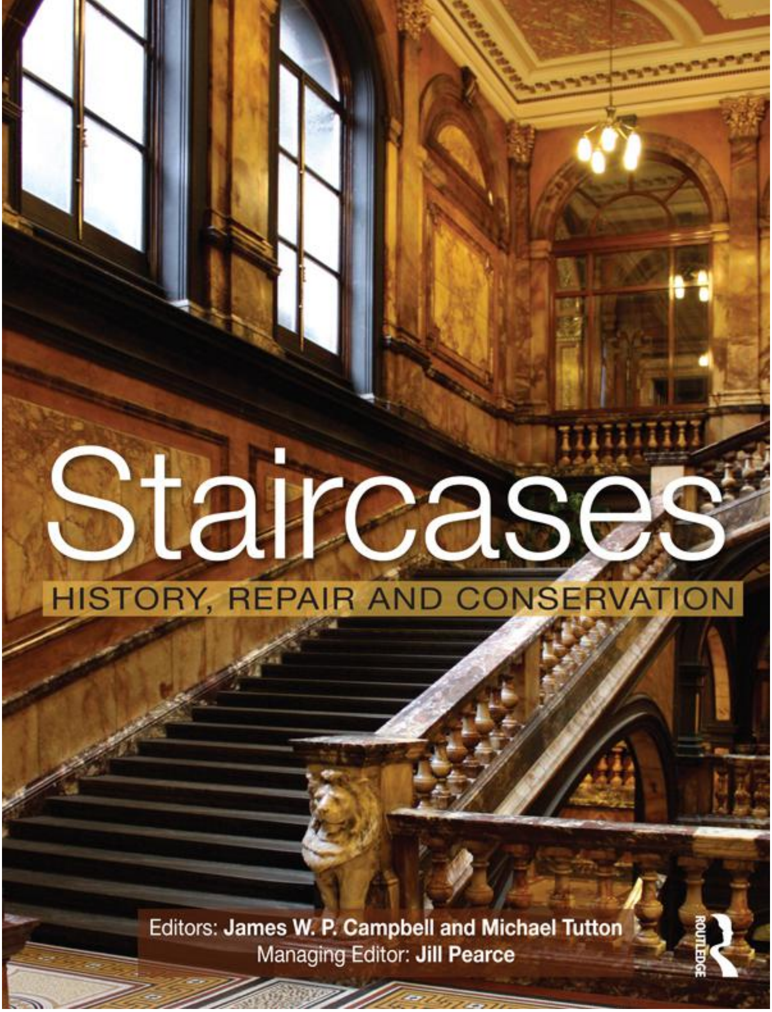
Staircases
HISTORY, REPAIR AND CONSERVATION
Editors: James W. P. Campbell and Michael Tutton
Managing Editor: Jill Pearce
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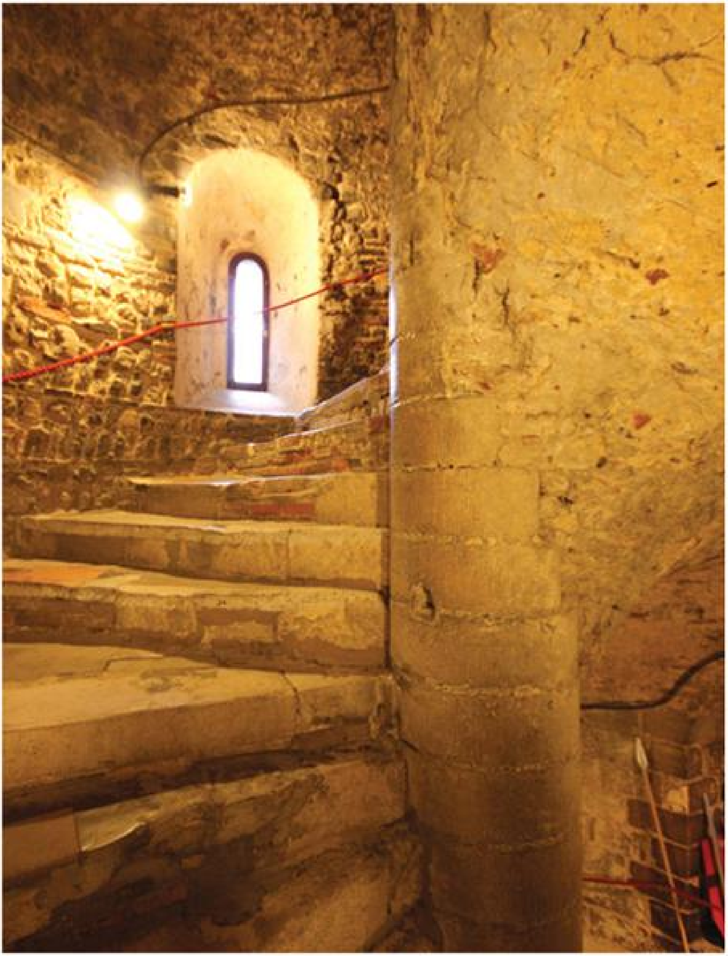
STAIRCASES



Staircases

History, Repair and Conservation

Editors

JAMES W.P. CAMPBELL

MICHAEL TUTTON

Managing Editor

JILL PEARCE

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Frontispiece Colchester Castle, Essex. The main staircase, begun *c*. 1076, at 4.6 m diameter is probably the widest early spiral stair in Europe, certainly in England. It rises clockwise, but a defending force would have had little advantage backing up it (see introduction). (Michael Tutton)

CONTENTS

Contributors

Robert Bowles, MA, CEng, MIStructE, Conservation Accredited Engineer, is a Director of Alan Baxter and Associates LLP with 35 years' experience of significant listed buildings such as St Paul's Cathedral, the Palace of Westminster and HM Tower of London. His work won the Institution of Structural Engineers' Heritage Award in 2006 and the Sustainability Award in 2012. He is co-author (with Poul Beckman) of *The Structural Aspects of Building Conservation* (2004)

James W.P. Campbell, PhD, FSA, IHBC, RIBA, is the Director of Studies and Fellow in Architecture and History of Art at Queens' College, Cambridge. He trained as an architect. He is chairman of the Construction History Society and has published widely on architectural history, including *Brick: A World History* (2003) and *Building St Paul's* (2007).

Donal Channer has been in business making and mending furniture and joinery since 1974. Stairs have always been a particular interest, with the Queen Square Stairs being his most important commission, but conservation projects include the Cope Chest at Wells Cathedral 1175 – the oldest piece of furniture to be in continuous use and to have been radio carbon dated in the British Isles. Current projects include copies of the furniture for Strawberry Hill House.

Tom Flemons is a qualified stonemason and conservator. He has worked in the field of stone conservation for over 20 years and was the recipient, in 1992, of the William Morris Craft Fellowship from the Society for the Protection of Ancient Buildings (SPAB). He manages the Somerset workshop
of Cliveden Conservation, and is the current Chairman of the Education, Training and Advisory Committee at the SPAB.

Linda Hall, BA, MIfA, FSA, studied archaeology and history at Southampton University. She is a member of the Vernacular Architecture Group and the Regional Furniture Society. Publications include *Rural Houses of North Avon and South Gloucestershire 1400–1720* (1983), *Fixtures and Fittings in Dated Houses 1567–1763* (1994 with Dr N.W. Alcock), *Period House Fixtures and Fittings 1300–1900* (2007), with contributions to *The Elements of Style* (ed. Stephen Calloway, 1991), *Hampshire Houses 1250–1700* (Edward Roberts, 2003) and *Glass and Glazing* (English Heritage, 2011).

Caroline Hardie is a graduate in archaeology from the University of Glasgow. Her professional life has included archaeological excavation, museum curation and local government archaeology, including County Archaeologist for Northumberland County Council for 13 years. In 2003 she founded Archaeo-Environment, a historic environment consultancy, covering archaeology, historic landscapes and buildings. Her passion for historic buildings extends into her private life, with the rescue of Scargill Castle in Teesdale with its very own quirky spiral staircase.

Michael Heaton is a professional archaeologist qualified in Building Conservation and Building Surveying, specialising in the analytical survey of historic buildings. His paper 'Building Palaeopathology: Practical Applications of Archaeological Building Analysis' was awarded 'Outstanding Paper 2010' by its publishers the Emerald Group, and he was awarded the RICS Prize at the University of the West of England in 2007, where he is an occasional Visiting Lecturer. He is a Trustee of the Construction History Society.

Lee Prosser is Curator of Historic Buildings at Historic Royal Palaces. He has been closely involved with several major projects, including the re-presentation of Kew Palace and, most recently, a major project at Kensington Palace, where issues of conservation and access have come to the fore. He is also involved in a research project on the origins of the English framed staircase.

Treve Rosoman, FSA, is a freelance historic building consultant. He was curator of English Heritage's Architectural Study Collection from 1986 until 2013. He was an antique dealer for ten years before joining the Historic
Buildings Division of the Greater London Council. As part of English Heritage's curatorial team responsible for their London houses, he was in charge of refurnishing the Art Deco Eltham Palace. He has written widely on furniture history and interiors, including *London Wallpapers: Their Manufacture and Use, 1690–1840*.

Michael Tutton, IHBC, has some 25 years' experience in the construction industry working principally on historic buildings as a site manager and clerk of works. He is a past chairman of the SPAB and is a Trustee of the Construction History Society. He currently divides his time as assistant architectural adviser to Hampstead Garden Suburb Trust and writing and editing. He is co-editor of *Windows, History, Repair and Conservation*, the first book in this series.

Geoff Wallis, C.Eng. M.I.Mech E, is a founder and former Managing Director of Dorothea Restorations Ltd, with 40 years' practical metalwork-conservation experience. He is a council member of the National Heritage Ironwork Group, West Dean College Masterclass Course Leader, and is current President of the Newcomen Society for the Study of the History of Engineering and Technology.

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James W.P. Campbell and Michael Tutton
March 2013

Preface

The staircase dates back to the very beginning of architectural history. Virtually every significant building from the ziggurats of ancient Mesopotamia to the present day has not only contained one or more staircases, but has celebrated them. For such an apparently simple part of a building they have been made in a bewildering variety of forms and from a wide range of materials. Every age has sought to out-perform the previous to produce ever more spectacular and gravity-defying designs.

Staircases is the first major reference volume devoted entirely to the understanding of staircases and the issues surrounding their repair and conservation. Each chapter has been especially written by experts in their respective fields. The book is essential reading for professionals and anyone with an interest in staircases. It deals with the history, dating, archaeology, surveying and recording, engineering, curating, repair and conservation of the staircase in a single volume. No other book offers such a wide range of detail.

The book is divided into three parts:

- Part One covers the history, development, identification and dating of staircases, providing detailed drawings and photographs and an introduction to the scientific techniques available to enable the accurate dating of staircases.

- Part Two covers the design, engineering and maintenance of the staircase, giving a clear guide to the latest research into the design of safe staircases and their structural stability.
- Part Three focuses on the materials commonly used to make staircases, detailing the appropriate techniques for their conservation and repair.

The result is a comprehensive study encompassing considerable and far-reaching research which aims to inform our understanding and advance the scholarship of the subject for years to come.

Introduction

James W.P. Campbell and Michael Tutton

STAIRCASES are extraordinarily diverse and their design can be traced through not just hundreds but thousands of years of human history. Even before humans made two-storey buildings they carved staircases into rock faces, and such staircases, worn by countless feet through the ages, provide a fitting reminder of the longevity of human ingenuity. Once human beings began to build upwards, stairs became a crucial element of architecture, and as buildings became more complicated so stairs, too, were created in ever more complex forms. Virtually every significant building, from the ziggurats of ancient Mesopotamia to the present day, has not only contained one or more staircases, but has celebrated them. For such an apparently simple part of a building they have been made in a bewildering variety of forms and from a wide range of materials. Every age has sought to out-perform the previous to produce ever more spectacular and gravity-defying designs.

While the basic function of any staircase in a building is to convey people from one level or floor to another they could also serve other purposes, although these are easily misconstrued. For instance, anyone visiting a medieval castle will invariably be told that medieval spiral staircases twist clockwise to aid the defender. As we shall see, this is a myth, but the story does contain an element of truth: some stairs were used for defence and were broken up by drawbridges and pits, overlooked by murder holes and designed to be partially demolished in the event of attack. Unbroken steep flights could be used to slow down an enemy, gave a clear line of fire and allowed defenders to push attackers back down on top of each other.

Throughout history staircases have carried symbolic and religious overtones. Greek temples were raised several steps above their surroundings, the stairs scaled for the gods, rather than humans. The altars of Christian churches similarly were raised above the rest of the church, while crypts for the dead were reached by descending stairs, as if to the underworld. In Ancient Mesopotamia and in Mexico, the temples and altars on top of the great stepped ziggurats or pyramids were reached only by climbing relentless flights of stairs ascending towards the heavens. Such stairs could be used as a way of asserting the separation between the gods and mortal men. They could, however, also be used in some instances as a method of human sacrifice, the victim pushed from the top providing a grisly reminder that stairs are as potentially deadly as they are useful.

Stairs still hold cultural references. In films, characters attending parties usually arrive descending a set of stairs. Many great buildings are organised around formal staircases, celebrating movement, whether it be the staircases of Grand Central Station in New York or Garnier’s Opera House in Paris, or the stairs that form the centre of many modern shop interiors. They mark the point in any building where both floors are simultaneously visible and the views from one to the other can be exploited to create drama and effect.

AIM of this Book

This book is written as a companion volume to Donhead's previous book, *Windows: History, Conservation and Repair*. Like that book, the aim here is to gather in a single volume everything the reader needs to know in order to date, design, maintain and repair the object in question. No single individual could possibly be an expert in all the various disciplines involved, so this book has brought together architects, historians, archaeologists, curators, craftsmen and engineers to produce what we hope will be an accessible and authoritative guide to the staircase. Each is a leading practitioner in their field, with a particular interest and experience in staircases. They have been asked to provide an introduction to their area of expertise for a professional audience. Each chapter has also been peer-reviewed to ensure that the material presented is as accurate as possible.

The challenge of writing a book on staircases is slightly different from writing one on windows. Stairs can be found inside or outside. We have chosen to limit the current book to staircases inside buildings and not those in gardens or landscapes, although similar issues will pertain. A window is a recognisable and distinct element. A staircase is often part of the building structure, and even if it is not helping to support the building, structure plays an important role in its design. Staircases are also made in a very wide range of materials.

I.1 Kings Weston, Bristol. The extraordinary timber hanging or flying staircase. The house by Vanbrugh, begun *c*.1719, has been substantially altered over time and this staircase in its present form cannot be original. It is, however, a work of brilliant virtuosity. (Michael Tutton)

Current Literature

Staircases: History, Repair and Conservation seeks to fill a definite gap in the literature. Considering how important staircases are to the design of virtually any building, it is perhaps surprising that there is not already a book devoted to their design, history, repair and conservation. The recent books published by English Heritage on practical building conservation do cover stairs in passing, but only with regard to maintenance, and they give very limited advice on dating and history. Indeed, history and dating are areas where there has been very little in the way of reliable literature. Most books on staircases have been general works, with little or no historical information. The picture books of staircase designs that have appeared in the last few years provide inspiration on how to design modern stairs: books like Eva Jiricna's *Staircases* (2001), Catherine Slessor's *Contemporary Staircases* (2000) or Carles Broto's *New Staircases* (2010). These usually lack any technical information to enable the architect to learn from the designs. They are of limited use to the designer except for those seeking inspiration and of no use at all to those looking for information on how to understand and maintain existing stairs.

Technical information on stairs is surprisingly difficult to find. There is a very sizable literature on the construction of domestic timber stairs, but this is almost entirely aimed at the DIY market and of limited interest to the designer or curator. Recent monographs on staircases for professionals are rare. Karl Habermann's *Stairs: Design and Construction* is now ten years old, and out of print. While it did provide a short history of European staircases, it said nothing of maintenance and was mainly concerned with designing to meet European building codes. Before that, the best book on staircases had been Alan Blanc's *Stairs, Steps and Ramps*, which came out as long ago as 1996. The first edition carried a good historical introduction but was muddled in its organisation. A better-organised, but much-abridged, second edition entitled simply *Stairs*, appeared in 2001 with most of the useful historical information removed. It still remains one of the best sources for technical details, but these are now beginning to look dated. The largest general study was John Templar's two-volume *The Staircase* published in 1992, 20 years ago. It was expensive to purchase then and now, is long out of print and is difficult to obtain second hand. The first volume gave a general survey of the history of the staircase, while the second was entirely devoted to the safety of stairs, the area which specifically interested Templar. The history in the first volume said very little about English stairs. The work as a whole contained nothing on the construction or maintenance

of staircases or how to record or date them. Walter Godfrey's *The English Staircase* remains the best historical account of the staircase in Britain, but was written over 100 years ago and is thus, not surprisingly, out of date. From this brief overview, it can be seen that it is hardly an exaggeration to say that stairs have not been well-covered in architectural literature and that a better survey is long overdue. It is this gap that the current work aims to help fill.

Layout of the Book

This book is designed to act as a useful work of reference, so it can be read as a whole or the chapters can be read individually, as problems arise. The organisation is thus as clear as possible. The book is divided into three parts.

Part One deals with the history, development and dating of the staircase. The first chapter, by Michael Tutton, aims to give a very general overview of the development of the staircase, based primarily on European examples. The second chapter, by James W.P. Campbell, provides a short introduction to the development of the British staircase, from its earliest origins to the present day. The third chapter, by Linda Hall, then looks at how to date a staircase from its details. This is based on extensive surveys of staircases from all over England. The fourth chapter, by Treve Rosoman, is designed to complement Chapter 3, and they should be read together. It looks at the special case of London, which had a slightly different history to the rest of the country. All these chapters look at the historical development of the staircases working from the visual appearance. Chapter 5, by Michael Heaton and Caroline Hardie, provides an introduction to the other ways of dating staircases, working from the archaeological point of view. It covers methods of measuring and recording staircases and the various scientific methods of dating available. Thus, Part One as a whole aims to provide all the information a practitioner might need to date and record an existing staircase.

Part Two looks at the design and maintenance of staircases. In Chapter 6, James W.P. Campbell examines the geometry of staircases and how this relates to safety and regulation. The chapter provides a summary of the aspects of size and form that need to be considered by anyone designing a staircase and the research that has been carried out on the subject. Chapter 7, by Robert Bowles, provides an introduction to the structure of staircases from the perspective of a working engineer with a lifetime of experience
in practice designing new staircases and repairing old ones. Staircases are full of pitfalls for the unwary and recent research has shown that many stairs do not act structurally as was previously believed. This chapter is thus essential reading for anyone considering repairing an existing staircase or designing a new one.

Part Three of the book looks at the curating and maintenance and the conservation and repair of the three most common materials used for historic stair construction. Chapter 8 is written by Lee Prosser, a curator at Historic Royal Palaces. It provides detailed guidance on caring for a staircase once it has been constructed and on regular regimes of inspection and maintenance. Chapter 9, by Donal Channer, provides a detailed account of how to repair, conserve, adapt and replicate, where necessary, timber staircases. Chapter 10, by Tom Flemons, looks at repair methods and other interventions for stone staircases, and Chapter 11 by

Geoff Wallis looks at metal stairs, giving a brief overview of the properties of iron and steel and the various methods of repair.

Each chapter carries its own list of sources in the references. A list of further reading on each chapter, together with general works on staircases, can be found at the end of the book, together with a glossary of technical terms.

A Brief Note on Terms and Definitions

There are a great many technical terms used in staircases. For easy reference a glossary is provided at the end of this book. This is mostly restricted to terms used in the text. Specialist branches of staircase construction have extensive vocabularies of their own. One of the problems with all attempts to define technical terms in buildings is that they are not rigidly applied and have a tendency to change over time. For instance, the *Oxford English Dictionary* (OED), quoting Moxon's *Mechanick Exercises* (1679), says that the word staircase 'originally' meant the 'inclosure [sic] of a pair of Stairs, whether it be with Walls, or with Walls and Railes and Bannisters'. Some people still protest that such a distinction should still be made – that the word 'staircase' should mean the enclosure and not the stair. However, this definition does not reflect either the OED or common usage. As the OED admits, the word staircase is now (and has been for some time) used to mean 'a flight of stairs or sometimes a whole series of flights of stairs with their supporting framework, balusters etc.' This book will follow the OED definition

and the general understanding, that a staircase means the whole,
made up of stairs, balusters, handrails, etc. from top to bottom. If there is a distinguishable space within which the staircase ascends this might be called a shaft, though often stairs will ascend in halls or other types of rooms.

Staircases may be made of timber, metal, stone or any other material. They are made up of flights of stairs, consisting of continuous steps that ascend between landings. Again there are some who prefer the term 'landing' to be reserved for the space that the flight reaches at each floor, and who insist that the term 'half-landing' should be used for intermediate places of rest. Still others insist that 'half-landing' should only be used for a landing in a dog-leg stair where the staircase turns through 180 degrees and that where the stair turns through 90 degrees the proper term should be a 'quarter landing'. While all these definitions are correct, they are confusing. This book will use the word 'landing' to mean any place of rest larger than a normal step occurring on a staircase between two flights. We will thus use the word 'flight' to mean any continuous run of steps between landings.

Each step is made up of two elements: a horizontal tread on which the foot comes to rest and a vertical riser. In a stone staircase both may be formed from a single piece of stone. The vertical distance from one tread to the next is called the rise. The horizontal distance from the front of one tread to the front of the next is now called the going. The clear distance across the tread from wall to wall or to the handrail is called the width. It is worth being aware that these terms have only recently begun to be used in this way and that confusingly in the seventeenth and eighteenth centuries the width of the stair was the distance from edge-of-tread to edge-of-tread in the direction of travel (what we now call the going), while the term 'going' was used for the clear space between walls which we would now call width. The terms seem to have changed meanings only at the end of the nineteenth century, 'going' becoming first the measurement of the whole flight and then only later settling into its current definition, used in the modern building regulations.

Staircases are also described according to their type. The grandest stair type was the 'Imperial Staircase', consisting of a single flight which then splits with two flights returning to the next floor parallel to the first. The term was coined in Spain in the sixteenth century. The simplest staircase would be a succession of straight flights; straight flights that return on themselves are called dog-leg stairs. Stairs that are circular on plan are called by various terms. Here we will simply use either the term 'spiral', which is generally accepted, or 'helical', although purists tend to prefer the latter. Stone spiral staircases where part of the newel and each step were formed from the same
piece of stone, one stacked upon the next, we will call in this book a 'newel stair'. Tapering treads are universally called winders. These sometimes taper from a single point, but this is unusual. Normally they 'dance', that is, the space at the centre line of the stair is kept equal and likewise the space at the narrowest point is kept constant. This prevents the stair being too steep at the newel and

allows the handrail to follow a continuous curve. The term ‘geometrical stair’ does not seem to have been applied consistently. It was used to mean a staircase consisting of a continuous flight – or flights – around an open well linked by a single uninterrupted handrail. It is often now loosely applied to spiral or oval staircases, which were particularly difficult to construct, and even to cantilever staircases. It is probably best avoided.

Stone stairs where the treads appear to cantilever from the walls are called cantilever stairs, although as we shall see, the word ‘cantilever’ is technically misleading. They have sometimes recently been misnamed ‘Palladian stairs’ because they appear in his *Quattro Libri di Architeturra*, but as they were neither invented by Palladio nor always used by him this term is misleading and is not used in this book.

As well as the steps themselves, the handrail is generally an important part of staircase design. The handrail was supported off the wall or if next to an open well by a balustrade. This is made up of individual balusters (often popularly called ‘banisters’, which the OED described as a ‘corruption’, but which it had to admit had crept in as early as the seventeenth century and has stuck). The types of balustrades form the subject of Chapter 3 and will be discussed in detail there. It is, however, worth noting that handrails often ended in a post called a newel (not to be confused with a newel post or a newel stair (see above), although of course they shared the same origin).

Scope

This book is aimed equally at the designer of new stairs and those seeking to maintain and conserve existing stairs. As the first chapters of this book show, the staircase has provided a focus for architectural elaboration since the beginning of architecture, yet the problems that govern its design are universal. Every staircase design should begin with understanding why and how the staircase has reached its current form, and the research that has gone into its evolution. For those faced with maintaining existing buildings, staircases offer particular challenges. Knowing what, when and how to replace elements is vital, as is knowing the various measures that need to
be taken in regular maintenance to ensure that the staircase continues to perform its many duties for tens, if not hundreds, of years to come. There are countless examples of staircases that have performed their allotted function without any need of repair but most stairs will require some kind of maintenance at some point. If doors or windows deteriorate the results may be expensive but are unlikely to threaten the health of the occupants. However, even minor faults in staircases can lead to serious accidents and major faults can lead to catastrophic structural failure, potentially involving building collapse and major loss of life. Architecturally, stairs have created some of the most dramatic spaces ever created and they have never been a subject to be approached lightly. Today new materials and ever more powerful computers are offering the opportunities to build staircases in more ways than ever before. Possibilities are seemingly limited only by the imagination of the designer. Staircases are essential in virtually every building; this book is aimed at anyone

involved in looking after an old building or designing a new one who seeks to understand them better.

Part One

History, Development, Identification and Dating

1

An Outline of the History and Development of the Staircase

Michael Tutton

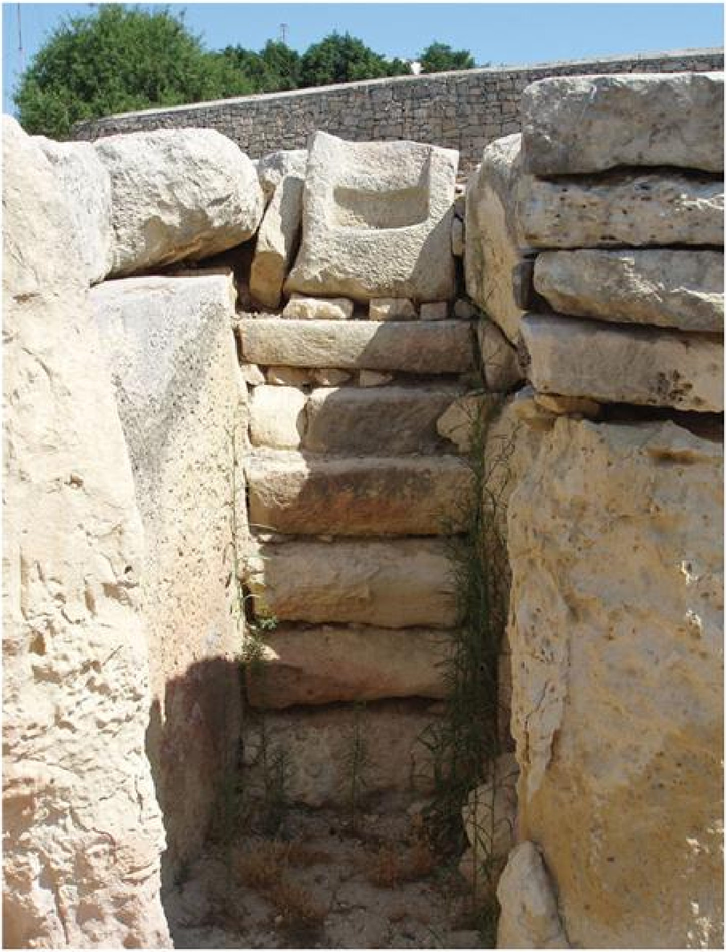
STAIRCASES are compelling and enigmatic; in the same way that a closed door invites opening, they invite ascent or descent, to discover what awaits above or below. The conveyance to different levels of a building, the basic function of any stairs and the principal artery for the circulation and access of people, as the architectural historian Kenneth Clark observed, ‘there is always something dramatic about a staircase’,[1] and almost any building greater than one storey will have one, be it of the most utilitarian type or a virtuoso work of high status and grandeur.

There are inevitably only a limited number of possible configurations for a stair, imposed by the basic materials of construction from antiquity to the nineteenth century. Thus, at any given time different architects or builders might produce similar designs without necessarily being influenced by each other. Technology plays a part. Certain types only become possible with innovations in tools or materials. Architects, engineers and builders adopt newly found or rediscovered ways of putting existing materials together. Thus the history of the staircase is not linear. Types of stairs are used but go out of fashion, they are then forgotten only to be reinvented at a later date, as is the case of the cantilevered staircase, invented by the Ancient Greeks, forgotten, then reinvented by Palladio in the sixteenth century.

From the earliest surviving examples through developments in Ancient Greece and the Roman empire; through European and Islamic Medieval worlds to the sumptuous achievements of the Renaissance and Baroque, this chapter provides an outline of the evolution of the staircase highlighting some particular types and notable examples. These are essentially stone and confined to Western civilisation, with some consideration of iron and steel types, including North America, in more recent times. Until the nineteenth century the emphasis is on spiral stairs, because these illustrate the more dramatic developments, although without excluding mention of straight flights.

Earliest Stone Stairs

From very early times mankind has hewn blocks of stone to form stairs, mostly within religious sites. The humble and even higher status house would have made do with wooden ladders where they were needed to access areas such as lofts and sleeping platforms. Within the prehistoric Tarxien Temple and Saflieni Hypogeum site in Malta, dating to 3600–2500 BC, which lay claim to being probably the earliest free-standing megalithic monuments in the world,[2] an ancient civilisation has left extensive remains which include a short staircase. Simple rectangular blocks have been laid between solid megalithic block walls to form a staircase of some nine steps to connect two temples (Figure 1.1).



