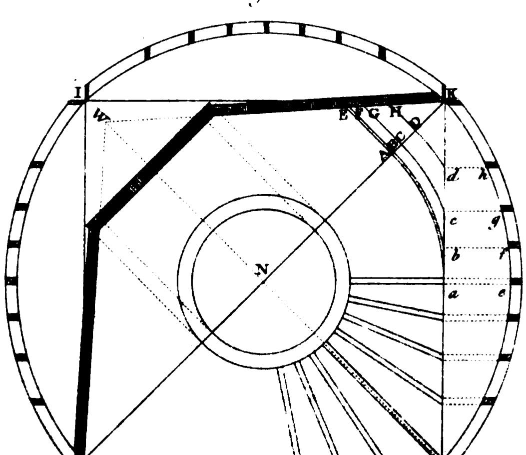
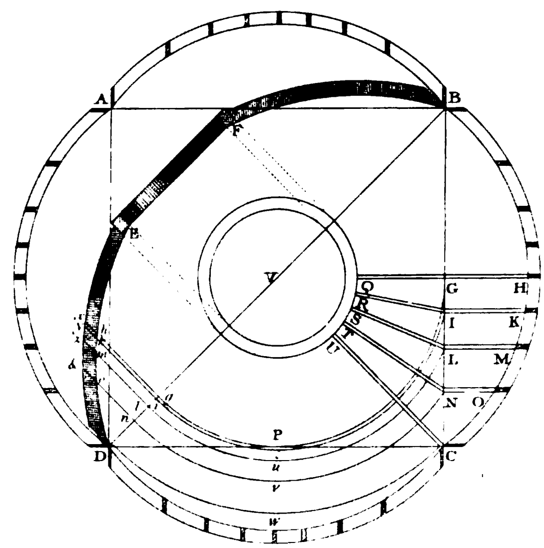


Fig. 3.



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sections of the sphere, and ABCD the base of the solid; when the surface extending between the semi-circular arcs is entirely spherical.

In *figure* 3, the pendentives are supposed to be placed on a conic surface, and the sides of the square not perpendicular, but equally inclined on every side, approaching nearer together as they ascend.

Thus, let ABCD be the plan, and the circumscribing circle the base of the cone, and EGF a section of the cone through its axis. Then, if the inclination of each of these four planes be the angle EHI, making HI parallel to FG, then the conic section is a parabola, and may be drawn as shown at *fig.* 3, No. 2, and as described in Art. 15 of this Work.

Figure 4, (*pl.* XXXIV,) shows the method of describing the springing lines, when the sides are perpendicular to the plane ABCD. From the centre of the square, and through the angular points, describe the circle ABCD, and draw the diameter EF, parallel to any one of the sides, cutting AD and BC in *c* and H. In E*c* take any number of points, *a*, *b*, &c., and draw *ad*, *be*, *cf*, perpendicular to EF, cutting the side EG, of the section of the cone, in the points *d*, *e*, *f*, &c. From the centre of the plan describe the arcs *ci*, *bh*, *ag*, cutting the side DC in *g* and *h*, and the arc *ci* touching it in *i*. Perpendicular to DC draw *im*, *hl*, *gk*, and make *im*, *hl*, *gk*, respectively equal to *cf*, *be*, *ad*. Then, upon the given base, DC, describe the symmetrical figure, D*mc*, which will form the springing line, in order to set the ribs upon the wall.

As this figure is an hyperbola, it may be described independently of tracing it from the plan, thus: In *fig.* 4, No. 1, draw HK perpendicular to EF, cutting the side GF of the cone in I, and meeting the other side EG, produced in K, and IK will be the axis, IH the abscissa, and HC or HB the ordinate: then describe an hyperbola, *fig.* 4, No. 2, which has its axis, abscissa, and ordinate, respectively equal to IK, IH, HB, or HC. See Art. 17.

Figure 1, (*pl.* XXXV,) is the elevation of the angle of a room with conical pendentives. In order to form the conic surface, the figure of an hyperbola must be described upon each side of the room. The figure in the plate exhibits two sides of the room. In this diagram *aglib* represents the springing line on one side of the room, and *bhc* that on the other side; the former corresponding to the straight line AB on the plan, No. 1, and the latter to the straight line BC on that plan.

Figure 2 is a section and angular elevation of the angle of a room with spherical pendentives; the plan being exhibited by No. 1.

160. *Figure* 3 shows the method of drawing the springing-lines on the walls; the plan and the rib over the diagonal of the plan being given to the elevation, *fig.* 2. Here the plan is the square ABCD, and the rib over the diagonal of the square is DEFB.

From the centre V, with a radius equal to half the side of the square, describe the arc *g*PG, which will touch the two sides DC, CB, of the square, at P and G, which are each in the middle of these sides; and let the arc, thus described, cut the line BD at *g*. Draw *gx*, perpendicular to DB, cutting the curve DE at *h*.

Let QG, RI, SL, TN, UC, be the seats of the ribs for one-eighth part of the whole; and since these are similar to those in every other eighth part, their formation will be sufficient for the whole of the ribs; since there will be four ribs, for every one of those in the eighth part, exactly alike, so that each rib becomes a mould for three more. The plans QG, RI, SL, TN, UC, divide any arc described from the centre, V, into four equal parts, and terminate upon the side BC of the square, in the points G, I, L, N; and from each of these points and the centre V, describe an arc to cut BD in *g*, *i*, *l*, *n*. Draw GH, IK, LM, NO, perpendicular to BC; also draw *iv*, *lz*, *nk*, perpendicular to DB, cutting the under edge DE of the rib over the diagonal in the points *k m, o.* Make GH, IK, LM, NO, each respectively equal to *g h, i k, lm, no*; then the curve HKMOC being drawn, will be half the springing-line over BC; the other half, being made similar, will be the whole of the springing line. This springing-line will serve as a mould for drawing the springing-lines upon each of the four walls. As all the ribs are portions of a circle of the same radius, that is, they will have the same curvature as the edge DE of the rib which stands upon the diagonal; the portion of each rib will be D*h*, D*k*, D*m*, D*o*, cut by the lines *h x, k y, m z, o k.*

161. *Figure* 4 shows the springing-lines for each wall, agreeably to the plan and elevation, *fig.* 1. The method is exactly the same as that described for *fig.* 3; and thus any further description will not be necessary.

CENTRINGS FOR ARCHES AND BRIDGES.

162. In Carpentry, a centre is a combination of timber-beams, so disposed as to form a frame, the convex side of which, when boarded over, corresponds to the intended concavity of an arch.

Having carried the piers or abutments to the height designed for the arch to spring from, the next object is to set up the centre, the proper construction and erection of which may well be considered as the most masterly operation in the building of arches.

In constructing the centre for an arch, the principal object to be kept in view is, to fix the beams in such a manner as to support (without change of shape) the weight of the stones and other materials that are to come upon them, throughout the whole progress of the work, from the springing of the arch to the fixing of the key-stone. This object has not always been sufficiently attended to by the architects, neither of this nor other countries; for, in many instances, it has been known that the centres of bridges, from the injudicious principles of their construction, have changed their shape considerably, or entirely failed before the arch was complete; and, in consequence of change of shape only, the arches built upon them have varied, both in form and strength, from the intention of the engineer. In the large works of this kind erected in Britain, however, no great inconvenience has ever been known to arise from change of shape; our best engineers having constructed their centres on principles calculated to support every weight, and resist every strain to which they might be exposed, and hence have arisen the most perfect models of masonic art that ever marked the progress of human industry.

Description of Centres.

163. In *plate* XXXVI, the upper figure is a truss of the centre for the middle arch of Blackfriars' Bridge; it is supported entirely by pieces strutting from the footings and pier. The span of the arch is 100 feet, and its rise 40 feet. The middle portion is described by a radius of 56 feet, and the springing curves with a radius of 35 feet.

The striking wedges, DD, were so placed that the corresponding faces of these wedges and the plates touched about half their length, and a loose block of wood was inserted at the back of each wedge to prevent it sliding back during the construction of the arch. The ends of the wedges, D, D, were bound by iron hoops, and a heavy beam of oak was suspended from two points of the centre to act as a battering-ram, in impelling back the wedges when the centre was to be lowered. The whole operation of freeing the centre from the arch was performed in a

References

AAAA *Timbers which support the centring.*

BB.CC. *Upper and Lower Striking Plates cased with copper.*

DD. *Wedges between the Striking Plates for lowering the centre.*

EEEE *Double trussing pieces to confine the Braces.*

FFFF *Apron pieces to strengthen the rib of the centre.*

GGGG *Bridgings laid on the back of the ribs.*

HHHH *Blocks between Bridgings to keep them at equal distances.*

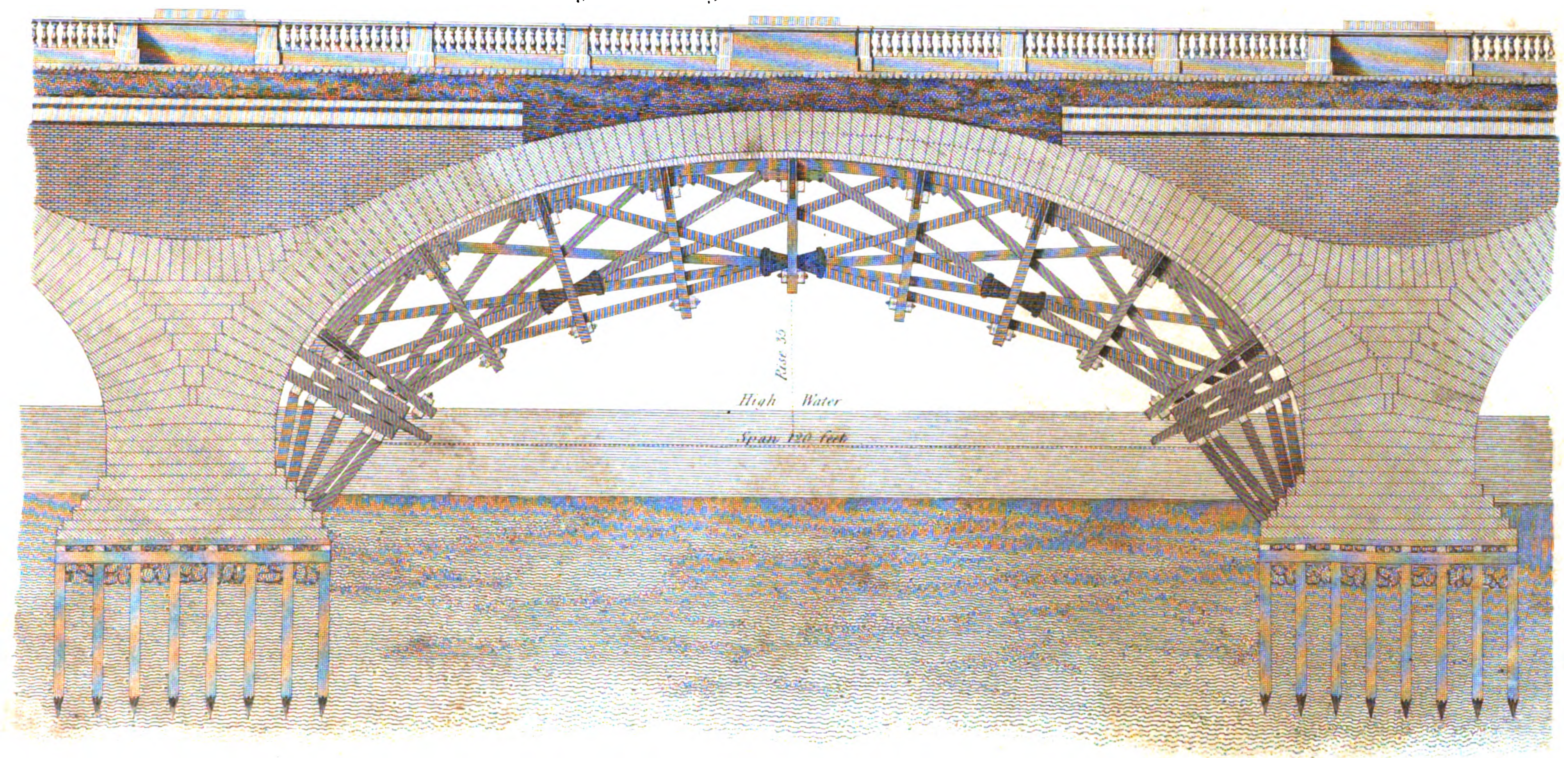
IIII *Small braces to confine the ribs tight.*

KKKK *Iron straps bolted to trussing pieces and apron pieces.*

LLLL *Ends of beam at the feet of the truss pieces.*

MMMM *Principal braces.*

SECTION *of an* ARCH *of* WATERLOO BRIDGE *with the* CENTRE.



few minutes. Other references will be found on the plate. Mr. Robert Mylne was the architect, and the foundation-stone of the bridge was laid in 1760.

164. The lower figure in *plate XXXVI,* is a section through the piers and one of the arches of Waterloo Bridge, London, built under the direction of Mr. John Rennie, Civil Engineer. In this section the piling for the piers, the construction of the arches, and the centring for turning the arches upon, are shown. The spandrils over the piers were formed by parallel brick-walls, with blocks of stone, from wall to wall, for supporting the road-way. The dotted line on the arch, near the middle of the depth of the arch-stones, shows the direction of the pressure in the arch when the whole load is upon it. This line is called the *curve of equilibrium,* and, when it passes every where at the middle of the depth of the arch-stones, the arch is of the best possible form. It will be seen that it is nearly in the middle in this case. It was formerly considered, that the soffit of the arch should be made of the same form as the curve of equilibrium, but the error was corrected by Dr. Young in his valuable treatise on Bridges, in Napier's Supplement to the Encyclopædia Britannica.

The centring was composed of eight frames or trusses, and was abundantly strong for the purpose. The disposition of the timbers will be seen by the elevation, in *plate XXXVI,* but a more perfect idea of the nature of the work will be obtained by a reference to the frontispiece.

Description of Plate XXXVII, (the Frontispiece.)

165. The principal object is the Centring of one of the Arches of the Waterloo Bridge, with part of the arch-stones set, and the work in progress. The framing, seen under the centring, is that of a temporary bridge for the use of the workmen. To the left, the coffer-dam, pile-engines, and machinery used in forming the next pier, are shown. The view of the work was taken at that period of its progress by Mr. Blore, an artist equally distinguished for his taste and fidelity of representation. This magnificent edifice has now been completed several years, and its simplicity of design, skilful arrangement, and solidity of execution, will render the Bridge of Waterloo a monument, of which the metropolis of the British Empire will have abundant reason to be proud, for a long series of successive ages.

OF GROINED ARCHES.

165. Groins are formed by the intersections of the surfaces of two or more vaults, or continued arches, crossing each other.

Groined Arches may be either constructed of brick or stone, and they are sometimes formed of wood, and lathed over for plaster.

When they are constructed of brick or stone, the arch-stones or bricks require to be supported upon wooden frames, boarded over, so as to form a convex surface, to fit that surface the groined vault is required to have, in order to sustain the whole during the time of building. This construction is called a centre, and it is removed when the work is finished. The framing of the centre consists of equidistant ribs, fixed in parallel planes, perpendicular to the axis of each vault; so that, when the under sides of the boards are laid on the upper edges of the ribs, and fixed, the upper sides of the boards will form the surface required to build upon.

In the construction of the centring for groins, one portion of the centre must be completely formed to the surface of the principal vault, without any regard to the cross-arches, so that the upper sides of the boards may form a complete cylindrical or other surface. The ribs of the cross-vaults are then set at the same equal distances as that now described; and parts of ribs are fixed on the top of the boarding of the principal vault at the same distances, and boarded in, so as to intersect it, and form the entire surface of the groin required.

Groins constructed of wood, in place of brick or stone, and lathed under the ribs, and the lath covered with plaster, are called *plaster-groins.*

166. PLASTER-GROINS are always constructed with diagonal ribs intersecting each other; then other ribs are fixed perpendicular to each axis, in vertical planes, at equal distances, with short portions of ribs upon the diagonal ribs; so that, when lathed over, the laths may be equally stiff to sustain the plaster.

167. When the axis and the surface of a semi-cylinder cuts those of another of greater diameter, the hollow surface of the lesser cylinder, as terminated by the greater cylinder, is called *a Welsh groin.*

WELSH GROINS are constructed either of brick, stone, or wood. If constructed of brick or stone, they require to have centres, which are formed in the same manner as those for other groins; and, if constructed of wood, lath, and plaster, the ribs must be formed to the surfaces.

In the construction of groins and vaults, the ribs that are shorter than the whole width are termed *jack-ribs*

168. Cellars are frequently groined with brick or stone, and sometimes all the rooms of the basement-story of a building, in order to render the superstructure proof against fire. The surface of brick or stone, on which the lowest course of arch-stones, or of bricks, is placed, is called the *springing of the arch* or *vault.* It is evident that the more weight there is put on the side-walls which sustain arches, the more they will be able to sustain the pressure of the arches; therefore the higher a wall is, the greater the weight should be on each of the side-walls: and for this reason, in upper stories, where the walls are high, and not much weight over them, groins are often constructed of wood, instead of brick or stone, as not being liable to thrust out the walls, or bulge them, by the lateral pressure of the arches. The upper stories of buildings are therefore never groined with stone or brick, unless when the walls are sufficiently thick to sustain the lateral pressure of the arches. The ceilings of old Gothic cathedrals were generally constructed with groined arches of stone, which were obliged to be supported by strong buttresses, at the springing points in the arches; and, in a few instances, the same method has been adopted recently.

Geometrical Lines for Groined Arches.

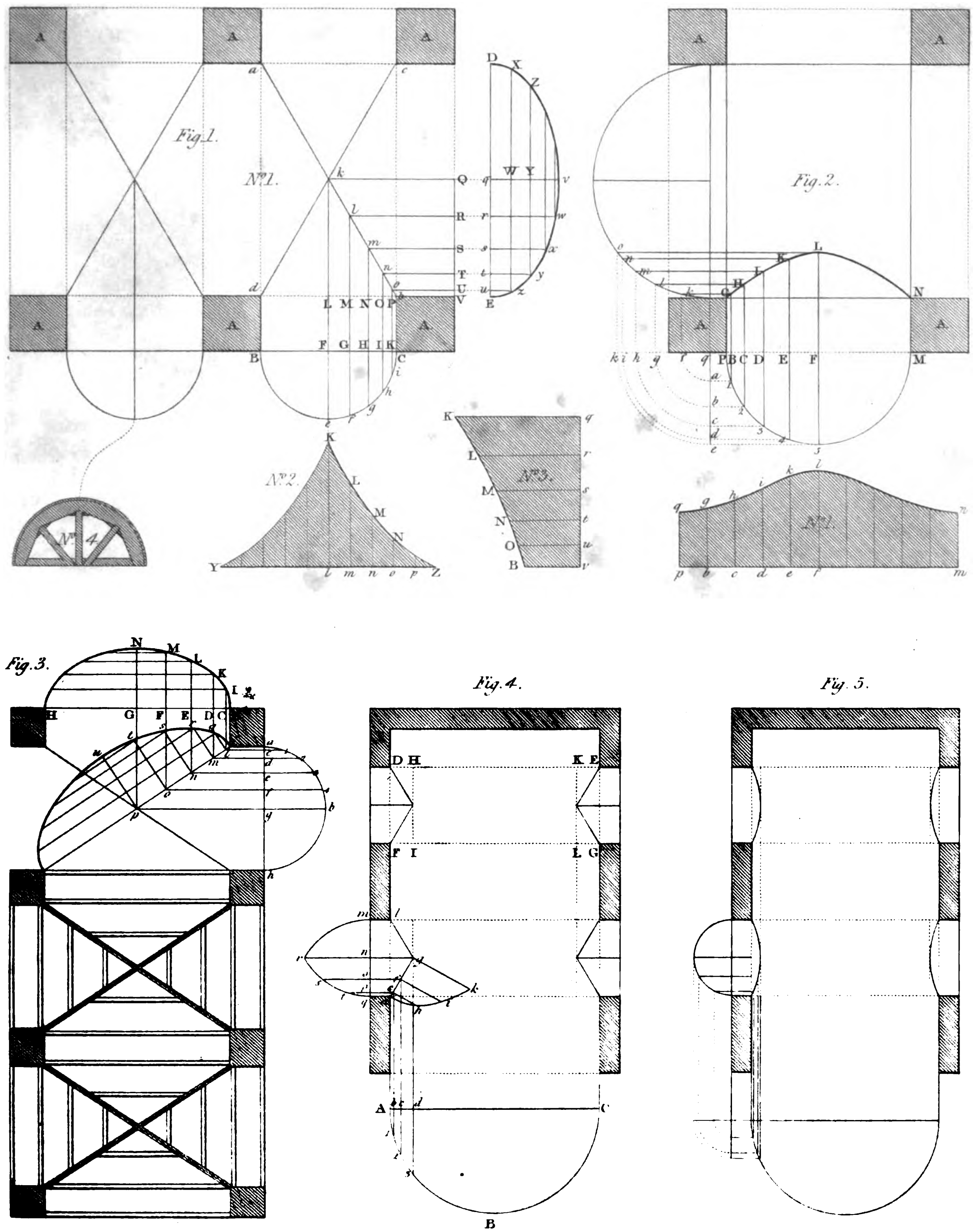
169. Given the plan of a rectangular groined arch or vault, of which the openings are of different widths, but of the same height, and a section of one of the arches, as also the plan lines of the groins, to find the covering of both arches, so as to meet their intersection.

In *fig.* 1, *pl. XXXVIII,* let A, A, A, &c., be the plan of the piers, and *ab, cd,* the plan lines of the intersection of the groin.*

Let the section of the arch, standing upon the lesser opening, BC, be a semi-circle: it is required to find the section upon the greater opening and the ends of the boards, so that the surfaces of the groin may meet in the given line of intersection.

* The difference between the *plan* of any body and the *plan line* is distinguished thus: The *plan* is a figure upon which a solid is carried up, so that all sections, parallel to the plan, are equal and similar to that plan, and the surfaces are perpendicular; but the *plan line* is not in contact with the intersection itself; but a perpendicular erected from any point in the plan line will pass through its corresponding point of the intersection.

GROINS AND ARCHES.



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On the diameter BC describe a semi-circle, and divide the quadrant into any number of equal parts, *ef, fg, gh*, &c.; and from the points, *e, f, g*, &c., draw lines, parallel to the axis, F*k*, to meet the plan line *ab* of the groin, or line of intersection of the two surfaces. From the points *k, l, m*, &c. of intersection, draw the lines *k*Q, *l*R, *m*S, &c., parallel to the axis of the other vault, to meet the line VQ, perpendicular to that other axis in the points Q, R, S, &c. Then, upon any line, DE, transfer the points Q, R, S, &c. to *q, r, s*, &c., and draw *qv, rw, sx*, &c. perpendicular to DE, and transfer the ordinates F*e*, G*f*, H*g*, &c. of the semi-circle, to *qv, rw, sx*, &c., and through the points *v, w, x*, &c. draw a curve; then *qv*E will be half of the section required.

To find the covering of the semi-cylinder. Upon any straight line, YZ, No. 2, set off the distances *lm, mn, no*, &c., each equal to the chord *ef* or *fg*, &c., in No. 1; and draw *l*K, *m*L, *n*M, &c., in No. 2, perpendicular to YZ. Make *l*K, *m*L, *n*M, &c., No. 2, equal to L*k*, M*l*, N*m*, &c., of No. 1, and through the points K, L, M, &c., No. 2, draw a curve. Then will the figure K*l*Z be half of the covering of the cylinder.

To construct the covering, No. 3, for the great opening.

In the straight line *vq*, No. 3, make *vu, ut, ts*, &c., equal to the parts, E*z, zy, yx*, &c., of the elliptic curve, No. 1. In No. 3, draw *v*B, *u*O, *t*N, *s*M, &c., and make *v*B, *u*O, *t*N, *s*M, &c., No. 3, equal V*b*, U*o*, T*n*, S*m*, &c., No. 1; and in No. 3, draw a curve through the points B, O, N, M, &c.; then *qv*BK*q* will be the covering required.

The mode of constructing the ribs for the centre is shown by No. 4.

170. To find the line of intersection of a Welsh Groin. *Plate XXXVIII, fig.* 2.

Let A, A, A, A, be the plans of four piers, which form the openings of different widths. On the lesser opening, PM, as a diameter, describe a semi-circle. Divide the quadrant next to P into any number of equal parts, and through the points of section, draw the lines 1G, 2H, 3I, &c., perpendicular to PM, cutting PM in B, C, D, &c., and through the same points 1, 2, 3, &c., draw the lines 1*a*, 2*b*, 3*c*, &c., parallel to PM, cutting a line *qe* perpendicular to PM in the points *a, b, c*; produce the line which contains the points *a, b, c*, through the greater opening; and upon the part of the line thus produced, which is intercepted between the piers, A, A, describe a semi-circle. Produce the line MP to *k*; and, from *q* describe arcs *af, bg, ch*, &c., cutting B*k* in the points *f, g, h*, &c. Draw *fk, gl, hm*, &c. parallel to the base of the greater semi-circle, to cut the arc of the same in the points, *k, l, m*, &c. From the points *k, l, m*, &c., draw the lines *k*G, *l*H, *m*I, &c. parallel to PM; then, through the points G, H, I, K, L, draw a curve GHIKL, which will be the plan of the intersection of the groin.

The covering to coincide with the groin is shown at No. 1. Draw *pm*, No. 1, and make *pb, bc, cd*, &c., each equal to P1, 1 2, 2 3, &c., in the semi-circular arc. In No. 1, draw *pq, bg, ch*, &c., respectively equal to BG, CH, DI, &c., and through the points *q, g, h, i*, &c., draw a curve; then will *pqnm* be the covering required.

Plaster Groins.

171. To find the diagonal rib of a groined Vault, of which the lesser openings are semi-circles, and the groins, in vertical planes, passing through the diagonals of the piers.

On *ah*, *fig.* 3, (*pl. XXXVIII,*) the perpendicular distance between two adjacent piers of the lesser opening, describe a semi-circle, *abh*; and, in the arc, take 1, 2, 3, &c., any number of points, and draw the lines 1*l*, 2*m*, 3*n*, &c., cutting the diagonal *ik*, in *l, m, n*, &c. Draw *lq, mr, ns*, &c., perpendicular to *ik*, and through the points *i, q, r, s*, &c. draw a curve; then *iuk* will be the edge of the rib to be placed in the groin.

The edge of the rib, for the other opening, will be found thus: From the points *l, m, n,* &c., draw the lines, *l*I, *m*K, *n*L, &c., parallel to the axis of the opening of the larger vault, cutting HB at the points C, D, E, &c. Make CI, DK, EL, &c., each equal to *c*1, *d*2, *e*3, &c.; then, through the points B, I, K, L, &c., draw a curve; and the line thus drawn will be in the surface of the greater opening, so that BNH will be one of the ribs of the body-range of vaulting.

The method of placing the ribs is exhibited at the lower part of the diagram, *fig.* 3, the ribs of each opening being placed perpendicular to the axis of each groin.

172. To find the groined and side ribs of a LUNETTE, where the groined ribs are in vertical planes upon the straight lines *ag, gl,* (*fig.* 4, *pl. XXXVIII,*) the principal arch being a semi-circle.

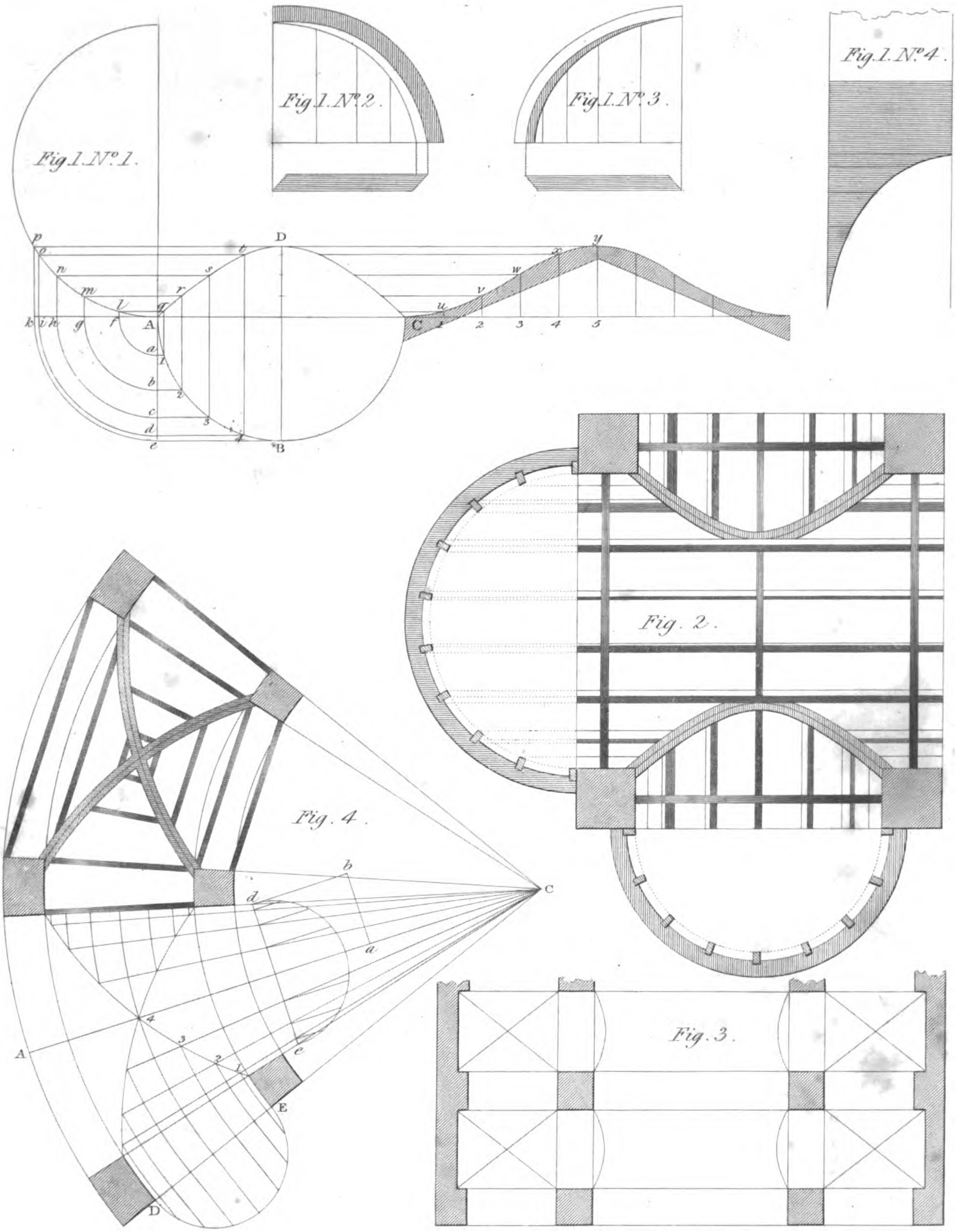
Let AC be the base of one of the principal arches, perpendicular to one of the sides of the main vault, the points A and C being in the same range with those sides. Let *mq* be the opening of one of the lunette windows. From the point *g*, the meeting of the plan lines of each groin, draw *gr* perpendicular to *mq*, cutting *mq* at *n*; draw *g*3 parallel to *mq*, cutting the semicircular arc ABC at 3. Between A and 3 take any number of intermediate points, 1, 2, &c., and, through the points 1, 2, &c., thus assumed, draw 1*e*, 2*f*, &c., cutting the line *ag*, of the first groin, in the points *e*, *f*, &c., and AC in *b, c, d,* &c. Perpendicular to *ag* draw *eh, fi,* &c., and make *eh, fi, gk,* each equal to its corresponding line *b*1, *c*2, *d*3, &c.; then, through the points *g, h, i, k,* draw a curve, which will form the groin belonging to the plan line *ag*. From the points *e, f,* &c., draw lines *et, fs,* &c., cutting *qm* in the points *p, o,* &c.; and make *pt, os, nr,* respectively equal to *b*1, *c*2, *d*3; then, through the points *q, t, s, r,* draw the curve *qtsr*, which will be one of the ribs of the lunette.

173. Given one of the ribs of a LUNETTE, and a rib of the main arch, to determine the plan-line of the intersection of the two surfaces of the groin. (*Plate XXXVIII, fig.* 5.)

This is, in fact, the same as a Welsh Groin; we shall therefore refer the reader to Art. 170, for its geometrical construction.

LUNETTES are used in churches, large rooms, or halls, and are made either in waggon-headed ceilings, or through large coves, surrounding a plane ceiling: they have a very elegant effect when they are numerous, and disposed at equal distances. Though it is not necessary to have the axes of the lunettes and the axes of the quadrantal cylindric surfaces in the same plane, they have the best effect when executed so; as the groin, formed by the meeting of the two surfaces, has, in this case, less projection: and, though the groins are curves of double curvature, their projections on the plan are perfect hyperbolas, and may be described independent of the rules of projection, the summit or vertex of the curve being once ascertained: by these means we shall have its abscissa and double ordinate; the transverse axis being the distance between the opposite curves.

174. In church-building, it frequently happens that the windows are either carried entirely across the gallery-floors, or their heads considerably above the ceilings of those floors; in either case, the light is so much intercepted, that it is necessary to hollow out the ceiling, in order to obtain a sufficient quantity of light. This may be done in a very elegant manner, when the head of the window is circular. For, if we conceive an oblique cylinder to form the head of the window, in the segment of the circle, the segment being the base of the cylinder to be inserted, and the cylinder displacing a portion of the ceiling, that portion of the ceiling must be a cylindric surface, and the shape of the hollow required to be formed. Now, it is evident that, if ribs be formed to curves of the same circle as the head of the window, and set in vertical planes, or parallel to the surface of the window, and properly ranged, they will form the cylindric surface required.



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E. Turrell sc.

In *plate XXVI, fig.* 3 represents the section through the centre of the window, in which *a h* is the ceiling line, and *a b* the height of the segment of the window-head, which extends above the ceiling. *Fig.* 4 is the elevation of part of the window-head, in which AD corresponds with the ceiling line. *Fig.* 5 is the plan of the curve formed by the intersection of the cylindric surface and the plane of the ceiling.

Let it be determined that the opening is to extend to *h*, on the ceiling; then, draw *b h*; and, on the line *a h*, set off the distances of the ribs, as at 1, 2, 3, 4, &c.; then draw 1*l*, 2*m*, 3*n*, &c. parallel to *h b*, cutting *a b* in *l, m, n*, &c. Transfer the divisions thus found on the line *a b* to the line DB, *fig.* 4, and from each point draw a line parallel to AD, which will determine the points 1, 2, 3, &c. in the arc AB. Draw HG in the plan parallel to *h a* in the section, and from each of the points 1, 2, 3, &c. in *a h*, draw a line parallel to *b* G; then, from each of the points 1, 2, 3, &c. in the arc AB, let fall a perpendicular to G *b*, and from the points thus found draw lines parallel to GH, which will meet the corresponding lines from the section in the points 1, 2, 3, 4, 5, 6, H in the plan, and the curve drawn through these points is the form of the curb.

The ceiling is, in the figure, supposed to be level, but it may be inclined at any angle, and yet the construction, as described, will give the true form of the curb, if, from the point G, the line GH be drawn parallel to *a h*, the line of the ceiling. The ribs, in both cases, will be portions of circles described by the same radius as the head of the window.

175. To find the angle ribs for a Welsh Groin, and the moulds for the boarding. *Plate XXXIX, fig.* 1.

A *Welsh Groin* is the intersection of one semi-cylinder, of a less diameter, with another of a greater diameter. The principal objects to be found are, the line of the angle rib on the plan, and the moulds for terminating the ends of the boards.

For this purpose, on any straight line, which has A at one of its ends, as a diameter, describe a semi-circle, as at No. 1, in the figure, terminating in A, for the section of the greater vault, or semi-cylindrical arch. As the axis of the one cylinder is supposed to cut the axis of the other at right angles, the sides of the cross-vaults will also be at right angles to each other: therefore draw the diameter AC, of the lesser vault, perpendicular to the diameter of the greater vault; and on AC, as a diameter, describe the semi-circle ABC: divide the quadrantal arc AB into any number of equal parts, as here into five. Draw A*e* perpendicular to AC, and produce CA to *k*. Through the points of division, in the quadrantal arc AB, draw 1*a*, 2*b*, 3*c*, 4*d*, B*e*, parallel to AC, cutting A*e*, in *a, b, c, d, e*. Again, through the same points 1, 2, 3, 4, B, in the quadrantal arc AB, draw straight lines 1*q*, 2*r*, 3*s*, 4*t*, BD, perpendicular to AC. From the point A, as a centre, with the several distances A*a*, A*b*, A*c*, A*d*, A*e*, describe the arcs *ek*, *di*, *ch*, *bg*, *af*, cutting A*k* in *f, g, h, i, k*.

Parallel to the diameter of the greater semi-circle, or parallel to A*e*, (*fig.* 1, No. 1,) draw *fl*, *gm*, *hn*, *io*, *kp*, cutting the greater semi-circular arc in the points *l, m, n, o, p*. Through the points *l, m, n, o, p*, draw *lq*, *mr*, *ns*, *ot*, *p*D, parallel to AC, cutting the perpendiculars 1*q*, 2*r*, 3*s*, 4*t*, BD, in the points *q, r, s, t*, D. Through the points A, *q, r, s, t*, D, trace a curve by hand, or put in nails at the points A, *q, r, s, t*, D, and bend a thin slip of wood so as to come in contact with all the nails; then, by the edge of this slip, which touches the nails, draw a line with a pencil, or find points; and the curve thus drawn will be half the plan line of the angle rib. The other half, being exactly the reverse, may be found by placing the distances of the ordinates at the same distance from the centre, upon the diameter AC, and setting up the perpendiculars by making them respectively equal to the others.

It will perhaps be eligible to make the whole curve ADC at once.

The mould for cutting the ends of the boards, which are to cover the ribs of the centres of the lesser openings, will be found as follows:

On any straight line, C5, as on the diameter AC produced, set off the equal parts A1, 1 2; 2 3, 3 4, 4B, of the quadrant AB, on the straight line C5, from C to 1, from 1 to 2, from 2 to 3, from 3 to 4, from 4 to 5, and draw the straight lines 1*u*, 2*v*, 3*w*, 4*x*, 5*y*, perpendicular to C5. Make 1*u*, 2*v*, 3*w*, 4*x*, 5*y*, each respectively equal to each of the ordinates comprehended between the base AC, and the plan line of the rib AD; then, through all the points C, *u*, *v*, *w*, *x*, *y*, draw a curve C*uvwxy*, as before; then the shadowed part, of which the curve line C*uvwxy* is the edge, is the *mould* for one side, which may also be made use of for the other.

To apply this mould, all the boards should be laid together, edge to edge on a flat or plane surface, to the breadth C5. Draw a straight line C5, perpendicular to the edge of the first board, at the distance of 5*y* from the end. At the distance C5 draw a perpendicular 5*y*, and set off the distance 5*y*. Then apply the proper edge of the mould from C to *y*, as exhibited in the plate, and draw a curve across the boards, and cut their ends off by the line thus drawn; then the ends, thus formed of the remaining parts, will fit upon the boarding of the greater vault, after being properly bevelled, so as to fit upon the surface of the said boarding.

No. 4, of *fig*. 1, exhibits the curve, in order to draw or discover the line on the boarding of the greater vault, in order to place the boarding of the lesser vault.

Nos. 2 and 3, *fig*. 1, show the method of forming the inner edges of the angle ribs, so as to range with the small opening in plaster groins. The under edge of the rib must be formed so as to correspond to the curve which is the plan line of its angle; and the little distances, between the straight line and the curve, must be set off on the short lines, shown at Nos. 1, 2, and 3; then a curve may be drawn through the points of extension, and the superfluous wood taken away; then, the rib being put in its real place, the angle will exactly fall over its plan. The diagram, *figure* 1, and its different numbers, answer both the purposes of centring for brick or stone, and of ribbing for plaster-ceilings.

Figure 2, *pl. XXXIX*, exhibits the method of forming the *Cradleing*, or ribs, for plaster-ceilings of Welsh groins. Here principal ribs are used only across at the piers. The ribs of double curvature, which form the groins, though here exhibited, in order to fix the ribs, are not always used by men of experience: but young workmen require every assistance, in order to acquire a comprehensive idea of the subject; it is, therefore, proper to show how the groined ribs may be found. The other ribs, for lathing upon, are made of straight pieces of quartering, fixed equi-distantly

Figure 3, *pl. XXXIX*, is a plan in which common groins and Welsh groins both occur. In London, an example may be seen in the gate-way leading from the Strand, into the court of Somerset-house.

176. To find the seats of the intersections of groins formed by the intersection of an annular and a radial vault, both being at the same height, the section of the annular vault being a semi-circle, and that of the radiating vault a semi-circle of the same dimensions, the plan being given. *Fig*. 4, *pl. XXXIX*.

Perpendicular to the middle line, or axis, AC, of the radial vault, draw a straight line, *ab*, from any point of that middle line; from the point thus drawn, set off *ab* equal to the radius of the circle of the annular vault; from the point *b* draw a line, parallel to the axis, AC, of the radiating vault, to meet the side of the plan as at *d*. From the point of meeting draw a straight line *de*, perpendicular to the axis, to meet the other side of the plan of that radiating vault: on the perpendicular thus drawn, between the two sides, as a diameter, describe a semi-circle: divide each quadrantal arc of this semi-circle, and each quadrantal arc of the semi-circle DE, which is the section of the annular vault, into the same number of equal parts. Draw lines througn the points of division in each arc, perpendicular to its base or diameter, to meet the said diameter. Through the points of section in the diameter of the annular vault, and from the centre, C, of the radiating vault, describe arcs. From the same centre C, and through the points of section of the diameter *cd* of the semi-circle, which is equal to the section of the radiating vault, draw lines to meet the arcs. Then, through the intersection of these lines, and the arcs drawn from the points of section in the diameter of the semi-circle, which is the section of the annular vault, trace curves, which will be the plan lines of the groin. The method of fixing the timber is exhibited at the other end of the figure. The ribs of both the annular vault and the radiating vault are all fixed in right sections of these vaults, as must appear evident from what has been shown.

OF THE CONSTRUCTION OF WOODEN BRIDGES.

177. Bridges of that sort adapted for gardens and pleasure-grounds are often of wood; they are cheaper, lighter, and make a great shew for little labour; but even in the great and serviceable kind of bridges this material is far from being excluded.

The first point to be considered, in the construction of a bridge, is that the timber be sound and well-seasoned: the next, that it be in sufficiently large pieces; as the timbers must be substantial and well-joined, or all will presently be in ruin.

It is not only the pressure above that must be guarded against in these bridges, but also the power of the water in an encreased quantity and forced rapidity. Fifty wooden bridges are destroyed by floods for one that fails beneath the weight above: the broader the river the larger will be the bridge; and in proportion to this the timber must be more massive; and the rapidity of the river, not only in its common state, but as increased by floods, must be computed, and the strength of the fixing proportioned accordingly.

178. There are many reasons for building a bridge of a single arch, and where the extent of the river is any thing considerable, no piece of wood-work will require more skill in the fabricator, nor will any do him more honour.

We have, in the preceding part of this work, *Art.* 57 to 83, and in treating of the framing of roofs, *Art.* 102 to 104, and other timber-work, shown the best modes of joining piece to piece; and it may be shewn that there is scarcely any length to which timbers may not be carried by this admirable art.

The advantages of a single arch are very great, because the common accidents which throw down bridges will have no power over one of this kind. And for one fabric which fails by any natural decay, thousands are torn or thrown down by torrents from land-floods, or by loads of ice or floating timbers, which the swelling of the water has brought from their places; and its force throws with an irresistible violence against the piers.

There are many places where a bridge is an annual charge, and whenever the extent is not beyond all reasonable proportion for a single arch, that should be the method of avoiding the accidents; and, if ten times the price were paid, it would be frugality; but, indeed, skill is required more than price in such a fabric. No bridge is more beautiful than one of a single arch; none more convenient; and besides the numerous accidents which are avoided, and from which security there results a promise of great duration, none is stronger; for a single arch, when well formed, composes a body more firm than if cut in a vast thickness from a single piece, the parts and the directions of the grain being combined in the framing so as to strengthen and support one another.

Palladio has given a figure of a Bridge of one arch which he laid across the Cismone, where the breadth of the river was a hundred Vicentine feet;* its strength appears incontestible from the structure, and experience showed it to be what it seemed; but there is yet another great advantage in this bridge, which is, that it lies level with the rest of the road, and does not tire the traveller with an ascent and descent.

179. In *plate XL, fig.* 1 is the elevation of a wooden bridge, similar to one of Palladio's designs, supported on the principle of an arch, and may be used with advantage where the ground rises on one side more than on the other. In order that this bridge may be sufficiently strong, and the road or path-way easily surmounted by passengers and carriages, the curvature of the lower or supporting arch is much greater than that above, which forms the road or path-way.

Figure 2 is a design for a wooden bridge, supported by brackets, projecting more and more as they rise. This design, as well as the following one, is adapted to a straight road or foot-way.

Figure 3 is a design of a bridge, with piers and any number of arches, in which the intrados of each arch is the arc of a circle. It is supported by wooden beams over the posts, acting as brackets; and, to prevent the ends of the supporting brackets from having a sharp edge, small keys are let in from the underside.

In order that this bridge may be sufficiently strong, when the space between the posts or piers is considerable, a truss is placed in the middle, so as to form part of the railing, which increases the strength, so that the span may be extended to two, or even three, times the length that it could be without it.

180. THE TIMBER FOOT-BRIDGE, over the Clyde, at Glasgow, is represented in *plate XLI.* This very neat and elegant structure was designed and superintended by Mr. Peter Nicholson, in the year 1808.

Figure 1 exhibits the elevation of the bridge. The form of the road-way is a flat curve, said to be the arc of a parabola. The land abutments are strong masses of masonry, to which the timbers of the floor, or foot-way, are well secured by cramps of iron bolted to the stone-work.

This bridge was constructed with the view of admitting a certain class of vessels to pass under it. Therefore, to keep the opening between the posts clear, the foot-way is suspended by trusses, formed in the railing. The breadth of the foot-way is about ten feet.

Figure 2 is a plan of the beams, which support the planking of the road-way.

Figure 3 is an elevation of the middle opening, or arch of the bridge.

Figure 4 is an elevation of an opening adjoining one of the land abutments.

Figure 5 is a transverse section, showing also the elevation of the posts and braces which form the piers.

Figure 6 exhibits the scarfing of one of the beams, the manner of bolting the parts together, and their junction with the post by which they are supported.

Figure 7 exhibits the manner of joining the braces and posts in the railing.

This bridge has resisted the most tremendous ice-floods; though the floods have risen sometimes to such a height, as only to leave a small part in the middle of the road-way dry; and

* The foot of Vicenza is equal to 1·136 English feet, hence the span of the bridge over the Cismone would be nearly 114 feet.—See *Ware's Palladio*, Book III, Chap. vii.

WOODEN BRIDGES.

Fig. 1.

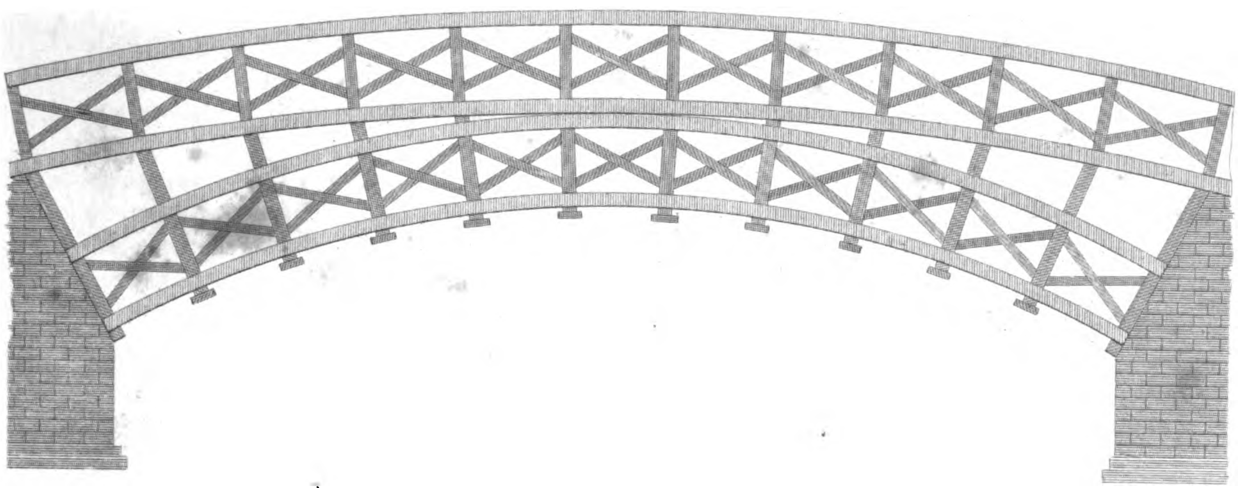


Fig. 2.

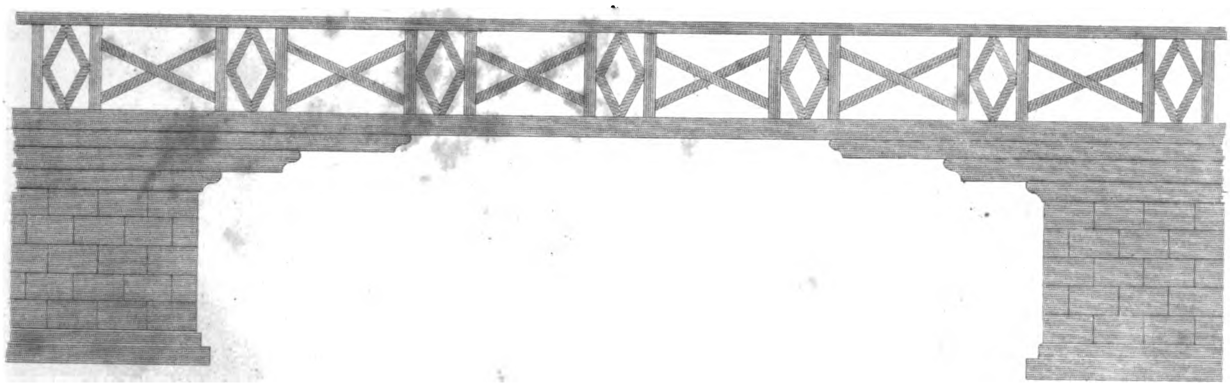
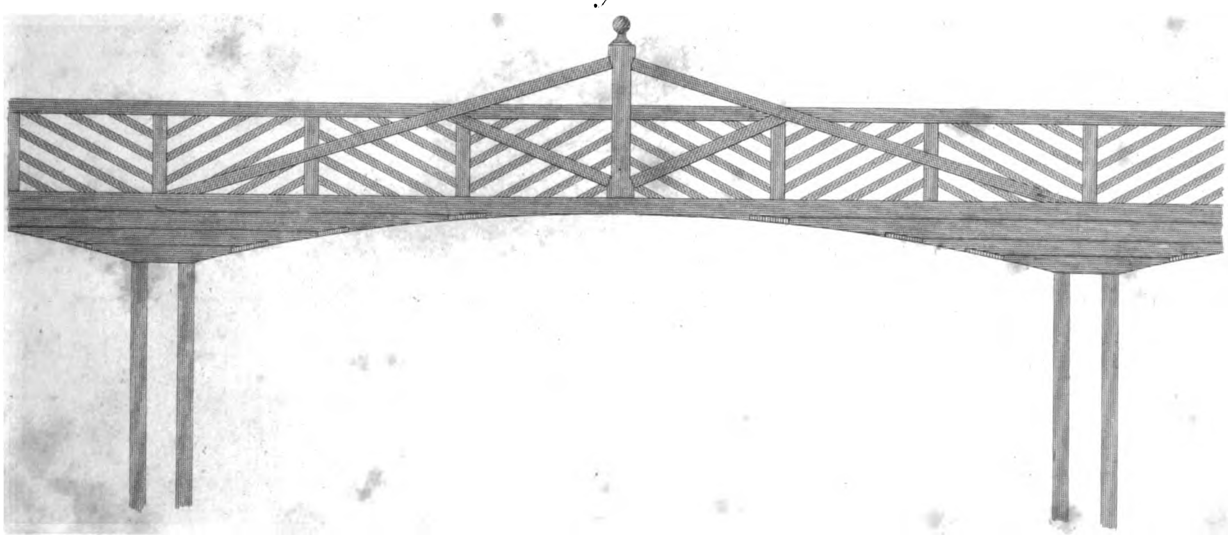


Fig. 3.



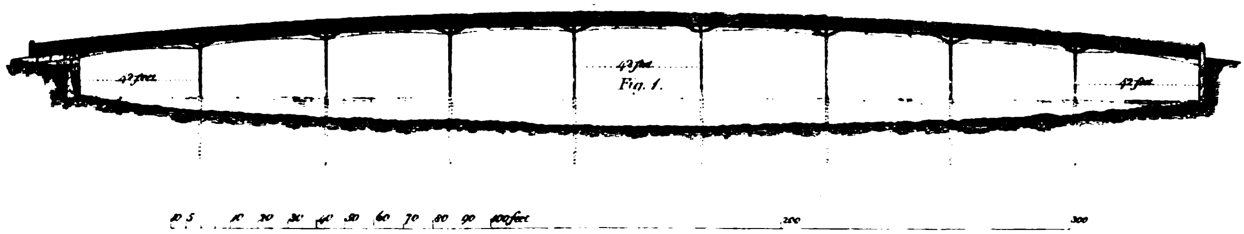
Engraved by R. Roffe.

London, Published by Thos. Kelly, 17 Paternoster Row, Jan. 22. 1836.

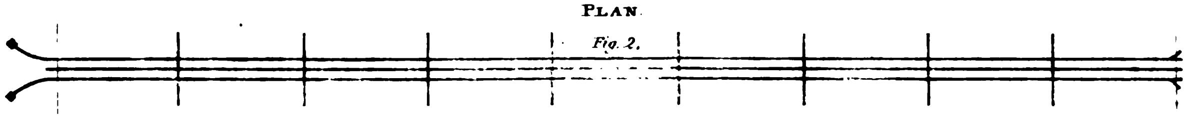
TIMBER BRIDGE,

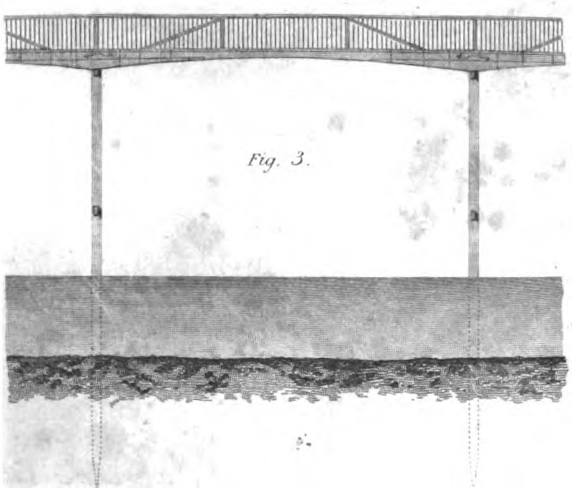
across the Clyde at Glasgow, superintended by Mr. Nicholson.

ELEVATION.



PLAN.





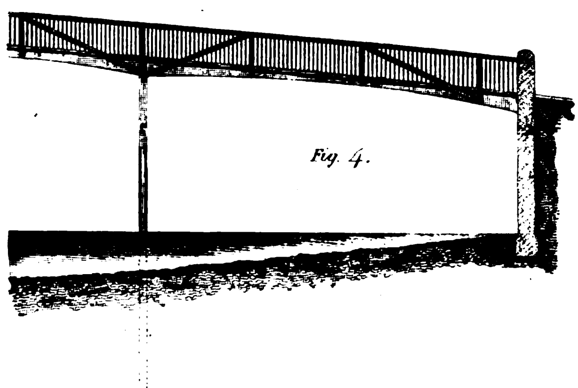


Fig. 6.

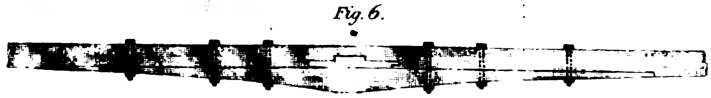


Fig. 5.

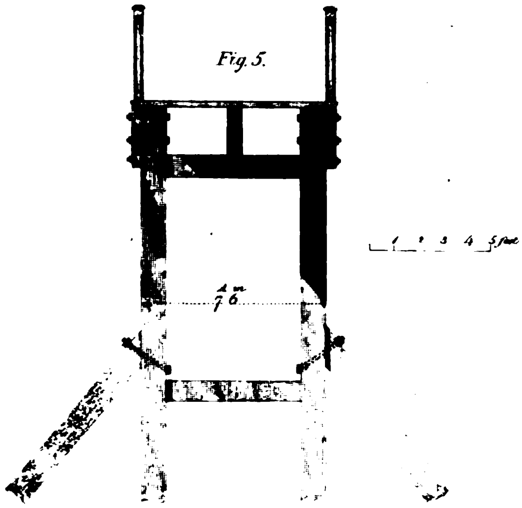
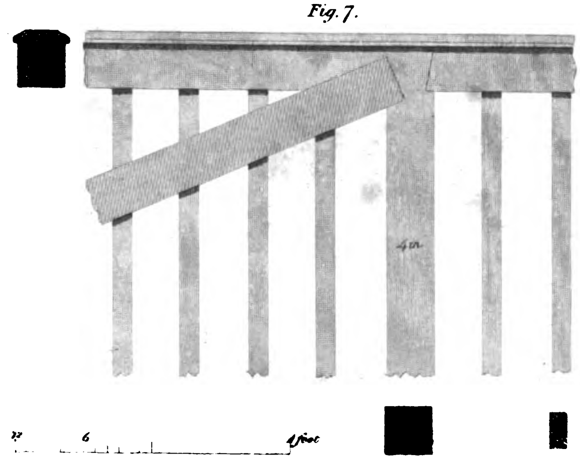


Fig. 7.



Drawn by M. A. Nicholson.

Engraved by H. Adlard.

London, Published by Thos. Kelly, 17, Paternoster Row, Jan. 2. 18[illegible]

both the late Mr. Rennie and Mr. Telford, the most eminent engineers this country has produced, have given their approbation of its construction, both in regard to its simplicity and strength, for the purpose for which it was designed.

REMARKS ON, AND INSTRUCTIONS FOR, CHOOSING TIMBER.

181. The kinds of timber used for buildings may be comprised under three heads: that is, Foreign timber from America; Foreign timber from different parts of Europe; and Home-grown, or British timber.

182. Of the Foreign European kinds, red or yellow Fir, in timber and deals, is brought from Norway, Russia, Prussia, and Sweden; the most esteemed kinds are from Riga, Memel, and Dantzic. White Fir, in deals, is brought from Norway, Sweden, and Russia; the most esteemed are from Christiana. Oak, in logs, is imported from Russia, Prussia, Germany, and Holland.

The red or yellow fir is that most usually employed in the construction of buildings, for girders, beams, joists, rafters, and almost all external carpenters' work; and, in the state of deals, it is used for greater part of the joiner's work. White deal is used for such parts of the joiner's work as are not exposed to the weather; and for cabinet-work.

183. Foreign Oak, commonly called wainscot, is used for floors, doors, and windows of principal apartments, and for furniture; the wood is of a fine grain, and generally free from knots, and it is easier to work than our native oak.

184. From America is imported Red and White Pine, White Deals, and Oak. The white pine is often a clean, uniform, and straight-grained wood, and is of an excellent quality for mouldings; but none of the American pines are durable, and when confined in close places, or built into walls, they are very subject to dry-rot.

The American White Oak is very little different from the European kind, but is rather inferior, has less figure, and is certainly subject to decay sooner. The American White Deal is very tough and strong, and often warps much in drying.

185. Of our home kinds of wood, Oak is the only kind that is generally useful in buildings, the wood of our planted firs being vastly inferior to that from the Baltic or Norway, and is not fit for any purposes where much strength or durability is expected.

186. Good Larch is, however, a very useful wood, and thrives well in this country, but that which is most common is of an inferior kind. The different species of Poplar and Lime-tree are useful for flooring, and some other purposes; but we must proceed to give a more detailed account of the different kinds.

Qualities of particular Kinds of Timber.

187. OAK.—In our particular description of the kinds of timber we shall begin with the Oak, a tree which, from its strength, hardness, and durability, has obtained the pre-eminent title of "King of the Forest."

On selecting a piece of oak, which shall have the greatest strength, or durability, it is often found to be a criterion of its excellence that it has grown on a soil which reared it slowly; as, in this case, it acquires from time a greater consistence of strength than it would acquire were it reared on soil of such a quality as to bring it hastily to maturity. This, however, is not always the case: because, from particular exposures, and favourable soils, a tree of oak may acquire a strength and hardness sufficient to undergo the greatest pression, although it has sprung from an acorn to a tree of "loftiest grandeur" in a very few years.

This is not mere conjecture; for we know, that the oaks on the estate of Roxburgh, in Scotland, for stature, for strength, and resisting quality, are not excelled by the oak of any other place in Britain, and that a very great number of years are not requisite for bringing this timber to full maturity; but, even on the same estate, there is a considerable difference in the quality of the oak: that which has northern exposure is found to be more strong and hardy than that which inclines to the sun at noon-day.

Another criterion is, to select that which, on being soaked in water, shall have its weight the least changed. This is evident, because the closeness of the fibres being sufficient to prevent the entrance of the fluid, must likewise, in this situation, indicate the strength of the wood. This observation is not confined to oak, but may be generally applied to timber of every description.

In selecting trees for felling, that are to be applied in cases where great strength and duration is expected, we must be particular in examining the state of health of those trees to which the axe is to be applied; for, if decay has taken place, we are sure that the timber is not so proper for our purpose as it would otherwise be. When the top of the tree is in a state of decay, it clearly bespeaks a decay in the tree itself; and, if a branch be decayed, or a stump rotten, it indicates a defect in that part of the tree to which it is attached.

Another circumstance to be particularly attended to, is, the time of cutting; most of the purposes of building requiring the greatest perfection of strength and texture, and duration. It is very generally supposed that these properties are obtained in the highest degree by cutting down the tree in winter, when it is freest from sap; as, in this case, it is more readily seasoned and rendered fit for use.

It, however, seldom happens that oak is cut down in winter; its bark being so valuable and useful for tanning of leather, that it is found to be more profitable to the owner to reserve the tree till spring, when the sap has ascended from the root, and loosened the bark from the wood, so that it may be easily stripped off; which it would not be were the tree cut down in winter.

The difference of seasons sometimes occasions a difference in the time of felling the wood, even for this purpose; but what ought to be particularly attended to, is, the state of the leaf. After the leaf begins to appear is a very proper time; for then the sap has expanded all round and over the tree, so that the bark is easily removed; if delayed till the leaf be fully expanded, the bark loses considerably in its value.

In the progress of decay, after a tree has been cut down, it has been observed that, the outer coat, being exposed to the action of the atmosphere, is first destroyed; then the second coat, and so on, gradually approaching the centre or heart of the tree: but we must understand this only of those which have been cut before they had begun to decay from age in the standing tree; as trees, that decay from standing too long, have their central part first destroyed, and the outer shell will even stand many years after the inner parts have been entirely wasted.

A skilful builder will, therefore, if the tree be old and large, be very particular in examining the central parts; especially that which lies next the root, or near decayed branches, as there the wasting will first begin.

For seasoning oak, the best method is to immerse it in water; this, in logs, should be done for several months; but, if cut into planks, so much time is not necessary. In either case, to soak and dry alternately is to be carefully avoided. The seasoning of planks can thus be always effected without much trouble; but, with respect to logs, it is troublesome, and they require nearly as much time after to dry gradually in the shade, as if they had not been soaked in water.

After having soaked *planks* in water, the usual mode of drying them is by placing a strong beam horizontally, so high as to admit one end of the plank to rest against it, in an inclined position, while the other rests on stones or slabs on the ground; observing to place the planks edgewise, and alternately one on one side of the beam, and another on the other, thus leaving a space between each for the air to pass freely.

188. BEECH.—Having said thus much in regard to oak, we shall now apply our observations to BEECH, a wood which, from its hardness, closeness, and strength, especially when exposed to particular strains, holds a prominent place among the trees of the forest.

Of Beech there are three kinds; a black, a brown, and a white. The brown is very common in Britain, and is most generally found in hedge-rows, or in the demesne lands about gentlemen's seats; being, when in full foliage, remarkable for its close and cooling shade.

About Mount Stuart, in the Isle of Bute, some of the trees in the avenues are immensely large, and yet appear to be in a thriving healthy condition; it is, therefore, probable that the soil necessary for rearing this wood ought not to be of the richest and heaviest kind; for here it is found in the greatest perfection that we remember to have seen it in any place, during a tour of the kingdom, and the soil is not remarkable for either of these qualities.

With respect to the nature of the trees of the other kinds we cannot say much, not having had an opportunity of examining them.

The wood of the beech is not well adapted for beams, because dampness soon brings on the rot; but for those purposes that require it to be continually under water, it is exceedingly durable: its principal use is for furniture, where its smoothness and compactness render it of great value; it is also much used for tools, and for turnery. Beech is very liable to be destroyed by worms.

189.—ASH is a species of wood very common in Britain, and for the purposes of the farmer there is perhaps none more valuable; oak itself not excepted. Carts, ploughs, harrows, and indeed almost all the implements of husbandry, are made of this wood. Like the oak, it requires particular exposures to render it the fittest for use, where great strains have to be overcome. A clayey soil has been found to answer very well for its propagation. On the lands of Limlaws, the property of Robert Ker, Esq. of Chatta, in Roxburghshire, there is a plantation of this wood, overhanging the precipitous banks of the Tiviot, and having a northern exposure: the trees in this plantation are immensely tall, straight, and tapering upwards, like a larch; the soil is clayey, and the wood is of the best quality imaginable, producing, at times, from 1½*d.* to 2*d.* per foot more to the proprietor than the same wood from any other place in the North.

On the demesne of Rokeby, near Greta Bridge, in Yorkshire, are trees of ash, very large and goodly to appearance, but we have not been able to ascertain any thing respecting the nature and particular qualities of the wood.

On the estate of Marchmont, in Berwickshire, are ash trees of very great size, which sufficiently prove that this wood is of a towering nature, although, on account of the many uses to which it is applied, it seldom arrives at maturity. The proper time to cut down ash is in winter, when the sap is at rest.

The quality is nearly the same through the whole substance of the tree, but the outside is rather the toughest. It soon rots when exposed to the weather, in a state of rest, but will last very long in constant use, if properly taken care of. It is of a porous structure; and that of which the fibres are long and straight is always considered the best.

190.—ELM is another tough and strong species of wood; it is, also, very useful for the husbandman, many implements being made of it; and, indeed, it is often preferred, for particular purposes, to ash itself. This is a very common wood, and is mostly found in hedge-rows, or around the skirts of plantations. On the demesne lands of Springwood Park, in the neighbourhood of Kelso, trees of this kind are very large, high, and branching, and contain a very great quantity of valuable timber. This circumstance authorises us to conclude, that a rich and loamy soil is the best for its production; as, in this particular place, the land is of such a quality, and also extremely fertile, the elms reared on it may be compared with any in the kingdom.

191. FIR.—The next species to which our attention shall be directed is Fir, than which there is no kind of timber more useful, or applied to more useful purposes. This, however, arises, not from its superior strength or durability, but from its being cheap, and yielding easily to the tools of the workman. It is common in almost all northern countries, and is brought, in great quantities, from Norway, Russia, Prussia, Sweden, and North-America.

The fir which is mostly used in carpentry is distinguished by the name of *Memel, Dantzic,* and *Riga Fir. Norway Fir* is also much used for smaller timbers, and answers extremely well when exposed to the air, or when kept under ground. The fir from North-America is softer than any just mentioned; it is likewise more free from knots, and, of course, suitable for the finer parts of joinery, such as panels and mouldings, and is called *pine wood.* What is termed in England *white deal,* is a species of *spruce fir,* and is very durable when kept dry, and for that reason is much used by cabinet-makers; but, as it does not stand the weather, it is used only for internal work in joinery.

In former times the Highlands of Scotland abounded in forests of fir-trees, as appears from the great number of stumps and roots still existing in the bogs and morasses. Above Lochiel-House, in Invernesshire, along the whole extent of Loch-Aghrigh, or Arkeig, is a forest of fir, in which many of the trees are yet in a high state of health, and of a great size: this wood is very strong, and so full of rosin, that many of the inhabitants use it in lieu of candles, it giving such a brilliant light as to render the use of tallow unnecessary.

192.—BIRCH is also a very common wood, and in the North of Scotland the dwarf kind grows spontaneously, in great abundance. The quality of birch is nearly the same quite across the tree; it is very tough, but will stand the weather, and worms are very hurtful to it. Birch is often used in works which lie under water. Some beautiful species of birch are imported from North-America in large logs; and they are much used for cabinet-work. The one of these species is called brown birch, and is frequently figured with dapples. When this kind is properly stained, it has much the appearance of mahogany.

193.—POPLAR is a tree that thrives well on wet ground, and is very often found on wet spots about gentlemen's seats. In beams it is liable to the same objections as beech, but it is well adapted for floors and stairs; but it rots when exposed to the weather.

The poplar and the aspen resemble each other; the latter is tough and soft, lasts better when exposed to the weather, and is equally good throughout the body of the tree.

194. SYCAMORE and LIME.—For the large timbers of roofing and flooring the SYCAMORE and LIME are subject to the same objections as the beech and poplar. The lime is, however, suitable for furniture; and makes good floors, being smooth, when wrought. When Sycamore is obtained of a considerable degree of whiteness and figured, it is much esteemed for cabinet-work.

195. WALNUT and CHESNUT.—We have also the WALNUT-TREE and the CHESNUT; the former of which has become too valuable in Britain, in consequence of the great consumption for gun-stocks; and mahogany has now nearly superseded its use in furniture.

The Spanish or Sweet Chesnut is frequently found in old buildings in England; it is very like oak, and is often confounded with it; but, notwithstanding, it differs from it in this, that, when a nail or bolt has been driven into oak before it was dry, a black stain appears round the iron, which in chesnut is not the case.

196. MAHOGANY is chiefly used in furniture, and sometimes also in doors and window-sashes, it is sawn out and seasoned by being kept under cover yet exposed freely to the air: it is extremely valuable, and grows in Jamaica. There is another kind, from Yucatan, called *Honduras mahogany*, but that of Jamaica is much the most beautiful and durable. The pores of the Honduras appear quite black; those of the Jamaica kind appear as if filled with chalk.

General Cautions and Remarks respecting Timber.

197. LAY your timber up, when perfectly dry, in an airy place, that it may not be exposed to the sun and wind, and taking care that it does not stand upright, but let it be laid along, one piece upon another; interposing, here and there, some short blocks, to keep them apart, and prevent that mouldiness which is usually contracted when the planks sweat.

Some persons, in the first stages of seasoning, keep their timber as moist as they can by submerging it in water, with a view to prevent it from cleaving. This is good in fir, and also in some other timbers. Lay your planks in a stream of running water for a fortnight, and then set them up in the sun and wind, so that the air may freely pass between them, and turn them frequently. Boards thus seasoned will floor much better than those which have been kept many years in a dry place.

But, to prevent all possible accidents, when you lay your floors, let the joints be fitted and tacked down only for the first year, nailing them close down the next; and, by this method, they will lie without shrinking in the least.

Amongst wheelwrights the water-seasoning is of special regard, and of such esteem amongst some, that the Venetians lay their oak some years in water before they employ it.

Elm felled ever so green, if kept four or five days in water, obtains a good seasoning, and is rendered more fit for immediate use. This water-seasoning is not only a remedy against the worm, but it also prevents distortions and warping. Some persons recommend burying timber in the earth, and others will have their timbers covered-in to heat; and we likewise see that scorching and hardening in the fire renders piles durable, especially those which are to stand in earth or water.

Green timber is sometimes used by those who carve and turn: but this for doors, windows, floors, and other close works, is altogether to be rejected; especially if walnut be the material, as they will be sure to shrink. It is, therefore, best to choose such as has had two or three years' seasoning, and which is neither too dry nor moist.

Where huge massy columns are to be used, it is a good plan to bore them right through, from end to end, as it prevents their splitting.

Timbers occasionally laid in mortar, or in any part contiguous to lime, as doors, window-cases, ground-sills, and the extremities of beams, &c., have sometimes been capped with melted pitch, as a preserver from the destructive effects of the lime; but it has been found to be rather hurtful than otherwise.

For all uses, that timber is the best which is the most compact and free from knots. As to the place of growth, that is generally esteemed the best which grows most in the sun; but, as we have already hinted, this is not always the case. The climate, however, contributes much to its quality, and perhaps a northern situation is preferable to all others.

198. Foreign Timber is always sufficiently seasoned to cut into scantlings; but home timber requires to be seasoned some time after felling, before it be cut up, otherwise it will warp, split, and often become unfit for use. After timber is felled, it should remain at least six months in the tree, and during that time it should be raised off the ground to admit a free circulation of air round each piece; and it should remain about one year in scantlings, before it be used in buildings.

199. The wood for Joiners' work should be all cut to the proper thicknesses, so as to allow them the most time possible to dry; by such arrangements, on the commencement of a building, every thing will be ready for its respective use, and well fitted for ensuring soundness and durability.

200. Respecting the selection of timber for principal beams we cannot offer much, in addition to the judicious directions of the Italian architect, Alberti, which are here given nearly in his own words.

Beams ought to be perfectly sound and clean; and, especially about the middle of their length, they ought to be free from the least defect. Placing your ear at one end of a beam while the other is struck, if the sound come to you dead and flat, it is a sign of some private infirmity. Beams that have knots in them are absolutely to be rejected, if there be many, or if they be crowded together in clusters. Whichsoever side of a beam has a defect, that runs crossways of it, let that side be laid uppermost; also, if there be a crack lengthways, do not venture it on the side, but lay it either uppermost or undermost. If you happen to have occasion to bore a hole in the beam, or to make any opening, never meddle with the middle of its length, nor its lower superficies. If, as in churches and large houses, the beams are to be laid in pairs, leave a space of some inches between them that they may have room to exhale, and not be spoiled by heating one another, and it will not be amiss to lay the two beams of the same pair different ways, that both their heads may not lie upon the same pillow; but where one has its head, the other may have its foot; for, by this means, the strength of the one's foot will assist the weakness of the other's head, and so, *vice versa*. Let the plates for the beams be exactly level, and perfectly firm and strong; and in laying them take care that the timber does not touch any lime, and let it have clear and open space all about it, that it may not be tainted by the contact of any other materials, nor decay by being too closely shut up.

Contraction and Expansion of Timber.