1.1 Early stone steps within the Tarxien temple and Saflieni Hypogeum complex, on the island of Malta, within a date range of 3800–2400 BC. The steps within the walls are mostly single blocks. There has undoubtedly been some restoration and reconstruction and the upper two steps, carved from a single block, are somehow unconvincing being much narrower – they may have been placed here from elsewhere. (David Davidson)

Early civilisations in Mesoamerica and Mesopotamia created grand stepped pyramids or ziggurats. Many such buildings incorporated ceremonial staircases, and the type, whether as tombs, for worship or other ceremonial purposes, were constructed over an enormous period of time, spanning some three millennia. The step mastabas or step pyramids of Ancient Egypt, although built in huge steps, did not have external staircases climbing to the top, although many incorporated internal staircases and ramps leading to tombs, as did the un-stepped pyramids. Particularly dramatic examples can be found at Ur, Iraq (2125–2025 BC) and in Mexico at Teopanzolco (1200–1521 BC), Tikal from *c*.800 BC, Cholula and Teotihuacan (Figure 1.2), both *c*.200 BC. Structurally, they are all extremely simple, consisting of bricks or stones cut to size and heaped up, one on top of the other.

1.2 Pyramid of the Sun, Teotihuacan 40 km west of Mexico City. (Michael Tutton)

Ancient Egypt and Ancient Greece

Egyptian temples had staircases often located in the entrance pylons. These were of stone or brick in straight flights within the massive outer walls, often
consisting of the only internal space within the lower part of the pylon. They date from the First Dynasty (3100–2600 bc) onwards.[3] They are to be found, for example, at the Temple of Khons at Karnak, 1200 BC and the Temple of Horus at Edfu, 237–42 BC. Egyptian houses had staircases, as evidenced by excavation, clay and wooden models found among grave goods and wall paintings. They ranged from single storey, often with an outside staircase to the roof, to two or sometimes three storeys. Many internal staircases were of timber carried on beams (carriage pieces) and had straight flights. The

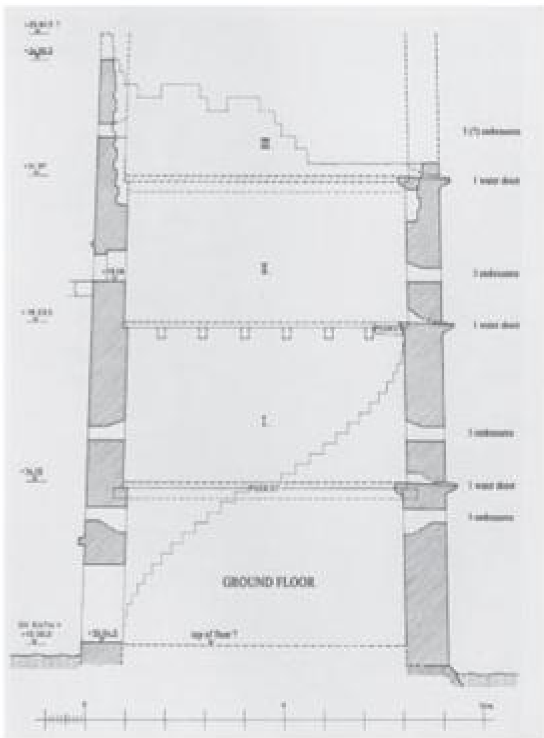
common external staircase to a roof terrace could be stone or brick.

Winding or spiral staircases are not so common in Egyptian architecture, but the earliest significant example, possibly as early as the Nineteenth Dynasty (1307–1196 BC), is at the complex of temples at Deir el-Medina. They became more widespread later, with examples at the pylon at Edfu, along with the other straight flight stairs and at the Egypto-Roman temple at El-Maharraqa.[4] Along the Nile, spiral staircases were often constructed to form wells or Nilometers, to measure the height of the Nile. They first appear from *c*.760 BC and continue to be built into the Roman era. There is a fine example at Kom Ombo.

Invention of the cantilevered stair

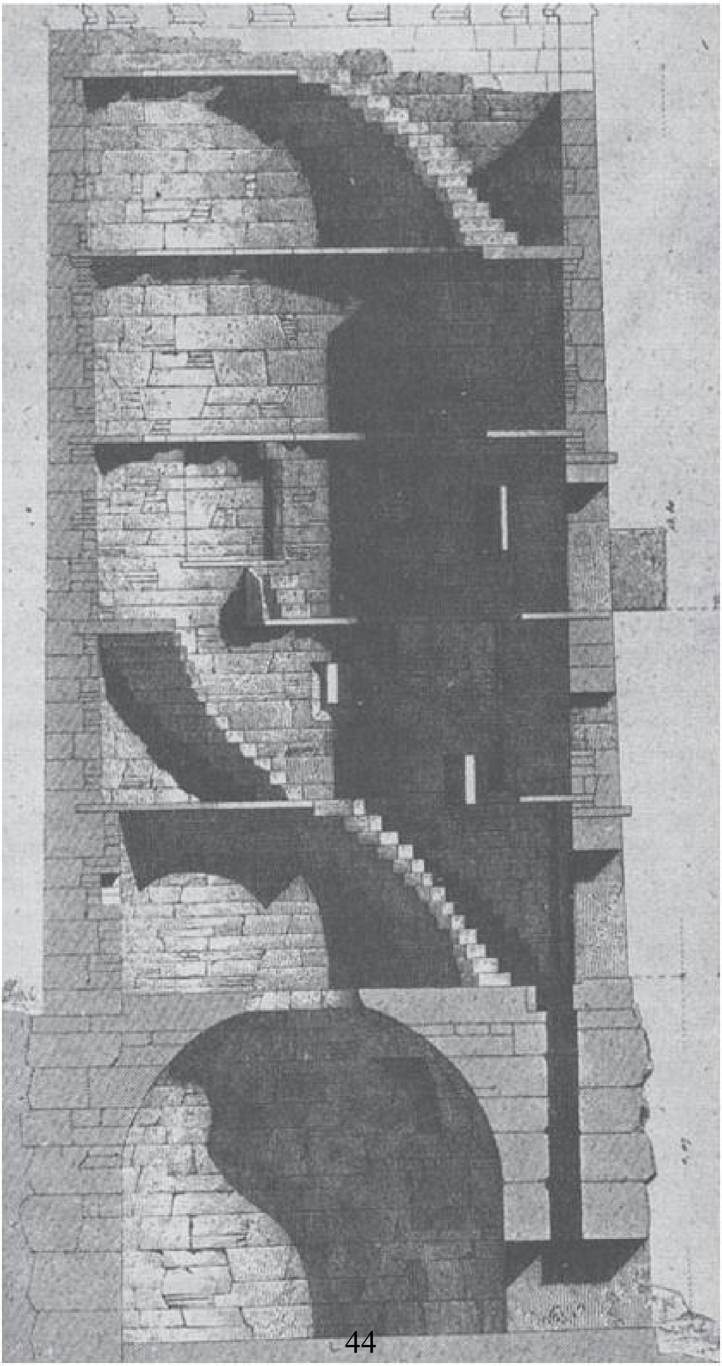
Among the most remarkable spiral staircases of antiquity are those to be found on the islands of Naxos and Andros in the Cyclades. Here the remains of two remarkable staircases, both of the Hellenic period (500–300 BC), survive within circular towers. These staircases are cantilevered, set into the outer walls of the tower and without visible support to the internal open well.

The tower on Naxos at Pyrgos Chimarrou is built of local marble and stands approximately 15 m high, although the top part has collapsed.[5] Internally, the remains of a marble staircase rise clockwise with treads embedded in the wall (Figure 1.3). The tower of Agios Petros on Andros, some 2 km inland from the town of Gavrio, is more impressive. It stands 20 m high and is built of local schist. The dramatic spiral staircase starts at the first-floor level, where there is a doorway or window in the wall but no immediately obvious access from the ground. A doorway at ground level gives onto a circular vaulted room, the top of which has collapsed thus giving a view of the staircase rising up through the tower (Figures 1.4–1.5).[6]



1.3 Pyrgos Chimarrou tower on Naxos. Schematic section and partial reconstruction. (Lothar Haselberger, 1972)

1.4 Remains of the cantilevered staircase in the tower of Agios Petros on the island of Andros. Taken from the ground-floor vaulted room through the collapsed crown of the vault. (Michael Tutton)



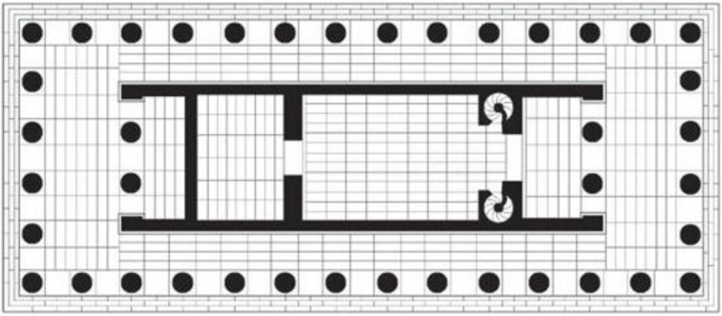
1.5 Engraved section of the tower of Agios Petros on the island of Andros *c.*1843, after a drawing by E. Landron in Le Bas and Reinach, 1888. Access to the first floor internally is via the shaft through the lintel of the lower doorway.[7] The representation is not entirely accurate and the machicolations are Landron's own interpretation, this being an ancient Greek building, not a Medieval one.

Both of these are spiral cantilevered staircases and such staircases may have been common. The tower of Agia Triada on the island of Amorgos, an oblong tower, contained several staircases in straight flights, the surviving remnants of which 'are cantilevered monoliths projecting from the west wall's inner face'.[8] Similar round or square towers of the same period were widely distributed throughout the islands and the Aegean. Some 150 have been identified, mostly contained within the inner group of the Cyclades islands. Others have been found elsewhere in the Ancient Greek world, including Attica, Asia Minor and the Crimea.[9] At many sites only the foundations remain. The cantilevered stair found its way into the Islamic world, in the Medieval to late Medieval periods, but was not taken up in Medieval Western Europe although it was certainly reinvented there during the Renaissance.

Much of Greek formal architecture was single storey, reached by external stairs of cut stone. Greek temples sat on symmetrical stripped plinths, in contrast to later Roman temples, which were generally approached by a set of stairs from the front. While plenty of external examples survive, internal Greek stairs are less common. The western Greek temples, principally those in southern Italy and on the island of Sicily, are unusual in having pairs of interior staircases which lead to the attic. They are generally sited within the cella, the sacred chamber, either side of the doorway from the pronaos or outer vestibule. It is thought that their function was to gain access to the upper space in the roof for ritual purposes rather than the utilitarian functions of storage or maintenance of the roof structure.[10] Many of these staircases are helical, usually built partly within the thickness of the internal walls. They are always in pairs opposite each other, one being clockwise and the other anticlockwise, typically with treads no more than approximately 650 mm wide. The most remarkable survival of these staircases is in the temple of Concord at Agregento, *c*.430 BC, on the south coast of Sicily (Figure 1.6), where both staircases survive to attic level and are still usable today.[11]

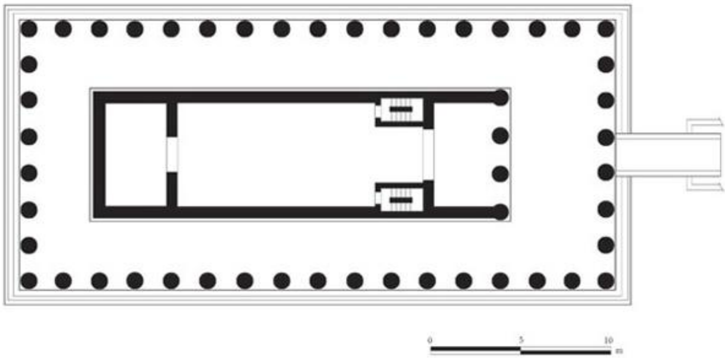
1.6 Temple of Concord, Agregento, Sicily. The pair of staircases are housed within the superstructure to the left within the colonnade; their landing at attic level is just below the inner pedimented section. (Michael Tutton)

Further up the coast to the west at the complex of temples at Selinunte, sufficient evidence of temple A, *c*.450 BC, remains for the reconstruction shown in Figure 1.7. The base of the shaft of the northern staircase and many treads and fragments survive to indicate a newel spiral staircase with a chamfered soffit (Figure 1.8).[12] Other examples of these staircases on mainland Italy were constructed in straight and dog-leg flights, particularly those at the temple of Hera at Foce del Sele, south of Salerno (Figure 1.9) and the second temple of Hera at Paestum (Figure 1.10).[13] These staircases in their spiral arrangement must be considered the forerunner of the medieval form.



1.7 Temple A at Selinunte, Sicily. Reconstructed plan and section. (Drawn by Niall Bird)

1.8 Temple A at Selinunte, Sicily. Stair tread *c*.450 BC. Here is clearly seen the precursor of the newel stair seen in virtually every house, fortress and church of the Romanesque and Medieval periods. (Margaret M. Miles)



1.9 Foce del Sele, Salerno, Italy. Temple of Hera. Reconstructed plan. (Drawn by Niall Bird)

1.10 Paestum, Temple of Hera II. Block of three stair treads, resting at an angle, in the middle foreground. (Margaret M. Miles)

The Orkney and Shetland Islands

Some of the earliest examples in Northern Europe are those in the Orkney Islands. The complex known as Mine Howe at Tankerness is yet to be dated with any precision, but there is little dispute that it is Iron Age (between 800 BC and fifth century AD).[14] It contains stone stairways. These stairs descend two storeys below ground and consist of a ladder-like construction of stone slabs forming the treads set into the side walls of inclined shafts (Figure 1.11) The purpose of these stairs is a mystery, they almost certainly had some ceremonial and religious function, possibly associated with burial and entry to the underworld. The solidity of their construction is compelling evidence for an early tradition in stairbuilding. Similar stone stairs exist elsewhere in Orkney; at Gurness within the famous Broch is a similar staircase leading down into a well. There are at least nine other sites in Orkney and structures in Shetland and Caithness that have similar features.[15] Continuing this tradition, the brochs of the far north and northwest Scotland, many built within the period 100 BC to AD 100 and possibly the greatest achievement in dry stone building,[16] had inter-mural staircases for access to upper floors. These are clearly seen at the Broch of Gurness (Figure 1.12) and at Burroughston on the Island of Shapinsay. Other notable examples are Dun Bharabhat, Cnip and Loch na Berie Dun Carloway, all on the west coast of Lewis and Mousa, the most complete on Shetland.[17]

1.11 Steps leading underground at Mine How, Tankerness, Orkney Islands, mainland. The purpose of these steps remains a mystery – a symbolic entry into the Underworld perhaps. (Michael Tutton)

1.12 Stairs at Broch of Gurness, Orkney Islands, mainland. (Michael Tutton)

The Roman World

The Romans made few advances in staircase design and construction. They carried on the Greek tradition of pairs of tight newel stairs in temples, particularly in Asia Minor. The sanctuary of Bel, AD 32, at Palmyra, Syria, contains a pair at the southern end on each side of the adytoni.[18] They are unusual in that the eastern one is in a square shaft and consists of a dog-leg stair, while the other on the western side is a spiral newel stair (Figure 1.13); the significance of this is not known. Within the outer enclosure or Temenos, at the northwestern corner are the remains of a spiral stair that would have led to the roof of the colonnade (Figure 1.14); there was probably one at each corner.[19] Although the actual stairs are narrow, they are built of monolithic blocks, comprising several treads, and is set within a group of pilasters forming the corner of the inner colonnade. Lying on the ground nearby are other blocks forming treads (Figure 1.15). Within the propylaea, or main gate, mid-way along the western wall of the sanctuary are a similar pair of staircases to those in the temple, either side of the entrance portals. Both of these are dog-leg stairs, again cut from monolithic blocks.[20]

1.13 The western stair within the inner chamber or adyton of the Temple of Bel, Palmyra, Syria. This is a newel stair where the newel and tread are one piece of stone and each section is separate rather than several treads being cut from a single block. This is the standard mode of construction adopted in Europe in the Medieval period, particularly in England from the end of the twelfth century onwards. Several treads have sheared off and have fallen through to the base and sections of displaced newel block the upper part of the stair; possibly damage associated with earthquakes. (Michael Tutton)

1.14 Temple of Bel, Palmyra, Syria. Northwestern corner of the outer enclosure, restored part of a spiral staircase which would have led to the roof of the colonnade. This is a newel staircase but made of large blocks of stone incorporating two or three treads. There would have been four such staircases, one at each corner. (Michael Tutton)

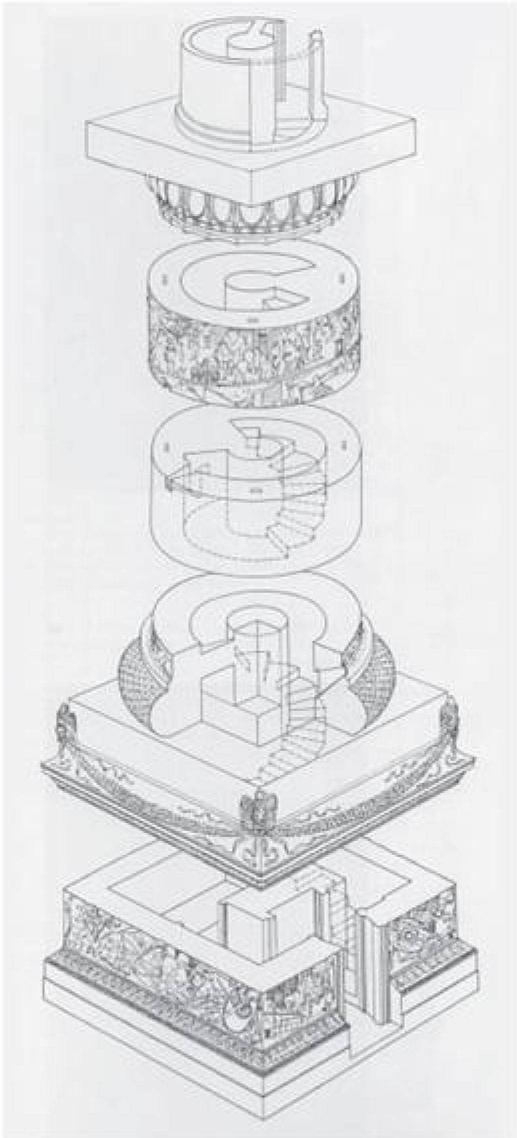
1.15 Temple of Bel, Palmyra, Syria. Newel and three treads all cut from a single monolithic block, part of the staircase shown in Figure 1.14. (Michael Tutton)

Similar pairs of dog-leg staircases are also found in the temple of Bacchus at the sanctuary of Jupiter Heliopolitanus, at Baalbek in Lebanon, begun 16 BC. This time they are each side of the entrance portal and accessible from both the exterior and interior. Part of the shaft and flights of the southern stairs are visible from inside the cella, where part of the wall has collapsed.

Also at Baalbek are the remains of ceremonial staircases within the monumental altar in front of the Temple of Jupiter. These are in straight flights and again have several treads cut from single large blocks (Figure 1.16).

1.16 Baalbek, Lebanon, Temple of Jupiter, ceremonial staircase forming part of the monumental altar, one of a pair either side of the altar. Huge blocks of stone are employed, a significant feature of Baalbeck; in the foreground are three treads and side walls all hewn from the same piece of stone. (Michael Tutton)

The culmination of forming staircases in monolithic blocks of stone comes with the construction of Trajan's Column in AD 113. Each piece of stone contained seven risers forming a half revolution (Figure 1.17).[21] The column is at once a vehicle for the spiral narrative told on the exterior, depicting Trajan's victory in the Dacian Wars, and a vehicle for the staircase within to the belvedere at the top. The stair is well lit with 40 windows at regular intervals so that there are ten at each cardinal point of the compass. The windows are splayed internally so as to accentuate the light. Such lighting levels indicate that the staircase and viewing platform were intended for regular use.



1.17 Exploded perspective of Trajan's Column. The shaft is made up of 19 solid blocks or drums of Carrara marble through which the staircase was cut, anticlockwise *in situ* before erection. Each drum contains one half of a revolution comprising eight risers and is typically 5 ft high (1.525 m), and has a constant 7 ft headroom (2.135 m) with a continuous smooth soffit. The stairs within the pedestal, which is 20 ft (6.16 m) high are otherwise composed of straight flights contained within eight massive blocks of stone. At the top the spiral stairs finish flush with the top of the capital drum that forms the balcony. On top of this the statue base rises a further 8 ft (2.5 m), within which is cut the opening onto the balcony. (Drawing by Mark Wilson Jones)

Aside from its particular mode of construction using very large blocks of stone, Trajan's Column was the precursor for many such staircases in lighthouses and similar monumental columns, the most notable one in England being the Monument in London (see Chapter 2). Indeed, within 100 years the column had been copied almost stone for stone in the Column of Marcus Aurelius, completed by AD 193 and not much more than half a mile away. Both columns are referred to in contemporary Roman documents, the *Curiosum Urbis Romae* and *Nottia Urbis Romae*, dating from the third and fourth centuries, respectively. Both are lists of buildings and monuments in which interestingly the columns are called *columnae coc(h)lides*, that is to say snail-shell-like.[22] This is an apt description for a spiral staircase, particularly one which rises anticlockwise, for a snail's shell, if cut through in section and laid flat, turns anticlockwise from its opening to the core, the highest point. The Spanish word *Caracol*, with a similar meaning, became widely used in the fifteenth and sixteenth centuries.

Other types of Roman stairs

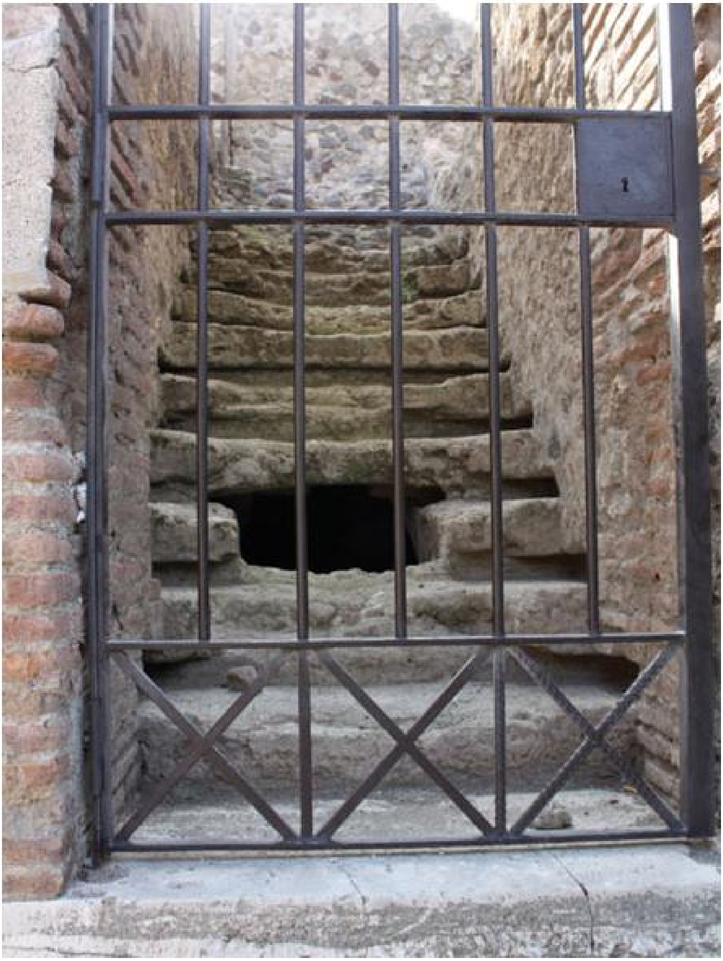
The sheer scale of Roman buildings meant they needed complex systems of stairs. For example, the amphitheatre at Pompeii, *c*.70 BC, has external double-flight staircases carried on an arched structure which transported spectators to the upper levels (Figure 1.18). There are two such double flights at the northwest and southwest, together with single flights at the north and south where the building abuts higher ground. Similar but smaller staircases exist at the theatre at Paestum, *c*.100 BC–AD 100, built in brick and supported on brick arches (Figure 1.19).

1.18 Pompeii, Italy, the amphitheatre. Double-flight staircases carried on mirrored diminishing arches. There are two such pairs of flights and this is the northern one. At the extreme north and south ends are single flight stair which climb up the bank where the building abuts higher ground. (Michael Tutton)

1.19 Paestum, the Roman theatre, started in the first century BC. The entire staircase structure is of brick. These stairs may have originally been external as at the Pompeii Amphitheatre. The theatre was altered and added to in the first century AD, with the outer colonnade adding both height and width. The stairs may date from this time as the brick exterior contrasts with the stone interior. (Michael Tutton)

There is much evidence for domestic stairs in residential and commercial properties, examples of which have survived at Ostia Antica, Pompeii, Herculaneum and Paestum. Straight flights of brick stairs to upper storeys can be seen at Ostia Antica. Very few timber examples survive intact. Those that do consist of simple straight flights of stairs of solid treads supported on strings or carriage pieces, such as those at Herculaneum. Most such stairs would have started with a small section of masonry steps to be continued in timber. The base of such a staircase can be seen within the remains of Roman housing at Paestum (Figure 1.20). Pompeii and Herculaneum abound in masonry staircases leading direct from the street to upper apartments over shops and other commercial premises. Most are straight flights carried on solid masonry or arches (Figures 1.21–1.22).

1.20 Paestum, base of an internal staircase in a Roman house. The Greek Temple of Athena can be seen in the background. (Michael Tutton)



1.21 Staircase in the Vicolo della Terme, Pompeii. There is a chute into, or ventilation for, the cellar below and a staircase down to that cellar immediately to the right. The treads were originally overlaid with a different material, the insets for which can be clearly seen. This has either perished or has been removed or stolen. It may have been a thick tile or brick, timber or marble. The staircase leads directly off of the street. (Michael Tutton)

1.22 Staircase leading from the street to an upper floor in Herculaneum. (Michael Tutton)

The Minaret

It is difficult to establish whether the Roman column model directly influenced the form and construction of the minaret of Islam. Certainly the minaret was influenced by the towers of Christian churches in Syria and possibly by early lighthouses such as the Pharos of Alexandria. The similarities are certainly there, the staircase within a monumental column going nowhere but the top for the purpose of viewing. In Muslim architecture the purpose was first to signify the presence of Islam and later to call the faithful to prayer by the Muezzin from the top. Towers were also built as landmarks and victory towers without being attached to mosques. They represent a high achievement in engineering, many in earthquake zones, and the art of constructing tall independent structures with integral staircases, which mostly rise anticlockwise.[23] Apart from the norm of single staircases in minarets, their builders employed various configurations of multiple spirals.

The earliest surviving minarets date from the ninth century and have external stairs. At Samarra in Iraq, the al-Malwiya minaret, built CE 847–861, associated with the great Mosque of Jami al-Mutawakkil, stands approximately 55 m high. The spiral ramp-like steps wind anticlockwise around the minaret five times and end in a circular chamber. The Mosque of Abu Dulaf, built CE 859–861, has a similar but smaller minaret with stairs that revolve four times. Both minarets are built of brick and clay and have been restored in recent times.[24] Another minaret of this type with an external spiral stair is in Cairo at the Ibn Tulun Mosque, completed CE 879 (Figure 1.23).

1.23 Minaret, Ahmad Ibn Tulun Mosque, Cairo. The circular drum with external spiral stairs is coeval with the mosque built between CE 876 and 879. The square base and lantern are later additions. (Berthold Werner, http://commons.wikimedia.org/wiki/File:Kairo_Ibn_Tulun_Moschee_BW_11.jpg)

The Jam minaret in western Afghanistan, built in the last quarter of the twelfth century, is a stunning and almost completely isolated victory tower, 'alone and perfect'.[25] It stands 65 m high and is constructed entirely of brick in four vertical sections: an octagonal base some 7 m high, the original entrance now buried beneath several metres of alluvial deposits, and three cylindrical shafts. The

three circular sections are divided by the remains of two balconies and the minaret is topped by a six-sided lantern composed of open arches. Inside the lower sections up to a height of 38 m to the level of the second balcony is a double spiral staircase (Figure 1.24) The steps are keyed into the minaret's central pillar and its exterior wall and are composed of, as is the whole structure, large flat bricks, almost very large tiles similar to Roman bricks. These bricks forming the treads are laid flat, without any attempt at vaulting, which is normal and almost universal in later brick staircases, and act as flat brick arches (Figure 1.25). Further up in the narrower upper shaft is a series of six vaulted brick platforms which complete the rest of the minaret's internal structure. There is much evidence of timber elements in this upper section, possibly structural reinforcement,
much of which has rotted away. The vaults are accessed by a series of six steep, staggered steps, five or six courses high, whose rough construction and narrowness are in marked contrast to the staircase below.[26]

1.24 Jam minaret, western Afghanistan, the two spiral flights clearly visible with a figure (the boots only visible) standing atop one flight while another in the left foreground nears the top of the other flight. Each tread has a rebate at the leading edge where there was once a timber element or nosing. (David Thomas, MJAP 2005)

1.25 Jam minaret, western Afghanistan. The flat brick soffit is shown at the top of the photograph. The staircase is 1.4 m wide near its base and tapers gradually to 1.0 m wide at its summit. Each step is *c*.0.4 m deep at the exterior wall and consists of four courses of four or five baked bricks, laid horizontally. The steps range in height from 0.21 m to 0.33 m. (David Thomas MJAP 2005)

At the Üç Serefeli (triple-galleried) Mosque, built 1438–1447, in the market square of Edirne, Turkey, the four minarets are worthy of examination. The minaret at the northwest corner has three balconies, said to be the first such minaret in Islam; the northeast corner minaret has two and the two remaining have one each[27] Each balcony is reached by a separate staircase, thus the northwest has a triple spiral stair:

Superimposed one on top of the other and leading from the ground to the summit of the tower, so that three people can ascend at the same time, one above the other, and each hear the footfalls of the others because they are only separated by the thickness of the steps.[28]

The northeast minaret similarly has a double spiral stair and the southeast and southwest only a single.[29]

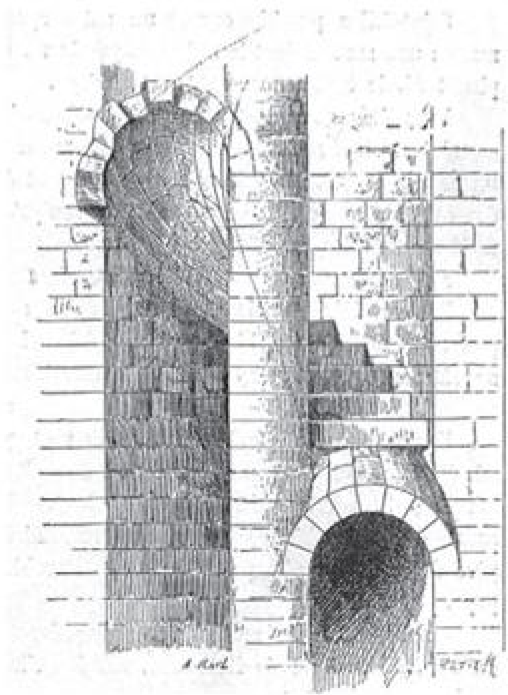
The Medieval Stair

Staircase types that had been common in the Greek and Roman worlds carried through to the Medieval period without much change or innovation. Indeed, the spiral stone vaulted staircase that became widespread throughout Europe (except England) during the

Medieval period had its antecedents in the first century AD Romano-Egyptian staircase at Kom-el-shoqafa, Alexandria. One of its direct descendants, although at some distance in time but not geographically, is the staircase within the wall of the Bab el Nasr gate in Cairo, which was built between 1087 and 1092 by Armenian masons from Urfa (Edesse in modern southeastern Turkey), who brought with them their particular skills possibly derived form Mesopotamian or Hellenistic origins, as well as those from Alexandria.[30] The staircase is constructed as a vault using large stones of 60–80 cm in length and employing complex geometry and stone-cutting skills (Figure 1.26).

The Bab el Nasr staircase is the precursor of the famous Vis de Saint Gilles at St Gilles du Guard in southern France (Figures 1.27 and 1.28). Built *c*.1150,[31] it became a site of pilgrimage, not for religious purposes, but for stone masons and apprentices to study its exacting stereometry. Thus the seeds were sown for the spiral vaulted staircase throughout France and further afield.[32]

1.26 Vault of the staircase in the Bab el Nasr, Cairo, Egypt. (L. Tamborero, 2002, see note 30).

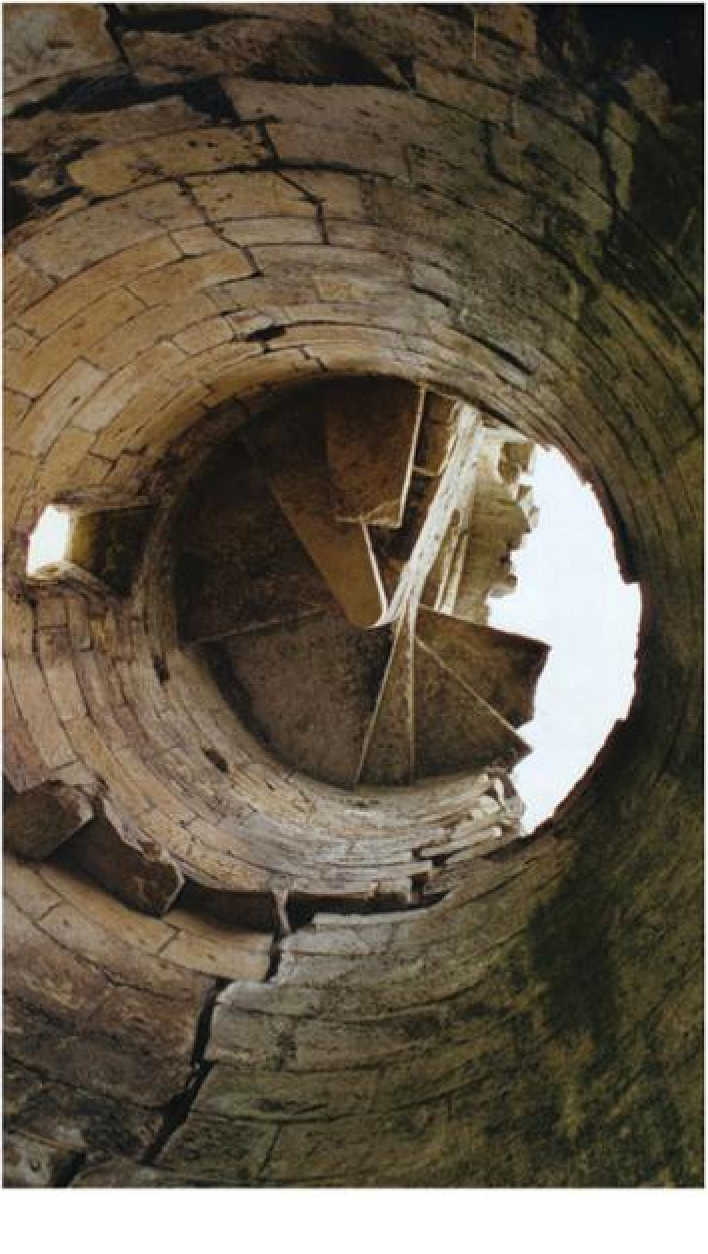


1.27 Sectional drawing by Viollet-le-Duc of Vis de Saint-Gilles, illustrating the principle of cut stone vault construction for spiral staircases.

1.28 Saint-Gilles du Gard, southern France. The famous Vis de Saint-Gilles. (BIERNE Remi)

Not all spiral staircases were cut stone vaults, many were formed with a very coarse or rubble matrix concrete using formwork. This particular

form of construction was exported by the Normans to England after 1066 (see the following chapter). The basic principle, as for stone vaults, is that the vault springs from the central column or newel and the enclosing wall of the drum or shaft. The tread, often made up of more than one piece of stone, is independent of both newel and shaft (Figure 1.28). The other basic type of spiral stair is the newel staircase in which the tread and newel are
all the same piece of stone, the whole being 'key-hole' shaped (Figure 1.29). Each tread acts as a beam with its thicker outer end built into the shaft and the rounded inner end stacked one on the other to form the newel.



1.29 The ruined spiral newel staircase at Rievaulx Abbey, looking up the shaft, showing the typical triangular or key-hole shape of the tread with the rounded end which forms the newel. The upper parts appear to act as a 'cantilever', but is probably consolidated by the Ministry of Works with hidden metalwork. (Michael Tutton)

Many staircases from the early to late Medieval period are to be found in fortifications, castles and religious buildings. Both straight flights and spiral forms are found and in many buildings a combination of the two. In castle buildings stairs and the configuration of floors that they serve are mainly designed for security and privacy. The architects and builders certainly took defence into account, but the idea that the clockwise spiral stair was designed to aid a defensive force is a popular myth.[33] These staircases vary considerably in size, although the newel type, at least until the late Medieval period, tended to be narrow due to the constraints in cost and practicality of obtaining long pieces of stone. The rubble vaulted eleventh-century main staircase at Colchester Castle, England, on the other hand, is just under 5 m in diameter. With a newel of less than half a metre diameter, this is the widest Medieval spiral staircase in Europe.

Late Gothic and Early Renaissance Spiral Stairs

One of the first developments was to bend or coil the newel itself into a spiral; the Spanish architect and sculptor Guillem Sagrera[34] designed and built such a staircase into one of the interior corner turrets of the Llotja (commodities exchange) in Palma de Mallorca, built 1426–1446 (Figure 1.30), the model of which came to be known as ‘Caracol de Mallorca’.[35] This type of staircase became popular throughout Spain, with examples in the Valencia Llotja (Figure 1.31), commenced 1483, Salamanca and Murcia. Valencia is particularly rich in these staircases, with further examples at the Torres de Quart (Figure 1.32) and in the Royal Chapel of the convent of Santo Domingo. Much later Gaudi would use a similar design for the tower stairs of the Sagrada Familia in Barcelona, commenced 1882. Some of these staircases where the central aperture is small are essentially newel staircases, and we can assume that the newel acts in a similar way to a vertical one. The departure from this comes with Segrera’s next commission in Naples[36] Here he produced a truly remarkable staircase in the Castel Nuovo. In a much larger shaft he opened out the aperture to produce an open well, the structurally enigmatic spiral vault, also known as a *caragol ull ubert* or ‘open-eyed’ staircase[37] (Figure 1.33).

1.30 Palma de Mallorca, Llotja, spiral vault staircase designed by Guillem Sagrera, built 1426–1446. (Jose Calvo-Lopez and Alberto Sanjurjo-Alvarez)

1.31 Valencia, Spain. The Llotja staircase, begun 1483. (Jose Calvo-Lopez and Alberto Sanjurjo-Alvarez)

1.32 Valencia, Spain, Torres de Quart. Looking up the staircase. (Felivet, http://commons.wikimedia.org/wiki/File:Torres_quart_escala.jpg)

1.33 Naples, Italy. The stunning spiral vault staircase in the Castel Nuovo. The figure in the right foreground gives scale to this exceptional piece of architecture and stair building by Guillem Segrera. (Jose Calvo-Lopez and Alberto Sanjurjo-Alvarez)

The spiral stair thus far had been relatively dark, with a solid central newel, or drum, effectively blocking the light from any windows and
limiting how far it could penetrate down the staircase. Likewise the outer wall remained solid, with relatively few openings. Even the open apertures and wells of the Spanish 'Caracol de Mallorca' staircases were mostly in gloomy shafts. However, this began to change in the late Middle Ages. In later Medieval domestic design the spiral stair often became a feature of the external design and enlarged to provide a dramatic entrance to grander

apartments on the first floor. The stairs themselves began to evolve as a result into external turrets with windows.

The brothers Ernst and Albrecht von Wettin in 1470 commissioned the architect Arnold of Westphalia to design a palace in Meissen adjoining the cathedral. The palace contains two spiral staircases. The lesser of the two is a derivation of the ‘Caracol de Mallorca’, without the open aperture, with a twisting ribbed newel. From this springs an intricate crystalline vaulted soffit without ribs, just curving arrises.[38] The stone treads with bold nosing are concave (Figure 1.34).

1.34 Meissen, Germany, Aubrechtsburg, by Arnold of Westphalia. (Michael Tutton)

The principal staircase (Figure 1.35) is unusual in having alternating convex and concave treads between landings. It has an open well with three slim vertical supporting columns (Figure 1.36). Through these run a ribbed and moulded string and handrail. Springing from the columns is a complex vaulted soffit starting with moulded ribs which meld into simple curved arrises. The columns, string, banister and ribs are all of one rust-red stone and the soffit plaster. The whole composition is one of exquisite complexity.

1.35 Meissen, Germany, Aubrechtsburg, by Arnold of Westphalia. The main staircase 'has a dynamism all its own, one that elicits the torsion of its architectural components'.[39] (Michael Tutton)

1.36 Meissen, Germany, Aubrechtsburg, by Arnold of Westphalia. The main staircase looking up through the centre. (Michael Tutton)

A similar staircase by the architect Hans Thoman Uhlberger is in the Œuvre Notre-Dame building in Strasbourg. An adjoining linked building known as the Frauenhaus served as the lodging for masons working on the cathedral,[40] which may explain the intricate design of the staircase which serves both buildings, built 1570–1574. This is a stair with a spiralling newel with the added support of three circular columns. The treads are straight, with bold squared nosings and a deep overhang. The staircase ends at the top in a riotous assembly of tightening spirals and columns which rise to the vaulted ceiling (Figures 1.37 and 1.38).

1.37 Strasbourg, France, staircase, built 1570–1574 in the Œuvre Notre-Dame building by Hans Thoman Uhlberger. The soffit, composed of parallel spiralling ribs in continuous lines, runs from the base to just above the first floor, where it ends abruptly and continues unadorned. The ribs are plain except for two outer and one central in the form of a tree or vine trunk. The supporting columns rise through the handrail and newel, just below the intersection with the newel are classical composite capitals. (Michael Tutton)

1.38 Strasbourg, France, staircase, built 1570–1574 in the Œuvre Notre-Dame building by Hans Thoman Uhlberger. The top landing. (Michael Tutton)

Some of the most dramatic skeletal or lattice spiral stairs were designed by Ulrich von Ensingen (d. 1419), such as at Ulm Cathedral where, as well as corner stairs, a central dazzling open staircase rises through the centre of the spire, taller than Strasbourg but only completed in the nineteenth century. He also designed the octagonal open-work north tower of Strasbourg cathedral[41] which has at its four corners quite audacious detached open lattice-work spiral staircases, built 1402–1419 by those same masons who lodged at the Frauenhaus. As the octagon rises and steps in, the vertical polygonal 'tubes' become more detached; apart from metal strengthening bars they are attached only by short bridges at the top, to the base of the spire (Figure 1.39).[42] Within the open lattice-work spire a whole series of staircases from each corner step inwards as they rise and the spire diminishes in girth.

1.39 Strasbourg, France, north tower of the cathedral with detached staircases at each corner. (Michael Tutton)

A series of three spiral staircases in the castle of Chateaudun in the Eure-et-Loir region of France span the watershed of the late Medieval and early Renaissance periods. They are situated at the southwest, northwest and northeast corners of the Cour d'Honneur. The southwest staircase is a classic late Medieval stair, commissioned in 1464, in a polygonal turret. It is a wide newel stair of massive treads with the undersides chamfered to form a slightly stepped soffit. The next stair in the northwest corner, of the same date, is also a newel stair, but about one and a half times wider than the former. It is built into a square shaft with distinctly un-gothic flat arches across the corners; these support the longer treads where joints in the stone have had to be utilised. The south side opens onto wide landings facing into the courtyard. which are lit with high Flamboyant Gothic windows; the influx of light is therefore the significant development from one staircase to the other. The northeast staircase was begun in 1509 and is the finest of the three. The

exterior tower – and it is more of a tower than the earlier central stair – is distinctly transitional. The staircase within, though, is essentially Gothic with Italianate Renaissance adornment. This staircase departs from its two neighbours in that its newel is an independent pillar or drum, approximately 650 mm diameter, into which the treads are housed. The treads are single slabs of pale orange limestone full of ammonite and similar fossils and contrast with the much tighter white oolitic limestone of the rest of the composition.

Some 50 km further south, at Blois, both Louis XII and Francis I commissioned two magnificent staircases. The first, finished *c*.1501, is markedly Gothic in the vaulting at the head of the staircase (Figure 1.40).

1.40 Blois, France, northern staircase of the Louis XII wing. The staircase turns around a central columned newel with wide treads consisting of single blocks of stone, the soffit is simply the underside of the treads without any decoration except for inner and outer mouldings. (Peter Stone)

The great central staircase at Blois, on the other hand, is pure Renaissance. Built *c.*1515–1520, the external elevation is a polygonal turret with open ramped balconies. The treads of the staircase within are subtly convexly curved with a sudden turn outwards at the newel so that the whole on plan has a double curve or cyma. The soffit is slightly curved with a rectilinear lattice pattern of ribs with medallions at the intersections. The bays of the outer curved wall are divided by responds in the composite order with pedestal bases. On the courtyard face these frame open arches onto the balconies with open, unglazed windows. On the inner face they are blind arches or frame the richly carved doorcases into the principle rooms and apartments. The newel column is carved with Italianate detail (Figures 1.41–1.42).

1.41 Blois, France, the main staircase of the Francois I wing. (Peter Stone)

1.42 Blois, France, exterior of the main staircase of the Francois I wing. (Peter Stone)

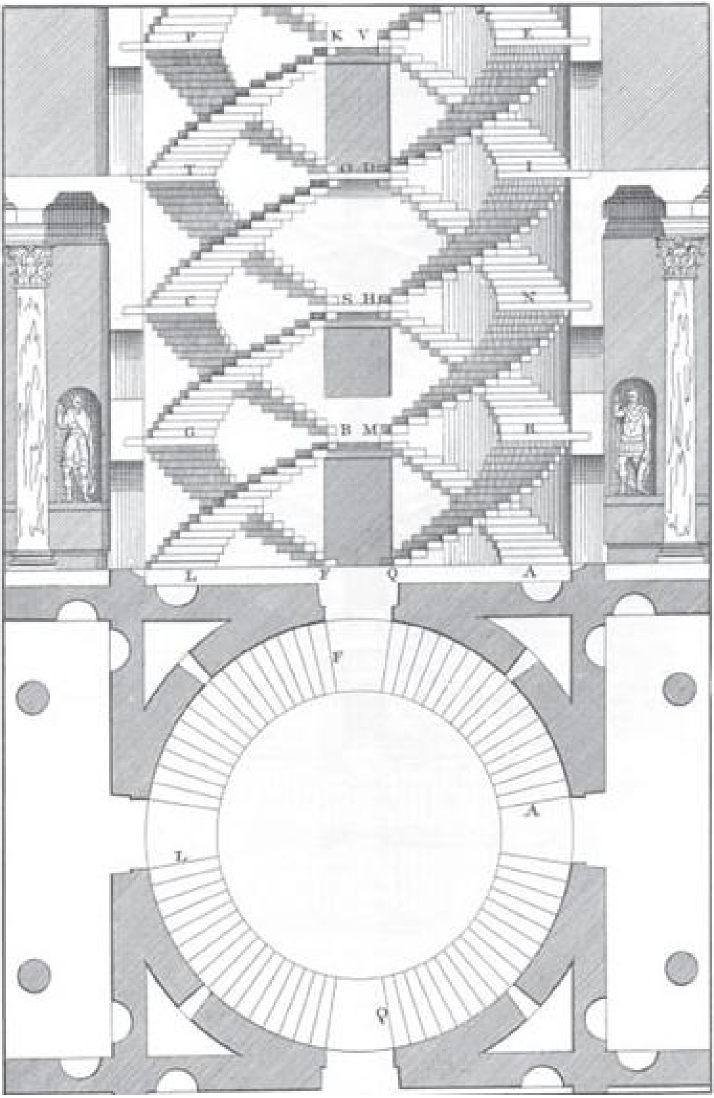
The Renaissance

Soon after Francis I had remodelled Blois,[43] he turned his attention to Chambord, begun 1519, some 12 km or so to the west, where he built a vast chateau which boasts some 77 staircases. Within the central cruciform keep is one of the grandest spiral staircases ever built (Figure 1.43). The central staircase at Chambord is a double helix which gently rises to each of the three principle floors of the keep. At the centre is an open well with windows looking into the central shaft (Figure 1.44). Reginald Blomfield described this staircase, along with those at Blois and the northeast one at Chateaudun, as the apotheosis of the newel staircase of the Middle Ages.[44]

1.43 Chambord, France, the majestic central staircase, here rising from the ground to the first floor. Access to the opposite spiral can be gained by passing through the central shaft rather than walking around the staircase, a necessity on the upper floors. (Peter Stone)

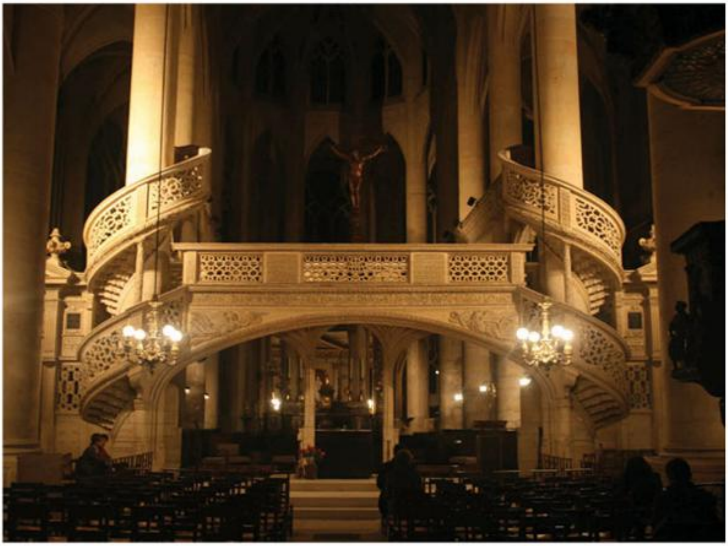
1.44 Chambord, France, the central shaft and internal windows. The shaft is reminiscent of the well of San Patrizio at Orvieto, built by Antonio da Sangallo in 1532, around which a ramp runs and the much earlier shaft at Kom el-Shuqafa in Alexandria, Egypt which forms the core of a spiral staircase down to the catacombs and dating to the first century ad. (Peter Stone)

The Chambord staircase quickly became justly famous and Andrea Palladio (1508–1580) famously included an accurate drawing and description of it in his first book of *The Four Books of Architecture* (1570) (Figure 1.45). It is quite clear, however, that he never saw it firsthand.[45]



1.45 Andrea Palladio: ‘Another beautiful sort of winding stairs was made at *Chambor*, (a place in *France*) by order of the magnanimous King FRANCIS, in a palace by him erected in a wood, and is in this manner: there are four stair-cases, which have four entrances, that is, one each, and ascend the one over the other in such a manner, that being made in the middle of the fabrick, they can serve to four apartments, without that the inhabitants of the one go down the stair-case of the other, and being open in the middle, all see one another going up and down, without giving one another the least inconvenience: and because it is a new and a beautiful invention, I have inserted it, and marked the stair-cases with letters in the plan and elevation, that one may see where they begin, and how they go up.' See note 45.

A further example of Renaissance finery can be found in the church of St Etienne-du-Mont in Paris. Here, a magnificent stone *jube* or screen incorporates a pair of spiral staircases which coil up the main columns at the intersection of nave and chancel. The stairs turn two complete revolutions;
at the end of the first they give onto the *jube* (rood loft) then continue up to longitudinal galleries, at right angles to the screen, along the length of the chancel. The 'fantastic boldness of the staircases and the inventiveness of the decorative detail' are attributed to Philibert de l'Orme and are dated 1530–1545 (Figure 1.46).[46]



1.46 Church of St Etienne-du-Mont, Paris, stone screen by Philibert de l'Orme, 1530–1545. (Emma Tutton)

Palladio and the 'Cantilevered' Staircase

Palladio is generally credited with the construction of the first 'cantilevered' or geometric staircase. The Ancient Greek examples discussed above must now supersede this widely held attribution. Furthermore, pre-Palladio cantilevered staircases exist in the Middle East.

The cantilevered staircase in Syria

There are several examples of fine cantilevered staircases in the khans[47] and higher-status houses in the city of Aleppo in northern Syria. Northeast of the Great Umayyad Mosque and almost hidden within the suq[48] is a small khan containing on the interior wall to the right of the gateway a beautifully detailed straight flight cantilevered stair of possibly late fifteenth-century date. It survives virtually untouched without any handrail (nor was any ever intended). The cantilevered treads are composed of cyma-reversa sectioned blocks thus forming a continuous repeat moulding to the outer face of the stairs (Figure 1.47).

1.47 Aleppo, Syria, cantilevered staircase in a khan in the suq adjacent to the Great Umayyad Mosque. (Michael Tutton)

The stairs rise to a now blocked doorway. The lower four cantilevered treads have been underbuilt, possibly to form some sort of enclosed storage space rather than for structural reasons. The lowermost eight or so treads are composed of solid masonry and the first four or five are missing.[49] A few metres from this first staircase within the same suq is another equally refined staircase, late fifteenth to late sixteenth century. This starts within a vault between a pillar and the corner of a building, but continues as a cantilever in its upper part around a slightly curved wall to the floor above (Figure 1.48). Here, a decorative, if crudely fixed, balustrade has been inserted as the staircase is still in regular use.

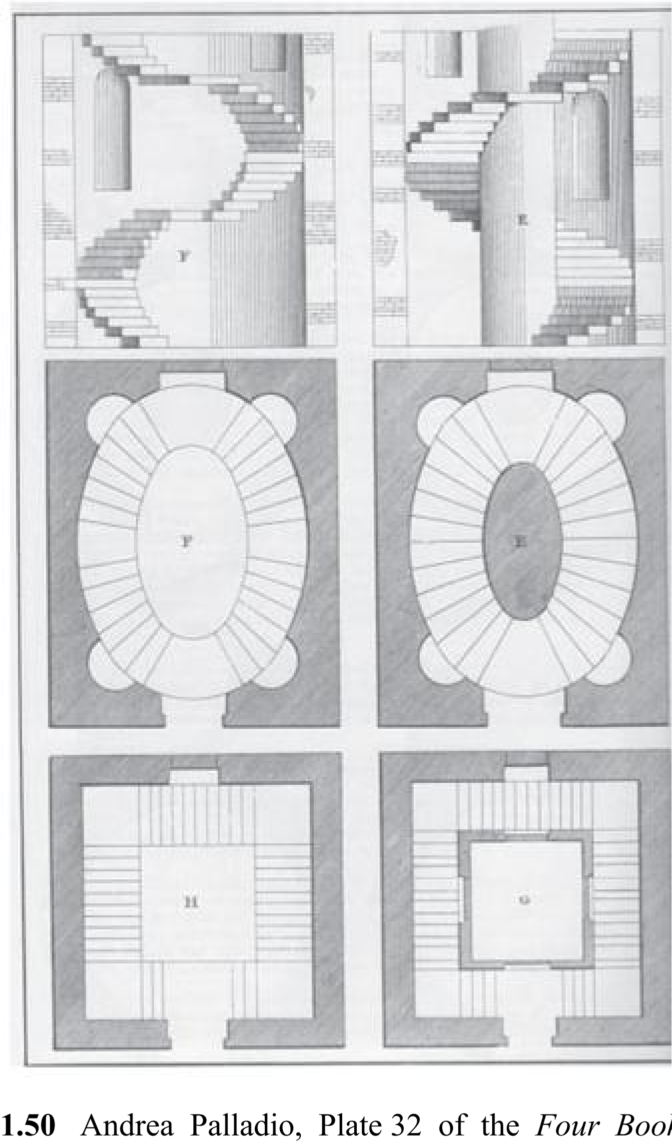
1.48 Aleppo, Syria, cantilevered staircase in the suq adjacent to the Great Umayyad Mosque. (Michael Tutton)

Such staircases are not uncommon and cannot be post-Palladio imports from the West. Given that the dates are tentative at present, they are at least contemporary or simultaneous inventions.

Palladio and the Convento della Carita

Palladio's first use of the cantilevered stair is not until *c*.1561, in the Convento della Carita in Venice (Figure 1.49): 'I have made a stair-case void in the middle, in the monastery de la Carita in Venice, which succeeds admirably.'[50] The convent was partially destroyed by a fire in 1630. Fortunately, the staircase survives, incorporated into the present buildings, the Gallerie dell'Accademia. The staircase is oval in plan and conforms to type 'F', the oval staircase without a column shown in Plate 32 of the *Four Books* (Figure 1.50). Its construction is robust and basic, without the Syrian finesse, being rectangular stone slabs set into the wall with a simple overlap of approximately 50 mm tread to tread, there are no mouldings or rebate. The balustrade is equally simple, each baluster is an oval wrought iron bar beaten flat where it is set into the ends of each tread, probably with a pin. Every fifth or sixth (they vary) baluster is square section and has a larger bracket or leg set into the tread. The handrail is also wrought iron forged to a 'D' shape.

1.49 Cantilevered staircase, *c*.1561, in the Convento della Carita in Venice, by Andrea Palladio. (Helen Rogers, www.stonestairs.net)

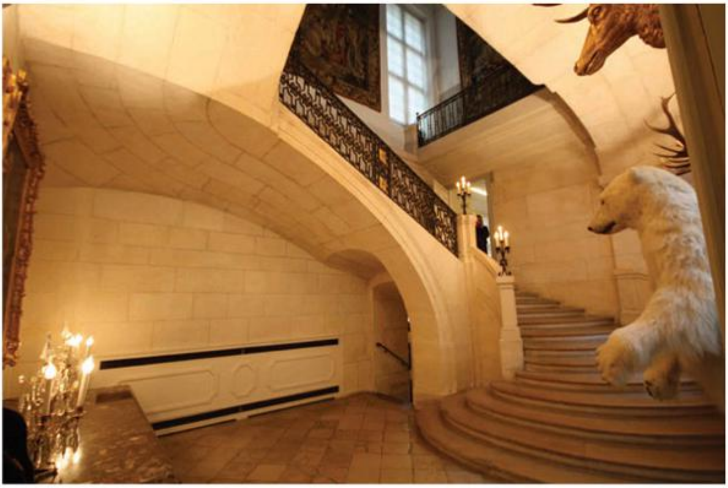


1.50 Andrea Palladio, Plate 32 of the *Four Books of Architecture*.

Palladio may not have invented the cantilevered stair, but he certainly popularised it. The publication of his own works led to his ideas being copied and adapted throughout Europe and further afield. English examples, which are discussed in the next chapter, are widespread and they became extremely common.

Straight Flights and Grand Stairs

The cantilevered staircase did not catch on everywhere. The French, for instance, although not to the total exclusion of the cantilevered staircase, preferred their sometimes called *vis d'honneur*, a derivation of the open-eyed spiral vault. These, adapted to straight and curving flights, often combined with fine wrought-iron balustrades,[51] were constructed as a combination of shallow arches and suspended vaults. They are widespread throughout France and are particularly prevalent in the Marais quarter of Paris, a district of fine mansions or *hotel particuliers*. These mansions were built from the late Medieval period through to the end of the seventeenth century (Figures 1.51–1.52).[52]



1.51 Staircase in the Hotel Guénégaud, rue des Archives, Paris, 1653, by Francois Mansart. (Michael Tutton)

1.52 Staircase in the eighteenth-century wing of the College des Bernardins, Paris, 1749. (Michael Tutton)

The culmination of this genre is the astonishing staircase in the Paris Observatory by Claude Perrault. Built in the 1670s, a masterpiece of stereotomy, it is aptly summed up by Perrault’s own definition, ‘the art of using the weight of stone against itself and supporting it in the air by the same weight that makes it fall’ (Figure 1.53).