201. It is well known that a tree contracts less in proportion, in diameter, than it does in circumference; hence a whole tree always splits in drying; and Mr. Knight has shown that, in consequence of this irregular contraction, a board may be cut from a tree, that can scarcely be made, by any means, to retain the same form and position when subjected to various degrees of heat and moisture. From ash and beech trees he cut some thin boards, in different directions relatively to their structure, so that the rings in the wood crossed the middle of some of

the boards at right-angles, and lay nearly parallel with the surface of others. Both kinds were placed in a warm room, under perfectly similar circumstances; those which had been formed by cutting the boards, so that the rings were nearly parallel, as at A in *fig.* 1, *pl. XLIII*, soon changed their form very considerably, the one side becoming hollow, and the other round; and, in drying, they contracted nearly $\frac{1}{4}$th in width. The other kind, in which the rings were nearly at right-angles to the surfaces of the boards, as at B, in the figure, retained with very little variation their primary form, and did not contract in drying more than about $\frac{1}{28}$th part of their width. As Mr. Knight had not tried resinous woods, the subject was further investigated by Mr. Tredgold, who had two specimens cut from a piece of Memel timber; and, to render the result of the observation more clear, conceive the figure to represent the section of a tree, the annual rings being shown by circles; BD represents the manner in which one of the pieces was cut, and AC the other; the board AC contracted about $\frac{1}{27}$th part in width, and became hollow on the side marked *b*; the board BD retained its original straightness, and contracted only about $\frac{1}{140}$th part of its width; the difference in the quantity of contraction being still greater than in hard woods.

From these experiments the advantages to be obtained, merely by a proper attention in cutting out boards for pannels, &c., will be obvious; and it will also be found, that pannels cut so that the rings are nearly perpendicular to their faces, will appear of a finer and more even grain, and require less labour to make their surfaces even and smooth. The results of these experiments are not less interesting to cabinet-makers than to joiners, particularly in the construction of billiard-tables, card-tables, and indeed every kind of table in use. For such purposes, the planks should be cut so as to cross the rings, as nearly in the direction, BD, as possible. We have no doubt that it is the knowledge of this property of wood, that renders the billiard-tables of some makers so far superior to those of others. In wood that has the large radiating lines, as the oak, for example, boards cut as BD will be figured, while those cut at AC will be plain.

202. There is another kind of contraction in wood whilst drying, which causes it to become curved in the direction of its length. In the long styles of framing we have often observed it; indeed, on this account, it is difficult to prevent the style of a door, hung with centres, from curving, so as to rub against the jamb. A very satisfactory reason for this kind of curving has been given by Mr. Knight, which also points out the manner of cutting out wood, so as to be less subject to this defect, which it is most desirable to avoid. The interior layers of wood, being older, are more compact and solid than the exterior layers of the same tree; consequently, in drying, the latter contract more in length than the former. This irregularity of contraction causes the wood to curve, in direction of its length, and it may be avoided by cutting the wood, so that the parts of each piece shall be as nearly of the same age as possible.

203. Besides the contraction which takes place in drying, wood undergoes a considerable change in bulk with the variations of the atmosphere. In straight-grained woods, the change in length is nearly insensible; hence they are sometimes employed for pendulum rods; but the lateral dimensions vary so much, by the dampness or dryness of the air, that a wide piece of wood will serve as a rude hygrometer. The extent of variation decreases in a few seasons, but it is of some importance to the joiner to be aware, that, even in very old wood, when the surface is removed, the extent of variation by damp is nearly the same as in new wood. It appears, from Rondelet's experiments, that, in wood of a mean degree of dryness, the extent of contraction and expansion, produced by the usual changes in the state of the weather, was,

In fir-wood, from $\frac{1}{360}$ to $\frac{1}{75}$th part of its width;
and, in oak, from $\frac{1}{412}$ to $\frac{1}{84}$th part of its width.

Consequently, the mean extent of variation in fir is $\frac{1}{124}$, and in oak $\frac{1}{140}$; and at this mean rate, in a fir board, about $12\frac{1}{2}$ inches wide, the difference in width would be $\frac{1}{10}$th of an inch. This will show the importance of attending to the maxims of construction we shall have to place before the reader, in treating of framing in joinery; for, if a board of that width should be fixed at both its edges, it must unavoidably split from one end to the other, by the mere effect of the weather.

The importance of a knowledge of these properties of timber is considerable in all arts where wood is operated upon in considerable pieces, and for good work; and we have to acknowledge the assistance in treating them we have received from the Treatise on Joinery in the *Encyclopædia Britannica,* written by Mr. Tredgold.

ON THE STRENGTH OF TIMBER.

204. The strength of materials used in mechanical constructions is exerted in five different ways; that is to say, in resisting a direct pull, in resistance to compression, to a transverse strain, to torsion, or twisting, and to percussion.

The strength which *resists extension* is the effect of cohesion. If cohesion opposes the extension, both act according to the same law, being as the extension, while the forces exerted are not great. There is a certain limit beyond which cohesion does not act: and if it be exceeded, a total separation takes place.

205. Materials also should be considered in relation to the effect a strain produces on them; they bend, they suffer alteration, and they break.

Bending may be occasioned either by a transverse or by a longitudinal force: when the force is transverse, the extent of the bending is nearly proportional to the force; but when it is longitudinal, there is a certain degree of force which must be exceeded, in order to produce, or rather to continue, the bending, if the force be applied exactly at the axis. But it is equally true, that the slightest possible force applied at a distance from the axis, however minute, or with an obliquity however small, or to a beam already a little curved, will produce a certain degree of bending; and this observation will serve to explain some of the difficulties and irregularities which have occurred in making experiments on beams exposed to longitudinal pressure.

206. Alteration, Dr. Young truly remarks, is often an intermediate step between a temporary change of form and a complete fracture. There are many substances, which, after bending to a certain extent, are no longer capable of resuming their original form: and in such cases it generally happens that the alteration may be increased without limit, until complete fracture takes place by the continued operation of the same force which has begun it, or by a force a little greater. Those substances which are the most capable of this change, are called *ductile,* and the most remarkable are gold, and a spider's web. When a substance has undergone an alteration by means of its ductility, its stiffness, in resisting small changes on either side, remains little, or not at all altered. Thus, if the stiffness of a spider's web, in resisting torsion, were sufficient, at the commencement of an experiment, to cause it to recover itself, after being twisted in an angle of ten degrees, it would return ten degrees, and not more, after having been twisted round a thousand times. The ductility of all substances, capable of being annealed, is

greatly modified by the effects of heat: hard steel, for example, is incomparably less subject to alteration than soft, although, in some cases, more liable to fracture; so that the degree of hardness requires to be proportioned to the uses for which each instrument is intended; although it was proved by Coulomb, and has since been confirmed by other observers,* that the primitive stiffness of steel, in resisting small flexures, is neither increased nor diminished by any variation in its temper. It is laid down as a principle, in Mr. Tredgold's work on the Strength of Iron, that the strain upon any material used in building should never be greater than that which causes alteration, and, by comparing numerous experiments, he has ascertained, that the force which first occasions sensible alteration is about one-fourth of that which causes fracture.

207. Breaking, or fracture, ought never to happen in practice, unless in the case of accidents; the object of calculation is to prevent it happening in any case; but often through a mistaken notion of economy, beams are only just made strong enough to bear a little more than the breaking weight, and perhaps the whole of the weight not carefully estimated, hence occur serious failures. If, however, the load to be supported be made one-fourth of the breaking weight, the structure will most certainly be secure, and do credit both to the calculator and the builder.

We must now proceed to treat of the different kinds of strength, and give the results of experiments on this interesting subject, so that the calculations of strength may be performed in the easiest possible manner.

208. *Cohesive Strength*, in prismatic bodies, is proportional to the area of the transverse section, taken at the smallest part; and it is measured by the weight required to tear a body asunder. In those substances, however, which possess ductility, the surface of fracture is not the true surface whose cohesion is overcome by the weight; for such substances stretch considerably on their application, and their diameter gradually contracts until they yield. Pieces of lead exhibit this kind of contraction in a remarkable degree.

The force required to tear a piece asunder suddenly, is much greater than what it can bear for a length of time; even iron, which suspends from twenty-seven tons to thirty-two tons for every square inch of its section, ought not to be trusted in any structure with more than eight tons on a square inch. Hard steel is much stronger than iron, as it requires a force of about sixty tons to pull a bar of steel an inch square asunder.

Experiments on timber are much more irregular than those on metals, from the irregularity of its fibres; there is also a considerable difference in the specimens from the same tree. Oak breaks with about five tons per square inch, and yellow fir five and a half tons; while ash requires nearly eight tons to break it. Where a rod, used to suspend a body, is of considerable length, its weight must be added to the load, and therefore the section should be continually less downwards.

209. The force necessary, according to the experiments of Muschenbrook, to tear asunder a square inch of different kinds of wood, is given in the following table:

Locust-Tree	20,100 lbs.	Willow	12,500 lbs.	Fir	8,330 lbs.
Jujebe	18,500 —	Ash	12,000 —	Walnut-Tree	8,130 —
Beech and Oak	17,300 —	Plum	11,800 —	Pitch-Pine	7,650 —
Orange-Tree	15,500 —	Elder	10,000 —	Quince	6,750 —
Alder	13,900 —	Pomegranate	9,750 —	Cypress	6,000 —
Elm	13,200 —	Lemon	9,250 —	Poplar	5,500 —
Mulberry-Tree	12,500 —	Tamarind	8,750 —	Cedar	4,880 —

* To verify this important truth, a series of experiments were made by Mr. Tredgold on the elasticity of steel, which were read before the Royal Society, in March, 1824, and published in their Transactions for that year.

210. The strength of a square inch of different metals to resist being pulled asunder, we have calculated from the experiments of Mr. George Rennie:

Description of Specimens.	Broke with	Strength of a Square Inch.
	lbs.	lbs.
¼ of an inch square of cast-iron bar, cast horizontally....	1166	18,656
¼ do. do. do. vertically......	1218	19,488
¼ do. cast-steel, previously tilted................	8391	134,256
¼ do. blister-steel, reduced per hammer..............	8322	133,152
¼ do. shear-steel, do. do.................	7977	127,632
¼ do. Swedish iron, do. do.................	4504	72,064
¼ do. English iron, do. do.................	3492	55,872
¼ do. hard gun-metal, mean of two trials..............	2273	36,368
¼ do. wrought-copper, reduced per hammer............	2112	33,792
¼ do. cast-copper	1192	19,072
¼ do. fine yellow brass	1123	17,968
¼ do. cast-tin	296	4,736
¼ do. cast-lead	114	1,824

211. From these experiments the strength of any of these substances to resist being pulled asunder may be easily calculated by simple proportion. That is, as the weight in lbs. that would break a piece one inch square is to one inch, so is the weight to be supported to the area of the piece in inches which would break by that weight; and four times that area should be the size of the piece used to support such a weight in a building.

For example, if it be wished to ascertain the size of a tie of iron that will resist a stress of 124,000 pounds in the direction of its length, it will be found that English iron will break with about 55,000 lbs. on a square inch; therefore

$$55{,}000 : 1 :: 124{,}000 : 2{\cdot}25$$

$$\begin{array}{r} 55{,}000)\,124{,}000 \\ \hline 2{\cdot}25 \text{ square inches.} \\ 4 \\ \hline 9{\cdot}00 \end{array}$$

9·00 square inches, the size that may be employed with perfect safety to support the load in practice.

212. *Repulsive Strength*, or the power of bodies to resist compression, is much more difficult of investigation, and the greatest analysts have been mistaken in their results. The relation between the cohesive and repulsive forces depends much on the structure of the bodies. Fir will support more than oak when employed as a pillar; and cast-iron resists compression with a force equal to twice its cohesion.

213. In a rectangular beam, if the compressive force be not applied in the direction of the axis, it will bend the beam; for the repulsive forces, acting against it on each side of a line, drawn through the point of application, must be equal; but the number of particles between it and the surface nearest to it, is less than that of the rest of the section; and if they were equally impressed throughout, their action could not be equal to that of the others; they must, therefore, be more compressed, which augments their repulsion, and compensates for inferiority of number. The column, therefore, must bend, as one of the surfaces, through greater compression, becomes shorter than the other, and there is a longitudinal section, which is neither compressed nor extended, which has obtained the appellation of the *Neutral Section*.

Between this section and the remote surface a portion of the beam is in a state of extension. It is obvious that a similar flexure would be produced by a force applied obliquely to the axis, or by a transverse strain, even when it acts directly transverse, and that the strength may be much increased as a pillar, if it be prevented from bending by lateral braces applied at its middle. If the piece be so prevented from bending in the middle, it may then be loaded with the same weight which it would safely suspend, and the resistance will be as the area of the transverse section in the smallest part.

214. And it also appears, from an investigation of Dr. Young's, as well as from experiments by Rondelet and others, that there is a determinate proportion between the length and diameter of a column, such that the column will crush rather than bend, and then the same rule just given applies to find its strength.

By applying Dr. Young's determination to the strength of wood and iron, compared with the measure of their elasticity, it appears, that a round column or a square pillar of either of these substances cannot be bent by any longitudinal force applied to the axis, which it can withstand without being crushed, unless its length be greater than twelve or thirteen times its thickness respectively: nor a column or pillar of stone, unless it be forty or forty-five times as long as it is thick. Hence we may infer, as a practical rule, that every piece of timber or iron, intended to withstand any considerable compressing force, should be at least as many inches in thickness as it is feet in length, in order to avoid the loss of force which necessarily arises from curvature or bending.

215. Mr. George Rennie's experiments on the force necessary to crush substances of various kinds.

Area of Specimens, one Inch square.	Specific Gravity.	Weight that crushed the Specimen.	Weight that would crush a square inch
		lbs.	lbs.
Elm	--	1284	1284
American pine	--	1606	1606
White deal	--	1928	1928
English oak, mean of two trials	--	3860	3860
Do. of 5 inches long, slipped with	--	2572	2572
Do. of 4 inches, do.	--	5147	5147
A prism of Portland stone, 2 inches long	--	805	805
Do. of statuary marble	--	3216	3216
Craig-Leith sand-stone	--	8688	8688
Area of Specimens, one Inch and a half square			
Chalk	--	1127	501
Brick of a pale red colour	2·085	1265	562
Roe-stone, from Gloucestershire	--	1449	644
Red brick, mean of two trials	2·168	1817	808
Yellow-face baked Hammersmith paving-brick, three trials	--	2254	1003
Burnt do. mean of two trials	--	3243	1441
Stourbridge or fire-brick	--	3864	1717
Derby grit, a red friable sand-stone	2·316	7070	3142
Do. from another quarry	2·428	9776	4334
Collalo white free-stone, not stratified	2·423	10,264	4562
Portland stone	2·428	10,284	4570

Area of Specimens, one Inch and a half square.	Specific Gravity.	Weight that crushed the Specimen.	Weight that would crush a square inch.
		lbs.	lbs.
Craig-Leith, white free-stone	2·452	12,346	5486
Yorkshire paving stone, with the strata	2·507	12,856	5714
Do. do. against the strata	2·507	12,856	5714
White statuary marble, not veined	2·760	13,632	6059
Bramley Fall sand-stone, near Leeds, with the strata	2·506	13,632	6059
Do. against the strata	2·506	13,632	6059
Cornish granite	2·662	14,302	6343
Dundee sand-stone, or brescia, two kinds	2·530	14,918	6630
A two-inch cube of Portland-stone	2·423	14,918	3729
Craig-Leith stone, with the strata	2·452	15,560	6916
Devonshire red marble, a variegated specimen	--	16,712	7428
Compact limestone	2·584	17,354	7724
Peterhead granite, hard, close-grained	--	18,636	8283
Black compact lime-stone, from Limerick	2·598	19,924	8866
Purbeck-stone	2·599	20,610	9160
Black Brabant marble	2·697	20,742	9219
Very hard free-stone	2·528	21,254	9446
White Italian veined marble	2·726	21,783	9670
Aberdeen granite, blue kind	2·625	24,556	10,914
Cast copper, $\frac{1}{4}$ by $\frac{1}{4}$, crumbled with	--	7318	117,056
Fine yellow brass, $\frac{1}{4}$ by $\frac{1}{4}$, reduced $\frac{1}{2}$ with	--	10,304	164,864
Wrought copper, $\frac{1}{4}$ by $\frac{1}{4}$, reduced $\frac{1}{8}$ with	--	6440	103,040
Cast tin, $\frac{1}{4}$ by $\frac{1}{4}$, reduced $\frac{1}{3}$ with	--	966	15,456
Cast lead, $\frac{1}{4}$ by $\frac{1}{4}$, reduced $\frac{1}{2}$ with	--	483	7728

216. Mr. Rennie's experiments on crushing cast-iron.

	Specific Gravity.	Weight that crushed the Specimen.	Weight that would crush a square inch.
		lbs.	lbs.
Cast-iron, from a block, area $\frac{1}{4}$, length $\frac{1}{4}$ of an inch	7·033	9774	156.384
Cast-iron, horizontal castings, area $\frac{1}{4}$, length $\frac{1}{4}$	7·113	10,114	161,824
Cast-iron, vertical castings area $\frac{1}{4}$, length $\frac{1}{4}$	7·074	11,137	178,192
Castings, horizontal area $\frac{1}{4}$, length $\frac{1}{2}$	--	9415	150,640
Vertical castings area $\frac{1}{4}$, length $\frac{1}{2}$	--	9983	159,728
Horizontal castings area $\frac{1}{4}$, by $\frac{3}{8}$ long	--	9006	144,096
— $\frac{1}{4}$, by $\frac{5}{8}$ —	--	8845	142,520
— $\frac{1}{4}$, by $\frac{6}{8}$ —	--	8362	133,792
— $\frac{1}{4}$, by $\frac{7}{8}$ —	--	6430	102,880
— $\frac{1}{4}$, by $\frac{8}{8}$ or one inch long	--	6321	101,136
Vertical castings area $\frac{1}{4}$, by $\frac{3}{8}$ long	--	9328	149,248
— $\frac{1}{4}$, by $\frac{5}{8}$ —	--	8385	134,160
— $\frac{1}{4}$, by $\frac{6}{8}$ —	--	7896	126,336
— $\frac{1}{4}$, by $\frac{7}{8}$ —	--	7018	112,288
— $\frac{1}{4}$, by $\frac{8}{8}$ —	--	6430	102,880

The strength of pieces to resist crushing is to be calculated in the same manner as that for resistance to pulling asunder, see *Art.* 211; and the same allowance of four times the strength should be made in practice; besides, observing that the length must be less in proportion to the diameter than the proportions stated in *Art.* 214.

ON THE STRENGTH OF TIMBER.

Fig. 1.

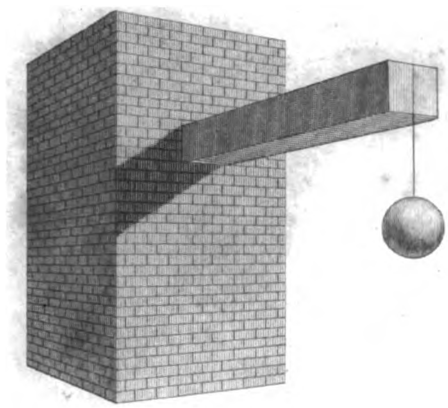


Fig. 2.

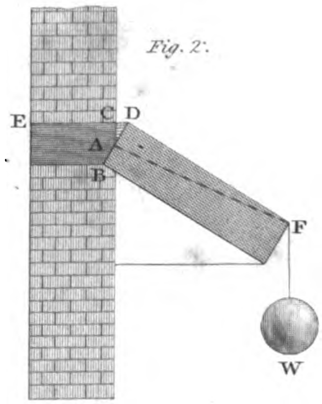


Fig. 3.

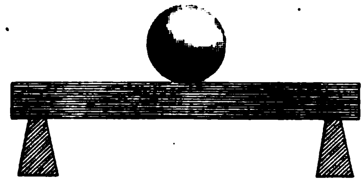


Fig. 4.

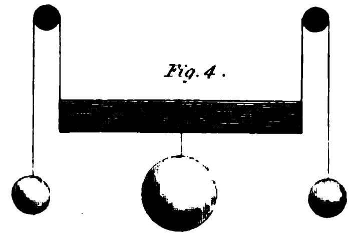


Fig. 5.

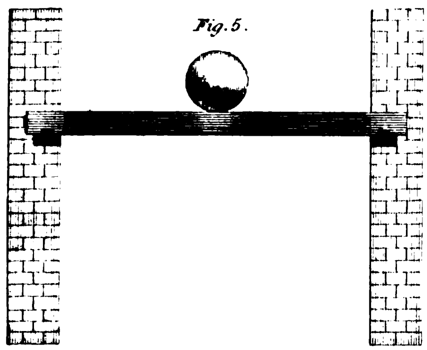


Fig. 6.

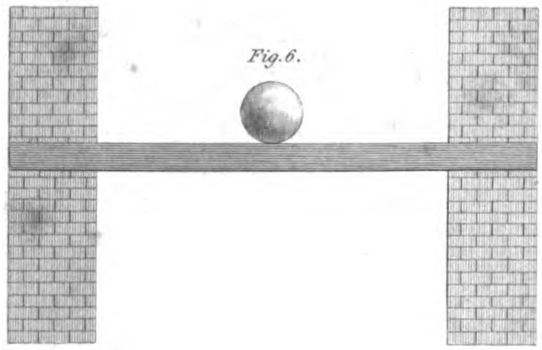


Fig. 7.

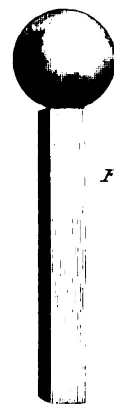


Fig. 8.

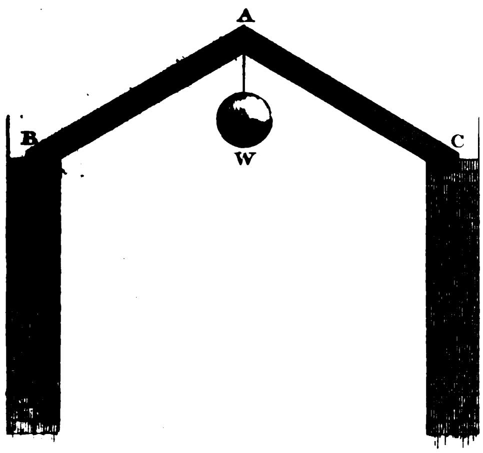
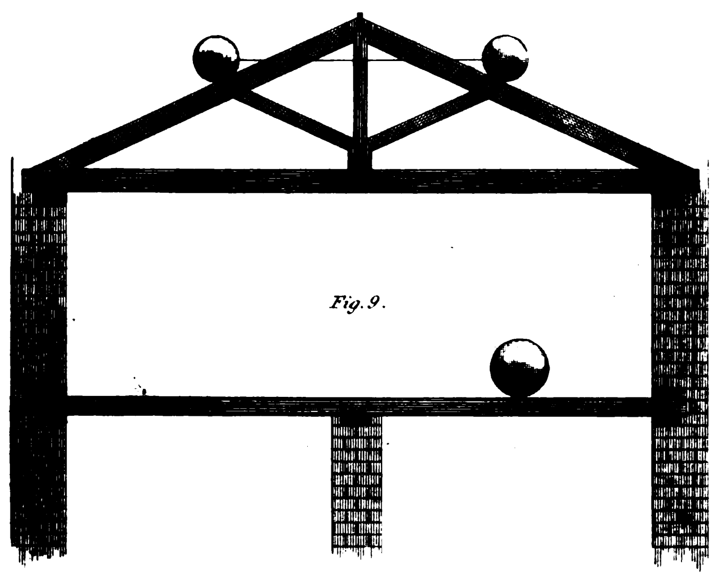


Fig. 9.



Engraved by H. A

London Published by Thos. Kelly, 17, Paternoster Row, Jan. 2, 1835.

217. *Transverse Strength.*—A piece of timber projecting from a wall, in which it is fixed, may be strained or broken by a weight suspended from the extremity, as in *fig.* 1, *pl. XLII,* or by a load uniformly distributed over it, as in the cantilivers of a roof.

Figure 2 exhibits a piece of timber in the act of breaking; the bar moves round a point, A, at or near the middle of the depth; the fibres above, from A to CD, are supposed not to be broken, they are therefore in a state of tension, and the fibres below the point A, from A to B, are in a state of compression: both these forces equally counteract the efforts of the weight W; the force of extension being equal to that of compression.

Figure 3 exhibits the manner in which a beam, supported at both its extremities, may be broken by the application of a force in the middle, or between its ends, as in the case of joists, binding-beams, and girders, which have not only to sustain their own weight, but also any accidental weights with which they may be loaded.

This manner of exposing timber to fracture is the same as that represented at *fig.* 4, where the weights are substituted for the props and made to pull upwards, each weight being equal to half the weight suspended in the middle.

Figure 5 represents a joist supported by two walls. We must here observe, that joists ought never to be firmly fixed in walls when they are inserted only nine or ten inches, as in common cases; for they would endanger the wall by causing it to bend or fracture, particularly when the wall is thin: however, when the wall is of sufficient thickness, and the timber inserted through the whole thickness, as in *fig.* 6, the effort to bend or fracture the wall will not be so great, and the timber, thus fixed, will be exceedingly stiff, the strength being increased by the mode of fixing.

A joist, as in *fig.* 9, reaching over two areas of equal breadth, is much stronger than two joists of the same scantling, reaching over the two areas of the same breadth.

Figure 7 exhibits another way in which timber may be broken, by being crushed, as in the case of columns, strong posts, principal rafters, &c.

In *figure* 8, which represents a pair of rafters, supported on two opposite walls, a weight, W, suspended from the vertical angle A, compresses the rafters AB, AC, in the direction of their lengths. We have already shown the reader how to estimate the effect of such a weight in spreading out the walls in *Art.* 62.

218. *Figure* 9 shows the efforts of two equal weights to break two rafters; but this may be prevented by two struts, branching from the king-post to the points in the rafters under the places where the weights are applied. The effect of the weights is, therefore, to crush both rafters and struts. For a force applied upon the back of a rafter presses in the direction of the struts, which again press on the lower end of the king-post, and the king-post presses on the tops of the rafters, the lower ends of which press the extremities of the tie-beam, which is therefore brought into a state of tension. Therefore, the rafters are in a state of compression, and the king-post in a state of tension, while the struts are in a state of compression.

219. With regard to direct *cohesion,* the strength is as the number of ligneous fibres, and therefore as the area of fracture; but, in transverse strains, the case is very different, where, instead of a direct application of the force in the line of the fibres, it is made to act upon them in the direction of the fibres, by means of levers, and therefore the effect of the force depends on the proportions of the levers, as well as on the area of the section of fracture.

Galileo, to whom the physical sciences are so much indebted, was the first who undertook to investigate the subject upon pure mathematical principles. He considered solid bodies as being made up of numerous small fibres, applied parallel to each other: he assumed the force which resisted the action of power to separate them, to be directly as the area of a section perpendicular to the length: that is, as the number of fibres of which the body is composed: he likewise supposed that bodies resisted lateral fracture by cohesion only, and that each particle was equally acted upon, and therefore the whole resistance to fracture of a rectangular beam, turning on a line in one of its sides perpendicular to the two edges, was the same as if the whole resistance had been comprised in the centre of gravity.

Now, in a rectangular beam, the centre of gravity is distant from the axis half the depth of the beam. Therefore, let b be the breadth, and d the depth, of the beam; then the distance of the centre of gravity will be $\frac{1}{2}d$, and the effort to resist fracture will be $bd \times \frac{1}{2}d = \frac{bd^2}{2}$.

Therefore, when a beam is solidly fixed in a wall, if l be the length, w the weight that will break it:

$$\text{Then } w : bd :: \tfrac{1}{2}d. : l. \quad \text{Whence } w = \frac{bd^2}{2l}.$$

From other investigations, which we shall not attempt to show here, Galileo endeavoured to prove that, whatever weight is required to break a beam fixed at one end, double that weight is necessary to break a beam of equal breadth and depth, with twice the length, when supported at both ends.

220. But *Marriotte*, a Member of the French Academy, discovered the inaccuracy of Galileo's theory, and was fortunate enough to arrive at the true one. The discovery of Marriotte attracted the attention of the philosopher *Leibnitz*, who, through some strange oversight, concluded that every fibre acted by tension only, and instead of acting with an equal force, each exerted a power of resistance proportional to the distance of extension, and that the beam turned on a line in one of its sides as a fulcrum. The high name and authority of Leibnitz caused his inaccurate views to be followed, and, till within a few years, the labours of Marriotte were not appreciated according to their value.

A complete investigation of the resistance of materials, according to the direction and situation of the forces applied, would require a volume. The reader who wishes for more information on this subject, cannot do better than consult the third Edition of Mr. Barlow's valuable "*Essay on the Strength and Stress of Timber;*" and Mr. Tredgold's "*Practical Treatise on the Strength of Iron and other Metals.*" We propose here to give the rules for plain rectangular beams, and in as simple a mode as possible.

221. The strength of beams of the same kind, and fixed in the same manner, in resisting a transverse force, is simply as their breadth, as the square of their depth, and inversely as their length. Thus, if a beam be twice as broad as another, it will also be twice as strong; but if it be twice as deep, it will be four times as strong: for the increase of depth not only doubles the number of the resisting particles, but also gives each of them a double power, by increasing the length of the levers on which they act. The increase of the length of a beam must also obviously weaken it, by giving a mechanical advantage to the power which tends to break it: and some experiments appear to show, that the strength is diminished in a proportion somewhat greater than that in which the length is increased.

The strength of a beam, supported at both ends, is twice as great as that of a single beam of half the length, which is fixed at one end; and the strength of the whole beam is again nearly doubled, if both the ends be firmly fixed; and the stiffness follows the same proportions, as far as the fixing and manner of supporting is concerned.

These proportions, combined with the following series of experiments, will be sufficient to enable the carpenter to compute the strength of the beams which are used in buildings, more complicated forms we do not attempt to give, as they are chiefly executed in iron.

222. Results of Experiments on the Strength of various Specimens of wood, from the *Minutes of Evidence* on the Timber Trade, taken before a Committee of the House of Commons, p. 22.

The trials were made upon pieces carefully selected as to quality and grain; the pieces were two feet in length and one inch square, and all of them from split portions of timber.

The order of Strength as ascertained by their being broken by the application of weight.

Description of the Specimens.	The piece was broken by	Strength of a piece one foot long, and one inch square.
	lbs.	lbs.
1. English Oak, from King's Langley	482	964
2. Norway yellow fir, from Long Sound	396	792
3. Riga oak, (wainscot,)	357	714
4. Christiana white spruce	343	686
5. American pine, from Quebec	329	658
6. White spruce fir, ditto	285	570
7. English oak, from Godalming	218	436
Other trials of strength were as follows, the size of the specimens being the same.		
1. Alice-Holt forest oak, full-grown timber, 1st specimen	455	910
2. Dantzic yellow fir	435	870
3. Alice-Holt forest oak, full-grown timber, 2d specimen	405	810
4. Christiana yellow fir	370	740
5. Archangel ditto	330	660

223. An account of the specific gravity, strength, and deflection of the several kinds of Foreign Fir, as found by Mr. Peter Barlow, by experiments made under his inspection, from timber supplied from his Majesty's Yard, at Woolwich, and delivered in evidence before the Committee on the Timber Trade, by Sir Robert Seppings.

The pieces tried were eight feet long, two inches square, supported by props seven feet apart, and had the weight placed in the middle of each piece.

Names of the Woods.	Average specific gravity.	Breaking weight.	Ultimate deflection.	Strength of a piece one foot long, and one inch square.
		lbs.	inches.	lbs.
American red pine	.657	511	5.82	447
New-England fir, or yellow pine	.553	420	4.66	367
Riga fir	.753	422	6.00	369
Norway spar	.577	655	4.00	573

224. The following series of experiments were made by Mr. George Buchanan, Civil Engineer, of Edinburgh, before the students of the School of Arts of that city. They were made with a peculiar apparatus he had constructed for the purpose, on the principle of the hydrostatic press. The experiments on timber were made on bars of Memel fir, supported at the ends, and the force applied at the middle of the length

From the evidence afforded by his experiments, Mr. Buchanan is satisfied that it is unsafe to load a beam with more than half the weight that would break it. Hence, when we say it should be loaded with one-fourth of the breaking weight only, the allowance is only double that required for absolute safety.

Description of the Specimens.	Distance between the Supports.	Weight that broke the Specimen.	Weight that would break a piece one foot long, and one inch square.
	ft. in.	lbs.	lbs.
1. A bar of Memel fir, 2 inches square	5 0	595	372
2. Another bar, 2 inches square	5 0	510	318
3. A bar, 3 inches broad, and 2 inches deep, laid on its side	5 0	850	354
4. Another bar, 3 inches by 2, but laid on its edge	5 0	1190	330
5. A bar, 4 inches by 2	5 0	1037	324
6. A bar, 2 inches by 3	5 0	1020	283
7. A bar of cast-iron, 1 inch square	2 8	770	2053
8. A bar of cast-iron, 2 inches by 1, laid on its side	2 8	1530	2040

225. We have next to detail an interesting series of experiments made by Mr. George Rennie, on bars of cast-iron, in which all the bars had the same area of section, but differently formed; consequently, these experiments show, at once, the advantage to be derived by adopting different forms for the sections of beams.

The bars were supported at the ends, and loaded in the middle, all the bars were cast from the cupola.

The last column in this, as well as in the preceding tables, we have calculated, and added for the purpose of rendering the experiments available in calculation, the mode of doing which we have shortly to describe.

Description of the Cast-Iron Bars.	Distance of Supports.	Weight that broke the piece in lbs.	Weight that would break a piece one foot long, and one inch deep, of the same proportions as the specimen.
	ft. in.		lbs.
1. A bar of 1 inch square	3 0	897	2691
2. Do. do.	2 8	1086	2896
3. Half the above bar	1 4	2320	3093
4. A bar of 1 inch square, the force acting in direction of the diagonal	2 8	851	802
5. Half the above bar, do.	1 4	1587	748
6. Bar of 2 inches deep by $\frac{1}{2}$ inch thick; or the depth to the breadth as 4 to 1	2 8	2185	728
7. Half the above bar, do.	1 4	4508	751
8. Bar 3 inches deep, by $\frac{1}{3}$ inch thick; or the depth to the breadth as 9 to 1	2 8	3588	354
9. Half the bar, do.	1 4	6854	338
10. Bar 4 inches, by $\frac{1}{4}$ inch thick; or the depth to the breadth as 16 to 1	2 8	3979	166

Description of the Cast-Iron Bars.	Distance of Supports.	Weight that broke the piece in lbs.	Weight that would break a piece one foot long, and one inch deep, of the same proportions as the Specimen.
	ft. in.		lbs.
Sections, equilateral triangles, tried with the angle up and down.			
11. Edge or angle up	2 8	1437	1660
12. ——— angle down	2 8	840	970
13. Half the first triangular bar, angle up	1 4	3059	1770
14. Half the second triangular bar, angle down	1 4	1656	960
15. A feather-edged, or ⊥ bar, cast of these dimensions, viz. 2 inches deep by 2 wide, tried with the edge up	2 8	3105	1035

Mr. Rennie remarks on the system of giving depth to the bar, and making it thin, that it could not be extended much further than the proportion of sixteen parts in depth to one in breadth; but even this must be received with limitation, for it is noticed in Tredgold's Carpentry, page 32, that the increase of depth must depend also on the length of the beam, and a rule is there given to fix the best proportion for wooden beams. It will not fail, however, to attract the attention of the reader to find that a bar four inches deep, and one-fourth of an inch thick, will carry nearly four times as much as a bar of an inch square, though the quantity of material is the same in both cases.

226. The next object of the experiments was to ascertain how far a variation of the form of the bar in the direction of its length affected the result; and it was found that when the bar was four inches deep, and one-quarter of an inch thick, and its side a semi-ellipsis, the bearings being 2 feet 8 inches apart as before, it broke with 4000 lbs. in the middle; hence it is evident, that, by reducing the outline of the depth, at different parts of the length, to the shape of an ellipsis, no strength is lost, for the bar of uniform depth broke with 3979 lbs. Another bar was formed into a parabolic shape on its lower edge, the section of the bar and the distance of the bearings being the same as in the preceding trial. The parabolic bar broke with 3860 lbs.

227. Other trials were made with bars fixed and supported in different ways, and which agreed with the results of theoretical calculation, as far as the bars fixed at one end were concerned; but the bar fixed at both ends, it seems, was not perfectly secured at the ends, and hence we infer that, as no material increase of strength was gained in this way, by the fixing adopted in an experimental trial, it is not right to calculate upon much accession of strength by such a method in practical cases, when the fixing the ends firmly is a greater difficulty.

Rules for the Transverse Strength.

228. In the preceding tables, the last column shows the weight that would break a beam, or bar, one foot long and one inch square, and as the strengths of rectangular beams are as the breadths multiplied into the square of their depths directly, and as the length inversely, we have this proportion:

As the weight that will break an inch-bar, one foot long,
Is to the length of the given beam in feet,
So is any given weight
To the breadth multiplied into the square of the depth of the beam it would break.
And *one-fourth* only of the breaking-weight should be the total load on the beam in practice.

229. If the load on the beam be distributed over the whole length of it, the effect will be the same as if *half* that load were collected in the middle.

EXAMPLES.

230. Suppose the floor of a warehouse has to support 4 cwt. on each square foot, and that it is to be supported by girders 16 feet long, and 8 feet apart, from middle to middle, what must be the size of the girders of Memel fir?

The area supported by each girder is $16 \times 8 = 128$ feet, and it is to be loaded with 4 cwt. or 448 lbs. on each square foot; therefore, the total load is—

$$\begin{array}{r} 128 \\ 448 \\ \hline 1024 \\ 512 \\ 512 \\ \hline 57344 \text{ lbs.} \end{array}$$

The stress at the middle will be the same as if half that weight were collected there, that is equal to

$$\begin{array}{r} 2)\,57344 \\ \hline 28672 \text{ lbs.} \end{array}$$

The weight that will break an inch piece, one foot long, of Memel fir, is about 330 lbs. therefore, by the rule,

$$330 : 16 :: 28672 : 1390 = \text{the breadth multiplied into the square of the depth.}$$

$$\begin{array}{r} 28672 \\ 16 \\ \hline 172032 \\ 28672 \\ \hline 330 \left\{ \begin{array}{r} 3,0)\,45875,2 \\ \hline 11)\,15292 \end{array} \right. \\ \hline 1390 \end{array}$$

The above would give the size of the beam that would break with the weight; and four times the sum, or $4 \times 1390 = 5560$ is the product that would arise from multiplying the breadth into the square of the depth for a beam to support that weight. If we say the depth must be 17 inches, then 5560 divided by the square of 17, will be the breadth: thus,

```
 17
 17
---
119
17
---
289) 5560 (19 inches the breadth.
     289
     ----
     2670
     2601
     ----
     ..69
```

From this calculation it appears, that a beam, 17 inches deep, and 19 inches in breadth, would be sufficient for the purpose; but any other depth may be fixed upon, and the breadth found in the same manner.

231. *Example* 2.—Let it be required to find the weight a beam of oak will break with when applied at the middle of its length, the length of the beam between the supports being 14 feet, its breadth 6 inches, and its depth 10 inches.

```
The square of the depth is 10 × 10 = 100
And the breadth ..................    6
                                    ---
                                    600
```

The second specimen of Alice-Holt Forest oak broke with 810 lbs.; therefore, reversing the order of the rule, we have this proportion—as the length : weight that broke the specimen :: breadth multiplied by the square of the depth : weight that would break the beam; that is,

14 feet : 810 lbs. :: 600 : 34714 lbs. the *Answer*.

```
             600
          ------
   ⎧ 2) 486000
14 ⎨    ------
   ⎩ 7) 243000
        ------
         34714
```

In cases of this kind, the fractions may always be neglected; it is quite sufficient to determine within a few pounds of the weight for any practical case; to attempt minute accuracy is mere affectation, since it will be seen that no two specimens were of the same strength exactly, though very nearly so.

232. *Example* 3.—Let it be required to determine the weight that would break a beam of cast-iron, the length between the supports being 26 feet, the breadth 1 inch, and the depth 18 inches, the weight being applied at the middle

The square of the depth is $18 \times 18 = 324$. And, by Mr. Buchanan's experiments, a specimen, 1 foot long, breaks with 2053 lbs.; therefore,

$$
\begin{array}{rrrrrrrl}
26 & : & 2053 & :: & 324 & : & 25583 \text{ lbs. the } \textit{Answer}. \\
 & & 324 & & & & \\
\hline
 & & 8212 & & & & \\
 & & 4106 & & & & \\
 & & 6159 & & & & \\
\hline
 & 26) & 665172 & (25583 \text{ lbs.} & & & \\
\end{array}
$$

The weight it might be loaded with in the middle, in practice, would be one-fourth of this weight, or—

$$
\begin{array}{r}
4)\,25583 \\
\hline
6396 \text{ lbs.}
\end{array}
$$

But if the load were distributed over the length, in an uniform manner, it would bear twice as much, with safety, or 12792 lbs.

Such a piece of cast-iron is sometimes put between two pieces of timber for a girder; hence, from the latter number, we can easily find what distance the girders should be apart to be perfectly safe. It has been shown in "Tredgold's Essay on the Strength of Iron," that the greatest probable load on a floor, including its own weight, is 160 lbs. per square foot; and the width is 26 feet, hence $26 \times 160 = 4160$ lbs. for the greatest stress on each foot in length of the floor; therefore—

$$
\begin{array}{rl}
416,0)\,1279,2 & (3 \text{ feet, the distance apart.} \\
1248 & \\
\hline
31 &
\end{array}
$$

If the iron part of the girder were two inches thick, the distance apart might be six feet, or twice as much; and, with three inches thick, they might be nine feet apart.

We have seen very serious mistakes committed in making cast-iron girders too weak, which a very little calculation would have prevented.

233. When beams are formed perfectly similar to the Specimens in the Table, *Art.* 225, the strength will be as the cube of the depth. Thus, a feather-edged bar, of the proportions described in No. 15 of that Table, may be found to support a given weight. Let the weight to be supported be 25583 lbs., and the length between the supports 26 feet, then taking the number 1035 from the Table, we have—

$$
\begin{array}{rrrrrrrl}
1035 & : & 26 & :: & 25583 & : & 642 = \text{the cube of the depth; and the} \\
 & & & & 26 & & \\
\hline
 & & & & 153498 & & \\
 & & & & 51166 & & \\
\hline
 & & & 1035) & 665158 & (642 & \\
\end{array}
$$

cube-root of 642 is nearly $8\frac{1}{4}$ inches for the depth of the bar; and its base should be of the same breadth as the depth.

Of the Stiffness of Beams.

234. Stiffness, or the power of resisting flexure, is measured by the force required to produce a given minute change of form. For beams similarly fixed, it is directly proportional to the breadth and the cube of the depth, and inversely, to the cube of the length. Thus, a beam, or bar, two yards long, will be equally stiff with a beam one yard, provided that it be either twice as deep, or eight times as broad. If the ends of a beam can be firmly fixed, by continuing them to a sufficient distance, and keeping them down by a proper pressure, the stiffness will be nearly four times as great as if the ends were simply supported. A hollow substance, of given weight and length, has its stiffness nearly proportional to the square of the diameter: and hence arises the great utility of tubes when stiffness is required; this property being still more increased by the expansion of the substance than the ultimate strength. It is obvious, that there are a multiplicity of cases in Carpentry where stiffness is of more importance than any other property; since the utility as well as beauty of the fabric might often be destroyed by too great a flexibility of the materials.

Numerous experiments have been made on the force necessary to bend a beam a given quantity, and from these we propose to select sufficient to obtain the proportion for each species of wood in use.

235. The following experiments on the force required to bend bars of different kinds of wood half an inch in the middle, when the bars were supported at the ends, in a horizontal position, on supports two feet apart, we have selected from the *Minutes of Evidence* before a Committee of the House of Commons, on the Timber Trade, page 22. These trials were made on the same specimens as we have already given the breaking weight for, in *Art.* 222. The evidence was given by Mr. John White, but it appears that the experiments were made by Mr. Tredgold.

	Description of Specimens.	Bent half an inch in the middle, by	Weight that would bend a piece one foot long and one inch square one-fortieth of an inch.
		lbs.	lbs.
1.	English oak, from King's Langley	237	94
2.	Yellow fir, from Longsound, in Norway	261	104
3.	Riga oak (wainscot)	233	93
4.	Christiana white spruce	261	104
5.	American pine, from Quebec	237	94
6.	White spruce fir, from Quebec	180	72
7.	English oak, from Godalming	103	41

236. The following experiments, by Mr. Buchanan, on the stiffness of bars of Memel fir and of cast-iron are important. The specimens were supported at the ends and loaded in the middle; and the effect of a successive increase of weight is shown.

Description of the Specimens, and Remarks on the effects observed on removing the Weights.	Distance of supports in feet.	Quantity the bar bent in inches.	Weight that bent it, in lbs.	Weight that would bend a piece one foot long and one inch square one-fortieth of an inch.
	feet in.		lbs.	lbs.
1. A bar, 2 inches square, of Memel fir	5 0	$\frac{1}{2}$ inch	170	66
Returned straight....	....	1	357	
Set with a bend of $\frac{1}{8}$th	....	1 $\frac{1}{2}$	442	
		$1\frac{7}{10}$	510	
		broke	595	
2. Another bar, 2 inches square, of do.	5 0	$\frac{1}{2}$ inch	170	66
Returned straight....	....	1	344	
Set with a bend of $\frac{1}{8}$th	....	$1\frac{1}{2}$	450	
		broke	510	
3. A bar of do., 2 inches in depth and 3 inches in breadth............	5 0	$\frac{1}{2}$ inch	255	63
		1	527	
		began to crack	680	
		broke	850	
4. Another bar of do., 3 inches deep and 2 inches in breadth	5 0	$\frac{1}{2}$ inch	357	41
Returned straight....	....	1	722	
Set with a bend of $\frac{1}{16}$th	....	$1\frac{1}{2}$	1045	
		2 inches, & broke	1190	
5. A bar of do., 2 inches deep and 4 inches broad	5 0	$\frac{1}{2}$ inch	340	66
		1	654	
		$1\frac{1}{2}$ inch, & broke	1037	
6. A bar of cast-iron 1 inch square	2 8	$\frac{1}{4}$ inch	357	677
Set with a bend of $\frac{1}{16}$th	....	$\frac{1}{2}$	765	
		broke	770	
7. A bar of cast-iron, 2 inches in breadth and 1 inch in depth....	2 8	$\frac{1}{4}$ inch	714	677
Set with a bend of $\frac{1}{16}$th	....	$\frac{3}{8}$	1062	
		broke	1530	

237. In carpenters' work it is obvious that a long beam may have a greater degree of bending than a short one, and yet be as fit for its purpose; hence, if we allow the quantity of bending of a beam in its place to be proportional to its length, the absolute stiffness being as the cube of the length, the comparative stiffness will be as the square of the length; and the last column in each of the preceding Tables shows the stiffness of a bar one foot long and one inch square, from whence that of any other sized beam may be obtained by proportion, as follows:

As the square of the length, in feet,
Is to the weight supported by the inch bar, one foot long,
So is the breadth multiplied into the cube of the depth
To the weight the beam should support.

238. In this proportion, the load or weight is supposed to be applied in the middle; but, if it be distributed regularly over the beam, eight-fifths of the weight found by the proportion would be sustained with an equal degree of bending.

EXAMPLES.

239. *Example* 1.—Required the weight a beam of Memel fir will support in the middle, without bending more than one-fortieth of an inch for each foot in length, its length being 10 feet, and its depth 9 inches, and breadth $4\frac{1}{2}$ inches.

The square of the length is $10 \times 10 = 100$;
The cube of the depth multiplied into the breadth is $9 \times 9 \times 9 \times 4\frac{1}{2} = 3282\frac{1}{2}$;
And, by the table, the weight supported by an inch bar, is 66 lbs.

Therefore, $100 : 66 :: 3282\frac{1}{2} : 2166$ lbs. the *Answer*.

$$
\begin{array}{r}
3282\frac{1}{2} \\
66 \\
\hline
19695 \\
19695 \\
\hline
1{,}00)\ 2166{,}45\ (
\end{array}
$$

If the weight had been to be uniformly distributed over the length, then it should have been divided by 5, and multiplied by 8; thus,

$$
\begin{array}{r}
5)2166 \\
\hline
433 \\
8 \\
\hline
3464
\end{array}
$$

3464 lbs.—the weight that might be distributed.

240. *Example* 2.—If the distance between the supports of a bressummer of Memel fir be 12 feet, and that five-eighths of the weight of the wall and floors it has to support be found to be 9600 lbs., and its breadth 14 inches, it is required to find its depth, so that the bending may not exceed the quantity stated in the rule.

The weight an inch bar would support by the table, is 66 lbs.
The square of the length is $12 \times 12 = 144$; therefore.

$$66 \;:\; 144 \;::\; 9600 \;:\; 1496 = \text{the cube of the depth.}$$

$$\begin{array}{rr}
 & 9600 \\ \hline
 & 86400 \\
 & 1296 \\ \hline
\multirow{2}{*}{$66\left\{\begin{array}{r}6)\\ \\ 11)\end{array}\right.$} & 1382400 \\ \cline{2-2}
 & 230400 \\ \hline
\text{Breadth } 14\left\{\begin{array}{r}2)\\ \\ 7)\end{array}\right. & \begin{array}{r}20945 \\ \hline 10472\end{array} \\ \hline
 & 1496 \\ \hline\hline
\end{array}$$

The cube root of 1496 is nearly $11\frac{1}{2}$ inches, the depth required.

These examples will, perhaps, be sufficient to direct the reader how to apply the rules to some of the most important cases in practice; but, if he wishes for further information, he will find various examples and tables ready calculated in *Tredgold's Elementary Principles of Carpentry*.

For the ordinary purposes of building, it is not necessary to calculate the bending of beams of cast-iron, provided they be not loaded with more than one-fourth of the breaking weight; but it may be useful to know, that the rule for strength will produce the same result as the rule for stiffness, when the length of a cast-iron beam in feet, is four-thirds of the depth in inches; and this is a very good proportion for the depth. If the depth be less than in this proportion, a cast-iron beam will bend more than half an inch in a length of 20 feet; and, if the depth be greater, it will bend less, and must have its proportions fixed by the rules for strength.

In oak and fir, the reverse happens; for, unless the depth in inches be about double the length in feet, the bending is always greater than the proportion assigned in the rules for the stiffness of beams.

PRACTICAL

CARPENTRY, JOINERY, &c.

BOOK II.

JOINERY.

CHAPTER I.

INTRODUCTION.

1. JOINERY is the art of uniting and framing wood, for the internal and external finishing of buildings. In Joinery, therefore, it is requisite that all the parts should be much more nicely adjusted to each other than in Carpentry, and all the surfaces which are to be exhibited to the eye should be made perfectly smooth.

2. In early times, says the author of an article on this subject in the *Encyclopædia Britannica,* very little that resembles modern joinery was known; every part was rude, and joined in the most artless manner. The first dawnings of the art appeared in the thrones, stalls, pulpits, and screens, of our Gothic cathedrals and churches; and even in these, it is of the most simple kind, and is indebted to the carving for every thing that is worthy of regard. Whether, in these ages, the carver and the joiner had been one and the same person, we cannot now determine, though we imagine, from the mode of joining in some of them, that this was the case.

During several centuries joinery seems to have been gradually improving, but nothing appears to have been written on the art before 1677, when Mr. Joseph Moxon, a Fellow of the Royal Society, published a work, entitled '*Mechanic Exercises, or the Doctrine of Handy-works.*' In this work the tools and common operations in joinery are described, with a collection of the terms then in use. It must have been a valuable work at that time, but to one who could previously work in the art it would convey little, if any thing, that was new. Sash-windows were introduced into England some time before the date of Moxon's work, but he has not noticed them. According to the observations of Dr. Thomson, this important improvement has not yet found its way into Sweden.—(*Travels in Sweden,* p. 8.)

About the beginning of the last century, several works on Joinery, of a most interesting description, made their appearance; and forms began to be introduced in architecture, which could not be executed at a moderate expense without the aid of new principles, and these principles were discovered and published by practical joiners. As might naturally be expected, these authors had but confused notions, owing chiefly to their want of sufficient geometrical knowledge; and, accordingly, their methods are often obscurely described, and they are sometimes quite erroneous.

The hand-rails of stairs offered many difficulties, and an imperfect attempt to remove them was first made by William Halfpenny, in his *Art of Sound Building*, which was published in 1725. Francis Price, the author of the *British Carpenter*, published in 1733, was more successful, and his remarks show a considerable degree of knowledge of the true nature and object of his researches. The publication of Price's work, of which we have seen five editions, must have produced a considerable sensation among the joiners of that period, for it was soon followed by many other works of different degrees of merit. Of these, the works of Batty Langley, and Pain's works, were the most popular.

The establishment of the principles of Joinery in this country, on the sound basis of geometrical science, was, however, reserved for Nicholson. In his *Carpenter's Guide*, and *Carpenter's and Joiner's Assistant*, published in 1792, he made some most valuable corrections and additions to the labours of his predecessors.

3. Corresponding improvements were also made in the practice of joinery, for which we are much indebted to the late Mr. James Wyatt, and the other branches of his family. That celebrated architect kept together some of the best workmen in London, and these were looked up to with a degree of emulation, by young men, which had a most beneficial effect on the progress of joinery. But the art is still far short of perfection. We conceive that many of those operations, on which the soundness of work chiefly depends, might be done with greater exactness, and less labour, by improving the tools used for these purposes, or by the invention of new methods of performing such operations.

4. The true geometrical principles of joinery were published in France at a much earlier period than in England, and by a very different class of writers. The extensive work of Frezier, entitled *Coupé des Pierres et des Bois*, in 3 vols. 4to. 1739, contains all the leading principles of the art, and explained with tedious minuteness; offering a striking contrast to the brevity of our English authors. The first elementary work on that part of geometrical science, which contains the principles of joinery, appeared in France, in 1795, from the pen of the celebrated Gaspard Monge, who gave it the name of *Géometrie Descriptive*. Much of what has been given as new in English works, had been long known on the Continent; but there does not appear to have been much, if any, assistance derived from these foreign works by any writer prior to Nicholson.

Rondelet's Treatise on the Art of Building, (*L'Art de Bâtir,*) published in 1814, contains a very good treatise on Joinery; but the latest French work we have seen on the subject is that of Krafft, published in 1820, in large folio, and in three languages. The English part very imperfect, and the whole work full of pretension which it never realizes. Rondelet's is decidedly the best French work on the subject we have seen; but it is not at all adapted to the state of joinery in England. In practice, the French joiners are very much inferior to our own. Their work is rough, slovenly, and often clumsy; and, at the best, is confined to external effect. The neatness, soundness, and accuracy, which are common to every part of the works of an English joiner, are scarcely to be found in any part of the works of a French one. The little correspondence, in point of excellence, between their theory and practice, leads us to think that their theoretical knowledge is confined to architects and engineers, instead of being diffused among workmen as it is in this country.

Definitions.

5. The wood employed in Joinery is in the state of BOARDS, PLANKS, and BATTENS; thus distinguished according to their breadths: BATTENS are from two to seven inches wide; BOARDS, from seven to nine inches; and PLANKS, from nine inches to any indefinite breadth.

The OPERATIONS of JOINERY consist in making surfaces of various forms; also of GROOVING, REBATING, MOULDING, MORTISING, and TENONING.

6. SURFACES, in Joinery, may be either plane or curved; but they are most frequently plane. Every kind of surface is first formed in the rough, and then finished by means of various appropriate tools.

7. GROOVING and REBATING consist in taking or abstracting a part which is every where of a rectangular section. A REBATE is formed close to the edge of a piece; and a GROOVE, at some distance from the edge.

8. A MORTISE is a cavity formed within the surface, for the purpose of receiving the end of a piece of timber, to be joined at a given angle. The end, which must be very nicely fitted into the mortise, in order to make the two pieces as strong as possible, is called a TENON. As the sides of the mortise are generally perpendicular to the sides of the piece, and at some distance from the sides of the piece in which the mortise is, a tenon is generally stopped by projecting sides, which are closely fitted upon the side of the piece of wood in which the mortise is made; and the parallel faces of both are made flush, and so closely united, as to appear almost like one single piece. That part of the surface of the piece which has the tenon, which comes in contact with the surface of the piece in which the mortise is made, is called the *shoulder* of the tenon.

9. FRAMES are joined together, so as most frequently to form a rectangle, with one, two, or more, rectangular openings: these openings are closed with thin boards, fitted into grooves in the interior edges of the frame, called PANNELS. In ornamental work, the edges of the frame next to the pannels, are moulded. The two outer vertical pieces of the frame, are denominated the STILES; all the cross-pieces are denominated RAILS; and the vertical pieces, that separate the pannels, MOUNTINGS; or, in Gothic work, MULLIONS.

10. PLANKS and BOARDS are joined together by planing the edges straight and square, and rubbing them together with hot glue until the glue has been almost forced out of the joint; then the ends and the proper faces being brought to their places, the rubbing is stopped, and, when the glue is quite dry, the two boards thus fixed will be almost as strong as one entire board.

11. MOULDINGS have several names, according to their forms, connection, situation, or size. When the edge of a thin slip of wood is semi-circular, it is said to be *rounded*. *Figure 2, plate XLIII,* represents the section of a piece rounded on the edge.

When a semi-cylinder is formed on the edge of a piece of wood, within both surfaces, so that the diameter may be parallel to one side, this semi-cylinder is called a BEAD; and the recess, between the surface of the cylinder and the solid wood upon the side, which is parallel to its diameter, is denominated a QUIRK; and the whole part thus formed is called a BEAD and QUIRK.

Figure 3, *plate XLIII,* is the section of a piece of wood, where a bead and quirk is run on the edge.

12. A BEAD and DOUBLE QUIRK is when a three-quarter cylinder is formed on the edge, so that the surface of the cylinder may touch each adjoining face.

Figure 4 exhibits the section of a *bead* and *double quirk*.

13. A TORUS-MOULDING consists of a semi-cylinder, and two rectangular surfaces, one perpendicular to the diameter, and the other in the diameter produced.

Figure 5 is a *torus-moulding:* the small rectangular surface in the plane of the diameter is denominated a FILLET.

Figure 6 exhibits the section of a DOUBLE TORUS.

14. A FLUTE is the concave surface of the section of a cylinder or cylindroid, depressed within the surface of a piece of wood.

Figure 7 exhibits the section of a piece of wood with three *flutes* on it.

15. When a piece of wood is formed into two or more semi-cylinders, touching each other, the semi-cylinders are called REEDS, and the piece of wood is said to be *reeded*.

Figure 8 exhibits the section of a piece of wood with four *reeds* wrought upon it.

16. *Figure* 9 is the section of a moulding denominated an OVOLO or QUARTER ROUND. It consists of the fourth part of the convex surface of a cylinder.

17. *Figure* 10 is the section of a moulding called a CAVETTO, or hollow, consisting of the fourth part of the concave surface of a cylinder.

18. *Figure* 11 is the section of a CYMA-RECTA, consisting of a round and hollow joined together by one common tangent plane; the one part of the surface being concave, and the other convex.

This curve may be drawn when the parts are composed of parts of circles, by joining the extremities *a* and *c* of the moulding: bisect *ac* in the point *b*, and draw *de* parallel to the longitudinal direction of the moulding; make *ad* and *ce* perpendicular to *de*; from *d*, with the radius *da*, describe the arc *ab*; from *e*, with the radius *ce*, describe the arc *bc*; and *abc* is the moulding required.

But architects, most esteemed for their good taste, never draw the forms of mouldings by these mechanical methods; they always make them of the most beautiful figures they can by the hand; and, like the ancient Greek architects, they avoid circles for mouldings, in consequence of their want of variety, both of outline and of light and shade. Hence, though we give the usual mechanical methods, they are not here recommended to be used in practice.

Figure 12 is also the section of a *cyma-recta*, of which the concave and convex parts are equal portions of a circle, but each portion less than the quarter.

To draw this curve, join the extremities *a* and *b*, and bisect *ab* in *c*: from *a*, with the radius *ac*, describe an arc *ce*; and from *b*, with the radius *bc*; describe an arc, *cd*; from *c*, with the radius *ca*, describe an arc, *ae*, as also the arc *bd*. With the same radius, from the centre *e*, describe the arc *ac*; and with the same radius, from the centre *d*, describe the arc *cb*; then *acb* is the curve, which is the section of the surface of the moulding.

19. *Figure* 13 is the section of an OGEE moulding, sometimes called a CYMA-REVERSA: this moulding is of the same form as the cyma-recta, except that the concave portion of the moulding of the one is where it is convex in the other.

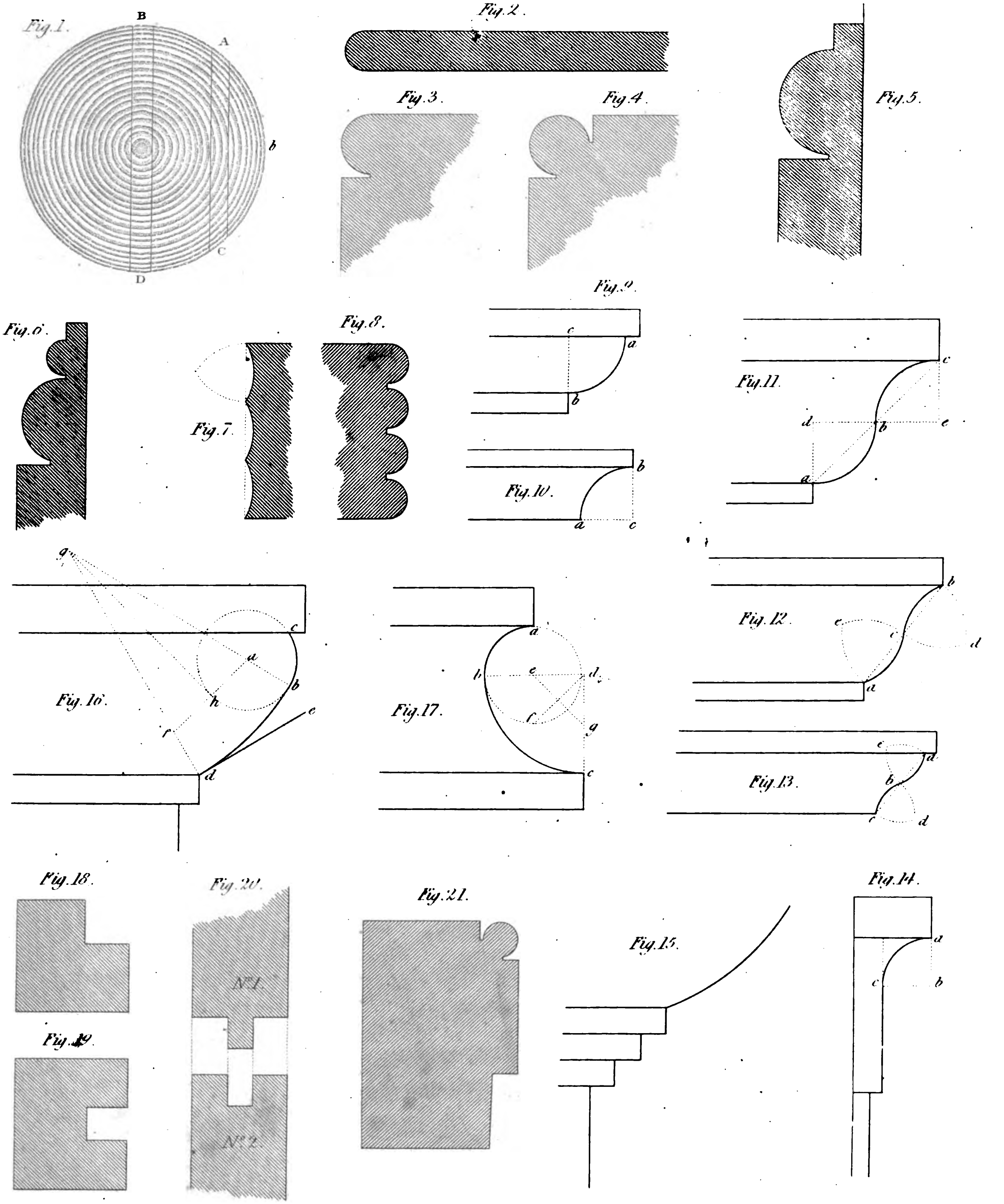
20. *Figure* 14 is the section of a moulding called a SCAPE, which is composed of the quarter of the circumference of a cylinder, and a plane surface, which is a tangent to the cylindric surface, in the line of their meeting.

21. *Figure* 15, part of the section of an *ovolo* with three *fillets*, which, when circular, or encompassing a column, are called ANNULETS.

Figure 16 is the section of a moulding denominated a QUIRKED OVOLO. This may be drawn thus: Suppose it were required to touch the line *de* at the point *d*: draw *dg* perpendicular to

JOINERY.

MOULDINGS.



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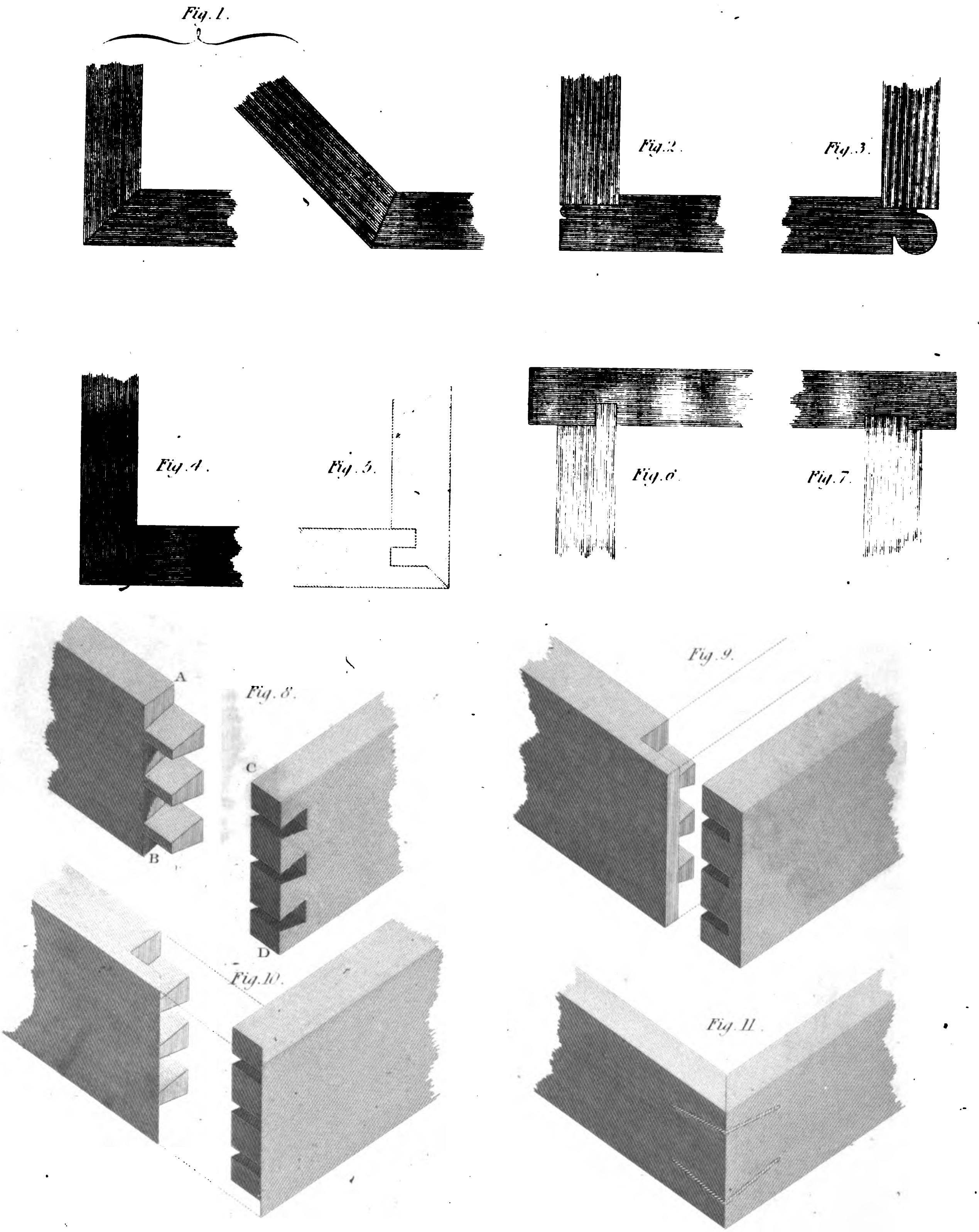
JOINERY.

FRAMING ANGLES.

PL. XLIV.



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R. Turrell.

de; describe the circle *bci*; make *df* equal to the radius of the circle *bci*, and join *af*. Bisect *af* by a perpendicular, *gh*, meeting *af* in *h*; then, with the radius *dg*, describe the arc *db*: *dbc* will then be the ovolo required.

22. *Figure* 17 is the section of a concave moulding called a Scotia. To form this moulding, describe the circle *dabf*, and draw *cd* perpendicular to the fillet. Make *cg* equal to the radius of the circle to be described, and let *e* be the centre of that circle: join *ge*, and bisect *ge* by the perpendicular *df*: from *d*, with the radius *dc*, describe the arc *cb*, and *cba* will be the scotia required.

23. *Figure* 18 represents the section of a piece of wood when it is said to be rebated. *Figure* 19, the section of a piece of wood said to be grooved. *Figure* 20, the sections of two pieces grooved and tongued together: where No. 1 shows the tongue, and No. 2 the groove, and these are so adapted to each other that they may be joined closely together. This method is used where it is required to join many boards together, so as to have the effect of one board, and prevent wind or air from coming through the joints between every two boards, without the risk of splitting, which would take place if the boards were glued together.

Figure 21 represents the section of a piece of wood said to be rebated and beaded.

FRAMING ANGLES.

24. When the length of a joint at an angle is not considerable, it is sufficient to cut the joint, so that when the parts are joined, the plane of the joint shall bisect the angle. This kind of joint is called a *plain mitre*, and is shown for different angles by *fig.* 1, *plate XLIV.*

25. When an angle of considerable length is to be joined, and the kind of work does not require that the joining should be concealed, *fig.* 2 is often employed; the small bead renders the appearance of the joint less objectionable, because any irregularities, from shrinkage, are not seen in the shade of the quirk of the bead.

A bead upon an angle, where the nature of the thing does not determine it to be an arris, is attended with many advantages; it is less liable to be injured, and admits of a secure joint, without the appearance of one. *Fig.* 3 shows a joint of this description. It is the method usually adopted for joining linings together at external angles.

26. *Figure* 4 represents a very good joint for an exterior angle, whether it be a long joint or a short one. It is employed for mitring dado together at external angles. The joint represented by *fig.* 5 is esteemed superior to it for long joints in the direction of the grain of the pieces, the parts being drawn together by the form of the joint itself, they can be fitted with more accuracy, and joined with more certainty. The angles of pilasters are often joined as in *fig.* 5.

27. Interior angles are commonly joined as shown by *fig.* 6. If the upper or lower edge be visible, the joint is mitred, as in *fig.* 1, at the visible edge only; the other parts of the joint being grooved, as in *fig.* 6.

In this manner are put together the skirting and dado at the interior angles of rooms, and the backs, and back-linings of windows, the jambs of door-ways, and various other parts of joiners' work.

Figure 7 shows the variation of this method which is used in rougher work, such as joining the angles of troughs, and the like. It is better adapted for a water-tight joint than one with a smaller groove.

28. *Figure* 8 represents an angle joined by common dovetails; the part AB represents the pins, and CD the dovetails.

29. *Figure* 9 shows the species called *lap dove-tailing*, in which the dovetails are concealed; it is used for portable desks, drawer-fronts, and other purposes. *Figure* 10 is another species of concealed dove-tailing, called *mitre dove-tailing*, the joint resembling a plain mitred joint. Tea-chests, work-boxes, and any kind of work requiring much neatness, is joined in this manner when it is not to be veneered.

30. *Figure* 11 shows the mode of joining a mitre-joint with keys: picture-frames and light boxes are frequently put together by this method.

The *figures* 8, 9, 10, 11, are drawn according to the mode of projection lately invented by Professor Farish, of Cambridge, and which he has so successfully applied to drawings of machinery. He calls it Isometrical Perspective, but it would be more correct to call it Isometrical Projection. In our treatise on Practical Architecture, which will form a volume similar to this, we propose to give a full account of Professor Farish's method.

PRINCIPLES OF FRAMING.

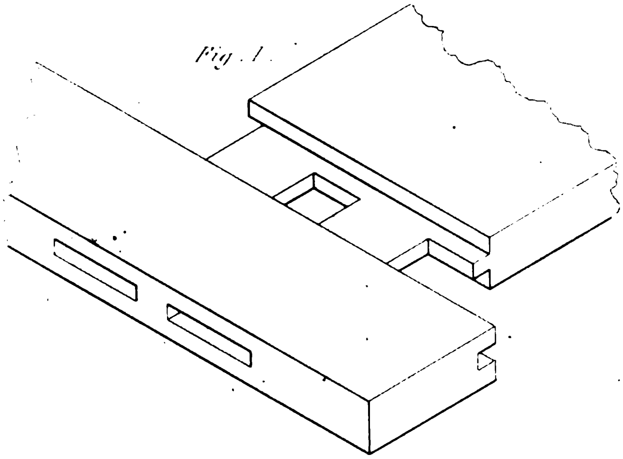
31. The goodness of Joiners' work depends chiefly upon the care that has been bestowed in joining the materials. In Carpentry, framing owes its strength to the form and position of its parts; but, in joinery, the strength of a frame usually depends wholly upon the strength of the joinings. The importance, therefore, of forming the joints properly, and fitting them together as accurately as possible, is obvious. Hence it is that we expect such accurate workmanship from a good joiner; and he not only should be able to connect his materials with truth and firmness, but also be able to make surfaces perfectly even and smooth, mouldings true and regular, and the parts intended to move, so that they may be used with ease and freedom.

32. Frames, in joinery, are usually connected by mortise and tenon joints, with grooves to receive pannels. Doors, window-shutters, &c. are framed in this manner. The object in framing is, to reduce the wood into narrow pieces, so that the work may not be sensibly affected by its shrinkage; and, at the same time, it enables us to vary the surface without the labour of cutting out for the depressed parts. From this view of the subject, the joiner will readily perceive that neither the parts of the frame nor the pannels should be wide. And, as the frame should be composed of narrow pieces, it follows that the pannels should not be very long, otherwise the frame will want strength. The pannels of framing should never be more than about fifteen inches wide, nor more than four feet long, and pannels so large as this should be avoided as much as possible. The width of the framing is commonly about one-third of the width of the pannel.

33. It is of the utmost importance in good framing, that the tenons and mortises should be truly made. After a mortise has been made with the mortise-chisel, it should be rendered perfectly even with a *float*;—an instrument which differs from a single cut, or float-file, only by having larger teeth, capable of being sharpened like a saw. An inexperienced workman often makes his work fit too tight in one place, and too easy in another; hence a mortise is often partially split in first driving the parts together, and the work is never afterwards firm; whereas, if the tenon fill the mortise equally in consequence of every part being accurately formed, the work will go together without using any considerable force in driving, and will be found to be firm and sound.

FRAMING.

Fig. 1.



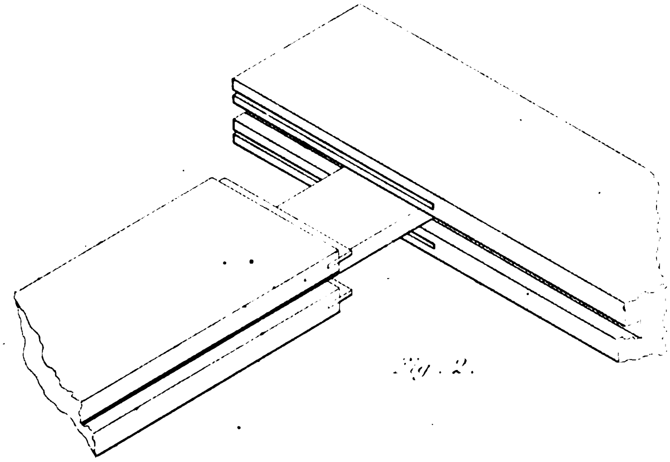


Fig. 2.