1.53 The suspended staircase in the Paris Observatory, *c*. 1670, by Claude Perrault. (Michael Tutton)

Straight flights had existed in the Middle Ages and there are many examples in castles throughout Europe and the Middle East. The coming of the Renaissance ushered in an era of the grand straight flight staircase. Before this, straight flights had passed between walls or wrapped around the outside of buildings or the inside of courtyards.

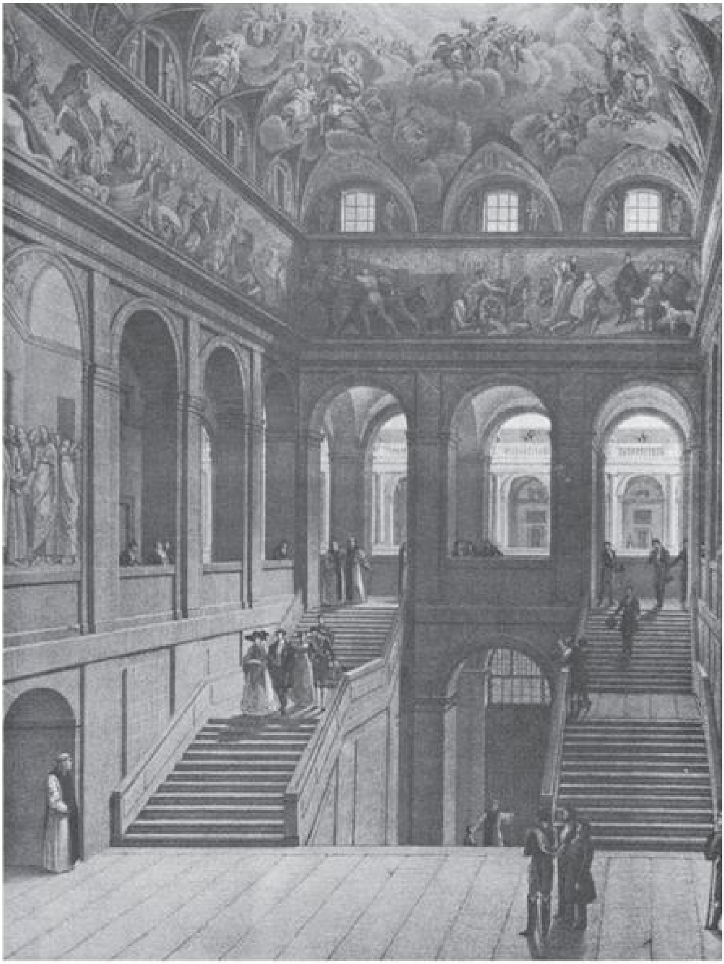
Developments in staircase design took place in Spain, for here we find two great innovations: the open-well stair and the Imperial stair. The first open-well stairs may have been based on drawings of unrealised Italian schemes.[53] Among the first to be found are in Toledo at San Juan de los Reyes, 1504, and the Hospital of the Holy Cross, 1504–1514 (Figure 1.54). Both are designed by Enrique de Egas[54] after designs by the Italian Francesco di Giorgio.[55] The Italian influence probably stems from external courtyard stairs, which are still widespread and can be readily seen in Venetian palaces. Here, the common form is for a staircase to start against a courtyard wall then turn at 90 degrees to continue up the face of the building to the main floor.

1.54 Toledo, Spain, Hospital of the Holy Cross. (Jose L. Filpo, www.panoramio.com/photo/43152817)

Renaissance developments led to the internalisation of staircases with stairs around two and three walls of an internal courtyard or stair hall. This basic form of staircase became common throughout Europe.

Once the principle of the stair hall had been established it was a small step to the invention of the Imperial staircase, where one central flight rises to a half landing of sufficient span to allow two further symmetrical flights to return at 180° to the first floor. An alternative is a staircase starting with two flights and continuing with one in the centre. The important difference between this particular type of staircase and other, say Italian types of the same configuration on plan, is that they are carried in open halls or atria. For instance, the staircase at the Scuola di S. Rocco in Venice, *c*.1546, by
Antonio Scarpagnino on plan resembles an Imperial staircase, but the flights are enclosed within walls with vaulted ceilings.

The first Imperial staircase was constructed at the Escorial, the royal palace and monastery built by Philip II just outside Madrid. This is attributed to Juan de Herrera and finished in 1571, although he followed a succession of other architects and changes in design (Figure 1.55).[56] Juan de Herrera developed the type further in the grand staircase at the Alcazar, Toledo, built *c*.1574[57] (destroyed 1936 and since reconstructed). Here the return flights at 180° are interrupted from the first by flights at 90°, thus resulting in a five-flight staircase (Figure 1.56).



1.55 The Imperial staircase, the Escorial, Madrid, Spain. (Fernando Brambilla, Lithograph from *Coleccion de las vistas del rl. sitio de sn. Lorenzo*, Madrid, 1832)

1.56 The Alcaza, Toledo, Spain. (José Luis Filpo Cabana, http://commons.wikimedia.org/wiki/File:Alcázar_de_Toledo._Escalera.jpg)

Spain exported her ideas to the colonies in South America. A particularly fine example of an open-well staircase, of the same type as the Alcazar, is in the Palacio Nacional in Mexico City (Figure 1.57). Another fine staircase is that in the School of Mines built 1797–1813 by Manuel Tolsa (1757–1816), a powerful baroque imperial staircase.

1.57 Palacio Nacional in Mexico City. The palace, built in the late seventeenth century after the former fortress on the site was destroyed during riots in 1692, is in a colonial baroque style. The staircase also contains the famous murals by Diego Rivera, painted between 1929 and 1935, depicting the history of Mexican civilisation. (Michael Tutton)

The invention of the staircase hall

The eminent architectural historian Ruldolf Wittkower suggests that the first completely enclosed staircase hall of Western architecture is the staircase in
the Biblioteca Laurenziana in Florence, designed by Michelangelo, started in 1524 and not completed until 1559.[58] The staircases at the Escorial and the Alcaza are not in completely enclosed halls, they are semi-open on the ground floor, opening onto courtyards or cloisters. The design of the Michelangelo staircase was also groundbreaking in that it was centrally placed before the door into the library, rather than flights around the walls (Figure 1.58).

1.58 Staircase in the Biblioteca Laurenziana, Florence, 1524–1559, designed by Michelangelo. Commissioned by Pope Clement VII, it was the Pope who stipulated a central staircase rather that twin stairs against the walls. (Timo Orre)

Baroque and Rococo

The Imperial staircases at the Escorial and the Alcazar set the scene for subsequent developments, but they are restrained in their design and decoration and exhibit a somewhat severe and particularly Spanish style: 'modular uniformity, utilitarian placement and structural simplicity'.[59] At the opposite end of the scale and the apogee in sumptuous decoration are the Imperial staircases of the high Baroque and Rococo designed by the German architect Balthasar Neumann (1687–1753) for the German prince bishops at Bruschsal, Wurzburg and Bruhl. At Bruschsal, the residence of the Prince-Bishop of Speyer, Neumann made plans in 1731 for a staircase perhaps more daring than any of his others. Not an Imperial staircase as such, but it certainly evokes Pevsner's phrase of 'princely magnificence'.[60] The staircase within an oval stair hall comprises two opposing curved flights which meet at the landing which extends into an oval platform (Figure 1.59).

1.59 Schloss Bruschsal, Germany, by Balthasar Neumann. The palace was heavily damaged in the Second World War and the vault and staircase destroyed. It was restored and rebuilt in the 1970s with exacting precision and expert craftsmanship. (Martin8721, http://commons.wikimedia.org/wiki/File:Schloss_Bruchsal_Treppenhaus.JPG)

The Residenz at Wurzburg is no less dramatic. It occupied most of Neumann's professional life.[61] The stair hall, which was begun in 1737 and completed in 1742, is one of the grandest baroque staircases in Europe (Figure 1.60).

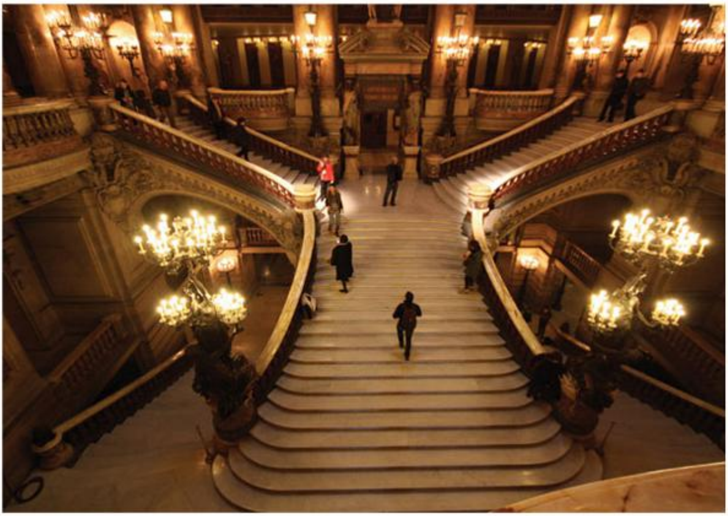
1.60 Schloss Wurzburg, Germany. The Imperial staircase and its crowning glory. On the vault above the stairs is Giovanni Battista Tiepolo’s fresco *Apollo and the Continents*, painted 1750–1751. (Graham Fellows)

At Bruhl in 1744 Neumann was called upon by the Elector Clemens August, Prince-Archbishop of Cologne, to make improvements to his favourite residence, Schloss Augustusburg. The staircase, another sumptuous composition, is of the classic imperial type. The upper flights are carried on arches from the ground, the first columns of which are surrounded by

Atlantes and Caryatids who appear to support part of the stair on their shoulders and arms.

The Nineteenth Century

It is the Renaissance and Baroque, of course, that define many of the grand staircases in nineteenth-century public buildings around the world. Countless examples can be found in government, municipal and commercial buildings. One particular example is Charles Garnier's design for the main stair of the Paris Opera House (1860–1875), built in masonry and finished in various marbles. This is an accomplished exercise in the movement of people through space to produce not only quick and safe exit from the auditorium, but also a brilliant piece of theatre in its own right (Figure 1.61).



1.61 Opera House, Paris. (Michael Tutton)

Iron

Perhaps the most remarkable staircase in Mexico City is to be found in the main post office, aptly named the Palacio de Correos. Designed by the Italian-born architect and engineer Adamo Boari (1863–1928), its many
flights and flying branches are an engineering tour de force in cast iron (Figure 1.62).

1.62 Palacio de Correos, Mexico City. A magnificent composition in cast iron and bronze of palatial splendour and proportions. (Michael Tutton)

The arrival of iron was hugely important. The tensile strength of iron, particularly wrought iron, and later steel and reinforced concrete, allowed flights of stairs and landings to be moved away from the walls, without support from underneath. The nineteenth century provided countless examples of beam structures and even hanging arrangements, and there is no better place to study these than North America.

In downtown Los Angeles the Bradbury Building, built 1889–1893, by George H. Wyman and Sumner Hunt. Behind its modest exterior lies a magnificent full-height, top-lit atrium containing an assembly of cast-iron balconies, stairs with marble treads, and open elevators (Figure 1.63).

1.63 Los Angeles, USA, the Bradbury Building, 'one of the most magnificent relics of nineteenth-century commercial architecture anywhere in the world'.[62] (Gowittylb, http://commons.wikimedia.org/wiki/File:Bradbury_Building,_Los_Angeles--interior_(1).JPG)

A year or so earlier in Chicago, Burnham and Root were building The Rookery and its nine-storey-high oriel staircase, which climbs from the second to the eleventh floor, composed of half spirals connecting each landing. Here, again, cast-iron is used to great effect (Figure 1.64).

1.64 The Rookery, Chicago, USA. The building has undergone several major interventions, including those by Frank Lloyd Wright and William Drummond. The latter installed an iron suspended staircase with double flights from the first floor connected to a half landing, all protruding into and suspended over the main light court; from the half landing a straight flight connects to the second floor and the base of the oriel staircase. (Flaplane, http://commons.wikimedia.org/wiki/File:The_Rookery_Building_court_(Chicago,_IL).jpg)

Louis H. Sullivan's designs incorporate fine straight flight staircases in iron and steel embellished with his distinct flair for curved and foliate decoration bordering on the European Art Nouveau style. Examples are the massive Imperial staircase in the east lobby of the Auditorium Building, built 1886–1890 and the fine staircase in the Stock Exchange of 1893 (demolished), both in Chicago. The model for these staircases can be traced to Europe and the earlier work of Karl Friedrich Schinkel in Berlin, in the Palais des Prinzen Albrecht (destroyed in the Second World War). Here Schinkel designed a remarkable lightweight five-flight Imperial iron staircase, constructed 1829–1833 (Figure 1.65).[63]

1.65 Palais des Prinzen Albrecht, Berlin (destroyed) (Mielke, 1966).

Schinkel used cast iron for a more conventional form of staircase at the hunting castle in the Granitz forest on the island of Rugen. A majestic spiral staircase climbs the 38 m central tower, with pierced treads and risers with solid quarter sections (Figure 1.66).

1.66 Granitz Castle on the island of Rugen, Germany. (Wiki05, http://en.wikipedia.org/wiki/File:Jagdschloss_Granitz_Treppe.jpg)

The Early Twentieth Century

In Berlin the German Empire court houses or Amtsgericht in the districts of Mitte and Wedding both contain remarkable staircases of compelling intricacy. Both date from the early twentieth century and are by Paul Thoemer and Rudolf Monnich, specialists it would seem in such buildings.

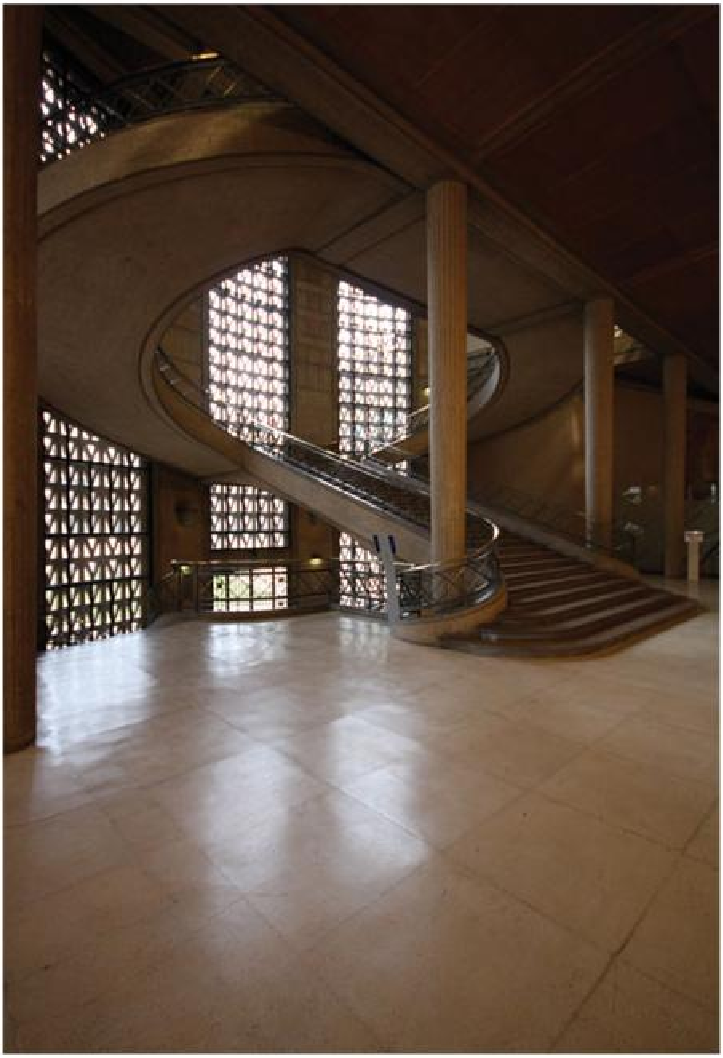
The vast High Baroque staircase hall or atrium, with some Art Nouveau elements, at the Mitte courthouse contains two opposing staircases of amazing intricacy, linked by a myriad of balconies supported on massive red and brown sandstone pillars (Figure 1.67). The Wedding district courthouse is much more romantically

‘Gothic’. Here, two identical staircases with intricate carved balustrades rise each side of the full-height and vaulted entrance hall, in very German Empire Gothic in brown sandstone (Figure 1.68).

1.67 Berlin, Mitte district courthouse, one of a mirror image pair in the huge central atrium, complete with large stoves at the base. (Michael Tutton)

1.68 Berlin, Wedding district courthouse. The photograph is taken from the half-landing of the opposite staircase which mirrors the first. (Michael Tutton)

Just as iron opened up other possibilities, so the increased use of concrete and steel in the twentieth century dramatically changed the form of stairs. Concrete was elegantly explored by Auguste Perret in his designs for the stairs in the foyer of the Theatre des Champs-Elysées, 1911–1913, and his truly majestic staircase in the then Musée des Travaux Publics,[64] built 1937–1943. The latter is a double curve helicoid connecting three floors, virtually (one has to look closely) without intervening support. It is a climactic exposition of the grace and beauty achievable in reinforced concrete (Figure 1.69). Perret had earlier built his own apartment and studio at 51 rue Raynouard, where another graceful staircase of one complete revolution connects the ground floor with Perret's studio on the first.[65] Of course, Perret was not the first with such elastic beauty in concrete; the precursor is Francois Hennebique's[66] staircase of 1898 in the Petit Palais in Paris. Le Corbusier's Villa Savoye at Poissy 1929–1931, on a smaller and more domestic scale is a further example. Erich Mendelsohn was another exponent with his staircases in the Metal Workers Union building in Berlin, built 1929–1930 (Figure 1.70).[67]



1.69 Paris. Perret's masterpiece of staircase design in the Palais d'Iena, the Conseil Economique et Social. Formerly the Musee des Travaux Publics. (Michael Tutton)

1.70 Berlin, Metal Workers Union building, Erich Mendelsohn. The balustrade and central light fitting, which is suspended throughout its full height of six floors, reflect the various metalworking skills. (Michael Tutton)

Now and the Future

We are perhaps too close to the end of the twentieth century to look at it objectively and select the best stairs. But there is no doubt staircases continue to occupy the imagination of architects. The reader will find the general bibliography useful in extending the study of the subject into the late twentieth and twenty-first centuries.

Notes

1 Kenneth Clark, *The Gothic Revival*, 1928, Constable and Co.

2 Prof. Sir Themistocles Zammit, *Prehistoric Malta Tarxien Temples and Saflieni Hypogeum*, 1994 (written 1935), Official guide, no publisher given.

3 Dieter Arnold, *The Encyclopaedia of Ancient Egyptian Architecture*, 2003, I.B. Tauris, p228.

4 Ibid., pp68, 85–86, 228.

5 J.P. Droop, 'A Greek Tower in Naxos', in *Annals of Archaeology and Anthropology*, Vol. 10, 1923, University of Liverpool, pp41–45, and Lothar Haselberger, 'Der Pyrgos Chimarru auf Naxos' in *Arghaologischer Anzeiger*, 1972, Part 2, Walter de Gruyter & Co., Fig. 5 p434. When I visited the tower in June 2009 it was in course of restoration with scaffolding both to the interior and exterior; however, it was clear that this had been erected for some time and there was no sign of any work having been done recently

and the site was deserted. Some of the stair treads were clearly visible through an aperture in the door, which was chained shut. Photography of the stairs with the internal scaffold present was not sufficiently successful for a clear illustration.

6 Access to the first floor internally is via a shaft through the lintol of this doorway. The shaft is easily missed as you have to crouch to gain access through the low doorway.

7 Philippe Le Bas and Salomon Reinach, *Voyage Archeologique En Grece Et En Asie Mineure 1842–1844*, 1888, Paris, Librairie de Firmin-Didot, pp140–141 and plate (the volume containing the plates has unnumbered pages). Part of the plate, the section, is reproduced in J.J. Coulton, *Ancient Greek Architects at Work: Problems of Structure and Design*, 1977, Cornell University Press, p150.

8 Manolis Korres, 'The Tower of Agia Triada on Amorgos' in Marina Yeroulanou and Maria Stamatopoulou (Eds), *Architecture and Archaeology in the Cyclades, Papers in Honour of J J Coulton*, 2005, Archaeopress, p189.

9 Archaeological Musuem of Paleopolis, Andros. See also Korres, 2005, p189.

10 Margaret M. Miles, 'Interior Staircases in Western Greek Temples' in *Memoirs of the American Academy in Rome*, Vol. 43, 1998–1999, pp 1–26, University of Michigan Press.

11 Ibid., p7. Access internally is now restricted with the general public kept to the exterior.

12 Ibid., pp9–13.

13 Ibid., pp5–7

14 Stephen Harrison, *Mine How Fieldwork and Excavations 2000–2005*, 2005, The Friends of Orkney Archaeological Trust.

15 Noel Fojut, *The Brochs of Gurness and Midhowe*, Official Guide, 1993, revised 2008, Historic Scotland, p12.

16 Euan W. MacKie, *The Roundhouses, Brochs and Wheelhouses of Atlantic Scotland c. 700 BC–AD 500 Part 1 The Orkney and Shetland Isles*, 2002, Archaeopress, p vi (Preface).

17 Ian Armit, *The Archaeology of Skye and the Western Isles*, 1996, Edinburgh University Press, Chapter 7 'The Atlantic Roundhouses', pp109–135.

18 There are two adytons or sanctuaries, see Iain Browning, *Palmyra*, 1979, Chatto & Windus, pp120–122.

19 Ibid. p111 and fig. 41 (Plan of the Sanctuary of Bel), p100.

20 Ibid, p100.

21 For an in-depth analysis of the design and construction of Trajan's Column, see: Mark Wilson Jones, 2000, *Principles of Roman Architecture*, Chapter

8 'Trajan's Column', Yale University Press; Mark Wilson Jones 'One hundred feet and a spiral stair: designing Trajan's Column', in *Journal of Roman Archaeology*, Vol. 6, 1993, pp 23–38; and Lynn Lancaster, 'Building Trajan's Column', in *American Journal of Archaeology*, Vol. 103, No. 3, July 1999, pp. 419–439.

22 Martin Beckmann, 'The Columnae Coc(h)lides of Trajan and Marcus Aurelius', in *Phoenix*, Vol. 56, No. 3/4, 2002, p355.

23 For a full discussion on minarets in the context of Islamic architecture, see: Robert Hillenbrand, *Islamic Architecture Form, Function and Meaning*, 1994 (paperback 2000), Edinburgh University Press, chapter 3, 'The Minaret', pp129–171.

24 Photographs taken in the early twentieth century show the minarets in a deteriorating state, particularly Abu Dulaf.

25 Freya Stark, *The Minaret of Djam*, 1970, John Murray. She travelled from Herat to Karbul by Landrover in the summer of 1968. See also Rory Stewart, *The Places in Between*, 2002, Picador. Stewart travelled, in 2002, almost the exact route followed by Stark, but on foot and in winter.

26 David Thomas. I am much indebted to David Thomas, an archaeologist who has visited the minaret and worked in Afghanistan, for making available to me various illustrations and photographs and a description of the minaret. See also: *SPACH (Society for the Preservation of Afganistan's Cultural Heritage)*

Newsletter, Issue 7, July 2001, p12; ArchNet: www.archnet.org/library/sites/
one-site.jsp?site_id=11345 (accessed 27 August 2009); and Ralph Pinder-Wilson 'Ghaznavid and Ghurid Minarets' in *Iran*, Vol. 39, 2001, pp. 155–186.

27 E.H. Ayverdi, 'Faith devri mimart eserleri', 1953, Istanbul, p96, quoted in Godfrey Goodwin, *A History of Ottoman Architecture*, 1971, Thames & Hudson, p99.

28 J. Von Hammer-Purgsall, *Historie de l'Empire Ottoman*, 18 Vols., 1835–43, III, pp354–355, quoted in Goodwin, op. cit., p99.

29 Other notable minarets are: Qutlugh Timur minaret in Uzbekistan (62 metres high with 145 steps to the top, construction started in CE 1009–1017, but was not completed until 1330); the Chihil Dukhtaran minaret in Isfahan, Iran built *c*.1107, rising 21 metres above a square plinth, then an intermediate octagon surmounted with a circular shaft. About half way up the latter is a large rectangular window facing
Mecca, through which the spiral stairs can be seen rising to the top; the magnificent Qutb Minar in Delhi is 72.5 metres high, with 379 steps consisting of five storeys divided by four balconies, the lower three built in red and buff sandstone in 1199, the upper two storeys in marble in 1368, following damage by lightning.

30 Luc Tamborero, 'The "Vis Saint-Gilles", Symbol of Compromise between Practice and Science' in Dunkeld *et al.*, *Proceedings of the Second International Congress on Construction History*, 2006, CHS, Vol. 3, pp 3026–3027. ArchNet digital library: Bab al-Nasr:

https://archnet.org/library/sites/one-site.jsp?site_id=3973 (accessed 27 September 2009). Caroline Williams, *Islamic Monuments in Cairo: The Practical Guide*, 2002, The American University in Cairo Press.

31 Tamborero, 2006, for the Cairo connection. See also Gothic Med: www.gothicmed.es (accessed 27 December 2010).

32 Robert Saint-Jean in *Languedoc Roman*, 1985, Editions Zodiaque, St Leger Vauban, France, pp43, 398. The French word Vis[e] or its English equivalent Vice became widespread usage for describing a spiral staircase although use, particularly of the English term, has now dropped off.

33 See Chapter 2 and G. Neil, 'The Rise of the Anti-clockwise Newel Stair', *Castle Studies Group Journal*, Vol. 25, 2011–2012, pp. 113–174.

34 Born Felanitx, Mallorca(?), died Naples 1454. In 1397 he was working on the cathedral of Palma de Mallorca, under his father, Antonio Segrera.

35 Caracol: Spanish for snail or coiled, see above: Trajan's Column.

36 See Jose Calvo Lopez and Eliana de Nichilo, *Stereotomy, Models and Local Declination of Stone Cutting Construction Between Spain and the Kingdom of Naples in the Fiftheenth Century:-Three Spiral Staircases in the Castel Nuovo at Naples, the Llotja in Valencia, and the Capilla de los Vélez in Murcia*, 2005 Ravenna, International Seminar Papers (in Italian).

37 Jose Calvo-Lopez *et al.*, 'The 100 Ft Vault: The Construction and Geometry of the Sala dei Baroni of the Castel Nuovo, Naples', in *Nuts & Bolts of Construction History*, Vol. 3, 2012, pp.53–59.

38 Cell vaults, devised by Arnold von Wesphalen; Nicola Coldstream, *Medieval Architecture*, 2002, Oxford University Press, p51.

39 Lewis Grodecki, *Gothic Architecture*, 1978, Electa, paperback edition 1986, Faber and Faber, p152; Grodeki does not use the word 'torsion' in its engineering sense.

40 www.musees-strasbourg.org/index.php?page=histoire-ond-en (accessed 14 October 2009) and Cecile Dupeux, *Œuvre Notre-Dame Museum*, 1999, Musees de Strasbourg, Editions Scala.

41 Robert Bork 'Rock, Spires, Paper: Technical Aspects of Gothic Spires', in Marie-Therese Zenner, *Villard's Legacy*, 2004, Ashgate Publishing.

42 The drawings by Ulrich, or possibly his son Matthias, survive in the Historisches Museum in Berne. They show one staircase in detail and one in outline only; the drawings were followed to the base of the spire, which was completed to a different design by Ulrich's successor Johann Hultz of Cologne: M.W Evans, Medieval Drawings, 1969, Paul Hamlyn, London.

43 Francis I was a prodigious builder; as well as remodelling Blois and building Chambord, he remodelled or reconstructed the Louvre, Amboise,

Fontainebleau, Saint-Germain-en-Laye and Villers-Cotterêts. In addition, he built the Chateau de la Muette in the gardens of Saint-Germain-en-Laye, Chateau de Madrid in the Bois de Boulogne and Chateau de Folembray in Picardy, all now demolished. He died long before Chambord was complete and while alive scarcely used it.

44 Reginald Blomfield, *A History of French Architecture 1494 to 1661*, 1911, Bell and Sons.

45 In fact, what he drew and described are pure caprice. His informant, probably Marcantonio Barbaro, who was the Italian ambassador to the French Court from 1561 to 1564, appears to have misled him, for what he depicted does not exist. It is curious that Palladio also attributes the invention of the 'cantilevered' staircase to Barbaro, yet if Barbaro were indeed a designer of such a revolutionary mode of staircase construction, why did he give such a poor and misleading depiction of the Chambord staircase? It is possible that he had access to and studied Leonardo's notebooks and sketchbooks, for there are several drawings and descriptions of multiple staircases, none of which were built.

46 Anthony Blunt, *Philibert de l'Orme*, 1958. Zwemmer, pp77–79.

47 A combined store or warehouse and shelter or hotel for travellers and traders.

48 The vaulted suq in Aleppo dates from the twelfth to the sixteenth centuries and is one of the most authentic market areas in the Middle East; Ross Burns, *The Monuments of Syria*, 2009, I.B. Tauris, pp28–29.

49 As the stairs are at present they end abruptly on line with the jamb of the gateway; if they proceeded to the ground they would partially block the gateway, thus impeding traffic in and out. Therefore they either turned outwards along the line of the entrance, or they predate the present gateway which was cut through them.

50 Andrea Palladio, *The Four Books of Architecture*, 1570, Book 2, chapter 6, p43, plates 20–22.

51 See Jean-Francois Leiba-Dontenwill and Roselyne Bussière, 2011, *Escaliers Parisiens sous l'Ancien Regime*, Somogy.

52 See Alexandre Gady, *The Marais: A Historical and Architectural Guide*, 2005, Le Passage, and *Les Hotels Particuliers de Paris du Moyen Age a la Belle Epoque*, 2008, Parigramme.

53 Nikolaus Pevsner, *An Outline of European Architecture*, 1943, Penguin Books, Revised Edition, 2009, Thames & Hudson, p148 and p153, respectively. Also, Catherine Wilkinson, 'The Escorial and the Invention of the Imperial Staircase', in *The Art Bulletin*, Vol. 57 No. 1, 1975 pp65–90.

54 Wilkinson, op. cit., attributes the Holy Cross staircase to Alonso de Covarrubias and dates it to the 1530s.

55 Pevsner, op. cit.

56 See Wilkinson, 1975, op. cit., and George Kubler, *Building the Escorial*, 1982, Princeton University Press, for the full story.

57 Catherine Wilkinson-Zerner, *Juan de Herrera: Architect to Philip II of Spain*, 1993, Yale University Press, pp71–75.

58 R. Wittkower, ‘Michelangelo’s Biblioteca Laurenziana’, in *The Art Bulletin*, Vol. 16, No. 2, 1934, p206. Wittkower describes the Biblioteca Laurenziana as the most important and influential Italian secular building of the sixteenth century.

59 As Kubler, op. cit., describes the Escorial staircase.

60 Pevsner, op. cit., p150.

61 Henry-Russell Hitchcock, *Rococo Architecture in Southern Germany*, 1968, Phaidon, p208.

62 Reyner Banham, *Los Angeles: The Architecture of Four Ecologies*, 1971, Allen Lane and the Penguin Press, p207.

63 Friedrich Mielke, *Die Geschichte der Deutschen Treppen*, 1966, Verlag von Wilhelm Ernst & Sohn, p238.

64 Now the Palais d’Iena, Conseil Economic et Social.

65 Karla Britton, *Auguste Perret*, 2001, Phaidon, pp144–151, and for the Palais d’Iena, pp158–185.

66 One of the great pioneers of early reinforced concrete, see: Peter Collins, *Concrete: The Vision of a New Architecture*, 1959, Faber and Faber.

67 There is a very similar but much shorter staircase in the De La Warr Pavilion at Bexhill on Sea, East Sussex, built 1935.

2

The British Staircase

James W.P. Campbell

Background

This chapter seeks to provide a broad overview of the historical development of the staircase in Britain. Considering the crucial role stairs play in virtually every building, it is perhaps surprising that the subject has received so little attention from architectural historians. The most serious study, Eduard Sekler's PhD, 'The Development of the English Staircase', was submitted to the Courtauld Institute of Art in London as long ago as 1948, but it was never published. Walter Godfrey's *The English Staircase* (1911) remains the best book on the subject, but Godfrey only covers the period up to 1754, and the text runs to barely 70 pages. And then there are the relevant parts of Thomas Marwick's *The History and Construction of Staircases* (1888), which has relatively little to say about staircases in Britain. The same could be said of more recent studies such as Templers *The Staircase* (1992) and Alan Blanc's *Stairs, Steps and Ramps* (1996): they are seeking to provide a global overview, not a specifically British study.

British staircases have been covered in chapters or sections in larger works on particular periods: books like Margaret Wood's *The English Medieval House* (1965); Andor Gomme and Alison Maguire's *Design and Plan* *in the Country House* (2008); Mark Girouard's *Elizabethan Architecture* (2009); and Damie Stillman's *English Neo-classical Architecture* (1988). Linda Hall's ongoing study of the details of historic stairs in the period 1567–1763 provides one of the best guides to the subject in that period, and for that reason the results of her research form the next chapter. This chapter has relied heavily on these sources and many others cited in the notes.

2.1 Sheen House, Richmond from Walter Godfrey's English Staircase (Godfrey, 1911, Plate LXI).

Earliest Examples

It is not clear what the oldest staircase in Britain is. There are relatively few staircases surviving from before the twelfth century. The Orkney iron-age examples mentioned in Chapter 1 are probably the earliest. The Romans would have built stairs, but there are no British equivalents of the staircases surviving in Ostia, Pompeii or Herculaneum.[1]

Most early Medieval houses (ad 300–1000) were single storey, made of timber and consisted of one or possibly two rooms at most. As such, they had no need of stairs. If there was an upper storey, the user reached it using a simple ladder. In modest dwellings, the ladder remained the normal way of accessing upper floors throughout the Middle Ages[2] Where there were timber staircases, the evidence for their position sometimes survives, but the staircase itself has almost always been removed or replaced.[3]

Thankfully, staircases made of stone have fared slightly better. Anglo-Saxon churches often had towers with a number of floors. These, too, were frequently accessed by ladders, but three staircases do survive at Brixworth, Broughton and Hough-on-the-Hill.[4] All of these seem to have been subsequently modified. All are spiral, with the treads made of several pieces of stone supported on roughly composed vaults; all are in external stair turrets.[5] An empty stair turret at Brigstock probably contained a wooden spiral staircase.[6]

Staircases in Norman Britain

The number of stone staircases in Britain rose dramatically when masonry construction increased in England after the Norman Conquest. The later Medieval house was often only one room thick. Where building ranges were subdivided vertically, access was generally provided by a number of staircases placed in turrets at regular intervals. These were used primarily for internal circulation and rarely communicated directly with the outside. In some cases, such as inns, the stairs were external, sometimes leading to galleries providing access to a number of rooms. Larger houses were in many cases fortified into castles. There has been a tendency to treat castles separately from houses. As recent studies have shown, they deserve to be considered not just as defensive works but also as great dwellings.[7] The most common type of stair in this period was the spiral (called the ‘turnpike stair’ in Scotland).

Forms of the English Spiral Stair

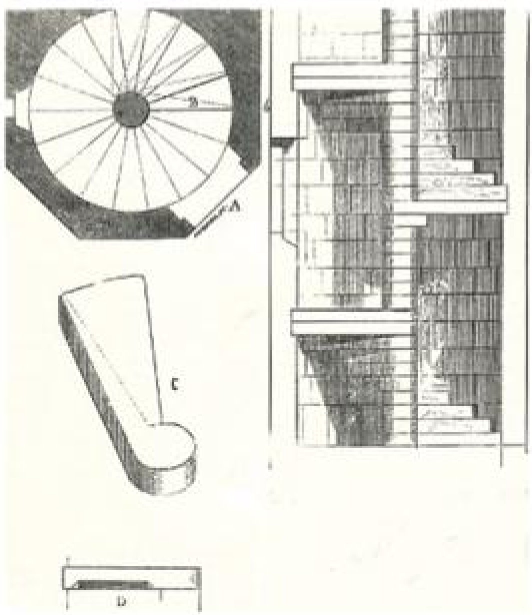
Medieval stone spiral stairs can be separated into several distinct types according to their details. The steps themselves have few distinguishing features. The nosing, so often the subject of later elaboration, is noticeably absent in Medieval stone stairs. Indeed, it does not seem to have been used at all in Britain before the sixteenth century. The chief feature of the step, apart from its height, is the number of pieces of stone that it is made out of and their relation to the solid newel post, column or drum, which always formed the centre of the Medieval spiral stair.

In the Anglo-Saxon examples already noted, the steps are formed of several pieces of stone. In this case the steps have to be supported on rotated barrel vaults. These are also called ploughshare vaults, because the upward-twisting spiral resembles the blade of a plough. The alternative is a twisting planar vault that follows the line of the steps and does not curve down at the edges to meet the wall. This is much more difficult to construct and most commonly found where the steps are made from single pieces of stone (see below) and the underside can be simply cut to shape. Both types of vault are found with or without ribs.

The manufacture of the whole step, together with a section of the newel, from a single piece of stone (which for convenience we will call the 'newel stair' throughout this book) was a later innovation. The construction of such a stair puts a limit on its size. First, there is the question of pitch. To provide headroom any spiral stair must rise over 7 ft in as many steps as it takes to turn 360 degrees. To do so, the stair must be either very steep or very large in diameter. The overall width of the staircase is what is important, because a shallow stair must be wide enough to ensure sufficient tread size at the outside edge of the stair.

The second limiting factor is the weight. A shallow-pitched stair round a large drum can be any width, but if each step is to include a piece of the newel and both are to be made of a single piece of stone, then the width of the step is also limited by the maximum practical size of pieces of stone available. A very large tread and newel would also be very heavy to lift into place during construction. To keep the stones within a reasonable size and weight, newel stairs therefore have to be narrow and have a small newel. As we have seen above, a small overall width means they have to be steep. Conversely, wide shallow stairs must always be made from multiple pieces of stone supported on a vault.

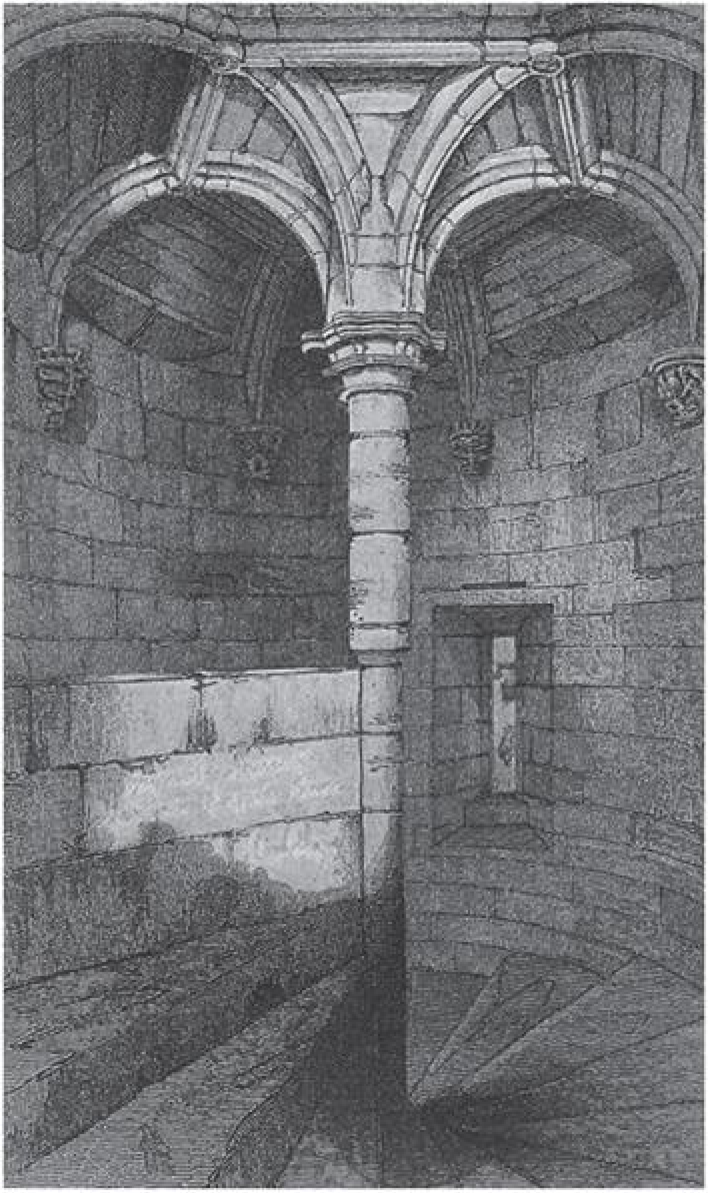
A preference for newel stair construction thus explains why most Medieval spiral stairs were surprisingly cramped and steep. The steepness and narrowness of newel stairs may have made them
rather inconvenient to use, but this was more than offset by the fact that they were much simpler and cheaper to build (Figure 2.2).



2.2 A newel stair showing its construction, each step and a part of the newel being made from a single piece of stone. (Viollet le Duc, *Encyclopaeida Medievale*, plate XX)

The underside of the newel stair is often left stepped, but it could be carved into a continuous surface. This was almost certainly finished *in situ* to produce an accurate and smooth surface, without the need for any concise setting out.

The top of the stair may occur within the building (in which case the stair may be simply blanked off). Alternatively, the stair may be stopped in a turret, giving access to the roof. In newel stairs, for structural reasons, the steps often continue beyond the top landing; the last few treads lead nowhere (Figure 2.3). This may cause the casual observer to think the stair has been truncated at some date. In fact these extra steps are helping to add weight to restrain the top of the newel to prevent it moving with the shifting forces of people going up or down.



2.3 Linlithgow Palace staircase showing the extra steps at the top of the stair.

One feature of spiral stairs that has exercised considerable curiosity is their direction of travel. Much ink has been wasted noting that stairs rose clockwise to aid the defender retreating up the stair. Many stairs were built ascending clockwise, but there are also a very considerable number that rise anticlockwise, and it is likely that room layout, superstition and tradition were more important determinants of direction than any notion of defence.[8] Once a defender had reached the base of an internal staircase the battle was effectively lost anyway.

Another important feature of the spiral staircase worth noting is the handrail, or rather the lack of it; most Medieval stairs had no handrail at all. The curvature of the staircase and the proximity of the wall lessened the risk of injury in a fall. A few have evidence of timber handrails and some have handrails cut into the outer wall. The later French habit of cutting a handrail in the newel itself is rarely found in Britain.

Chronological Development

These, then, are the features of the stair that need to be considered. What of their chronological development? Initially, spiral staircases in the castles were all vaulted and could thus be quite wide. Orford,[9] Dover (Figure 2.4), Hedingham and Rochester all have good examples.[10] Widths of steps could be as much as 10 ft. The interesting point to note here is the construction of the vaults. With very few exceptions (e.g. Tower

Staircase, Lincoln Cathedral; Fyvie Castle),[11] British staircases appear to have had vaults constructed from rough masonry, plaster being applied to produce a uniform surface.

The elaborate cut stone vaults often evident on the continent were noticeably absent to such an extent that it is not unreasonable to suggest that the few examples that do exist might have been made by foreign craftsmen.

2.4 Spiral staircase at Dover Castle. (Michael Tutton)

Brick staircases always had to be carried on vaults. The supposedly twelfth-century brick stair at St Botolph's Priory, Colchester is shown in Nathaniel Lloyd's *A History of English Brickwork*,[12] but brick construction remained rare in Britain before the 1400s. The beautiful brick spiral stairs at Oxburgh Hall, Norfolk (1482)[13] and Faulkbourne Hall, Essex (1494) are also excellent early examples. Both have curving brick ploughshare vaults.[14] The best preserved, however, is in the Moot Hall, Maldon, Essex (1424) (Figure 2.5).[15]

2.5 Moot Hall, Maldon. (Michael Tutton)

Ploughshare vaults are complex shapes to make in brick. The bonding pattern changes at the centre line. The bricks on the outside are laid parallel to the walls, while those on the inside are laid in courses that roughly radiate from the centre, and have to be drastically cut to fit. The result is a rather haphazard pattern (Figure 2.5) which was probably originally plastered. An alternative method of building brick spirals is found at Laughton Place, Sussex (1534), where the stairs are supported on radiating arches leading to a stepped soffit (Figure 2.6), which is less elegant, but was probably easier to construct.[16]

2.6 Laughton Place (Victor Bayon)

The newel stair (with the step and newel being made from a single piece of stone) appears as early as the end of the twelfth century.[17] Its narrow width (determined by the maximum size of stone) was necessarily compact on plan (see above) so it could be easily fitted within the depth of thick castle walls, often in combination with short, straight flights. Sometimes newel stairs were pushed out into turrets, which might be circular (e.g. White Tower, Tower of London; Beaumaris), square (e.g. Orford; Colchester; Bamburgh) or octagonal on plan (in many gatehouses).

The newel stair became the most common form of staircase throughout the rest of the Middle Ages. A good survey is found in Neil Guy's *The Rise of the Anti-clockwise Newel stair*.[18] As Sekler noted (and Guy shows), the Medieval spiral stair in Britain showed an extraordinary lack of development in its details. Types were established very early and then repeated across the centuries. That does not mean that all Medieval stairs are without interest on plan or unimportant: their treatment varied according to building type.

Spiral Stairs in Medieval Monasteries and Churches

In Medieval churches, the newel staircase predominated as a way of gaining access within towers, to the roof and upper galleries. Smaller straight and spiral staircases also gave access to pulpits and the upper parts of rood screens. Again, there is as yet no comprehensive study of church staircases. In cathedrals and larger churches spiral flights were often concealed within the walls. In smaller churches, stairs are found in the corner of the tower or as projecting stair turrets, usually symmetrically arranged.[19] Most spiral staircases were simple spirals. There are, however, some more interesting examples to be found: for instance, the double helical staircases of All Saints' church, Pontefract, West Yorkshire and St Editha's church, Tamworth, Staffordshire, both dating from the mid-thirteenth century. Quite why these otherwise undistinguished parish churches merited special treatment is unclear and no documents have survived to throw any light on the subject, but the similarity suggests the same mason may have been involved.

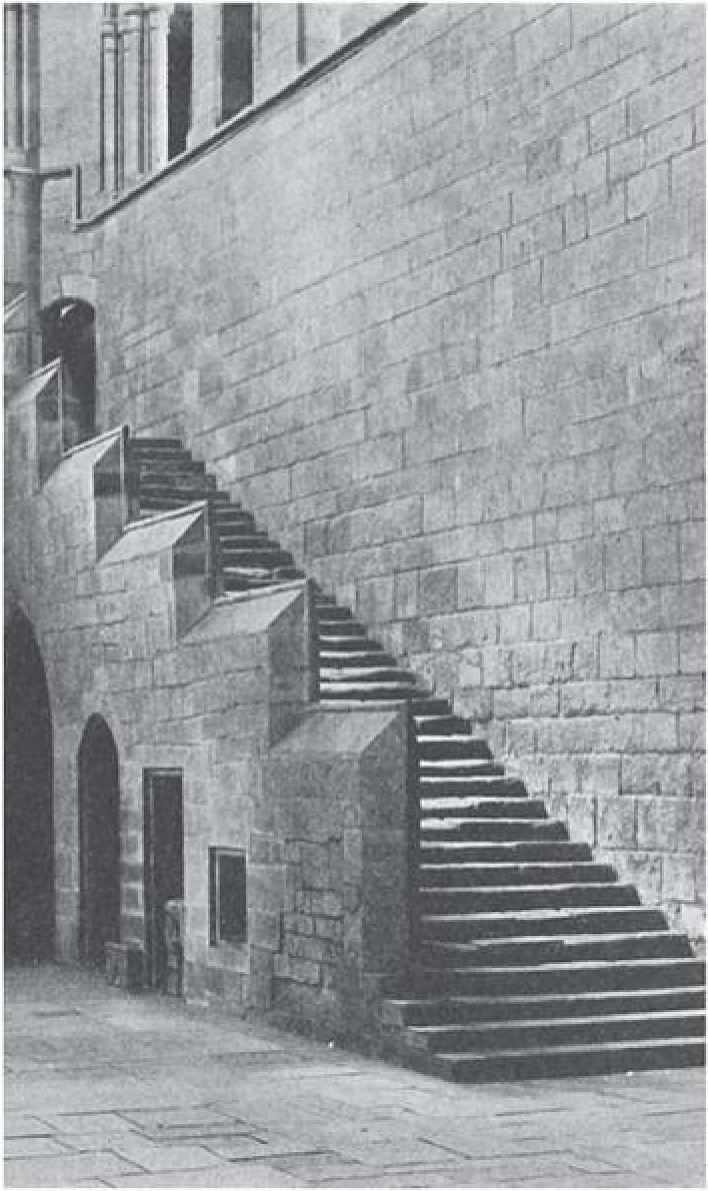
Straight Flights of Stairs in the Middle Ages

From the account so far, it is all too tempting to presume that the spiral staircase was the only type of stair used in Medieval Britain. In fact, from the earliest times straight flights of stairs had been used to great effect. Such flights have no nosings and are generally long, steep and uninterrupted by landings, except where they change direction.

In cathedrals the lifting of the east end of the church over a crypt led to dramatic straight flights of stairs up from the nave to the choir and down to the crypt, as at Canterbury or Old St Paul's. In Wells one of the finest Medieval staircases leads to the Chapter House (1264) (Figure 2.7).[20]

2.7 Cathedral Stair at Wells leading to Chapter House (right). (James Campbell)

In monastery buildings, the stairs from the dormitory to the choir – the so-called night stairs – were usually straight (e.g. Hexham Priory[21] – Figure 2.8). This enabled half-asleep monks to make it down into the church safely for services held well before dawn. Many of these stairs survive in reasonable condition, although heavily worn.[22]



2.8 Hexham Priory staircase to dormitory. (Godfrey)

In the great houses and castles of the Medieval period the most important rooms were the great hall and the withdrawing chamber. In a castle, the great hall might be inside the keep (e.g. Dover) or in a separate building (e.g. Bodiam). The withdrawing chamber was always on the first floor, while the great hall might be either at first floor or ground level.

Where the great hall was on the ground floor, the staircase to the withdrawing chamber was accessed from the high end of the hall, behind the high table. Often it was placed in a turret called an oriel (not to be confused with the oriel window which was later also a feature of the high ends of great halls). A remarkable survival of an original oak staircase, in this case on the
rear wall of the hall, can be found at Stokesay Castle (*c*.1280) (Figure 2.9). It gives an idea of the likely method of construction of early timber stairs.[23] It consists of solid triangular steps supported on stout carriage pieces. A simple chamfered rectangular balustrade is supported on the minimum number of plain timber posts, one at each corner.[24] The stair is positively crude in its
construction, without any of the decoration or carving that will characterise later English timber stairs. It may well have been typical.

2.9 Stokesay Castle, staircase in hall. (*Country Life*)

If the great hall was on the first floor, the withdrawing chamber could connect with it on the same floor directly or via an ante-chamber. Then the great hall needed an access stair from the ground. The ascent to a great hall was always via a straight flight. Where this needed to be fortified, as in a castle, the flight might be in an outbuilding. That might be of timber, so it could be quickly demolished. Alternatively, a drawbridge, a pit or some other defensive device, might interrupt the stair. All the timber examples have long since disappeared, but a number of stone ones still survive. Three of the most dramatic examples are Rochester (*c*.1127), Newcastle (1171–1175) and Dover (1180–1186) (Figure 2.10). The entrance stair at Rochester Castle, Kent, *c*.1127 built by Archbishop William de Corbeil, consists of a stone staircase wrapped around the northwest angle of the keep[25] Built largely of Kentish ragstone, like the rest of the keep, only the superstructure and ramp with traces of treads survive. A modern timber staircase is suspended above it.

2.10 The entrance staircase to Dover Castle, originally with drawbridge where wooden stairs now are. (*Country Life*)

The main entrance stairs in the castle keep at Newcastle-upon-Tyne, 1168–1178, consist of a straight flight rising steeply to just below the second-floor great hall, then through 90° (a quarter-turn) and culminating in a short flight to the main doorway into the hall. The keep was designed and built under the supervision of Maurice the Engineer[26] On completion of works at Newcastle, Maurice moved south to Dover. There, the keep is almost twice the size of Newcastle, on plan[27] Built 1181–1187, the entrance stairs at Dover (Figure 2.10) ascend up to, and through, a fore building before turning through 90° and crossing an internal drawbridge[28] The straight flight of stairs provide a grand entry, as at Castle Rising.[29] In all these examples, the Medieval stair is characterised by its long, steep, continuous unbroken flights.

Staircases in other Medieval Building Types

Before leaving the Middle Ages it is necessarily to turn our attention briefly to those other late Medieval institutions of note; namely colleges, schools and almshouses. It is at first tempting to presume that these institutions were constructed along the lines of monasteries and religious institutions with which they were so often associated. In fact, examination of each quickly reveals that – although there are superficial similarities – each established characteristics of their own. Most were founded around a courtyard with a

chapel and dining hall. The chapel and hall were normally, but not always, on
the ground floor. When they were lifted up a floor, there was an opportunity for a staircase of some drama (e.g. dining hall, Magdalen College, Oxford; dining hall, Winchester College; dining hall, New College, Oxford (Figure 2.11)). However, some examples, such as the stairs to the dining halls at Merton College[30] or Christ Church, Oxford, and the stairs to the chapel at Eton,[31] are actually misleading later additions. Medieval staircases to dining halls were generally internal, the external examples mostly dating from 1600 onwards. Alongside these larger elements were the lodgings or dormitories.

2.11 Staircase to dining hall, New College, Oxford. (Stephen Oliver)

Medieval almshouses could be single- or two-storey buildings, sometimes with sets of chambers on each floor or sometimes divided vertically into separate houses.[32] If the latter, as at Ewelme,[33] then the staircases were internal. Where chambers were found on each floor, such as at St Cross in Winchester, then the arrangement followed that of colleges, schools and domestic ranges. These were usually two storeys high and consisted of pairs of chambers or dormitories accessed off staircases. Sometimes these stairs were stone newel stairs in a corner turret, but more often they were straight timber flights rising to a landing, with rooms under the landing and over the entrance.[34] Often, accommodation would be added in the attic at a later date, requiring a further flight of stairs, usually in the form of a tight spiral from an enlarged first-floor landing, the space being taken from one of the rooms (e.g. Old Court, Queens' College, Cambridge). Alternatively, garret rooms were entered off corridors, with extra stairs only being provided at the ends (e.g. Great Quadrangle, New College, Oxford).[35] Straight flights in these buildings tend to be plain. It is to be presumed that in most cases the timberwork has been largely replaced, though a comprehensive survey of such structures has yet to be undertaken.

The Great Changes of the Sixteenth Century

The idea that all Medieval stairs were spiral has hopefully been dismissed by the foregoing account. English Medieval staircases were of widely differing types. They might be spiral, but they could also be straight and might have winders. They were, however, largely plain in decoration and generally bounded by walls on each side. Any decoration was confined to the vaulting. The richly decorated stairs with open wells in the centre or open arcades on the exterior, found in the later Middle Ages in Continental Europe (see Chapter 1), were conspicuously absent in Britain. This changed in the late sixteenth century. There were two driving forces: changes in plan and changes in woodworking.

Changes in House Plan in the Sixteenth and Seventeenth Centuries

The late Medieval and early Elizabethan house was normally one room thick. Corridors were rare. To get from one room to the next usually involved passing through each room in turn or going down to a different floor and back up again. For privacy, ranges were often provided with large numbers of staircases. During the sixteenth and seventeenth centuries more compact house designs began to develop, no doubt inspired by books on architecture from abroad.[36] There was a great deal of experimentation with plan forms during this period and in many the stair hall gradually began to take centre stage, while the dining hall became correspondingly less important. The first indicators of these changes in England are the surviving drawings of Robert Smythson and John Thorpe. Their plans show large symmetrically placed staircases. Many are spiral, but dog-leg and open-well stairs are also shown, the latter consisting of many short flights with landings in between.

Further changes took place in the eighteenth century when the Great Hall was replaced by a salon or dining room. The staircase hall became the largest and most impressive space in the plan; the only space to pass through two floors.[37] The precise moment at which the change from Medieval-style dining hall to modern entrance hall occurred is difficult to pinpoint. The shift was gradual. Andor Gomme suggested that the entrance hall first appeared at Whitehall, Shrewsbury (1578–1582). It is a smallish house, a villa, a rather modest place to mark the beginning of such an important change.[38] This was one instance that reversed the general trend of innovations occurring in large houses and making their way down the social scale. Smaller houses were the first to do away with the great hall because it had become seen as an unnecessary extravagance.

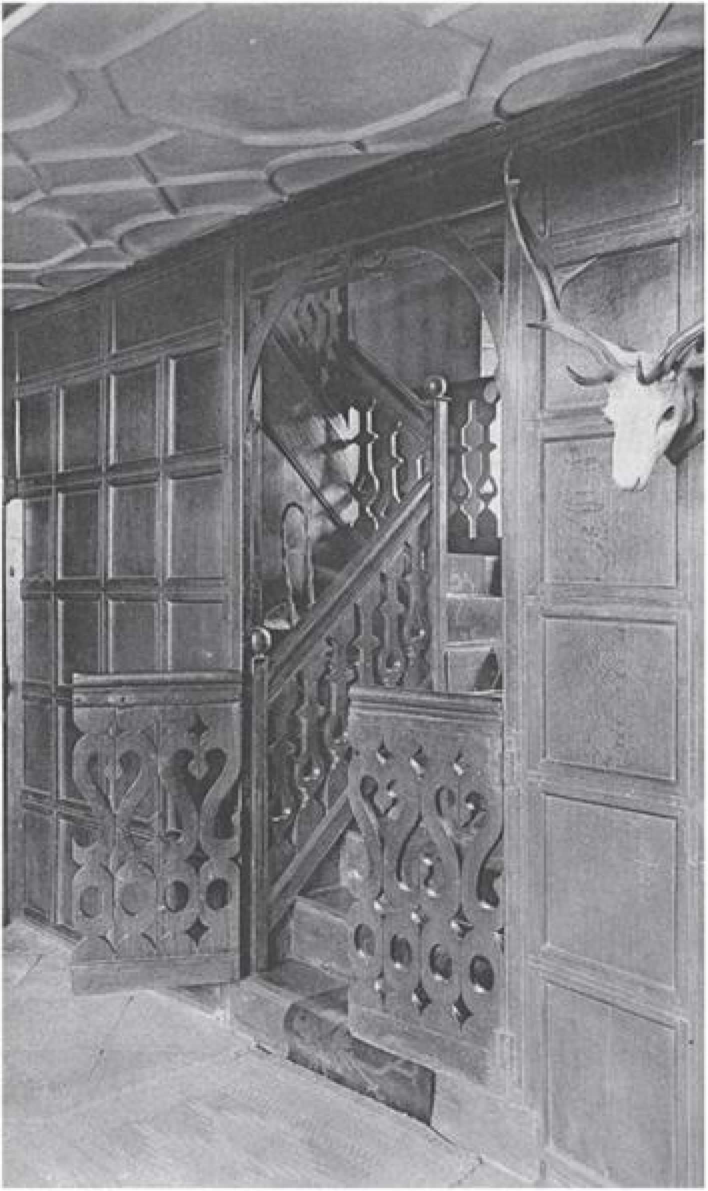
From Carpentry to Sophisticated Joinery

In parallel with changes in room use and plan there were a number of changes in construction technique. From 1500 onwards, carpentry and joinery in Britain were becoming increasingly sophisticated. Carpenters had traditionally made whole-timber buildings. For masonry buildings they made the timber floors, staircases and roof structures. Joiners, meanwhile, had made the panelling (where there was any) and furniture.[39] During the early part of the period these distinctions were largely retained, but staircases became a point of overlap and contention. The papers of Roger Pratt of the mid-seventeenth century show that carpenters were still primarily responsible for building staircases, but they relied on 'carvers' to do the decorative work and 'turners' to provide the balusters. By the Georgian period it seems possible that certain craftsmen may have been specialising in timber staircase erection alone.