Fig. 3.

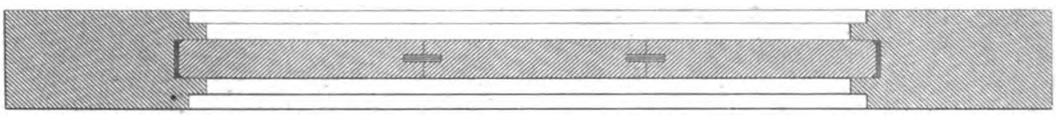


Fig. 4.

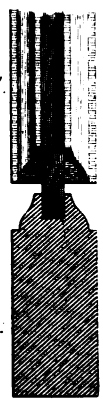


Fig. 5.

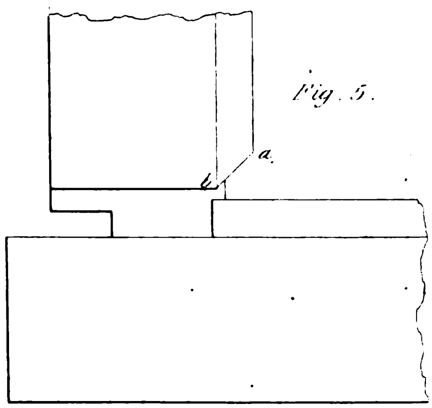


Fig. 6.

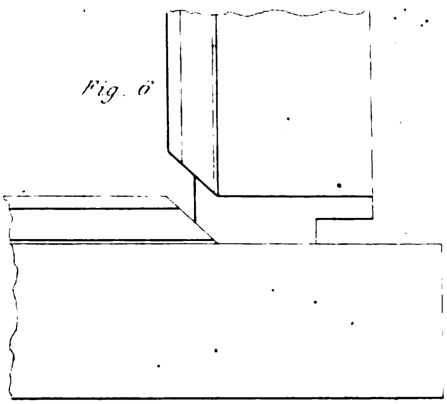


Fig. 8.

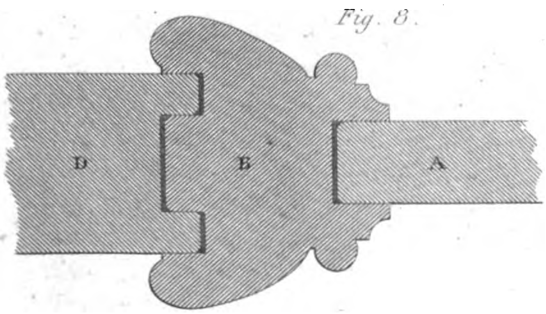
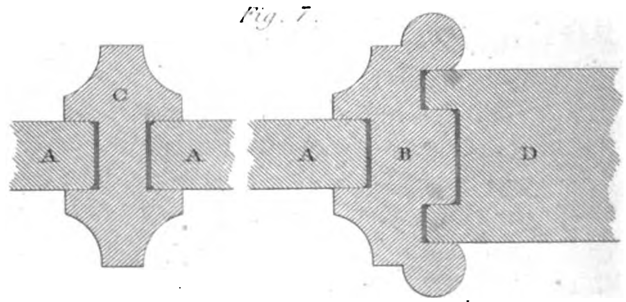


Fig. 7.



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44. The thickness of tenons should be about one-fourth of that of the framing, and the width of a tenon should never exceed about five times its thickness, otherwise in wedging, the tenon will become bent, and bulge out the sides of the mortise; therefore, if a rail be wide, two mortises should be made with a space of solid wood between. *Fig.* 1, *plate XLV,* shows the tenons for a wide rail.

35. In very thick framing, the strength and firmness of the joint is much increased by putting a cross or feather-tongue in the shoulder on each side of the tenon; these tongues are about an inch in length, and are easily inserted by means of a plough adapted for such purposes. The projected sketch (*fig.* 2.) shows a joint with these tongues put in, the stile having grooves ploughed to receive them. Sometimes, in thick framing, a double tenon in the thickness is made, but we give the preference to a single one, when tongues are put in the shoulders, as we have described; because a strong tenon is better than two weak ones, and there is less difficulty in fitting one than two.

36. The pannels of framing should be made to fill the grooves, so as not to rattle, and yet not so tight as to prevent the pannels from shrinking; for then there is much risk of their splitting. And where pannels are wide, and their thickness will allow of it, they should be glued up with *feather-tongues* in the joints, as represented in *fig.* 3.

37. When the edge of a frame next the pannel is moulded, there are two modes of making the joint at the moulding; the one called *Scribing,* and the other *Mitring.*

38. In scribing, the shoulder of the rail is cut to fit the moulding upon the stile as far as is deemed necessary. But it will be obvious that only some kinds of mouldings can be scribed together; where, however, the moulding will admit of it, scribing is the best method. To illustrate this mode of joining, *fig.* 4, *plate XLV,* represents the section of a stile with a rail scribed to fit the moulding. *Fig.* 5 shows the side of the frame. If the moulding, on the rail, be cut to a true mitre for the angle, as *a b,* and the portion be cut out neatly to the line where the plane of the mitre intersects the moulding, the recess so cut out will exactly fit the moulding on the stile. Scribed joints are also frequently used in fixing mouldings.

39. Joints, which cannot be scribed, are mitred, as represented in *fig.* 6; and, where a joint admits of both methods, they are sometimes both employed in the same joint.

40. When the mouldings of a frame project before the stiles and rails, it is sometimes found necessary to frame the mouldings round the pannels, and afterwards to fit the compartments of mouldings and pannels within the framing. In *fig.* 7, we have shown this method for Gothic framing having tracery; and, in *fig.* 8, its application to another case. The mouldings are grooved to fit tongues on the stiles and rails. The French make great use of this mode of obtaining depth for their mouldings.

In *fig.* 7, A is the pannel, B the moulding, C a mullion of the tracery, and D a stile or rail of the frame. In *fig.* 8, A is the pannel, B the moulding, and D the stile.

41. Where curved parts, or curved parts and straight ones have to be connected in a frame, so as to preserve a continuous line, the parts are either joined by bolts and nuts, by mortises and pins, or by keys. We propose to show an example of each of these methods in joining the parts of a Gothic window-frame. *Figure* 1, *plate XLVI,* shows part of the frame with the plan, at the joint of the mullion, A, and the jamb, B. The outer and inner parts of the frame are usually made in separate pieces, and tongued together. The arches which spring from the mullion may be screwed together, as shown by the dotted lines; the screw having two nuts with washers to them, and the nuts are inserted by mortices in the same manner as in bed-screws; a feather-tongue inserted in the joint prevents it being displaced. The joint at the top is

usually done in the same manner, but sometimes it is put together with a wooden key, tightened by wedges, as shown in the figure. The plan of the upper side of the joint is shown by *fig.* 2; and *fig.* 3 shows the section through the joint.

One mode of joining at the springing is shown by *fig.* 4; and another by *fig.* 5.

42. When thick planks are to be framed together, it is usual to mortise the opposite parts of the joint, and insert tenons; such tenons are generally termed keys. *Fig.* 6, *plate XLVI,* shows this mode of framing. A tongue is sometimes grooved into the joint. A and B show the sections of the parts to be joined.

43. Where both the surfaces are to be plain, and the width is considerable, boards are kept straight by clamping. A piece framed across at the end being called a *clamp.* The edge of the clamp is grooved to fit a tongue on the end of the board, and a tenon in the middle of the clamp, by which it is secured, at the middle only, by glue and wedges, this is the best mode of clamping; for then the board may expand and shrink without splitting. But frequently clamps are tenoned all along, and mitred at the angles, as shown in *fig.* 7; when this is done, the wood should be well seasoned.

GLUEING UP WORK.

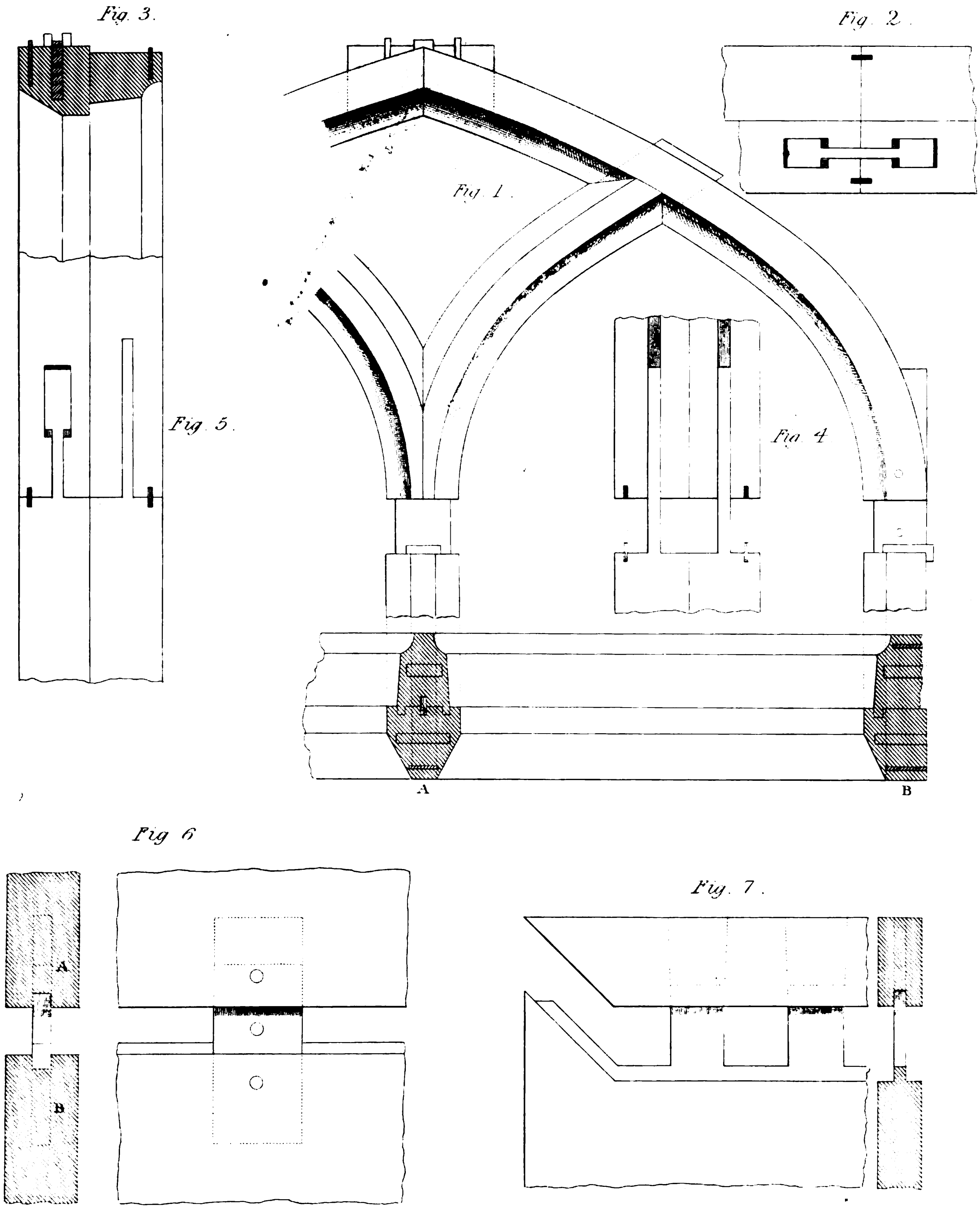
44. It is seldom possible to procure boards sufficiently wide for pannels without a joint, on account of heart-shakes, which open in drying; and, in cutting out pannels for good work, shaken wood should be carefully avoided. That part near the pith or centre of the tree is generally most defective. If the pannels be thick enough to admit of a feather-tongue in the joint, it is desirable that one should be inserted; for then, if the joint should fail, the surfaces will be kept even, and light be prevented from passing through the joint.

45. Sometimes plane surfaces, of considerable width and length, are introduced in joiner's work, as in dado, window-backs, jamblings, &c. Such surfaces are commonly formed of inch, or inch-and-quarter boards, joined with glue, and a cross or feather-tongue ploughed into each joint. When the boards are glued together, and have become dry, tapering pieces of wood, called keys, are grooved in across the back of the boards with a dove-tailed groove. These keys preserve the surface straight, and yet allow it to shrink and expand with the changes of the weather. *Fig.* 1, *plate XLVII,* shows the mode of inserting a key of this kind. AB is the section, DC the keyed-side, and EF a section through the key. Keys of this kind are inserted at about two feet, or three feet, apart; or, where only one is required, in the middle of the length.

46. In glueing up plane curved surfaces of greater length than the pieces of which they are formed, sometimes the joints are plain square ones; sometimes oblique, as in *fig.* 2; and not unfrequently of very complicated forms, as in *fig.* 3. We prefer an oblique joint, as in *fig.* 2.

Where surfaces of double-curvature, or curved both ways, are to be formed, the object is attained sometimes by projecting the parts one over another so as to produce the intended form, as in *fig.* 4. But in this plan there is both much waste of material and a great deal of labour, whether the surplus parts be removed before or after being glued together. The best method is to saw out the parts to be glued together to their proper form at once, and then glue them up. *Fig.* 5 shows the pieces together, when done by this method.

47. Our task would be endless, were we to attempt to describe all the methods that have been employed to glue up bodies of such varied forms as occur in joinery; and every joiner



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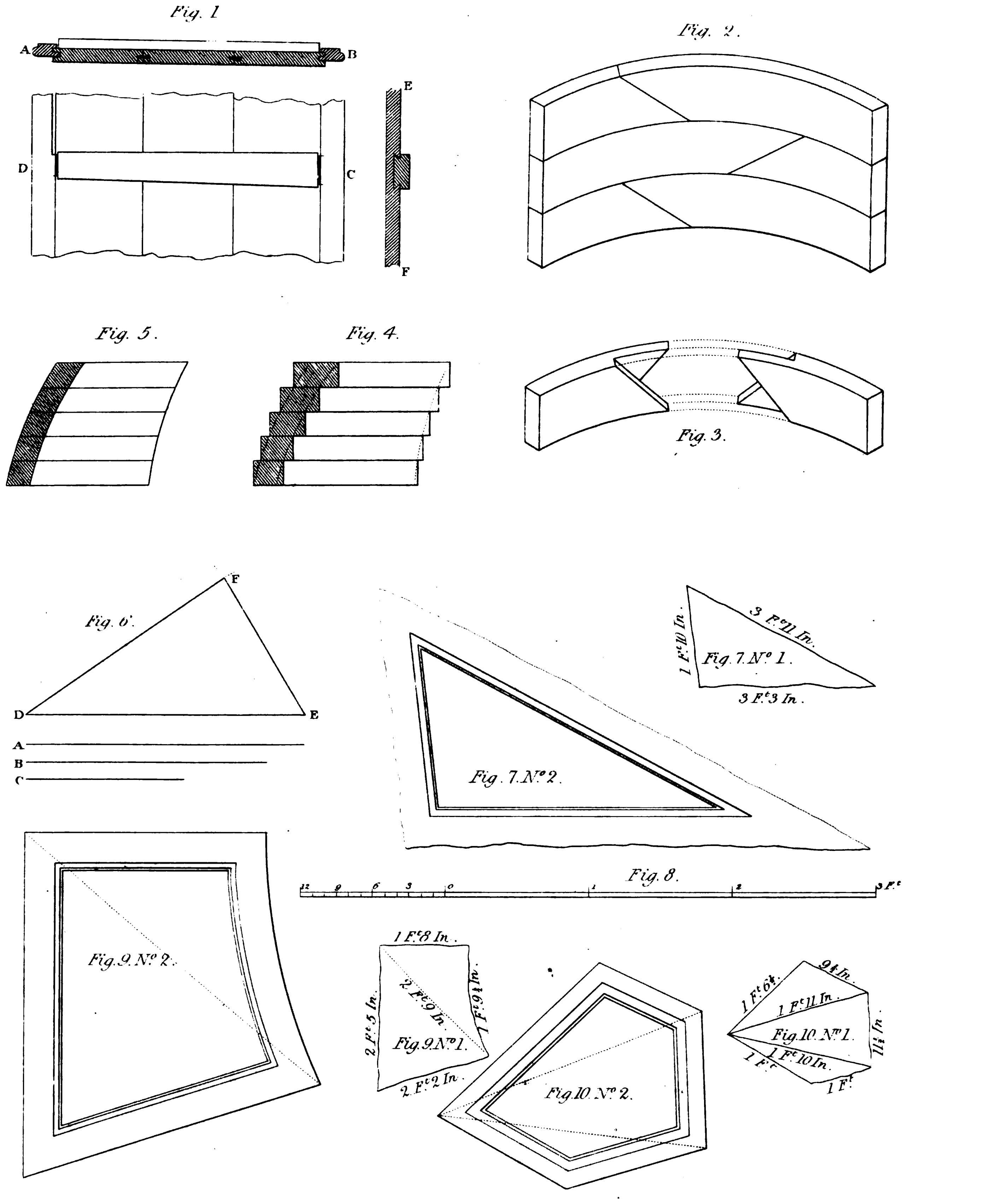
GLUEING UP WORK AND TAKING DIMENSIONS.



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forms methods of his own, and, merely from his being most familiar with his own processes, he will, following his own methods, do his work in a better manner than by strange ones, even if to an unprejudiced mind the methods he followed were evidently inferior.

The end and aim of a joiner, in all these operations, is to avoid the peculiar imperfections and disadvantages of his materials, and to do this at the least expense of time and wood. The straightness of the fibres of wood renders it unfit for curved surfaces, at least, when the curvature is considerable. Hence, short pieces are glued together as nearly in the form desired as can be, and the apparent surfaces are covered with thin veneers; or the work is glued up in pieces that are thin enough to bend to the required form. Sometimes a thin piece of wood is bent to the proposed form, upon a saddle or solid cylinder; and blocks are jointed, and glued upon the back; the whole is then allowed to become completely dry, and it will preserve the form that has been given to it by the saddle. But, when a piece of work is glued up in parts, it should be extremely well done; and, not as frequently happens with the joints black and irregular, and springing open in places. The difficulty of doing work of this kind well, has led to the trial of a variety of other methods.

48. If a piece of wood be boiled in water for a certain time, then taken out, and bent while hot into the proposed form, and it be retained in that form by screws or wedges till it be perfectly dry, it is found to preserve nearly the same figure that has been given to it. The quantity it springs back, when relieved, is not easily allowed for; and it is equally uncertain how long it may continue to return towards its natural straightness.

49. The same effect may be produced by steaming, as by boiling wood; and, indeed, more effectively. Both methods have been long practised, to a considerable extent, in the art of ship-building; but we are not aware that any general principles have yet been discovered either by experiment or otherwise, that would enable us to apply it with that degree of certainty and precision which is required in joinery. It has frequently been tried to bend wood by these means for the joiner's purpose, but we still want to know what relation there is between the curve to which it may be bent, and that which it will retain; and also the degree of bending we may with safety give to a piece of wood of a given thickness; for it clearly must not be bent so as to injure the grain of the wood.

The time that a piece of wood should be boiled or steamed, in order that it may be in the best state for bending, should also be made the subject of inquiry by experiment; and this being determined, the relation between the time and the thickness of the pieces should be ascertained.

For the purposes of joinery, we think that the process might be improved by saturating the pores of the convex side of each piece with a strong solution of clear glue immediately after bending it; for, by filling in this manner the extended pores, and allowing the glue to harden thoroughly before relieving the pieces, they would retain their shape better.

METHODS OF TAKING DIMENSIONS AND SETTING OUT WORK.

50. TAKING dimensions of plain square work is so simple, that we need not consider it; but, when irregular figures are to be framed, it requires more skill. The methods to be followed, in such cases, depend upon the method of describing a triangle, when its three sides are given. Thus, let ABC (*fig.* 6, *pl. XLVII,*) be the three given sides of a triangle; in any convenient

place draw the straight line DE, equal to the given line A, and from D, with the straight line B, as a radius, describe an arc at F; and, from E, with the straight line C, as a radius, describe another arc, cutting the former in F; join DF and EF: then will DEF be the triangle required. In order to take the dimensions of a place which is to receive a piece of framing, make an eye-sketch, as in *fig.* 7, No. 1; and upon each line mark the dimensions of the sides; then make a scale, *fig.* 8, and take the lengths of the sides from the scale; and, on No. 2, find the angular points of the triangle, as was done in constructing the triangle, *fig.* 6.

Having cut each piece of wood to its proper length, scribe each edge down to its place; then lay together the ends which are to meet, one piece being on the top of the other, and draw the shoulders of the joints. When the place which is to receive the framing consists of more than three sides, sketch the figure, as before; draw lines from one corner to every other corner, and mark the dimensions upon these lines, and the dimensions of each side of the figure upon its respective line. This is fully exemplified in *figures* 9 and 10, No. 2, in each figure, being set out from the same scale.

METHODS OF ENLARGING AND DIMINISHING MOULDINGS.

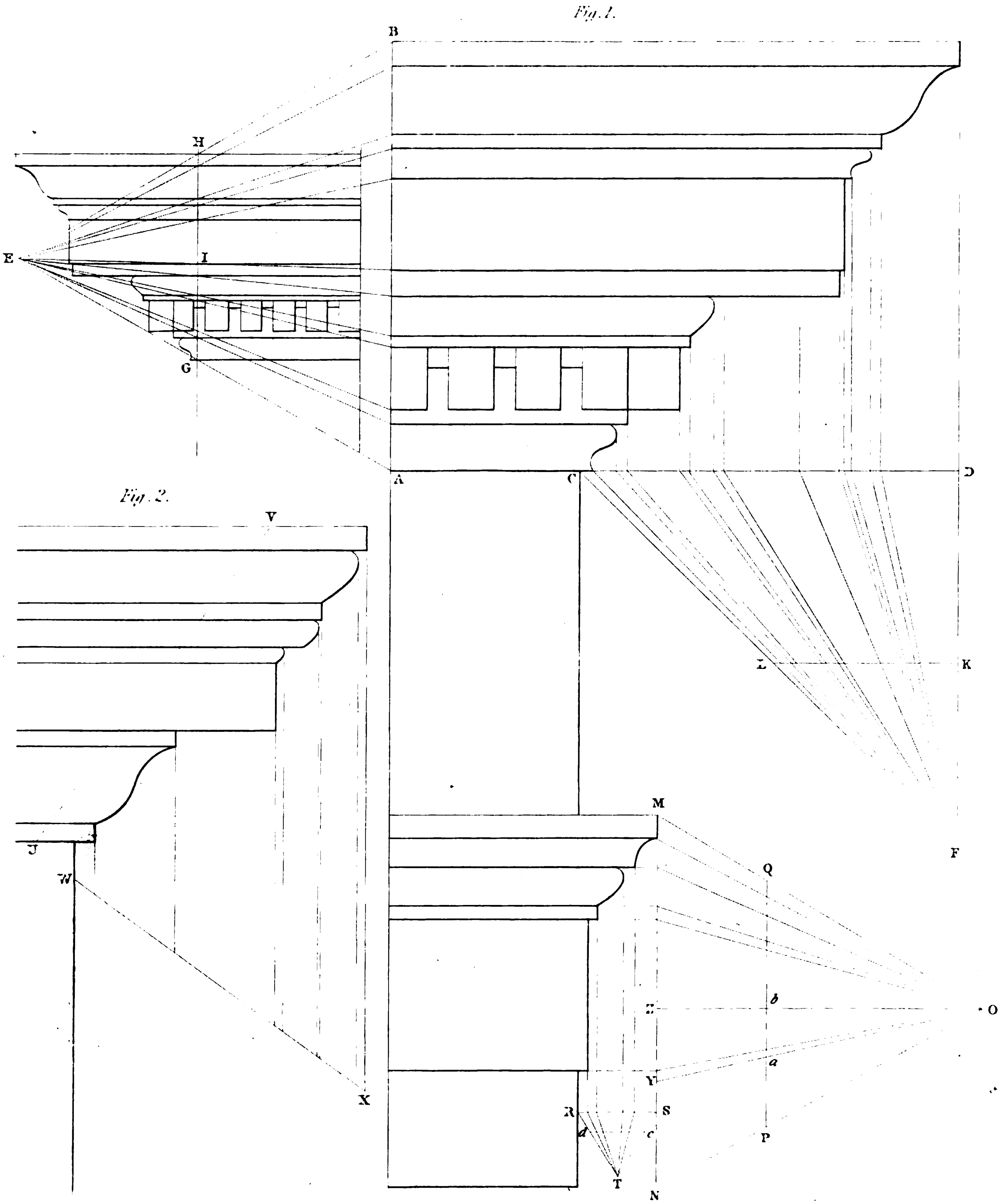
51. THESE methods depend entirely on the proportion which any two lines, of different lengths, have to one another, when divided in the same ratio.

Euclid proves, and indeed it is self-evident, that, if a line be drawn parallel to one side of a triangle, and if lines be drawn from the opposite angle, through any number of points taken in one of the parallels, to cut the other, these two parallels will be divided in the same ratio. This is one of the principles of proportioning cornices.

Another method of proportion, emanating from a similar principle, proved by the same geometrician, and which is equally evident, is, that when any number of straight lines are drawn parallel to one side of a triangle, so as to cut each of the other two sides in as many points, each of the two sides thus divided have their corresponding segments in the same proportion. Hence we have only to construct a triangle, which shall have two of its sides given; for, if the divisions in one of these lines be given, we may divide the other in the same ratio, by drawing lines parallel to the third side of the triangle: or, according to the first principle, if a straight line be drawn parallel to one side of a triangle, this straight line will divide the triangle into two similar triangles; therefore, if the triangle to be divided be equilateral, the smaller triangle, when divided, will also be equilateral. Therefore, if the divided line be greater than the undivided line, we have only to construct an equilateral triangle, and set the length of the undivided line from one of the angular points upon one of the sides, and draw a straight line through the point of extension, parallel to the side opposite to that angular point; then, placing the parts of the divided line on the greatest of the two parallel lines, we have only to draw lines, through the points of division, to the opposite angle, and the lesser parallel line will be divided in the same proportion.

52. Let AB, *fig.* 1, *plate XLVIII,* be the height of a cornice, divided by the height of the members into as many parts. Upon AB describe the equal sided on equilateral triangle ABE; from the points of division in AB draw lines to E. On the side EB or EA, of the triangle, make EH or EG equal to the height of the intended cornice, and draw GH parallel to AB; then GH will contain the heights of the members of the new cornice. The projections are found thus: AC, being the lower line of the cornice, produce AC to D; and, from all the points of

METHOD of ENLARGING and DIMINISHING MOULDINGS.



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projecture, draw lines perpendicular to CD, cutting CD in as many points as the lines thus drawn. The point D, being the extreme projecture, produce the line downwards from D to F, and make DF equal to the perpendicular of the equilateral triangle AEB. Draw lines from the divisions in CD to the point F. Make FK equal to the perpendicular EI, as terminated by the line HG, and draw KL parallel to CD, cutting all the lines drawn from the points of division in CD; then KL will contain the projectures of the new cornice, of which the height is GH: and thus, having the heights and projections of the members of the new cornice, it may be drawn by the usual methods.

The mouldings of the architrave are proportioned in the same manner. Thus, describing an equilateral triangle MNO; on the height, MN, of the architrave, produce the lines of division in the height to meet the line MN; from the points of division in MN draw lines to O, the apex. Make OQ equal to the height of the new or intended architrave, and draw PQ parallel to MN, and PQ will be divided in the same proportion as MN. To find the projections draw RS perpendicular to MN, and describe the equilateral triangle RST. From the points of projecture, in the lines dividing the height, draw lines parallel to MN, cutting RS, the side of the equilateral triangle. Draw lines from the divisions in RS to the opposite angle T. Any where in the line MN make YZ equal to the side RS of the equilateral triangle, and draw YO and ZO, cutting PQ in *a* and *b*. On the side TS, of the small equilateral triangle, make T*c* equal to *a b*, and draw *c d* parallel to RS; then *c d* will be divided in the same proportion as RS.

53. To Enlarge a Cornice, according to any given height: *Figure 2.* From any point, V, with a radius equal to the intended height of the cornice, describe an arc cutting the opposite edge in U; and the line VU, being drawn, will contain the heights of the members of the new cornice.

To find the Projections.—Draw any line, WX, perpendicular to UV, between the extreme vertical lines of projecture; and from all the extreme points of projecture, draw verticals to cut the line WX, which will be divided into the proper projections.

RAKING MOULDINGS.

54. When an inclined or raking moulding is intended to join with a level moulding, at either an exterior or an interior angle, the form of the level moulding being given, it is necessary that the form of the inclined moulding should be determined, so that the corresponding parts of the surfaces of the two mouldings should meet in the same plane, this plane being the plane of the mitre. It may be otherwise expressed, by saying, that the mouldings ought to mitre truly together.

If the angle be a right angle, the method of finding the form of the inclined moulding is very easy; and as it is not very difficult for any other angle, it will perhaps be best to give a general method, and to illustrate it by such examples as are of common occurrence.

55. *General method of describing a Raking Moulding,* when the angle and the rake, or inclination of the moulding is given. Let CBD, *fig.* 1, *plate XLIX,* be the plan of the angle of a building or other piece of work, which is to have a level moulding on the side BD, and this level moulding is to mitre with an inclined moulding on the side CB. Also, let ABD be the angle the inclined moulding makes with a level or horizontal line.

Produce DB to b, and draw Cb perpendicular to D b; also, make AC perpendicular to CB, and a C perpendicular to b C. Set off C a equal to C A, and join a b; then the inclined moulding must be drawn on lines parallel to b a. Draw EF perpendicular to DB, and let 1, 2, 3, 4, &c. be any number of points in the given section of the level moulding; from each of these points draw a line parallel to DE, to meet the line EF; also draw E c perpendicular to a b, and draw lines parallel to a b from each point to cut E c. Set off the points of division on EF, at the same distances, respectively, from the line E c as the corresponding points 1, 2, 3, 4, &c. are from the line EB, and through the points 1′, 2′, 3′, &c. draw the moulding. The moulding thus found will mitre with the given one; also, supposing the inclined moulding to be given, the level one may be found in like manner.

If the angle CBD be less than a right angle, the whole process remains the same, but when it is a right angle, CB coincides with C b, and the method of describing the moulding becomes the same as that usually given: as it does not then require the preparatory steps which are necessary when the angle is any other than a right angle. It having several times happened that we have had occasion to find the inclined moulding for octagonal buildings, we thought it desirable to give a method which suits for any angle whatever.

56. When a building with mouldings or a horizontal cornice, crowning the walls, has a pediment, with a similar cornice upon the rake, the upper mouldings are mitred together, so that the mitre-plane may be perpendicular to the horizon: the question then is, having the section of the one, how to find the section of the other. And, since in this case, the horizontal cornices are generally wrought first, the section of the horizontal moulding at the top is given, in order to find that of the pediment.

Therefore, in *fig.* 2, there is given the horizontal section, $a\,b\,c\,d\,e\,f\,g$, to find the section of the inclined moulding. Let the points a, b, c, d, e, f, g, be any number of points taken at pleasure; draw lines through these points, parallel to the rake; and, also, draw lines through the same points, perpendicular to the horizontal cornice, so that all shall cut any horizontal line in the points h, i, j, k, l, m, n. Transfer the distances between the points h, i, j, k, l, m, n, any where upon the raking line, to $h', i', j', k', l', m', n'$; and, from these points, draw lines perpendicular to the rake, cutting the inclined lines at the points, $a', b', c', d', e', f', g'$; then, through the points $a', b', c', d', e', f', g'$, draw a curve, which will be the section of the inclined moulding.

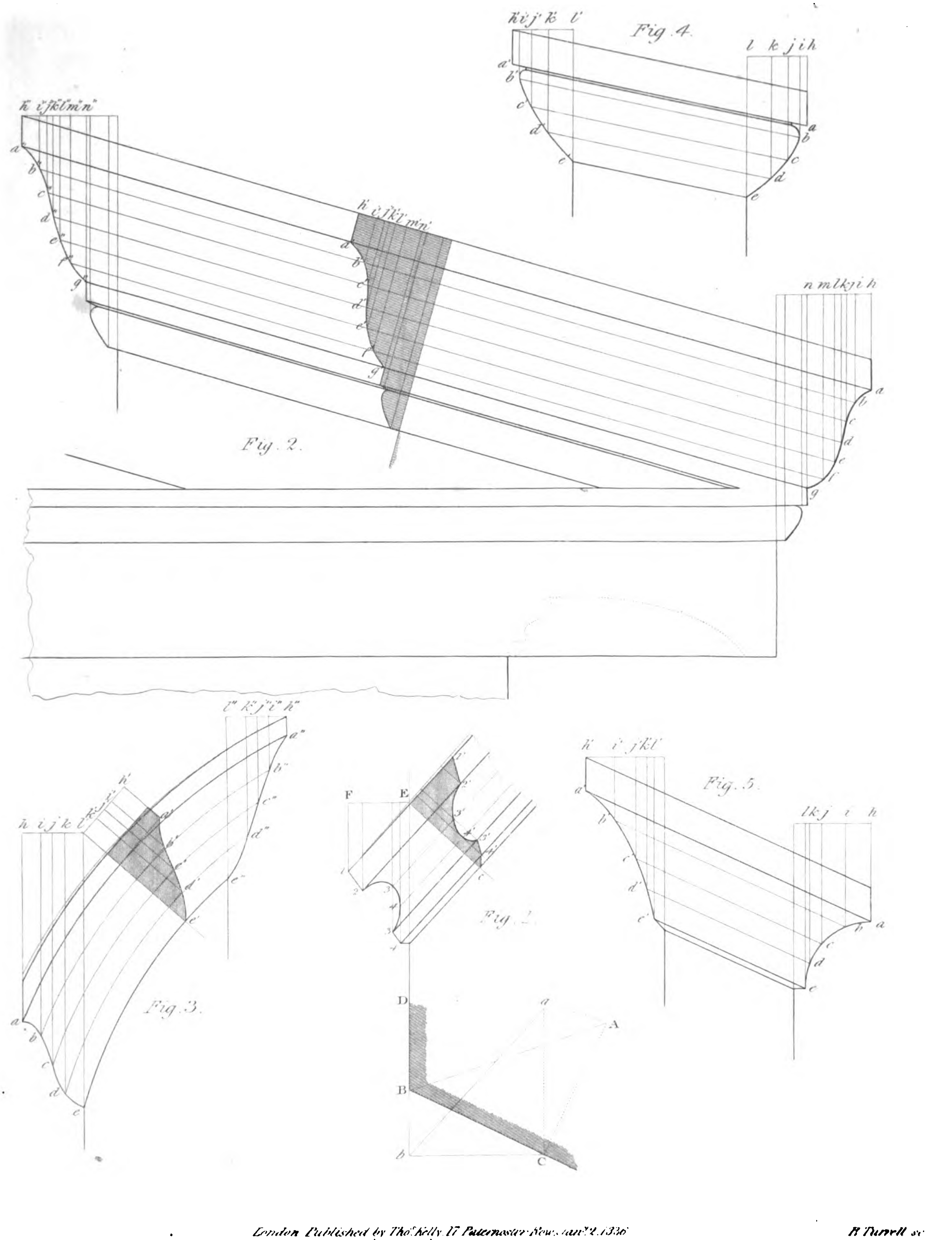
Again, suppose it were required to return the moulding upon the rake to a level moulding at the top, as is sometimes done in open pediments. Upon any horizontal line, transfer the distances between the points h, i, j, k, l, m, n, to $h'', i'', j'', l'', m'', n''$; and, from these points, draw lines perpendicular to the level cornice, cutting the raking-lines before drawn at the points a'', b'', c'' d'', e'', f'', g''; then, through the points $a'', b'', c'', d'', e'', f'', g''$, draw a curve, which will form the return-moulding at the top.

Figure 3.—The lower section is the horizontal part, and the upper section is that of the upper return-moulding, found in a similar manner to *fig.* 2, excepting that, as the mouldings themselves are circular, the lines drawn through the points b, c, d, must also be circular; and, instead of laying the parts between the points, b, c, d, &c., upon the raking-line, they must be laid upon a straight line, which is a trangent to the circle.

Figure 4 shows the method of finding the return-mouldings for a *raking ovolo;* the lower section being the given moulding, and the upper one that of the return horizontal moulding.

Figure 5 exhibits the method of finding the return of a *raking cavetto.*

57. Plate L, *fig.* 1, shows the steps of a stair, where the base-moulding continues along the rake, and returns both at the bottom and top of the stair. *Figure* 2 exhibits the moulding



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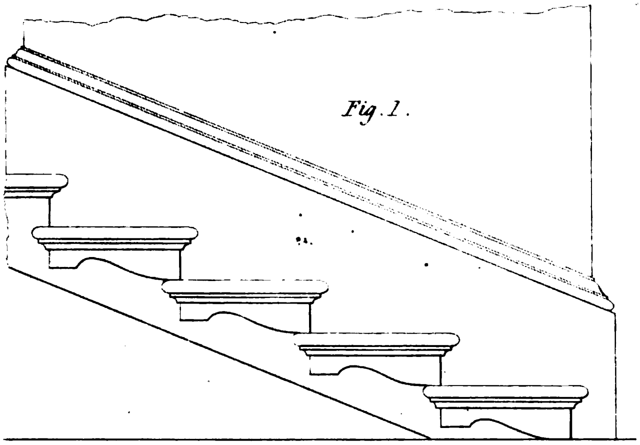

Fig. 1.

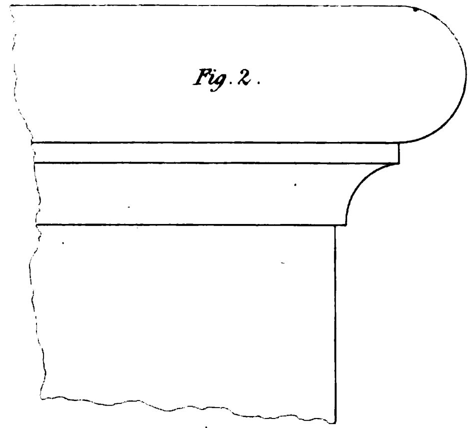

Fig. 2.

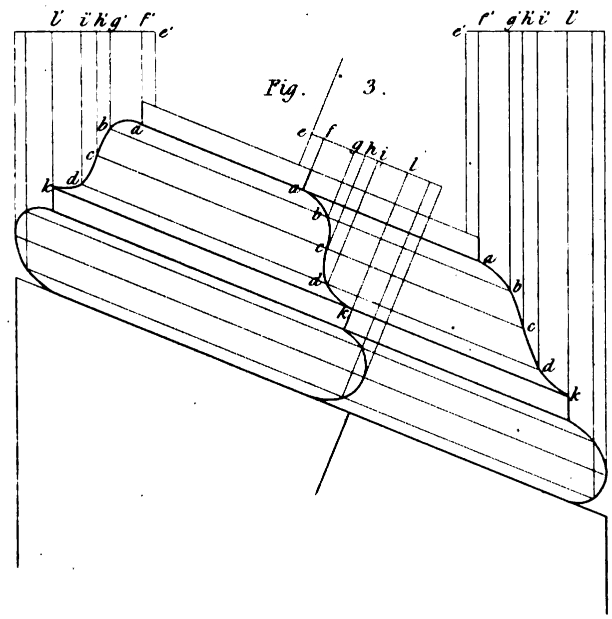

Fig. 3.

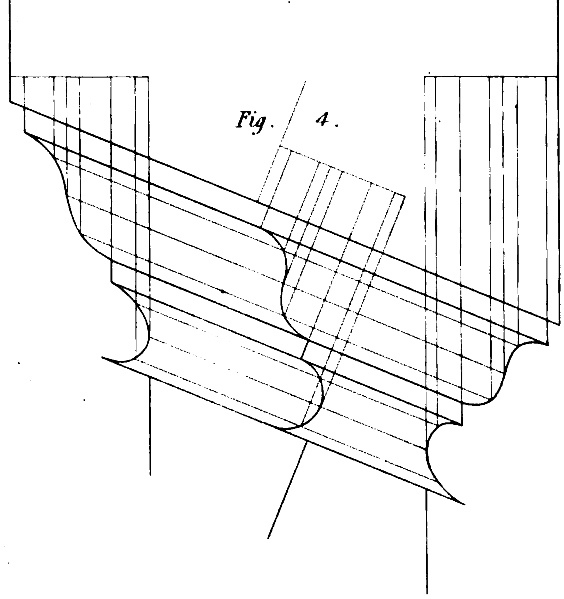

Fig. 4.

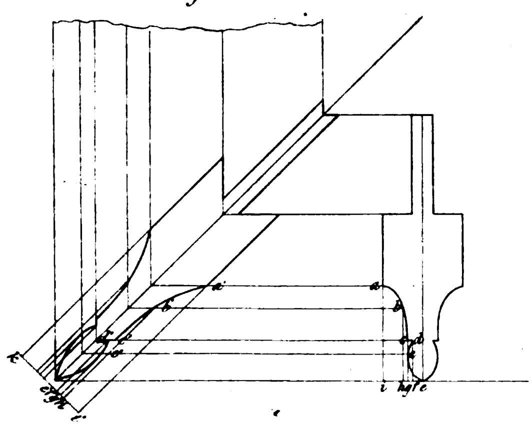

Fig. 5.

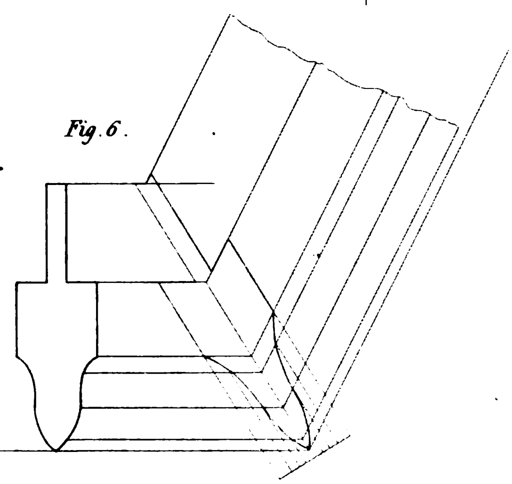

Fig. 6.

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upon the nosing; *fig.* 3, the raking-mouldings, found as in *fig.* 1, *pl. XLIX.* *Figure* 4 shows the same thing, when the mouldings are to be placed around an internal space.

58. *Figure* 5, *plate L*, represents raking-mouldings for angle-bars of shop-fronts: *abcd*, &c. is the given moulding. Take any number of points, *a*, *b*, *c*, *d*, &c., in the curve, and draw lines, *aa'*, *bb'*, *cc'*, *dd'*, &c., parallel to the face of the window; draw a line *k' i'* perpendicular to the mitre line. Then, through the points *a*, *b*, *c*, *d*, &c., draw lines perpendicular to the line of the face of the window, cutting it at the points *e*, *f*, *g*, *h*, *i*. Transfer the distances between the points *e*, *f*, *g*, *h*, *i*, to the line *k' i'*, which is drawn perpendicular to the mitre-line, at *e'*, *f'*, *g'*, *h'*, *i'*; then draw lines parallel to the mitre-line, cutting the lines drawn parallel to the front at the points *a'*, *b'*, *c'*, *d'*, &c., and, through the points, *a'*, *b'*, *c'*, *d'*, &c., draw a curve, and it will form one side of the angle-bar: then, making the other similar, the whole angle-bar will be formed.

Figure 6 shows another design of a bar, where the window returns at an obtuse angle. The method of forming the angle-bar is the same as in *fig.* 5.

HINGING, AND THE FORMATION OF JOINTS.

59. A considerable degree of care is necessary to hang a door, a shutter, or any other piece of work, in the best manner. With regard to the hinge, the pin should be perfectly straight and cylindrical, and the parts accurately fitted together.

The hinges should be placed, so that their axes may be in the same straight line; as any defect, in this respect, will produce a considerable strain upon the hinges every time the door or shutter is moved, and it not only prevents it moving freely, but is also very injurious to the hinges.

60. In hanging doors, centres are often used instead of hinges; but on account of the small quantity of friction in centres when they are well made, a door moves too easily, or so that a slight draught of air accelerates it so much in falling to, that it shakes the building, and is disagreeable. We have seen this, in some degree, remedied, by placing a small spring to receive the shock of the door. The greatest difficulty, in hanging doors, is to make them to clear a carpet, and yet shut close at the bottom. To do this, that part of the floor which is under the door, when shut, may be made to rise about a quarter of an inch above the general level of the floor; which, with placing the hinges so as to cause the door to rise a little as it opens, will be sufficient, unless the carpet should be a very thick one.

Several mechanical contrivances have been used for either raising the door, or making a part to spring close to the floor, as the door shuts.

The latter is much the better method. But, by attention to rise the floor, and hinging the door properly, these contrivances are rendered of little value, while, when they are resorted to, they are seldom long in order.

61. Various kinds of hinges are in use. Sometimes they are concealed, as in the kind of joints called *rule-joints;* others project, and are intended to let a door fold back over projecting mouldings, as in pulpit-doors: when hinges project, the weight of the door acts with an increased leverage upon them, and they soon get out of order, unless they be strong and well fixed.

62. The different objects to be attained by hinges will be best illustrated by examples.

Figure 1, *plate LI*, exhibits the METHOD of HINGING ONE FLAP TO ANOTHER, the joint being what may be termed a *lap-joint*, and is usually employed for shutter-flaps. The centre of the hinge is placed opposite to the joint.

When one flap revolves upon another, it is often required that the edge of the flap, when folded close upon the back of the other, shall be at a given distance from the joint: to do this, the centre of the hinge must be placed at half that distance from the joint: this is exemplified in *fig.* 2.

63. *Figure* 3 SHOWS the METHOD of HINGING A RULE-JOINT, the axis of the hinge being in the axis of the cylindric surface that forms the rule-joint.

Figure 4 shows the joint when open.

This method is sometimes used in window-shutters, but chiefly in tables and other furniture. If one of the straps of the hinges were cranked a little, as shown by *fig.* 5, these joints would be much less difficult to form. With the common hinges, it is usual to make the joint extend a little further than the quadrant of a circle, which renders it difficult to make the parts fit well when the joint is open.

Hinging Doors and Shutters.

64. *Figure* 6 shows a hinge for a door to open so as to fold flat back against an architrave, or other moulding. The dotted lines show the door when open; and the centre of the hinge should be at half the quantity of projection from the face of the door.

65. *Fig.* 7 shows the case where the hinge of a flap is on the reverse side of the rebate from the usual one. In such cases, we are often required to fold back the flap to a given place. Let us suppose from A it is to fold to B. Then, join AB, cutting the lines of the flaps at C, which is the proper place for the centre of the hinge. To find the bevels, on AC, as a diameter, describe a semicircle. Draw AD at any angle that may be esteemed convenient for the oblique portion of the joint, join DC, and set off A*a* for the depth of the rebate, then draw *a b* parallel to AD; and *bd* perpendicular to the face of the flap, which will complete the joint A*abd*.

66. *Plate LII*, *fig.* 1, Nos. 1 and 2, represents the form of the joint of two stiles, in order to fit each other. No. 3 shows the same when hinged together.

Figure 2, Nos. 1 and 2, exhibits a plane-joint, beaded alike on both sides: No. 3 shows the same when hinged together.

Figure 3, Nos. 1 and 2, exhibits the same thing with a double-lapped joint. No. 3 shows the two parts put together.

Figure 4, Nos. 1 and 2, shows the same thing, with a single lapped-joint.

67. *Figure* 5 exhibits the manner of hinging a shutter to the sash-frame.

Figure 7 shows the method of hinging shutters, so as to conceal the hinges.

68. *Figure* 6 exhibits the manner of hanging a door upon centres. If the door has any mouldings which project a bead, A, or other moulding, should be formed of sufficient thickness for the door to open square, and yet the mouldings on it not touch the jamb. To find the place for the centre make CB, its distance from the line of the jamb, about a sixteenth of an inch more than CD, which is half the thickness of the door. In doors, for principal rooms, a moulding is formed on each side of the stile, as shown by the dotted lines, to prevent the joint from appearing open when the door is open.

HINGING.

Fig. 1.

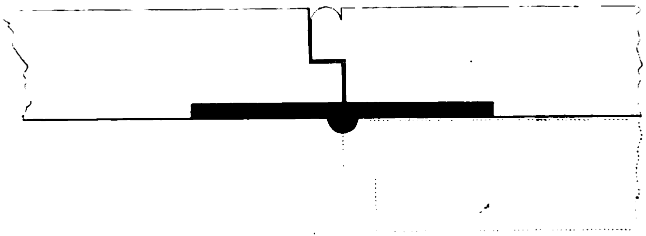


Fig. 2.

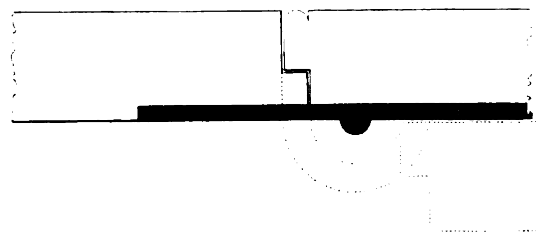


Fig. 3.

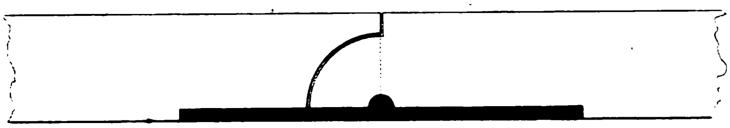
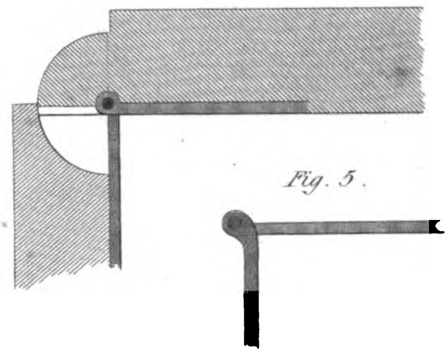


Fig. 4.



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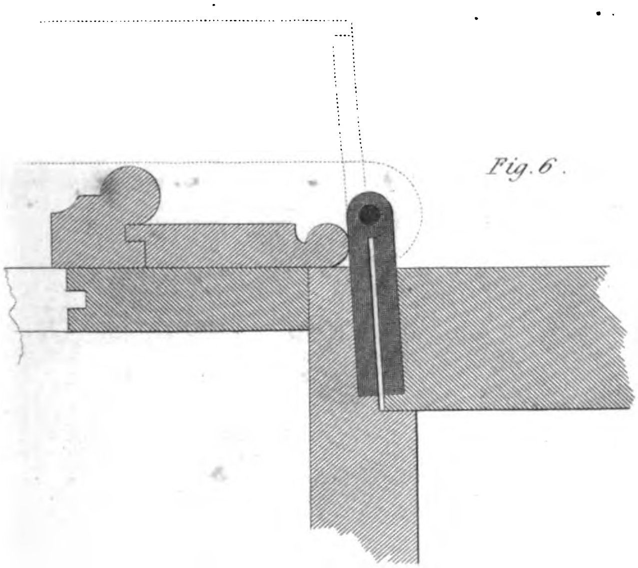
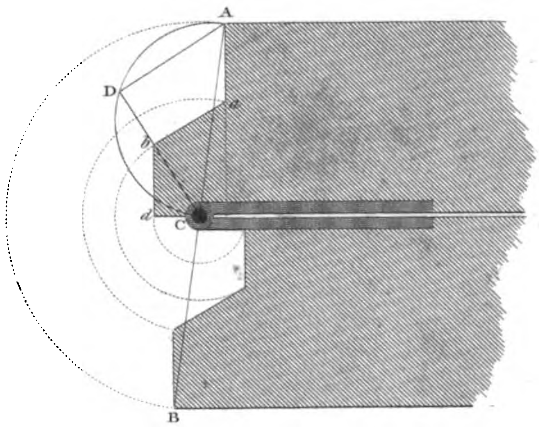


Fig. 6.

Fig. 7.



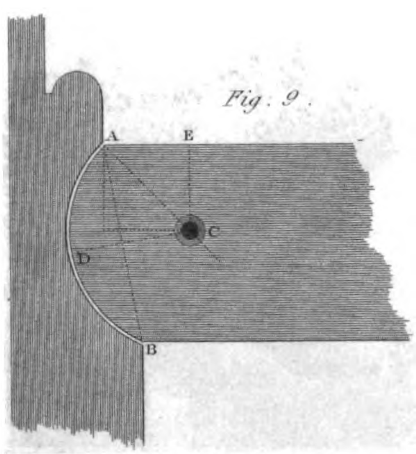
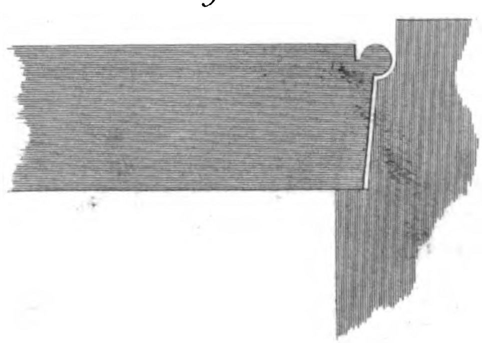


Fig. 9.

Fig. 8.

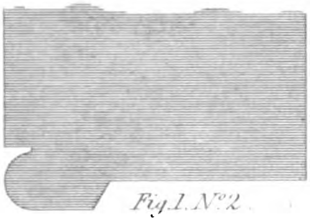


London, Published by Thos. Kelly 17 Paternoster Row. Jan. 2. 1836.

E. Turrell sc.

HINGING DOORS AND SHUTTERS.

Fig. 1. No. 1.



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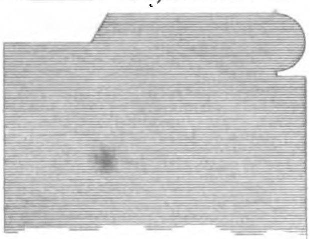

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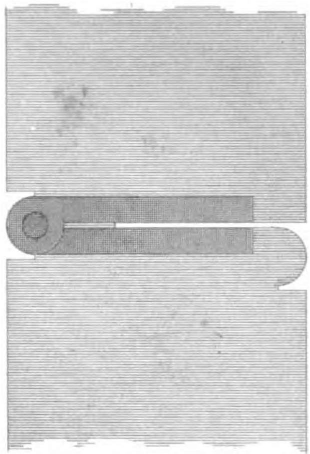

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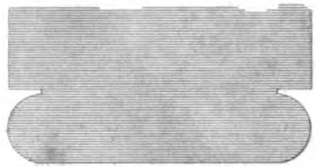

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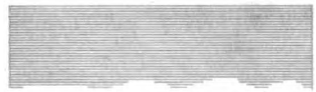

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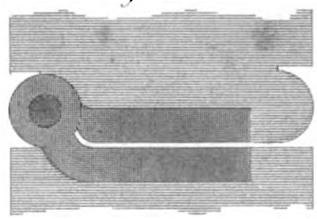

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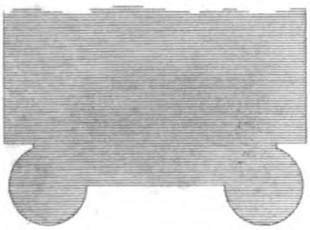

Fig. 3. No. 2.

Fig. 3. No. 3.

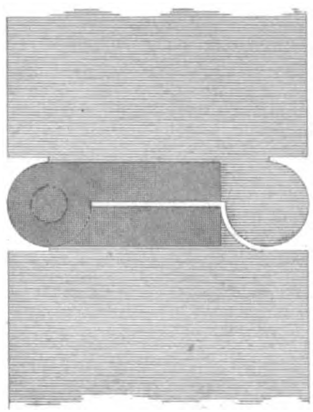

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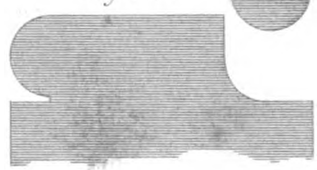
Fig. 4. No. 2.



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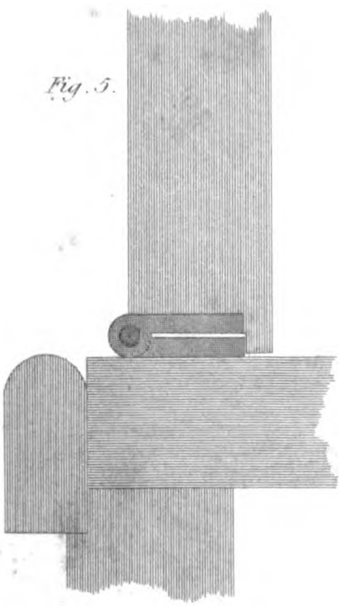

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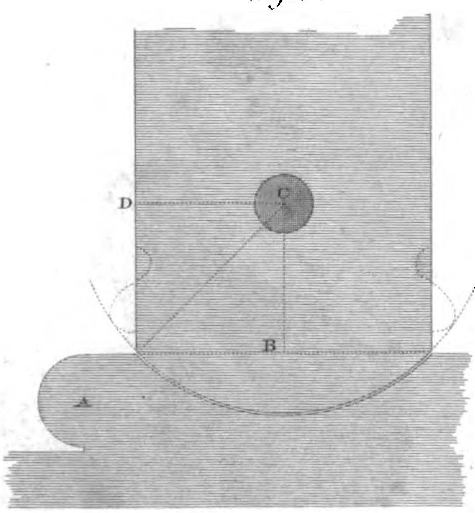

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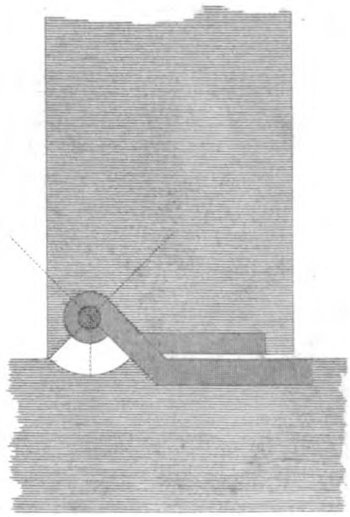

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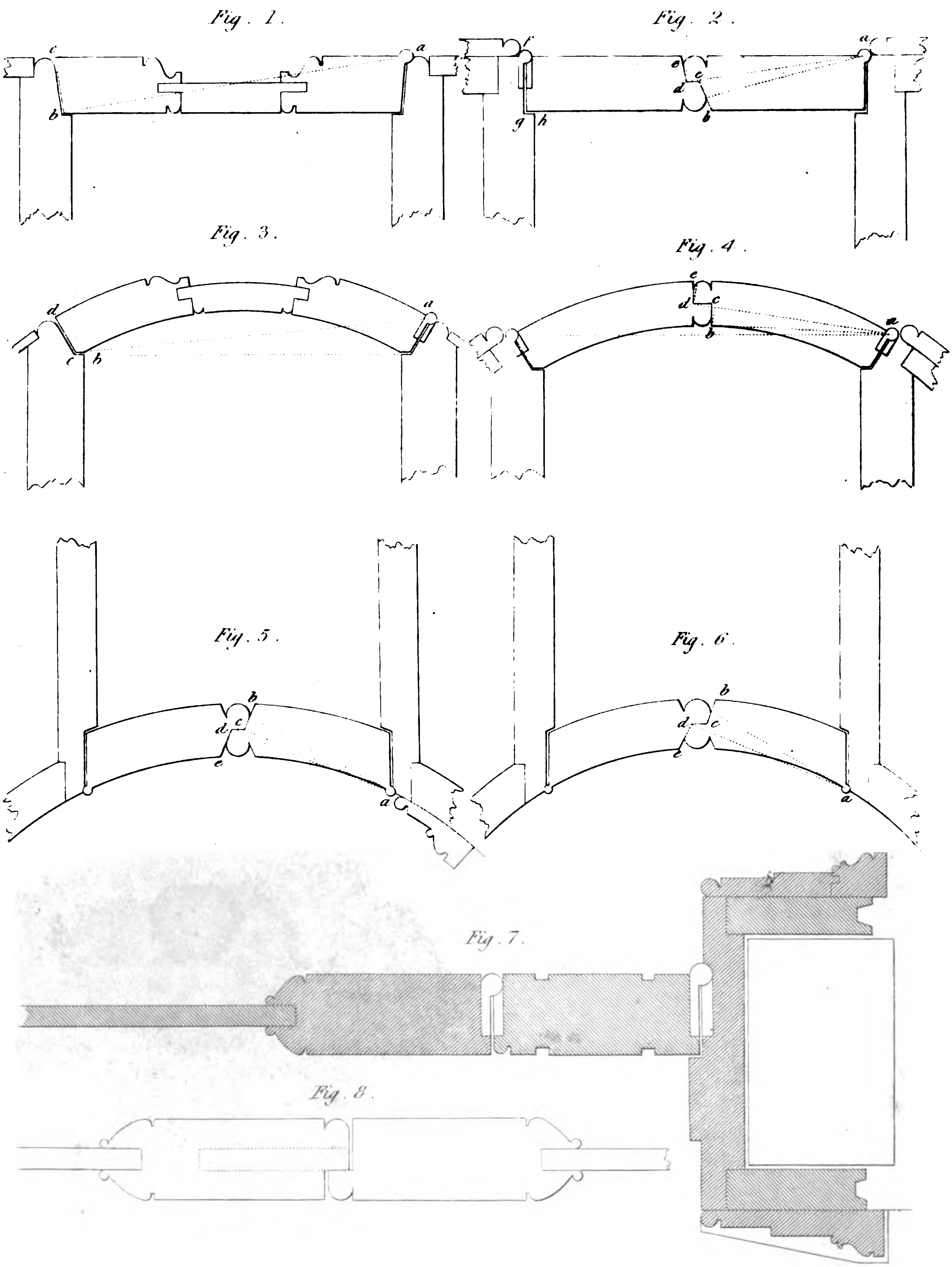
FORMATION of the SHUTTING JOINTS of DOORS.

PLATE [illegible]



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E.Turrell. sc.

69. Another mode of hanging a door on centres is shown by *fig.* 9, *plate LI.* To find the place for the centre, join AB, and bisect it by the perpendicular DC. Make EAC an angle of 45 degrees, and then the point in which DC intersects AC will be the centre required.

70. The door of a room should be so formed and hung, that, in opening the door, the interior of the room cannot be seen through the joint. This may be done by making the joint according to *fig.* 8. The bead should be continued round the door, and a common but-hinge answers for a joint of this kind.

On the Formation of the Shutting Joints of Doors, Shutters, &c.

71. THE proper bevel for the edge of a door or sash may be found by drawing a line from the centre of motion *a*, *fig.* 1, *plate LIII,* to *b*, the interior angle of the rebate, and drawing *b c* perpendicular to *a b*, which gives the bevel required. In practice, the bevel is usually made a little less, leaving an open space in the joint when the door is shut; this is done on account of the interior angle of the rebate often becoming filled with paint.

72. *Figure* 2, on the same plate, represents the section of a pair of *folding-doors* with jambs, upon a straight plan. Here we must suppose that one of the doors is shut, while the other opens. Let the half which is shut be *edcbhgf,* and let *aedcb* be the other half, which opens. Draw the line *dc*, parallel to the face of the door, bisecting the thickness, so that the middle of *cd* may be in the middle of the breadth of the door. Draw the line *ad,* and draw *de* perpendicular to *ad*; also draw the line *a b*; taking the bottom of the quirk of the bead for the point *b,* and make *bc* perpendicular to *ab,* then will *edcb* be the form of the joint.

The principle of the operation is evident; since no length can be applied in a placo shorter than itself. The most remote point of the thickness in the moving part must, in the act of opening, pass every other part of the rebate that is stationary. The principle, therefore, amounts to this: that, since in the opening every point in the edge of the moving door describes the circumference of a circle, no line drawn from the point *a* to the line *bc*, should be less than the line *ab*; and, because the angle *abc* is a right angle, every line drawn from *a*, to meet the line *bc*, will be the hypothenuse of a right-angled triangle, of which one of the legs is the line *ab*; therefore, *ab* is shorter than any line that can be drawn from the point *a* to the line *bc*; consequently, the point *b*, in the act of opening, would fall within the extremities of every line drawn from *a* to the line *bc*.

It may, also, be shown that, if any point be taken in *bc*, and a line be drawn from that point to the point *a*, the line thus drawn will be less than any other line drawn from *a* to any other point of the line *bc*, between the former point and the point *c*.

In the same manner, because *ade*, *fig.* 2, is a right-angle, the line *ad* is less than any other line that can be drawn from *a* to any point of the line *de*, between *d* and *e*; and every other line drawn from *a*, to any point between *d* and *e*, will be less than any other line drawn from *a* to any other point in *de*, between that point and the point *e*.

Having thus shown the reason of the method, its application in *figures* 3, 4, 5, 6, will be evident on inspection; or, at least, by comparing it with the former part of this description; and it only remains to add, that the angle may be as much greater than is given by this method as the appearance of the work requires, as in *fig.* 3 and 4.

73. *Figure* 7 is a section of the jambs of a pair of folding-doors, with part of the section of the door, adapted for folding back against the wall: *fig.* 8 is the section of the meeting-stiles of the doors; the dotted line in the stile shows the place for the lock.

OF THE CONSTRUCTION OF DOORS.

74. Doors are of various kinds, and are usually described by the number of pannels, and the kind of framing.

Figure 1 represents a SIX-PANNELED DOOR, having an *ovolo* and *fillet* on the stiles, with plain pannels.

Figure 2 is a section of part of a stile and pannel moulded with a quirk-ovolo and fillet; the pannel being flat on both sides.

Figure 3 represents FOLDING DOORS, which meet together with a lap-joint, exhibiting a bead on both sides of the door.

Figure 4 exhibits a one-pannel or dwarf door, with BEAD and BUT framing.

Figure 5 shows one with BEAD and FLUSH framing. The difference between bead and but and bead and flush is this: In bead and but, the bead is run on the edges of the pannel, in the direction of the grain only; but, in bead and flush, the bead is run round all the four edges of the frame. Sometimes beads are inserted across the ends of the pannels.

Figure 6, section of part of the stile and pannel of square framing.

Figure 7, section of part of a stile and pannel, having quirked ovolo and bead on the framing, with square pannel.

Figure 8, section of a part of the stile and pannel of a door, with quirked cyma-reversa on the framing.

75. External doors for houses should not be less then $1\frac{1}{4}$ inches thick, when finished, in order to be firm and durable. They should be made of yellow deal or oak, framed with pannels, and may be moulded, or the external face may be plain with a flush-bead round each pannel, (called bead and flush,) with a substantial oak or yellow fir frame. The height and width of external single doors are made in various proportions; they should never be less than 6 feet 8 inches in height, nor narrower than 2 feet 10 inches; and large doors should be avoided, because they lessen the apparent magnitude of a building. When folding-doors are employed, there should be space to admit one person to enter when only one of the doors is open, and therefore they should never have less than two feet clear opening when one door is open, and the height to this width may be about 8 or 9 feet.

76. Internal doors are made of various kinds of materials, but most commonly of yellow fir or white deal, the latter should be preferred. Doors of principal apartments are often made of oak, and sometimes of mahogany, and other expensive woods. Mahogany acquires a dull heavy colour with age, which gives a room a gloomy appearance, when it is employed in large masses, as in doors; therefore, when it is used, means should be used to prevent it turning dark. Good varnishing with copal varnish is, perhaps, the most effectual.

The proportions of internal doors, depend, in some degree, on the size of the apartments; in a small room, a large door always gives it a diminutive appearance. With regard to the proportions of the doors themselves, if we take a door, 2 feet wide and 6 feet 3 inches high, as a standard, and then for any other width add half the difference between 2 feet and that width to 6 feet 3 inches, will give the height required. The height should never be less than is given by this rule, and we wish it to be understood, that it is given rather to assist than to direct the taste of the builder. Writers on Architecture observe, that doors should never have more height than double their width, nor less than the diagonal of a square formed on the width.*

* Alberti's Architecture, Vol. I p. 12.

DOORS.

Fig. 1.

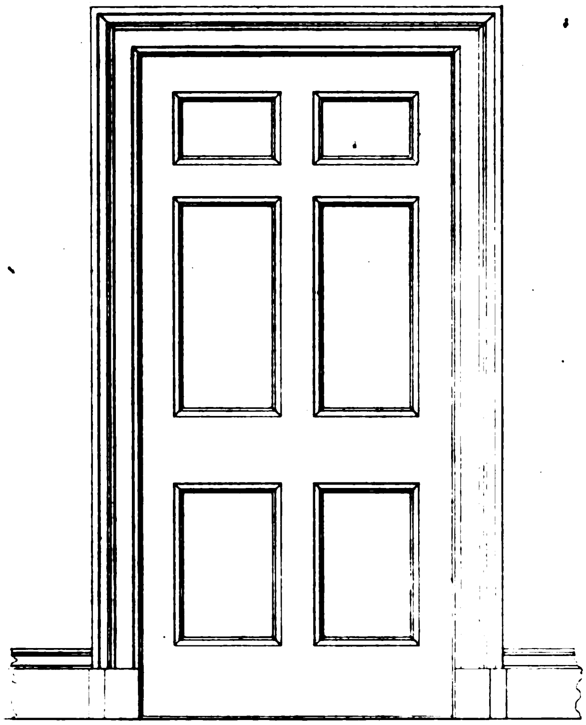
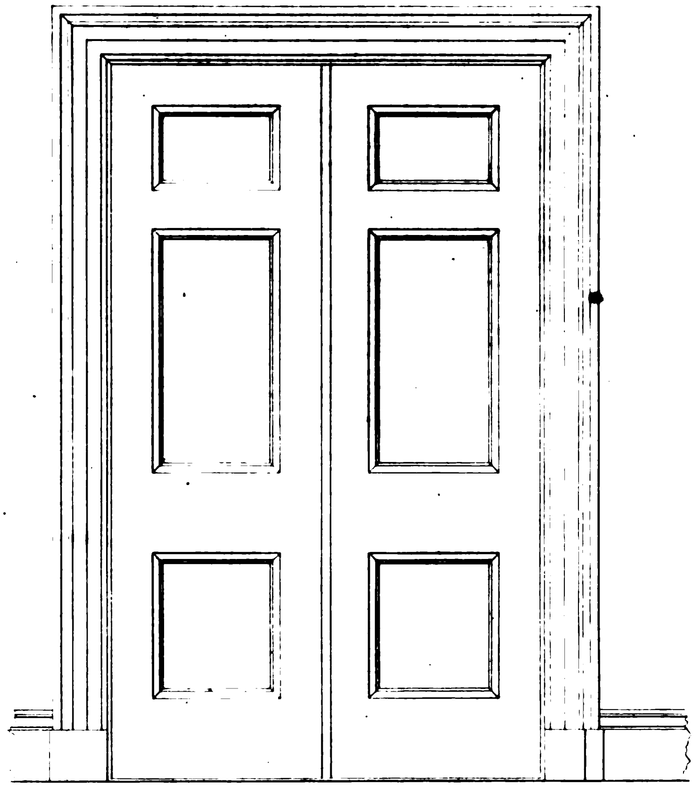


Fig. 3.



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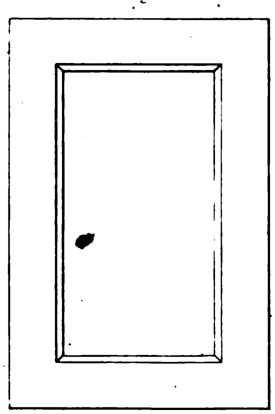

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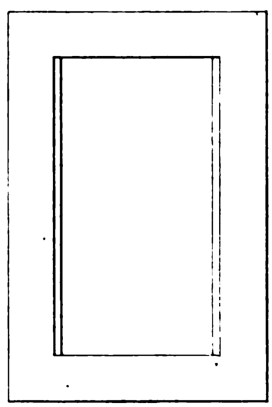

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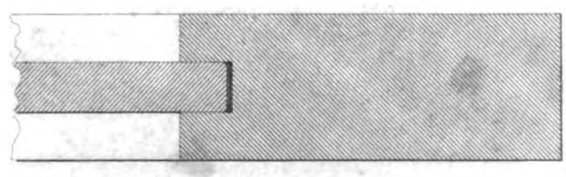


Fig. 2.

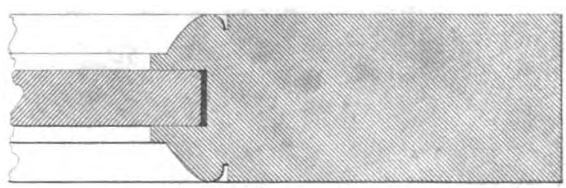


Fig. 8.

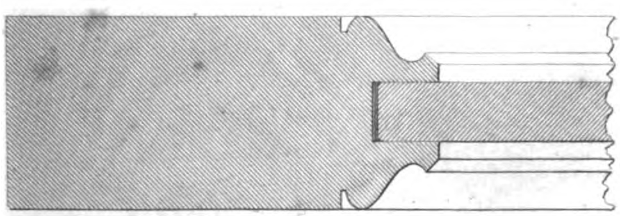
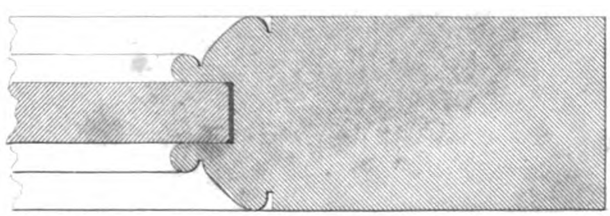


Fig. 7.



London Published by Thos. Kelly 17. Paternoster Row. June 2 1830.

Fig. 1.

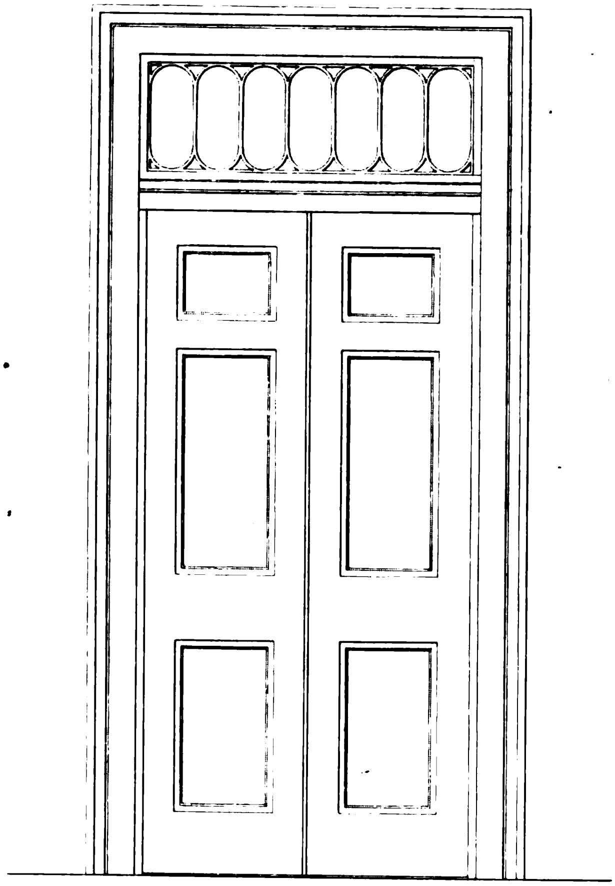


Fig. 3.