Two technical changes are evident in staircases, although exactly when these technical changes occurred is unclear. The first change was purely structural. Stairs were by now increasingly being made by rebating the ends of the treads into ‘strings’ on each side. We take this type of construction for granted, but surviving earlier stairs consisted of solid triangular treads supported from below on carriage pieces, e.g. Stokesay Castle, noted above. Another fine continental example can be seen on display in the Victoria and Albert Museum. It is not clear exactly when the transition from carriage pieces to side strings occurred. It seems likely to have been sometime in the sixteenth century.[40]

The next stage was to make the steps themselves out of two pieces of wood, rather than just one: i.e. making separate treads and risers. Again, this is such a common arrangement today that it goes largely unnoticed. The transition date is similarly unclear. It appears to belong to the second half of the sixteenth century. In some early examples the tread and riser met at a straight joint, mimicking the Medieval English stone stair (e.g. Downholland Hall, near Ormskirk (early sixteenth century) (Figure 2.12) and Oakwell Hall (1583)[41] (Figure 2.13)). However, practicality soon led to the projection of the tread so that the riser could be placed in a groove on its underside. This way the riser was prevented from warping and supported the step. The projection became the nosing.

2.12 Downholland Hall, near Ormskirk (early sixteenth century). (Godfrey)



2.13 Oakwell Hall (1583). (Godfrey)

In timber stairs, nosings may have developed for purely practical reasons, but their form was almost certainly influenced by stone precedents. A definitive study of the development of the stone nosing has yet to be written. They were used in Italian Renaissance architecture. Whatever the source, nosings in stone steps were only introduced in England in the sixteenth century. To give them added weight and classical detail, nosings were often semi-circular in profile with a *cavetto* moulding added underneath.

Once the steps were rebated into the strings, they no longer needed to be supported on both sides by walls. Timber stairs typically revolved around a square cupboard or column. The next stage in the development was to remove the cupboard or column altogether, to leave a so-called framed-well. This let light down the staircase for the first time. Early examples can be found from the 1550s. The corner posts are at first continuous, but it was soon realised that this, too, was unnecessary. The corner posts could be reduced to mere devices for supporting the ends of balustrades as they turned the corners. The earliest surviving timber English examples of this type of open-well staircase date from the third quarter of the sixteenth century (see Chapter 3). Where the well was very narrow the result was a dog-leg stair. Open dog-leg stairs and open-well stairs developed at about the same time (1575 onwards) and remain closely related.

The appearance of the open-well stair marked an enormous leap forward in English staircase design. Hitherto most internal flights of stairs had risen between walls; handrails had been largely unnecessary. Now they became essential to stop the users falling down the well. From 1575 until 1700 the newly truncated corner posts (or 'newel posts' as they were called) were kept and decorated. In the first few decades of the eighteenth century the wish to have a continuous uninterrupted handrail – possibly to mimic fashionable iron rails where newel posts were unnecessary – led to an increasing number of timber staircases doing without newel posts altogether. They relied instead on the curvature of the handrail and the balusters to provide lateral support. This was often not sufficient and iron strengthening then had to be introduced after the stairs were completed to stop the handrails swaying.

Balusters were almost always made by a turner on a lathe. As shown in the next chapter, they were made in increasingly elaborate twisting forms, becoming masterful exercises in the turner's art. They were not made on site. The accounts of Roger Pratt show that the balusters were ordered and delivered to site, where they were cut to fit – an early example of prefabrication[42]

A distinction quickly developed between the back stair and the main stair. Back stairs were comparatively crude and simple; they were made by carpenters. The main staircase was increasingly a specialist piece of the joinery and in many houses came to represent a significant cost.

Jacobean Stairs

Some of the finest surviving examples of timber staircases belong to the Jacobean period. Indeed, few grand timber staircases survive from before 1603. Fine Jacobean staircases are characterised by decorative sculptures on the newel posts. The great staircase at Hatfield (1612) is one of the most exuberant (Figure 2.14). A gently sloping set of five ‘cantilevered’ flights ascends through one tall storey. The balustrades are ‘square’ and richly carved. Sculpted animals and cherubim stand on top of the newel posts, which are themselves covered in decoration.[43]

2.14 The great staircase at Hatfield. (*Country Life*)

Similar figures sit atop the newels of the open-well stair at Knole in Kent, but here the balusters are turned (Figure 2.15).[44] As we shall see in more detail in Chapter 3, turned balusters will become more common as the century progresses, although richly carved square balusters remained popular for the most expensive stairs well into the Restoration period.

2.15 Knole in Kent, with decorated newels, but here the balusters are turned. (Lloyd)

Caroline Stairs

New types of decoration appeared in the 1630s: carved strapwork balustrades – examples are Aston Hall (1618–1635) (Figure 2.16) and Rawdon House, Hoddeson (1622) (Figure 2.17).[45] Sekler showed how these patterns can be related to illustrations in continental publications, particularly De Vries' *Panolplia seu arcmentorium* and De Cerceau's *Cartouches* and *Fleurons*. He also shows a similar staircase could be found in the Brewer's Hall in Antwerp, suggesting Flemish craftsmen may even have been involved in the construction of some British examples[46] The fashion for carved balustrades had a surprising longevity, with examples still being found into the 1680s. Gradually, naturalistic foliage replaced the earlier strapwork, as at

Tyttenhanger, Hertfordshire (*c*.1654), Sudbury Hall (1670) (Figure 2.18) and Cassiobury Park, Hertfordshire (1674–1680).

2.16 Strap work at Aston Hall. (Godfrey)

2.17 Rawdon House, Hoddeson (1622). (Godfrey)

2.18 Sudbury Hall (1670) (Sudbury Hall). (National Trust)

Cantilever Stairs

While timber staircases were becoming increasingly elaborate, stone stairs remained relatively restrained in

Britain until the early seventeenth century. The most notable change in the Elizabethan period was the division of the staircase into many separate flights, interspersed with landings. Flights, however, typically rose between walls, without elaborate balustrades. Such flights were essentially sloping corridors. They lacked the drama of the more elaborate staircases that were being produced on the continent in the same period. Again, the big changes had to wait for the seventeenth century. The major innovation was the ‘cantilever stair’. It is Inigo Jones who can be credited with introducing the ‘cantilevered’ staircase into Britain, in 1629–1635 at the Queen’s House in Greenwich.

Jones had travelled twice to Italy and was familiar with Palladio’s work. The Tulip staircase is a circular and much more refined version of the Carita staircase (Figure 2.19). Jones’s stair is particularly delicate in its detailing, with an ornate iron balustrade. The treads are sculpted at the ends and underneath for decorative effect.

2.19 The Tulip Staircase. (© National Maritime Museum, Greenwich, London)

The influence of this stair was initially limited. The reason was that it was known to relatively few people. It was tucked away in a building not directly accessible to the public. Moreover, the Civil War had disrupted the building of lavish palaces and houses for the rich. The Tulip Stair's direct influence in the seventeenth century was thus restricted to a few individuals who had access to it: Talman, Wren, Vanbrugh and a handful of others with connections at court. Wren would later use it as a model for the Dean's stair at St Paul's (1704–1705) and with Hooke for the extraordinary staircase in the Monument to the Great Fire (1671–1676) (Figure 2.20). Many of Wren's less well-known back stairs at Hampton Court are also 'cantilevered' stone stairs. The pair of winding staircases *c*. 1724 at Seaton Delaval, Northumberland by Sir John Vanburgh (Figure 2.21) are also fine examples. In 1696 Talman produced a dramatic straight-cantilevered stair at Chatsworth, with iron balustrades by Tijou. The master blacksmith's publication of designs in his *New Book of Drawings* in 1693 led to an increased interest in iron balustrades.

2.20 Monument to the Great Fire (1671–1676). (Ping Gong)

2.21 Winding Staircase *c*. 1724 at Seaton Delaval. (Michael Tutton)

The Iron Balustrade

Iron balustrades were not unusual in stone stairs in this period, and varied from the simple stick balusters of the backstairs at Hampton Court to very complex ones such as those in the Dean's Stair at St Paul's.

The reason for using iron in these stone stairs was simple, but rarely seems to be mentioned in print: it is nearly impossible to fix wooden balusters to stone treads. Iron is set into a drilled hole and fixed in place with molten lead. Molten lead would burn timber. Iron was also lighter than the alternative, which was a stone balustrade. The architect might consider using a stone balustrade on a supported flight, but it was impractical for cantilevered stairs where the weight applied at the ends of the treads would lead to structural failure. In such a situation iron balustrades were the only practical solution. That distinction – timber balusters go with timber stairs and iron or stone balusters go with stone ones – remains the case until the late eighteenth century when you do start to find iron balustrades used in timber stairs (e.g. Portsmouth Dockyard, Hampshire)[47] Stone stairs never have timber balusters.

The rise of the use of the iron baluster thus goes hand-in-hand with the increase in use of stone 'cantilever' stairs, which by the end of the eighteenth century had made their way down the social scale to such an extent that they could be found in larger terraced houses.

Other Developments on Plan

Although the stone 'cantilever' stair was slow to take off, European influence can be seen in increasingly grand and prominent staircases in the early seventeenth century. Jones had visited Italy, while Wren and Vanbrugh had been to France. Engravings were also widely available. In public staircases, the grandiose stone flights of the King and Queen's staircases at

Hampton Court are notable, but they are single flights. The symmetrical sets of stairs found on the continent were slower to appear.

One of the most famous early examples of a grand symmetrical staircase is that at Coleshill (destroyed) by Roger Pratt (Figure 2.22), where the entrance hall was entirely dominated by a huge double staircase. Here we have two symmetrical staircases, one on either side of a hall. The true Imperial stair – where a single flight divides and returns as two – is often cited as an eighteenth-century innovation. In fact, it does appear occasionally in the seventeenth century. John Webb built one at Gunnersbury House in 1658;
there was one in Madam Boone's House in Lee, Greater London in 1670; and in the 1680s Wren proposed a grand Imperial staircase (never executed) in front of a great window for a country house in Tring.[48]

2.22 Coleshill (destroyed) by Roger Pratt. (*Country Life*)

However, most British seventeenth-century staircases were asymmetrical and ran around the outside of a room. The reasons for this were interrelated and were to do with the convenience of the position on plan and problems of lighting.

Lighting the Staircase Hall

All staircases need light and with all the early examples this was provided by windows. One popular solution was to put the staircase on one side of the building on plan. In this position, it would rise towards windows on one of the end facades. It would stop at a half-landing and then return to the centre of the plan at the first floor. This kind of arrangement is seen at Barnham Court (*c*.1640),[49] Mawley Hall (*c*.1728)[50] and Easton Neston (1702–*c*.1731) (Figure 2.23).[51] Although dramatic on the inside, this position made it difficult to compose symmetrical facades on the exterior: the ideal window position was midway between the floors. In the crudest examples the landing simply cut a window in half, but in most cases the lower window was omitted and a larger higher window was provided in its place.

2.23 Easton Neston (1702–*c*. 1731). (*Country Life*)

The most dramatic and revolutionary solution to the problem was to have the staircase in the middle of the building and light it from above. This solution first appears in Ashburnham House, Westminster in 1662 (Figure 2.24). Here, an elegant classical stair climbs to the first floor in a top-lit hall, surmounted by a dome. The date and architect are both subject to debate. Current thinking is that it was designed either by John Webb (1611–1672) or William Samwell (1628–1726).[52] This is probably the first example of a top-lit staircase in Britain. It was an extraordinarily prescient arrangement, but not one taken up elsewhere at the time. At Blenheim and Castle Howard, Vanbrugh lit the stair by borrowing light from the clerestory windows of the entrance hall and Talman drew a design for a circular stairhall surmounted by a dome (unexecuted).[53] But despite these precedents, the British staircase in the seventeenth century was typically lit from the side.

2.24 Ashburnham House, Westminster in 1662. (*Country Life*)

Open-String and 'Cantilever' Timber Staircases in the Late Seventeenth Century

Only the grandest buildings in seventeenth-century England boasted stone stairs. Timber stairs were the norm. There was a simple reason for this: they were cheaper. Medieval staircases had been made of oak or elm, but increasingly in the seventeenth, eighteenth and nineteenth centuries they were made of Baltic pine, painted to disguise its inferior finish. The undersides of the flights were usually plastered.

Although they appear to cantilever, timber 'cantilever' stairs have nothing in common structurally with their stone counterparts. In stone 'cantilever' stairs there is no need for a string and indeed it creates unwanted weight in precisely the wrong place (furthest from the wall where it exerts maximum leverage). In timber stairs, however, the string (cut or uncut) is essential, as the step and riser are separate elements and they are not stiff enough to act on their own.

Increasingly, seventeenth-century gentlemen wanted their timber stairs
to look like stone ones. The move to open-string (or cut string) timber stairs in the 1690s (see Chapter 3) served no practical purpose in timber stairs: it was purely in imitation of their stone counterparts. The string could not be done away with. Instead, it had to be replaced by a carriage underneath, or more commonly cut so that the upper surface had a sawtooth pattern onto which each tread was fixed. In neither case could the timber stair manage the slim profile of the stone cantilever it sought to imitate. Alec Clifton Taylor was wrong in saying that timber 'cantilevered' stairs are stronger because they are lighter; they are weaker because they are less stiff and the joints tended to loosen further with age, leading to sagging as countless examples show.[54] The most

dramatic ‘cantilever’ stairs would always, and could only, be made out of stone. The more ambitious timber ones were prone to lean, sometimes at the most alarming angles (e.g. Provost’s Lodge, Trinity College Dublin)

Despite their shortcomings, ‘cantilever’ timber stairs with cut strings were popular. The cut string was inelegant so the nosing of each tread was mimicked by planting a moulding on the side, and often the carpenters went as far as adding a decorative pattern (a bracket) to increase the impression that each tread was separate, like its stone counterpart.

In open-tread timber stairs the balusters sit on the tread end. Usually they number two per tread, but in shallower stairs they are three per tread. This leads to a particular problem: as the handrail slopes, each of the set of two or three balusters on each step must be a different length, but aesthetically they should look the same. The normal solution is to keep the plinths top and bottom the same length and vary the length of the shaft. One way of hiding this was to twist the balusters (twisted balusters thus became more common at the end of the seventeenth century – see Chapter 3). Another was to make each baluster of a set on each step a different pattern (fluted and unfluted, or Doric, Ionic and Corinthian, etc.) so the difference in length of shaft was less obvious. A similar problem existed for the iron railings on the stone cantilever stairs, but this was typically solved by having one piece of decorative wrought ironwork per step or plain stick balusters.

Early Books on Staircase Design

Despite the growth of architectural publishing in Britain and the increased importance of staircases in design in the seventeenth and eighteenth centuries,[55] staircases barely received a mention in books on architecture in the period.[56] They are shown in plan in *Vitruvius Britannicus* (1715),

Gibb's *Book of Architecture* (1728) and his *Rules for Drawing the Several Parts of Architecture* (1733), but not discussed. Likewise Adam, Chambers and James Wyatt all fail to mention staircase design. They are given passing mention in more practical works (see Table 2.1). All deal with the subject of staircases as part of general building construction, and the entries are slight. Francis Price's *British Carpenter* (1735), for example, gives only summary information on calculating tread and riser size.

Table 2.1 List of early books on staircase design

First published	*Author, Title*
1678	Joseph Moxon, *Mechanick Exercises*
1703	Richard Neve, *City and Country Purchaser*
1725	William Halfpenny, *Art of Sound Building*
1730	Edward Oakley, *The Magazine of Architecture, Perspective and Sculpture*
1734	*The Builders Dictionary*
1734	William Salmon, *Palladio Londinensis*

First published	*Author, Title*
1735	Francis Price's *British Carpenter*
1745	A. Swan, *The British Architect or the Builder's Treasury of Staircases*
1758	William Pain, *The Builders Companion*
1765	R. Manwaring, *The Carpenter's Complete Guide to the Whole System of Gothic Railing*
1766	Edward Oakley, *Everyman a Compleat Carpenter*
1774	William Pain, *Workman's General Assistant*
1774	William Pain, *Practical Builder*
1778	William Pain, *The Carpenter's and Joiners Repository*
1786	William Pain, *The British Palladio*

The first book devoted entirely to the subject of staircases – Swan's *British Architect: Or, The Builder's Treasury of Staircases* (1745) – is particularly disappointing. It has only 14 plates and its illustrations show stairs with heavy balusters and newels that were long out of fashion by the time it was written.

All the early books on the subject were limited to timber staircases. Timber predominated in domestic staircases in England before 1750 (by way of contrast, timber was never used much in Scotland). Closed strings with turned balusters were used for lesser stairs, while the main stair usually had twisted balusters, ramped handrails, open strings and decorative bracketing.

Stone cantilever stairs, with iron balusters and mahogany handrails, became common even in terraced London houses for the main stair from 1750 onwards. By the end of the eighteenth century and throughout the nineteenth, stick balusters and sinuous curved continuous handrails were common.

The increase in stone staircases in even quite modest houses in the late eighteenth century gradually began to be reflected in building manuals from the second half of the century onwards. Thus, while Pain's *The Builders Companion* (1758) contains only timber stairs, his *Workman's General Assistant* (1774) and *The British Palladio* (1786) have both timber and stone examples.

Developments on Plan in the Eighteenth Century

In grand buildings the development of the eighteenth-century stair went hand-in-hand with changes in plan. The Palladian influence led to the placing of major rooms on the first floor or *piano nobile*, which in country houses was usually reached by a large external staircase. Thus the visitor actually entered one storey above ground level. In such a design, the internal staircases were of secondary importance because the visitor was already on the main floor. For example, at Chiswick House the dramatic stair is on the outside. One particularly fine exception to this rule was Holkham

Hall, Norfolk (Figure 2.25), where the visitor entered a huge entrance hall to be confronted by a dramatic single flight of curved marble stairs, which appear to flow out of the main salon door above, while galleries above give views back onto the entrance hall.[57] The hall is lit from windows in the entrance facade.

2.25 Holkham Hall, Norfolk. (*Country Life*)

As mentioned above, the top-lit stair had been introduced in the seventeenth century, but it remained rare in Britain until the second half of the eighteenth century because of the difficulty of making glazed rooflights. Two of the earliest and most dramatic examples were William Kent's stair, constructed for Lady Isabella Finch for 44 Berkeley Square (1742–1745) (Figure 2.26), now the Clermont Club,[58] and Isaac Ware's Chesterfield House (1748–1749) (Fig 2.27).[59]

2.26 44 Berkeley Square. (*Country Life*)

2.27 Chesterfield House. (*Country Life*)

Once the technical problems were solved, the domed circular hall soon became a popular solution for fine houses. William Chambers designed a dramatic top-lit domed staircase for the Duke of York in 1759 (unexecuted).[60] The circular theme was successfully used by Adam at Home House (1775) (Figure 2.28)[61] and Paine at Wardour Castle (1770–1776) (Figure 2.29).[62]

2.28 Adam at Home House. (*Country Life*)

2.29 Paine at Wardour Castle. (*Country Life*)

An oval hall appears in Adam's 1761 plan for Syon House (unexecuted) and in his work of 1785–1790 at Culzean.[63] Soane produced an oval staircase in his own house and at Buckingham House (1792–1795).[64] Holland's Carlton House (1784–1789) was perhaps the most dramatic example, with a flying stair (two flights with a single central flight returning, followed by two more) (Figure 2.30).[65] The flying staircase was also used by Chambers at Melbourne House, London (1771, demolished) and Dundas House, Edinburgh (1771, demolished).[66] S.P. Cockerell's version at Sezincote (*c*.1805) survives (Figure 2.31),[67] as does St Pancras Chambers (Figure 2.32), where the theme is taken to its extreme in a series of flying staircases one above the other.

2.30 Holland's Carlton House (1784–1789).

2.31 S.P. Cockerell's flying stair at Sezincote (*c*.1805). (*Country Life*)

2.32 St Pancras Chambers. (Will Pryce; www.willpryce.com)

In public buildings perhaps the best examples were again by Chambers. Somerset House involved a whole series of dramatic cantilever staircases. The Navy Office staircase (Figure 2.33), built *c*.1780, consists of two curved flights in an oval well which meet and then continue in a single flying flight to the first floor. Also notable are cantilevered staircases in the Strand front in the Courtauld Institute, the east and west staircases, formally the Royal Society and Royal Academy staircases. These are both in semi-circular wells with curved flights to straight landings.

2.33 Somerset House, the Navy Office Staircase. (Michael Tutton)

Gothic Revival

The practice of building Gothic architecture never really disappeared in England. Oxbridge Colleges continued to adapt their existing buildings and extend them in the Gothic style throughout the seventeenth and eighteenth centuries with complete disregard for the whims of architectural fashion. Whenever architects were asked to design a Gothic staircase they were left without much in the way of precedent to follow. This does not seem to have held them back. Indeed, quite the reverse is true: it seems to have given the architects license to exercise their imaginations to the full. The staircase at Strawberry Hill (*c*.1753) by Horace Walpole and Richard Bentley is an early example (Figure 2.34). Walpole and Bentley produced a strange concoction: a Neo-Jacobean stair with filigree neo-gothic detailing. The strings are decorated with pointed arches and the walls with perpendicular tracery.[68]

2.34 Strawberry Hill (*c*.1753). (*Country Life*)

The exquisite staircases at Penrhyn Castle (1820–1845) by Hopper (Figure 2.35),[69] and those in the Houses of Parliament by Barry and Pugin are particularly fine early nineteenth-century examples, but the master of the Gothic stair was James Wyatt (1746–1814).

2.35 Penrhyn Castle 1820–1845 by Hopper. (*Country Life*)

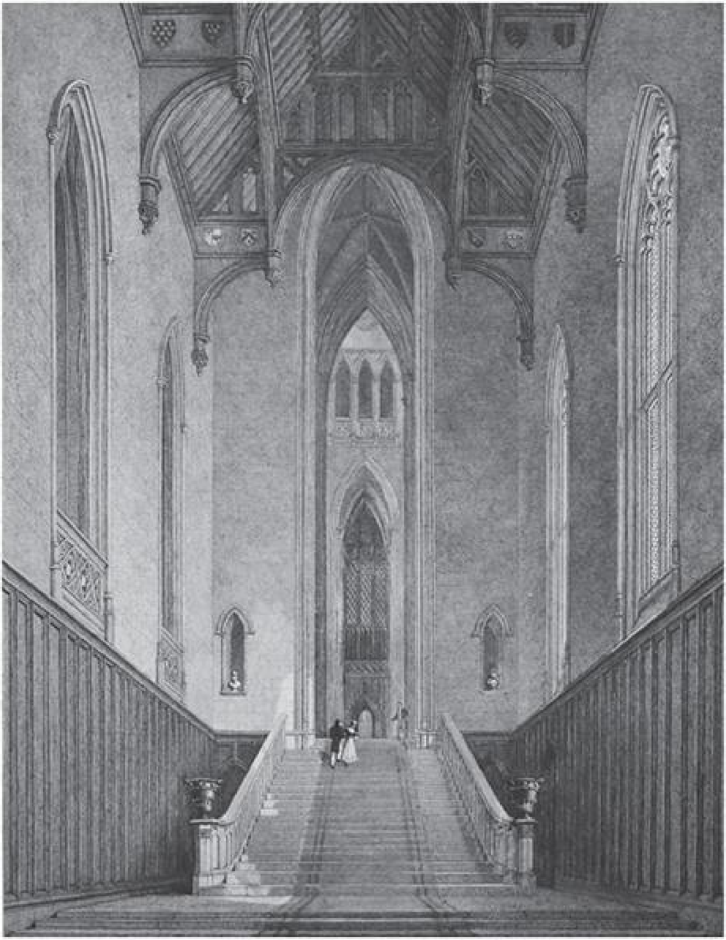
At Ashridge (1808–1817), Little Gaddesden (Figure 2.36), Wyatt created a dramatic staircase by placing it around the walls of a huge stair hall. The effect is vertigo inducing. The hall is definitely Gothic in feel, but the staircase itself pays little more than lip service to Gothic architecture, with pointed arches in the balustrade detailing.[70] By way of contrast, Wyatt's

staircase for Christ Church, Oxford (1805) (Figure 2.37), which rises to the hall in a seventeenth-century vaulted space, is so perfectly in keeping with the architecture that it regularly fools observers into thinking it is contemporary with the sixteenth-century Medieval-style dining hall it leads to.

2.36 Ashridge. (*Country Life*)

2.37 Christ Church. (With thanks to Christ Church, Oxford. Ralph Williamson Photography)

The Christ Church staircase is indicative of a growing interest at the turn of the century in the study of the details of Gothic architecture. With it, a new generation produced Gothic stairs that made at least some attempt to follow the spirit of the architecture, even though the results were far more elaborate than any Medieval stair ever had been. Wyatt, although the master of this tradition, was not without his faults. His staircase for Fonthill Abbey (Figure 2.38), which he designed for William Beckford, may have been one of the finest Gothic staircases produced in England, but Wyatt failed to supervise the work and the building subsequently collapsed.



2.38 Fonthill Abbey. (Rutter's *Delineations of Fonthill*, 1823)

The end of the nineteenth century saw the great Gothic staircases by George Edmund Street in his Law Courts in the Strand and Alfred

Waterhouse's Natural History Museum (Figure 2.40). The main staircase in Eaton Hall, Cheshire, demolished, designed by Waterhouse for the then Marquis of Westminster, is one of the finest examples. Photographs show a series of Gothic arches rising towards the light (Figure 2.39).[71]

2.39 Gothic stair at Eaton Hall, demolished 1961–63. (*Country Life*)

2.40 National History Museum by Alfred Waterhouse. (Ping Gong)

Technical Advances and Stylistic Changes in the Nineteenth Century

The big technical change in the late nineteenth century was the growing use of iron. One of the first architects to take it up enthusiastically was John Nash (1752–1835). His use of iron frames in the remodelling of Buckingham Palace for the Prince Regent met with much criticism at the time. But the grand curvilinear Imperial stone staircase with iron balustrades remains one of the most impressive spaces in the palace. The whole first floor,

including the staircase, is supported on iron beams. Nash used an iron frame again at
the Brighton Pavilion, where the open tread staircases are more obviously iron, complete with iron balustrades mimicking bamboo.

The spiral staircase in the Palm House (1844–1848) (Figure 2.41) at Kew is the most public example of an early cast-iron spiral stair. This type of stair was simple to mass-produce and by the 1850s similar designs were being shipped by English and Scottish manufacturers to the furthest ends of the earth. But perhaps no building better expresses both the Victorian spirit and the new structural possibilities of iron than the great staircase in Midland Grand Hotel (St Pancras Station, London) by George Gilbert Scott, built in 1870[72] (Figure 2.32). This staircase is apparently simple on plan, with a straight flight at each floor rising to a half-landing and then branching into two symmetrical curvilinear flights. Such a simple description belies the incredibly complex views created in a stair that ascends in a rich crimson oval shaft through three storeys. It remains one of the world's most theatrical and exhilarating staircases. The Midland Grand Hotel also marks the end of an era in hotel design. The elevator did away with the need for a large staircase in a hotel building and later hotels cease to celebrate their existence.

2.41 Palm House (1844–48), Kew. (Ping Gong)

Mass Production

Iron staircases such as that at the Palm House at Kew (Figure 2.41) had to be prefabricated in the foundry, to be re-assembled on-site. By the middle of the century they were available from catalogues. Fire-proofing was their major selling point. Building regulations in the late nineteenth century were beginning to focus on this issue in public buildings. Iron stairs were thought to be one answer, with carriages designed to carry terracotta, stone or iron treads.

Georgian timber staircases had been made on-site, with only limited elements such as turned balusters kept in stock by joiners' shops for use when required. Before mechanisation, timber staircases were made with as little in the way of drawings or written description as the architect cared to supply.[73] The setting out seems to have been the craftsman's prerogative, the architect only providing sketches for decorative elements and a general plan.