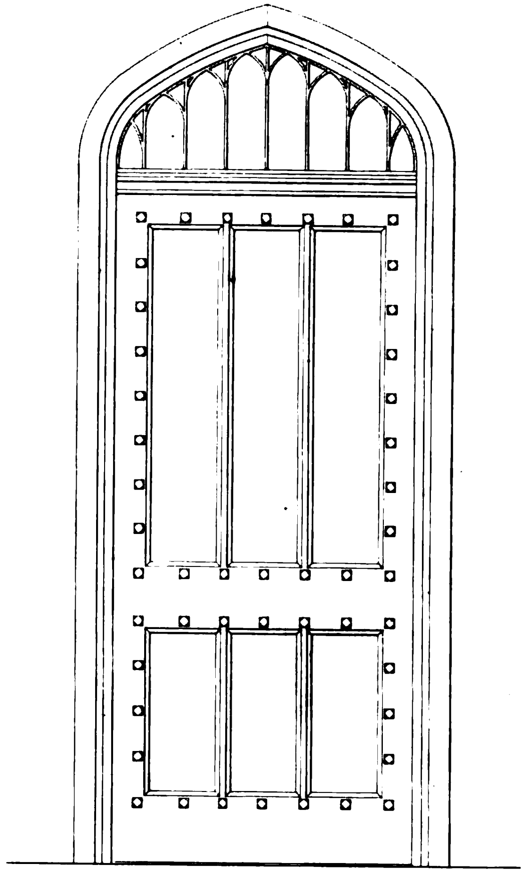
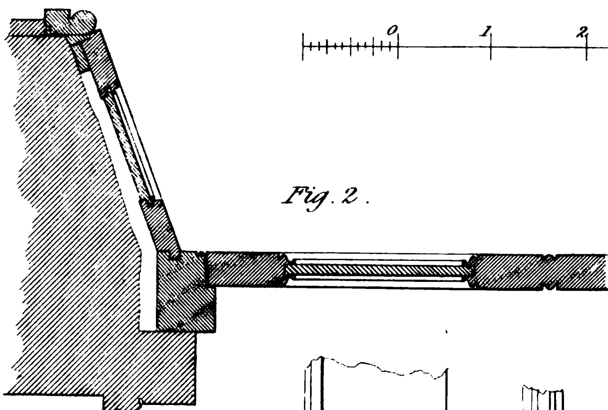


Fig. 2.



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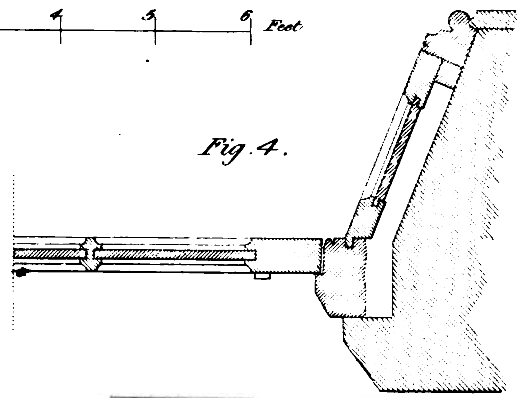

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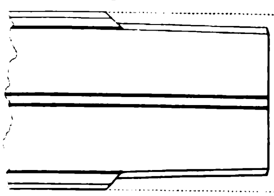

Fig. 6.

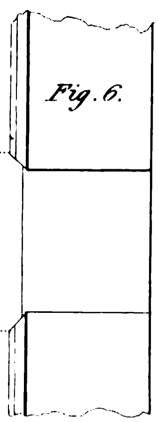

Fig. 7.

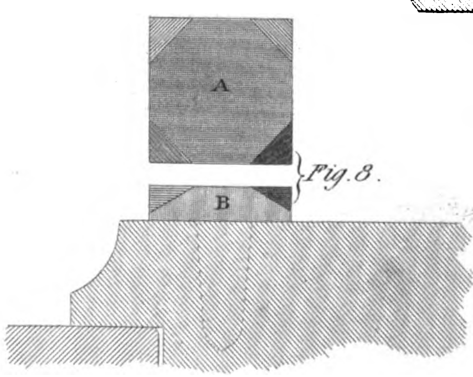

Fig. 8.

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F. Turrell sc

77. As examples of the species of working-drawings required for doors, we will give two specimens; the one from a building of modern architecture, and the other from a Gothic building.

Fig. 1, *plate LV*, is the elevation of an external door, with a light over it. It may either be made folding or to open in one, and framed to represent a folding-door. *Fig.* 2 shows half the plan of the door-way to double the size of the elevation; and, in practice, this plan is usually made of the full size of the parts. The lights over doors are now generally formed by metal bars.

78. When a door is framed to represent a folding-door, it is called a *double-margined door*. In framing a door of this kind, the middle stiles must appear to cross the top, lock, and bottom rails. *Fig.* 5, 6, and 7, show how this may be done; *fig* 5 is the double stile; *fig* 6 the side of the bottom rail; and *fig.* 7, the edge of the bottom rail with the double stile inserted. The joints are made to bevel a little, so that they may be perfectly close when the rail is driven to its place, but they should not be beveled more than is absolutely necessary for that purpose.

79. An elevation of an external door for a Gothic building is shown by *fig.* 3; and *fig.* 4 is the plan of the door and jamb to double the size of the elevation, in order to show the parts more distinctly. Doors of this kind are frequently ornamented by nail-heads along the mouldings; and lately such heads have been cast in iron; their peculiar form is shown in *fig.* 8; where A is the top of the head, and B its side, with part of the moulding. When the nail-heads are formed in wood, they are let in within the surface about a sixteenth of an inch.

Of Jib-Doors, Book-Doors, &c.

80. A Jib-door is one intended to be concealed, either from its leading to a private room, or from there being no corresponding door, and it is therefore made flush with the surface of the wall, being generally canvassed and papered over, or painted the same as the room; the design being to conceal the door as much as possible, or to preserve the symmetry of the side of the room which it is in.

Fig. 1, *plate LVI*, represents the side of a room, in which KLMN is a *jib-door*, I the base moulding of the room, and H the surbase, both continued across the door.

Now, in order to make the jib-door open freely, the mouldings must be so cut that no point of the moving part may come in contact with the jamb of the fixed part. This may be done by forming the end of the moving part, and the end of the jamb or stationary part, in such a manner that all the horizontal sections may be circles described from the centre of the hinge. In short, by making the end of the base and surbase, and the edge of the jamb, the surface of a cylinder, of which the axis line of the hinges is the axis of the cylinder. This is shown by *fig.* 4, where A is part of the jamb; B represents a section of the door, upon which the iron containing the centre is fixed. C is the centre. The parallel lines in front represent the projections of the mouldings. Draw C*d* perpendicular to the front line, and make *de* equal to C*d*: from C, with the radius C*e*, describe the circular line *ef*, and where the points of *e*C cut the parallel lines will be the extremities of the radii of the other circles.

Figure 2 exhibits the section of the surbase, marked H, in *fig.* 1; and B, *fig.* 3, is the elevation of the base, shown at I, *fig.* 1; and *fig.* 5 shows the section of the base moulding.

81. In libraries, concealed doors to private rooms or book-closets are frequently made to match the book-cases, and to appear as though the door was part of the book-case. For this

purpose, pieces of wood are formed to the shape of book-backs, and covered with leather, and gilt and lettered, so as to resemble real books. When the book-backs are well imitated, the deception is very complete.

Doors are also concealed by covering them with maps strained on canvas, and well varnished, the joint of the door being in the frame of the map; and where some device of this kind cannot be employed, the edges of the doors soon become soiled, and their appearance disagreeable; particularly where there is no other reason for employing them than to preserve the symmetry of a room.

OF THE CONSTRUCTION OF WINDOWS.

82. Windows are described by the manner in which they open, and are of three kinds: Sash-windows, Casements, and Sliding-casements.

83. Sash-windows are balanced by weights, and slide vertically. They are, for most purposes, both more convenient than other windows, and better adapted for keeping out the weather.

84. Casements open on hinges in the manner of doors, and they are usually employed in Gothic buildings, being more in character with that style of architecture than sash-windows. When casements are employed with other species of architecture, they are called French windows. The objection to these windows is the difficulty of making them water-tight, without rendering them very inconvenient to open and shut; otherwise they are well adapted for windows to walk out at on to a lawn or a balcony.

85. Sliding-casements are used only for cottage-windows, and they slide horizontally, and often have small rollers in the bottom rail to lessen the friction.

86. The frames of windows are usually made of yellow fir, or of part fir and part oak, and for frames, as well as for every other purpose, where wood is to be painted, it should be well seasoned.

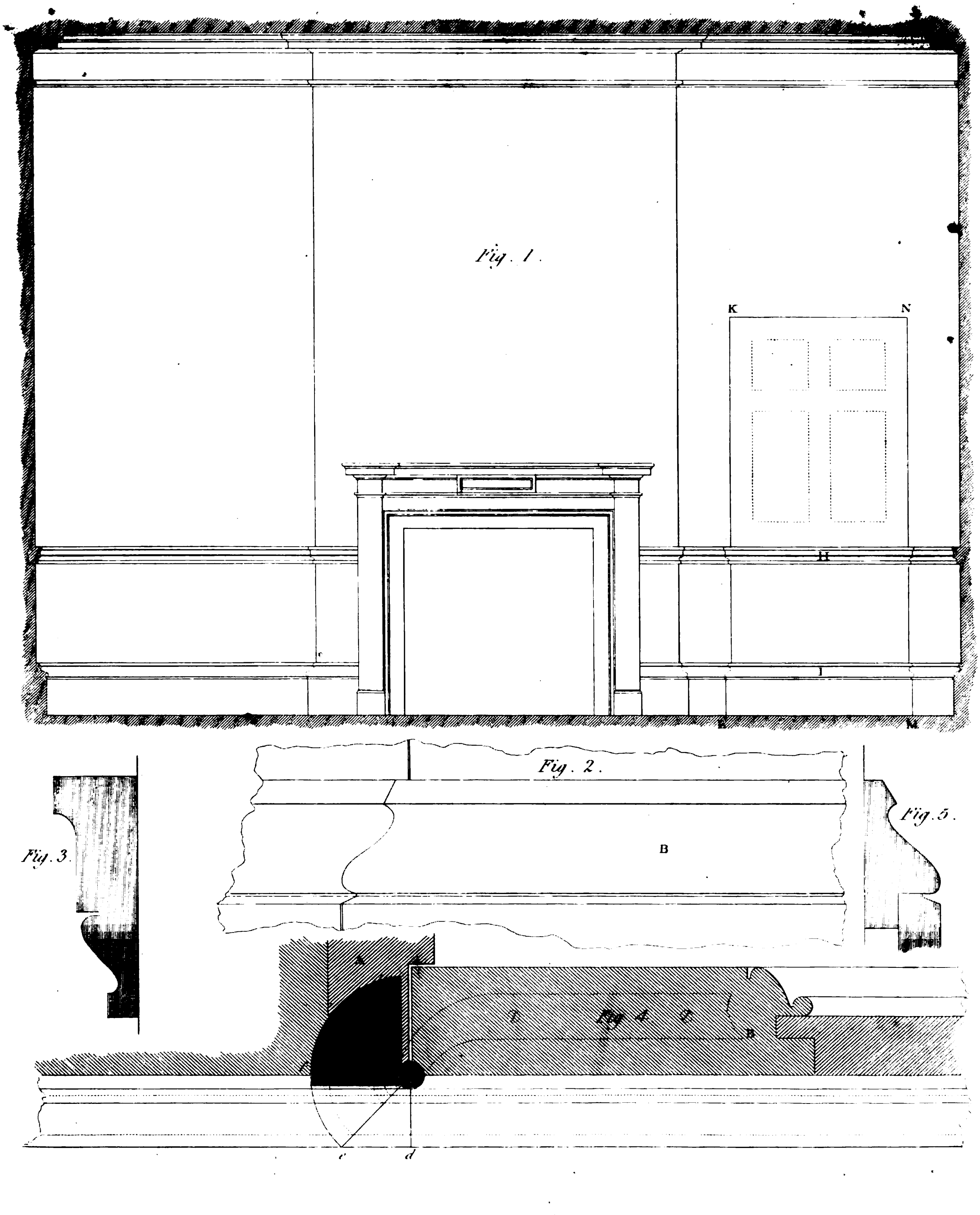
Sashes and Casements for principal rooms are often made of oak; and sometimes sashes are made of mahogany. Neither sashes nor casements should be made slight, as, however well they may fit at first, they soon get out of order if made too slight. The thickness of sashes should never be less than of those called $1\frac{1}{4}$-inch sashes, which are about $1\frac{1}{2}$-inch when finished, and casements should be thicker.

Proportions of Windows.

87. The stone sills of windows, unless they begin from, or nearly from, the floor, are generally fixed with the upper side thirty inches above the floor line, and the tops of the windows should be about $\frac{1}{10}$th of the height of the room below the ceiling to allow space for the window-cornice, and for the cornice of the room. When there is more than one window in a room, it is usual to place them so, that, if the pier between two windows be divided into three parts, the jamb of each end window may be two of these parts distant from the wall.

Windows should never be very wide, because then the shutters become heavy and inconvenient, and get very soon out of order; also, wide openings weaken the walls of a building, but as rooms should be well lighted without making larger openings than is necessary, a rule for that purpose is useful.

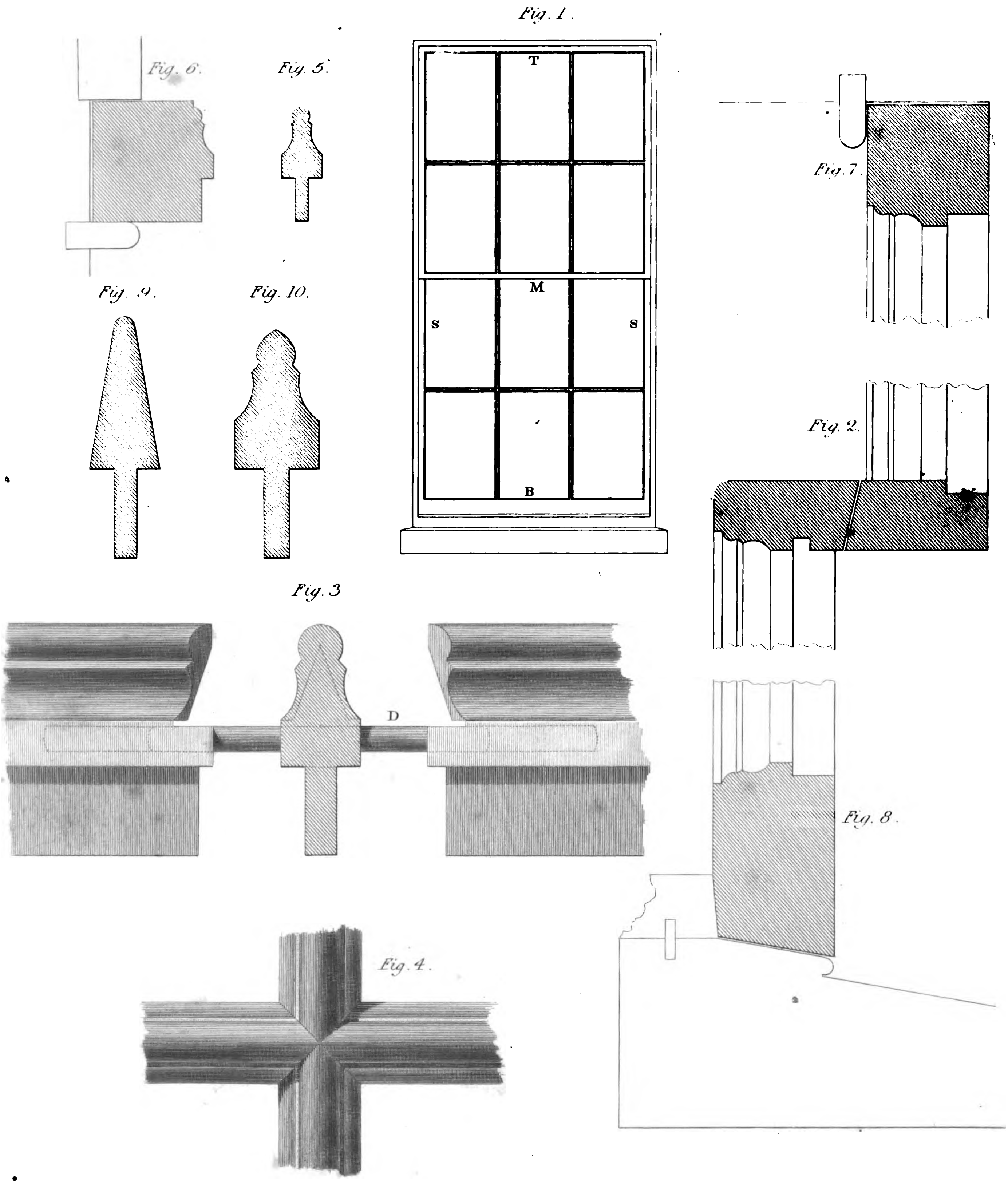
JIB DOORS.



London, Published by Thos. Kelly, 17 Paternoster Row, Jan. 2, 1836.

E. Turrell sc.

WINDOWS.



London, Published by Thos. Kelly, 17 Paternoster Row, Jany. 2. 1835.

E. Turrell sc.

The following rule for proportioning the *Quantity of Light* for a room agrees very well with our own observations, and is very convenient for use. Divide the number of square feet contained in the room by 45, and the quotient is the least width for the windows in feet; and may be divided into such a number of windows as is convenient.

But, if the windows extend down nearly to the floor, divide by 60 instead of 45.

Example.—If a room be 30 feet in length, and 20 feet in width, then $30 \times 20 = 600$, which is the number of square feet in the area of the room; and, 600 divided by 45, gives 13 feet 4 inches for the sum of the widths of the windows, and may be divided into three windows of 4 feet 6 inches each.* If the same room had windows extending down to the floor, 10 feet would be sufficient for the sum of the widths of the windows; and, provided less than this proportion of light be not given, the windows may be of any suitable proportions for appearance.

Parts of Windows.

88. *Figure* 1, *plate LVII,* shows the external elevation of a sash-window, where T is the top rail of the sash, M the meeting bars, B the bottom rail, and S, S the stiles.

Fig. 2 is a section of the meeting bars, with a small portion of the stiles fixed to each.

Fig. 3 shows a section of an upright bar with a cross bar inserted, but not driven close; our object being to show, in a clear manner, the method of framing the bars by means of dowels; the pin, D, is called a dowel. The parts which are cut away, on the moulded sides of the upright bar, are called the *franking*. The object in this joint is to preserve the upright bar as strong as possible, and yet insert the cross bars, so that the moulding may not be liable to break off at the edge.

Fig. 4 shows the bars when joined.

Fig. 5 is the section of one of the bars, being called astragal and hollow.

Fig. 6 is a section of one of the stiles of the sash, with its astragal and hollow mouldings.

Fig. 7 shows a section of the top rail; and *fig.* 8 of the bottom rail of the sash.

Fig. 9 is a plane diminished bar, such are frequently used for shop-fronts.

Fig. 10 is a section of a bar with a Gothic point, instead of an astragal.

Construction of Circular Sashes in Circular Walls.

89. To form the Cot-bar of the Sash.—*Figure* 1, *plate LVIII,* is an elevation of the window. Divide the half arc of the cot-bar, PR, into any number of equal parts, as six; and, from the points of division, draw perpendiculars to the horizontal line ag; transfer the parts of the horizontal line ab, bc, cd, &c. to *fig.* 2, from 0 to 1; 1, 2; 2, 3; 3, 4; &c., to 6; and reverse the order from the central point 6; then draw perpendiculars upwards from these points: and make the heights of the perpendiculars, *fig.* 2, to correspond to the distances taken from the plan, *fig.* 1.* Through all the points draw curves, which will give the form of the mould for the veneers for glueing up the bar in thicknesses sufficiently near for practice.

90. *To form the Head of the Sash.*—Divide the elevation round the outer edge into any number of equal parts, and draw lines perpendicular to the springing line from each division to the chord of the half plan. From the points where these lines intersect the chord of the half plan, draw ordinates, perpendicular to the chord of the half plan. Make the ordinates FI, GK,

* It is of some importance to attend to the circumstance, that a window is charged as two windows for the window-tax, if it be more than 4 feet 9 inches in width, unless its height be less than 3 feet 6 inches.

HL, &c. equal to B1, C2, D3, &c.; and the ordinates of the inner curve equal to CM, DN, &c.; then, through the points E, I, K, L, &c., draw a curve; and within, through the other points, draw another curve; and this will form the face-mould for the sash-head.

Figure 3 is the development of the soffit of the under side of the sash-head. *Figure* 4, that which is applied to the outer or convex side of the same: so that, by cutting away the superfluous wood on the outside of the space contained by the two lines, the sash-head will fit the surface of a cylinder made to the radius of the plan of the window.*

91. *To find the Radial Bars.*—Let *nγ*, *fig.* 1, be the place of a radial bar. In *nγ* take any number of points, *n o p q*, &c., and draw the perpendiculars *nv, ow, px, qy*, &c., to *nγ*. Draw also, *ni, ok, pl, qm*, &c., perpendicular to the springing line of the elevation, cutting that line at the points *a, b, c, d*, &c.; and cutting the plan of the convex side of the sash at the points *e, f, g, h*, and the concave side at *i, k, l, m*, &c. Make the distances *nv, ow, px, qy*, &c., respectively equal to *ai, bk, cl, dm*, &c.; and, through the points *v, w, x, y*, &c., draw a curve, which will form the convex edge of the radial bar. In the lines *nv, ow, px, qy*, &c., make the distances *nr, os, pt, qu*, &c., each respectively equal to *ae, bf, cg, dh*, &c.; and, through the points *r, s, t, u*, &c., draw another curve, which will give the inner edge of the radial bar.

OF THE CONSTRUCTION OF WINDOW SHUTTERS.

92. When the walls of a room are sufficiently thick, the window-shutters are made to fold into a recess within the thickness of the wall, and for the more free admission of light and air the window recess has its sides splayed to a greater or less angle, the splay most frequently adopted appears to be from one-third to two-fifths of the depth of the window recess.

In *plate LIX* we have represented the parts of a Sash-window, and its shutters, finished in this manner; and in all its detail according to the style of the working drawings of the most eminent architects of the present time.

Figure 1 is a vertical section through the window, with parts removed to enable us to give it on a larger scale on the plate.

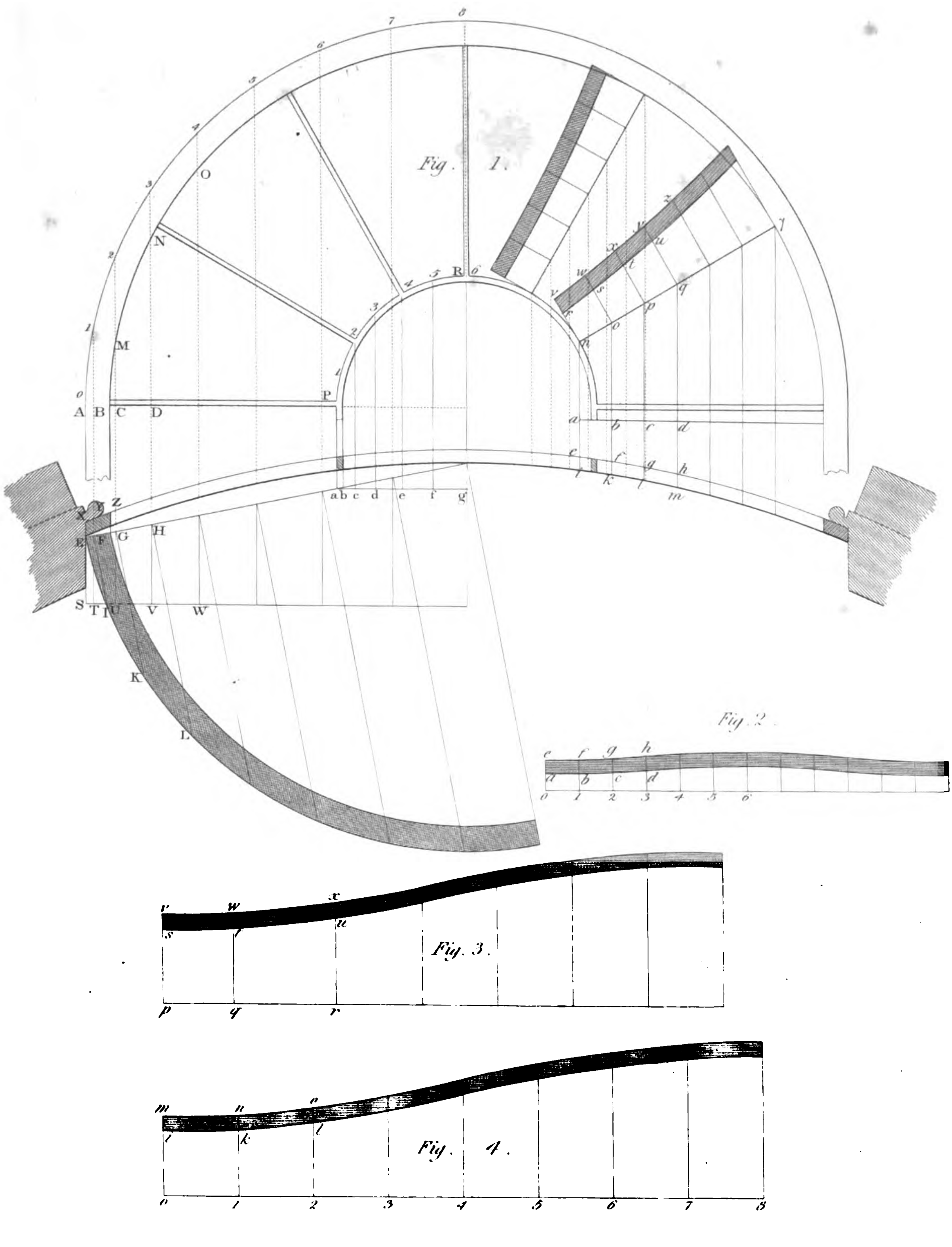
Figure 2 is a plan of the same, showing the shutters as folded back into the boxings; for so the recess formed behind the architrave to receive them is called. *Fig.* 3 shows the elevation of the lower part of the window and shutters, and the construction of the plain back and plinth to the window recess.

In *fig.* 1 S is the sill of the sash-frame; W the stone sill with a sinking to prevent water collecting at the edge of the wooden sill so as to decay it; and B is the bottom rail of the sash. M is the meeting bars of the sashes; T the top rail of the upper sash; and H is the head of the sash-frame, with the soffit grooved into it. A is the architrave, and P its plinth.

In *fig.* 2, F is the pulley stile of the sash-frame. We recommend this mode of rebating for the beads into the pulley stiles from many years experience of its utility; and we also recommend fixing the beads by means of screws with small pieces of brass let in and counter-sunk for their heads.

* The methods in this and the preceding article, (Arts. 89 and 90,) apply only to the case when the bars and stiles are parallel to the radius of curvature at the middle of the breadth; but the bars and the stiles ought to be perpendicular to the curve, and then the true form for the mould may be found from the development of part of the surface of a wedge formed solid, having a semi-circular end, on the principles we have laid down in Carpentry, Art. 50 and 53.

CONSTRUCTION OF CIRCULAR SASHES.



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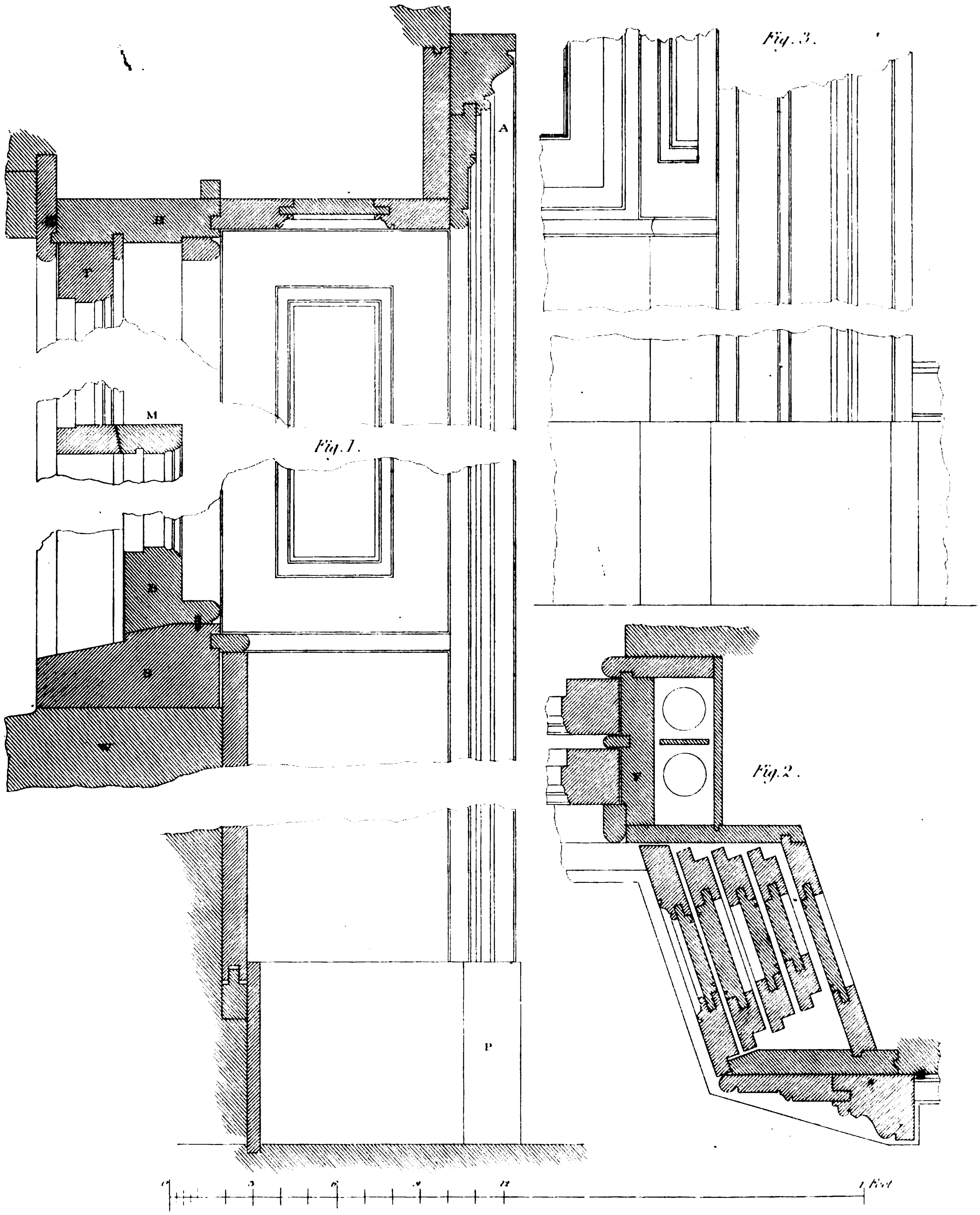
WINDOW SHUTTERS.



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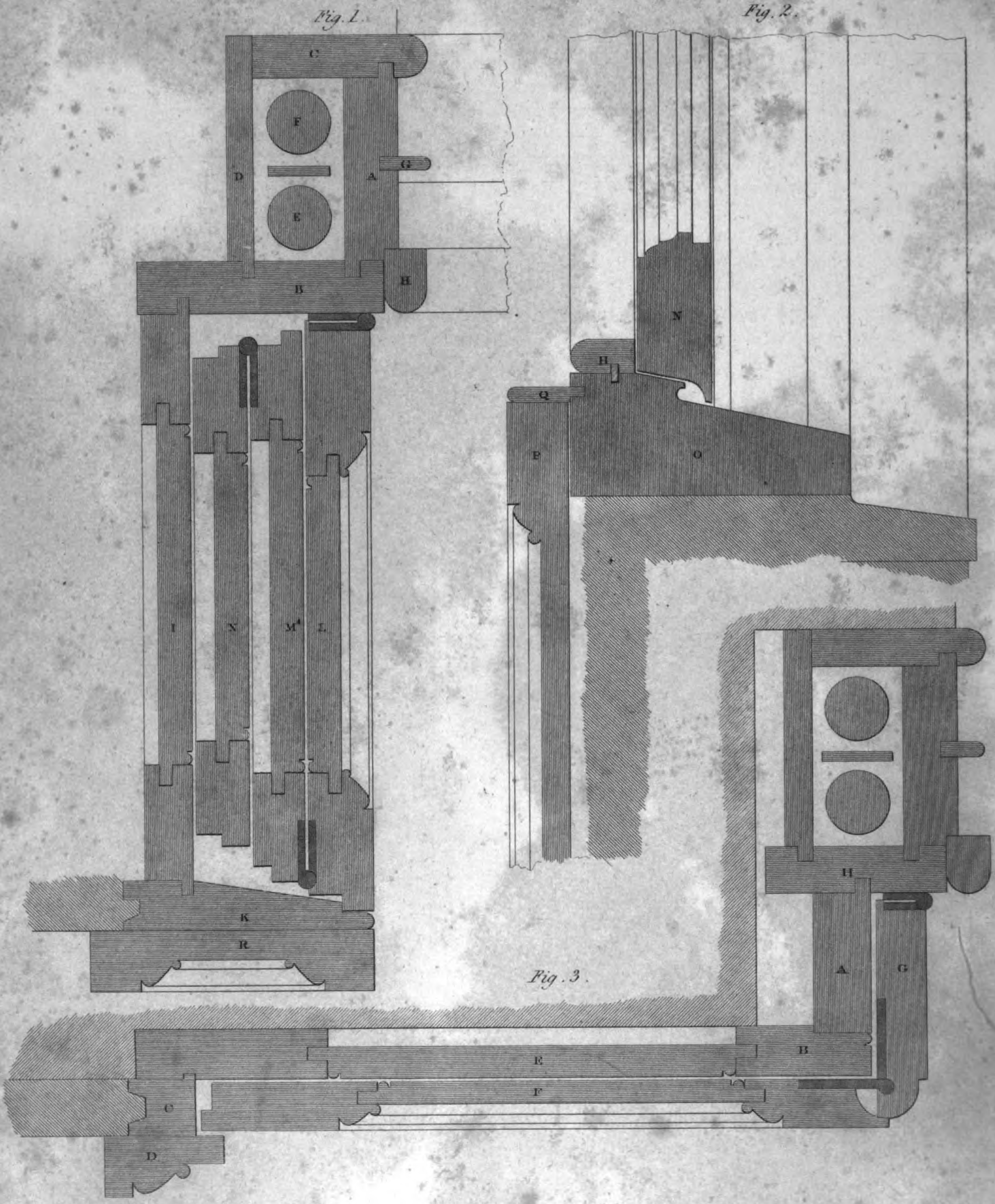
DESIGNS FOR WINDOW SHUTTERS.



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WINDOW SHUTTERS.

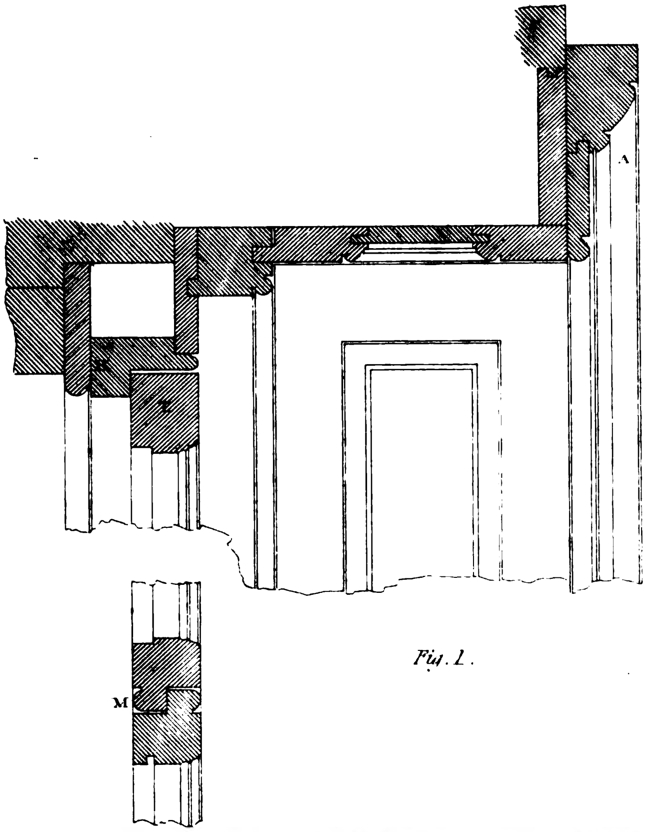
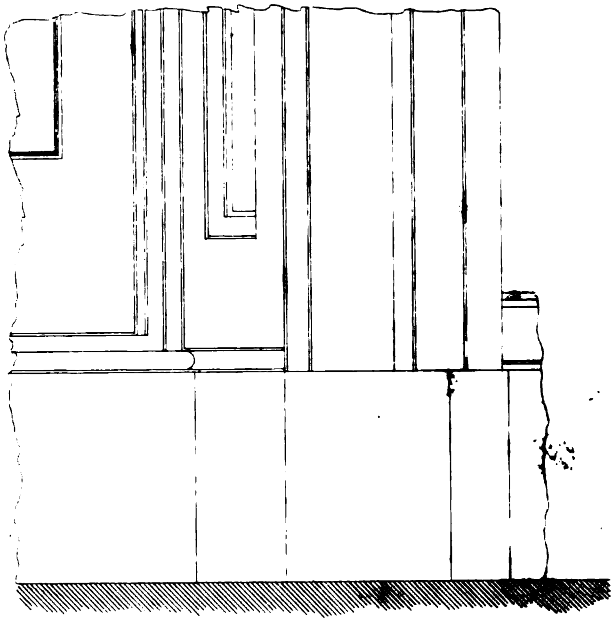


Fig. 1.



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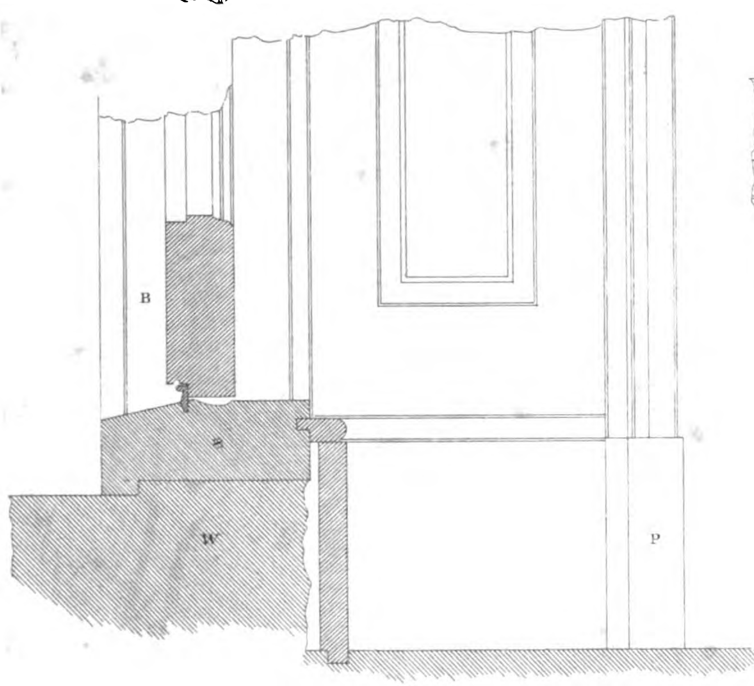

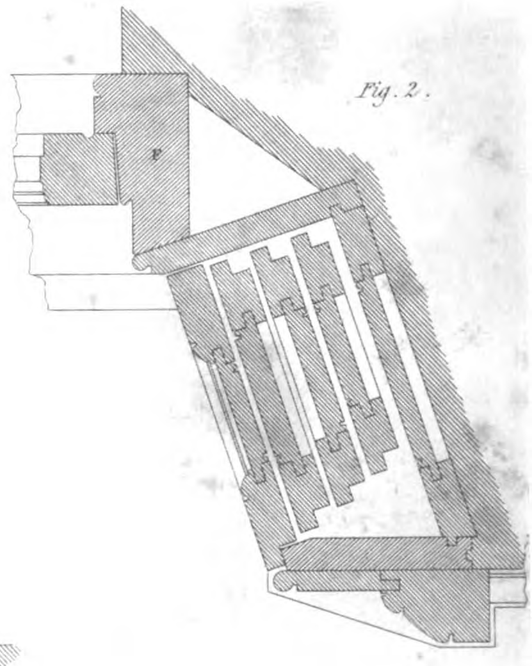

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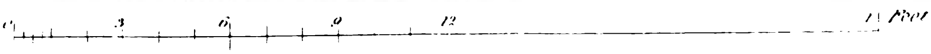

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93. *Plate LX* represents the parts of a CASEMENT or FRENCH WINDOW and its SHUTTERS.

Figure 1 is a vertical section through the window showing its parts.

Figure 2 is a plan of the window-frame and shutters, showing the manner in which they fold into the boxings.

Figure 3 is an elevation of part of the lower part of the window, showing the continuation of the plinth round the window recess.

In *fig.* 1 *w* is the stone sill with the wooden sill S rebated to fit down upon it. B is the bottom rail of the casement, with a metal stop or weather-bar to prevent rain blowing in. Under the bottom rail a hollow is sunk to collect the water which does get in, and from whence it is let out by a very small copper tube inserted in the sill in an inclined direction, so that the water may run to the outside. M is the meeting rails when the casement does not open the whole height; to these we often add a thin plate of brass screwed to the upper rail so as to cover the external joint, as a further guard to keep out the rain. T is the top rail of the casement, and H the head of the frame; and we usually allow a space of about 2½ inches above the head of the casement for the reception of roller blinds. A is the architrave, and P its plinth.

In *fig.* 2, F is the jamb of the window frame; and in setting out the parts, a space is allowed between the shutters, when closed, and the casement for the projection of the handles and fastenings both of the shutters and casements; and the same space allows room for the blind to be down when the shutters are closed.

The same general principles of construction apply to Gothic casements, the differences being chiefly confined to the forms and characters of the mouldings.

94. Where shutters are not splayed a similar construction is adopted, an example for a sash-window is shown in *fig.* 1, *plate LXI.*

The parts A, B, C, D, E, F, G, H, *fig.* 1, form the section of the sash-frame, A is the pulley-stile of the sash-frame; B, the inside lining; C, the outside lining; D, the back lining; and E and F, the weights to balance the sash; H, is a section of the inside bead of the sash-frame; G, the parting-bead, which serves to separate the upper from the lower sash, in order that they may work freely and independently of each other.

Here the pulley-stile, A, is tongued into the inside lining, B, and into the outside lining, C. The back-lining, D, laps over the edge of the outside lining, C, and is tongued into the inside lining B, the parts K, I, B, form a recess for receiving the shutters, and this recess is called the boxing. I, is called the back-lining of the boxing, and is tongued into the inside lining of the sash-frame; K, is a ground, of which the outside is flush with the plaster. The inside lining of the boxing is also tongued into the ground K. R is an architrave, or pilaster.

Figure 2, is a vertical section of the wood-work of the sash-frame, and the parts connected with it. H, is the inside bead, forming a rebate for the lower sash to fall into. This bead is tongued into the sill to prevent rain blowing in at the joint. N, is the bottom rail of the lower sash. O, the sill of the sash-frame, and P, the section of the back lining of the window; with its capping, Q, tongued into the window sill.

95. *Figure* 3, is a section of a sash-frame and shutters, where the wall is not sufficiently thick to admit of boxing-room for the shutters. Here A B E C D is a framed casing of wood, in order to receive the shutters, the shutters are made in two folds, F and G, the one F, being parallel to the wall, and connected to the other, G, by a rule-joint, and G is connected to the sash-frame by but-hinges. This mode of managing the shutters covers too large a proportion of the wall of the room, and is therefore not often adopted.

OF THE CONSTRUCTION OF SKYLIGHTS.

96. SKYLIGHTS are windows in the roofs of houses, and are necessary when light cannot be had in the sides of the room or apartment required to be lighted.

Figure 1, No. 1, *plate LXII,* is a portion of the plan of a square skylight. No. 2, is the elevation.

97. *To find the Seats of the Hips.*—Bisect the angle ABC, No. 1, by the straight line BE; and bisect the angle BCD by the straight line CE: then BE and CE are the seats of the hips.

98. *To find the Length and Angles of the Hips.*—Draw EF perpendicular to CE, and make EF equal to the height of the skylight, and join CF; then CF is the length of the hip, ECF the angle which it makes with its seat or base, EFC the angle which it makes with the perpendicular.

99. *To find the Backing of the Hips.*—From any point G, in EC, draw GL perpendicular to CF, cutting FC in L; and, through G, draw HI, perpendicular to CE, cutting BC in H, and CD in I. In CE make GK equal to GL, and join HK and IK: then will HKI be the angle required.

100. *Figure* 2 is the plan and elevation of an octagonal skylight. The method of finding the seats of the hips, their lengths, angles, and backing, is the very same as in the preceding example; and, therefore, any farther explanation will be unnecessary.

101. *Figure* 3, an octagonal skylight, cut by the inclined side of a roof. The method of drawing the curb for such a roof requires some explanation, in order to be understood. No. 1 is the *plan*, No. 2, the *elevation,* showing the part above the roof, which is exactly the same as that of a common skylight.

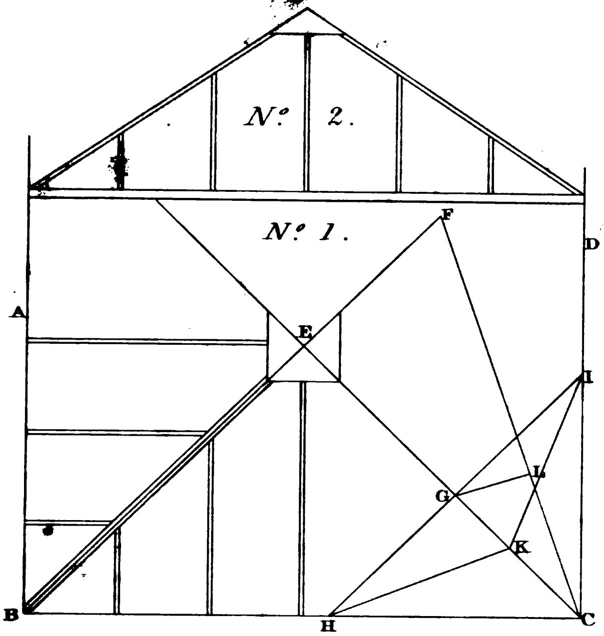
In No. 2, through the summit S, draw ST, parallel to the base, cutting the sloping line of the roof in T.

In No. 3 draw PQ equal to the breadth of the octagon, No. 1. Bisect PQ in U, by a perpendicular, UL. Make UL equal to RT, and join PL and QL. Through L draw KM, parallel to PQ, and make LK and LM each equal to UP or UQ. Draw PM and KQ, cutting each other in I, PL in V, and QL in W. Join VW. Make UC and UD each equal to half the side of the octagon. Draw CK, cutting PL in B, and DM, cutting QL in E. Through I draw NO, parallel to PQ, meeting CK in N, and DM in O. Draw NM, cutting BL in A, and VW in H: also, draw OK, cutting QL in F, and VW in G; then ABCDEFGHA is the outline or exterior edge of the curb. The interior edge, *abcdefgha,* is drawn by means of the same points, K, L, M, and the edges *cd* and *hg,* parallel to CD, so as to meet each other upon the diagonals *a*I, *b*I, *c*I, *d*I, &c.

This is the same operation as finding the perspective representation of an octagon, when the eye of the spectator is at S, No. 2; and RT the section of the picture, and RX a section of the original plane. In perspective K, L, M, No. 3, are called the *vanishing points;* L is the centre of the *vanishing line;* PQ is called the *intersecting line;* PK, or QM, is the *height of the picture;* and S, No. 2, is the *point of sight.*

The points K and M, No. 3, would have been ascertained in perspective, thus: produce UL to Y, and make LY equal to ST. Now, supposing the plan, No. 1, on the other side of PQ, No. 3, with two sides of the octagon parallel to PQ, one of them may coincide with the part CD of PQ. Then, through Y draw a line YK and YM, parallel to the diagonals of the square which form the sides of the octagon; then the points K and M are the *vanishing points.*

Fig. 1.



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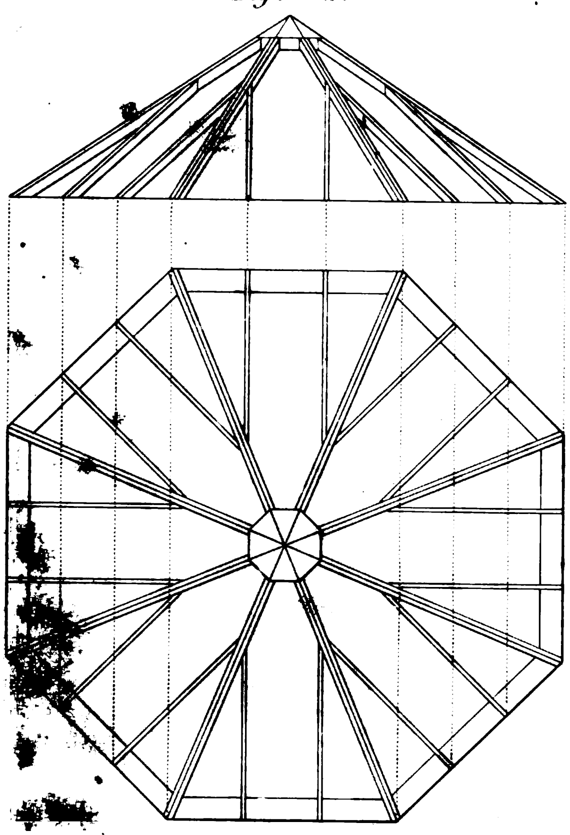

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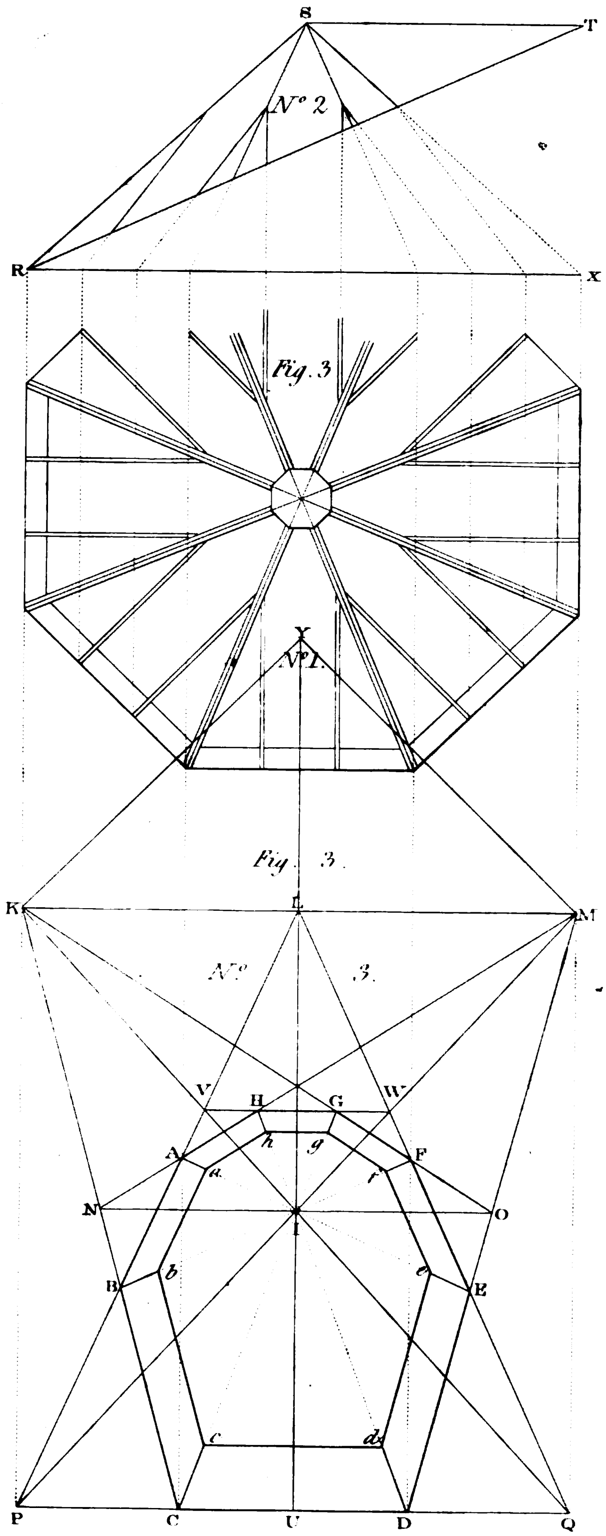

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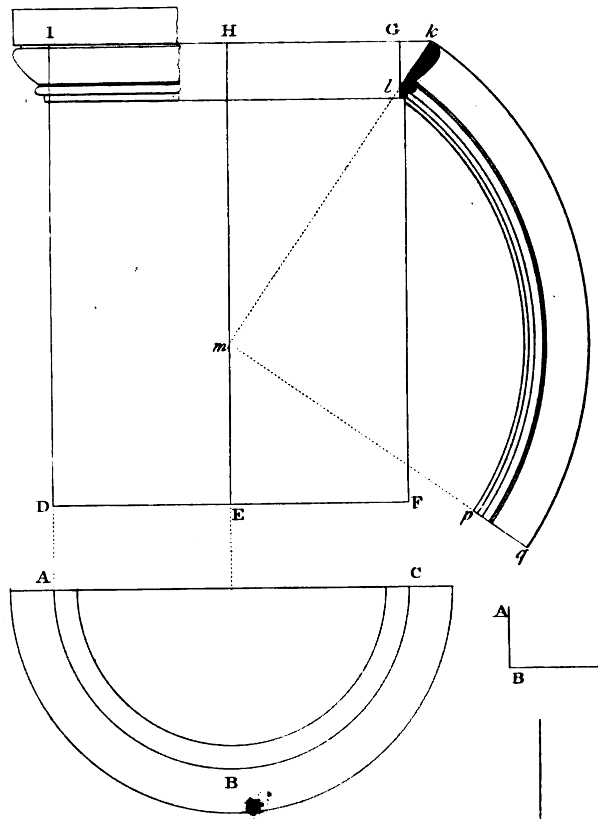
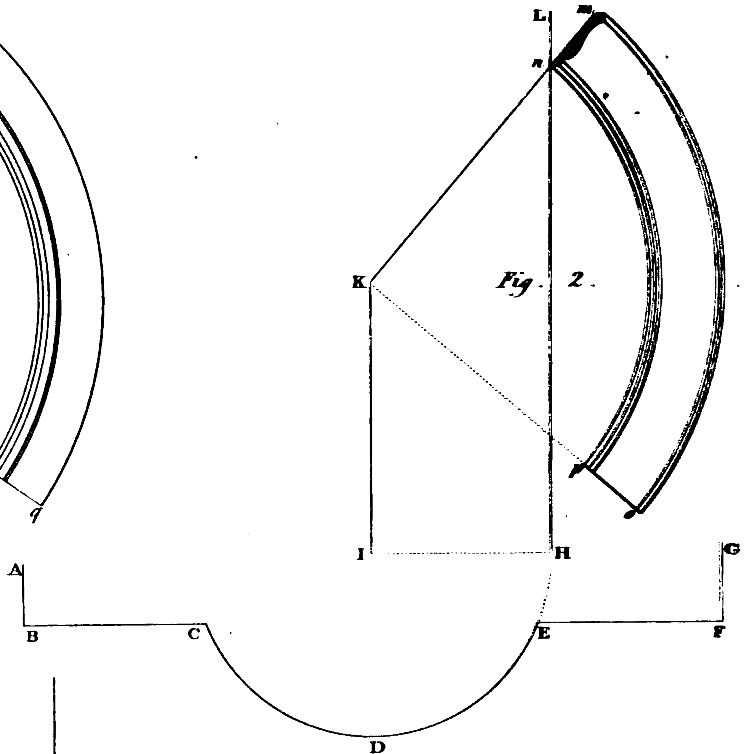
Fig. 1.





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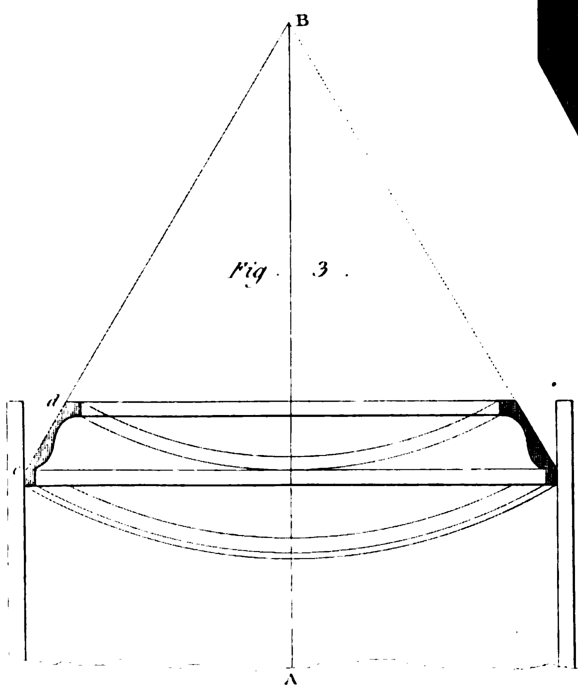

Fig. 3.

Fig. 4.

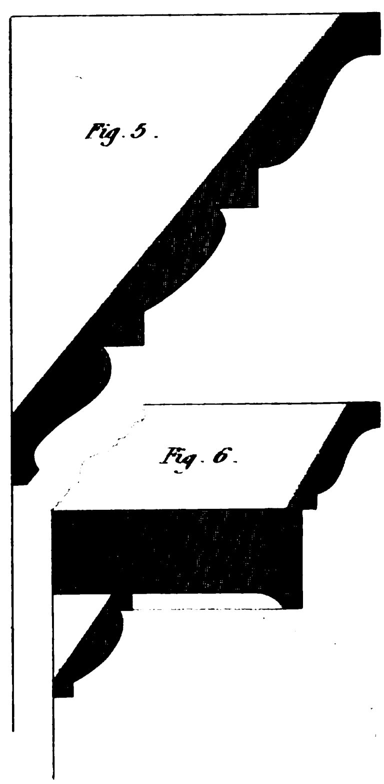

Fig. 5.

Fig. 6.

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SPRINGING AND BENDING MOULDINGS.

102. *Figure* 1, *plate LXIII* is the elevation of a cylindrical body. At the upper end, C and I are the profiles or sections of a cornice, to be put round the cylindrical body. If the moulding be formed from a solid piece, it must be formed in short lengths; for, if the pieces are very long, the grain will run across them, and besides being difficult to work, and not looking well when done, it cuts a great quantity of wood to waste.

In order to avoid cutting across the grain as much as possible, the best way is to form the moulding out of a board as if it were cut by a plane, as nearly parallel to the face as possible; and then, the moulding may be bent in the same manner as in covering the frustum of a right cone. Thus may the moulding be got out of a thin board. Bisect the breadth DF, in the point E, and draw EH parallel to FG or DI. Produce the back of the cornice *k l* to meet the line of the axis in *m*; then, from the point *m*, as a centre, with the distances from *m* to each edge of the fillets and moulding, describe arcs, and these will represent the lines for working the moulding on the board.

Figure 2 shows the method of describing the moulding, when put round the segment of a cylinder CDE. Here the whole semi-circle must be completed, and the moulding placed as before, and described after the same manner.

Figure 3 exhibits the method of describing the moulding for the interior surface of a cylinder.

Figure 4, the section of a base moulding, to be bent on the spring.

Figure 5, a cornice where the mouldings are almost in a straight line. This is well adapted for the surface of a cylindric body.

Figure 6, is the profile of a cornice, when both the cyma-recta and bed moulding are intended to be sprung. Here these parts must be bracketed behind in order to keep the mouldings firmly in their places. The corona is made in a solid piece, by which a variation of outline is obtained that cannot be done when the whole moulding is bent as in *fig.* 5.

DIMINISHING AND FLUTING COLUMNS.

103. To *diminish a column* is to give such a form to the surface, that the sections through the axis will all form convex curves on their edges.

To DIMINISH THE SHAFT OF A COLUMN, as in *fig.* 1, *plate LXV.*—Draw the line representing the axis, on which set off the height of the column; then, from any point in the continuation of this line, at the bottom, describe a semi-circle of a radius equal to that of the bottom of the column, and let the diameter of this semi-circle be perpendicular to the line of the axis. Through each extremity of the axis, draw the diameter of the shaft, at the top and bottom of the column. Through one extremity of the diameter of the top of the column draw a line parallel to the axis, to meet the circumference of the semi-circle. Divide the portion of the arc, between the point of section and the diameter, into any convenient number of equal parts; the more the truer the result will be. Divide the height, or axis, of the column into as many equal parts as those contained in the arc of the semi-circle; and through the points of division, both in the semi-circle and in the axis, draw lines perpendicular to that axis. Through each point, beginning at the bottom of the arc, draw a line, parallel to the axis of the column, to meet its respective diameter; then, through all the points of section, draw a curve, which will form the contour of the shaft, or a section of the column through its axis.

In *figure 2*, instead of dividing the arc into equal parts, divide the distance intercepted on the axis and on the radius of the semi-circle into equal parts, and proceed as in *fig.* 1.

104. To DRAW THE FLUTES OF A COLUMN, as in *fig. 3, plate LXV.*—Draw a semi-circle and the axis of a column, as before. Divide the arc of the semi-circle into as many equal parts as it is to contain flutes; and, because the number of flutes are twenty, and the middle of a flute in the middle of the elevation of the shaft, the semi-circle is divided into ten equal parts, and half a part at the extremity of the diameter. Then, having found the diameters at the different heights of the shaft, as in *fig.* 1, on the lower diameter describe an equilateral triangle. Draw lines through each point of division in the semi-circle, parallel to the axis, to cut the base of the equilateral triangle. From the points of section in the base, draw lines to the vertex. Apply each diameter from the vertex, on the side of the equilateral triangle, and mark the extremity of that side. Through each point of section, on the side, draw lines parallel to the base; and these lines will give the divisions of the flutes, which, being placed on the lines passing through the axis of the shaft, will give the points through which the flutes are to be drawn.

In the corresponding points stick in pins, or nails, and bend a pliable slip of wood round the nails, which will form the curve-line of one side of a flute; do the same for all the remaining sets of points, and we shall obtain the representation of the flutes required. The representation of the shaft thus fluted is shown in *fig.* 4.

Figure 5 exhibits the *diminishing rule*, which is to be applied to the side of the shaft, in order to form the curve of the surface of the shaft, as required.

The Method of Setting-Out the Flutes and Fillets of Pilasters and Columns.

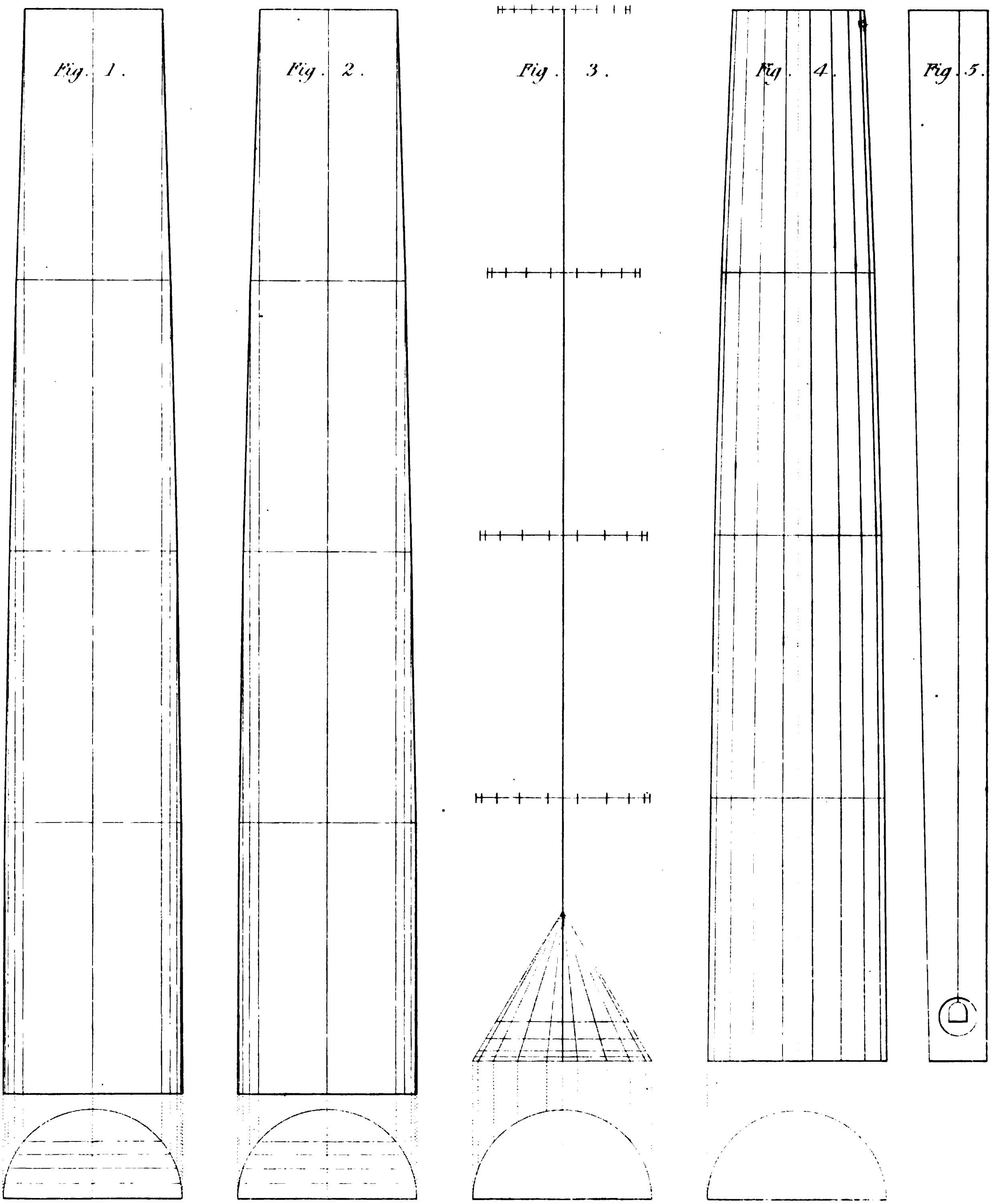
105. To SET OUT THE FLUTES AND FILLETS OF A PILASTER; *figure* 1, *plate LXVI.*—Let us now suppose that the breadth of a flute is to that of a fillet as four to one; and, that the breadth of the fillet, at the corner, is double to one of the intermediate fillets, or half the breadth of one of the flutes.

In the line BC, set off any convenient distance; set another interval, double of that distance; then the next part equal to half: repeat the intervals, so that an interval of one may be between every two intervals of four; and that the intervals of four may be seven in number, and the intervals of one six in number; and that there may be an interval of two upon each extreme.

Then, with the distance BC, containing all the intervals, describe an equilateral triangle ABC. Draw lines to A from every point of division in BC. Now, it being understood that the distance BC is not less than the breadth of the pilaster to be divided; therefore, on each of the sides of the equilateral triangle, make A*d* and A*e* equal to the breadth of the pilaster, and draw the line *de*; then will *de* be equal to the breadth of the pilaster, and will be divided into the number of flutes and fillets required.

Nothing farther is necessary than to lay the parts of the line thus divided upon the edge of a rod; and thus the divisions may be transferred to each end of the pilaster.

106. *Figure 2* exhibits ANOTHER METHOD OF DIVIDING THE FLUTES AND FILLETS OF A PILASTER. The parts being placed on the line AB, in the manner before described, draw BC at any angle so that the distance between the point A and the line BC may be less than the breadth of the



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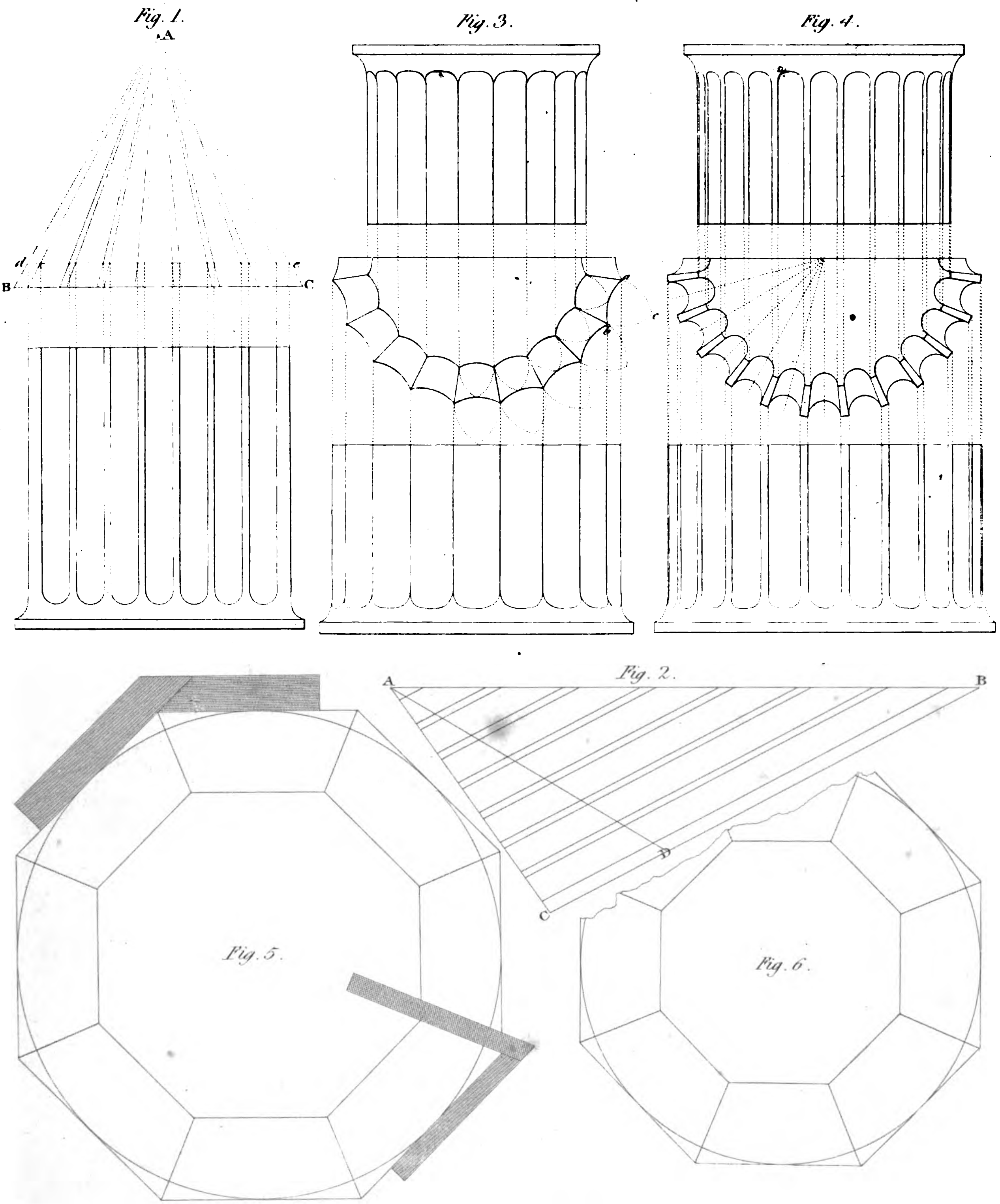
FLUTING OF COLUMNS AND PILASTERS.



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pilaster. Through all the points of section in AB, draw lines parallel to BC: then take the breadth of the pilaster, with a rod or compasses; and with that distance, as a radius, describe an arc from A, cutting the line BC in D, and draw AD: then apply AD as before.

If the sides of the pilaster be convex, the several breadths must be taken equi-distantly throughout its length, and the divisions applied to the lines in the breadth of the pilaster at each part.

The flutes and fillets may be transferred to different circles, taken equi-distantly on the surface of a column, in the same manner; but, instead of applying the parts upon a rod, they must be applied upon as many slips of parchment as the number of circumferences taken in the height of the column. But, in order to regulate the flutes, so that their edges may be all in planes passing through the axis of the column, draw a line on the surface of the column, so as to form the edge of a flute or fillet, or the middle of a flute or fillet; then one of the ends of the slip may be applied to the line where each circle intersects it, and the slip itself stretched round the circumference till the other end meets the line again; then mark the divisions of the flutes and fillets on the circumference of the column. Through every row of equi-distant points, on the circumference of the column, from the line previously drawn, draw a line, which will be the line of demarcation of a flute and fillet.

107. *Figure* 3 shows the METHOD OF DRAWING THE FLUTES AND FILLETS OF A DORIC COLUMN. One particular to be observed in this, is, that a plane, passing through the axis of the column, must pass through the middle of a flute, when that plane is perpendicular to the front, and when it is parallel to the front.

The whole circumference of the Doric column is generally divided into twenty equal parts, by the arrises of the flutes, which terminate upon each other, without the intervention of fillets.

108. *Figure* 4 shows the METHOD OF DESCRIBING THE FLUTES AND FILLETS on the shaft of the IONIC, CORINTHIAN, and COMPOSITE COLUMNS: and here we must observe that, as in the Doric, a plane passing through the axis, perpendicular to the front, in which the column stands, generally passes through the middle of a flute; and, that a plane, passing through the axis, parallel to the front, passes also through the middle of a flute.

The number of flutes and fillets in the Ionic, Corinthian, and Composite orders, are generally twenty-four each; the fillet being about one-fifth part of the breadth of a flute.

109. *Figures* 5 and 6 show the METHOD OF GLUEING UP THE SHAFT OF A COLUMN in *staves.* The number may be more as the diameter of the column is greater. In the example before us, the number of staves is eight; therefore we must describe circles, one to the diameter of the top, and another to the diameter of the bottom, of the column, and circumscribe an octagon round each circle; then draw another octagon, of which the sides are parallel to those of the octagon already drawn; so that the distance of the parallel sides of the octagons may be equal to the proper thickness of stuff required to make the shaft of the column. From the angles of the octagon draw lines to the centre, which will give the directions of the joints; but, though the angle shown by the bevel in *fig.* 5, would not differ sensibly from the truth, the proper method to find it is the same as finding the backing of a hip-rafter; and, if the outside of the column is curved, it will be eligible to apply the bevel from the inside; because, if applied to the convex side of the column, every different place would require a different angle.

ARCHITRAVES, SURBASES, AND BASES.

110. The forms of mouldings used for architraves, bases, and surbases, are various: in *plate LXIV*, we have given a few examples drawn of the usual proportions, and showing the best mode of joining and fixing them.

Fig. 1, 2, and 3, show different architraves, for doors or windows. In *fig.* 1, the ground G is shown; in the others, it is only partly shown.

The connection of the moulding to the plain face of the architrave was formerly effected by glueing on a piece, M, for the moulding, with the joint at the dotted line; but the common practice of good joiners is to tongue the plain part into the moulding; as shown in the figures. *Fig.* 3 is called a double-faced architrave.

111. *Fig.* 4 shows a projecting Gothic architrave, for a door or window; and *fig.* 5, one which does not project before the face of the wall. The latter is most in conformity with the old examples of this species of architecture, but the former is most convenient, because it forms a stop for the surbase and base mouldings. The lines of the plinths are shown, and the upper surface of these plinths should be sloped from *a* to *b*, with a rise of about one-fourth of an inch in an inch.

112. *Fig.* 6 and 7 show a surbase moulding and base moulding with their grounds. Surbase mouldings are not so often employed as formerly; indeed they are seldom used except where they are necessary as a chair-rail, for the protection of the wall of the room.

Fig. 8 and 9 show a surbase and base-moulding for a Gothic room, with their grounds, and mode of fixing.

SHOP FRONTS.

113. The modes of fitting-up Shop Fronts are usually adapted to the nature of the business they are intended for.

Those shops which are intended for exhibiting an extensive assortment of light and elegant articles, require a corresponding degree of lightness and elegance in their structure. Of this character may be esteemed shops for articles of dress and jewellery; as those of silk-mercers, haberdashers, linen-drapers, and jewellers. *Fig.* 1, *plate LXVII*, and *figures* 1 and 3, *plate LXIX*, are examples; of these, it may be remarked, that when the front has a due proportion of length, the central door-way adds much to the importance of the front.

114. There are other businesses which require fronts of a more substantial, though still of an ornamental, species; such are those for the sale of splendid china, furniture, books, &c. *Fig.* 2, *plate LXVII*; *figures* 1 and 2, *plate LXVIII*; and *fig.* 2, *plate LXIX*, are any of them adapted for this purpose, and the good taste of the reader will easily perceive the similar objects to which they may be applied with propriety.

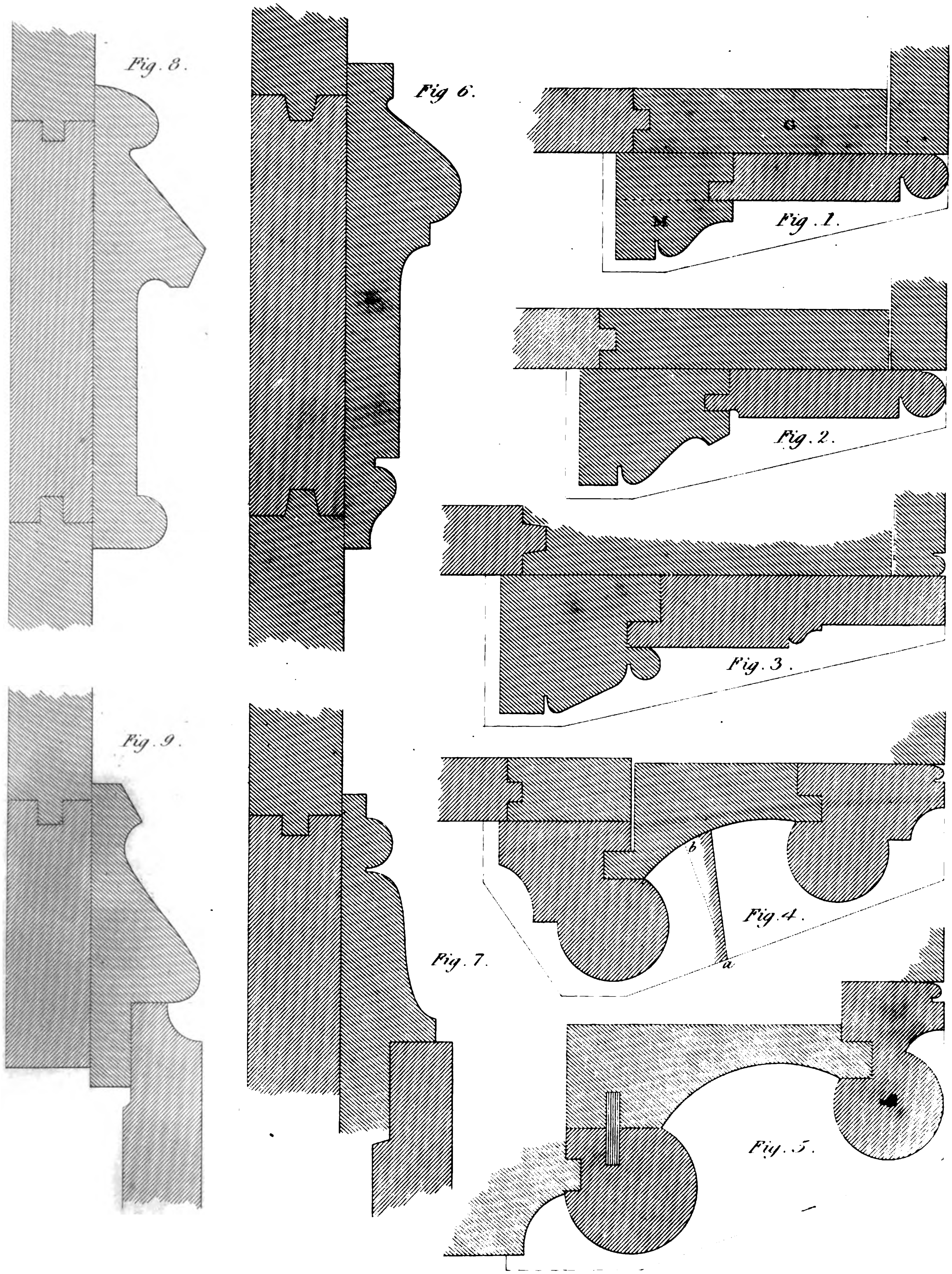
Fig. 8.
Fig 6.
G
M
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 9.
Fig. 7.
b
a
Fig. 4.
Fig. 5.

SHOP FRONTS.

Fig. 1.

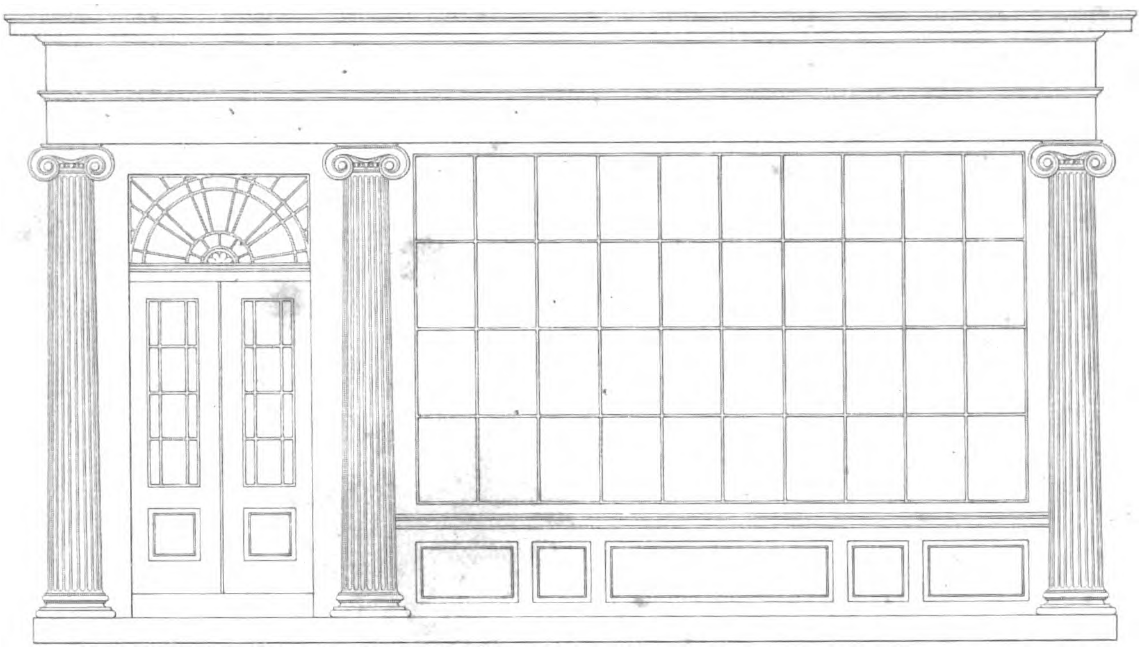

Fig. 2.

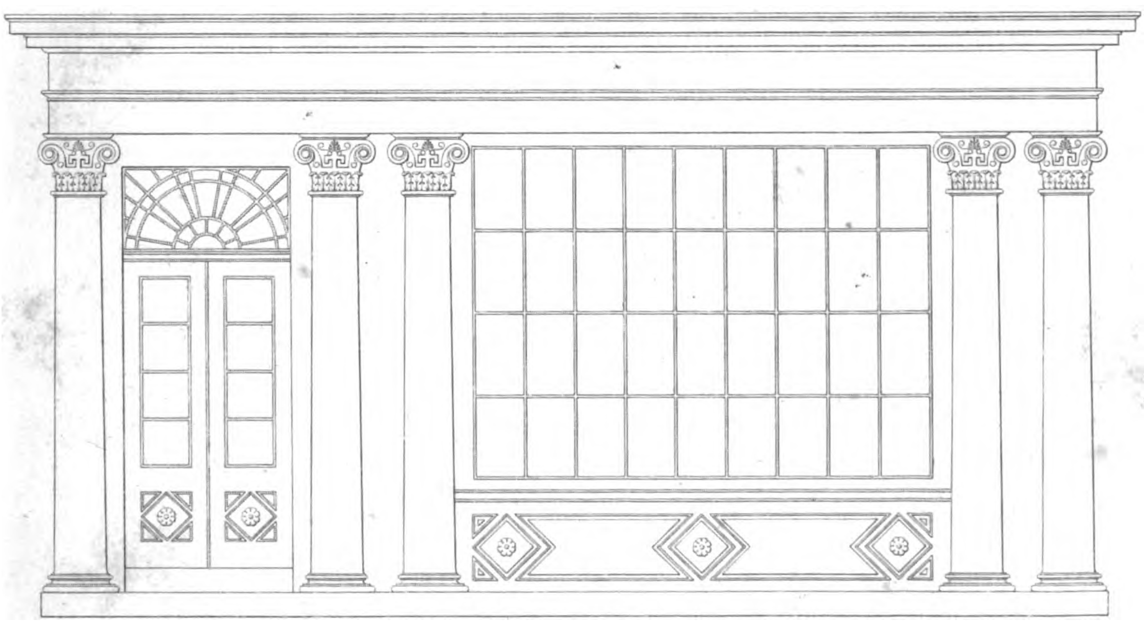

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Fig. 1.

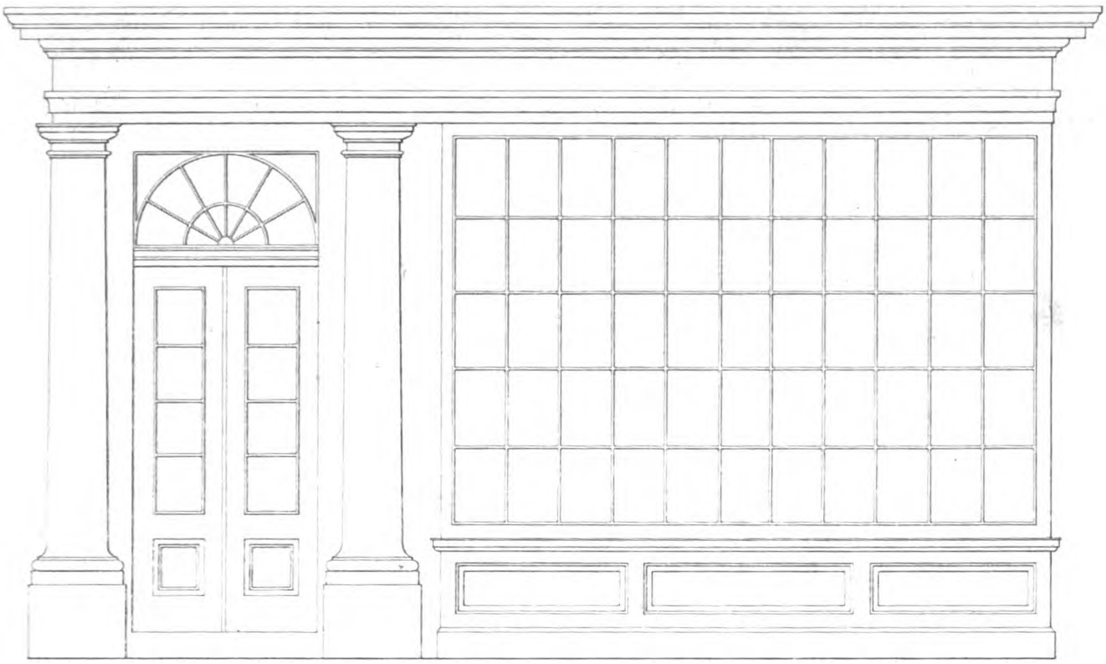
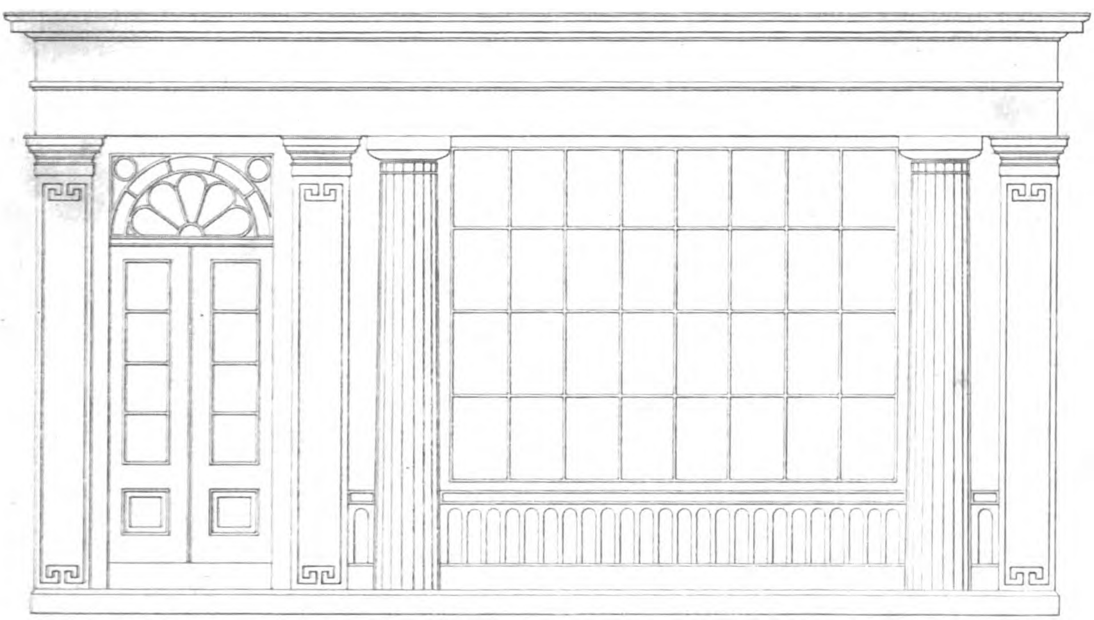


Fig. 2.



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SHOP FRONTS.

Fig. 1.

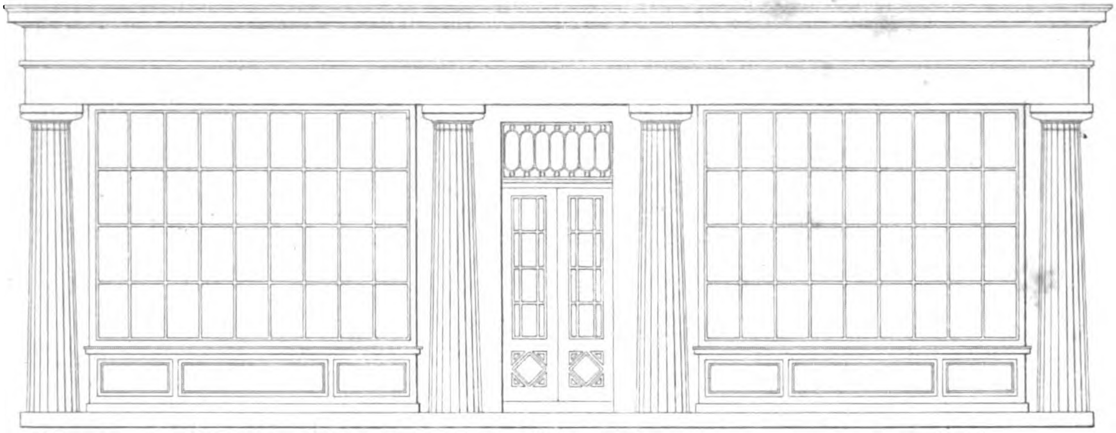


Fig. 2.

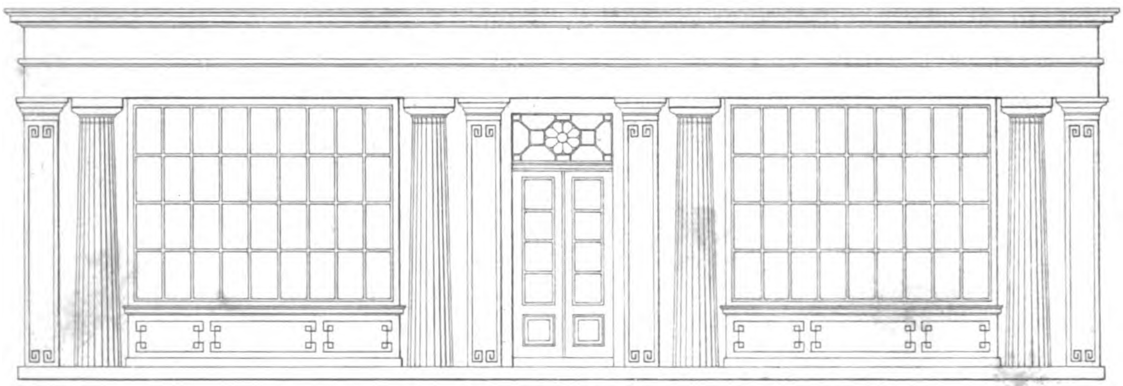
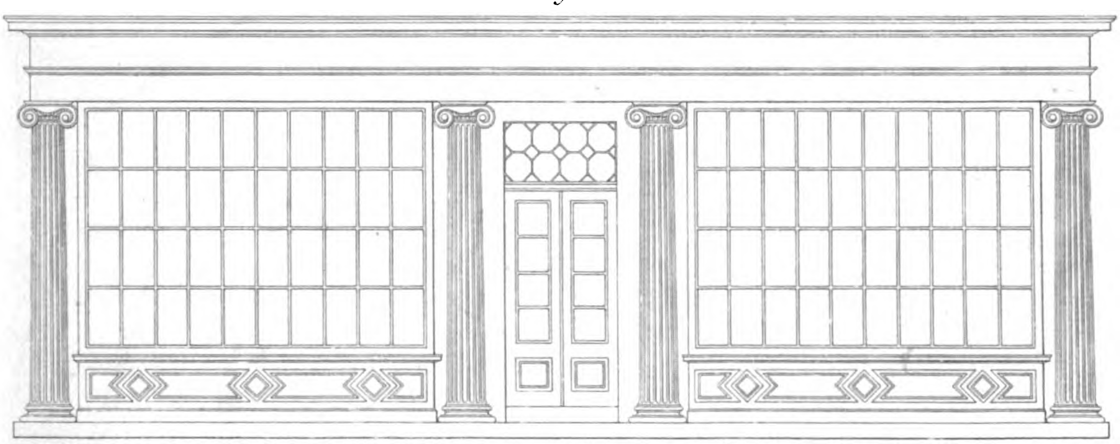


Fig. 3.



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STAIRS AND STAIRCASES.

115. STAIRS and STAIRCASES are made of various forms, but convenience, safety, strength, and simplicity, are the most essential characters of a good one. In a convenient house, the place of the staircase should be easily recognised, and yet without its being exposed to the entrance. The ascent should be easy and regular; and winding steps should be avoided, if possible. There should be landings at convenient distances, a rule which is too frequently neglected in modern houses; Alberti, in his Architecture, says, the best architects never put above nine steps to one flight.

The rail should be of a proper height and strength for safety, and the stairs should be firm and well supported.

Definitions of the Parts of Stairs.

116. BY Stairs we mean an assemblage of steps, so formed and united, that, by walking on them, we ascend or descend from one height to another.

117. The surfaces on which we set our feet are called TREADS; and these, for the convenience of walking, are set at equal distances, and parallel to each other.

118. In order to give a solid appearance to the whole, every tread has a vertical piece beneath it, called a RISER. A riser and tread, when fixed together, forms what is called a STEP.

119. The inclosed space in which the steps are fixed, is called the STAIR-CASE. One end of each step is commonly supported by a wall of the staircase.

120. If the ends of the steps terminate so as to leave an open space in the centre of the staircase, the space left open is called the WELL-HOLE. The form of the well-hole is sometimes square, or rectangular, but most frequently it has parallel sides and circular ends.

121. Stairs that have a well-hole, or hollow in the centre, and the steps supported by their ends in the walls of the staircase, are called GEOMETRICAL STAIRS.

122. The front edge of the tread is called the NOSING, and is usually rounded, or both rounded and moulded. The line which may be drawn to touch the nosings of a series of steps is called the LINE of NOSING.

123. When the treads of a series of steps are each parallel, such a series of steps is called a *straight flight*, and the steps are denominated FLYERS.

124. When the treads of the steps diminish in breadth towards the central part of the staircase, the steps are called WINDERS.

As the ends of the steps, called winders, generally terminate upon a surface which is perpendicular both to the risers and treads, the surface on which they thus terminate is commonly called that of a cylinder; though only strictly so when the well-hole is circular.

125. When the tread of a step is so broad as to be equal to two or more of the other steps, and situated between floors, it is called a *landing*, or RESTING-PLACE.

126. If the resting-place be a square, or, if the riser to a resting-place be at right angles to the riser from it, the resting-place is called a QUARTER-SPACE OR QUARTER-PACE.

127. When the breadth of the resting-place extends across the staircase, or the riser to the resting-place be parallel to the riser from it, the resting-place is called a HALF-SPACE OR HALF-PACE.

128. Half-spaces and quarter-spaces, on a level with floors, are properly called *landing-places.*

Proportions of the Parts of Stairs.

129. The breadth of the treads of the steps of common stairs is from nine to twelve inches. In the best staircases of noblemen's houses and public edifices, the breadth ought never to be less than twelve, nor more than fifteen inches; the latter is the breadth of the treads of the stairs of the Palace at Hampton Court.

130. A step of greater breadth requires less height than that of a less breadth; and the first person who attempted to fix the relation between the height and width of a step, upon correct principles, was, we believe, Blondel, in his "*Cours d'Architecture.*" If a person, walking upon a level plane, move over a space, P, at each step, and the height which the same person could ascend vertically at one step with equal ease, were H; then, if h be the height of a step, and p its width, the relation between p and h must be such that when $p=P$, $h=o$; and when $h=H$, we must have $p=o$. These conditions are satisfied by an equation of the form $h=H\ (1-\frac{p}{P})$.

Blondel assumes 24 inches for P, or the step a person can make with ease on a level plane, and 12 inches for H, or the height a vertical step can be made with equal ease; and, putting these numbers for P and H, in our equation, it becomes $h=\frac{1}{2}(24-p)$, which is precisely Blondel's rule. We do not think that the rise, which is equal to a level step of 24 inches, is more than 11 inches, but it would be difficult to ascertain the ratio exactly, and the above are so near, and agree so well with our observations on stairs of easy ascent, when the breadth of the tread includes the nosing, that they may be taken for the elements of a practical rule. Hence, according as the tread p, or the rise h, is given, we have $h=\frac{24-p}{2}$; or $p=24-2h$.

Thus, if the height of a step be six inches, then $p=12$, and $\frac{24-12}{2}=6$, the rise for a step that has a tread of 12 inches, including the nosing. And, as the nosing ought not to exceed an inch, we have these general rules.

131. *To find the proper Rise for the Steps when the Tread is given.*

From 23, substract the breadth of the tread in inches, and half the difference will be the rise.

Thus, if the tread be 12 inches, then

$$\begin{array}{r} 23 \\ 12 \\ \hline 2)\ 11 \\ \hline 5\tfrac{1}{2} \end{array}$$

inches, the rise requred.

132. *To find the proper Tread when the Rise for a Step is given.*

Substract twice the rise from 23, and the remainder will be the proper width for the tread.

Thus, if the rise be 5 inches,

$$\begin{array}{rr} & 23 \\ 2\times 5 = & 10 \\ \hline & 13 \end{array}$$

inches, the tread required.

Again, if the rise be 7 inches, then,—

$$\begin{array}{r} 23 \\ 2 \times 7 = \underline{14} \\ 9 \end{array}$$ inches, the tread for a step with a rise of 7 inches.

133. Before we set out the stairs in a building, we must consider the height of the story, and determine upon the height or rise of the steps; which being done, we must take the height of the story in inches, and divide the number of inches in the height of the story by the least rise proposed for a step; if the result be fractional, divide the height of the story by the number, neglecting the fraction, and the result will be the exact height of the rise. Thus, for example, suppose the height of the story to be ten feet four inches, and the height of a step to be not less than seven inches, how many steps will be required in order to ascend to the given height?

Here (10 *ft.* 4 *in.*) × 12 = 124 inches. Now, $\frac{124}{7} = 17\frac{5}{7}$, which, neglecting the fraction, is the number of steps required; and $\frac{124}{17} = 7\frac{5}{17}$ inches, the height of the rise. But, if there be no winders in the stairs, an even number of steps will be more convenient than an odd number: therefore, either eighteen or sixteen may be adopted; if we must have sixteen, $\frac{124}{16} = 7\frac{3}{4}$ inches; which may answer very well: but, if we are still confined for room on the plan, we must be obliged to have recourse to winders.

134. The breadth of a staircase may be from five to twenty feet, according to the destination of the building; but if the steps be less than two feet four inches in length, they become inconvenient for the passing of furniture, and such narrow stairs should be avoided even in small houses.

135. When the height of the story is very considerable, resting-places become necessary. In very high stories, that admit of sufficient head-room, and where the plan or area for the stairs is confined, the stairs may make two revolutions in the height of the story; that is, in ascending or descending, we may go twice round the newel or well-hole; and this becomes necessary, otherwise the steps would be enormously high, or extravagant floor-room must be allowed for the stairs.

As grand and principal staircases require broad and low steps, they therefore require to be numerous, and admit of only one revolution in the height of the story; the plan being always proportioned to the height of the building.

136. It may not be amiss to give an example here for a principal building, in order to show the number of steps both in the grand and in the common staircase.

For this purpose, suppose the story of a house to be sixteen feet high from floor to floor, the height of the steps of the servants' staircase to be not less than seven inches, and that of the grand staircase to be not more than six inches.

Now the height of the story reduced to inches is 192, and first dividing by 7, thus—

$$7)\underline{192}$$
$$27\tfrac{3}{7}\text{; therefore, } 27)\underline{192}$$
$$7\tfrac{1}{9} \text{ inches the rise.}$$

then, for the principal stairs, dividing by 6, thus—

$$6)\underline{192}$$
$$32 \text{ steps.}$$

So that the servants' stair requires twenty-seven steps, and the grand staircase thirty-two: but the space or area required to execute the common would not be much less than that required to execute the grand staircase; the common stairs must therefore have two revolutions in the height. This being allowed, will reduce the area to half of what it otherwise would have required.

We must, however, observe that, when the height of the story is less than fourteen feet, the stairs will not admit of two revolutions.

In planning a large edifice, particular attention must be paid to the situation of the stairs, so as to give the most convenient and easy access to the several rooms.

137. With regard to the lighting of a grand staircase, a lantern-light, or a sky-light with a horizontal light under it, is the most appropriate. By introducing these, more effect is produced, and the light admitted is more powerful; but, indeed, where one side of the staircase is not a portion of the exterior wall, a lantern or skylight is the only way in which the light can be admitted.

138. In stairs constructed of stone, the steps are made of single blocks; quarter-spaces and half-spaces are, however, often made in two or more pieces, and joggled together: but, when the material is wood, the risers and treads must be made of boards, which are fastened together with glue, brackets, and screws; and these, though done with the utmost care, can never be made so firm as not to yield a little to the passenger.

To prevent stairs from becoming ricketty, in length of time, the steps must have an additional support under them; and that the appearance may be both light and pleasant, the whole must be confined to as small a space as possible. This additional wood-work, which is necessary to the firmness and durability of the construction, is called the CARRIAGE OF THE STAIR.

139. The *carriage of a stair* usually consists of several pieces framed together; and each flight of steps is generally supported by two pieces of timber, placed under the steps, and parallel to the wall, being fastened at one or both ends to pieces perpendicular to the walls.

The pieces of timber which are thus placed under the steps are called ROUGH STRINGS.

140. DOG-LEGGED STAIRS are those which have no well-hole, and consist of two flights, with or without winders. The hand-rail, on both sides, is framed into vertical posts, in the same vertical plane, as well as a board which supports the ends of the steps. The boards are called STRING BOARDS, and the posts are called NEWELS. The newels not only connect the strings, but they afford the principal support to the rail; and thus it may be affirmed that the newels, posts, and hand-rail, are all in one plane. (See *plate LXX.*)

141. OPEN-NEWELLED STAIRS are those which have a rectangular well-hole, and are divided into two or three flights.

142. BRACKETED STAIRS are those where the string-board is notched, so as to permit the risers and treads to lie upon the notches, and pass over beyond the thickness of the string-boards: the ends of the steps are concealed by means of ornamental pieces called BRACKETS.

Geometrical stairs (defined *art.* 121) are generally bracketed; but, in dog-legged and open-newelled stairs, only those of the best kind are bracketed.

143. A PITCHING-PIECE is a piece of timber wedged into the wall, in a direction perpendicular to the surface of that wall, for supporting the rough strings at the top of the lower flight, when there is no trimmer, or where the trimmer is too distant to be used for the support of the rough strings.

144. BEARERS are pieces of timber fixed into, and perpendicular to, the surface of the wall, for supporting winders when they are introduced; the other end of the bearer is fastened to the string-board.

A NOTCH-BOARD is a board into which the ends of the steps are let: it is fastened to the wall, or one of the walls, of the staircase.

145. CURTAIL-STEP is the lowermost step of stairs, and has one of its ends, next to the well-hole, formed into an ornament representing a spiral line.

These are the principal parts which belong to a stair or stairs; other parts connected with it belong to the HAND-RAIL, and will be all defined in treating of Hand-railing.

Construction of Dog-Legged Stairs.

146. HAVING taken the dimensions of the stair, and the height of the story, lay down a plan and section upon the floor, to the full size, according to the design representing all the newels, string-boards, and steps; by this method the exact lengths and distances of the parts will be ascertained, as also the angles which they make with each other. The quantity of head-room, the situation of apertures and passages, and whether quarter-spaces, half-spaces, or winders, are to be introduced, having been previously settled on the drawing.

In order to have the most variety in the construction, we will suppose the stairs to have two quarters of winders; the whole being represented as framed together, the string-board will show the situation of the pitching-pieces, which must be put up next in order, by wedging the one end firmly into the wall, and fixing the other end into the string-board; which, being done, put up the rough-strings, and put up the carriage part of the flyers. In dog-legged staircases the steps are seldom glued up, except in cases where the nosings return; we shall therefore suppose them in separate pieces, and proceed to put up the steps.

Place the first riser in its intended situation, fixing it down close to the floor, the top at its proper level and height, and the face in its true position. Nail it down with flat-headed nails, driving them obliquely through the bottom part of the riser into the floor, and then nailing the end to the string-board.

Place the first tread over the riser, observing to give the nosing its proper projecture over the face of the riser; and, to make it lie more solid upon the string, notch out the wood at the farther bottom angle of the riser, where it is to come in contact with the rough-strings, so as to fit it closely down to a level on the upper side, while the under edge beds firmly on the rough-strings at the back edge, and to the riser at the front edge: nail down the tread to the rough-strings, by driving the nails from the place on which the next riser stands, through that edge of the riser, into the rough-strings, and then nailing the end to the string-board.

Begin again with the second riser; which, being brought to its breadth, and fitted close to the top of the tread, so that the back edge of the tread below it may entirely lap over the back of the riser, while the front side is in its real position. Then nail the tread to the riser from the under side, taking care that the nails do not go through the face, which would spoil the beauty of the work.

Proceed with riser and tread, alternately, until the whole of the flyers are set and fixed.

Having finished the first flight of steps, fix the top of the first bearer for the winding-tread on a level with the last parallel riser, so that the farther edge of this bearer may stand about an inch forward from the back of the next succeeding riser, for the purpose of nailing the treads to the risers, upwards, as was done with the treads and risers of the flyers. The end of this bearer being fitted against the back of the riser, and having nailed or screwed it fast thereto, fix then a cross-bearer, by letting it half its thickness into the adjacent sides of the top of the riser, and into the top of the long bearer, so as not to cut through the horizontal breadth, nor through the thickness of the riser, which will weaken the long bearer, and injure the appearance of the work: then fix the riser to the newel.

Try the first winding step-board to its place; then, having fitted it to its bearings, and to the newel, with a re-entrant angle, or bird's mouth, fix it fast. Proceed with all the succeeding risers and step-boards until the winders are complete.

Having finished the winders, proceed with the retrogressive or upper flight, exactly in the same manner as has been done with the lower flight.

The workman must then proceed to strengthen the work in the following manner: fix rough brackets into the internal angles of the risers and step-boards, so that their edges may join upon the sides of the rough-strings, to which they are fixed by nails, and thus the work is completed.

147. In *plate LXX, figure* 1, is represented a DOG-LEGGED STAIR with flyers only; that is, which consists of steps of equal breadth of tread. No. 1 is the Plan, showing the length and tread, or breadth of the steps; or that which shows their exact area; the dotted lines show the lines of the fronts of the risers. No. 2, the Elevation, shows the sections or ends of the steps.

Figure 2 represents a DOG-LEGGED STAIR with winders, connecting the two straight flights. No. 1 is the Plan, showing the areas of the treads of the steps, as before. No. 2, the Elevation, shows the ends of the steps in the two flights, and the risers in both quarters of the winders.

148. It is proper to remark that, in the best dog-legged stairs, the nosings are returned, and sometimes the risers mitred to the brackets, and sometimes mitred with quaker-strings. In this case, a hollow must be mitred round the internal angle of the under side of the tread and face of the riser. Sometimes the string is framed into a newel, and notched to receive the ends of the steps; and, at the other end, a corresponding notch-board, and the whole of the flyers are put up in the same manner as a step-ladder.

By paying proper attention to what has here been said, a workman of good understanding will be able to execute such stairs, and put them up in the most sufficient manner, although he might never have seen one made or put up before.

Bracketed Stairs.

149. HERE the same method of laying down the plan and section must be observed as in dog-legged stairs. The balusters must be neatly dovetailed into the ends of the steps, two dovetails being put in each, in such a manner that one of the balusters may have one of its faces in the same plane with the riser, and the other face in the same plane with the face of the bracket.

Geometrical Stairs.

150. THE steps of Geometrical Stairs ought to be neatly finished, so that they may present a handsome appearance. The riser and step-boards ought not to be less than one inch and a quarter thick. The risers and step-boards ought to be well glued and secured together, with blockings glued in the internal angles. When the steps are set, the risers and step-boards must be fixed together by screws, passing from the under side of each horizontal part into the riser. The brackets must be mitred to the risers; and the nosings, with a cavetto underneath, should be returned upon the brackets, and stopped upon the string-board. The under side may be finished with lath and plaster. In many old buildings, where the principal stairs were

STAIRS.

Fig. 1.

No. 2.

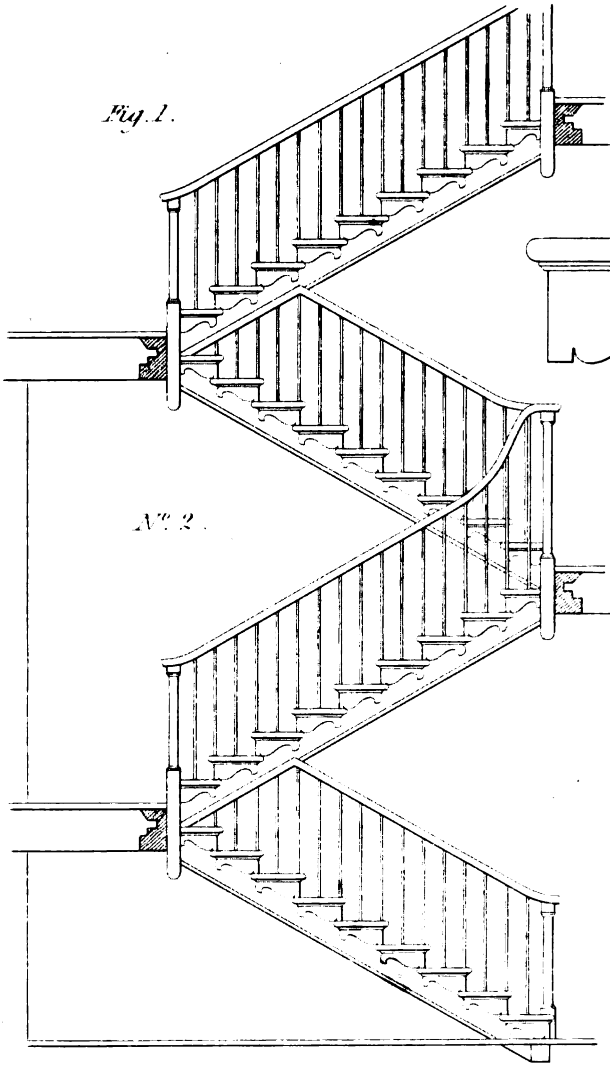

Fig. 2.

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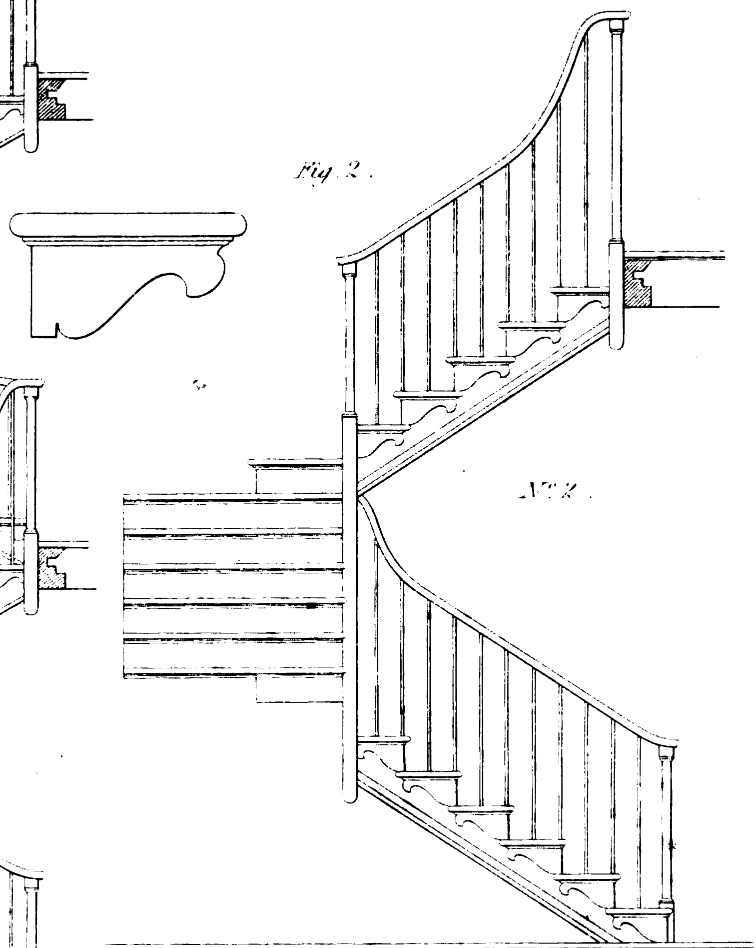

Fig. 1.

No. 1.

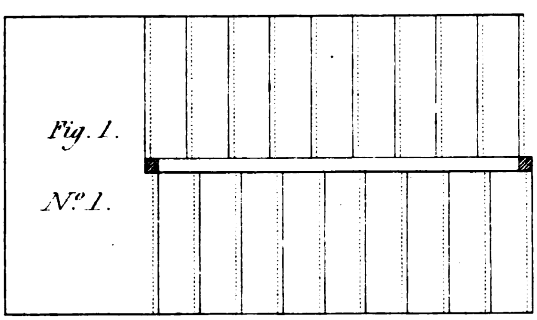

Fig. 2.

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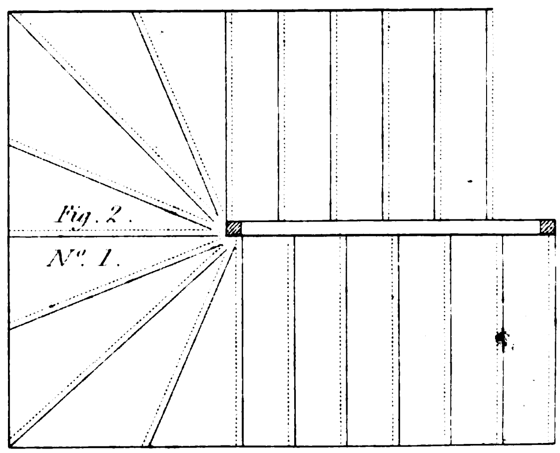

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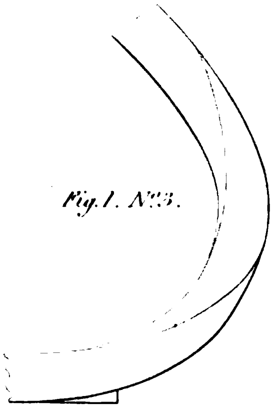

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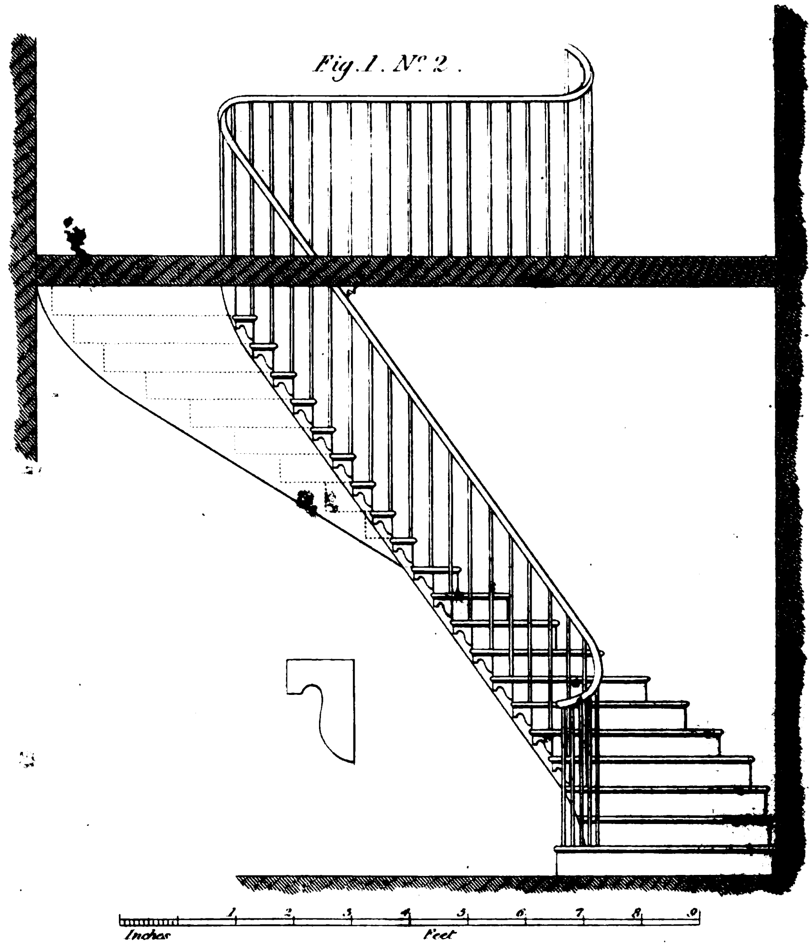


Fig. 1. No. 2.

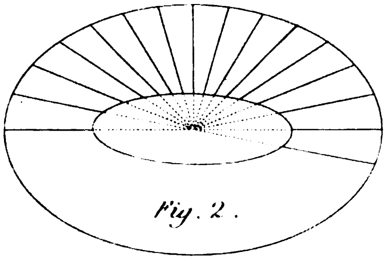


Fig. 2.

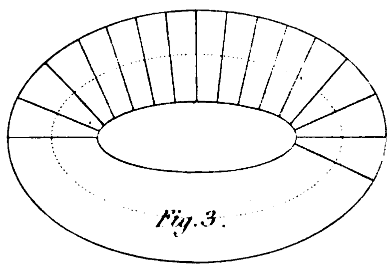
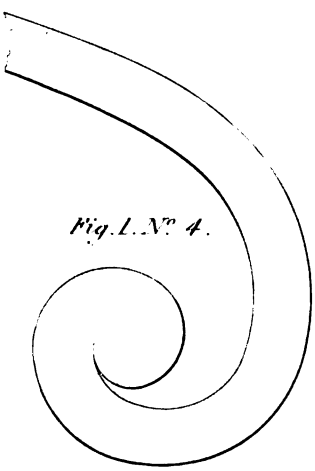


Fig. 3.



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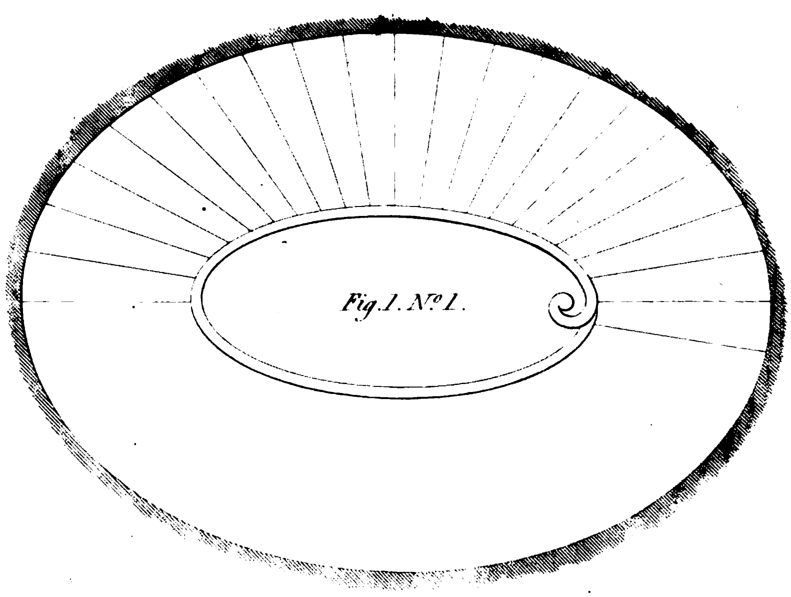

Fig. 1. No. 1.

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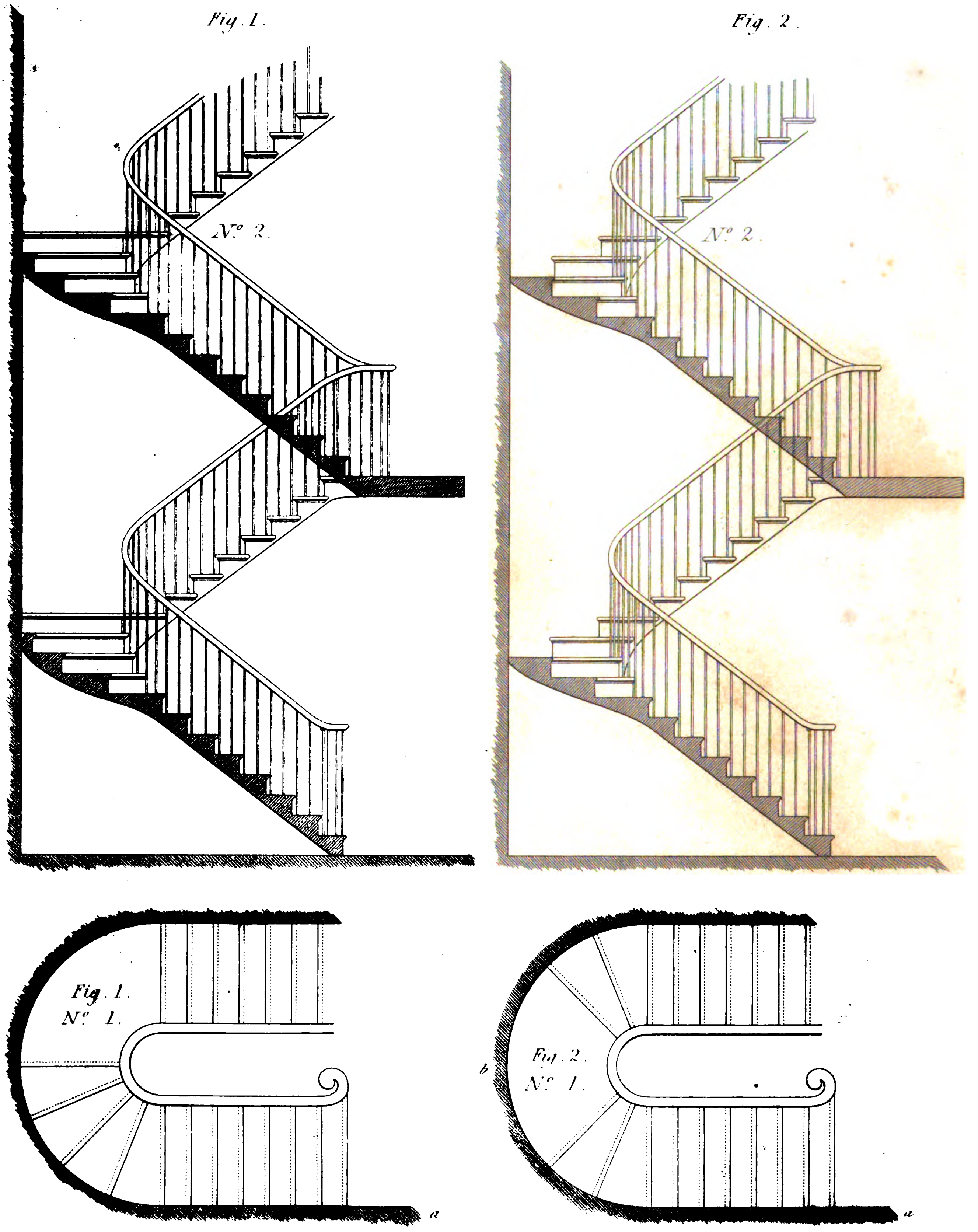
GEOMETRICAL STAIRS.



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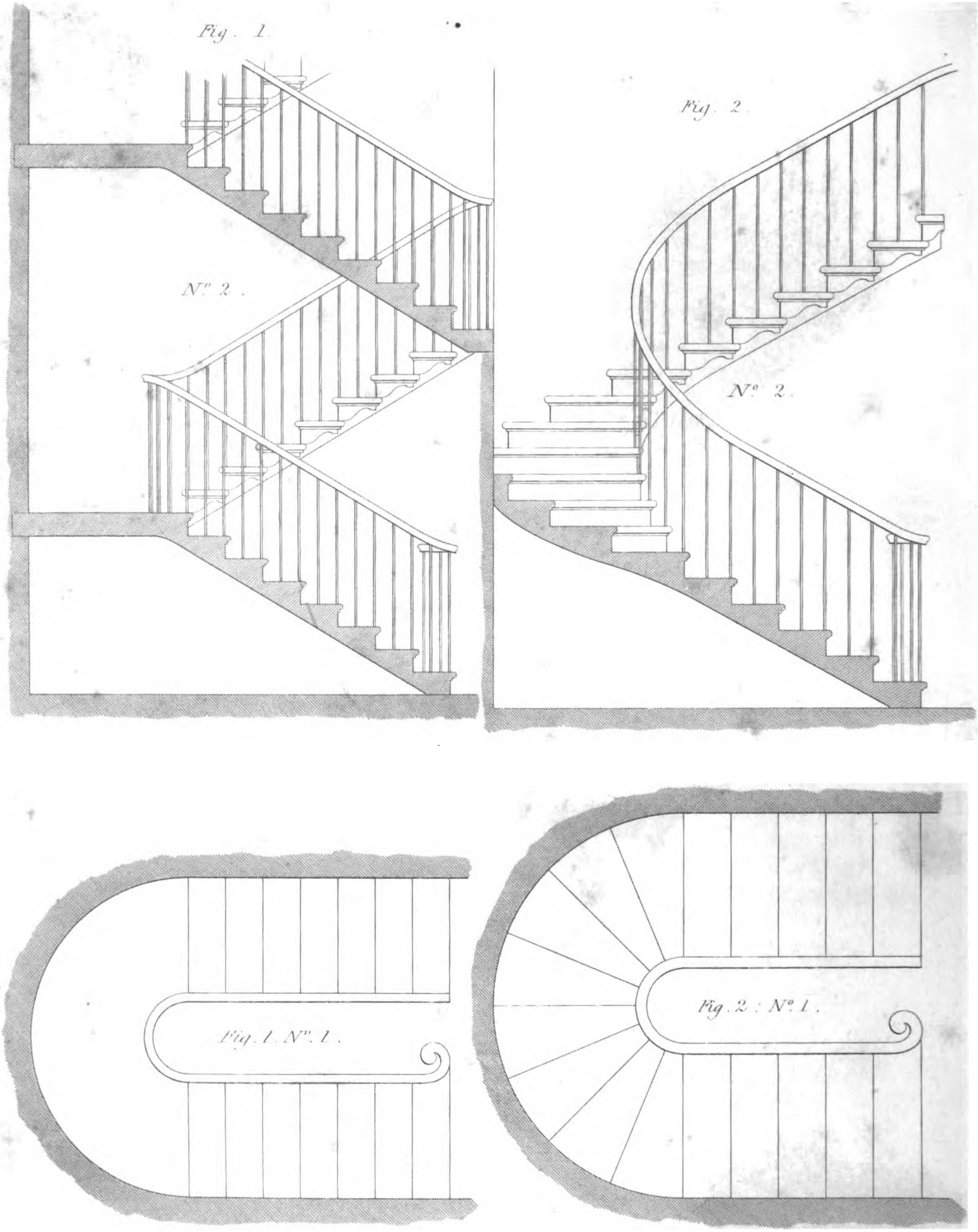

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constructed of wood, it was customary to pannel the soffit; but this is now very seldom done, except in pulpit-work, as the difficulty and time required to execute the work occasions very great expenses to the proprietor.

Geometrical Stairs are sometimes finished without brackets, the risers being mitred to the string-boards, instead of brackets; and this mode is mostly practised in ordinary works.

As the parts of a geometrical stair form the subject of the following article upon hand-railing, the other connecting parts will be specified in their proper place.

Geometrical Stairs are mostly on a semi-circular plan, with a flight below, and another above; sometimes the plan is formed by four lines, at right angles with each other, and connected by quadrants of circles.

151. *Figure* 1, *plate LXXI*, is a Geometrical Staircase, without winders. No. 1 is the Plan, and No. 2, the Elevation of the same.

Figure 2, a Geometrical Staircase, with winders in both quarters. No. 1 is the Plan, showing the areas of the steps; and No. 2 is the Elevation, showing both the height and breadth of the steps, as, also, the proper turnings of the rail.

152. *Figure* 1, *plate LXXII*, represents a Geometrical Staircase, with winders in one quarter. No. 1 is the Plan; and No. 2, the Elevation, shows the turnings of the rail, agreeably to the plan.

Figure 2 is a Plan and Elevation of a Geometrical Staircase, with winders adjoining each flight, and a space between the winders. No. 1 is the Plan; and No. 2, the Elevation of the same. This construction is much better than the preceding one.

153. *Figure* 1, *plate LXXIII*, is a representation of an Elliptical Staircase. No. 1, the Plan; No. 2, the Elevation.

No. 3 is the Elevation of the Twist and Scroll, which terminates the rail.

No. 4, Plan of the Scroll, agreeing in size with No. 3.

154. In No. 1, the steps of the stair are equally divided round the wall-line, and equally divided round the inside of the rail. This mode of division lessens the acuteness which would otherwise be occasioned at the angles when the lines are drawn to the centre of the plan. The effect of drawing the lines to the centre, which represent the risers of the steps, is exhibited in *fig.* 2, where the half of the outside ellipse is divided equally, and the lines which represent the risers are drawn to the centre of the plan.

When the steps are equally divided at the well-hole, the developement of the external as well as the internal points of the steps will form a straight line. But, if they are divided as in *fig.* 2, as the breadth of the steps increases towards the extremities of the major-axis, the points of the external and internal angles of the developement will be in a curve of contrary flexure.

155. There are several ways in which we can conceive the steps to be divided: one of these is to suppose them perpendicular to one of the curves; for they cannot be perpendicular to both: but this method renders the steps very unpleasant to the eye, as it makes them so very broad next to the wall, and so very narrow at the rail, that it has a very unpleasant effect in comparing the whole together. Another method is to proportion their breadths to the curvature of the wall and rail-lines: but this must be done only with regard to the inner curve, as the steps ought to be of an equal breadth at the middle.

156. The most natural method of division is to draw a line in the middle of the steps, and divide it into equal divisions, then draw the lines of the risers perpendicular to this curve; *fig.* 3 shows a plan divided in this manner; and it may further be remarked, that no other mode of dividing the steps of an elliptical stair renders it so easy and agreeable to ascend or descend.

HAND-RAILING.

157. THE HAND-RAIL of a Stair is a rail which is put up, in order to prevent accidents, by falling into or through the well-hole, and to take hold of as a guide, in the ascent or descent of the staircase.

158. A general idea of the nature of hand-railing may be derived from considering the parts of that for a geometrical staircase, *plate LXXIV*; we shall then treat of the hand-rails for Dog-legged Staircases, and afterwards of the more difficult kinds of curvilinear Hand-railing.

159. *Figure* 1, *plate LXXIV*, is the representation of a GEOMETRICAL STAIRCASE, consisting of a series of flyers between two quarters of winders. *Fig.* 1 is the plan, and *fig.* 2, the Elevation.

Fig. 3 is the developement of the ends of the steps next to the wall. This is found by extending the base-line upon a straight line; as AB, *fig.* 1, upon AB, *fig.* 3; the arc BC, *fig.* 1, upon BC, *fig.* 3; the straight line, CD, *fig.* 1, upon CD, *fig.* 3; DE, *fig.* 1, upon DE, *fig.* 3; and EF, *fig.* 1, upon EF, *fig.* 3: so that ABCDEF, *fig.* 3, will be the line ABCDEF, *fig.* 1, extended in a straight line. Through all the points of division draw lines perpendicular to AF. Set the heights of the steps upon the perpendicular line FG, and through the points of division draw lines parallel to AF; then the horizontal parts meeting their corresponding heights will form the steps.

Figure 4 is a developement of the scroll and the steps, and rail next to the well-hole, found exactly in the same manner as that of the wall-line, *fig.* 3.

These developements are of the greatest utility to the workman, as they enable him to determine the proper form for the rail and the soffit, so as to make them change their directions in the most agreeable and easy manner. Wherever there is an angle, that angle must be reduced by taking it off in the form of a curve, which is more pleasant to the eye than a sudden change in the direction of the line. The taking away of an angle, either of the rail or string-board, is called by workmen the *easings* of the rail, or of the string.

Figure 5 is the Plan of the Scroll to about one-sixth part of the real size.

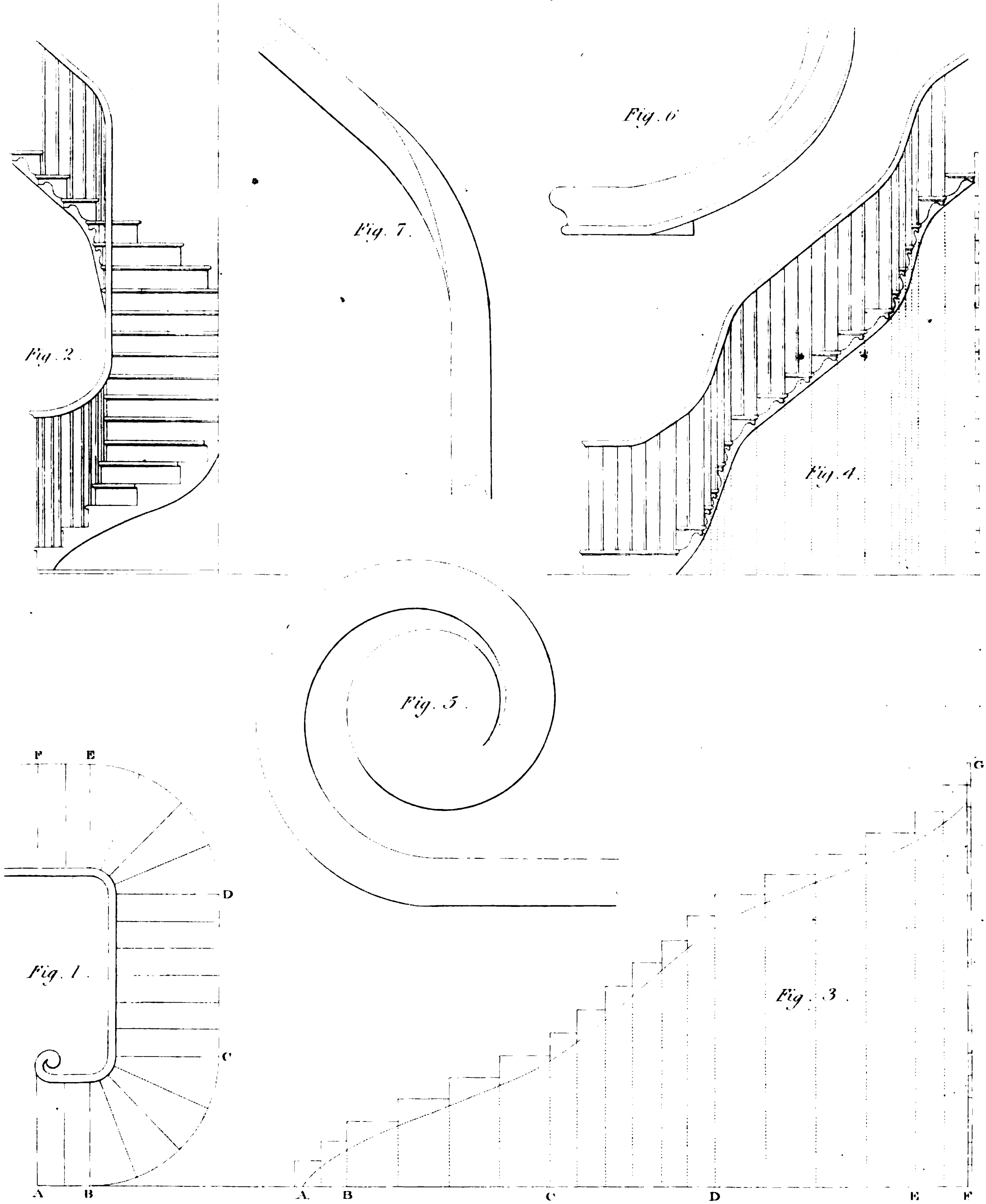
Figure 6, the side Elevation of the Scroll.

Figure 7, the wreath or twisted part, at the turn of the rail above, between the winders and the upper flight of steps.

A Method of describing the Section of a Hand-Rail and its Mitre-Cap for Dog-legged Stairs.

160. THE hand-rails of stairs may be of various forms, but a very convenient form for the hand may be described as follows: Draw the straight line ab, and make it equal in length to the breadth of the rail. Bisect ab by the perpendicular iG, cutting ab at w; make wi equal to two-sevenths of the depth of the rail, and wd equal to five-sevenths of the said depth. Draw dn perpendicular to di. Produce di to c, and make wc equal to wd. From d, with the radius di, describe the arc ign. Join nb, and produce nb to g. Draw gd, cutting ab in r. Make ws equal to wr. Join ds, and produce ds to f. Join cr, cs, and produce cr to l, and cs to k. From d, with the radius di, describe the arc fg. From r, with the radius rg, describe the arc gph; and from s, with the radius sf, describe the arc fae. Make hl equal to hr,

STAIRS AND HANDRAILS.



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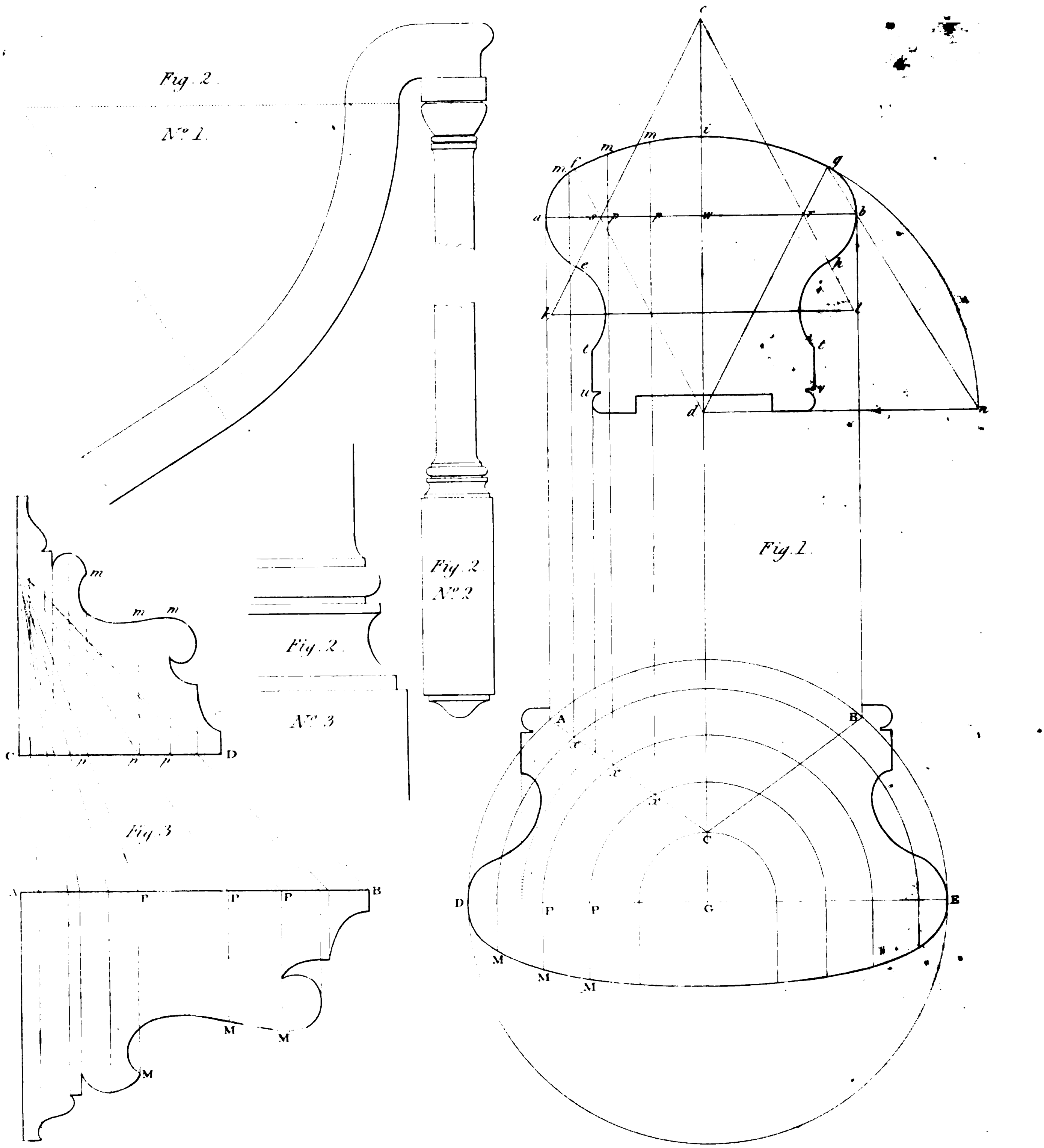

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ek, equal to es, and join kl. From k, with the radius ke, describe the arc et; and from l, with the radius lh, describe the arc ht, and draw tu and tv, parallel to id; which completes the geometrical part of the section.

161. The MITRE-CAP of a rail is a block of wood, of a greater diameter than the breadth of the rail, and turned to such a figure as will mitre with the rail. It is used to cover the newel which terminates the railing of a Dog-legged staircase, and gives them a neat appearance at a small expense.

To draw the Mitre-cap, from any centre, as G, in the line id produced, with a radius equal to that of the mitre-cap, describe the circle ABEFD; and draw EGD at right angles to Gd. Draw aA, bB, parallel to dG. Join AC and BC, for the angle of the mitre; the point C being taken at pleasure. In the curve of the section of the rail, take any number of points, m, m. Draw the lines mx parallel to iG, cutting AC in the points x. From G, with the radii Gx, Gx, &c., describe arcs xP, xP, &c. Draw the ordinates PM, PM, &c., perpendicular to DE, and make them equal to the corresponding ordinates pm, pm, &c., in the section of the rail. Then, when as many of the points are found as is necessary, draw a curve DMM, &c. through them, and this curve will be the contour of the section of the mitre-cap.

162. *Figure 2* exhibits the method of drawing the Swan-neck of a dog-legged stair. No. 1, the Swan-neck and part of the top of the newel; No. 2, the base; No. 3, the base, more at large.

163. *Figure 3*, the method of tracing the brackets for the winding-steps from those of the flyers. Supposing CD equal to their length, and AB equal to those of the flyers. Having divided CD in the same proportion as AB, make the ordinates, pm, equal to the corresponding ones, PM; and through the points thus found draw the contour of the bracket.

CURVILINEAR HAND-RAILING.

164. THE ART OF FORMING HAND-RAILS round circular and elliptic well-holes, without the use of a cylinder, or mould of the form of the well-hole, is a late invention. Mr. Price, the author of '*The British Carpenter*,' was the first in this country who appears to have had any idea of forming a wreath-rail; and the English writers immediately following him contributed little or nothing towards the advancement of this most useful branch of the Joiner's profession, but contented themselves with the methods laid down by Price, which are very uncertain in their application; and, consequently, lead to very erroneous results in practice.

The method of squaring the wreath, upon geometrical principles, was first published by Mr. Peter Nicholson, in 1792. None of our previous authors seem to have had any idea of describing the section of a cylinder through any three points in space, making a mould to the form of the section, and applying it to both sides of the plank, by the principles of solid angles; so that, by cutting away the superfluous wood, the piece thus formed might be made to range over its plan.

Since the first publication of the method, Mr. Nicholson's great attention to, and researches on, this subject, have added many essential requisites, which were not thought of at first; and it has also been carefully studied by others, so that this branch, as here presented, is now in a very improved state.

165. The principle of projecting the rail furnishes the workman with a method by which he can ascertain, with great precision, the thickness of the plank out of which the rail must be cut. To do this in the most convenient way, the diagram must be made to some equal division of the

full size, as one-half or one-third, which will supersede the necessity of drawing it to the full size on a floor. It must, however, be observed that the thickness of stuff found by this method is what will completely square the wreath or piece. But, as the form of the rail is never square, the section being more or less round or oval, hence much thinner stuff may be made to answer the purpose; so that, generally, for rails of the common size of $2\frac{1}{8}$ or $2\frac{1}{4}$ inches thick, instead of requiring a three-inch plank, one of two and a half may be made to answer the purpose. The economy of material is therefore very considerable.

Definitions.

166. THE MOULD, which, in the old method, was used for forming the wreaths, and fitting the rail together, is now of no other use than merely to help the conception of the learner. In this case, we shall still be obliged to use the idea of such a mould. It was called by workmen a CYLINDER, whatever might be the form of the base or right section; but, as the word cylinder is used to define a geometrical solid, and has had the sanction of the learned for upwards of two thousand years, we must not use the word cylinder in two different senses without some word of qualification; as, otherwise, it will be impossible to know which of the two bodies is meant. We shall therefore call the cylinder used by workmen *a working-cylinder.*

167. Supposing the working-cylinder to be covered with a thin pliable substance, as paper, and to be inserted in the well-hole, as if it were a solid newel, and the planes of the risers and treads to be continued, so as to intersect the covering; the indented line, formed by the intersections of the risers and treads, in the developement of the covering, supposing it extended on a plane, is called the *envelope* of the well-hole.

168. The straight line formed on the envelope by the base of the cylinder is called the *base of the envelope.*

169. The line passing through the points of the external angles, on the developement of the steps, is called the *line of nosings.*

THE THEORY OF HAND-RAILING.

170. SUPPOSE any line to be drawn on the surface of the working-cylinder, and the working-cylinder to be cut entirely through, from this line to the opposite surface, so that a straight line, passing through any point of the line, drawn perpendicular to the surface, will coincide with the section made by cutting the solid, through the line thus drawn; every such line will be parallel to the base of the working-cylinder.

Suppose, the upper portion of the working-cylinder, separated from the lower, to be removed, and the lower to be inserted in the well-hole; then, if the surface of separation coincide with the nosings of the steps, while the base rests on the floor; and, if we again suppose the whole to be elevated to a certain height without turning, so that the base may be parallel to the floor, the surface of separation will form the top of the hand-rail in the square; and the two vertical sides of the hand-rail will be a portion of the vertical surfaces of the working-cylinder.

Again, suppose that, while the portion of the working-cylinder, thus formed, remains in the situation now described, another portion next to the top is again separated from the lower portion, but not removed, in such a manner that the uppermost part may be every where of a certain thickness between the surfaces of separation; the upper part, thus separated, would exactly form the hand-rail in the square; and this is the solid which we would wish to form, first in parts, and then to put the parts together, so as to constitute the whole *Helix*, or screw-formed solid, as if it had been cut out of the solid of the working-cylinder.

171. The form of the solid helix, now defined, is called by workmen a square rail; the method of preparing the rail, in parts, of this form, is called the *squaring of the rail.*

The square rail is therefore contained between two opposite surfaces, which are portions of the surfaces of the working-cylinder, and two other winding-surfaces, contained between each pair of curves of the helix.

172. The Plan of a Hand-rail is the space or area which the base of the working-cylinder would occupy on the floor. This area is therefore bounded by two equi-distant lines, on which each of the working-cylindric surfaces stand erect, and the breadth of the space between these two equi-distant lines is called the *breadth of the rail.*

173. The Story-Rod is a rod of wood, equal in length to the height of the stairs, or the distance between the surface of one floor and that of another. It is divided into as many equal parts as the number of steps in the height of the story: its use is to try the steps as they are carried up.

174. For the conveniency of forming a square-rail out of the least quantity of stuff, and in the shortest time, the rail is made in various lengths; so that, when joined together, the whole may form the solid intended.

If the rail, thus joined, be set in its true position, and if the joints be in planes perpendicular to the horizon, and to the surface of the working cylinder, the joints are called *splice-joints.* But if each joint be in a plane perpendicular to one of the arrises, the joint is called a *but-joint.*

175. It is evident that any portion of a hand-rail may be made of plank-wood of sufficient thickness and length: because such a portion of the rail may be considered as a portion of the working-cylinder, contained between two parallel planes, which may represent the faces of the plank; and the two sections of the working-cylinder, made on these planes, will represent a mould to draw the same upon the surfaces of the plank: then, if the surrounding wood be cut away in the same manner, the vertical sides of the rail will be formed agreeably to the definitions which we have given.

176. A mould made to the form of a section of the working-cylinder is called a *face-mould.*

177. A mould made to cover one of the vertical surfaces of a square rail is called a *falling-mould.* A falling-mould made to cover the convex surface of the square rail is called the *convex falling-mould;* and that which is made to fit the concave surface is called the *concave falling-mould.* The form of the falling-moulds can be ascertained by geometrical rules; and, consequently, if the proper portion of the falling-mould be rightly applied to the rail-piece, when cut out of the plank, and if lines be drawn by the two edges of the falling-mould, and the superfluous wood cut away, so as to be every where perpendicular to the surface of the working-cylinder, that portion of the rail will be formed.