The nineteenth century saw the gradual, if somewhat reluctant mechanisation of the timber industry, starting with the mechanisation of saw mills. This went hand-in-hand with a switch from Baltic timber to American pine, which had fewer knots and was thus easier to convert by machine.[74] New machines allowed every element to be mass-produced and with mechanisation came standardisation. By 1867 Alexander Kay, a joiner, was able to report that every part of a staircase could be manufactured by machine.[75] W.H. Lascelles Steam

Joinery advertised a catalogue of stair designs in issue 1 of *The Architect* in January 1869.

Handrails and balusters were the simplest elements to mass-produce, but by the end of the century carving machines could replicate even complex carved decoration of the mid-seventeenth century balustrades, and routing machines made the grooves in strings. The most obvious result was the use of increasingly elaborate turned timber balusters. These could be cheaply mass-produced and were available off-the-peg. The late Georgian domestic stair had often had simple stick balusters. By contrast, Victorian domestic stairs more often employed heavy, over-decorated ones.

In 1878 the *Illustrated Carpenter and Builder* printed a lament to the disappearance of the 'old staircase hands' who 50 years before had insisted on building their staircases 'step-by-step' on site rather than preparing them in the workshop, and guarded the secrets to their art, now freely available to all through books.[76] This move to off-site production was important, but timber staircases were never so standardised that they were available 'off-the-shelf'. They were made to order to measurements provided according to standard types and details. Much the same applies today.

The last material to appear in the nineteenth century was reinforced concrete. Concrete stairs were being illustrated in the *Builder* from the late 1870s, with granolithic finishes appearing in the 1880s. Granolithic and terrazzo floor finishes remained very popular well into the second half of the twentieth century and offer considerable challenges to the modern conservation architects seeking to repair them today.

Staircases and Late Victorian Civic Pride

Many of the finest nineteenth-century staircases are to be found in civic and government buildings. The style of the building might vary, but a stately staircase had to be provided. This applied equally to the great buildings of state and the most modest town halls. For the most part inspiration was taken from the architecture of the Renaissance and Baroque.

In London perhaps the finest examples are the stairs in the Foreign Office and Treasury buildings in Whitehall. The central staircase in the Natural History Museum by Alfred Waterhouse in a Gothic idiom also stands out (Figure 2.40). Outside London, the pair of principal staircases in Glasgow City Chambers (1882–1890) designed by William Young (1843–1900) provide particularly grand examples (the 'working' or lion staircase illustrated on the front cover), but countless others could be cited.[77]

Books and Journals in the Nineteenth and Early Twentieth Centuries

Nineteenth-century architects drew on a wide variety of sources. They were increasingly travelling abroad and many of the buildings they were influenced by were known to them firsthand. However, there were also a wealth of topographical books they could consult; books like Street's *Brick and Marble Architecture of the Middle Ages* (1855) or Letarouilly's *Edifices de Rome Moderne* (1840–1857), as well as richly produced self-promoting monographs such as Charles Garnier's one on his Paris Opera House.

Technical manuals were also increasingly common. Peter Nicholson was the leader in the field. Many of his general works, including *New Practical Builder* (1823), dealt with staircase construction. His *Treatise on the Construction of Staircases and Handrails*[78] first published in 1820, was entirely devoted to the subject. In it he devoted considerable space to the geometrical problems involved in setting out continuous timber handrails for stairs and comparatively little space to ornamentation and design of layouts. It would be impossible to build a staircase using just the advice found in these books. They presume the reader has firsthand knowledge of construction and concentrate on the problems of setting out. They are particularly useful in providing guides to contemporary terminology.

The setting out of handrails and curving strings formed the primary subject of most later books on staircases, including John Jones, *Handrailing: The Square Cut* (1886); W.H. Wood, *Practical Stairbuilding and Handrailing* (1894); William Mowat, *A Treatise on Stairbuilding and Handrailing* (1900), W.A. Scott, *Handrailing for Geometrical Staircases* (1915), John W. Wright, *Handrail and Staircase Joinery* (1931) and George Ellis, *Modern Practical Stairbuilding* (1932), but in all of these comparatively little attention was given to the layout on plan or to constructional details. This changes towards the end of the century. *The Illustrated Carpenter and Builder*, Vol. III, No.48 (5 July 1878) and books like Hasluck's *Practical Staircase Joinery* (1910) provided clear descriptions sufficient for the carpenter to be able to build a stair. Detailed drawings were increasingly provided in general building manuals in the twentieth century. The reason was simple: these books were aimed at architects and surveyors who were beginning to be expected to provide detailed drawings of the construction of staircases for the workman.

Modernist Stairs in the UK

Nineteenth-century domestic staircases were primarily based on historical styles. The Arts and Crafts movement was influential in simplifying ornament. Mackintosh and Lutyens provide good examples, with Mackintosh's stair for the Glasgow School of Art and Lutyen's stair for Castle Drogo standing out. Modernism was slow to catch on in Britain. Art Deco and stripped-classicism were considered more acceptable alternatives. Hornsey Town Hall (1934–1935) by Reginald Uren carries overtones of both. Its staircase is classical in inspiration, although executed in concrete and bronze.

Outsiders were often more successful. Wells Coates had been born in Japan, son of Canadian missionaries. He had moved to London as a student in 1922 and stayed. His Lawn Road Flats exhibited a type of external stair that became popular in modern architecture with solid concrete balustrades, so the whole staircase reads as a single sculptural element appearing as diagonal folded planes on the facade.

Another popular modernist form consisted of steel flights with tubular handrails strongly reminiscent of the sort of stairs found on ocean liners. These had been popularised by Le Corbusier’s *Vers Une Architecture* that became the bible of early modernist architects. British examples are Connell, Ward and Lucas’s 66 Frognall, London (1936–1937) and Oliver Hill’s Landfall, in Poole, Dorset (1936–1938).

The early British Modernists rarely exposed the edge of the treads in their stairs, preferring strings that gave straight lines or smooth curves. In the De La Warr Pavilion at Bexhill on Sea, East Sussex, built in 1935 by the German architect Erich Mendelsohn (1887–1953) with the Russian Serge Chermayeff (1900–1996), the stairs consist of an apparently smooth spiral of concrete rising inside a glass drum. The concrete strings form a kerb to the edge of each tread so that the edge of the stair presents a smooth continuous strip to the outside world. The tubular ship-type handrails are almost invisible from outside the building, further reinforcing the impression that the stair is a smooth concrete spiral ascending within a curved glass cylinder (Figure 2.42).

2.42 De La Warr Pavilion (built 1935). (Photograph by Richard Walker)

Spiral stairs in all forms were popular throughout the 1920s and 1930s. Sir Owen William's oval open-well spiral staircase for the Daily Express
Building (1929–1932) in London picks up a similar theme. Here the kerb is raised to waist level and topped by a thin ribbon of steel painted blue. A similar grand example is found in Joseph Emberton's Simpsons in Piccadilly, London (1935–1936), where a marble staircase rises gracefully around three sides of an open well, lit from the side. Art Deco often led to imaginative balustrade designs, such as the lit balustrade of the Strand Palace hotel by Oliver Bernard (1930).[79]

Most stairs in post-war housing blocks were unremarkable. Rare exceptions are those created by another émigré: Berthold Lubetkin (1901–1990). In

Bevin Court, and in the two blocks of the Dorset Estate in Islington, London, Lubetkin created extraordinary staircases of dazzling complexity (Figures 2.43–2.45).[80]

2.43 Berthold Lubetkin (1901–1990), Bevin Court. (Michael Tutton)

2.44 Berthold Lubetkin (1901–1990), George Loveless House. (Michael Tutton)

2.45 The Royal Festival Hall (1951). (Ping Gong)

Post-war public buildings continued to celebrate the staircase despite the ubiquity of the lift and the escalator. The Royal Festival Hall (1951) was undoubtedly one of the most influential. Although it had banks of lifts on both sides of the building, grand stairs were still intended as the primary mode of circulation. The main flights to the auditorium are concrete open stairs with cantilevered treads and particularly fine bronze tubular handrails supported on widely spaced bronze posts with ceramic tubes forming decoration (Figure 2.45). Pieces of clear glass form the balustrade. The stairs ascending towards the light on either side of the auditorium give spectacular views of the river and are clearly seen from outside.

The open-tread stair of the kind used at the Royal Festival Hall has a number of disadvantages for visually impaired users and its open treads on long, cantilevered flights create a sense of exposure that can also be a problem for vertigo sufferers. Nevertheless, the way the open stair revealed its construction and perceived rationalism of doing away with the apparently superfluous riser appealed to British modern architects then, as it continues to do so now.

Steel open-tread stairs with timber treads featured prominently in Smithson's hugely influential Hunstanton School (1949–1954), where the stair's industrial aesthetic went well with the building's Mies van der Rohe inspired minimal architecture.[81] The Smithsons also used timber open-tread stairs in their house designs. The mass-produced steel escape stairs which were to be found everywhere from the beginning of the twentieth century provided the obvious inspiration. These were also the greatest influence on the so-called 'Hi-Tech architects'. Open-tread examples litter 'Hi-Tech architecture'. There are examples by all the leading exponents: Grimshaw, Foster, Rogers and Piano. One of the more recent and vertigo-inducing is the Law Faculty

Library (1990–1995) for Cambridge University by Norman Foster where a series of flights cantilever over a large void (Figure 2.46).

2.46 Law Faculty Library (1990–1995) for Cambridge University. (Ping Gong)

The High-Tech architects changed the external fire escape staircase from something to be hidden into something to be celebrated, often using such stairs as the principal elements in façade composition. Rogers, for instance, typically uses dog-leg stairs with curved landings and solid balustrades. These balustrades are wrapped in various ways and painted bright colours to provide the effect of dramatic banded tubes (see Lloyds Building (Figure 2.47), Channel 4 Television 88 Wood Street, London and his designs for the National Gallery Extension).

2.47 Lloyds Building. (Ping Gong)

Other architects have exploited solid stairs to great advantage. They have played with the idea of the building creating an internal landscape where the staircase appears to climb up the side of a man-made cliff and looks like it is carved out of it. This was not a new idea. Many historical stairs had created a similar effect, but it became a modernist type. Aalto used it in the Festival Hall of the Pedagogical Institute (now University) in Jyvaskyla (1952–1957) and in England he may have been the chief influence on the modern architects. The idea of stairs in an Italian hill town is explicit in the Smithsons tapering and cut-back external entrance stairs at the Bath University School of Architecture and Building Engineering (1982–1988).[82] Internally there are countless examples, but the most prominent and thus perhaps most influential are James Stirling's Clore Gallery (1980–1985)[83] extension to Tate Britain and the stairs in the entrance lobby of the British Library by Colin St Wilson.[84] A similar but defiantly Postmodern version is Venturi's tapering staircase for the National Gallery Extension.[85] The hillside theme is also explicit internally in David Chipperfield's BBC Scotland building in Glasgow.[86]

Shops and shopfitting is perhaps the area that has led most directly to experimental stair design, with the stairs very often becoming the focus of the whole space. In the 1980s British-based architects like Nigel Coates and Eva Jiricna successfully carried out shopfitting projects at home and abroad, producing hugely imaginative and inventive staircases. Coates specialised in cladding stairs in exotic materials such as copper and forming them into sensual curving shapes. Chipperfield and Pawson produced refined minimalist stairs.[87] Eva Jiricna pioneered a series of extraordinary stainless steel and glass staircases (e.g. Bergdorf Goodman, New York;[88] Joan and David, Bond St., London;[89] Joseph Store, Sloane St., London[90]). These beautiful staircases obviously relied heavily on the work of the engineers (Matthew Wells and others), although it is symptomatic of the attitude too often evident among architects that they usually fail to credit the engineers involved.[91]

One of the fascinating aspects of such projects is their transitory nature. The contemporary shop fit-out will rarely last more than ten years. The stair is then almost always stripped out and thrown away. This is, of course, not a new phenomenon. Staircases were stripped out of sixteenth- and seventeenth-century houses and sold on to be re-used elsewhere (e.g. seventeenth-century staircase from Cassiobury Park, Hertfordshire now in the Metropolitan Museum of Fine Art in New York). Antique staircases are still regularly offered up for sale. Modern ones are more often discarded despite their obvious expense. Staircases are treated not as part of the structure of the building but as fittings, like bookshelves. They are seen as furniture attached to the walls and, like furniture, they are easily thrown away.

Contemporary staircases share another feature with modern furniture: in their relentless quest to be more radical and extreme, both in form and in material, there is no longer anything significantly British about their design. Looking through the architectural magazines you will find British designers working in New York, Japan and Korea; and Korean, Japanese and American architects working in Britain. It is impossible to recognise any particularly British trend in modern staircase design. The world of staircases in the early twenty-first century appears to be truly international.

The same is not true of mass-produced staircases, which are more easily recognisable through tradition and their sensitivity to local building regulations. Such stairs are rarely exported. A mass-produced British domestic stair is thus easier to tell from its foreign counterparts than its architect-designed equivalent.

Although Modernism had sought to mark itself out as a break from the past, in Britain it began as an imported style. As such it was slow to find acceptance in an insular culture proud of its heritage. Today, architecture is not limited by stylistic convention but by fashion and materials. Ironically that may make contemporary staircases easier to date – fashions change fast.

The chief limitations for the contemporary designer are imagination, economics and engineering. For instance, plastic stairs continue to be rare, despite the ubiquity of the material in product design. This is because of its relative expense and because stairs are subject to greater wear and tear than most products. Plastics tend to scratch easily and lose their lustre quickly. As their pristine lustre is usually the reason for their use, plastics are rarely used for anything but the most transitory interior design projects. Titanium and carbon fibre could theoretically be used for stairs but they are expensive, their lack of weight is not an advantage, and their use would represent little more than affectation when cheaper materials are perfectly adequate.

While advances in materials have made little difference, improvements in computers have made the structural design of stairs much easier. The staircase creates a number of problems for the engineer. They need to be able to prove that the materials will not break under the loads, but they also need to be able to control movement. A stair that bends and creaks as the users ascend or descend may be in absolutely no danger of collapse, but it may feel so unsafe that no one wants to use it. Stiffness is thus critical in staircase design. The introduction of computerised finite element analysis has meant that engineers can now calculate the stiffness of staircases with a much greater degree of certainty. The most obvious result has been the development of staircases where the landings are cantilevered from the flights, a form that was previously too difficult to determine.

There is perhaps no more interesting time to be designing a staircase. Certainly there has never been a period when fewer limitations have been placed on the imagination of the designer. Having said that, the architect or interior designer approaching staircase design today still faces many of the same problems that architects and builders have always faced. Engineering and new materials may allow more elaborate structural forms, but the design still needs to fit the basic dimensions of the human body. In that sense the staircase is a timeless architectural problem. Like the chair it appears deceptively simple, but is fiendishly difficult to get right, and its shortcomings are immediately obvious to the user. The British stair may no longer be recognisably British, but the staircase will continue to dominate the thoughts of British designers for centuries to come.

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3

Dating Through Details

Linda Hall

Introduction

Dating a staircase by style involves two elements, the type of staircase (newel, closed well, open well) and the style of the different components. Churches provide useful comparisons, being full of balustrades (altar rails, pulpit stairs, west galleries) which are often dated, either by inscribed dates or by references in church wardens' accounts. The same carpenters produced items for both churches and houses, and any distinction between domestic and ecclesiastical architecture is a false one.

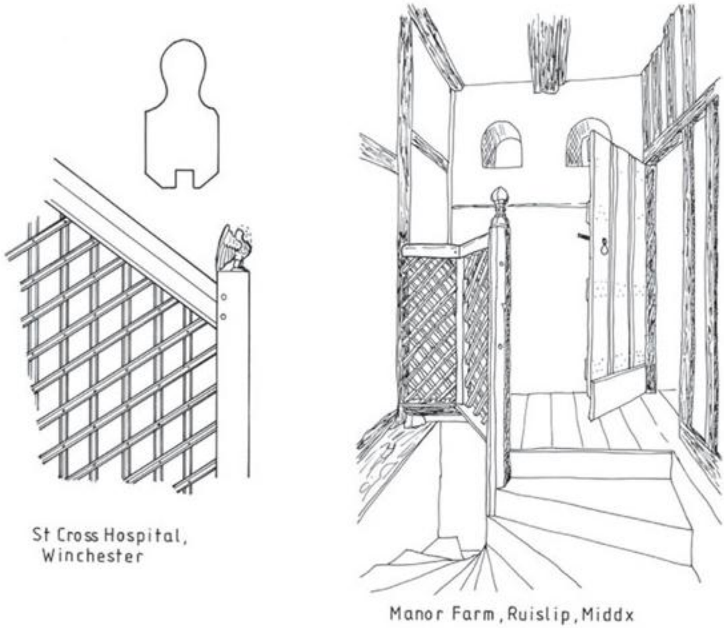
It is important to consider all aspects of a stair and not derive a date from a single element. For example, at Clare College, Cambridge stairs E (1638–1642) and F & G (1669–1676) have identical strings, while the newel post mouldings of the Perne Library stair (Peterhouse College, 1590s) and Clare stairs A and E (1638–1642) are also identical. Yet in each case the other features are different and point to the true date. A few domestic stairs have inscribed dates or have been dendro-dated, but examples in dated buildings provide most of the framework for dating. It is, however, important to check whether the stair belongs with the dated phase, or if it has been moved or reassembled, something which happened surprisingly often.

With a few notable exceptions, high status has more effect on the size of a stair and the amount and quality of the carving than on the design of balusters or mouldings. The quality of the carving can also distinguish status within a building; Aston Bury Manor, Herts has two open-well stairs of very similar size and style, but the superior one is slightly larger and has much finer mouldings on the balusters. It also tends to be assumed that fashions derive from London and that there will be a time-lag before styles arrive in more remote counties. Yet Staircase House, Stockport, Cheshire has a small open-well stair with a geometric pierced balustrade, installed by the gentry owners in 1618; a very similar but much larger stair was constructed three years later at Radclive Manor, Buckinghamshire, which is much closer to London.

Medieval Stairs

The evidence for Medieval stairs is limited, and most surviving examples are stone straight or spiral stairs. Brick spiral stairs occur from the later fifteenth until the early seventeenth century; some have an integral moulded handrail in the wall (Chenies Manor, Buckinghamshire). The simple straight flight in stone or wood was common in Medieval times. Many open-hall houses have three doorways leading from the hall to buttery, pantry and stair, and even if subsequently rebuilt the stair was clearly a straight flight against the wall. Downholland Hall near Ormskirk, Lancashire (Figure 2.12, Chapter 2) has a straight wooden stair with a heavy plank string pierced with tracery, which is clearly Medieval, but such survivals are extremely rare.[1]

Stokesay Castle, Shropshire, has an external stone stair to the parlour block and a remarkably long straight stair in the great hall (Figure 2.9), with solid wooden treads, triangular in section, nailed to sloping bearers, and a grip handrail. Its date is unknown, but similar stairs survive in a few Medieval buildings (Crook Hall, Durham; Colville Hall, White Roding, Essex). Medieval balustrades are virtually unknown, but the unusual wooden lattice balustrade at St Cross Hospital, Winchester (Figure 3.1)[2] may be sixteenth century. Similar balustrades exist at Manor Farm, Ruislip (1506–1511)[3] and in a Medieval house at Pinner, both West London; the date of the stair is not known. The St Cross stair may be similar to the 'iron trellice on the staircase before our chamber' referred to in the Liberate Rolls of Henry III in 1241.[4]



3.1 Lattice balustrades. The straight stone stair leading from hall to solar at St Cross Hospital, Winchester has a wooden lattice balustrade with a grip handrail. The newel post has the remains of a finial in the form of a pelican, the badge of Bishop Fox (Bishop of Winchester from 1501 to 1528), implying an early sixteenth-century date. At Manor Farm, Ruislip (1506–1511) the stair has been moved but may have reused the original octagonal newel and balustrade. The balustrade may, however, date from the period when the stair was moved, possibly the early seventeenth century.

Winder Stairs

Compact winder stairs were fitted into the corner of a room or next to the fireplace; larger ones may have projecting turrets. The stone or timber treads wind around a central timber, which usually doubles as a doorpost, and if the stair continues to a second floor there is a separate post for the upper flight. Doors were usually fitted to reduce draughts. Stone winder stairs occur in Medieval and later buildings; some have wooden treads on a rubblestone base. Many wooden winders survive in seventeenth-century houses, and even prestigious buildings such as the parlour block added to Daneway House, Sapperton, Gloucestershire in 1674 have winder stairs. The type remained popular in small houses and cottages into the twentieth century, although where space allowed many were replaced by straight flights.

Newel Stairs

The term 'newel' or 'newel post' (see p167) has two slightly different meanings, although both are a main support for the staircase. The earliest type of newel stair is circular and has a tall post, usually round in section but occasionally octagonal, into which wooden steps are tenoned. Round ones are sometimes called 'mast newels' from their resemblance to a ship's mast (*not* because they are re-used masts!) and they often rise through more than one storey. The steps may be solid baulks of timber, or composed of separate treads and risers. Solid treads are generally earlier, but dated examples are rare and more research is needed to establish a date range. Many newel stairs are small and compact, but they can be large and impressive, contained within a turret, wing or porch and rising to the attics. Examples are 1576 Gloucestershire,[5] 1594 Wiltshire[6] and 1599 and 1601 Monmouthshire[7]; all have solid treads. The 1628 Gloucestershire has heavy treads and risers and an octagonal newel. The 1664 Gloucestershire is a late example of a spacious newel stair in a large turret. Newel stairs may have a short balustrade at the top, with a handrail tenoned into the newel (1627 Wiltshire[8] and 1628 Gloucestershire[9]). Hill House, Olveston, South Gloucestershire has a massive newel with short balustrades attached; the newel was carved in the centre to resemble the turned balusters.[10]

Well Stairs

Closed well

The well stair appears in the mid-sixteenth century and in the seventeenth century was the most popular type in larger houses. The earliest version was the closed well, with short straight flights separated by quarter-landings rising around a square or rectangular core. The core can be solid masonry or a timber frame with the panels infilled with wattle and daub. Solid-core stairs occur in some of the grandest houses, such as Burghley House, Lincolnshire (1556), Parham, Sussex (1577), Littlecote, Wiltshire (1592) and Montacute House, Somerset (1598–1601). Smaller solid-core stairs in Devon date from the same period, with examples from 1567, 1593 and 1605,[11] while Fox and Raglan attributed several Monmouthshire examples to the period *c*.1590–1630.[12] Framed-well stairs occur at Rayne Hall, Essex (mid-sixteenth century), Beckley Park (*c*.1540) and Broughton Castle (1558), both in Oxfordshire.[13] Examples in Hampshire date from *c*.1560 and 1597–1606,[14] while another of 1561–1576 was lost in a fire in 1969.[15] According to *Sandwich: The 'Completest Medieval Town in England'*, the Guildhall in Sandwich, Kent, built as the new Court Hall in 1579,[16] has a framed-well stair with moulded corner posts. Other dated examples are Lawford Hall, Essex (1583) and Wigborough Manor, Somerset (1585).[17] Chastleton Manor, Oxfordshire (1607–1612) has both an open-well stair with turned mirror balusters and a framed-well stair. The four corner posts of the latter have pyramid finials at the top; a balustrade along one side of the closed well continues along the landing.

Open well

The framed well developed into the open-well stair, which became a feature of display with decorative balustrades and square newels at each corner, with elaborately carved pendants and finials. A framed well surrounded by a 'cage' of elaborate turned balusters at 1559 Suffolk shows how the open-well stair with balustrades may have developed. Collacombe Manor, Lamerton, Devon (1574) has a similar arrangement, albeit with a difference. Pevsner describes a stair with mirror balusters (see below) 'rising round a core which contains a remarkable garderobe sluice with access from two upper levels. A stream flows along a paved channel beneath.'[18] Excavation and fabric analysis at Hill Hall, Theydon Mount, Essex shows that the 1574–1575 phase included an open-well stair in a turret; some balusters were reused in the attic (see below).[19]

Grove Place, Nursling, Hampshire (1561–1576) has two matching stair turrets, one housing a unique stair which indicates a possible development of the open-well stair from the circular newel stair. The stair rises in a continuous curve around a small circular open well from the ground floor right to the observation room at the top of the turret, four floors above. The handrail follows the curve, and is interrupted at frequent intervals by newel posts with decorative finials and pendants. Curved stairs such as this are extremely rare in Britain[20] and the idea may have come from France.

The small open-well stair at Great Kewlands, Burham, Kent (1599) clearly shows the derivation from the framed well. The space below the handrail is divided by a horizontal timber, and is infilled below it and open above, with a secondary rail parallel to the main handrail. The landing has a balustrade with turned balusters.[21] Most of the surviving grand open-well stairs date from the seventeenth century (e.g. Knole, Kent, 1605–1608 (Figure 2.15)). Although most have a square well, some have a long, thin well and are closer to the dog-leg stair in design (Boston Manor, Brentford, West London, 1623). Open-well stairs are also found in smaller houses, such as The White Hart, Littleton-upon-Severn, South Gloucestershire, a late seventeenth-century building with good surviving woodwork.[22]

Dog-Leg Stairs

The dog-leg stair, an alternative to the open well, could be equally impressive. It has two parallel flights separated either by a half-landing or, if space was limited or the ceilings high, by winders.[23] Simple versions have a timber-framed partition between the two flights, with corner posts which are usually chamfered or moulded and stopped to match the doorframes (e.g. Moorend Farm, Hambrook, South Gloucestershire, 1676). The 1565 stair at Chequers, Buckinghamshire has the forerunner of the open balustrade, with a panel of turned balusters set into the partition between the two flights. Kirstead Hall, Norfolk (1614) and Cornish Hall, Holt, Denbigh (1618) are early dated examples, but the type has remained popular until the present day. Some houses have an open-well stair for the main stair and a dog-leg for the secondary stair(s), such as Tredegar House, Newport, Monmouthshire (1664–1672). The dog-leg stair was not necessarily regarded as inferior, and Groombridge Place, Kent (1652–1674) and Erddig, Denbigh (1683–1687) have dog-legs for both main and secondary stairs.

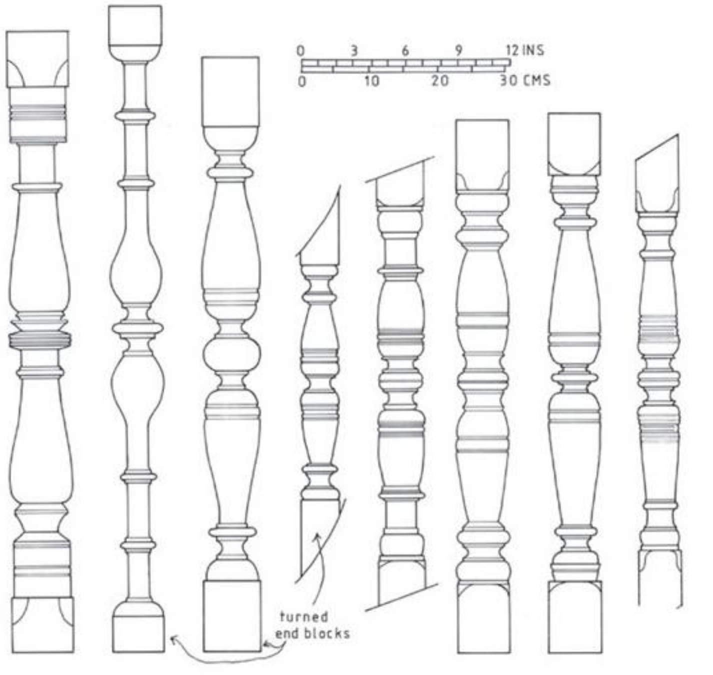
Baluster Design

Turned

St Nicholas' Church, Compton, Surrey has a wooden balustrade of *c*.1180. The plank-like top piece contains nine round arches, with slender turned columns complete with capitals tenoned into the top board. No other wooden structures of similar form and date have survived, but it suggests that later baluster design can be traced back to Classical columns with moulded bases and with capitals supporting a frieze (the handrail).

The earliest dated turned balusters (Figure 3.2), dating from the second half of the sixteenth century, are mirror balusters, symmetrical above and below the centre. Breccles Hall, Norfolk (1583)[24] and Acland Barton,

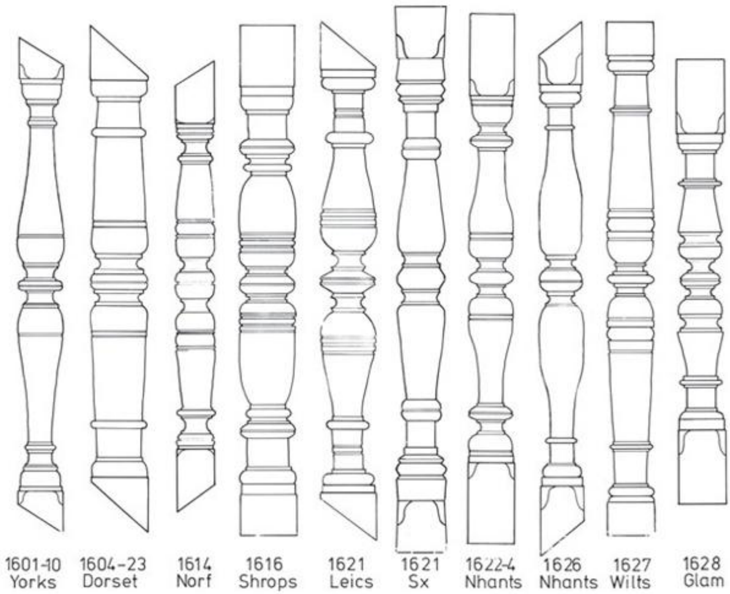
Landkey, Devon (1591)[25] have straight stairs with turned balusters; another
at Chawton House, Hampshire may incorporate mirror balusters from 1590, reset with later handrail and string. The Triangular Lodge, Rushton, Northamptonshire (1593–1597) has turned mirror balusters in the attic.