178. The Scroll is the termination of the hand-rail of a geometrical stair, in the form of a spiral, and is placed above the curtail-step, which is made to correspond with the scroll.

179. Balusters are vertical pieces of either a plain or an ornamental kind, which are fixed on the steps for supporting the hand-rail. In straight flights, the balusters are placed equidistant, and when plain square balusters are used, so that every step may have two balusters; and that one side of each baluster may be in the plane of each riser, and the whole thickness of each baluster so placed that it may stand within the solid of the riser.

In order to keep the hand-rail steady, and to provide against accidental violence, iron balusters must be inserted into the range, at equal distances, and strongly fixed to the steps. In common stairs, where wooden balusters only are used, the balusters are placed against the nosings, and let into the step-board below; and, being fastened to the nosings with nails, will be very secure.

180. The RAMP, in a dog-legged and open-newel staircase, is the upper end of a hand-rail adjoining to the newel, formed, on the upper side, into a concavity, but straight with regard to the plan.

181. A SWAN-NECK, in dog-legged and open-newelled staircases, is a portion of the rail, consisting of two parts, the lower being concave and the upper convex on the top, and terminating in a framed newel, so as to be parallel to the horizon. (See *Art.* 162.)

182. A KNEE, in a dog-legged and open-newelled staircase, is the lower end of a hand-rail, next to the newel, formed either into a concavity on the upper side, or made to terminate upon the newel with a short level, mitred into the raking or sloping part of the rail, which follows the curvature of the steps.

The same part of a rail may therefore be both *ramped* and *knee'd*; that is, ramped at the upper end, and knee'd at the lower; or it may be *swan-necked* at the upper end, and *knee'd* at the lower.

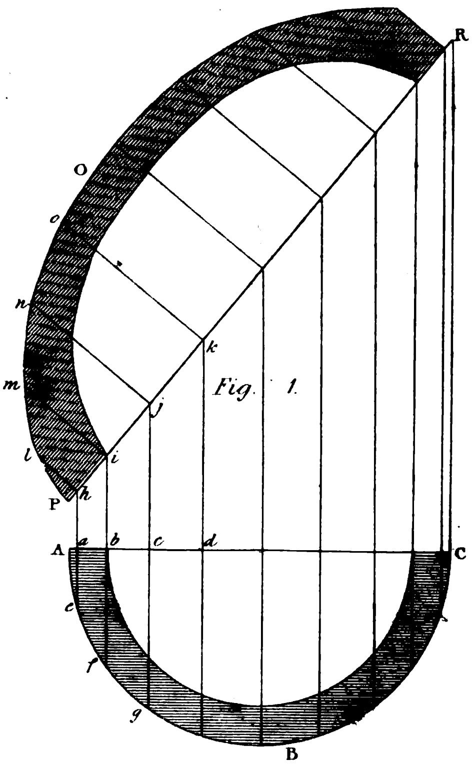
183. When there is any sudden rise in the balusters, the top of the rail ought to be kept to the same height throughout, as nearly as possible; but, should the height of the steps lead the top of the rail to irregularity, in the curvature of the rail, the line of fall must be rendered agreeable, by taking away the angles, and reducing the whole to a uniform curve. These curves are called the *easings of the rail.* By this mean, the irregularities which the hand would feel, in passing along the back of the rail, will be removed, and it will pass along agreeably instead of being suddenly interrupted at every junction. When the risers of three or more steps terminate in the same vertical line, in order to connect the lower and upper ends of the rail in the most agreeable manner, the intermediate part will require to be *ramped,* as is done in dog-legged staircases. But where not more than two risers terminate in the vertical line, the rail is frequently continued, so as to form an elbow in the intermediate part, in such a manner, that the top of the three parts thus connected may be all in one plane; which will be as pleasant to the eye as it is convenient; since the parts, thus joined, may be cut out of the thinnest wood possible.

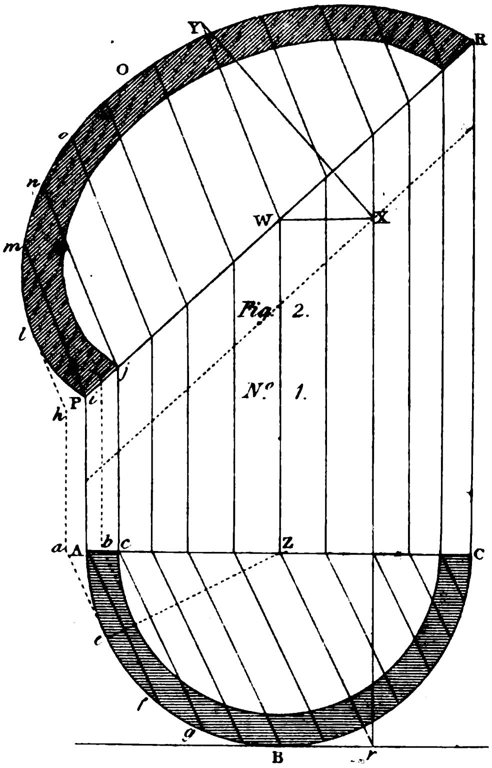
To fix the rail in such a position as to differ the least from being parallel to the line of nosings, or the string-board, the top over the upper part may be depressed half the height of a step, while that over the lower part may be as much elevated; so that, though the rail may not be entirely parallel with the line of the nosings, the lower part rising higher as it advances towards the abrupt change in the line of nosings, and the upper part approaching nearer to the line of nosings, as it is more remote from abrupt change, the whole appearance will be more agreeable to the eye.

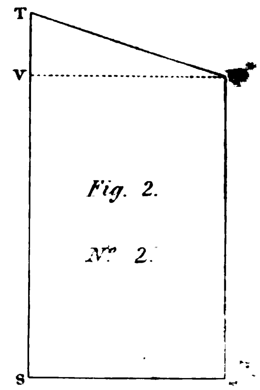
These rules were laid down by Mr. Nicholson; and he further remarks, where winders are necessary, and the well-hole very small, the top of the rail must be kept higher over the winders than over the straight part; as, otherwise, the person who ascends or descends will be in danger of tumbling over into the well of the stairs.

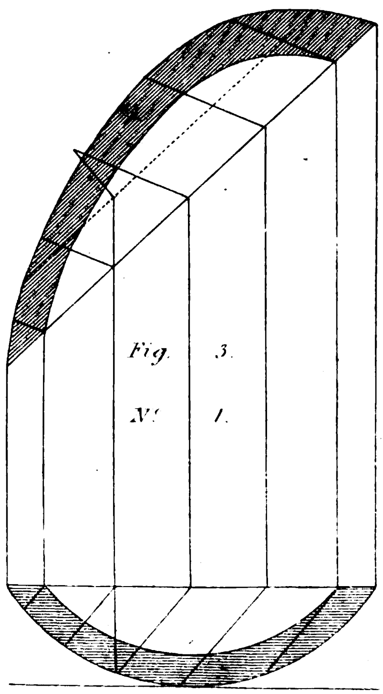
And also, that the rise of the rail, over the circular plan, cannot be regulated by geometrical principles, but must be left to the discretion of the workman. The rail ought not to be raised to any considerable degree over the winders, unless in very extreme cases, as it occasions not only a deformity in the fall of the rail, but a great inconvenience to the workman, by obliging him to prepare the semi-circular part of the rail to different face-moulds; whereas the same moulds might be alike applied to both parts of the rail. Where this practice is necessary, the

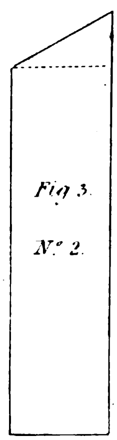
HAND RAILING.

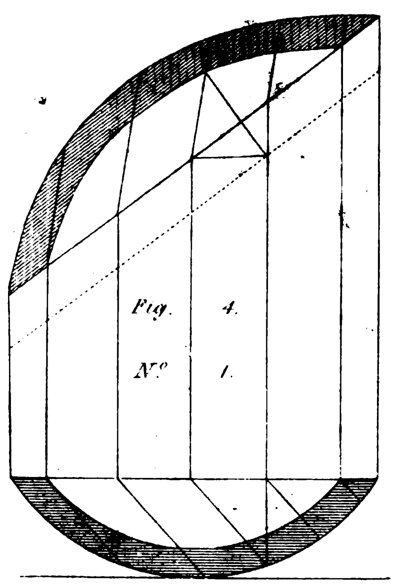


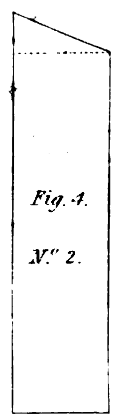












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easing of the rail, at the upper end, will be over the circular part of the plan; while that at the lower end will be entirely on the straight part below the winders; and thus, as it occasions the upper part to have less slope than the lower, so it occasions also the face-mould of the upper part to be considerably shorter than that of the lower part.

184. We, however, have been long in possession of a very simple and accurate principle of adjusting the height of the rail at any point. *It consists in making the rail every where at an equal height above the middle of the breadth of the step, and where the ends of the steps are narrower than the proper breadth, at the same height above the nosings.* When this principle is followed, the rail rises sufficiently for protection over the circular part of the plan, and yet so uniformly as to be agreeable, and if we attend to the place of the hand in ascending or descending a stair, we easily perceive that it must be at a mean between the heights above the fronts of any two adjoining steps, and therefore our rule is founded on just principles.

The proper height for the top of a hand-rail above the level-landing of a staircase is 40 inches, and the top of the rail should be 40 inches, less the height of a step, above the middle of the breadth of each step, when measured in a vertical line. Thus, if the height of a step of the stairs be 7 inches, the top of the rail should be 33 inches above the middle of the breadth of the step.

185. To FIND THE SECTION OF A CYLINDER, when it is cut by a plane perpendicular to a given plane, which is parallel to the axis of the cylinder. (See *fig.* 1, *pl. LXXVI.*)

Let ABC (*fig.* 1,) be the base, and ACRP the plane parallel to, or passing along, its axis, and PR the line of section.

In ABC take any number of points, *e, f, g*, and draw the lines *he, if, jg*, &c., parallel to AP or CR, cutting AC in *a, b, c, d*, &c., and PR in *h, i, j, k*, &c.: perpendicular to PR draw *hl, im, jn, ko*, &c. Make *hl, im, jn*, &c., respectively equal to *ae, bf, cg*, &c. Through all the points *l, m, n, o*, &c., draw a curve, which will be the section required.

If the cylinder be hollow, the inner curve will be described in the same manner.

186. When the plane of section makes an acute angle with the given plane, as in *fig.* 2, *plate LXXVI.*

Let STU (*fig.* 2, No. 2,) be the angle at which the cylinder is to be cut. Draw DU parallel to ST, at that distance from ST which is equal to the radius of the semi-circular base. Draw B*r*, in No. 1, parallel to AC, and parallel to PR draw the dotted line X, at the distance TV (No. 2,) from PR. From the centre, Z, of the semi-circle, draw ZW, parallel to AP or CR, cutting PR in W. From W draw WX parallel to AC, to meet the dotted line in some point X, and draw X*r* parallel to AP or CR. Join Z*r*; and draw XY perpendicular to PR. From W, with the radius Z*r*, describe an arc, cutting XY at Y, and join WY.

In the arc ABC take any number of points, *e, f, g*, &c., and parallel to Z*r* draw the ordinates *ea, f*A, *gc*, &c., cutting AC in *a*, A, *c*, &c. From the points *a*, A, *c*, &c., draw *ah*, A*i*, *cj*, &c., parallel to AP or CR, cutting PR in *h, i, j*, &c. Draw *hl, im, jn*, &c., parallel to WY, and make *hl, im, jn*, &c., respectively equal to *ae, fb, cg*: then, through all the points *l, m, n*, &c., draw a curve, and it will be the section required.

If the cylinder be hollow, the inside curve will be traced in the same manner, and from the same parallels Z*r* and WY, and by the very same ordinates; only observing the points where the inner semi-circle cuts these ordinates.

Upon the principle here shown, the sections of *figures* 3 and 4 are to be found: both these figures are segments of cylinders; *fig.* 3 being cut at an obtuse angle, and *fig.* 4, at an acute angle.

187. To find the section of a Cylinder, or of any solid of which the sections parallel to the base are every where the same, so as to pass through three given points in its surface, (*figure* 1, *plate LXXVII.*)

Let the places of the three given points be ABC, in the plan or base ABC of the cylinder, and let ADEC be a plane standing perpendicularly upon the plan, and coinciding with the points AC.

Join the points A and C, by the straight line AC, and produce AC to F, and draw BH parallel to AF. Draw AD, BG, and CE, perpendicular to AF or BH. Make AD equal to the height of the point, over its place A, on the plan; BG equal to the height of the point over its plan B; and CE equal to the height of the point over its plan C. Join DE, and produce DE to F. Draw GH parallel to DF; and, through the points H and F, draw FI.

In AF take any point, J, and draw JI perpendicular to AF; and draw JK perpendicular to DF. From J, as a centre, with the radius J*l*, describe the arc *lm*, cutting AF in *m*, and join *m*I.

In the base ABC take any number of points, *a*, *b*, *c*, *d*, &c., and draw the lines *ae*, *bf*, *cg*, *dh*, &c., parallel to FI, cutting AF in the points *e*, *f*, *g*, *h*, &c.

Draw *ei*, *fj*, *gk*, *hl*, &c., parallel to AD, BG, or CE, cutting DE in *i*, *j*, *k*, *l*, &c. Through the points *i*, *j*, *k*, *l*, draw *ip*, *jq*, *kr*, *ls*, &c., parallel to I*m*, and make *ip*, *jq*, *kr*, *ls*, &c., each respectively equal to *ea*, *fb*, *gc*, *kd*, &c.; then, through the points E, *p*, *q*, *r*, *s*, &c., draw a curve, which will be the section of the cylinder as required.

The angle J*m*I is that which the plane of section now found, makes with the vertical plane ADEC.

188. Another method of finding the section of a prismatic solid, which is to pass through three given points in its surface.

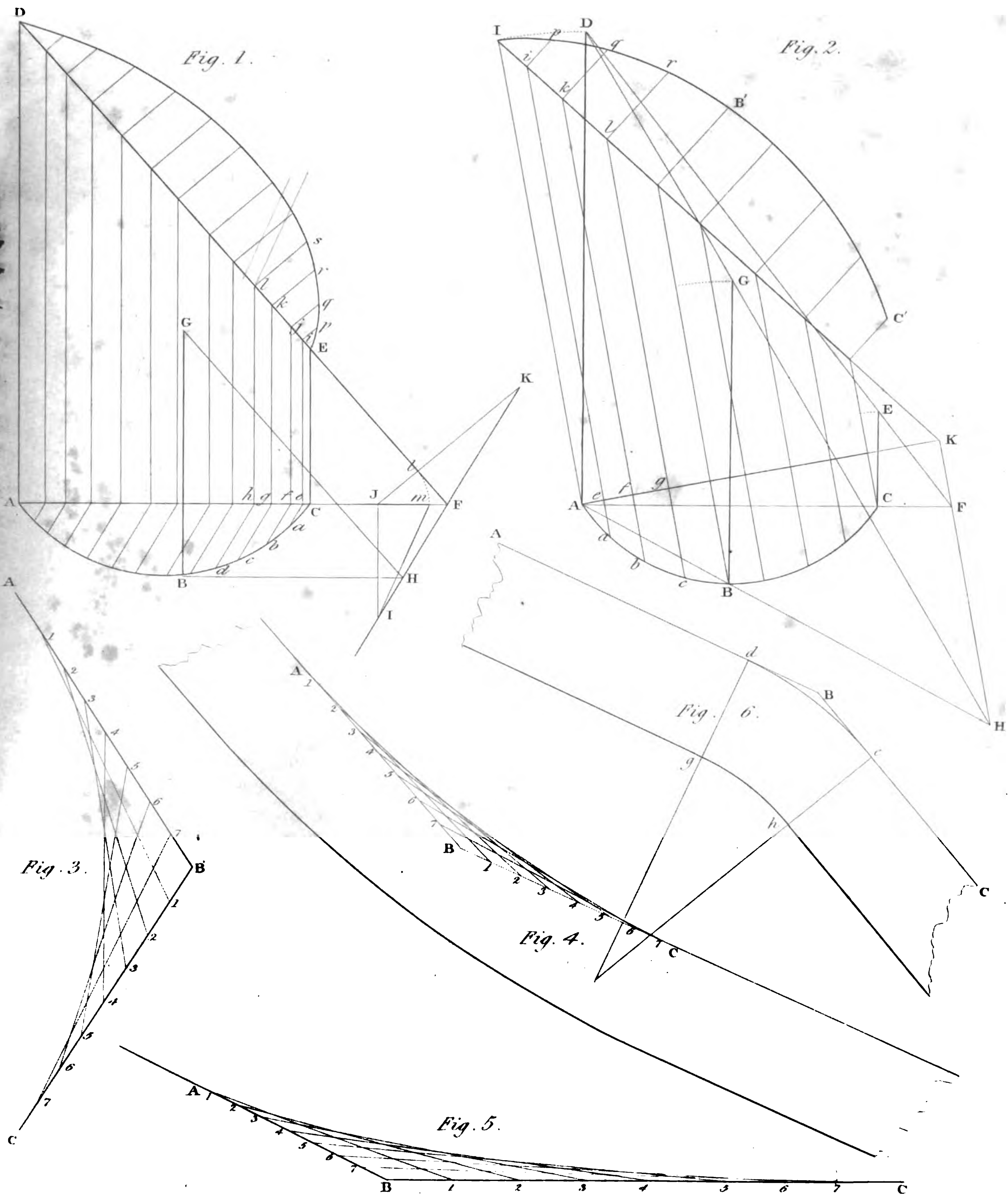
Let ABC be the plan of the points, and draw a line through the most distant ones, as AC, then from each of the points erect a perpendicular to that line, and make each of these equal to the height of the corresponding point above the base; the points thus found will be DGE. Through A, B and D, G, draw lines and produce them till they meet at H; also, draw a line through DE, to meet AC in F, and draw FH.

Draw AK perpendicular to FH, and from the points A, *a*, *b*, *c*, &c., in the base, draw lines parallel to KH; cutting AK in *e*, *f*, *g*, &c. Make AI equal to AD, and join IK, cutting the parallels in *i*, *k*, *l*, &c.; then, from the points *i*, *k*, *l*, &c., draw lines or ordinates perpendicular to IK, and make *ip* equal to *ae*, *kq* equal to *bf*, &c.; then the curve drawn through the points I, *p*, *q*, *r*, &c., is the section required.

We give this new method, because it is more direct and obvious than the preceding one of Nicholson's.

189. The whole of the art of hand-railing depends on finding the section of a cylinder to pass through three given points on its surface; the reader is therefore requested to understand this thoroughly, before he actually commences his study upon hand-rails; for, if the principles are not comprehended, he will always be in difficulties, and liable to spoil his work.

The hand-rail of a stair is made in various lengths, and each portion is got out upon the principle of its being the section of a cylinder, and is cut out of a plank not exceeding two and a half inches in thickness. It would not be practicable to get a rail out in pieces for more than a quarter of a circle: a portion of the rail got out in one length, answering to the semi-circumference of the plan, would require a very great thickness of stuff; how much more then would a whole circumference require? for the thickness of stuff increases in a much more rapid ratio than the circumference.



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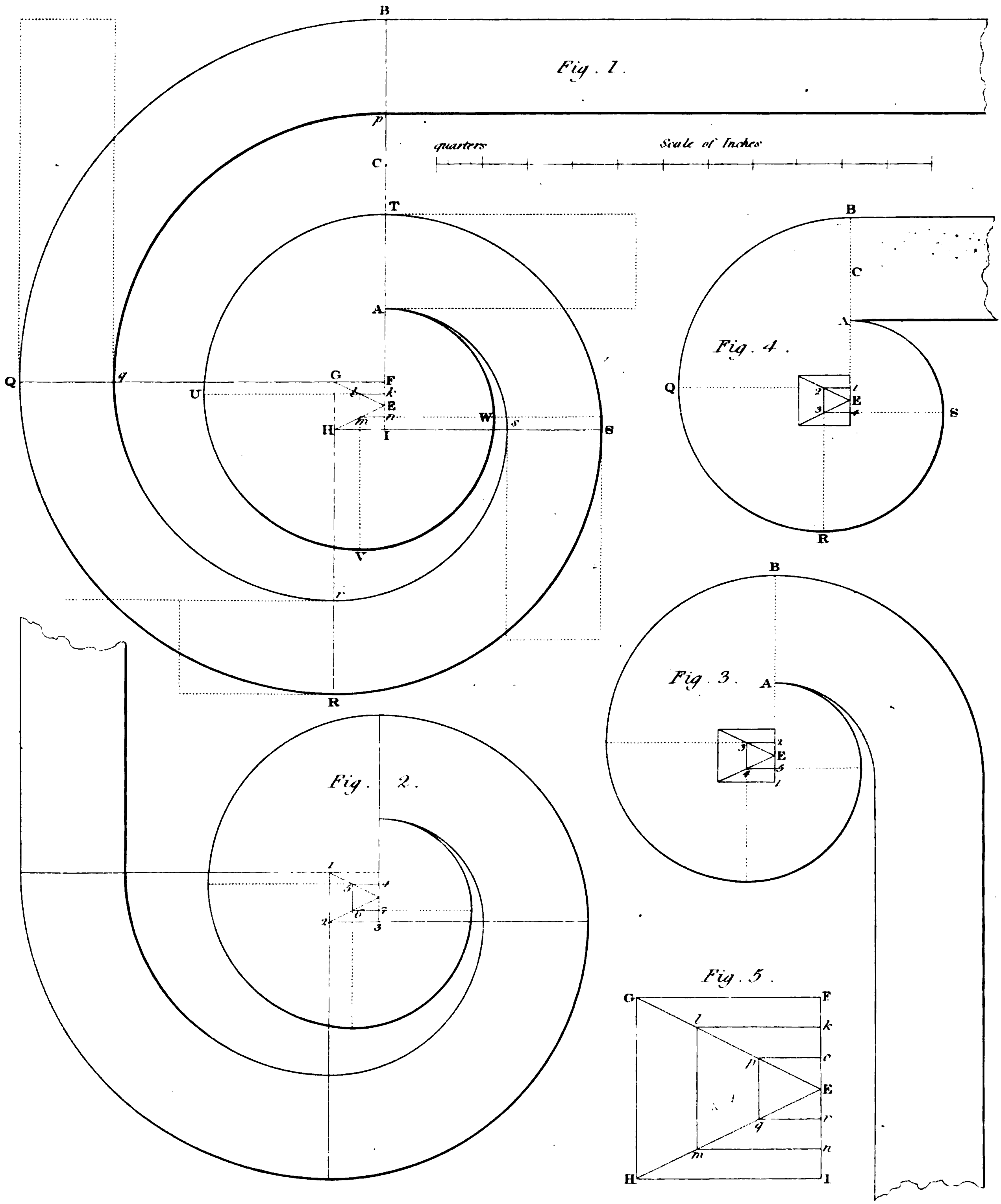

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190. *Figure* 3 (*plate LXXVII,*) is the method of drawing a curve, which shall touch two straight lines, AB, BC, in two given points A and C.

Divide AB, BC, each into any number of equal parts; beginning at A and B, draw the straight lines 11, 22, 33, 44, &c., through the corresponding points of division, and the lines thus drawn will be tangents to the curve.

The reducing of a piece of wood from an angular to a curved form is called by workmen the *easing off the angle.*

Figure 4 is an application of this to the hand-rail of a stair.

Figure 5 shows how the same may be done when AB and BC are unequal.

Figure 6 is another method of easing the rail at an angle. Let ABC be the angle, and let it be required to round it in a very small degree.

Make B*d* equal to B*e*. From *d* draw *df* perpendicular to AB, and *ef* perpendicular to BC. From *f*, with the radius *fd* or *fg*, describe the arcs *de* and *gh*, which will form what workmen call a *knee* in the rail.

THE METHOD OF DRAWING SCROLLS FOR HAND-RAILS, ANSWERING TO EVERY DESCRIPTION OF STAIRS

191. First, let it be required to describe a spiral to any number of revolutions, between two given points, in a given radius.

Let E (*fig.* 1, *pl. LXXVIII,*) be the centre, EB the given radius, and let the two given points be A and B, between which it is required to draw any number of revolutions.

Divide AB into two equal parts, in the point C, and divide AC or CB into equal parts, consisting of one part more than the number of revolutions; then, in the line EB, make EF and EI each equal to the half of one of these parts; then, upon FI, construct the square FGHI. Draw GE and HE. Divide GE and HE into as many equal parts as the spiral is to have revolutions; through these points construct as many squares, of which one side will be in the line FI, and the other sides terminate in the lines GE and HE; then the angular points of the outer square will be the centres for the first revolution, the angular points of the next less square the centres for the second revolution; the angular points of the next less square will be the centres for the third revolution, and so on; one quadrant of a circle, which is one quarter of a revolution, being described at a time.

To apply this to the present example, which is to have two revolutions, divide, therefore, AB into two equal parts, as before, in the point C, and divide AC or CB into three equal parts; that is, into one part more than the number of revolutions. Make EF and EI each equal to half a part, and on FI describe the square FGHI. Join GE and HE, and divide GE or HE into two equal parts, being as many as the number of revolutions, and complete the inner square *klmn*. Produce FG to Q.

From the centre, F, with the distance FB, describe the quadrant BQ.

Produce GH to R; then, from the centre G, with the radius GQ, describe the arc QR.

Produce HI to S; then, from the centre H, and, with the radius HS, describe the arc RS.

From the centre I, with the radius IS, describe the quadrant ST; which finishes the first revolution of the spiral.

Again, produce *kl* to U, *lm* to V, *mn* to W; then, from *k* with the radius *k*T describe the arc TU; from *l*, with the radius *l*U, describe the arc UV; from *m*, with the radius *m*V, describe the arc VW; from *n*, with the radius *n*W, describe the arc WA, which will complete the second revolution, and terminate in the point A, as required.

192. To draw the second spiral, and thereby to make the scroll complete.—In the straight line EB set B*p* towards E, equal to the breadth of the rail; then from F, with the radius F*p*, describe the arc *pq*; from G, with the radius G*q*, describe the arc *qr*; from H, with the radius H*r*, describe the arc *rs*; from I, with the radius I*s*, describe the arc A*s*, which will complete the scroll.

The whole breadth of this scroll, as now drawn by the scale, is about twelve inches and five-eighths of an inch, and is intended for a very large step. The breadth of the scroll, *fig.* 2, is ten inches and a half; the breadth of the next scroll, not shown here, is eight inches and three-eighths of an inch; which will be a proper breadth for an ordinary-sized step. The breadth of *fig.* 3 is six inches and seven-eighths of an inch; which is applicable to hand-rails where there is very little room.

All these scrolls are only portions of the great scroll, *fig.* 1, and show that one mould may be made so as to answer any number of revolutions; these scrolls are all drawn from the same centres as that of *fig.* 1. *Fig.* 1 consists of eight quadrants; *fig.* 2 of seven quadrants: the other, consisting of seven quadrants, is not shown, from want of room. *Fig.* 3 consists of five quadrants; and *fig.* 4, of four quadrants, and may be drawn, independent of *fig.* 1, by the very same rule, which must be adapted to one revolution: divide AB into two equal parts, in the point C, as before. Divide AC into two equal parts, that is, into one part more than the number of revolutions; because it is to consist of only one revolution. Then, making E the middle of the side of the square, describe the square 1234. From the centre 1, with the radius 1B, describe the arc BQ; from the centre 2, with the radius 2Q, describe the arc QR; from the centre 3, with the radius 3R, describe the arc RS; and, from the centre 4, with the radius 4S, describe the arc SA, which will complete the scroll, as required.

Fig. 5 shows the construction of the centre for three revolutions, drawn to a larger scale.

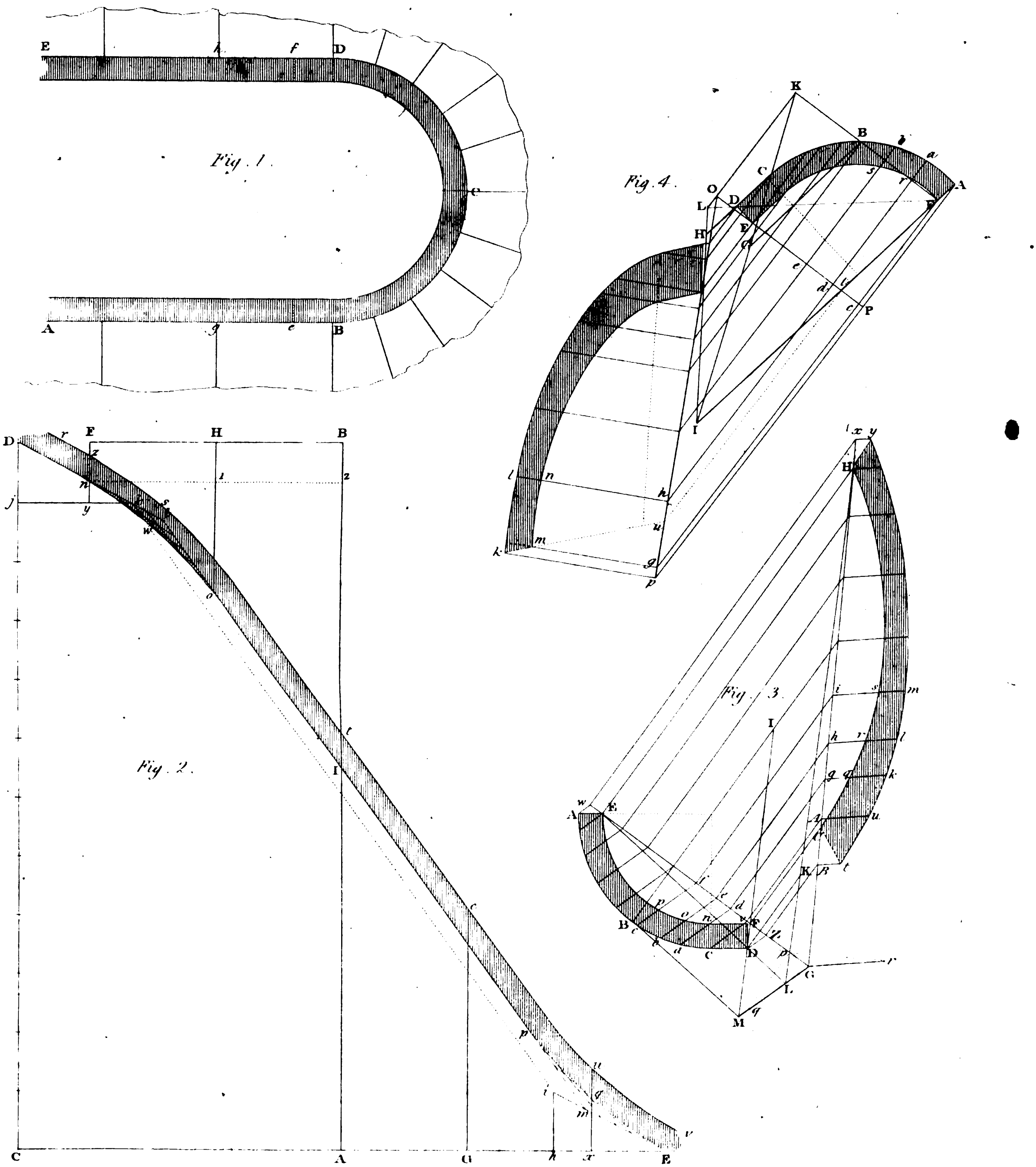
TO FIND THE MOULDS FOR EXECUTING A HAND-RAIL.

193. Let *fig.* 1, *pl. LXXIX*, be the plan of the rail; AB and DE be the straight parts; BCD the circular part, which is divided into equal parts by the point C; and, consequently, BC and CD are each quadrants.

To Construct the Falling-Mould.

194. In *fig.* 2 draw the straight line AB; and through A draw CE, perpendicular to AB. Make AC and AE each equal to the stretch-out of the quadrant BC or CD, (*fig.* 1,) together with the breadth B*g* or D*h* of a flyer. Draw CD (*fig.* 2,) parallel to AB. Make CD equal to the height of twelve steps; that is, equal to the ten winders, together with the breadth of the two flyers, one on each side of the winders. Make E*h* equal to the breadth of one of the flyers, and draw *hi* perpendicular to CE, and make *hi* equal to the height of a step. Join *i*E. In like manner, in the straight line CD, make D*j* equal to the height of a step. Draw *jk* parallel to CE, and make *jk* equal to the breadth of one of the flyers. Join D*k*, and *ki*.

As it is customary with some workmen to raise the rail higher upon the winders than upon the straight part, though not necessary, draw *lm* parallel to *ki*, at such a height as the workmen may think proper. Make *ln*, *no*, *mp*; each equal to *m*E; then ease or reduce each of the



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angles *lno* and *pm*E to curves *nwo*, *pq*E, by the methods described in *art.* 190; then draw a line *rstuv* parallel to D*nwopq*E, comprehending a distance equal to the depth of the rail, and this completes the falling-mould of the rail.

To find the Face-Mould of the Rail.

195. For the convenience of joining, a small portion of the straight rail is formed in the same piece with the wreath, or twist, for each quadrant of the rail; and the length of this straight part is usually made about three inches, therefore set off B*e* and D*f*, *fig.* 1, each equal to three inches. Transfer this distance to *hx* and *ky*, *fig.* 2.

In *fig.* 2, draw *xu* perpendicular to CE, cutting the upper edge of the falling-mould at *u*; also draw *yz*F perpendicular to CE, cutting the under edge of the falling-mould at *n*, and the upper edge of the same at *z*.

Through any point F draw FB, parallel to CE, and divide A*x*, and FB, each into two equal parts at the points G, H. Draw GC perpendicular to CE, cutting the top of the rail at *c*, and draw H*o* perpendicular to FB, cutting the under edge of the rail at *o*.

In *fig.* 3 lay down the plan for one quarter of the rail, *fig.* 1, taking in the straight part. ABC, *fig.* 3, being the quadrant, and CD the straight part of the rail.

It is found that, if the part of the rail over the plan ABCDFE, *fig.* 3, were actually executed, that a truly plane board would touch the three points of the rail in places coinciding with the perpendiculars erected upon the plan at the points E, B, D.

Join EF, (*fig.* 3,) and produce EF to G. Draw EH, BI, and DK, perpendicular to EG. Make EH equal in height to A*t*, *fig.* 2; BI equal to G*c*, *fig.* 2; and DK equal to *xu*, *fig.* 2. Join ED, and produce ED to L. Draw BM parallel to EL. Join HK, and produce HK, meeting ED in L; and draw IM parallel to HL, meeting BM in M. Join ML, and produce ML to meet EG in G. In GM, take any point, *q*, and draw *pq* perpendicular to EG, cutting EG in *p*; and draw *pr* perpendicular to HG. From G, with the radius G*q*, describe an arc cutting *pr* in *r*; join G*r*. In the curve AC take any number of points, *a*, *b*, *c*, &c., and draw *ad*, *be*, *cf*, &c., parallel to GM, cutting EG in the points, *d*, *e*, *f*, &c.

Draw *dg*, *eh*, *fi*, &c., perpendicular to EG, cutting HG in the points, *g*, *h*, *i*, &c. Draw *gk*, *hl*, *im*, &c., parallel to G*r*. Make *gk*, *hl*, *im*, &c., each respectively equal to *da*, *eb*, *fc*, &c.; and, through all the points, *k*, *l*, *m*, &c., draw a curve, which will give the outer edge of the face-mould. The inner edge, *q*, *r*, *s*, &c., is found in the very same manner: viz. by transferring the ordinates *dn*, *eo*, *fp*, &c., to *gq*, *hr*, *is*, &c., and drawing the curve *qrs*, which is the inner edge of the face-mould.

Though the same principle serves to find the straight part of the rail, as well as the circular part, the straight part of the face-mould will be more accurately ascertained thus: Let FD (*fig.* 3,) be the end of the straight part on the plan, and C*n* the line which divides the straight and circular parts of the rail.

Through the points *n*CD draw the ordinates *nd*, C*v*, and D*z*, parallel to GM, cutting EG in the points *d*, *v*, *z*. Draw *dg*, *vA*, and *zB*, parallel to EH, cutting HG in the points *g*, *A*, *B*. Draw *gq*, *Au*, and *Bt*, parallel to G*r*. Make *gq* equal to *dn*, *Au* equal to *v*C, and B*t* equal to *z*D. Draw F*C* parallel to EH, cutting HG in *C*. Join *Cq* and *Ct*. Draw *qu* parallel to *Ct*, and *tu* parallel to *Cq*; then *Cqut* will be that portion of the face-mould answering to the straight part *n*CDF on the plan.

The joint-line of the face-mould will be very accurately found thus:

Produce (*fig.* 3) GE to *w*. Draw A*w* parallel to MG, and *w x* parallel to EH, cutting GH produced in *x*. Draw *x y* parallel to G*r*, and make *x y* equal to *w*A; and by this method the whole of the face-mould is found in the most accurate manner.

196. The mould for the other part may be found in a similar manner: it is, however, proper to remark, that the operation is inverted for the conveniency of finding the mould from the under side of the falling-mould, instead of from the upper side. But we shall here take the opportunity of showing a different method.

In *fig.* 4, draw the plan ABDFE, and let the resting points be F, B, D. Join DF, and produce DF to L. From the resting points F, B, D, draw lines parallel to each other in any convenient direction, as FI, BG, and DH; and make the lines FI, BG, DH, respectively equal BI, H*o*, F*n*, in *fig.* 2. Then, through the points IH, draw a line to meet the line FD in L; also, through the points IG draw a line to meet another drawn through the points FB, the point of meeting being K, and join LK.*

Through E, draw OP perpendicular to KL; and from F draw F*cg* parallel to KL, and make *cg* equal to FI, and draw the line O*g*.

In the curve take any number of points, A, *a*, *b*, &c., and from each point draw lines parallel to KL, to meet O*g* in *p*, *g*, *h*, &c., and from each of the points thus found in the line O*g*, draw perpendiculars, as *pk*, *gm*, *hl*, &c.; then make *pk* equal to PA, *gm* equal to *c*F, *hl* equal to *da*, &c., by which means any number of points may be found through which the curved lines of the mould may be drawn.

The joint-line will be found most accurately by producing AF to meet OP as in *t*, draw *tu* parallel to KL, and join *uk*, which is the direction of the joint as required.

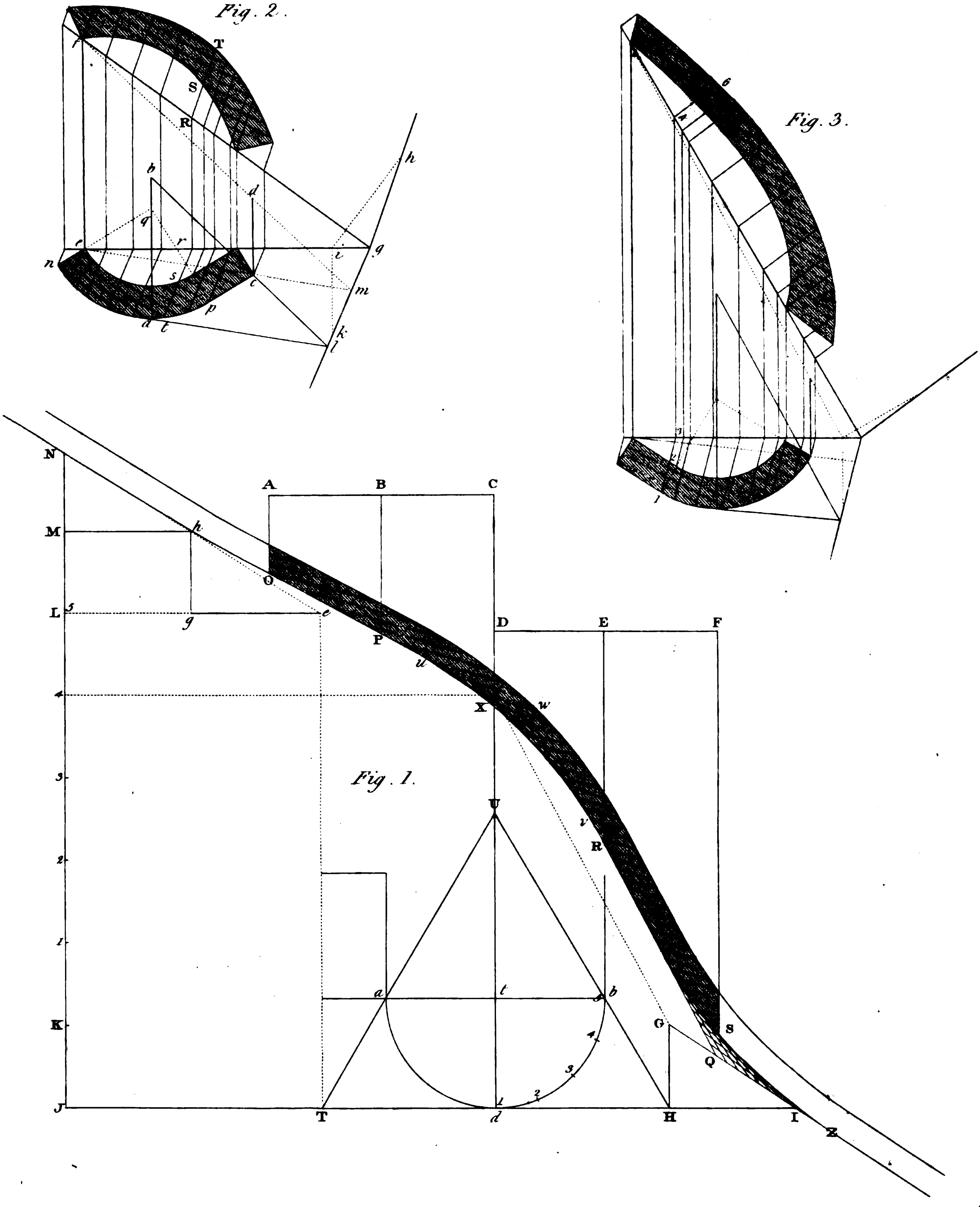
We have now placed it in the Joiner's power to contrast the two methods, both in point of simplicity of operation, and accuracy of determination.

TO FIND THE MOULDS FOR EXECUTING A HAND-RAIL ROUND A SEMI-CYLINDRIC WELL-HOLE, WITH FOUR WINDERS IN ONE QUARTER, THE OTHER BEING FLAT, AND FLYERS ABOVE AND BELOW.

197. *To find the Falling Mould*, (*fig.* 1, *pl. LXXX.*)—Draw the straight line JI, in which take any point, *d*, and draw *d*C perpendicular to JI. In *d*C make *dt* equal to the greater radius of the plan of the rail, and, through *t*, draw *a b* parallel to JI. From the centre *t*, with the radius *td*, describe the semi-circle *adb*. In *t*C make *t*U equal to *t b*, together with three-fourths of *tb*. Join U*a* and U*b*. Produce U*a* to meet JI in T, and U*b* to meet JI in H; then TH is the rail stretched out on the plan, being an example of the method shown in *art.* 46, CARPENTRY. In JI make HI equal to the breadth of one of the flyers. Draw HG perpendicular to HI, and make HG equal to the height of a step, and join GI. Make TJ equal to the breadth of two of the flyers.

Draw JN perpendicular to JI. In JN make JK equal to the height of a step, K4 equal to the height of four steps, KL equal to the height of five steps, KM equal to the height of six steps, and KN equal to the height of seven steps. Draw 4*f* parallel to JI, meeting *d*C in *f*.

* The process is more neat and simple when from the point *u* a line *u*2 is drawn parallel to FB, *fig.* 2, and AI, BG, *fig.* 4, are made respectively equal to 2I, and 1O, for then the points L and D coincide. We shall have occasion to give other examples where this simplification is adopted.



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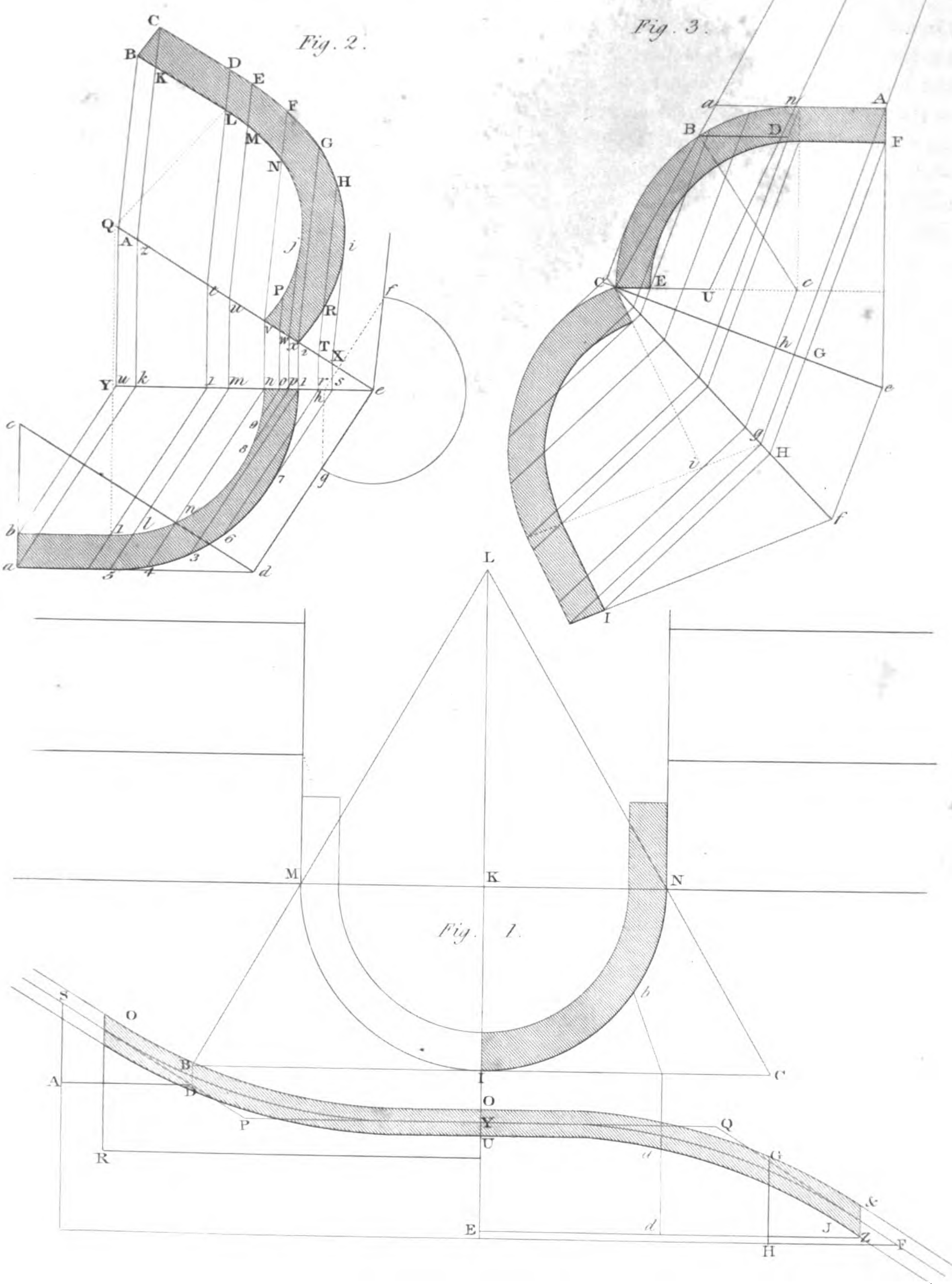

Fig. 2.

Fig. 3.

Fig. 1.

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Draw L*e* parallel to JI, and T*e* perpendicular to JI. Draw M*h* parallel to L*e*, and make M*h* equal to the breadth of a step. In L*e* make L*g* and *ge* each equal to the breadth of a step; and join N*h* and *he*. Join also *hf* and *f*G. Produce *hf* to *w*, and draw *w*Q parallel to *f*G. In the lines *wh* and *w*Q make *wu* and *wv* each equal to the hypothenuse of a step. Draw the curve *uv* to touch the straight lines *wh* and *w*Q, in *u* and *v*. The same being done below, where the two straight lines join at Q, the crooked line N*huv*SZ will be the under edge of the falling-mould. From the under edge of the falling-mould draw a line, at the distance of the depth of the rail above it, and the falling-mould will be complete.

198. *To find the Face-Mould*, (*fig.* 2.)—Here *napc* is the convex side of the rail, being one quadrant, and *pc*, a tangent at *p*, being a portion of the straight part.

Through C, *fig.* 1, draw AC perpendicular to *d*C, and make CA equal to the stretch-out or developement of the curve-line *cpan*, *fig.* 2. Let *d*C intersect the under edge of the falling-mould in X. Bisect AC in B, and draw BP and AO parallel to CX, meeting the under edge of the falling-mould in the points P, O.*

Having completed the inner line of the plan, *fig.* 2, draw the chord-line *eg*. Draw the lines *ef*, *ab*, *cd*, perpendicular to *eg*; *ab* being drawn through the centre *q*. Make *ef*, *fig.* 2, equal to CX, *fig.* 1; *ab*, *fig.* 2, equal to BP, *fig.* 1; *cd*, *fig.* 2, equal to AO, *fig.* 1. In *fig.* 2, join *ec*, and draw *al* parallel to *ec*. Join *fd*: and produce *fd* to meet *ec* in *m*. Draw *bl* parallel to *fm*, and join *lm*, which produce to *g*. In *lg* take any point, *k*, and draw *ki* perpendicular to *eg*, meeting *eg* in *i*. Join *fg*; and draw *ik* perpendicular to *fg*. From *g*, with the radius *gk*, describe an arc intersecting *ih* in *h*; and join *gh*.

In *eg* take any point, *r*. Draw *rt* parallel to *gl*, intersecting the inner curve of the plan of the rail in *s*, and the outer curve in *t*. Draw *r*R parallel to *ef*, meeting *fg* in R, and RT parallel to *gh*. In RT make RS equal to *rs*, and RT equal to *rt*; then will S be a point in the concave curve of the face-mould, and T a point in the convex curve of the face-mould. In the same manner we may find as many points as are necessary, and by this means complete the whole face-mould.

In the same manner, by means of the three lines DX, ER, FS, *fig.* 1, we may construct the face-mould, *fig.* 3, in every respect similar to that in *fig.* 2.

Then the face-mould, *fig.* 3, applies to the lower half where there are winders, and *fig.* 2, to the upper half.

TO FIND THE MOULDS FOR A SEMI-CIRCULAR STAIR WITH A LEVEL LANDING.

199. *To construct the Falling-Mould*, (*fig.* 1, *pl. LXXXI.*)—Draw the straight line MN and IL perpendicular to MN, intersecting MN in K. From K, with a radius equal to that of the convex side of the rail, describe the semi-circle MIN. Make KL equal to the radius, together with three-quarters of it. Join LM, and produce LM to B; and join LN, which produce to C: then BC is equal to the developement of the semi-circumference of the winders. (See *art.* 46, *Carpentry.*) Proceed and complete the falling-mould as in the former cases. In this, FHG is the section of the lower flyer, DAS the section of the upper flyer, the whole height being three steps; the middle part of the falling-mould between AD and HF is level.

* This method gives the resting-point *a*, nearly, but not accurately; to find it correctly, draw a line parallel to *ec*, *fig.* 2, to touch the curve; or, from the centre of the circle, draw a line perpendicular to *ec*, and it will cut the curve in the resting-point. Hence, instead of bisecting AC, *fig.* 1, in B, the point ought to be found by developing the exact place of the resting-point.

200. *To describe the Face-Moulds.*—*Figures* 2 and 3 exhibit the methods of tracing out the face-mould. In *fig.* 2 produce the straight line *a*5 to *d*; and, through the centre Y, draw Y*e* parallel to *ad*. Draw *ac* and YQ perpendicular to *ad* and Y*e*. Make the angles *acd* and YQ*e* each equal to the angle ASD or HGF, *fig.* 1. Join *de*. Then, to find any point in the face-mould. In Y*e* take any point, *m*, and draw *mu* parallel to YQ, meeting Q*e* in *u*. Find the line *ef*, as in the description of *plate LXXX, art.* 198; draw *u*E parallel to *e*F, and *m*5 parallel to *ed*, intersecting the concave side of the plan in *l*, and the convex side in 5. Make *u*M equal to *ml*, *u*E equal to *m*5; then M is a point in the inside curve of the face-mould, and E a point in the outside curve: a sufficient number of points being thus found, the whole face-mould may be completed; and the other part in the same manner.

201. *Another Method.*—The preceding mode of obtaining the face-mould requires more thickness of plank than is necessary; hence, we propose to show how to do it in a more economical manner.

Let ABCEF, *fig.* 3, be the plan of one quarter, with a straight portion of the rail. Join AC; for, on a little consideration, it will be evident, that all the resting-points of a plane on the squared rail would be on its convex side. From the centre, *c*, draw B*c* perpendicular to AC; then, B is the other resting-point. Let *b* be the place of the point B when put in the plan, *fig.* 1; and through *b*, from the point L, draw a line to BC, which gives the place of *b* on the developement. From Z, *fig.* 1, draw ZE, parallel to BC.

From C and B, *fig.* 3, draw lines parallel to one another, as CU, and BD; and make CU equal to EU, in *fig.* 1, and BD equal to *da*, in *fig.* 1. Join UD, *fig.* 3, and produce the line till it meets a line drawn through the points BC; but, if it would require a greater extent of paper for them to meet, as in the engraving, then draw a line A*a*, and another *db*, parallel to A*a*; and make the line *bd* in the same proportion to A*a*, as *bm* is to *an*, and draw a line through the points *d*A. Produce this line, and draw C*e* perpendicular to it; also, make *hg* equal to CU, and from C, through the point *g*, draw the line C*f*.

Then, *e*C*f* is the angle which the plane of section makes with the base or plan. Therefore, to find any point in the mould, draw a line, from the point in the plan, perpendicular to *e*C, to meet the line C*f*, thus let it be from the point F on the plan; then draw FH perpendicular to *e*C, and from the point H draw HI perpendicular to C*f*, and equal to GF, by which the point I is determined.

To find the joint-lines, produce AF to *e*, and make *ef* perpendicular to *e*C; then from *f*, through T, draw a line, which is the line of the joint. Also, from *c* the centre, draw *chg* perpendicular to *e*C, and *gi* perpendicular to *f*C; make *gi* equal to *hc*, and join *i*C, which is the direction of the joint.

202. *Plate LXXXII* shows the falling-moulds and face-moulds for a rail, where the opening of the well-hole is only three inches; and, though the operation of finding the moulds for executing the rail is exactly the same as has been shown, their forms are entirely different. *Fig.* 1 is the plan, *fig.* 2 the falling-mould, and *figures* 3 and 4, the face-moulds; all of which are found by the method described in *article* 194 and 195

Application of the Moulds to the Plank.

203. The face-mould, though last found, must be first applied to the plank, in the following manner. First, bevel the edge of the plank, according to the angle A*m*I, shown in *fig.* 1, *plate LXXVII*, of the sections of a cylinder. Near the upper end of the bevelled edge apply

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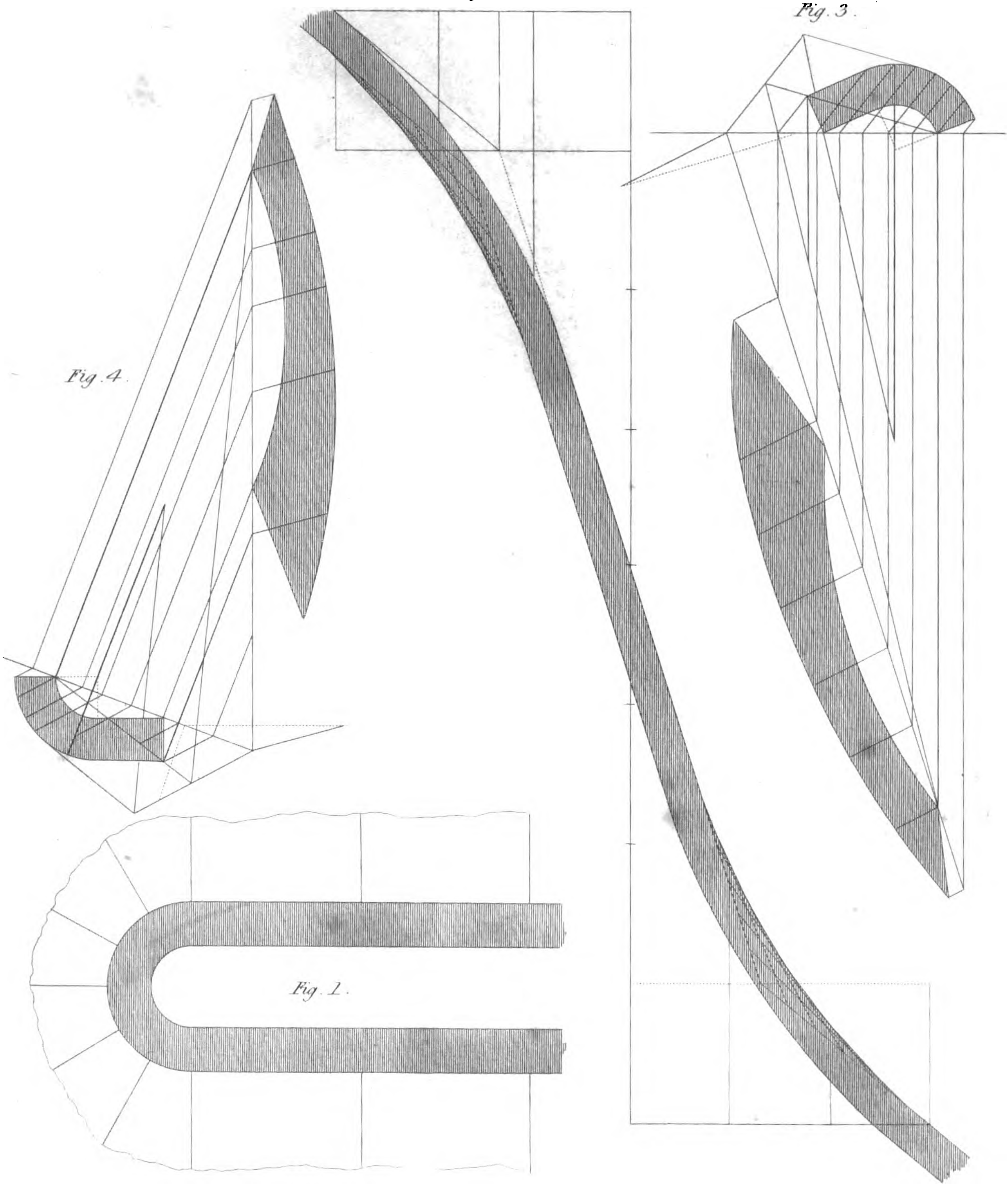

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 1.

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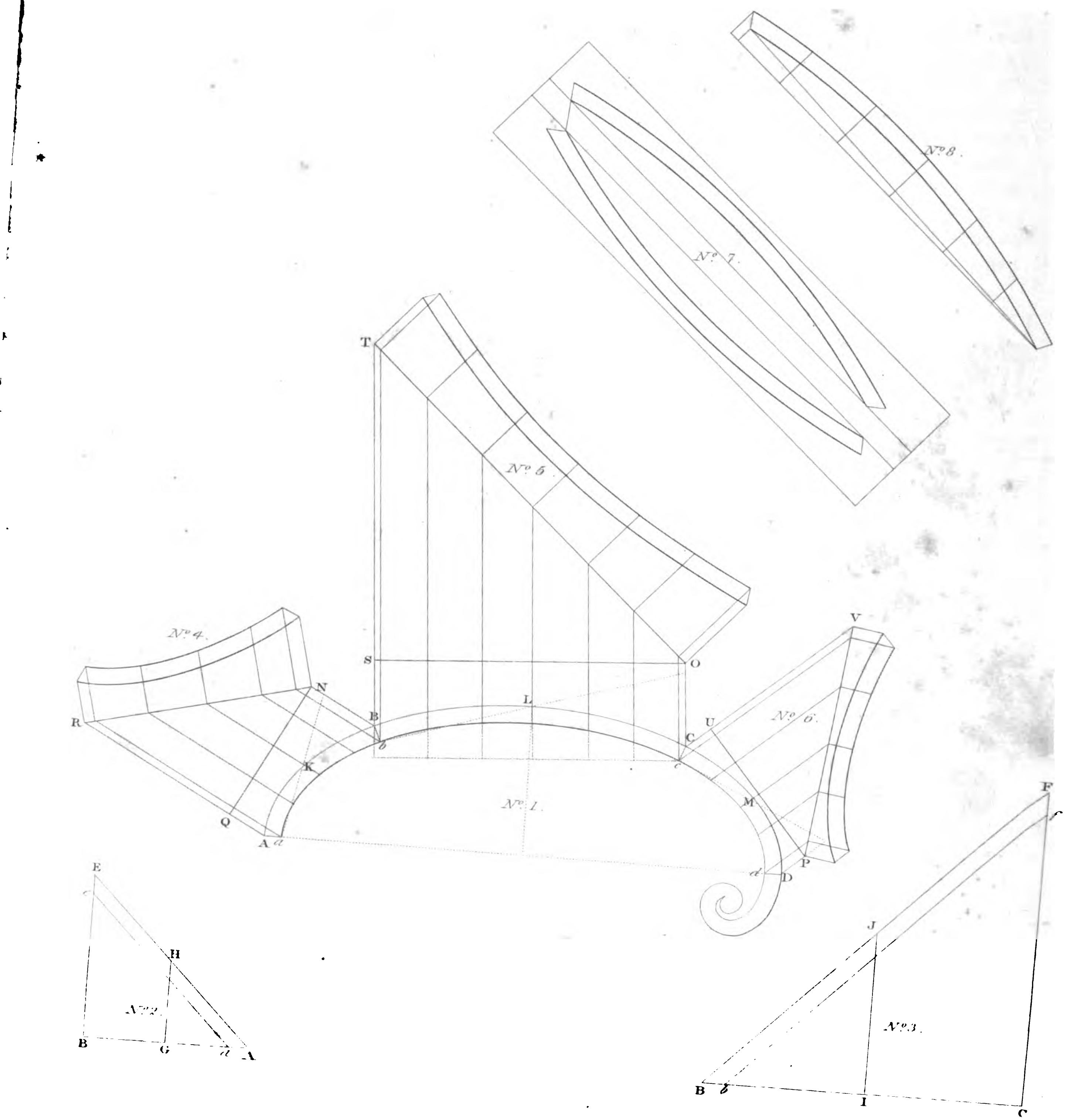

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the angle ADF; then apply one extreme point of the inner edge of the face-mould to the top of the plank, and bring it to that point of the arris* where the line intersects, and bring the other extreme point to the same arris; then, the under side of the face-mould coinciding with the face of the plank, draw a line by each edge of the mould. Apply the mould to the under side of the plank in the same manner: then cut away the superfluous wood on the outside of the lines drawn on the plank; which being done, apply the falling-mould to the convex side of the piece thus formed.

It is not easy to give such directions as to make a workman perfectly understand at once the application of the face-mould and falling-mould; but, by a little practice, a perfect knowledge of the terms, and ruminating upon the subject, the directions here given will conduct him through every difficulty; and, unless a person collects his ideas into a proper train, except on self-evident subjects, the plainest directions that can be written may be mistaken.

HAND-RAILS OF ELLIPTICAL STAIRS.

To find the Falling and Face-Moulds for the Hand-Rail of an Elliptical Stair, where the Steps next to the Well-hole are equally divided.

204. Let ABCD (*pl. LXXXIII,* No. 1) be the plan of the external side of the rail, and *abcd* that of the internal side; these two curve lines comprehending between them the breadth of the rail.

In order to cut the rail out to the greatest advantage, or, so as to waste the least wood, it is made in three lengths AB, BC, CD; the joints being represented by B*b*, C*c*, D*d*, the scroll and the adjoining part being formed of a separate piece.

205. The first thing to be done, as in all other cases of this kind, is, to find the falling-mould. For this purpose, let AB, No. 2, be the stretch-out of the line AB on the plan; and make AB, BE, in the proportion of any number of steps to their height, and draw the line AE. Then draw *ae*, at such a distance from AE, that AE, *ae*, may comprehend between them the thickness of the rail. In like manner, draw BC, No. 3, equal to the stretch-out of BC on the plan, and make BC to CF as the tread of any number of steps next to the well-hole is to their height, and draw *bf* parallel to BF, so that BF and *bf* may comprehend between them the entire thickness of wood for the rail.

Bisect AB, No. 2, in G, and draw GH perpendicular to AB, cutting AE in the point H. Bisect BC, No. 3, in the point I, and draw IJ perpendicular to BC, cutting BF in J. Divide the length of the curve AB, No. 1, into two equal parts in the point K; also divide the curve BC into two equal parts in the point L, and divide the curve CD into two equal parts in the point M; then the points *a*, K, B, are the three resting points for the portion of the rail over AKB; and the three resting points of the rail, over BLC, are *b*, L, C; and the three resting points of the rail, over CMD, are *c*, M, D. Now, according to the falling-mould, laid down at No. 2 and 3, the height at A, No. 2, is nothing; therefore, the height upon A, No. 1, is nothing: the height of the rail upon the point K, No. 1, is equal to the line GH, No. 2; and the height upon the point B, No. 1, is equal to the straight line BE, No. 2. Again, since in the falling-mould, No. 3, the height upon B is nothing, so the height upon B, for the rail over its plan BLC, is nothing; the height upon L is the line IJ, and the height upon C is the straight line CF. The heights upon the points *c*, M, D, of the rail over CMD are the same as the heights upon the points *a*, K, B, of the rail over AKB.

* The explanation of *Arris*, and other terms, will be found in the Glossary of Technical Terms at the end.

Therefore, with the heights GH, BE, No. 2, find the intersections BN, No. 1, of a plane that would pass through the point *a*, and through the upper extremities of the lines erected upon K and B: next find CO, the intersection of a plane that would pass through the point *b*, and through the upper extremities of the lines standing upon L and C, and find DP, the intersection of a plane passing through the point *c*, and through the lines standing upon M and D.

Draw any line, QN, in No. 1, perpendicular to BN. Draw any line, OS, perpendicular to CO, and draw any line, PU, perpendicular to DP. Draw AR perpendicular to QN, cutting QN in Q; draw BT perpendicular to OS, cutting OS in S; and draw CV perpendicular to PU, cutting PU in U. Make QR equal to BE in No. 2, ST equal to CF in No. 3, and UV equal to BE in No. 2. Join NR, OT, and PV. The moulds, No. 4, 5, and 6, being traced in the usual manner, are applied to the plank, as at No. 7, where the edge and the two adjacent sides of the plank are stretched out so as to be seen at once. The moulds are usually traced, as at No. 8; but this position will evidently give the same thing as the method here taken, exhibited in No. 4, 5, and 6.

206. *To find the Face and Falling-Moulds of the Scroll of the Hand-rail.*

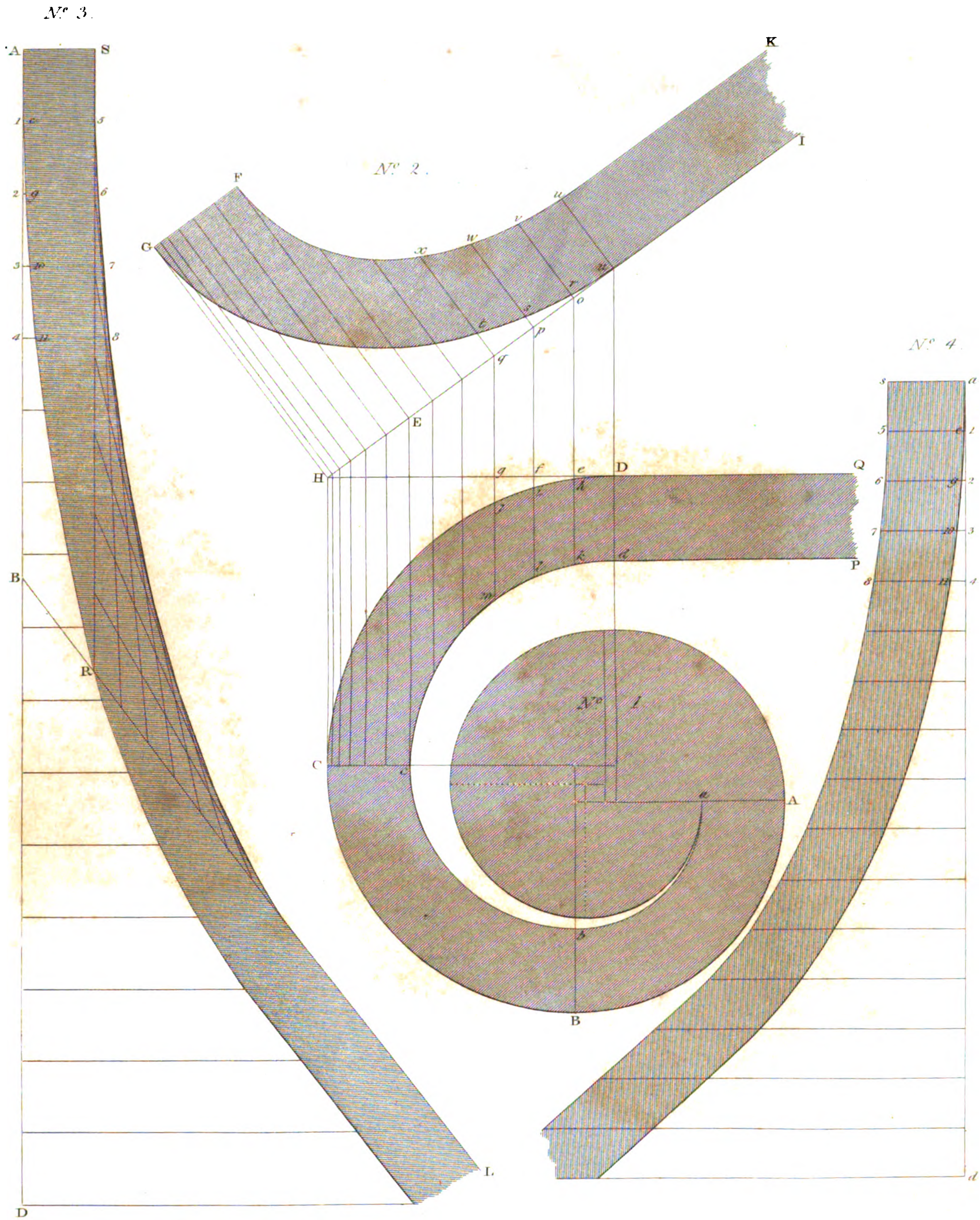
Place the edge DH, *plate LXXXIV.* of the pitch-board DHI, upon the side DQ of the shank of the scroll, as exhibited in No. 1 and No. 2.

In DH take any number of points, *e, f, g*, &c.; and through these points draw lines, perpendicular to DH, cutting the convex edge of the scroll in *h, i, j*, and the concave edge in the points *k, l, m*, &c. Produce the lines *ke, lf, mg*, &c., to meet the other edge, HI, of the pitch-board in *o, p, q*. Draw the straight lines *orv, psw, qtx*, perpendicular to HI, and make the distances *ov, pw, qx*, &c., respectively equal to *ek, fl, gm*, &c.; then, through all the points, *u, v, w, x*, &c., draw a curve.

Again, make *or, ps, qt*, &c., respectively equal to *eh, fi, gj*, &c., and through the points *n, r, s, t*, &c., draw a curve, and the two curved parts of the face-mould will be completed. Draw *c*E, CH, and D*n*, perpendicular to HD, meeting the edge HI of the pitch-board in the points E and *n*. Draw HG, EF, *nu*, perpendicular to HI. Make HG equal to HC, and draw GF parallel to HI; also make *nu* equal to D*d*, and draw *u*K parallel to HI; then the whole of the face-mould will be completed. The part I*nu*K is termed the *shank of the face-mould*, the same as the part P*d*DQ is termed the *shank of the plan of the scroll.* The part C*cd*PQDC is got out of the plank by means of the face-mould, by drawing the pitch-line on the edge of the stuff, then applying the mould, No. 2, to both sides of the plank, so that the same point of the face-mould may agree with the pitch-line, while the shank is parallel to the edge of the plank; then, the stuff being cut away, the piece, thus formed, being set up in its due position, will range to the plan.

207. *The Falling Moulds for the concave and convex Sides of the Rail*, are to be found as follows:

Suppose now that the rail is to have a continued fall to the point A, see the plan, No. 1. Stretch out the curve ABCD, No. 1, and draw the straight line AD, No. 3, and make AD, No. 3, equal to the curve line ABCD, No. 1. Apply the angular point of the pitch-board to some convenient point, B, in the line AD, No. 3, so that the edge may be on the line AD; then the other edge, LB, will form an angle, LBA, with AD. Draw AS perpendicular to AD, and make AS equal to the thickness of the scroll. Draw SR parallel to AD, cutting BL in R: ease off the angle LRS, by means of a parabolic curve, as shown in *art.* 190; and this being done, will form the upper edge of the falling-mould, for the convex side of the rail: then, through the point A, draw a curve line parallel to the upper curve; and thus the whole of the outside falling-mould will be completed.



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The inside falling-mould will be found as follows: take the stretch-out of the curve *abcd*, No. 1, and draw the straight line *ad*, No. 4, which make equal to the said curve. Divide AD, No. 3, and *ad*, No. 4, each into the same number of equal parts, the more the truer the work will be effected. We shall here suppose that sixteen equal parts will be sufficient; therefore each of the lines AD, *ad*, being divided into sixteen parts, at the points 1, 2, 3, 4, &c. Through all the points 1, 2, 3, 4, &c., No 3, draw lines perpendicular to AD, cutting the upper curve at the points 5, 6, 7, 8, &c., and the under curve at the points, 9, 10, 11, &c. Again, through the points 1, 2, 3, 4, in the line *ad*, No. 4, draw perpendiculars 1-5, 2-9-6, 3-10-7, 4-11-8, &c. Make 1-5, 2-6, 3-7, 4-8, &c., in No. 4, respectively equal to 1-5, 2-6, 3-7, 4-8, &c., No. 3; then, through all the points 5, 6, 7, 8, &c., draw a curve; also draw *as*, in No. 4, perpendicular to *ad*, and join the point *s* to the curve: this being done, will complete the upper edge of the falling-mould, for the concave side of the rail: then, through the point *a*, draw another curve; which, being done, will form the under line of the said falling-mould.

The falling-mould, No. 3, is applied to the convex side of the said piece of the wood; and the other mould, No. 4, to the concave side of the said piece. The joint is made at the line C*c*, and the remaining part of the scroll is made out of a single level block; but part of each falling-mould, No. 3, and No. 4, is used as far as the line A*a*; the remaining part of the block from the line A*a* being level.

208. In Elliptical Stairs, where the steps are not equally divided next the well-hole, the stretch-out of the line, representing the ends of the steps on the plan, must have the places of the risers marked upon it, and a perpendicular being drawn to each of these places, and made equal to the height of the corresponding step above the plan, the line drawn through extremities of the perpendiculars will give the form of the edge of the falling-mould.

The upper and lower edges of the falling-mould will always be a curved line when the steps are not equally divided at the well-hole, but we think the extra trouble this occasions is fully compensated for by the stairs being so much more agreeable in use, when divided as we have recommended in *art.* 156, *fig.* 3, *plate LXXIII.*

The face-moulds for steps, divided unequally at the well-hole, are found in the same manner as when they are equally divided, (see *art.* 205, and *pl. LXXXIII,*) the only differences being, that BF, *bf*, in No. 3, and AF, *ae*, in No. 2, are curved lines found in the manner we have described in the first part of this article.

To draw the Form of a Hand-Rail upon the Plank by continued Motion.

209. If a plank be placed in the true position in respect to the plane of the plan, and distance from the centre of the well-hole; then, if the well-hole be a part of a circle on the plan, let a cylindrical rod be fixed, as an axis, in the centre of the circle, and in a vertical position, with an arm of sufficient length that will slide up or down on the rod, and turn round on it as on an axis. The arm should have a slider with a pencil, in order that the point of the pencil may be adjusted to the proper distance from the centre; and the hole in the arm through which the axis passes, should be of sufficient length to keep it truly at right angles to the rod.

Let the pencil be adjusted to the proper distance from the centre, and commencing at the upper end of the plank, if the pencil be moved round the axis, it will descend and describe on the plank the curve of one side of the rail; and by setting the pencil again, the other side may be described. By turning the pencil point upwards, the under side of the plank may have the lines drawn upon it in like manner.

210. The form of the rail for elliptical stairs may also be described by continued motion by fixing a trammel (see *Carpentry, art.* 8,) on the top of a square bar, which bar should be made to slide up and down in the centre of the well-hole.

All these contrivances are, however, more expensive, and generally more troublesome to the workman than the ordinary method by finding points in the curves; though we think that the attempt to apply them in practice gives very accurate notions of the forms and properties of hand-rails.

211. The curved parts of hand-rails, for either circular or elliptical well-holes, may be described by continued motion by the trammel, when it is placed in the same plane with the plank.

The centre of the well-hole being found in that plane, draw a line through the centre on the plan, and perpendicular to the line of intersection between the plane of the plank and the plane of the plan; and, from the point in which the perpendicular meets the intersecting line, draw a line through the centre found in the plane of the plank; this line will be the larger axis of the ellipsis, the shorter one will be at right-angles to it, and the lengths are easily found by the methods of finding the points in the curves of hand-rails. These particulars being found, the portions of ellipses may be described by the trammel.

OF FIXING JOINERS' WORK.

212. The methods of fixing joiners' work, so that it may be firm, preserve its form, and not be liable to split by shrinking, are of considerable importance; as however well a piece of work may have been prepared, if it be not properly fixed, it cannot fulfil its intended purpose in a manner creditable to the workman.

We have treated very fully on the expansion and contraction of timber, in *Carpentry, art.* 201, and those following it; and we have also shown how timber should be cut, so that the boards may preserve their form, and we now have to apply the truths, there stated, to the fixing of wood-work.

Of Fixing Grounds.

213. The architraves, dado, skirtings, and surbase mouldings, and, indeed, nearly all the apparent surfaces in joinery, are fixed to pieces of wood called *Grounds;* and, as the straightness and accuracy of these mouldings and surfaces must depend upon the care that has been taken to fix the grounds truly, it will appear, that fixing grounds, which is a part often left to inferior workmen, in reality requires much skill and attention. Besides, grounds are almost always the guide for the plasterer, and, consequently, the accuracy of his work also depends on them.

When plasterers' work joins to the edges of grounds, they should have small grooves ploughed in the edges, to form a key for the plaster, as is sufficiently illustrated in the various figures we have given in the plates.

The thickness of the grounds should be equal to the thickness of the plastering and laths, and it is from three-quarters of an inch to an inch, according as the plasterers' work is done, in an inferior or in the best manner.

The faces and edges of grounds should be fixed exactly plumb and level; or, as the more scientific carpenters may express it, the faces and edges should be fixed exactly in vertical and horizontal planes.

Of Fixing Dado, Skirtings, &c.

214. If the piece of joiners' work to be fixed consist of boards jointed together, but not framed, it should be fixed so that it may shrink, or swell without splitting, and the quantity allowed for motion must depend on the dryness of the timber.

The nature of the work will generally determine how this may be effected. Let us suppose that a plain piece of dado of considerable breadth is to be fixed. Let us suppose that the dado has been prepared as described in *art.* 45, and that it is kept straight by a dovetailed key. Now let the dado be firmly nailed at the upper edge, and let a narrow skirting ground, with a groove and cross tongue in its upper edge, be fixed to bond timbers or plugs in the wall, the tongue being inserted also into a corresponding groove in the lower edge of the dado. It is obvious, that the tongue being loose, the dado may contract or expand, as a pannel in a frame. The backs and elbows of windows should be fixed in the same manner.

In the principal rooms of a mansion, the skirting is usually grooved into the floor, and fixed only to the narrow ground, called the skirting ground. By fixing in this manner, the skirting never shows an open joint. Sometimes in inferior rooms the skirting is scribed and nailed fast to the floor, and grooved into the base-moulding, and, when either method is adopted, there cannot be an open joint between the skirting and floor, as is too frequently the case in houses.

When it is considered, that an open joint, in such a situation, must become a receptacle for dust, and a harbour for insects, the importance of adopting those methods of fixing skirtings will be apparent.

It is a good plan to fix skirtings only in a temporary manner till a house has become seasoned, and all the timbers have shrunk and settled to their proper bearings; but a due attention to the methods here proposed will render this precaution less necessary.

In fixing any board that exceeds about 5 inches in width it is necessary to take precautions to prevent it from splitting, or deranging the form of the work; and, in general, it may be fixed along one edge, and the other may be confined by grooves or similar means, that have the property of allowing it to expand and contract. Sometimes both edges are left at liberty, and the board is fixed in the middle. Any joiner who has examined the state of work in a house, after it has been inhabited for about a couple of years, will be able fully to appreciate the value of an attention to those seemingly minute precautions.

Wide plain surfaces, such as landings of stairs, tops of tables, and the like, are frequently fixed down by buttons screwed to the under-side so as to turn into grooves in the joists, bearers, or frames. Then, when the wood shrinks or expands, the buttons slide a little in the grooves, and no splitting takes place.

The very general introduction of the method of ploughing and tongueing the parts of wood-work together is one of the most important improvements in modern joinery; it is an easy, effectual, and useful mode of combination, both in as far as it provides against the greatest defect of wood-work, its shrinkage, and the scope it affords for obtaining variety of outline at a comparatively small expense of either labour or material.

Of Laying Floors.

215. In our remarks on construction, we must not omit to say a few words on laying floors, because it will give us an opportunity of pointing out a defect which might be easily remedied. The advice of Evelyn, to tack the boards down only the first year, and nail them down for good the next, is certainly the best, when it is convenient to adopt it, but, as this is very seldom the case, we must expect the joints to open more or less.

Now these joints always admit a considerable current of cold air, and also, in an upper room, unless there be a counter floor, the ceiling below may be spoiled, by the accidental spilling a little water, or even by washing the floor.

To avoid this, we would recommend a tongue to be ploughed into each joint, according to the old practice; and, when the boards are narrow, they may be laid without any appearance of nails, in the same way as a dowelled floor is laid, the tongues serving the same purpose as the dowels. In this case we would use cross or feather tongues for the joints. We have had oak floors laid in this manner instead of with dowels, and we find it to be a much easier method.

Parquet Floors.

216. The fashion of laying floors with various coloured woods, disposed in patterns, seems now to become more general in this country. It has long been much in use in France, and such floors are often called *parquet* floors; though that name only applies to such as are framed in compartments of about 3 feet square each, divided into small square or lozenge pannels, with the pannels grooved in so as to be flush on the upper surface.

The imitations of the parquet floors which have been done in this country have often been done with thin boards, about half an inch thick, glued, and nailed or screwed down, on a common deal floor. Lately, however, another method has been adopted; it consists in devising a pattern so that its joints shall coincide with the joints of a floor laid with boards of equal breadth. The thin boards which form the pattern are then glued to the floor boards at the bench, and screwed to them from the under side, and afterwards the boards are laid either by dowels or tongues as a plain oak floor would be done.

The patterns are formed by disposing the grain of the wood of the pannels in different directions, by making the pannels of black wood, or by making the different parts of different coloured species of oak, and when the smaller divisions are of the rich dark brown varieties of English oak, and the others of fine Dutch wainscot, such floors are uncommonly beautiful.

INDEX AND GLOSSARY OF TECHNICAL TERMS

USED IN CARPENTRY AND JOINERY;

WITH REFERENCES TO THE PAGES IN WHICH THE VARIOUS SUBJECTS ARE TREATED, AND AN EXPLANATION OF SUCH TERMS AS ARE NOT ALREADY PARTICULARLY DEFINED IN THE WORK.

A.

ABUTMENT; the meeting surfaces, in the joint, of two pieces of timber, which are perpendicular to the fibres of one of the pieces, pages 15, 20.

Angle-Bar; an upright bar at an angle of a window constructed on a polygonal plan, 93.

Angle-Bracket; a bracket placed in an angle in the direction of the mitre line, 45.

Angles, method of framing, 85.

Annular-Vault; a vault which springs from two walls that are circular on the plan, 54.

Annulet; a fillet round a column, 84.

Arch; a part of a building supported by two walls or piers, with the under surface concave.

Architrave; that part of the entablature which lies upon the capital of a column; also a moulded frame to a door or window, 106.

Arris; the edge, or line, in which two plane surfaces meet.

Ashlering; perpendicular quartering from the rafters to the floor of rooms in a roof, to nail the plastering laths upon.

Ash-timber, 59.

B.

BACK of a hand-rail; the upper side of it.

Back of a hip; the upper edge of a rafter, between the two sides of a hipped roof, formed to an angle, so as to range with the rafters on each side of it, 34.

Back-shutters or Back-flaps; additional breadths hinged to the front-shutters of a window, for covering the aperture completely, when required to be shut, *see* 100.

Back of a window; the board or wainscoting between the sash-frame and the floor, uniting with two elbows, which are in the same plane with the shutters. When framed, it is commonly with a single pannel with mouldings on the framing, corresponding with the doors, shutters, &c. in the apartment in which it is fixed.

Balusters, 117.

Base-mouldings, 106.

Basil; the sloping edge of a chisel, or of the iron of a plane.

Batten; a scantling of stuff from two inches to seven inches in breadth, and from half an inch to two inches and a half in thickness.

Baulk; a piece of fir from eight to sixteen inches square, being the trunk of a tree of that species of wood, generally hewn to a square, for to be used in building.

Bead; a round moulding, commonly made upon the edge of a piece of wood: of beads there are two kinds, one flush with the surface called a *quirk-bead*, and the other raised, called a *cock-bead*, 83.

Bead and but, 96.

Bead and flush, 96.

Beam; a horizontal timber, used to resist a force or weight; as a tie-beam where it acts chiefly as a string or chain, by its tension; as a straining-beam, where it acts by compression; and as a bressummer where it resists a transverse insisting weight, *see* 27, 29, and 73.

Bearer; any thing used by way of support to another, 110.

Bearing; the distance of the supports by which a beam or rafter is suspended in the clear: thus, if a piece of timber rests upon two opposite walls, the span of the void is called the bearing, and not the whole length of the timber.

Beech timber, 59.

Bench; a platform supported on four legs, and used for planing upon, &c. &c.

Bending-mouldings, 89, 103.

Bevel; one side is said to be bevelled with respect to another, when the angle formed by these two sides is either greater or less than a right angle.

Binding-joists, 22.

Birch timber, 60.

Bird's-mouth; an interior angle, formed in the end of a piece of timber, so that it may rest firmly upon the exterior angle of another piece.

Blade; any part of a tool that is broad and thin; as the blade of an axe, of an adze, of a chisel, &c.: but the blade of a saw is generally called the plate.

Blockings; small pieces of wood, fitted in, or glued, or fixed to the interior angle of two boards or other pieces, in order to give strength to the joint.

Board; a substance of wood contained between two parallel planes, as when a baulk is divided into several pieces by the pit-saw, the pieces are called boards. The section of boards is sometimes, however, of a triangular, or rather trapezoidal form; that is, with one edge very thin; these are called *feather-edged* boards.

Boarding circular roofs, 39.

Bond-timbers; horizontal pieces, built in stone or brick-walls for strengthening them, and for fixing the battening, lath, and plaster, &c. Bond-timbers should only be inserted where they are absolutely necessary.

Book-doors, 97.

Bottom-rail; the lowest rail of a door, a sash, or a casement.

Boxings of a window; the two cases, one on each side of a window, into which the shutters are folded, *see* 101.

Brace; a piece of timber, used in truss-partitions, or in framed roofs, in order to form a triangle, and thereby render the frame immovable; when a brace is used by way of support to a rafter, it is called a strut. Braces, in partitions and span roofs, are always, or should be, disposed in pairs, and placed in opposite directions, 21.

Brace and Bits, the same as stock and bits.

Bracketing, 45.

———, spandril or pendentive, 46.

Bracketed-stairs, 110, 112.

Brad; a small nail, having no head except on one edge, the intention is, that it may be driven within the surface of the wood, by means of a hammer and punch, and the cavity filled flush to the surface with putty.

Breaking-up; in sawing, is dividing a baulk into boards or planks; but if planks are sawed longitudinally, through their thickness, the saw-way is called a ripping-cut, and the former a breaking-cut.

To Break-in; to cut or break a hole in brick-work, with the ripping-chisel, for inserting timber, &c.

Breaking-joint is a joint formed by the meeting of several heading-joints in one continued line, which is sometimes done in common floors.

Bressummer or Breastsummer; a beam supporting a superincumbent part of an exterior wall or building, and running longitudinally below that part, 24.

Bridged-gutters; gutters made with boards, supported below by bearers, and covered over with lead.

Bridges, centring for, 48.

———, wooden, 55.

Bridging-floors; floors in which bridging joists are used, 22.

Bridging-joists; beams in naked flooring for supporting the boarding for walking upon, 22.

Butting-joint; the junction formed by the surfaces of two pieces of wood, of which, one surface is perpendicular to the fibres, and the other in their direction, or making with them an oblique angle.

C.

Camber; the convexity of a beam upon the upper side, in order that it may not become concave by its own weight, or by the burden it may have to sustain, in course of time.

Camber-beams; those beams used in the flats of truncated roofs, and raised in the middle with an obtuse angle, for discharging the rain-water toward both sides of the roof, 30.

Cantilevers; horizontal rows of timber, projecting at right angles from the face of a wall, for sustaining eaves, mouldings or balconies, sometimes they are planed on the horizontal and vertical sides, and sometimes of rough timber and cased with joiner's-work.

Carriage of a stair; the timber-work which supports the steps, 110.

Carcase of a building; a term applied to the naked walls, and the rough timber-work of the roofing, flooring, and quarter-partitions, before the building be plastered or the floors laid.

Carpentry defined, 14.

Carry-up; a term used among builders, or workmen, denoting that the walls, or other parts, are to be built to a certain given height; thus the carpenter will say to the bricklayer, Carry-up that wall, carry-up that stack of chimneys; which means build up that wall, or stack of chimneys.

Casement-windows, 98.

Casting or **Warping**; the bending of the surfaces of a piece of wood from their original position, either by the weight of the wood, or by an unequal exposure to the weather, or by unequal texture of the wood, *see* 62.

Cavetto, 84.

Ceiling-joists, 22.

Centring for Bridges, 48.

Chamfering; cutting the edge of any thing, originally right-angled, to a slope or bevel.

Chesnut-tree, 61.

Circle, methods of drawing a portion of, 1.

Circular-roofs, 37.

Circular-sashes, 99.

Clamp; a piece of wood fixed to the end of a board, by mortise and tenon, or by a groove and tongue, so that the fibres of the piece, thus fixed, traverse those of the board, and by this means prevent it from casting; the piece at the end is called a *clamp*, and the board is said to be *clamped*, 88.

Clear Story Windows, are those that have no transom.

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Cohesive Strength of Timber, 65.

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Columns, method of fluting, 103.

——— of diminishing, 103.

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Cornices, Bracketing for, 45.

———, enlarging and diminishing, 90.

Cot-bar, in Sashes, 99.

Cove-Bracketing, 45.

Cross-grained Stuff, is that which has its fibres running in contrary directions to the surfaces; and, consequently, is more difficult to make perfectly smooth, when planed in one direction, without turning it, or turning the plane.

Crown-Post; the middle post of a trussed roof.—*See* King-post.

Curling-Stuff; that which is occasioned by the winding or coiling of the fibres at the bough of a tree, when they begin to shoot from the trunk.

Curtail Step, 111.

Curves, method of Transfering, 5.

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Cyma recta, 84.

Cyma reversa, 84.

D.

Dado, modes of joining, 85.

——— of fixing, 131.

Deal-timber; the timber of the fir-tree, as cut into boards, planks, &c., for the use of buildings. *See* 60.

Developement, 7.

——— of surfaces, 10.

Dimensions, 88.

Diminishing rule, 104.

Discharge; a post trimmed up under a beam, or part of a building which is weak, or overcharged by weight.

Dog-legged Stairs, 110, 111.

Domes; construction of, 38.

——— covering, 41.

Doors, 96.

Door-frame; the surrounding case of a door, into which, and out of which, the door shuts and opens, 96.

Dormer, or Dormer-window; a projecting window in the roof of a house; the glass-frame, or casement, being set vertically, and not in the inclined sides of the roofs: thus dormers are distinguished from skylights, which have their sides inclined to the horizon.

Dove-tailing, 86.

——— lap, 86.

——— mitre, 86.

Dowelling, 99.

Drag; a door is said to drag when it rubs on the floor or carpet; this arises in some cases from the loosening of the hinges, or the settling of the building.

Dragon-Beam; the piece of timber which supports the hip-rafter, and crosses the angle formed by the wall-plates.

Dragon-Piece; a beam bisecting the angle formed by the wall-plates, for receiving the heel, or foot of the hip-rafters.

E.

Edging; reducing the edges of ribs or rafters, externally or internally, so as to range in a plane, or in any curved surface required. *See* 43.

Elevations, 7.

Ellipsis, to draw, 2.

———, false, 3.

Elliptical Stairs, 113, 127.

Elm-Timber, 60.

Expansion of Timber, 62.

Enter; when the end of a tenon is put into a mortise, it is said to enter the mortise.

F.

Face-Mould; a mould for drawing the proper figure of a hand-rail on both sides of the plank; so that, when cut by a saw to the required inclination, the two surfaces of the rail-piece, when laid in the right position, will be every where perpendicular to the plan, 117.

Falling-Mould, 117.

False ellipsis, a mode of drawing, 3.

Fang; the narrow part of the iron of any instrument which passes into the Stock.

Feather-edged Boards; boards thicker at one edge than the other, and commonly used in the facing of wooden-walls, and for the covering of inclined roofs, &c.

Feather-tongues, 87.

Fence of a Plane; A guard, which guides it to work to a certain horizontal breadth from an arris.

Filling-in Pieces; short timbers, less than the full length, as jack-rafters of a roof, the puncheons, or short quarters, in partitions, between the braces and sills, or head-pieces.

Fine-set; a plane is said to be fine-set, when the cover of the plane-iron is set very close to the cutting edge.

Fir-Timber, qualities of, 60.

Fir-Poles; small trunks of fir-trees, from ten to sixteen feet in length, used in rustic buildings and out-houses.

Fishing a beam, 18.

Fixing grounds, 130.

Flooring, naked, 21.

——— laying, 132.

——— parquet, 132.

Float, 86.

Fluting, 84, 103.

Flyers, 107.

Framing, in Carpentry, 14.

———, in Joinery, 86.

Franking, 99.

Free-Stuff; that timber or stuff which is quite clean, or without knots, and works easily without tearing.

French Windows, 101.

Frowy Stuff; short, or brittle and soft timber.

Furrings; slips of timber nailed to joists, or rafters, in order to bring them to a level, and to range them into a straight surface, when the timbers are sagged, either by casting, or by a set which they have obtained by their weight, in length of time.

G.

Gable-ended Roofs, 30.

Geometrical Stairs, 107, 112.

Girder; the principal beam in a floor for supporting the binding-joists, 22, 76.

Girder Truss, 23.

Globe or Sphere, Section of, 7.

Glue; a tenacious viscid matter, which is used as a cement by carpenters, joiners, &c.

Glueing-up work, 88.

Gothic Arches, methods of drawing, 3, 5.

Gothic Soffits, 13.

Grind-Stone; a cylindrical stone, which being turned round its axis, edge-tools are sharpened, by applying the basil to the convex surface.
Groined Arches, 49.
Grooving, 83.
Ground-Plate or Sill; the lowest plate of a wooden building, for supporting the principal and other posts.
Grounds; pieces of wood fixed to walls and partitions, with their surfaces flush with the plaster, to which the facings or finishings are attached, 130.

H.

HAND RAIL, 111.
Hand railing, 114.
Handspike; a piece of wood used as a lever for raising or carrying a beam, or other body.
Hanging Stile; the stile of a door or shutter to which the hinges are fastened; also, a narrow stile fixed to the jamb on which a door or shutter is frequently hung, 95.
Hinging, 93.
——— Doors, 94.
——— Shutters, 95.
Hip-rafter; an inclined rafter placed in the angle in which the surfaces of a roof meet, 34.
Hip-roof; a roof, the ends of which rise immediately from the wall-plate with the same inclination to the horizon, as its other two sides, 30. The Backing of a Hip-rafter is the angle made on its upper edge to range with the two sides or planes of the roof between which it is placed, 34.
Hoarding; an inclosure of wood which in streets is put about a building, while erecting or repairing.
Hyperbola, methods of drawing, 4.

J.

JACK-RAFTERS; all those short rafters which meet the hips.
Jack-ribs; those short ribs which meet the angle ribs, as in groins, domes, &c.
Jack-timber; a timber shorter than the whole length of other pieces in the same range.
Jib-doors, 97.
Intertie; a horizontal piece of timber, framed between two posts, in order to tie them together.
Joggle-Piece; a truss post, with shoulders, and sockets for abutting and fixing the lower ends of the struts, 20.
Joints, in Carpentry, 91.
Joinery, 81.
———, History of, 81.
Joists; those beams in a floor which support, or are necessary, in the supporting, of the boarding or ceiling; as the binding, bridging, and ceiling, joists; girders are, however, to be excepted, as not being joists, 22.
Iron Girders, 23.
————, strength of, 76.
Juffers; stuff of about four or five inches square, and of several lengths; this term is out of use, though frequently found in old books.

K.

KERF; the way which a saw makes in dividing a piece of wood with two parts.
Keys, 88.
—— of Dado, 88.
King-Post; the middle post of a trussed roof, for supporting the tie-beam at the middle, and the lower ends of the struts, 28.
Knee; a piece of timber cut at an angle, or having grooves to an angle. In hand-railing a knee is a part of the back, with a convex curvature, and, therefore, the reverse of a ramp, which is hollow on the back, 118.
Knot; that part of a piece of timber where a branch had issued out of the trunk.

L.

LANDINGS, 107.
Lime-tree, 61.
Lines for roofs, 34.
—— for circular roofs, 36.
Lining of a wall; a timber boarding, of which the edges are either rebated or grooved and tongued.
Lintels; short beams over the heads of doors and windows, for supporting the inside of an exterior wall; and the superincumbent parts over doors, in brick or stone partitions.
Lock-rail. See *middle-rail*.
Lower rail; the rail at the bottom of a door, or next to the floor.
Lying pannel; a pannel with the fibres of the wood disposed horizontally.

M.

MAHOGANY, 61.
Margins; the flat part of the stiles and rails of framed work.

Margins, double. *See* 97.

Middle-rail, or lock-rail; the rail of a door which is upon a level with the hand when hanging freely, but bending a little the joint of the wrist. The lock of the door is generally fixed in this rail.

Mitre; if two pieces of wood be formed to equal angles, or if the two sides of each piece form equal inclinations, and they be joined together at their common vertex, so as to make an angle, double to that of either piece, they are said to be *mitred* together, and the joint is called the *mitre*, 85, 87.

Mitre-Cap, 115.

Mortise and Tenon, 83, 86.

Mould, 116.

Mouldings, 83.

———, enlarging, 90.

———, diminishing, 90.

Mullion or Munnion; a large vertical bar in a window-frame, separating two casements, or glass-frames, from each other, 83. Those divisions which extend horizontally are *transoms*.

Muntins or Mountings; the vertical pieces of the frame of a door between the stiles, 83.

N.

Naked flooring; the timber-work of a floor for supporting the boarding, or ceiling, or both, 21.

Newel; the post in dog-legged stairs, where the winders terminate, and to which the adjacent string-boards are fixed, 110.

Niches, 43.

Nosings, 107.

Notching, 19.

Notch-board, 111.

O

Oak Timber, 57.

Octagon, how to draw, 6.

Ogee; a moulding, the transverse section of which consists of two curves of contrary flexure, 84.

Ovolo, 84.

P.

Pannel; a thin board, having all its edges inserted in the grooves of a surrounding frame, 83.

Parabola, 3.

———, methods of drawing, 3.

Parquet floors, 132.

Partitions, 21.

Pendentives, 46.

Pilasters, 104.

Pitch of a Roof; the inclination which the sloping sides make with the plane, or level of the wall-plate; or, it is the proportion which arises by dividing the span by the height. Thus, if it be asked, What is the pitch of such a roof? the answer is, one-quarter, one-third, or half. When the pitch is half, the roof is a square, which is about the highest that is now in use, or that is necessary in practice. *See* 26.

Pitching-piece, 110.

Plan, 7.

Plank; all boards above nine inches wide are called planks.

Plaster-groins, 51.

Plate; a horizontal piece of timber in, or upon, a wall, generally flush with the inside, for resting the ends of beams, joists, or rafters, upon; and, denominated floor or roof plates; or wall-plates.

Pole plate, 29.

Polygonal roofs, 36.

Polygons, to describe, 37.

Poplar wood, 61.

Posts; all upright or vertical pieces of timber whatever; as truss-posts, door-posts, quarters in partitions, &c., are called posts.

Pressure of beams and trusses, 16.

Prick-posts; intermediate posts in a wooden building, framed between principal posts.

Principal posts; the corner posts of a wooden building.

Principal rafters, 27.

Prism, 7,

Punchion; any short post of timber. The small quarterings in a stud partition, above the head of a door, are called punchions.

Purlins; the horizontal timbers in the sides of a roof, for supporting the spars, or small rafters, 29.

Pyramid, 7.

Q.

Quartering; the timbers of a partition.

Quarters; the timbers used in stud partitions, bond in walls, &c.

Quarter-space, 107.

Quarter-round, 84.
Queen-posts, 28.
Quirked ovolo, 84.

R.

Rafters; all the inclined timbers in the sides of a roof; as principal rafters, hip-rafters, and common rafters; the latter are called in most counties, *Spars*. See 27, 29.
Rails; the horizontal pieces in which the upper and lower edges of the pannels are inserted, and which contain the tenons in a piece of framing.
Raising-plates, or Top-plates; the plates on which the roof is raised.
Raking-mouldings, 91.
Ramps, 118.
Rank-set; the edge of the iron of a plane is said to be rank-set when the cover is set considerably back from the cutting-edge.
Rebating, 83.
Reeds, 84.
Repulsive strength, 66.
Return; in any body with two surfaces, joining each other at an angle, one of the surfaces is said to return in respect of the other; or, if standing before one surface, so that the eye may be in a straight line with the other, or nearly so: this last is said to return.
Ridge; the meeting of the rafters at the vertical angle, or highest part of a roof, 29.
Ridge-piece; the board against which the rafters meet.
Ring, 7.
Riser; the vertical part of a step of stairs, 107.
Roof; the covering of a house: but the word is used in carpentry, for the wood-work which supports the slating, or other covering, 25.
Roofing, lines for, 34.
———, circular, 36.
Rule-joints, 93.

S.

Sagging, 27.
Sash-windows, 98.
Sashes, circular, 99.
Scantling; the transverse dimensions of a piece of timber; sometimes, also, the small timbers in roofing and flooring are called scantlings.
Scape, 84.
Scarfing; a mode of joining two pieces of timber, by bolting or nailing them transversely together, so that the two appear but as one continuous piece. The joint is called a *scarf*, and the timbers are said to be *scarfed*. See 17.
Scotia, 85.
Scribing, 87.
Scroll, 117, 121.
Section, 7, 8.
Segment of a circle, 1.
Setting-out, 6, and 89.
Shaken Stuff; such timber as is rent or split by the heat of the sun, or by the fall of the tree, is said to be shaken.
Shingles; thin pieces of wood sometimes used for covering, instead of tiles, &c.
Shop-fronts, 106.
Shreadings; a term not much used at present. See *Furrings*.
Shutters, 100.
Skirting or Skirting-boards; the narrow boards round the margin of a floor, forming a plinth for the base of a dado, or simply a plinth for the room itself, when there is no dado, 106, 131.
Skirts of a Roof; the projecture of the eaves.
Skylights, 102.
Sleepers; pieces of timber for resting the ground-joists of a floor upon; or for fixing the planking to, in a bad foundation. The term was formerly applied to the valley-rafters of a roof.
Soffits, 12.
———, Gothic, 13.
Solids, sections of, 8.
Span, 27.
Spars; a term by which the common rafters of a roof are best known in almost every provincial town in Great Britain; though generally called in London *common rafters*, in order to distinguish them from the principal rafters.
Springing Mouldings, 103.
Staff; a piece of wood fixed to the external angle of the upright sides of a wall at chimney-breasts, and the like, for floating the plaster to, and for defending the angle against accidents.
Staff-bead; when a staff for an angle is formed into a bead to be flush with the plastering with the quirks formed in plaster.
Staircases, 107.
Steps, 108.

Steps, in scarfing, 18.
Stiffness of Timber, 77.
Stiles of a Door, are the vertical parts of the framing at the edges of the door.
Stock and Bits; a stock is an instrument with a revolving head, and a socket and spring to receive boring-tools of various kinds, called bits.
Straining Beam, 29.
——— Sill, 29.
Strength of Timber, 64, 73.
Struts; pieces of timber which support the rafters, and which are supported by the truss-posts, 24, 29.
Summer; a large beam in a building, either disposed in an outside wall, or across in the middle of an apartment, parallel to such wall. When a summer is placed under a superincumbent part of an outside wall, it is called a bressummer, as it comes in abreast with the front of the building.
Surbase; the upper base of a room, or rather the cornice of the pedestal of the room, which serves to finish the dado, and to secure the plaster against accidents from the backs of chairs, and other furniture on the same level, 86.
Swan-neck, 118.
Sycamore, 61.

T.

Tabling, 18.
Taper; the form of a piece of wood which arises from one end of a piece being narrower than the other.
Templates, 22.
Tenon, 83.
Tie; a piece of timber, placed in any position, and acting as a string or tie, to keep two things together which have a tendency to spread apart from each other.
Tie-beam, 17, 27.
Timber, kinds of, 57.
Torus, 84.
Transom. See *Mullion*.
Transom-Windows; those windows which have transoms.
Transverse Strength of Timber, 69.
Treads, 107.
Trimmers; joists into which other joists are framed, 22.
Trimming-joists; the two joists into which a trimmer is framed, 23.
Truncated Roof; a roof with a flat on the top.
Truss; a frame constructed of several pieces of timber, and divided into two or more triangles by oblique pieces, in order to prevent the possibility of its changing its figure, 15, 24.
Truss-Girders, 17, 23.
Trussed Roof; a roof so constructed within the exterior triangular frame, as to support the principal rafters, and the tie-beam at certain given points, 27.
Truss-Post; any of the posts of a trussed roof, as a king-post, queen-post, or side-post, or posts into which the braces are formed in a trussed partition.
Trussels; four-legged stools for ripping and cross-cutting timber upon.
Tusk; the bevelled upper shoulder of a tenon, made in order to give strength to the tenon, 19.

V.

Valley-Rafter; that rafter which is disposed in the internal angle of a roof.

U.

Uphers; fir poles, from 20 to 40 feet long, and from 4 to 7 inches in diameter, commonly hewn on the sides, so as not to reduce the wane entirely. When slit, they are frequently employed in slight roofs; but mostly used whole for scaffolding and ladders.

W.

Wall-plates; the joist-plates, and raising-plates.
Walnut-tree, 61.
Web of an Iron; the broad part of it which comes to the sole of the plane.
Well-hole, 107.
Welsh Groin, 53.
Windows, 98.
Window-Shutters, 100.
Winders, 107.
Wooden Bridges, 55.
Working Cylinder, 116.
Working Drawings, 1, 7.

PRACTICAL

CARPENTRY, JOINERY, &c.

BOOK III.

CABINET-MAKING.

CHAPTER I.

INTRODUCTION.

1. CABINET-MAKING is the art of constructing all such parts of the ***Furniture*** of a Dwelling-house as are formed of *Wood.*

The term Cabinet-maker has, no doubt, at its first introduction, been applied only to those who made cabinets for containing collections of medals, coins, manuscripts, or natural curiosities; and when, on account of their superior skill, they were afterwards more generally employed in the construction of household-furniture, they still retained the name which was applied when cabinets alone were the objects on which they were occupied.

The general term Cabinet-making, includes the particular art of *chair-making,* and a few others of less importance; and, a rather comprehensive knowledge of some of the higher species of art, as of *design,—carving,—modelling,* &c., is essential to form a good cabinet-maker; this we will endeavour to render apparent by a more full statement of the objects to which the attention of the cabinet-maker ought to be directed.

2. When we consider the end and object to be attained in furniture, it soon appears that it admits of more freedom and grace in the contour of its parts than can be allowed in the parts of buildings; indeed, many pieces of furniture must be more or less adapted to the beautiful curved lines of the human figure; and, therefore, should be designed to associate with such forms; and so that either jointly or separately, either occupied or unoccupied, these species of furniture should make perfect and agreeable objects.

It is further necessary, that a piece of furniture should be designed so as to be easy and fit for its purpose; and, it is worthy of remark, that it will possess these properties in the highest degree when it best combines with the contour and attitudes of the human figure when it is in use.

3. It has been stated that it is an easy matter to design furniture, and that it is susceptible of an incalculable variety of new forms; but the remark is obviously made without experience in design, or a knowledge of the obvious truth that a piece of furniture should have novelty,

fitness, and propriety, as well as harmony of parts. A change of form must be considerable, otherwise we do not produce novelty, the number of changes is therefore limited by this condition; and the number of changes is further limited by the condition that the furniture must be fit, or perfectly adapted, to its purpose, and the number is again limited by the condition that the parts should bear that harmonious proportion to each other which is required to give grace and elegance.

Hence, the number of novel and pleasing variations of a design, for the same object, is extremely limited; and he is happy, indeed, who is so fortunate as to hit on any thing truly new; though we are fully aware, that there is abundant scope for taste and talent in this delightful research.

4. It has also been supposed that a knowledge of geometry, and particularly of that portion of it which treats of the description of curved lines, is of great use to the cabinet-maker; but, with the exception of a knowledge of perspective, and of a few simple methods of drawing common curves, geometry is of little use to him; and, when it is studied too closely, it leads to a harsh and mechanical mode of designing.

The best advice we can give the cabinet-maker, in acquiring a graceful, easy, and free method of drawing, is, to draw as much from nature, or from good casts, as possible. It is not of material consequence whether vegetable or animal forms be drawn, but a mixture of both is desirable, as they have very distinct characters, which will be easily traced in attempting to delineate them.

GENERAL PRINCIPLES OF DESIGN FOR CABINET-FURNITURE.

5. We have already shown that furniture is to associate with the forms of human figures, and to be adapted to their use; but it is equally obvious that furniture should be capable of arranging and uniting in harmony with the more geometrical forms of architecture. Consequently, in furniture, the rounded forms of the human figure should be combined with the straight lines and angular forms of architectural structures to such a degree, that the two may blend and unite with each other.

Of Outline or Contour.

6. The outline of the figure of a piece of furniture is generally much limited by the circumstance of its being fit for its use; but, that form which renders it so being arranged, the novelty of the design will depend chiefly on the change that can be introduced in the outline, without rendering it less fit for its object.

In the disposal of this outline, as much variety of general form should be obtained as possible, but carefully avoid breaking it into small parts of similar forms.

The change of form in the outline should be bold in proportion to the size of the piece of furniture, and those small variations which do not interfere with the general form should be grouped in masses, and not regularly scattered along the outline. The object to be attended to is the production of variety, and to produce this variety proper intervals of plain space are essential; for continuous ornament always produces sameness.

7. In Design, the central or principal part of the object requires most notice. The other parts should be so far subordinate to it as not to distract the attention from the centre; and, yet they should be so united in harmony with it, as to be obviously essential to complete the design.

The connection between the principal and the inferior portions of the design should be preserved by the continuance of some of the leading lines of the principal part to the inferior ones; and, whether these lines be straight or curved, they should never be so far interrupted by ornament as to render it doubtful whether or not they are continued; and, as the idea of firmness or stability is a necessary accompaniment of good taste in the design of furniture, the leading lines of the principal part of the design should descend in such a manner to the base as to give an idea of firmness, as far as the nature of the thing requires it.

Firmness does not always suppose massiveness; for what a pleasing idea of firmness is conveyed by the simple, light, and elegant tripod of the ancients. The pillar of a table branching into three or four claws is another example of firmness, where the continuity of the principal lines, or of direct branches from them, to the base exist as supports. Indeed, firmness of standing is a species of fitness which cannot be departed from without giving offence to the eye of taste, while it is most gratifying to find it combined with lightness.

Relative Proportion of Parts of Furniture.

8. Proportion should be considered as it regards fitness; as it regards the magnitude of one part compared with another; and also, as it regards the quantity of ornament on one part compared with another.

9. In speaking of magnitude, it must always be understood that the relation of magnitudes, in design, we always consider to be measured by the extent of surface exposed to the eye, and as this is different in the same objects placed in different positions, as to height, it is obvious that the actual position in which the figure is to be placed in respect to the eye, must always be taken into consideration in making the design.

10. Proportion, as far as it depends on *fitness*, is chiefly arranged by experience; those parts which give strength and firmness should be equal to their office; but, they seldom will bear much excess of strength without producing clumsiness; and the only exceptions are, when large rooms require a corresponding massiveness in the furniture. On the other hand, slightness, or, as we would express it, *want of firmness*, should never be apparent in good furniture.

The proportions which render furniture convenient is another portion of the study of fitness, which supposes an extensive experience, as well as a knowledge of the various changes due to the fashions of the times.

11. Proportion, as it depends on the relative *magnitude of parts*, is, sometimes, wholly left to the good taste of the designer; and, when cases occur where it is within his power, one part in a design must form the principal object, and ought not to have a rival in magnitude; also, when the piece of furniture is seen in its best position, this principal part should be as near the centre of the whole as possible.

The principal part of a design should be sufficiently prominent for the eye to pass from it to the whole, or the reverse, without perceiving the change of magnitude to be abrupt; and the same remark applies to the relation of the subordinate parts of the design to the principal one.

If this attention be given to the proportion of the parts so that the eye may pass from the consideration of one to another, and not feel the change abrupt, the design will be pleasing.

If too small a proportion be assigned to the principal part, the design will be flat and unmeaning. If the proportion be too large, the whole will be absorbed in the part, as a modern mansion is not unfrequently all portico. A due proportion of the principal part to the whole gives boldness and propriety.

12. The proportions of parts are always most agreeable when they bear an obvious relation to one another, as 1 is to 2, 1 to 3, 2 to 3, &c. &c., till the numbers expressing the relation suppose the greater part to be divided into more than 4, for then the relations cease to be apparent to an ordinary eye. Also, when the subordinate parts of a whole, or the minor divisions of a part, or an ornament, have a less obvious relation than 4 to 1, the contrast is too great.

The cause of objects appearing most beautiful when there exist some simple and obvious relations among their parts, is probably derived from the pleasure felt in contemplating those relations; whereas, when all parts are of equal magnitude the effect is monotonous, and the pleasure which would be produced by variety, as well as that which would arise from harmonious proportion of parts, is lost.

13. When the magnitude of any part is fixed by fitness for its purpose, and so that it is not in good proportion with the other parts of the design, its apparent bulk may be reduced by division of its surface into parts by pannels, mouldings, ornaments, or a combination of these means, while the subordinate parts should not be broken by division into parts of corresponding smallness. This, and other artifices of a similar kind, are required at times to obtain pleasing combinations, but, in general, that which is most fit for the purpose it is designed for is also most beautiful.

14. Proportion, as it depends on the relative *quantity of ornament*, is a most important part of design, and attention to it is a distinguishing mark of good taste. Ornamented surfaces require the relief of contrast with the plain ones, and it is obvious that were ornamented surfaces alone employed, the object would want contrast, and that quality which in painting is termed repose.

Richness is produced by introducing as much ornament as the object will bear, without destroying the relation between the plain and ornamental parts; a design, overcharged with ornament, becomes frittered, and wants both variety and repose.

The opposite quality to richness is meagreness, or a deficiency of ornament; and want of attention to its proportions. Between the extremes of overcharging and meagreness, an immense variety of degrees of combination of ornamented with plain surfaces may be selected.

When the ornament consists of moulded work only, the piece of furniture is termed plain; but, in rich furniture, the combined effect of moulded and carved work is necessary. In either species, the proportions of the ornamental and plain parts to each other should be regulated by like principles as the magnitude of the parts. These principles we have illustrated in *art.* 11 and 12.

Selection of Ornaments for Furniture.

15. In this the Cabinet-maker is not, and ought not, to be negligent of the beauties of vegetable nature; indeed, in some instances, we find works which abound with imitations of them, and so admirably adapted to the purposes to which they are applied, that they are viewed by the artist, not as copies, but as original inventions. The Greeks, who studied combinations of form with the greatest care, adopted, as prototypes for ornament, those ligneous plants which best permitted an arrangement of graceful lines, and which they could use as a medium for connecting one part of the design with another, or for leading the eye of the spectator by the course most advantageous to the general design. In Carving these, they observed the same principle of relief, and of light and shade, that is so beautifully exemplified in their compositions where the human figure was employed.

16. In selecting ornament from vegetable nature, the Greeks usually chose those where the stem prevailed over the quantity of foliage; whereas, in Roman decorations, the stem was made subservient to its luxuriant burden. The Roman examples of ornament show how capable their artists were of using these means of decoration most amply, though not always without seeming to overcharge the object which they intended to ornament.

17. Our own country also affords some fine specimens of a peculiar style of ornament, in the carved work of those cathedrals and churches which are usually said to be of pure Gothic, but, with more propriety, of English Architecture. In these we find the parts of plants, and chiefly the leaves moulded into graceful forms to ornament, connect, or terminate parts, as the pleasure of the artist, or the nature of the primitive form of the work rendered necessary. The plants of the neighbouring woods furnished the prototypes; and from these the artist selected parts and forms adapted to his purpose, selecting those which could be combined with effect, and yet not otherwise than as the natural plants might have been trained to grasp and ornament a solid mass formed to receive them.

In preference they seem to have chosen the stem, leaves, and acorns of the British oak; and, next in predominance, we find those of the graceful vine;—also the trefoil, and various other plants, more or less adapted for their objects. The cathedrals of Westminster, York, Litchfield, Winchester, &c.; and the churches of Southwell, Sefton, &c., afford various specimens, many of them carved in oak with singular spirit and beauty.

18. The introduction of animal forms, in furniture, is common, and in conformity with the example of the Greeks, and in a few instances it has been done by the old English carvers. But, high as we esteem these authorities, and beautiful as we acknowledge the forms of the Dolphin, the Serpent, &c., to be, we hesitate in admitting that such forms may be employed with propriety in the design of furniture; and still less are we inclined to allow that the human figure should, in any state, form a part of such designs. We ground our opinion on the fact, that a living animal cannot be so employed, neither are they adapted to such purposes; and imitative forms cease to be pleasing when we cannot imagine them to exist in the state they are represented. Our opinion may be considered as formed on too refined a view of the subject, but we only express it for the reader's assistance, in forming his opinions and practice, and leave him to be guided by his own judgment.

19. In speaking of these different styles of ornament, we have already mentioned the principles which ought to be kept in view in the addition of ornament; and we have only to repeat that, in the use of natural forms, they should be such as are not inconsistent with nature, modelled by art. The fantastic and chimerical combinations of the old German style of ornament may be instanced as the very reverse of the chaste and natural species which is now sought after by people of good taste; and we are happy to observe that this corrupt German style is now nearly obsolete even among Upholsterer's carvers.

Combination of Coloured Woods, Metals, &c. for Furniture.

20. Sometimes richness of effect is no further attempted than is obtained by the natural beauty of the wood which is employed; and when this natural beauty is considerable, this simple kind of furniture is most highly valued.

But wood, so fine in colour and figure, as alone to give richness of effect to furniture, is very rare, and still more frequently defective; hence, the more usual mode of combining different coloured woods, or of metals and shells with woods, require some degree of attention. The prevailing combinations are formed by coloured bands, lines, and ornaments of wood, or by lines, beads, or ornaments of brass; the brass being in many instances cut into beautiful forms, and further embellished by engraved lines on its surface.

The circumstances to be attended to in forming these combinations, are, harmony of colour, due proportion of the coloured parts to one another, and relief by contrast.

21. Contrast is produced by opposition in colour, and it should not be more powerful than is necessary to produce an agreeable distinctness of figure. For example, the contrast of bandings should not be too strong for the body of the work to which the banding is joined; as, in that case, the beauty of the wood would be partly lost, in consequence of the eye being most attracted to the banding. Strength of contrast is produced both by opposition of colour, and opposition in the strength of the natural figure of the woods.

Where a richly-figured ground is to be extended to a larger size by a border, contrast may be gained by the joint effect of a difference of colour and of figure, but in this case we prefer that the difference in colour should be only in shade, and not of a different species; for instance, a darker or lighter variety of the same wood with a stronger figure; the separating lines should be of an opposite colour, but so narrow as only to determine the boundary between the border and the centre, about as distinctly as the form of an object is determined by a line on paper.

22. As opposite colours produce contrast, some explanation of a mode of knowing the colours which are directly opposed to each other, will be of use to the artist.

All the various colours in nature may be produced by combining the three primitive colours, *red*, *yellow*, and *blue*: if a circle be drawn, and divided into six equal triangular parts by straight lines from the centre, and one triangle be coloured yellow, the next to it green, the third blue, the fourth purple, the fifth red, and the sixth orange; then, the colours which are opposite one another in the circle, are most opposite in their nature; as orange is opposite to blue, purple to yellow, and red to green.

If the three primitive colours be properly chosen, it will be found that the yellow and blue being mixed, they produce the green between them; the blue and red being mixed, they produce the purple; and the red and yellow, being mixed, produce the orange; and, by varying the proportions in the mixtures, an immense variety of tints may be produced. Again, if any two colours which are opposite in the circle be mixed, the result will be a brown or neutral tint; thus, purple and yellow make brown, red and green make brown, and orange and blue make brown, and the neutral colour brown combines with indifference with any of the others. (See *plate II, Cabinet-Making.*)

23. Those colours which are opposite in the circle produce contrast, and those which are nearest to being side by side approach nearest to harmony. Contrast, however, must always be sparingly introduced, and in small lines or bands, and when it is properly managed, it enlivens the appearance of the work, while a little excess of contrast renders the effect florid, and the excess pushed a small degree further renders the object gaudy and vulgar.

The theory of the combination of colours may also be illustrated by drawing an equilateral triangle, and from each of its angles describe an arc of a circle, with a radius equal to two-thirds of one of its sides; by this means the area of the triangle is divided into seven parts; and, if the centre be brown, and the angular parts of the primitive colours, and the other three of the compound colours, the opposite colours in the triangle will be of opposite natures as in the circle before described. (See *plate II, Cabinet-Making.*)

The advantage of a clear idea of the relations of colours, is not only of use in the combination of woods in cabinet-work, but also in upholstery, and, indeed, in all works where the object is to produce richness of effect by colours.

Referring again to the circular diagram, the agreement of our principles with the maxims of painters may be easily shown; for they divide colours into two classes, warm and cold, and one side of our circle has the warm colours yellow, orange, and red, and the opposite the cold colours green, blue, and purple; the warmest colour is orange, and it is opposed to the coldest or blue.

24. The maxim of Dufresnoy—

"Forbid two hostile colours close to meet,
And win with middle tints their union sweet,"

may be attended to with much advantage, in cases where it becomes desirable to use coloured woods which have opposite colours; as the object may be attained by band lines, or ornament between them, having the colours of the middle tints in the circle between the opposing colours.

25. We shall close our remarks on combination of colours with a few general maxims. Much depends on the colour of the principal mass of the piece of work, which we call the predominating colour. If this colour be rich, very little variety of other colours should be added. On the contrary, if the predominating colour be light and delicate, it will bear to be enlivened and supported by contrast with fine lines or borders of an opposing colour; taking care that the mass of opposing colours be so small as not to produce opposition instead of contrast; for contrast, skilfully managed, gives force and lustre to the ground, while opposition destroys even its natural beauty.

CHAPTER II.

OF THE STYLES OF FURNISHING.

26. The styles of furnishing ought obviously to be of a similar character to the architecture of the interior of the buildings, and, it scarcely need be added, that, at least, a similarity of character should be preserved in the same room.

This, then, leads us to consider the nature of different styles, with a view to distinguish their peculiarities; and determine the latitude we may take in their application.

In our researches to ascertain these points, we have been astonished to find that there was so little attention paid to the design of furniture before our own times. Indeed, before the appearance of Mr. Thomas Hope's splendid work, on *Household Furniture*, it appears to have been considered a subject scarcely susceptible of improvement from the application of the principles of taste and design;—happily, however, it has now assumed a more exalted character, and is not esteemed unworthy of occupying the attention of people of taste and fashion.

27. The prevailing species of furniture at present adopted in this country, is of a style which associates well with either Grecian or Roman Architecture. It has, however, more affinity to the mixed elements of the Roman than to the pure and simple elements of the Greek. But, as a few years changes the character of the prevailing style, we must endeavour to separate the distinguishing features of the different styles, commencing with that of the Greeks.

Greek Style of Furniture.

28. THE articles of household furniture among the Greeks were far from being numerous; they consisted chiefly of beds, foot-stools, chairs, couches, tables, tripods, and vases; and of these we have only such knowledge as can be collected from vases, medals, &c. These had been partially collected by Winkelman, Count Caylus, and others; which, with some scattered notices of particular objects by Stuart, &c., formed all that was known on the subject. It still remained to seize the characteristic features of these isolated fragments, and to embody them into a general system of design, and this was done by Mr. Hope.

We have already stated in what their furniture consisted, and we now shall endeavour to give the peculiar character of each article.

29. The seats of the Greeks were adapted for one, or for more persons; those for more than one were obviously seats for conversation; and often in the form of a half-circle, so that the persons conversing might be more or less opposite one another. These seats were generally furnished with foot-stools. Those for single persons have generally very simple and elegant forms, remarkably adapted for combining with the contour of the human figure, (see *art.* 3); while others are stiff, massive, and ornamented with heads, legs, and paws of animals. It is singular that the specimens we have just noticed, as extremely simple and chaste, very much resemble the Egyptian ones collected by Denon and Winkelman; and that the use of the foot-stool seems to have been common in both places; perhaps, in consequence of the little attention they paid to their floors, either as to construction or cleanliness. But we ought, at the same time, to remark, that the foot-stool seems to have been a regular mark of distinction belonging to dignified persons.

30. The custom of eating in a half-reclined posture seems to have been introduced into Greece about six centuries before the Christian Era; the couches for that purpose were of different forms, and the legs often highly ornamented. The plan of the couch was sometimes three sides of a square, sometimes half a circle; and it was, in general, divided into three parts; the centre one being the place of honour, and the master of the house took the one to the right of the centre one. The table was placed so as to be surrounded on three sides by the couch, and the other side was open to those who served the repast. The tables used for the purpose, seem to have been very plain.

31. The tripod, or stand, for supporting the species of brazier used for warming their apartments, was generally of a very elegant form; sometimes it was plain, and essentially composed of three legs supporting a ring to receive the brazier; but, not unfrequently, these legs were composed of an incongruous assemblage of heads, paws, and legs of animals.

32. But the most abundant and most ornamental part of Greek furniture was their vases. Of these there appears to have been three classes: those for domestic use; those for ornament; and those for containing the ashes of their dead.

The class we here call ornamental is so termed only in consequence of our want of knowledge of any uses to which these vases may have been applied; and the beauty of their forms and ornaments indicate that whatever use was made of them, they were also designed to please the eye. Here again we have to remark the singular circumstance that the prototypes of these vases were most certainly of Egyptian origin; at least such is our opinion, arising out of a comparison of the forms collected in Egypt by Denon with those of the Greek vases.

33. Their customs and conveniencies of life being so different from ours, we have, in designing furniture to accord with Greek architecture, nothing to limit the artist besides the general principles of design, except attention to their species and style of ornament. Their absurd mixtures of the parts of animals we would recommend the artist to avoid, and indeed to avoid such forms altogether. But their beautiful mouldings composed of varied curves with flat portions, to give breadth of middle shade, and contrast to the small deep-cut rectangular mouldings which accompany them;—their principle, of giving depth of shade by depth of sinking in preference to making considerable projections;—and, in a word, their chaste simplicity of design, and judicious admixture of bold and simple ornament, we cannot too strongly press on the attention of the artist.

Roman Style of Furnishing.

34. The remains of Roman furniture discovered among the ruins of Herculaneum and Pompeii, and the imperfect descriptions their authors have given, are almost the only sources from whence we have any information respecting the style of furnishing adopted by the ancient Romans. But these inform us that it did not materially differ from that of the Greeks.

The custom of dining in a reclined posture was introduced among the Romans about the time of the second Punic war, but it never became general, and was evidently considered a luxurious and immodest innovation.

The conversation-seats of the Greeks seem to have been imitated, and also their tripods for braziers, as well as their tripods for religious ceremonies. Of the tables of the Romans, some were sustained by a single pillar, with a flat base or pedestal; others by a pillar with a base, supported by three or four low turned feet; others with three or four legs, these legs not unfrequently standing on a flat base, and sometimes on a flat base raised a little either on turned feet or paws of animals.

The most splendid articles of Roman decoration seem to have been their candelabra; of these it appears there were two kinds: one used for supporting lamps, the other for supporting fire, or lights, in religious ceremonies. The candelabrum was sometimes six feet in height.

35. The general character of the ornament of Roman furniture was considerably inferior to that of the Greeks; it was more confused, wanted proportion of the parts to the whole, and chimerical figures were employed in greater abundance, and combined with less taste. The ornaments from the vegetable kingdom have been selected with less care, and often disposed in garlands and festoons; and these are artificial arrangements of the productions of nature which must ever fail to harmonize with solid matter.

The mouldings of the Romans are composed solely of rectangular and circular forms, combined in various ways;—shade and relief are obtained by projection, and the under-cutting and deep-cut channels of the Greeks do not seem to have been, in any case, a subject of imitation, their mouldings are also more divided into small parts.

These peculiarities render the Roman articles of furniture, in some degree, formal and mechanical; and here we use the term mechanical to express the absence of that knowledge of the principles of art which is requisite to the perfection of design.

*Old English Furniture.**

36. For this division of our subject, there remains very little to guide the taste of the artist in the selection of furniture that shall be appropriate for a mansion in the purest and best

* Commonly styled Gothic furniture.

style of Old English Architecture; for, before houses sufficiently commodious and adapted to the reception of a splendid assortment of furniture had been erected, the decline of taste in cathedral-architecture had manifestly taken place in England.

37. The old English house-architecture, which is now so much imitated, was formed during this decline, and seems to be the result of a mixture of the rectangular cathedral style, with the semblance of castle-architecture. Parts of such houses unite well with a picturesque landscape, and, in the hands of an artist, may be turned to account in producing "pretty bits" of composition; which, not unfrequently, tempt people to fix on having their residences in this style. It was introduced during the reign of Elizabeth, and it has been justly remarked, that the taste of that time is easily recognized by an affectation of elegance, amid an ostentatious parade of puerile ornament and fantastic decoration. A strange mixture of the emblems of religion, with armorial bearings and mythological figures, was not uncommonly introduced in the same design. The style of the whole being harsh, formal, and vulgar.

Rectilinear parts, either turned to resemble an assemblage of balls, or flat and ornamented with carving, having very little relief, were most predominant in this style of furnishing.

38. But, from want of examples, no peculiar features may be said to limit the application of the principles of design followed by the old English to furniture beyond the obvious one, that nothing inconsistent with their mode of designing should be adopted.

The continuity of the principal vertical lines, or parts, crowned with finials, should be preserved instead of the horizontal ones, and yet, buttresses, and arches, and battlements, should be sparingly introduced, if at all, it being directly contrary to good taste to imitate the external features of a building in its furniture.

39. It is too common for people to imagine that to make furniture in the old English style, nothing more is necessary than to use pointed arches, and clustered columns; and even these are generally executed in a barbarous style. Neither of these, however, are essential, and the clustered columns can rarely be used with propriety in small works.

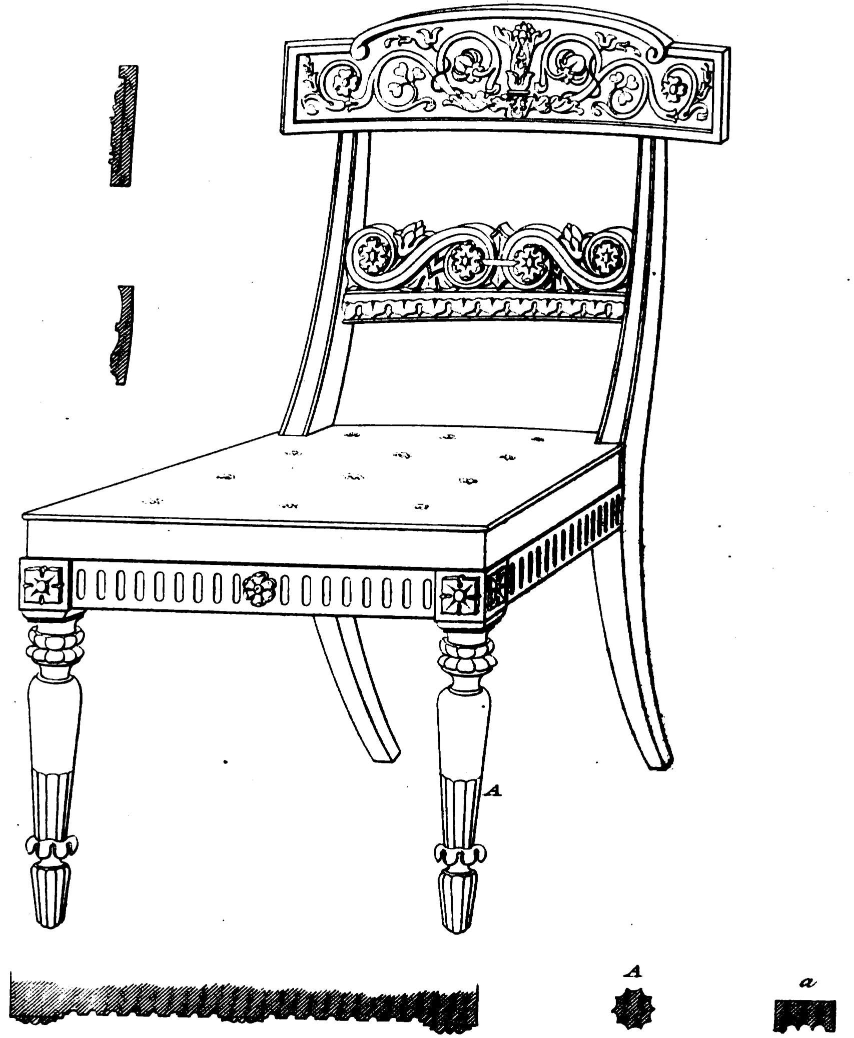
It is in the peculiar mouldings and the ornaments that the features of the style must be sought; and the best knowledge of these will be gathered from the internal screens, niches, canopies, pews, seats, and monuments, of ancient Cathedrals and Churches.

The mouldings of this style are bold, and remarkable for their strong contrast of light and shade; their sectional curves are very frequently of contrary flexure, and their flat parts rarely at right-angles to one another. Their ornaments are often set in dots in a moulding designed to receive them. When finials are not incompatible with fitness, the principal lines should either simply, or joined, terminate in such ornaments.

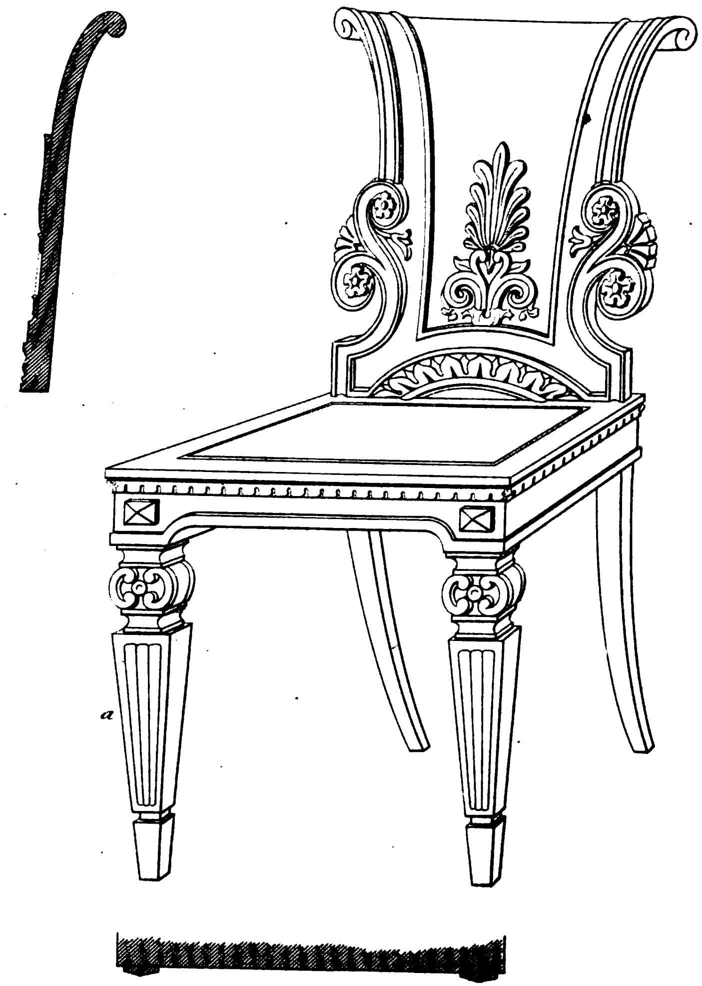
Tracery is one of the peculiar characteristics of this style, but in its imitation the modern artist rarely succeeds from want of attention to the beauty of form, and proportion of the works, of our forefathers. Acute angles and harsh intersecting circles are used where oblique surfaces and easy varying curves ought to be employed.

There is a wide scope for novelty in this style, and if ever it be taken up by a person of good taste, who is perfectly familiar with the habitudes of the ancient artists, we may expect it to predominate among people of fashion; but such furniture cannot become common, so long as Greek and Roman architecture are so prevalent.

LIBRARY CHAIR.



HALL CHAIR.



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London. Published by Thos. Kelly, 17, Paternoster Row. Jany. 2. 1836.

E. Turrell sc.

CHAPTER III.

OF THE DIFFERENT KINDS OF FURNITURE.

40. In furnishing, the first thing which calls for attention is the right appropriation of furniture to its object; and in this a considerable degree of variety, and consequently pleasure, is afforded to the visitant and inhabitants of a mansion; for, with every change of occupation, a corresponding variation is met with in the furniture.

Of the Furniture of Entrance-Halls, Saloons, Galleries, Anti-Rooms, &c.

41. In rooms of this class, we are to remember that they are used only as places of passage being, at the most, only used for waiting, or while examining the works of art they contain. Hence, in addition to sculpture or paintings, the furniture should be confined to a suitable number of marble tables, with massive carved or plain frames, and a convenient number of seats and chairs, of simple and elegant forms, such as will bear strict examination, and yet not be attractive from colour; for these rooms ought to produce their impression by architectural effect, or through the works of art they contain, either of which would be diminished by rich and attractive furniture.

In the entrance-hall, marble side-tables, as temporary places for putting any thing down, are very convenient and necessary.

The chairs of the entrance-hall usually bear the crest of the owner. Hall chairs are generally executed in oak, owing to the dullness and heaviness of the colour of mahogany; the seats being of the same wood as the rest of the chairs, of whatever kind of wood they are made.

42. We give an example of a richly-carved Hall Chair in *plate I, Cabinet-making*. It may be easily reduced to a plainer species by omission and alteration of the ornament. The scrolls may terminate in flat round pateras instead of roses, and much of the ornament may be omitted; so that, in fact, a plain simple chair may be formed from this design, though one of the richest that need be used for this purpose.

In Staircases, Galleries, and Anti-rooms, seats are more appropriate than chairs; they should be designed for one, two, or three persons. Narrow tables, supported by scroll-brackets springing from a plinth, and fixed to the walls, form neat and useful appendages, and there should always be such a quantity of furniture of this description as to fully stock the rooms, without rendering them so full as to be inconvenient. The Entrance-Hall is a room where paintings are out of place, but sculpture, armour, and the like, may be effectually employed as means of preventing the walls appearing bare.

43. Rooms for games, such as billiards, &c., should have furniture of a little plainer kind than that of the hall; and whatever ornaments them should have some analogy to the use made of the rooms.

Of the Furniture for Drawing-Rooms, Music-Rooms, Libraries, &c.

44. These are esteemed the principal apartments in a mansion, and require a corresponding attention to the mode of furnishing.

To produce good effect, the furniture should be abundant in quantity, and of the best quality. It should be arranged symmetrically, but yet so as to admit of as much variety as possible. These general remarks being made, we may proceed to treat of the separate species of rooms.

45. The Drawing-Rooms are the chief apartments of a house; they are devoted to the reception of formal visits, and to receive company. In the Drawing-Rooms company assemble before dinner, and also after dinner is over; they should, therefore, be well furnished, and with such articles as are adapted for display of taste and for amusement.

The furniture of a Drawing-room consists of tables, sofas, seats, chairs, footstools, commodes, pier-tables, candelabra, fire-screens, bronzes, and vases. Large glasses are frequently placed over the chimney-piece and pier-tables, with splendid frames; and the walls are further ornamented by appropriate paintings, none of which, however, should be large, otherwise they cause the room to appear small.

The tables, sofas, &c., are disposed so as to occupy much of the central part of the room, and, when well-proportioned and disposed, they increase its apparent magnitude considerably. Tables are made of rich-figured British oak, rose-wood, choice mahogany, and a few other fine foreign woods are sometimes employed; the tops are often inlaid with brass and other ornamental borders of the kind, shown in *plate VI, Cabinet-making.*

Beautiful Mosaic tables are also sometimes added as pieces of drawing-room furniture, and with good effect.

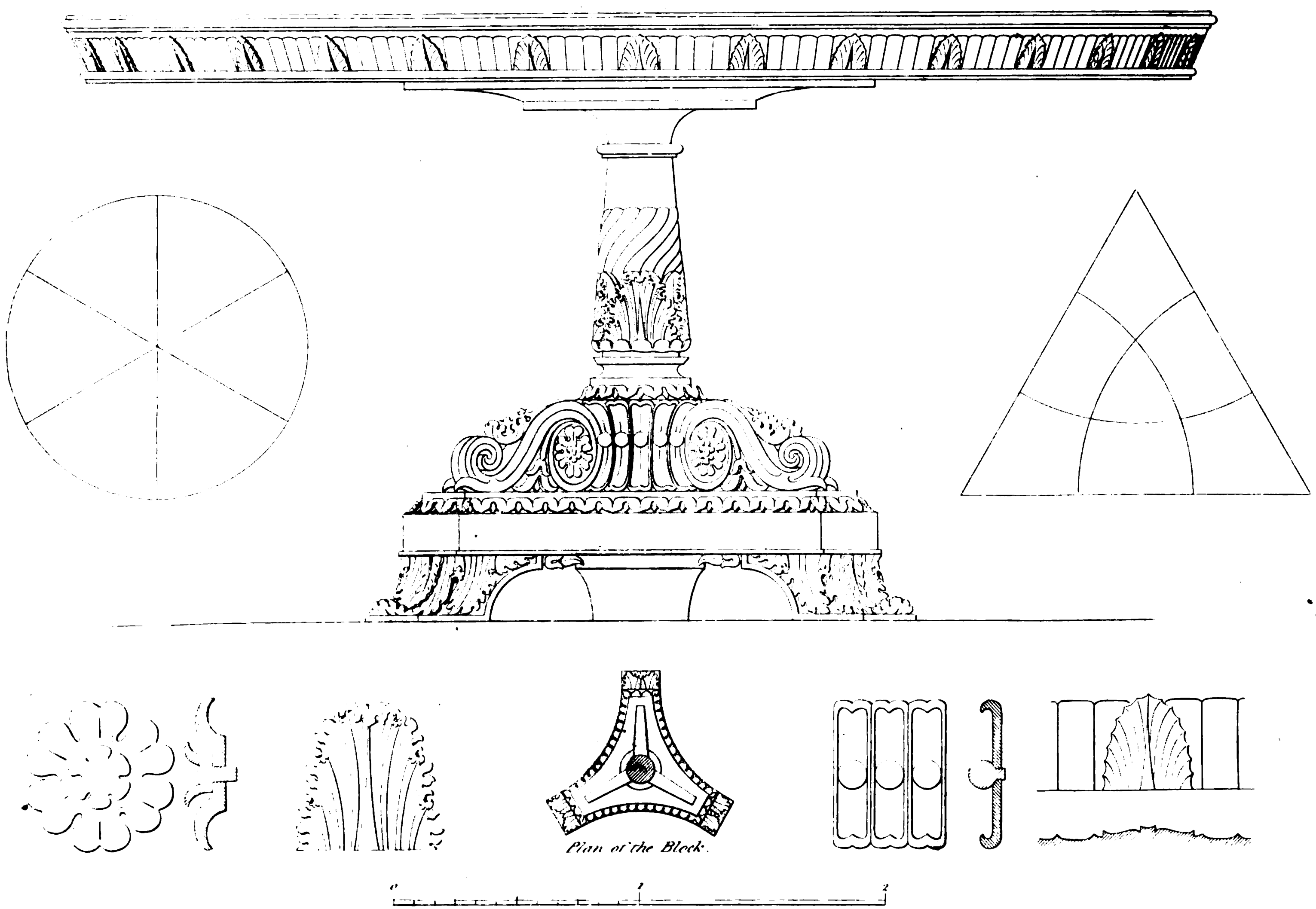
A design for a *Loo-Table* for a drawing-room is given in *plate II, Cabinet-making;* and in *plate III* will be found a design for a *Drawing-room Chair,* made in conformity with the present taste. The Couches and Sofas should be made to correspond with the chairs.

The expression of the *tout ensemble* of a drawing-room should be more gay than grave; hence, the predominating colours should be rather light and delicate, with a considerable proportion of gilding. We have already treated of the management of colours, so as to avoid the tawdry theatrical style which may arise out of an attempt to give an expression of gaiety. (See *art. 23.*)

46. A library is that portion of a dwelling-house which is appropriated to receive books, prints, maps, and other things affording intellectual information or amusement. It is also not unfrequently used for receiving the visits of intimate friends.

A library requires less ornament than a drawing-room, but the difference should not be very marked between them. In our opinion, the difference should chiefly consist in the one being splendid and lively, the other sober and rich; each capable of exciting admiration, but by qualities, in some degree, opposed to each other. If our judgement be correct in this respect, these characters may be easily obtained by attention to the predominating colours of the rooms, and to the relief of the gay one by judicious contrast. The first object to be considered in a library is the arrangement of the book-cases, and these are done in different manners. Some are made in one height from the plinth to the cornice; others in two heights, the top of the

LOO TABLE.



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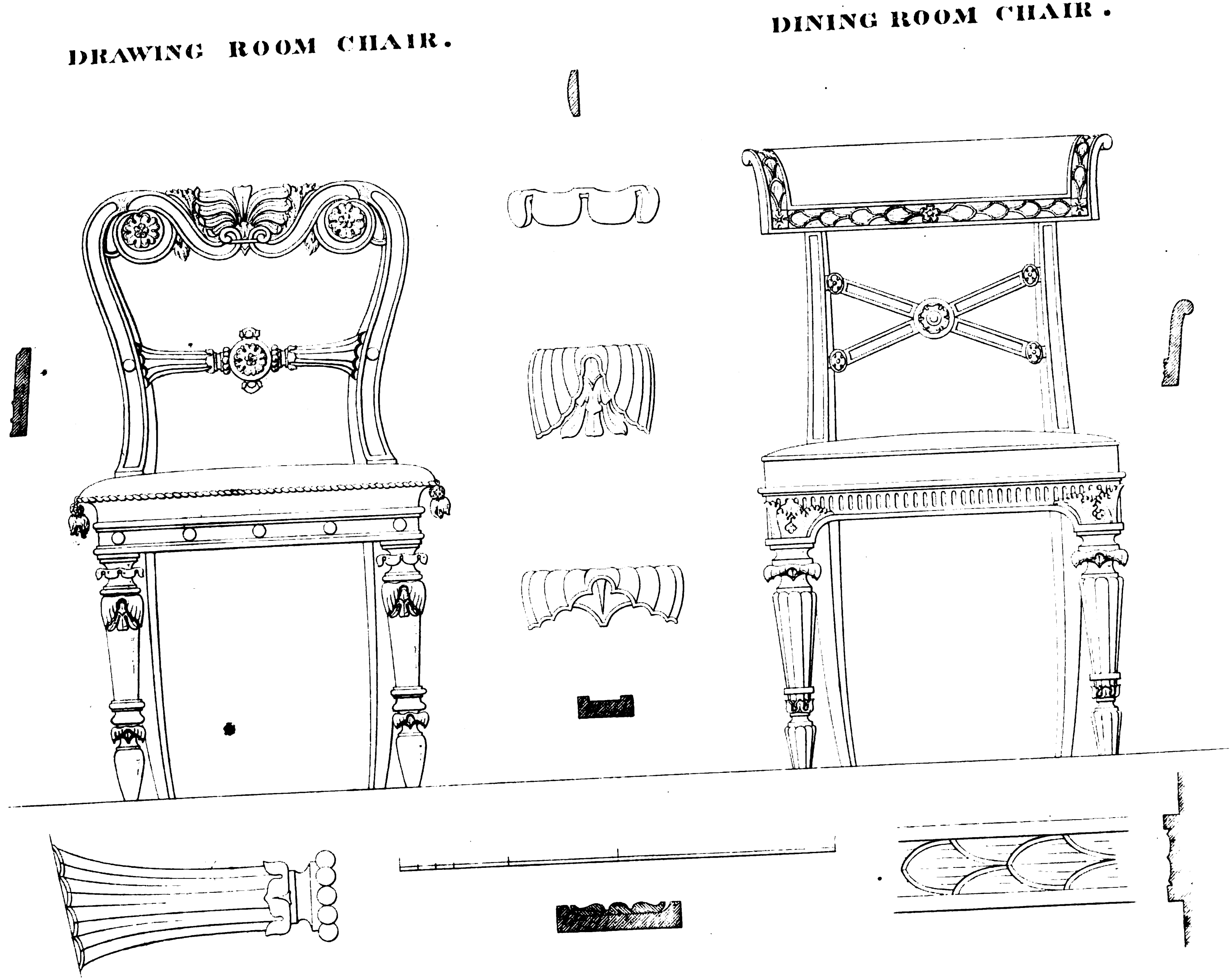

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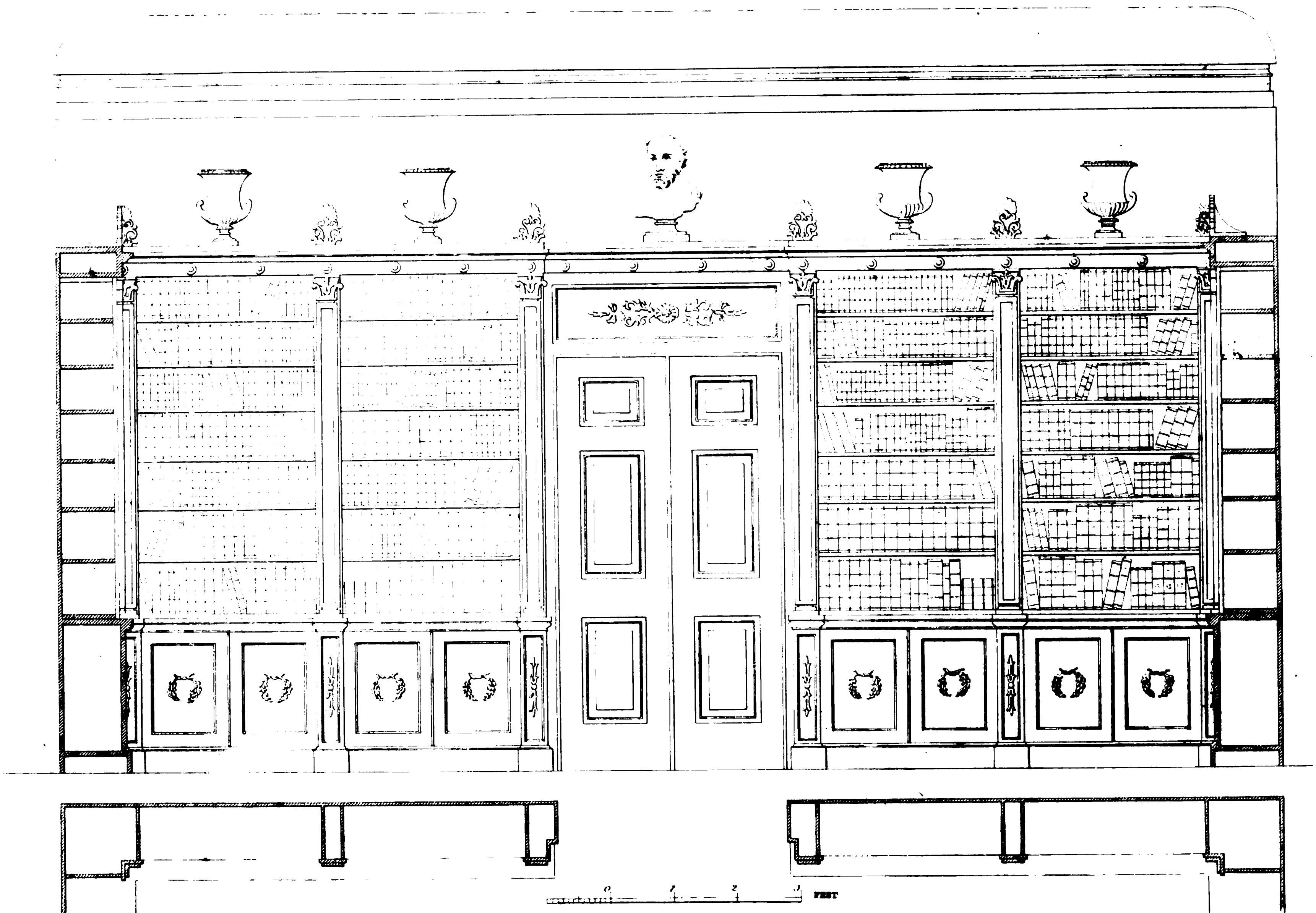
LIBRARY BOOKCASES.



Designed by H. Whitaker.

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lower one corresponding with the surbase of the room, and projecting before the upper one so as to hold deeper books, as well as to form a shelf to put books upon occasionally, in adjusting or returning the volumes to their places.

47. In illustration of this subject, we have given the design of the *Door-End of a Library* fitted with book-cases in the style last described, (see *plate IV, Cabinet-making*.) In this design the shelves are rendered of a proper length, by dividing the book-cases into parts by pilasters. The lower part has doors, but sometimes these are omitted. The cornice is continued over the room-door, so as to connect the design; busts of eminent men, and sometimes ornamental vases, are placed on the top; and, when the height of the room admits of it, the space above the book-cases is appropriated to portraits.

Book-cases are generally of oak, inlaid with dark brown oak, or black, and with carved roses and other ornaments; but sometimes rose-wood is used with brass and gilded ornaments, and inlaid with brass.

In public libraries, and others of considerable height, the book-cases are made in two heights, with a gallery for the upper part, supported on handsome brackets, and provided with an ornamental railing.

48. The shelves of book-cases are usually moulded on the edge; and not unfrequently the edge is made a flat round, with a brass bead put in along the middle.

The shelves are made to rest on racks, or on round pins of hard wood, of about half an inch in diameter, inserted in the end about three-eighths of an inch, and projecting as much; half that portion of the pin which projects being cut away, and the other half let into the underside of the shelf, each shelf resting on four such pins.

Instead of wooden pins, we sometimes use square-headed brass pins, the holes for them being made in narrow brass plates, and the square part, or head, is let into the under-side of the shelf, each shelf resting on four of these as before, the pin part is about one-fourth of an inch in diameter.

49. The distribution of the shelves should be according to the sizes of books, and the racks, or holes for the pins, should be adjusted so as to alter to any of the usual sizes. It is usual to provide for four species of books; viz.—Folio, Quarto, Octavo, and Twelves, of which the extreme sizes are—

Large folio,	19	inches high, and	13	inches wide.
Small folio,	15	do.	11½	do.
Large quarto,	13	do.	10	do.
Small quarto,	10½	do.	8	do.
Large octavo,	18	do.	6½	do.
Small octavo,	9	do.	5½	do.
Twelves,	7½	do.	4½	do.

The lower range should always be deep enough for the largest folios; and the upper ones for the largest quartos.

50. The central part of a library should be furnished with tables, chairs, sofas or couches, writing-tables, reading-desks, globes, and apparata of a similar nature. Library steps are sometimes required, but it is much better to design the book-cases so that the books can be taken down without steps, avoiding, at once, the trouble and danger of them.

A design for a *Library Chair* is shown in *plate I. Cabinet-making*, in which our designer has endeavoured to preserve the essential character of the library when contrasted with the lightness and elegance of the Drawing-room Chair in *plate III*. In Library Tables convenience should be as much studied as ornament. They are usually provided with drawers, places for port-folios, &c.

51. When a Library is intended occasionally to be used as a drawing-room, it should be of a mixt kind, partaking of the principal features of both rooms. And either through the increasing partiality of ladies to literature, or the decreasing taste of gentlemen for severe study, the fashion of making drawing-rooms into libraries, or libraries into drawing-rooms, has become not unfrequent.

52. Of Music Rooms, we have merely to remark, that the splendour of the Drawing-room should be imitated, but with sufficient distinction to form, with the peculiar object of the room, a decided variety. Emblems of music introduced in the ornament are appropriate, and the forms of antique instruments may be occasionally used with good effect; the Hamilton Vases afford, perhaps, some of the best examples for imitation. If antique masks be in any place appropriate for ornament, it is in rooms for music; and the fine composition of some of these almost inclines us to say they might be used, or if not, at least they might be studied as examples of composition in ornament.

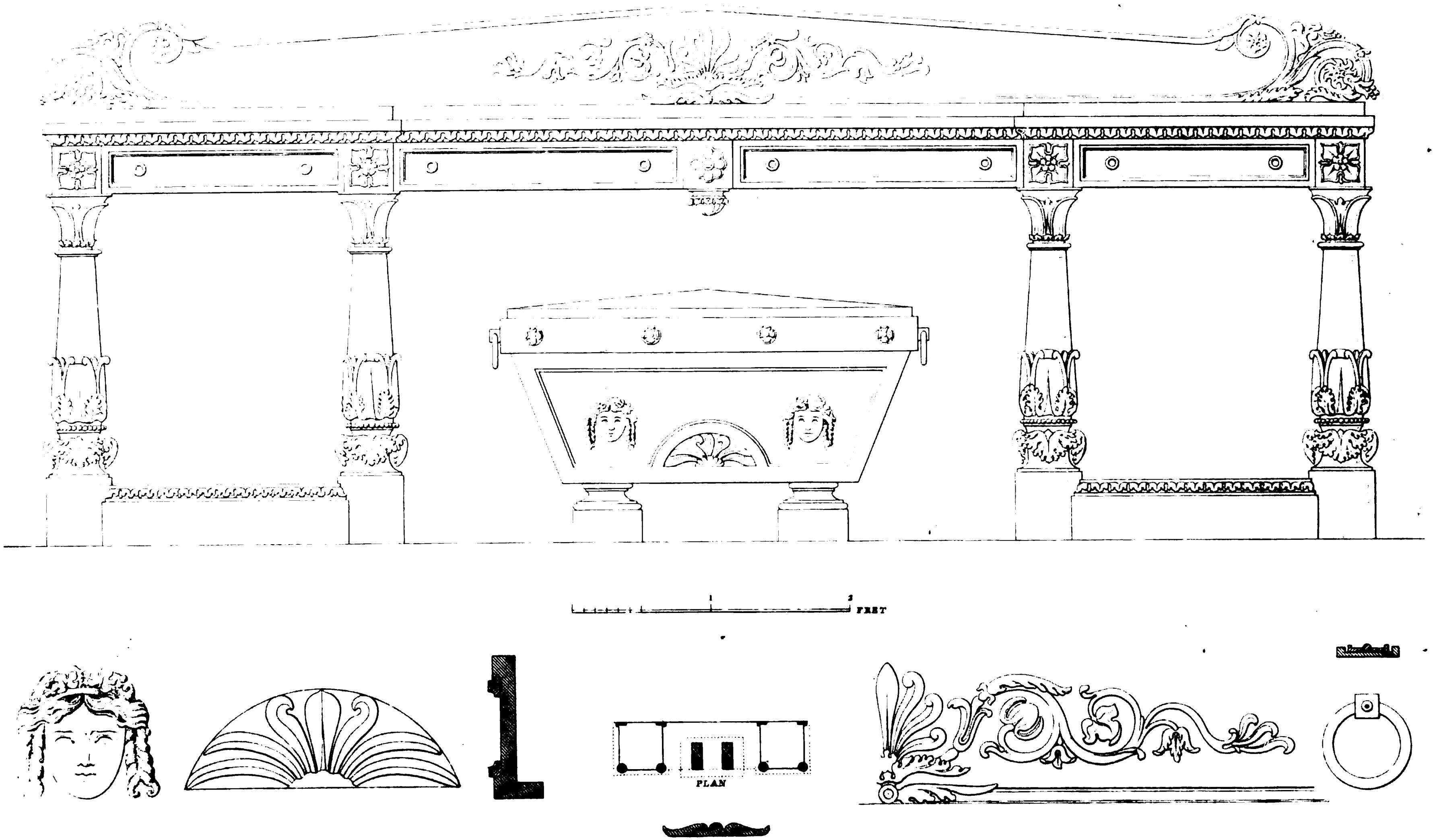
Of the Furniture for Eating-Rooms.

53. The rooms devoted to the entertainment of company should be furnished with a view to answer that purpose with the best possible effect. The intention of the rooms should be apparent, and they should contain nothing calculated to divide the attention of the guest from the hospitable board of his entertainer. A few plain portraits are always sufficient to relieve the walls, and may sometimes serve also to relieve the mind of a guest, who is yet *tout honteux* either from youth or want of education. But sometimes the walls are so ornamented with pictures, we might imagine that the table had been set out in a picture-gallery, lest the pleasures of the table and the mind of the host should be incompetent to banish dulness for the short season devoted to refreshment; besides showing a total want of reliance on the company invited.

54. In the Dining Room, therefore, all should be consistent with the object of the apartment. The chief furniture should be a sideboard, with its adjuncts, and dining-tables, chairs, side-tables, waiters, &c.

55. The richest piece of furniture in the room should be the *side-board*, and, having to contrast with plate, it should have a species of richness which looks well alone, and yet shows the service of plate to the best advantage. Brass-work and gilding, or or-moulu, destroys the effect of plate in a considerable degree, and therefore we would avoid such modes of ornament; and depend on the natural effect of beautiful wood-work, with carved ornaments, and highly polished; the handles being of bronze, or ebony. Variety may be obtained by sometimes using bronze ornaments in the place of carved ones. The choice of the wood must depend on the style of furnishing, if it be old English, oak should have the preference; while oak, unless it be of a rich brown tint and considerably figured, does not seem so strictly applicable to other styles of furnishing.

SIDEBOARD AND CELLARET.



Designed by H. Whitaker

London, Published by Thos. Kelly 17 Paternoster Row, Jan. 2. 1836.

E. Turrell sc.

The usual height of the top of a sideboard is 37 inches, its width from 30 to 33 inches, and length from 5 to 10 feet, according to the size of the room. The *cellaret*, or wine-cooler, is most convenient when separate, and is generally placed under the centre of the side-board when not in use. The smallest size should be formed to hold 9 bottles, and for larger rooms the length may be increased so as to receive 12, and for very large rooms 15 bottles, the depth should not be less than 13 inches. The clear space for each bottle is usually $3\frac{1}{4}$ inches square.

56. A Design for a *Side-board* and *Cellaret*, according to the prevailing fashion, is shown in *plate V, Cabinet-making;* with the most difficult parts to a larger scale on the lower portion of the plate. When the reader wishes to examine the effect of the side-board, it will be found an advantage to cover the detail ornaments on the plate with a piece of plain paper, and the same plan may be adopted for the other cases of a like kind, and, also, when there are two designs on the same plate.

57. *Dining Tables* are of various kinds, but may be divided into two classes: first, those with frames and legs; secondly, those with pillars and claws: each kind has its peculiar advantages.

Tables with legs have the advantages of being steady, easily extended or contracted by means of frames which occupy very little space, and of being less expensive than other kinds.

Tables with pillars and claws are esteemed more elegant; and they are free from the objection of the legs rendering some of the seats at table incommodious.

The best mode of making the tables with legs seems to be, to form the frame in two parts with sliders between them, part of the sliders having legs. When the parts are drawn asunder, one or more loose leaves are inserted between the fixed beds, till the table be of the proper size for the number to dine, and then they are secured by forked fastenings.

When the size of the table is proposed to be altered considerably, additional legs to screw-in may be necessary, but it should be the object of the artist to make the trouble of changing as small as possible. Tables intended to draw out to a larger size should always be on castors.

In some instances, a place for the loose leaves is provided in the frame, but a case for them under a side-table, or in an adjoining waiting-room, is better. This kind of dining-table was called patent, but the patent-right in it, as well as the following kind, has now expired.

Tables, on pillars and claws, are made capable of enlargement by adding the drawing parts to extend between the blocks of two or three of these tables, so as to allow of one or two leaves being inserted between two adjoining blocks; the leaves and beds are then connected by forked fastenings. The loose leaves of these tables cannot be conveniently put in the frame when they are not wanted.

The height of a Dining-table should not exceed $28\frac{1}{2}$ inches, and we think 28 inches a better height; the breadth of the table may be from 4 to 6 feet, according to the size of the room, and the length should be such as to allow *two feet* for each person at the sides of the table; when a less space is allowed than two feet, the table becomes crowded, and the removal of the courses difficult for the servants, and troublesome to the company.

The wood of dining-tables should be of an even, hard, and uniform quality, and it should be equally figured over the whole table, with a small, in preference to a large, figure. Strongly-veined woods should be particularly avoided, and particular attention should be paid to the colour and polish.

The object of these remarks is to make the table show to the best advantage when the dessert-course is upon it; and we never observed one look well on a light-coloured, or a strongly-veined, nor on an ill-polished, table. Perhaps, the best wood for the purpose is good Spanish mahogany.

58. *Dining-room Chairs* should correspond with the general character of the room; so far as the cabinet-maker is concerned, the effect should be dependant on the joint effect of carving and the natural beauty of the wood employed. Dining-room chairs should be easy, and substantial without heaviness; they should not be larger than is necessary to accord with the size of the room, and may vary from 17 to 19 inches in the front, according as the room is a small or a large one. The height of the seat should not exceed 18 inches, and the top about 34 inches.

A Design for a *Dining-room Chair* is shown in *plate III, Cabinet-making;* where our designer has conveyed our ideas on this subject with considerable taste and accuracy.

59. A separate Breakfast Room is not unusual in large houses, and it is generally a species of family room, where convenience and elegance should be substituted for formality and grandeur. The arrangement of such a room must be more dependant on the taste and habits of the owner than any other, and therefore it would be difficult to assist the cabinet-maker further than may be derived from an attention to the object of the room.

Of the Furniture of Sleeping and Dressing Rooms.

30. In rooms for these objects it is scarcely necessary to remark, that neatness, convenience, and comfort, should be their distinguishing characters. Superfluity in furniture, in such rooms, becomes a real evil by diminishing their space, and preventing that free change of air which is so conducive to health. We may further remark, that there should be a preference given to such simple forms of furniture, and modes of construction, as render the essential operations of cleaning most easily performed, and therefore less liable to neglect.

The wood employed for the furniture of sleeping-rooms should be sound and perfect; and, if of a compact close grain, and yet not liable to the worm, so much the better. If defective parts be used, they ought to be carefully filled up even with the surface with hard stopping; and a like method may be adopted with the cracks of furniture already in use. (See Chap. V.)

The expression of rooms devoted to sleeping and dressing should, in our opinion, be rather sober and grave, than of the opposite cast, but equally avoiding gloominess and glare. The mild gray tints of the morn precede the meridian splendour of day; and hence, in sleeping-rooms, and the like, we would advise the use of neutral tints, and avoid bright and light colours; and also the use of contrast.

61. In *Bed Rooms*, the cabinet-maker has to furnish bedsteads, dressing-tables, drawers, washing-stands, dressing-glasses, clothes-horses, night conveniences, and various other small articles, most of them so well known as not to need more description.

62. In *Dressing Rooms* more scope for taste is required. The furniture should consist of a dressing-table, drawers, wardrobe, writing-table, or secretary and book-case, cabinets, sofas, chairs, stools, &c.

We have thus endeavoured to inform the artist of those circumstances which are most important in the arrangement of a well-furnished house, and must now proceed to treat of the construction of furniture.

CHAPTER IV.

OF THE CONSTRUCTION OF FURNITURE.

63. In this portion of our work we intend to give such notices of methods of executing work as are most likely to be useful to the young workman.

Methods of Framing.

64. Framing, in cabinet-making, requires the same precautions as framing in Joinery, (see *Practical Joinery, art.* 24—43,) when it is applied to form large surfaces, such as the tops of billiard-tables, the doors of wardrobes, and the like. For, owing to shrinkage, and warping of wood, large even surfaces can be formed only by means of pannelling.

The width of the style of a frame should be about one-sixth or one-seventh of the whole width of a compartment of the frame; we prefer one-sixth, and think less renders the effect poor; the tenons should be one-fourth of the thickness of the framing, and the width of a tenon not more than five times its thickness.

65. But, where surfaces of considerable width are to be formed without an appearance of framing, whether those surfaces are to be veneered or not, we should avoid framing them with other pieces where the grain of the wood is in the contrary direction, for the difference of the shrinkage of the two ways of the wood is so considerable, that it can scarcely be expected to stand without either warping or splitting when confined. Where warping is to be prevented, we strongly recommend that holes should be bored through, and strong iron wires inserted, at short distances apart, across the piece. These would act as clamps in preventing warping, and, at the same time, would not be affected by the shrinkage in width.

66. Angles are framed in various ways, depending chiefly on the object of the work. External angles of mouldings and pilasters are either simply mitred, or rebated, or both rebated and mitred together, as in *fig.* 1 to 4, *plate VII.*; and *fig.* 5 shows another method. Internal angles are generally grooved together, as *fig.* 6 and 7, with the outer edges mitred. Where the front edge only is to be mitred, a dovetail groove is made, and rather narrower at the back than at the front, so that the tongue tightens as it is driven in.

When a strong firm connection is wanted, and the wood is to be joined end to end, dovetailing is to be preferred; see *fig.* 8, where AB is the part having the pins, and CD that with the dovetails. When the dovetails are not to appear, they may be formed as shown in *fig.* 9, which is called *lap-dovetailing;* and, when the dovetails are cut through, it becomes the kind used to join the angle between the front and end of a drawer. When a joint is to appear as if it were mitred, the method of *dovetailing* employed is called *mitre-dovetailing,* and is shown in *fig.* 10. The apparent edges are in this case always mitred to a depth of about an eighth of an inch. *Fig.* 11 shows the method of joining by *keys*; the parts being neatly mitred, then saw-kerfs are to be made for the slips of wood called keys, which are to be inserted with glue when the joint is put together.

67. Drawers are always dove-tailed together, but are made variously in other respects; small drawers for cabinets, secretaries, and the like, are made by ploughing grooves in their sides, or ends to receive the bottom; sometimes the groove is a half-dovetailed one. Rebating in the bottoms is objectionable, because the drawer-bottom frequently loosens and scrapes against the partition on which it runs; but in those inserted with a dovetail-groove, which is made with a plane, the bottom is secured from sinking down, and is kept about a sixteenth of an inch clear of the partition. We, however, think a plane-groove, with narrow longitudinal slips glued into the angle between the side and the under side of the bottom, is better than a dovetail-groove; and large drawers are generally done in the same manner. When a drawer is of considerable length, a grooved-muntin is often used to divide the bottom into two lengths, so that thinner and lighter bottoms may serve. Drawers made of unseasoned wood, break at the joints: to prevent this, slips are sometimes glued on the inside of drawer-sides or ends, and these are grooved to receive the bottom, and the upper edge rounded; this is esteemed the best method for preventing drawer-bottoms from splitting, which sometimes happens when they are confined by a slip glued down to the under-side.

68. In framing chair-work, and the like, the tenons should always be in the direction of the grain of the wood, and the mortises made obliquely to receive them. This is easily done by supporting the piece to be mortised on a proper saddle, so that the chisel may enter in a vertical direction.

Great care must be taken in mortising, that the mortise may not be wider at the bottom than at the entrance; and that the tenon be not smaller at the point than at the shoulder, as its firmness in the mortise depends on attention to these circumstances; we have found it an advantage where much fitting was required to ease the entrance of the mortise slightly with a float previous to fitting together.

The mortises should be well glued when the parts are put together; and, in applying the cramp to force the joints close, let the direction of its action be in the direction of the tenons, otherwise, either immediately or afterwards, failure may be the consequence of its pressure being oblique.

69. The mode of finding the bevels for framing, in cabinet or chair-work, is so exceedingly simple, that it seems unnecessary to mention it, unless it be for the assistance of youth. To find the bevels for chair-rails: on a plain piece of thin deal, or drawing-board, the front edge being straight, draw a line perpendicular to it; then, if the front of the chair is to be 17 inches, and the back 14, 3 inches being the difference, take half of it, or 1½ inches, and along the edge of the board set off that distance from the line. Also set off, on the line, the distance from the front to the back, which suppose to be 14 inches, then draw a line from this point to the point on the edge 1½ inches distant from the first line, and it will be the bevel required; and, by setting off the size of the front leg, the length of the rail is found. If the rails be curved, the inner-sides may be made straight to apply the bevel; or a template may be made adapted to the curve. Usually, however, curved forms are obtained by glueing additional parts to straight rails after the tenons are formed.

Before we quit the subject of framing, it may be useful to state, that the beauty of work of this kind greatly depends on the forms of the parts being agreeable and easy; if they be graceful so much the better, and to obtain the power of making graceful curves, and scrolls, we refer the reader to the advice we have already given in *art.* 4. It has been remarked, that a difference is observable when chairs or sofas are made from the same patterns by different workmen, and chiefly from want of taste in the beauty of outline; but the difference which appears when dif ferent people attempt to execute the same design is much greater, and sometimes almost inconceivable; the one making it a clumsy, ill-formed caricature; the other embodying, in solid forms, the real conception of the designer; and this can be done only by one already, in some degree, acquainted with the art of design, and possessed of a correct eye for beautiful forms.

We have seen attempts to supply a deficiency of taste by geometrical rules, but, unfortunately for these learned and formal gentlemen who made the attempt, they cannot produce a complex outline, without having to patch it out of curves differently generated; and they know very well that such curves cannot be joined to produce agreeable forms. The best machine for producing curvilinear forms is the *hand, trained by practice to obey the eye, and move in easy graceful lines.* Practice in drawing on a large scale soon improves both the eye and the hand; while every mechanical substitute for practice ought to be avoided. It was justly remarked by Hogarth, "that Albert Durer, who drew mathematically, never so much as deviated into grace, which he must sometimes have done in drawing from life, if he had not been fettered by his own impracticable rules of proportion." The cabinet-maker, by this time, feels that his art is more nearly allied to painting than to mathematics; and we trust a second reference to our remarks in *art.* 2, concerning the adaptation of furniture to the beautiful forms of the human figure, will confirm him in this opinion.

Of Veneering, Banding, &c.

70. VENEERING is the art of laying down with glue a very thin piece of wood, of a fine quality, called a veneer, upon common wood. Veneers are laid either by means of a tool called a veneering-hammer, or by cauls.

In veneering with the hammer, the ground should be warmed at the fire, and the outside of the veneer being wetted with warm water, or thin glue, with a sponge, and the side to be laid covered with a coat of thin glue, and warmed at a fire, the veneer is to be quickly laid on the ground and worked by the hammer, and commencing at one end, work from the middle to each side till neither air nor glue will come out.

The object of veneering is cheapness, by saving beautiful wood; otherwise it would have no advantage, for the ground, glue, and extra time, are fully equivalent to the expense of plain solid wood. Veneering with the hammer answers very well, when veneers are tolerably straight and even; but this is rarely the case with finely-figured woods, hence it is necessary to employ another method called veneering with a caul.

71. A Caul is made out of solid wood, shaped to the surface to be veneered, and, being well heated, and afterwards oiled and greased, it is screwed down upon the veneer, and by the pressure and its heat sends out the glue, causing the veneer to bed close to the ground. For curved surfaces, sometimes thin wainscot is used for cauls, and, by heat, made to bend to the crooked surface. In general, cauls of one-inch deal, keyed across to keep them straight with wainscot, are used for card-table tops.

Various opinions are held regarding the use of cauls, but where the veneer is of a nature to admit of being laid by the hammer, we would prefer it.

If a caul be employed, the veneer must necessarily be rendered of a very uniform thickness; or, wherever there is a thin place the glue will collect, and, consequently, the veneer be imperfectly laid, and liable to blister. In order to heat the cauls regularly and sufficiently, a large hot-plate is employed by some cabinet-makers. A hot-plate consists of a thick plate of cast-iron, with a furnace-fire below it. One heated by steam is more safe, and not liable to over-heat; and we may add, that steam-pipes are extremely well adapted for drying, and for warming work-shops, in consequence of their safety against fire. On this subject, Mr. Tredgold, in his treatise on Warming and Ventilating Buildings, remarks, that, "in the manufacture of various articles made of wood, it is desirable that the work-rooms should be dry, and sustained at a moderate heat in winter, about equal to that of dwelling-rooms; but it is not good either for the health of the workmen, or for the articles made, that the temperature should be higher; and steam is certainly the safest mode of heating such places, besides having advantages in heating glue, drying wood, and laying veneers, which cannot be easily obtained by other methods."

72. Whether veneers be laid with the hammer, or by cauls, the superfluous glue and the air must be driven out, and the veneer prevented from rising in parts, where it had warped in seasoning; much, however, of the trouble which crooked veneers occasion might be avoided by having them kept straight from the time of cutting till they be wanted. Veneered work should never be suffered to dry very quickly.

When veneers are to be joined without showing a joint, the line of joining should follow the grain of the wood, in some vein which may be easily imitated by stopping. This method cannot be applied in many cases, on account of the size of the veneer rendering it difficult to match the parts in such a manner as to appear as one piece of wood. If the match cannot be made, joinings, in some regular manner, do better; as, for example, to meet in the centre of a table, pannel, or other piece of work.

73. Banding is a term applied to a narrow strip of veneer used as a border, or part of a border, either to a large veneer, or to solid wood; in the latter case, a rebate is sunk for the banding. Banding is of three kinds: it is called *Straight-banding* when the wood is cut lengthwise of the grain; *Cross-banding* when the wood is cut across the grain; and *Feather-banding*, when cut at an angle between the two. The latter kind is not often used, nor does it produce a good effect.

Between the banding and the central part, one or more lines are generally inserted, and sometimes a narrower band. The chief object of banding is to increase the beauty of a plane surface by forming a species of border to it; and it requires considerable skill to give the desired effect. In considering the *Combination of Coloured Woods*, we have already given the principles which ought to be understood in applying banding. (See *art.* 20—25.)

The joints of Banding should be as well matched as possible, both in respect to colour and grain; and, excepting the mitre-joints, it is an advantage to make the joints at the veins of the wood.

Of Inlaying, Buhl-Work, &c.

74. Inlaying, in cabinet-work, was formerly much in use; but it was executed in a tasteless gaudy style, which led to its being neglected. It is also an expensive mode of ornamenting furniture, and, when not well done, it is subject to speedy decay: it has lately been revived in a more chaste and correct style.

The art of inlaying with woods, metals, and shells, is very old; it is said to have been brought from the East by the Romans with their Asiatic spoils. It was practised in Italy with considerable skill in the 15th Century. John of Verona, a painter, and contemporary of the celebrated Raphael, was the first who introduced the use of dyed-woods, and may be considered the founder of the taste for imitating natural objects in coloured woods. His followers improved on his methods by adding the art of browning wood by heat, so as to obtain graduating shades of different intensities.

Towards the middle of the 17th Century, the art of Inlaying was carried to great perfection in France, and many very able artists appeared about that time: of these, the famous Buhl, or Boule, was the most distinguished; and so numerous and excellent were his works, that it is not uncommon to ascribe to him alone the perfection of the art; indeed, such work is familiarly known here by the name of *Buhl-work.*

The art declined in France for want of encouragement; and, in England, it was never successfully cultivated till within the last ten years, when it was revived here in very good taste, the object being to form ornamental patterns, borders, &c., instead of barbarous and, at best, gaudy imitations of fruit, flowers, birds, animals, and landscapes, in materials so imperfectly adapted for such purposes.

75. In this art the part for the ornament, and that for the ground, are glued together, and the design being drawn upon one, both are at once cut through by a very fine species of bow-saw. Thus, there are four parts obtained, which, being put together in two, the one is the ornament designed in its proper ground; and the remainder of the ground, combined with the remainder of the ornament, gives another pattern called the *reverse.*

76. The plates of brass or other metal should be of the usual thickness of a veneer, or as thin as can be conveniently worked, and made rough on both sides with a coarse file, or toothing-plane. The veneers of wood or other matter to be combined with them should also be toothed; and, both the plates and veneers being warmed, first pass a coat of glue over one of the metal plates and cover it with a thin sheet of paper, then coat the paper with glue, and cover it with the veneer. Place them between two smooth and even boards, and let them be kept together either by a screw-press, or by hand-screws, and remain till dry; they will then be found to adhere together with sufficient firmness for cutting to the pattern.

77. The pattern should be drawn on the veneer, or if, from the colour, it should not be sufficiently distinct, a piece of paper may be pasted on the veneer, and after it is dry the design may be drawn upon it. The lines of the pattern should be cut with a bow-saw, having a very thin and narrow blade; such a saw may be made of part of a watch-spring, and the bow, or the stretcher, of the saw, is required to be at such a distance from the blade as will admit the latter to turn and follow the lines of the pattern in any direction. The frame of the saw should be as light as possible. Where the pattern does not in any place approach the edge, a small hole must be made for inserting the saw; and it is usual to saw upwards, that mode of sawing rendering it more easy to follow the lines correctly. When the whole of the pattern is cut out, the veneer or shell may be separated from the metal by exposing them to steam, or to warm water.

78. The next object is to join the parts so as to produce two complete ornaments; the one composed of veneer inlaid with metal, the other of metal inlaid with veneer. For this purpose, on a plain surface, place a piece of paper of sufficient size, and the veneer upon it, then with strong glue insert the metal-part in the veneer, and rub it well down with the veneering-hammer and glue; next, cover the whole with another piece of paper, and place it between two plain boards, which had been previously well warmed and rubbed with tallow, and screw or press them together. If this be properly done, the work will separate from the boards when dry; and, the paper being removed, it may be laid in its place as a veneer; but a caul is usually employed in preference to the hammer, (see *art.* 71.) The reverse pattern, it is obvious, should be prepared for laying in the same manner.

79. The process is the same whether metal and wood, or metal and tortoise-shell, or two woods of different colours be used. When shell is employed, the under side of the shell is

sometimes coloured with some bright colour, as red, yellow, &c., mixed with varnish; and not unfrequently it is gilt. When the colour is dry, the veneer is laid with the coloured or gilt side down; and it produces a pretty effect through the transparent substance of the shell.

80. In order further to illustrate this interesting department of the art, we have given two designs for inlaid Borders in *plate VI, Cabinet-making*. The upper one is rich and full, and to give the proper effect the assistance of the graver will be necessary. The lines cut by the graver should be filled with melted mastich, coloured black or brown, to match the colour of the wood.

The lower figure, in *plate VI*, is less complex, and in a bolder and better style for use. In this, also, part of the effect must be obtained by the graver, and filling its cuts with coloured mastich.

81. The woods used for inlaying should be of a dense, close-grained texture, particularly when inlaid with metal.

Brass is much employed; and, in selecting it, some attention should be given to obtain that of a good colour; for, by varying the quantity of zinc in its composition, both its colour and quality is much affected.

The brown and yellow-brown coloured woods combine with either white or black; but, when the brown approaches to red, brass does better; and, in some cases, hard, close-grained satin-wood, of a good colour, might be substituted for brass with good effect, though not with equal brilliancy of relief. The parts of ornaments, in black or white, in any ground, should be kept small to avoid dull heaviness in the one, and too strong a glare of light-colour in the other.

82. We have no doubt that dyed woods may be used with considerable effect in inlaying, provided the error of introducing unnatural colours be avoided. It is a great mistake to imagine that a variegated patch-work of high coloured parts will ever be esteemed by people of good taste; but it is one equally great to suppose that there is any objection to the use of dye when it is applied under proper restrictions; that the beauty of work is indebted to dye must be concealed, and its use should be merely to imitate or improve the brilliancy of natural tints, so as to render beautiful furniture less expensive.

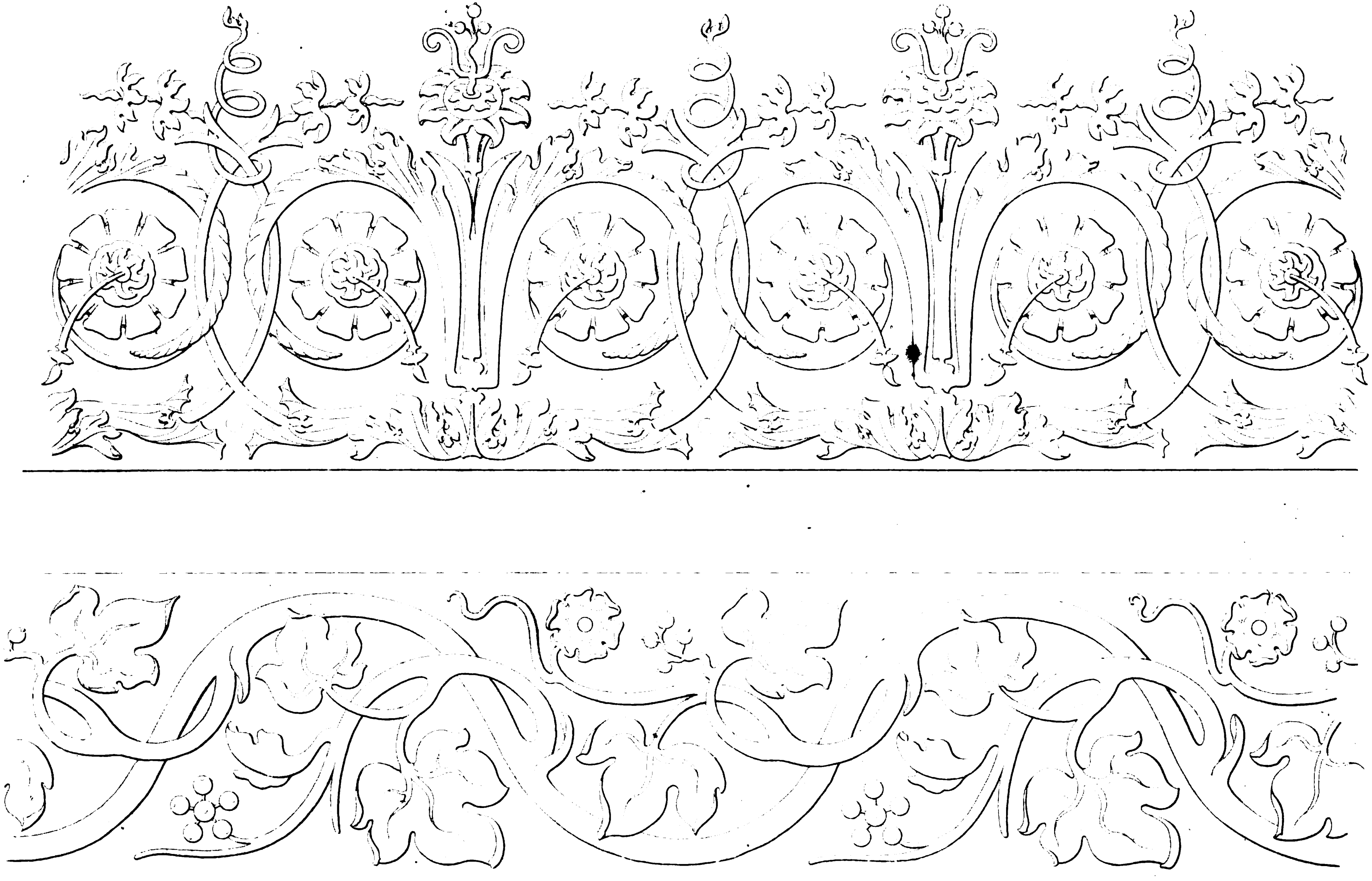
Of Carving, Reeding, &c.

83. The first subject that requires attention, in carving, is the quality of the wood. It ought to be perfectly seasoned, and free from cracks or faults, and as uniform in its texture as possible.

The first process is to form the object or ornament roughly, but in its true proportions; this is called *boasting*, and in this sense it is the principal ground-work of the art, and requires the skill of a master in carving.

84. The carver who is best skilled in drawing is, for the most part, employed in boasting, as he has the best idea of the quantity of projection that should be given to the respective parts, to accord with the design as exhibited on the plane surface of the paper. After making out the sketch, the carver has to shape the outline with saws or gouges, and then make out the prominences of each part when necessary or proper, by glueing on pieces of wood for that purpose. The roughly-formed pieces are fixed for carving, and, in some cases, this is done by glueing them to a board, with paper inserted between, to enable the carver to take the carving

BORDERS FOR INLAYING.



Designed by H. Whitaker.

London, Published by Thos. Kelly 17, Paternoster Row, Jany. 2 1835.

off with more ease when it is finished. When the work is properly fixed, the carver proceeds to place his gouges; and, by a judicious choice of such kinds only as will suit the turn of the parts in boasting, endeavours not to have more than he can use without confusion.

85. Next, the principal lines of the whole piece are formed, so as to be a sufficient guide in finishing; the work is then put into the hands of the finisher, who completes it by means of gouges and cutting-tools of various forms. In some cases, this division of work is not followed, but one carver begins and finishes the whole of a carving; but where there are a number of hands employed, and in pieces that require much skill, the other is much the best method.

86. In carving valuable species of wood, it is usual to contrive to put the ornament together in parts, and attention to this subject is necessary in the design of the ornament, so that the carver may avail himself of joining. The mode of forming the large roses for the scrolls of the Loo Table, *plate II,* and the leaves to go round the portion of the pillar, to which the scrolls join, will illustrate this principle. The central portion of the rose is inserted, and so are the balls in the leaves, and greater effect may often be obtained by this mode of combination, as well as more perfect workmanship, than by any other.

87. The most of the carved work in the designs in *plate I, II, III, and V,* is shown on an enlarged scale in separate figures, on the plates for the use of those who have not easy access to good specimens of ornament. The confusion that is occasioned by thus filling the plates with figures may be avoided in examining any one of the designs by covering the plate with a paper which has a rectangular opening cut in it large enough to show the object to be examined.

88. The union of carved and turned work has almost always a beautiful effect; but, in producing richness with the smallest degree of labour, the combination may be carried to a great extent.

When a patera is turned to a proper form, the carver, by a few simple operations, gives it the effect of a rose. Leaves may be formed round turned legs by the like simple means; and the species of effect thus produced is bold, chaste, and simple; and in our opinion vastly superior to the more minutely laboured works commonly produced by the carving tool.

89. Reeding is a species of ornament much used by cabinet-makers; and we think often with good effect in chair, and in all species of turned work. It is preferable to fluting or cabling in appearance, for it produces a bolder effect in small works than fluting. It has been remarked, that reeding is the only ornament that has escaped the notice of the ancients; but this is a mistake arising from its not being used by them in architecture, where it is decidedly inferior to fluting. When reeding is introduced, on flat surfaces, there ought always to be three, five, or seven, and so on, the odd one being in the centre. If reeds be on a table leg, or bed pillar, or the like, there should be a central reed in each front.

Moulding Ornaments, Figures, &c., in Imitation of Wood.

90. To avoid the expense of carving in wood, several attempts have been made to cast figures and ornaments to resemble wood. The most approved process we here present our readers. It was invented by M. Lenormand, and rewarded at the Exposition of French Products, in 1823.

Make a very clear glue with five parts of Flanders glue, and one part of isinglass, by dissolving the two kinds separately in a large quantity of water, and mix them together after they have been strained through a piece of fine linen, to separate the filth and heterogeneous parts which could not be dissolved. The quantity of water cannot be fixed, because all kinds of glue are not homogeneous, so that some require more and some less; but the proper degree of liquidity may be known by suffering the mixed glue to become perfectly cold, it must then barely form a jelly. If it happens that it is still liquid when cold, a little of the water must be evaporated by exposing the vessel in which it is contained to heat. On the other hand, if it has too much consistence, a little warm water must be added. The glue, thus prepared, is to be heated till you can scarcely endure your finger in it; by this operation a little water is evaporated, and the glue acquires more consistence. Then take raspings of wood, or saw-dust, sifted through a fine hair-sieve, and with the glue form it into a paste, which must be put into plaster or sulphur moulds, after they have been well rubbed over with linseed or nut-oil, in the same manner as when plaster is to be moulded. Care must be taken to press the parts into the mould with the hand, in order that the whole may acquire the perfect form: then cover it with an oiled board, place over it a weight, and suffer it in that manner to dry. The drying may be hastened a little, and rendered more complete, by a stove. When the casting is dry remove the rough parts, and if any inequalities remain behind they must be smoothed, and then the ornament may be affixed with glue to the article for which it is intended.

It may be varnished or polished in the usual manner. This operation is exceedingly easy; nothing is necessary but moulds, and, with a little art, the ornament may be infinitely varied.

91. When large articles or figures are made, a paste, similar to the former, should be made with very fine saw-dust, and place a stratum, of about three-sixteenths of an inch in thickness, on every part of the mould, after which it is left to dry almost entirely. In the mean time, paste of coarse saw-dust should be prepared with common glue, adding to it a sixth of isinglass. First, put together two parts of the mould, after introducing into the joints between them a thin stratum of the fine paste, made very clear, and applied with a small brush. Fill up the vacuity between the two pieces with coarse paste, and then apply the third piece as the second, and so on until the whole be adjusted, always filling up the vacuities with coarse paste. Set the whole to dry in the mould; in this way may be obtained a figure resembling solid wood, executed with all the delicacy of plaster figures. It is necessary to learn the art of determining the proper degree of drying, for if the figure be taken from the mould before it be properly dried, it will become warped, and if it be too dry, it cannot be corrected but with a file, which is tedious and laborious; whereas, if the proper moment be seized, the paste may be cut like wax; especially if the saw-dust used for the exterior has been fine. The figures may afterwards be completely dried in a stove, by which means they will acquire a degree of hardness and solidity hardly to be conceived. Figures, thus moulded, may be bronzed or varnished; they will then be unalterable by the effect of moisture or dryness.

For ornaments to be often repeated in the same work, for continued ornamented mouldings, and all similar purposes, a means of casting a direct imitation of wood is most valuable. A mould is easily procured from a modeller, at a small expense, and no further art is necessary than what we have detailed.

92. The species of ornament called COMPOSITION ORNAMENT, is used where the mass is not great, and the surface can be covered with gilding or paint, and is not exposed to wear. Sunk roses, and other ornaments, which are protected by projections or mouldings, may be done in this manner, and it may be successfully applied to all objects beyond the reach of accident.

The composition is formed by adding as much whiting to thin glue, as will render it of the consistence of glazier's putty, and pressing it into a mould which has been previously oiled with sweet oil. It may then be taken out and placed to dry; unless it is to be applied to a curved surface, as, in that case, it should be bent while soft to the proper form.

No more should be mixed than can be used before it becomes sensibly hard.

Composition ornaments should be well glued on, and, in some cases, they will require to be further secured by needle-points or brads.

Composition ornaments are chiefly used for picture and glass frames; we have also seen them employed for ornaments on the top of oak book-cases, and, when grained by a good painter, they answer as well as when carved in wood.

CHAPTER V.

OF FINISHING AND POLISHING FURNITURE.

93. FURNITURE is so much indebted to the finishing processes for its effect that we have classed them together, and treat of them under Cleaning, Stopping, Staining, Common Polishing, French Polishing, and Varnishing, with some remarks on the Management of old Furniture.

Cleaning off Wood-Work, &c.

94. The finishing the surface of wood-work is sometimes called polishing; but, to avoid using the same word in two senses, we shall apply the ordinary term of *cleaning off*. The mode of commencing this operation depends on whether it be a veneered or a solid surface that is to be cleaned off. In solid wood the surface is rendered as even as possible; first, by a finely-set smoothing-plane, and then by a steel scraper, to remove the marks of the plane. The surface is afterwards rubbed with glass-paper, finishing with the finest kind, so as to render the surface as smooth as possible.

If the wood should not be very compact, the surface thus obtained will become spongy and rough on being moistened with oil or other matter used for polishing. This roughness is what is termed the rising of the grain. To prevent this rising of the grain, as soon as the surface of the wood has been smoothed with glass-paper as before directed, let it be uniformly wetted with a wet sponge; and, on its being dry, rub it a second time with glass-paper till the surface has the proper degree of smoothness. Or, while it is wet, with a flat piece of fine pumice-stone rub in the direction of the grain of the wood, keeping the surface moist with water; then let the work dry. On wetting it again, the grain will be less raised, and the process of rubbing being repeated, the surface will be found more compact and smooth, and will bear a better polish.

The fineness and evenness of the pumice-stone should be particularly attended to; and in using it, rub it in the direction of its fibres. The use of dry pumice-stone in finishing is also attended with so much advantage, that we are surprised to find it so little used, particularly in the country.

95. In cleaning off veneers, after the glue has been removed from the surface, let it be toothed in a diagonal direction, and in proportion as the surface is rendered even, give the plane less hold; and, finally, use a plane with very fine teeth; then remove the tooth-marks with the scraper, and finish the surface with glass-paper, or pumice-stone and glass-paper. Veneers are scarcely ever of so soft and porous a nature as to require raising the grain.

96. When veneers are inlaid with brass, the brass should be filed level with a fine single-cut file, and next rubbed with pumice-stone; then take fine powdered tripoli, and mix it with linseed-oil, and by means of a piece of felt, or hat, rub the brass-work with it till the desired surface be produced. When the ground is of ebony, or dark rose-wood, the brass may be brought to a still better surface with very finely-powdered charcoal.

Of Stopping the Defects of Wood-Work.

97. When there are defects in wood, and they are most common in the finest figured woods, a stopping to imitate the colour of the wood must be inserted before the surface be finished. For hard wood, very fine saw-dust of the wood to be stopped, mixed with clear glue, and rubbed into the defective places, is by far the best species of stopping. When the surface is to be painted, whiting may be used to mix with glue instead of saw-dust of the wood. This mode of stopping is applied when the surface has been planed or scraped, so as to show where its defects are; and the stopping must be allowed to be thoroughly dry before it be attempted to finish it.

98. Defects are also frequently stopped with a composition called cement, made to imitate the colour of the wood at the place to be stopped. Such cements are composed by weight of one part of rosin, and four parts of bees'-wax, melted together, and one part of colouring matter is then added.

The colouring matter added to imitate mahogany is Indian red mixed with a small proportion of yellow ochre, which requires to be varied according to the colour of the wood. To imitate oak, yellow ochre and umber may be used in proportions according to its colour. The cement is melted and rubbed into the defective places, where it hardens on cooling. The objection to this kind of cement is, that it softens by heat; but, for various cases, where it is not liable to be exposed to heat, it is very convenient.

99. Another cement may be formed by grinding, in spirits of turpentine, the colours required to match the wood, to the consistence of a stiff paste; and then, slightly softening this paste with turpentine-varnish, stop the defects with it; in about a day, in a warm place, the turpentine evaporates and leaves the stopping very hard, and it has the advantage of not softening by heat.

Common work is usually stopped with glazier's putty, which is mixed with colour to imitate the wood. Painted work should not be stopped till it has been primed; and putty should never be applied where the defects are of considerable extent.

OF STAINING WOOD-WORK.

100. The term Staining is applied to the art of imitating rare or beautiful species of wood by dyeing the surface of some common wood, which is a like texture. It will be the most convenient to follow the arrangement of the species of imitation in use. Staining is chiefly employed for Chairs, Sofas, and Bedsteads; and the surface is afterwards polished or varnished as that of the natural wood.

Black Stain, or Imitation of Ebony.

101. First, form a stain of galls and logwood, in the proportion, by weight, of 12 parts of logwood to 2 parts of galls, and give the work one coat with this stain. Add one part of verdigris to the stain, and give the work another coat. Then add one part of sulphate of iron; and apply one or more coats as may be deemed necessary.

The woods most adapted for imitation of ebony are holly, pear-tree, and beech; and it is employed for chairs, mouldings, pateras, &c.

Brown veined Stain, or Imitation of Rose-Wood.

102. For the ground, make a stain by boiling 16 parts of logwood in 64 parts of water, till the liquor acquires a deep red colour. Then add one part of carbonate of potash, and apply the stain hot, letting the work become nearly dry between each coat, till a good rose-wood ground be formed; after which let it become quite dry.

To form the veins, heat the black stain above described, as used for the last coat, and with a graining-brush, such as is used by painters, make the dark veins on the work. The veins should be disposed to represent the dark parts of the natural wood with as much taste and skill as possible.

The process may be reversed, and the wood first stained black, and the light veins produced by the Dyers' solution of tin, applied by means of a graining-tool formed for the purpose.

The wood used for staining, in imitation of rose-wood, is chiefly beech; and chairs, sofas, and the like, are stained in this manner.

Brown Stains to Imitate Mahogany.

103. The surface may first be rubbed with a diluted solution of aqua-fortis; then one ounce of dragon's-blood being dissolved in a pint of spirit of wine by heat, and one-third of an ounce of carbonate of soda being added, the mixture is filtered, and afterwards laid on with a soft brush. On being done over a second time, the wood acquires the external appearance of mahogany.

104. The process is effected with less expense by rubbing the work with a diluted solution of aqua-fortis, and then exposing it to heat. Small articles it is sufficient to hold before the fire, but larger ones require to be placed in an oven, or covered with hot sand. The strength of the solution, and the degree of heat, are easily tried by a small specimen of wood of the kind to be stained; for different kinds require different treatment: we have found for beech that half water and half aqua-fortis is a good proportion; and the degree of heat best adapted for striking it in, about 300°, or a little below the heat of an oven for baking. The colour depends much on the colour of the wood it is used upon. Box-wood acquires a beautiful brown by this method.

105. A stain resembling dark mahogany is produced by archil, applied cold, but it speedily fades. It may be rendered more permanent by washing the work over with lime-water, and letting it dry previous to applying the stain. The stain may also be improved by brushing it over with a hot solution of potash. It may be of use to remark that all alkaline substances strengthen and restore vegetable purples; while all acids change them to reds, and render them more permanent.

106. A cheaper dark mahogany colour may be obtained, by staining the wood twice or thrice with a strong decoction of log-wood, applied hot, and then add a small portion of common soap to the stain, and give the work two coats, with the stain hot, after the soap has been added. Adding potash produces the same colour as soap, but the work does not polish so well. This stain is chiefly used on beech for bedsteads, and sometimes for chairs.

107. An imitation of mahogany may also be made by brushing the wood of the cherry-tree with lime-water; that is, water in which quick-lime has been dissolved. The lime that remains on the surface must be carefully brushed off, and the chairs oiled or polished in the ordinary manner.

108. The operation of staining is founded on similar principles to the art of dyeing, and we think both these arts are capable of great improvement. The greatest defect is the want of permanency of the colours. In all the processes of staining an attention to clean vessels, and soft-water, is necessary, to obtain clear bright colours. Previous to stain being applied, it is an advantage to brush the surfaces well to free them from dust, and if they be slightly washed with a sponge and clean water, and suffered to become nearly dry, they will take the stain much better than when perfectly dry, and the same remark, about the degree of dryness, applies to the repetition of the coats of stain.

OF POLISHING WOOD-WORK.

109. The object of polishing is to make the surface of wood-work bright and smooth, and to improve and protect its colour. By rendering it bright, it reflects light, and exhibits the natural figure and colour of the wood with much greater effect; but it also renders every defect more apparent, and therefore the more perfect the polish, the better the workmanship ought to be. French furniture has always been much admired, in consequence of the beauty of its polish, and we may add the care bestowed in finishing the surface, as well as in avoiding soft and porous wood for good furniture; as we well know that polish alone does nothing unless it be employed on an object worthy of polishing.

There are several methods of polishing depending on the use of the articles, or the modes of operation.

Common Polishing.

110. The most simple is OIL-POLISHING, used for ordinary work. It is merely oiled with linseed-oil, which causes the colours of the wood to be reflected more strongly; and, by slight oiling and rubbing, a bright gloss may be produced wherever the wood has been well cleaned off. Where it is intended to improve upon the natural colour of the wood, the oil is coloured by alkanet-root, dragon's-blood, or other colouring matters which dissolve in oil; the solution being assisted by gentle heat. Sometimes, for porous woods, insoluble colouring matter, such as ochres, rose-pink, &c., are added, but these seem to have very little effect.

In getting a polish on new furniture, the oil is applied with very fine sifted brick-dust. The object of this addition is to wear the wood to a smoother surface than is obtained by cleaning it off. The brick-dust and oil forms a kind of putty under the rubbing cloth, and when it does so, no further addition of dust should be made, but the rubbing continued till the desired degree of smoothness be obtained. The French cabinet-makers use tripoli instead of brick-dust, and certainly with better effect. The brick-dust or tripoli is cleared off when the proper degree of smoothness is obtained, by rubbing with bran. This is still esteemed the best method of polishing dining-tables.

111. The next, in simplicity, is WAX POLISHING. It consists in rubbing the surface with hard bees'-wax, and polishing it with corks, brushes, and linen cloth-rubbers. This mode of polishing is much used for the inside parts of work; also for chairs, bedsteads, and various stained articles.

To lessen the labour of applying the wax, it is sometimes, for common stained work, dissolved in linseed-oil by a slow heat, and rubbed on with a rag, and polished by brushes and linen cloths.

112. A wax composition, called Furniture Paste, is also used for polishing; it is formed by dissolving bees'-wax in a small quantity of spirit of turpentine by a gentle heat, and adding about a sixteenth part of powdered rosin. The composition is rubbed on, and polished in the same manner as wax. It is for new work sometimes stained by the addition of alkanet-root, or rose-pink; the colour of the alkanet-root must be extracted by the turpentine before it be added to the wax. The addition of a small quantity of copal varnish to the dissolved wax while it is warm, is esteemed better than the addition of rosin.

Of French Polishing.

113. Lately a new mode of polishing has been adopted for furniture, called French Polish, which consists in applying a considerable thickness of transparent gum-lac over the wood, and by that means rendering it less necessary to give the wood itself so fine a surface, as when that surface is the one which is polished. In the new method, the surface of the gum is the polished surface.

114. French polish is a species of spirit-varnish, chiefly composed of shell-lac; which, when dissolved in spirit of wine, forms the hardest and most durable spirit-varnish known. It is mixed with certain portions of gum-mastich and gum-Sandarach, for the purpose of rendering its colour paler, which is a desirable circumstance in some of the works to which it is applied.

It differs from varnishing in the manner of applying it to the articles. This is done by rubbing it upon their surface with a fine cloth, and using oil and spirit of wine during the process, as will now be more particularly described.

The varnish is composed of—

Shell-lac, three parts;
Gum-mastich, one part;
Gum-Sandarach, one part;
Spirit of wine, 40 parts.

The mastich and Sandarach must first be dissolved in the spirit of wine, and then the shell-lac: the process may be performed by putting them into a bottle loosely corked, and placing it in a vessel of water heated to a little below 173°, or the boiling point of spirit of wine, until the solution be effected; the clear solution may be poured off into another bottle for use.

In applying it to large surfaces, use a rubber formed of a flat coil of thick woollen cloth, such as drugget, which must be torn off the piece, in order that the face of the rubber, which is made of the torn edge of the cloth, may be soft and pliant, and not hard and stiff, as would be the case were it to be cut off, and thereby be liable to scratch the soft surface of the varnish. This rubber is to be securely bound with thread, to prevent it from uncoiling when it is used; and it may vary in its size from one to three inches in diameter, and from one to two inches in thickness, according to the extent of the surface to be varnished.

The varnish is to be applied to the middle of the flat face of the rubber by shaking up the bottle containing it against the rubber; it will absorb a considerable quantity, and will continue to supply it equally, and in a due proportion to the surface which is undergoing the process of polishing. The face of the rubber must next be covered by a soft linen-cloth doubled, the remainder of the cloth being gathered together at the back of the rubber to form a handle to hold it by, and the face of the cloth must be moistened with a little raw linseed-oil, (which may either be coloured with alkanet-root, or not,) applied upon the finger to the middle of it, and the operation be commenced by quickly and lightly rubbing the surface of the article to be polished in a constant succession of small circular strokes; and the operation must be confined to a space not more than 10 or 12 inches square, until such space is finished, when an adjoining one may be commenced, and united with the first, and so on, until the whole surface is covered. The varnish is inclosed by the double fold of the cloth; which, by absorption, becomes merely moistened with it, and the rubbing of each place must be continued until it becomes nearly dry.

The rubber may, for a second coat, be wetted with the varnish without oil, and applied as before. A third coat must also be given in the same manner; then a fourth, with a little oil, which must be followed, as before, with two others without oil; and thus proceeding until the varnish has acquired some thickness, which will be after a few repetitions, and depends on the care that has been taken in finishing the surface. Then a little spirit of wine may be applied to the inside of the rubber after wetting it with the varnish, and being covered with the linen as before, it must be very quickly and uniformly rubbed over every part of the surface which will tend to make it even, and very much conduce to its polish. The cloth must next be wetted a little with spirit of wine and oil without varnish, and the surface being rubbed over, with the precautions last mentioned, until it is nearly dry, the effect of the operation will be seen; and if it be found that it is not complete, the process must be continued with the introduction of spirit of wine in its turn, as directed, until the surface becomes uniformly smooth, and beautifully polished. The work to be polished should be placed opposite to the light, in order that the effect of the polishing may be better seen. In this manner a surface of from one to eight feet square may be polished at once, and the process, instead of being limited to the polishing of rich cabinets, or other smaller works, can now be applied to tables, and other large pieces of furniture, with very great advantages over the common way of polishing witn wax-oils, &c. In some cases, it is esteemed preferable to rub the wood over with a little oil applied on a linen cloth before beginning to polish; but we doubt the propriety of this method.

115. When the colour of the wood to be polished is dark, a harder polish may be made by making the composition of one part of shell-lac and eight parts of spirit of wine, and proceed as before.

Various receipts for the French polish have been published, in which ingredients are inserted that are insoluble in spirit of wine, and therefore useless; and others contain ingredients that are soluble in water, so as to render the mixture more easily injured.

For work polished by the French polish, the recesses, or carved work, or where the surfaces are not liable to wear, or difficult to get at with the rubber, a spirit-varnish made, without lac, and considerably thicker than that used in the above process, may be applied to those parts with a brush or hair-pencil, as is commonly done in other modes of varnishing.

116. The French polish is not proper for dining-tables, nor for any thing where it is liable to be partially exposed to considerable heat; but the beautiful effect it produces has caused it sometimes to be improperly applied.

Of Varnishing Furniture.

117. There are several species of furniture which are varnished; such as works in white-wood, boxes, and other small articles much used, and carved work, which is difficult to polish. Lately, varnish has also been used for tables, side-boards, and chairs. The best method of proceeding is to purchase the varnish ready made for use, as the process of making is tedious and expensive.

118. Copal varnish is of an extremely durable kind; it is transparent, and forms one of the most beautiful and perfect varnishes for coloured wood, where a slight tinge of brown is not objectionable. It is difficult to make, but may be procured of japan-manufacturers or coach-makers. It may be used for various articles, and is the only species which succeeds for dining-tables. The coats should be laid on as thinly as possible, and allowed to become well dry between each.

119. For light coloured woods, hard white varnish is used. Various receipts are given for this purpose, in all of which particular attention must be given to choosing colourless gums.

A fine colourless varnish may be made by dissolving four parts of gum-Sandarach, and one part of Venice turpentine, in 16 parts of spirit of wine by a gentle heat.

120. A more compound varnish is used by the French artists: it consists of

Spirit of wine, 32 parts;
Gum-Sandarach, 5 parts;
Mastich, 2 parts;
Gum-elemi, 1 part;
Oil of lavender, 1 part.

The whole being dissolved in a vessel placed in a water-bath kept at such a temperature that the spirit does not boil. After the solution is cold, it is to be filtered for use.

121. From four to six coats of either of these varnishes are laid on the work, taking care to let each coat become perfectly dry before another be added; and when the last coat is dry, the work must be polished with tripoli and water, by means of a compact rubber of drugget or list, and the surface being next washed with water, it is finally rubbed off with a clean fine linen rag and bran.

Of Cleaning Old Furniture.

122. The modes of keeping furniture in order, depend on the manner in which it has been polished. When articles have been finished with French polish, they may be cleaned with a little spirits of turpentine, which will remove grease or dirt without softening the varnish, if it be quickly done.

Furniture that has been polished with wax-composition should be kept in order by the use of the same composition (see *art.* 112) used in small quantity, and well rubbed off.

And where furniture has been polished with oil, it may be occasionally slightly rubbed with oil stained by alkanet-root, (see *art.* 111,) and well cleared off by continued rubbing.

123. When tables or other articles have got into a bad state by improper treatment, but are not stained, the best mode is to wash them clean with spirits of turpentine, and repolish them with furniture oil. But when stains are to be removed, the surface should be washed with stale beer, or common vinegar, warmed; and the stains removed by rubbing them with a rag dipped in spirits of salt, after which it may be repolished in the manner of new work.

The lacquered brass-work of furniture should be cleaned by washing it with warm water by means of a soft linen or muslin rag. Spots not removable by this method cannot be got out without re-lacquering.

124. Where old furniture of mahogany has to be repaired with new wood, the colour of the new parts may be darkened by applying soap and water; or, where very dark wood is to be imitated, the new parts may be washed with lime-water.

INDEX AND GLOSSARY OF TECHNICAL TERMS

USED IN CABINET-MAKING;

WITH REFERENCES TO THE PAGES IN WHICH THE VARIOUS SUBJECTS ARE TREATED, AND AN EXPLANATION OF SUCH TERMS AS ARE NOT ALREADY PARTICULARLY DEFINED IN THE WORK.

A.

ALKANET; a plant, the root of which imparts a beautiful red colour to pure spirits of wine, to oils, and to wax, 29.
Angles, mode of framing, 17.
Animal forms, remarks on using, 5.
Anti-room furniture, 11.
Antique Ornaments are such as were used by the Greeks and Romans.
Archil; a species of lickhen which gives a rich purple tincture, but it speedily fades, 28.
Arm-chair; a chair having resting-places for the arms—they are sometimes called elbow-chairs.

B.

BAMBOO; a species of cane which grows to a large size in India, and is used there for chairs, tables, &c. The external appearance of bamboo is often imitated for bed-room chairs.
Banding. *See* 20.
Base; the lowest part of a support. *See* 3.
Basin-stand; a stand placed in bed and dressing-rooms to hold vessels, &c. for washing.
Basso-relievo; carving in which the figures project less than their thickness from the ground.
Bead; a semi-circular moulding; when it projects before the surface it is a *cock-bead.*
Bed-room furniture, 16.
Bed-stead; a frame of wood or metal for a bed to be laid upon; metal bedsteads are made either of iron or of tubes of brass, 16.
Beech; a hard compact wood much used for chairs, bedsteads, sofas, &c. it is very soon injured by worms.
Bevel of chair-rails, 18.
Bidet; a seat containing a pan of japanned-tin, or earthen-ware, generally made in the form of a stool with a loose cover.
Billiard-room furniture, 11.
Billiard-table; a table covered with cloth to play at billiards upon, the top of which should be perfectly even and level. The top is framed in small pannels, and, in order that they may not warp, both the frames and pannels should be cut so that the annual rings of the wood are perpendicular to their upper surfaces.
Black-stain, 27.
Blind; an appendage to a window, to screen a room from the direct rays of the sun, or from being looked into from without; for the latter purpose low blinds of wire-gauze, fixed in mahogany frames, are now much used.
Block; a piece of wood glued into an angle to strengthen it; also, the part on which the bed rests in a pillar and claw-table.
Boasting, 22.
Book-cases, 13.
—— shelves, 13.
——, sizes of, 13.
Borders, 6, 22.
Bow-saw; one of which the saw is stretched by a bow, 21.
Bracket, a support fixed against a wall.
Brass, inlaying with, 21.
——— work, on cleaning off, 25.
Breakfast-room furniture, 16.
Bronze; a compound of tin and copper used for casting ornaments, &c. The term is also applied to the green colour this metal acquires by age.

Brown; its composition in colouring, 6.
Buhl-work, 20.
Bureau, a desk.
Bust, in sculpture, a carved portrait of a man down to the breast.

C.

Cabinet-making, 1.
Cabling; an imitation of the twisted-strands of a rope, 23.
Caddy; a small box used for keeping tea.
Cap; the top of a pillar or pilaster.
Capital; the top of a column.
Card-table; a table covered with green cloth to play at cards upon. The tops are made to fold together to preserve the cloth.
Carving, 22.
Cast; to form by putting in a soft state into a mould, 23.
Casting ornaments in wood, &c. 23.
Casters; rollers, with revolving sockets, for supporting articles of furniture which it is desirable to move.
Cauls, 19.
Cedar; a name applied to two species of wood, the one called pencil-cedar having a powerful scent, the other is of a similar appearance, but without scent.
Cellaret; a wine-cooler, or wine-cistern, 15
Cement-stopping, 26.
Chair-making, 18.
Cleaning off work, 25.
——— old furniture, 31.
Colours, on the combination of, 5.
———, theory of, 6.
Column; a tall support having a regular capital and base.
Commode; a species of low ward-robe; also a piece of drawing-room furniture, the lower part enclosed with doors, and the upper having book-shelves.
Compartment; one of the divisions of a design.
Composition-ornament, 24.
Contour; the outline, 2.
Contrast; great difference of colour, figure, or proportion, 6.
Conversation-seats, 8.
Copal; the concrete juice of an American tree, which is a hard, shining, odoriferous substance of a transparent citron colour. It will neither dissolve in spirit of wine nor essential oils without peculiar treatment, but may be dissolved by digestion in linseed oil. It makes the best varnish known. *See* 31.
Cornice; a compound moulding at the top of a piece of furniture.
Couch; a long seat, occasionally used to lie down upon.

D.

Defects, stopping for, 26.
Design, principles of, 2.
Desk; a piece of furniture with the conveniences for writing. Portable-desks are made to fold together for travellers.
Dining-room chairs, 16.
Dining-room furniture, 14.
Dining tables, 15.
Dove-tailing, 17.
Drawers, on making, 18.
Drawing, remarks on learning, 2, 19.
Drawing-room chairs, 12.
——— ——— furniture, 12.
Dressing-room furniture, 16.

E.

Eating-room furniture, 14.
Ebony; a beautiful and dense black wood much used for small cock-beads, mouldings round pannels, &c.
——— stain, 27.
Emblems of music, 14.
Entablature; the architrave, frize, and cornice of one of the architectural orders of columns.

F.

Figure, human, furniture to agree with, 1.
Firmness, 3.
Fitness or propriety, 3.
Flutes; a series of semi-elliptical or semi-circular hollows sunk in a plain surface, with or without narrow spaces between; of the latter kind are the flutes of Corinthian and Ionic columns; of the former are the flutes of the Doric column, 23.
Foliage; ornaments from vegetable nature, 4.
Foot-stools, 8.
Framing, 17.
French-polish, 29.
Frize; the portion between the architrave and the cornice in an entablature. In cabinet-work the frize has seldom more than a small moulding below it.
Furnishing, styles of, 7.
Furniture, construction of, 17.
——— oil, 29.
——— paste, 29.

G.

Gallery furniture, 11.
Geometry, 2.
German style of carving, 5
Gilding; an excess of gilding should be carefully avoided, except where the theatrical style is the object.

Glue.—In preparing glue for use, it should be steeped in cold water for six or eight hours. It should then be dissolved, by gently raising it to a boiling heat, carefully stirring it during the time. To give glue its full effect in uniting two pieces of wood, the glue should be thoroughly melted, and used while boiling hot; secondly, the wood should be dry and warm; and lastly, the surfaces to be united should be covered only with a thin coat of glue, and, after having been strongly pressed or rubbed together, to exclude the air, should be left in a moderately warm situation, till the glue be completely dry. The qualities of glue are much impaired by frequent meltings, and it becomes of a dark and almost black colour. See 19 and 23.
Gothic furniture, 9.
—— ornaments, 5.
Graceful forms, 19.
Grain, rising of the, 25.
Greek furniture, 8.
Grooves, dovetail, 18.
Group, the individual parts collected; the furniture of a room in place, when the parts combined make an agreeable whole, they may be said to group well.

H.

Hall chairs, 11.
—— furniture, 11.

I.

Inlaying, 20.

K.

Keys, 17.

L.

Lap-dovetailing, 17.
Library chairs, 14.
—— furniture, 12.
Loo table, 12.

M.

Mahogany stain, 27.
Mahogany, to colour to imitate old, 32.
Masks.—The theatrical mask of the ancients was a cover for the whole of the head, which, besides the form of the face, had the representation of hair, ears, beard, &c. Those for Tragedy were made expressly for inspiring terror, representing frightful figures, such as gorgons, furies, &c. Those for Comedy chiefly verged towards the ridiculous; but there are some of fine composition of both species. *See* 14.
Mitre-dovetailing, 17.
Mortising, 18.
Mosaic work, inlaying with coloured marbles. Beautiful tops for tables are done in Mosaic work.
Mouldings, Greek, 9.
—— Roman, 9.
—— Gothic, 10.
Music-room furniture, 14.

O.

Oak.—In old trees covered with excrescences, the wood composing them is often beautifully curled, and of a rich umber brown colour. Pollarded trees most frequently afford such wood, but it is also common in stunted trees of slow growth. This kind of oak has lately been much used for furniture; and even when it is without figure, the deep coloured kinds make mouldings, which, added to lighter coloured oak furniture, produce a good effect.
Oil, for furniture, 29.
Old English furniture, 9.
Ornaments, on the selection of, 4
—— proportion of, 4.
—— moulded, 23.
—— composition, 24.
Or-moulu; a species of gilding by means of mercury, to which French furniture owes most of its effect. As far as our experience goes, it will not stand the humid atmosphere of this country; nevertheless, the nature of this gilding, which enables the French to add such spotty brilliancy to exceedingly plain wood-work, was worth inquiry. It appears that leaf-gold is used, but the leaves are not so thin as for other gilding. The surface of the copper ornament to be gilt is rendered perfectly clean, and freed from the acid used for that purpose; then it is covered over with an amalgam of gold and mercury* by means of a brush of brass wires, that are separated by passing them through a comb. A double coat of leaf-gold is next put on the work and pressed to by a piece of cotton, otherwise the gold would all retire into the hollows, and the gilding have neither continuity nor brilliancy. The work is placed to let the mercury drain from it for about an hour, and next put over a charcoal fire about a minute or two, on each side, till it becomes bright; then draw it from the fire, and strike it with the wire-brush to drive the gold into the deep parts. It is placed again on the fire about two minutes till the mercury evaporates, and leaves it the colour of box-wood, it is then cooled in water and washed. The amalgam of mercury is applied a second, and sometimes a third time, but without apply-

* The mode of forming this amalgam is not described in the French work from whence this process is taken, hence we infer it is made in the usual manner.

ing leaf-gold. To get rid of the box-colour, the work is brushed with a wire-brush in a weak solution of vinegar, and the work being well rubbed with a linen rag, it is put on an iron grate over a fire to dry; and, after being covered with a saline powder, it is again put over the charcoal fire half a minute on each side; it is next washed, and dried in the air, and rendered completely dry over the charcoal.

The saline powder is a subject of much mystery; the examination of several coincided in giving as its composition,

8 parts of salt-petre;
7 ——— sea-salt;
5 ——— alum.

Parts that are to be bright are burnished by a bloodstone-burnisher in preference to one of agate.

Outline, 2.

P.

Patent dining-tables, 15.
Pateras, carved, 23.
Pedestal; a support for a bust, vase, or column.
Pediment; the triangular figure formed by the end of a roof, in architecture. It is not in strictness applicable to internal work.
Pilaster; a portion of a square column projecting from a plain surface.
Plinth; the lower part of a support.
Polishing, French, 29.
——— Oil, 29.
——— Wax, 29.
Proportion of parts of furniture, 3.
Pumice-stone, use of, 25.

R.

Reeding, 23.
Richness of effect, 5—7.
Roman furniture, 9.
——— ornaments, 5.
Rose-wood stain, 27.

S

Saloon furniture, 11.
Sculpture; carved work executed in stone or wood.
Shrinkage of wood, 17.
Side-board, 14.
Sofa; a seat for two or more persons. The term is applied, in Turkey, to a splendid raised alcove, with rich carpets, to use as a throne or seat of state.
Sofa-table; a long table to stand before a sofa.
Staining, 27.
Stains, to remove, 32.
Staircase furniture, 11.
Stopping, 26.

T.

Table, card, dining, &c. See *Card-table*, &c.
Tracery; the division-mouldings between pannels in Gothic architecture, 10.
Tripod, 8.
Tripoli; a soft silicious stone of a yellowish gray colour used for polishing wood, varnish, metal, stones, and glass. *See* 29 and 32.
Turning, combination of, with carving, 23.

V.

Varnish, copal, 31.
——— hard, 31.
Varnishing furniture, 31.
Vases, Greek, 8.
Veneering, 17.

W.

Warping of wood, 17.
Wax-polishing, 29.
Wood, moulded, 23.
——— work, cleaning off, 25.

PRINTED BY J. RIDER, LITTLE BRITAIN, LONDON.