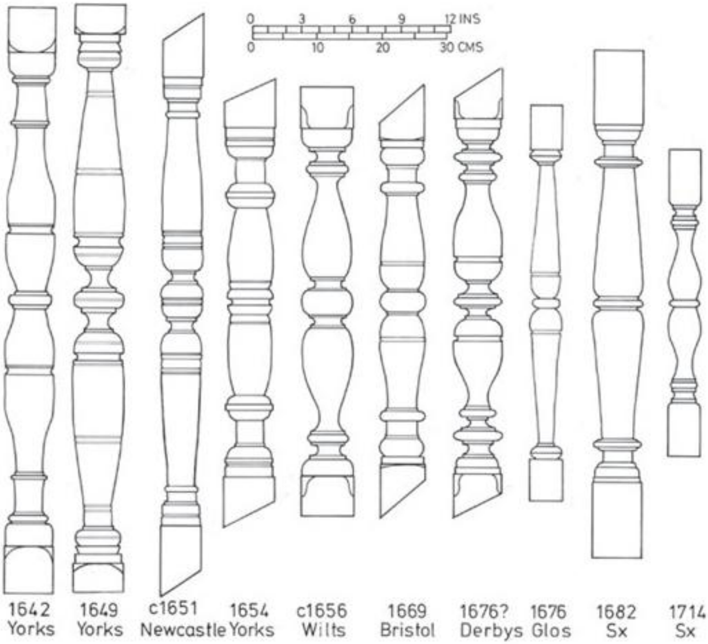
3.2 Sixteenth-century turned mirror balusters. The shorter balusters at Crows Hall (1559, Suffolk) are almost mirror balusters, except that both the upper and lower sections are tapered in from bottom to top; the longer balusters have three sections stacked on top of each other. They have short unturned top and bottom blocks which have a large concave moulding at each corner, and shallow incised lines around the centre and end cylinders. Chequers (1565, Buckinghamshire) has a panel of tall, slender mirror balusters with a strong vase-shaped profile, and the exceptional height allows for two rings around each shaft instead of the more usual one.

Some early balusters are turned for their entire length; most were reset when the houses were remodelled or rebuilt, but 1565 Buckinghamshire and 1561–1576 Hampshire are *in situ*. The latter are unusually short, and at the top of the stair turret identical balusters support a built-in bench in the tiny look-out room.[26] Some 1574–1575 balusters at Hill Hall, Theydon Mount, Essex were reused in the attic; photographed in 1951, they were destroyed in a disastrous fire in 1969.[27] Undated examples occur at 35 Stonegate, York, reused in the upper flight,[28] and Groombridge Place, Kent, reused in the kitchen and attic.[29] However, they may have a wider date range as they also occur in the mirror balusters of the 1635 altar rails and West Gallery front at Puddletown, Dorset. The 1709 altar rails at Penmark, Glamorgan are also turned for their entire length; the dated communion table has legs of identical design except that they have the usual square-sectioned end blocks.

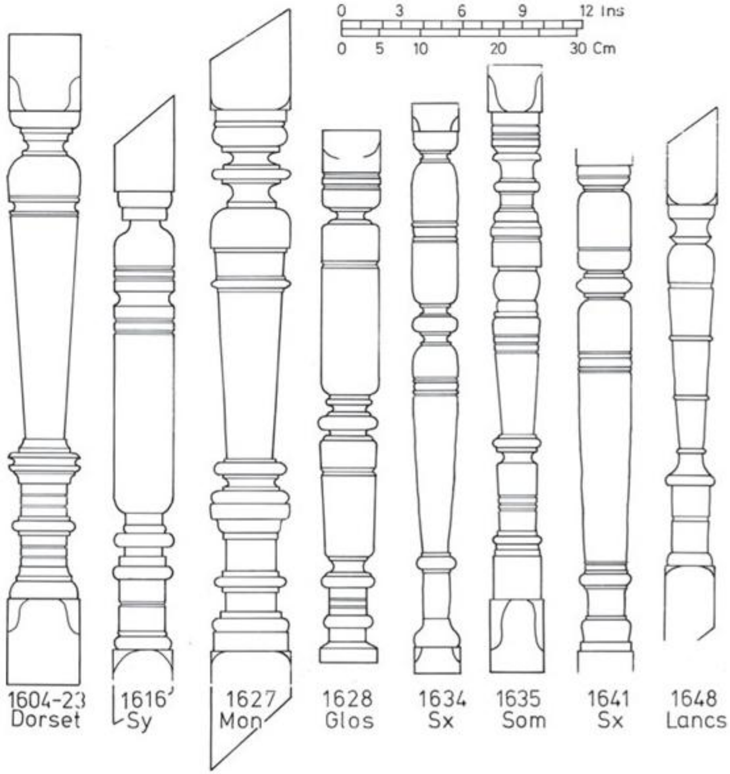
Mirror balusters remained popular until about 1660, with a few later examples, but not all balusters in this period were symmetrical. Until the mid-seventeenth century the turned shaft is usually either straight-sided or has a taper which is wider at the top; from the 1630s the vase baluster, which is wider at the base, begins to gain favour.[30] Late sixteenth- and early seventeenth-century balusters often have fine incised lines on the main shafts and on smaller turned elements, a feature rarely found after about 1660. In this period the end blocks are relatively short and most have ogee mouldings at the corners, or a simple curve. This curve gets progressively shallower until, by the eighteenth century, it is barely perceptible (Figures 3.2–3.5).



3.3 Early seventeenth-century mirror balusters. Early mirror balusters in grand houses may have an elegant vase shape (Burton Agnes Hall, Yorkshire, 1601–1610 and Quenby Hall, Leicestershire, 1621). The Talbot Hotel (Oundle, Northamptonshire, 1626) has a more angular bottle shape and a fine incised line on the central ring; most have incised lines on the main shafts.



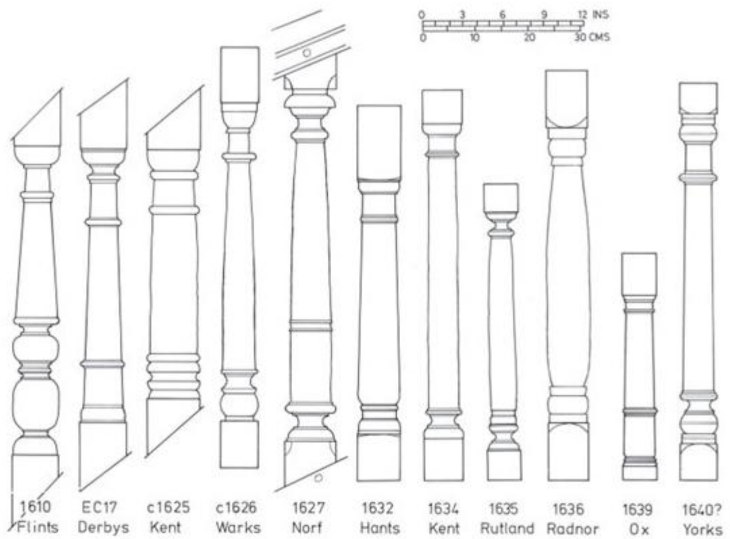
3.4 Mid-to late-seventeenth-century mirror balusters.



3.5 Early seventeenth-century turned balusters. Non-symmetrical balusters are less common than mirror balusters, but are similar in design.

Gun-barrel balusters

The gun-barrel baluster (Figure 3.6), popular in the first half of the seventeenth century, has a plain tapered shaft which, unlike other turned balusters of this period, is wider at the base, with minimal decoration apart from a neck ring and simple mouldings top and bottom. Dated examples between *c*.1625[31] and 1640 include three west galleries[32] and one set of altar rails.[33] Great Ellingham Hall, Norfolk[34] and Tissington Hall, Derbyshire[35] have undated examples. Known later examples are the 1673 altar rails and west gallery in Gwydir Uchaf Chapel, Gwynedd and in the gallery of the Friends' Meeting House, Alton, Hampshire (1672). At Alton the design of the turned shaft is typical of the earlier period but the long top and bottom blocks are more characteristic of the later seventeenth and eighteenth century, and confirm the 1672 date. The Gwydir Uchaf gallery balusters have an additional cylindrical element, but the altar rails are very similar to the earlier examples.



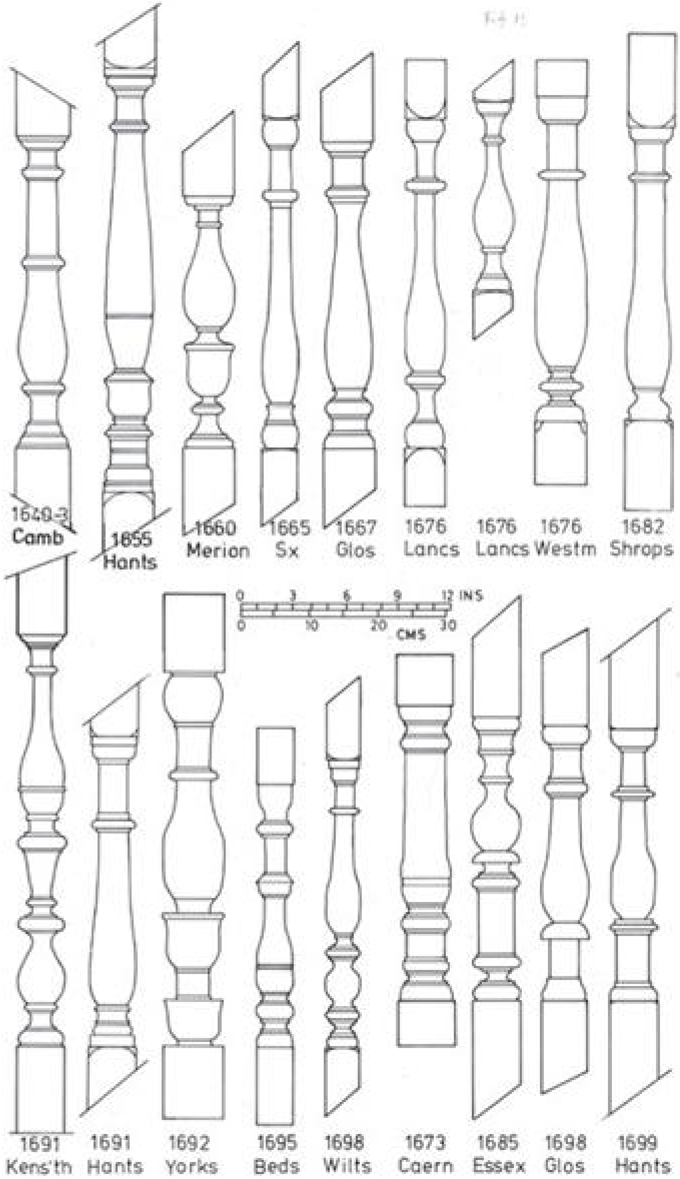
3.6 Gun-barrel balusters. Plas Teg, Flintshire (*c*.1610) shows a possible prototype, which has the characteristic straight-sided tapered shaft, but has more elements below the shaft than later versions.

Tenoned and pegged balusters

The balusters at Crows Hall and on the kitchen flight at Groombridge Place are all tenoned and pegged into the rails and strings. This feature has been noted in a number of early seventeenth-century stairs; dated examples are Burton Agnes Hall, Yorkshire (1601), Hatfield House, Hertfordshire (1607–1611), Kirstead Hall, Norfolk (1614), Quenby Hall, Leicestershire (1621), Strangers' Hall, Norwich (1627) and St John's College, Oxford (1631–1636).[36] The stairs in the Fellows' Building, Christ's College, Cambridge (1640–1643) have alternate balusters pegged. Here the pegs are or were concealed beneath applied mouldings, so tenoned and pegged balusters may be more common than is immediately apparent. In most seventeenth-century and later stairs the balusters on the sloping flights are nailed to the string and handrail, although those on the straight landing balustrades may be tenoned and pegged, or simply tenoned. Nailed balusters could be removed, leaving little trace, and it is not uncommon to find one baluster set upside down; the author had assumed this to be the result of a nailed baluster working loose and being carelessly replaced. It has been claimed, however, that this was done deliberately as a form of good luck charm, an alternative to the apotropaic mark.[37]

Vase and bottle balusters

The introduction of the vase and bottle shapes from the 1630s (Figure 3.7) effectively reversed the direction of the taper, with balusters now being wider at the bottom than the top. The vase is elegantly curved, the bottle shape more angular; both were popular until *c*.1700. Like earlier balusters, they are generally turned from a three-inch square block, although in the 1670s and 1680s larger ones are occasionally found. Early photographs of a grand stair at Beachampton Farm (1603?) show this type in a simple chunky form, but most are more elegantly shaped.[38] Among the earliest vase balusters are Kew Palace 1631 and the President's Lodging, St John's College, Oxford (1631–1636) (Figure 3.34)[39] with very similar balusters in two other Oxford colleges.[40]

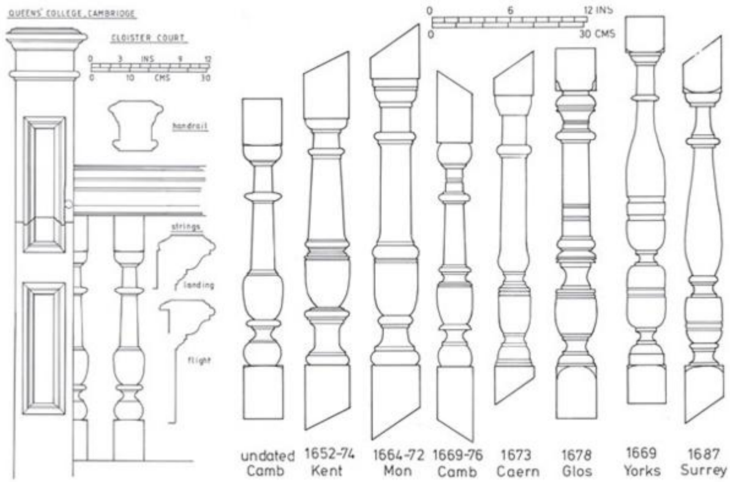

1640-3
Camb
1655
Hants
1660
Merion
1665
Sx
1667
Glos
1676
Lancs
1676
Lancs
1676
Westm
1682
Shrops
0 3 6 9 12 INS
0 10 20 30
CMS
1691
Kens'th
1691
Hants
1692
Yorks
1695
Beds
1698
Wilts
1673
Caern
1685
Essex
1698
Glos
1699
Hants

3.7 Vase and bottle balusters. Vase and bottle balusters were popular in the second half of the seventeenth century. Early examples are Christ's College, Cambridge (1640–1643) and Chawton House, Hampshire (1655). Most have rings, balls or smaller vases below the main shaft, but a small late seventeenth-century group has a straight-sided cylinder (the four illustrations on the bottom right); this feature is first seen at St John's College, Oxford (1631–1636, see Figure 3.34). The 1673 Caern is the west gallery balustrade at Gwydir Uchaf Chapel, Llanrwst.

One group of late seventeenth-century balusters has a tapered shaft above an urn or straight-sided vase shape; dated examples occur from 1664 to 1687.[41] Most are in prestigious buildings, but very similar balusters occur in the attic at the top of a winder stair at Rookery Farm, Pilning, Gloucestershire, a yeoman farmhouse of 1678. The house may be of lower status, but its baluster design closely follows those of grander buildings of exactly the same period.

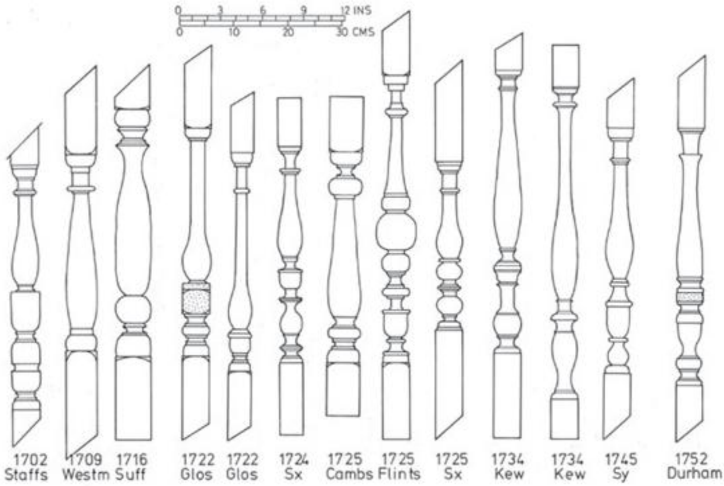
The 1669 Yorkshire and 1687 Surrey are variants with a bottle-shaped and a vase-shaped shaft, respectively. Gwydir Uchaf Chapel, Llanrwst, Caernarfonshire (1673) has similar balusters in the stair to the West Gallery;
the balusters in the gallery front are slightly different. The stair in Cloister Court, Queens' College, Cambridge is undated but the design of the string and handrail as well as the balusters suggest that it belongs to the same period. However, while the other stairs all have ball finials, Queens' College has none. The newel posts have a moulded cap matching the handrail, but a carefully

plugged round hole in the top of each suggests that ball finials have been removed.

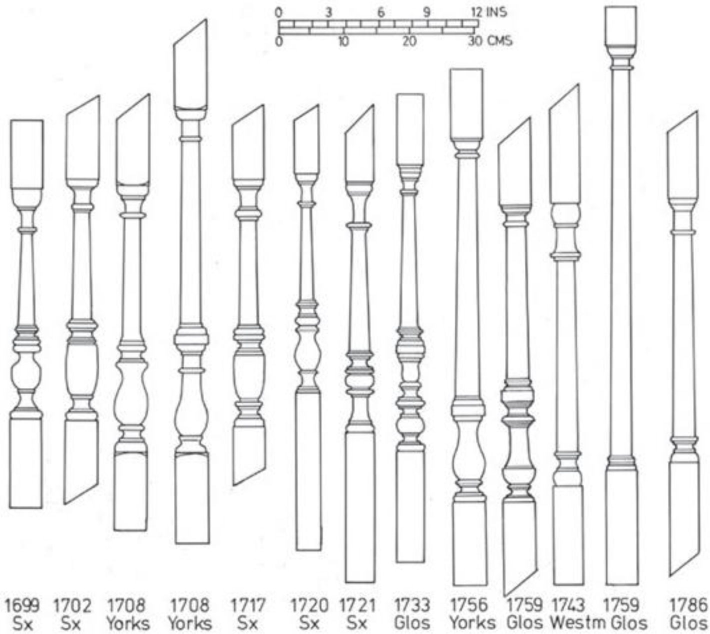


3.8 Balusters with tapered columns, 1669–1676 Cambridge (Clare College, staircases F and G) and 1678 Gloucestershire (Rookery Farm, Pilning) are very similar to the balusters in this undated stair in cloister court, Queens'.

After 1700 the bottle shape disappeared, but a slimmer vase continued to be popular. An alternative is the tapered column, often including a small vase or urn shape below the column. Both designs continued throughout the eighteenth century, getting even more slender towards 1800. The unturned blocks top and bottom became longer in relation to the length of the shaft. In the later eighteenth century simple columns with minimal decoration top and bottom became common; they were sometimes used for the upper flights leading to the servants' quarters, with more elaborate balusters for the main flight.



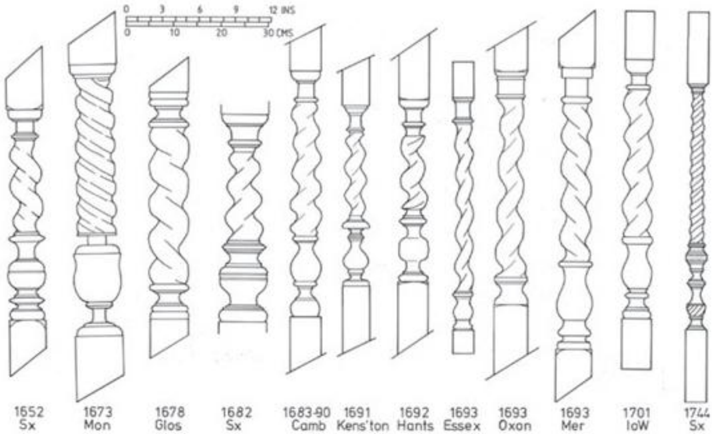
3.9 Eighteenth-century vase balusters.



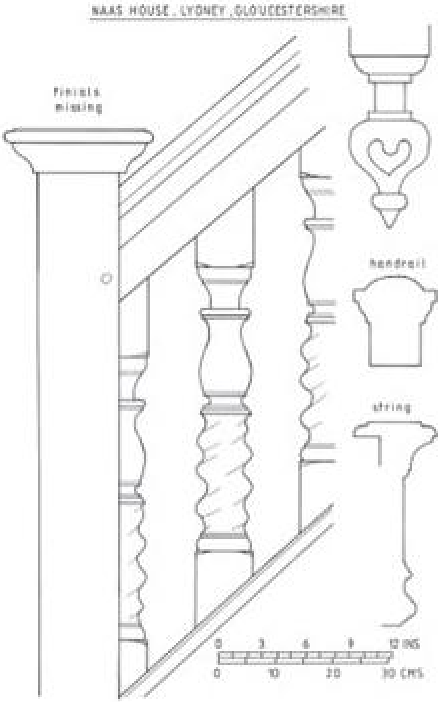
3.10 Eighteenth-century tapered balusters. Balusters with tapered columns often include a narrow unturned block between the main column and the decorative elements below, a feature rarely found in vase-shaped balusters (1708 Yorkshire, 1733 Gloucestershire, 1756 Yorkshire, 1759 Gloucestershire; see also Figure 3.55).

Twisted balusters

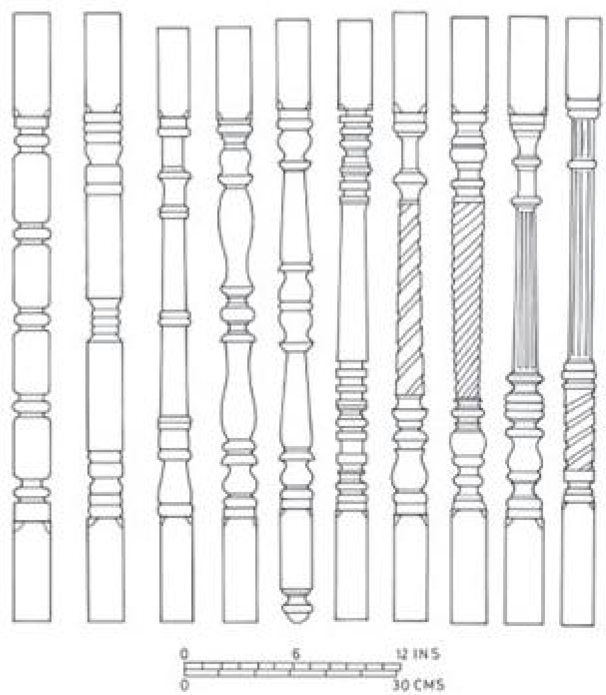
Twisted balusters first appeared in Sussex in 1652, but most examples date from the 1670s onwards, with a peak in the 1690s. Eighteenth-century examples gradually became thinner; they went out of favour around the middle of the century, with the latest examples dating from the 1760s. They reappeared in the Victorian period, often with a much tighter spiral (Figure 3.13). In an open-string stair twisted balusters may be combined with other designs, either columnar or fluted or both.



3.11 Twisted balusters; many have a vase element below the twisted shaft.



3.12 Naas House, Lydney, Gloucestershire. This house is undated, but the very chunky design of the balusters of the open-well stair suggests a date in the 1670s or early 1680s. The balusters are unusual, with the small vase element above the twisted shaft instead of below it. The handrail is also unusual, with its very simple profile and wide, curved top.



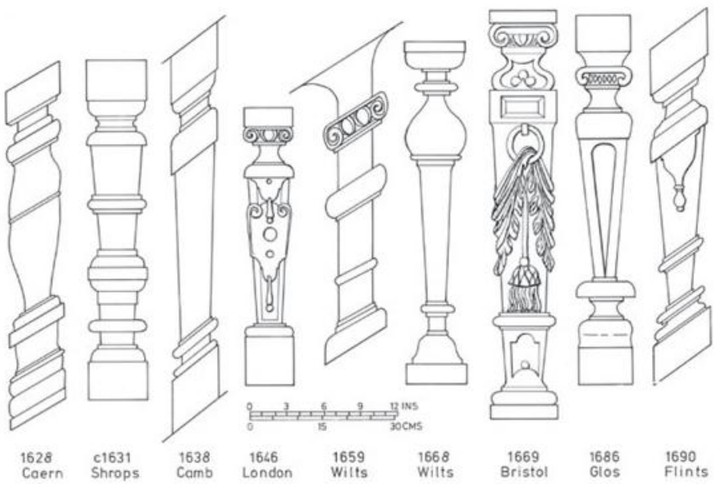
3.13 Victorian machine-made turned and twisted balusters, taken from a late nineteenth-century catalogue.

Carved or moulded balusters

Carved or moulded balusters are carved from a thick rectangular block of wood and usually have mouldings on all four sides. Unlike the other baluster types, most seem to taper from top to bottom regardless of date, and are confined to the seventeenth century. Most of the grandest early seventeenth century stairs have carved balusters, many with Ionic capitals; simpler carved balusters occur at Clare College, Cambridge (staircase A, 1638). A few square-sectioned balusters are known, such as the mirror balusters at the top of the closed-well stair at Chastleton House, Oxfordshire (1607–1612). Others are at Queens' College, Cambridge and Strangers' Hall, Norwich. Forde House, Newton Abbot, Devon (probably installed for Charles I's visit in 1625) has unusual octagonal balusters with matching newels.

Balusters joined by arches

The very early open-well stair at Handforth Hall, Cheshire (1562) has short, carved heart-shaped balusters joined by round arches, with another band of pierced decoration above. The whole effect is extremely rich and totally in keeping with the Elizabethan love of pattern. A group of large and impressive stairs with carved balusters joined by arches dates from the first quarter of the seventeenth century, including Audley End, Essex (1603–1616);[42] Hatfield House, Hertfordshire (1607–1611); Blickling Hall, Norfolk (1618) and Boston Manor, Middlesex (1623).



3.14 Carved balusters; these are moulded on all four sides.

Wall balustrades and painted balustrades

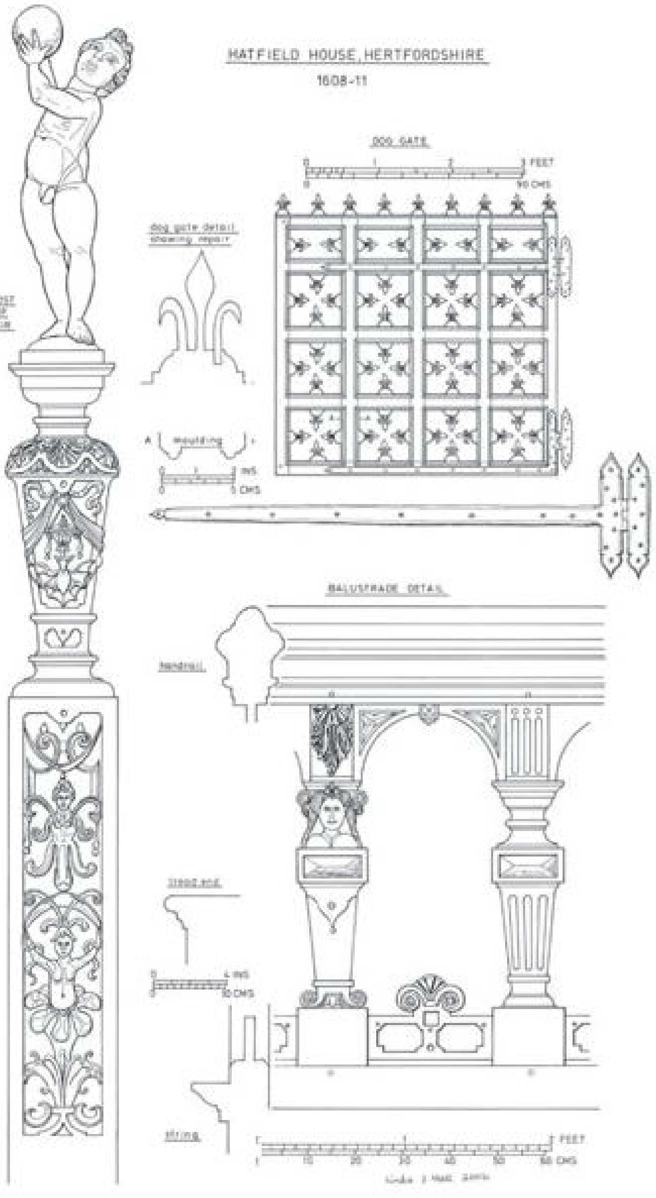
This group of stairs shares other characteristics such as wall balustrades, newel posts covered in fine carving and finials in the form of heraldic figures or beasts. Wall balustrades occur throughout the seventeenth century; examples are Plas Teg, Hope, Flintshire (1610); Llancaiach Fawr, Gelligaer, Glamorgan (1628); Mount Grace Priory, North Yorkshire (1654) and Castle House, Monmouth (1673, twisted balusters). Later seventeenth- and eighteenth-century stairs in better-quality houses have wall panelling with a half handrail supported on half newel posts; an early example is Brickwall, Northiam, Sussex (1685).

Painted or fictive balustrades are a cheaper version, but still occur in some of the grandest houses such as Knole, Kent (1605–1608), Boston Manor, Middlesex (1623) and Kew Palace (1631). Examples have been found from the late sixteenth century (Harvington Hall, Chaddesley Corbett, Worcestershire) to at least *c*.1680.[43] They may record details such as finials which have been lost from the actual stair.[44]

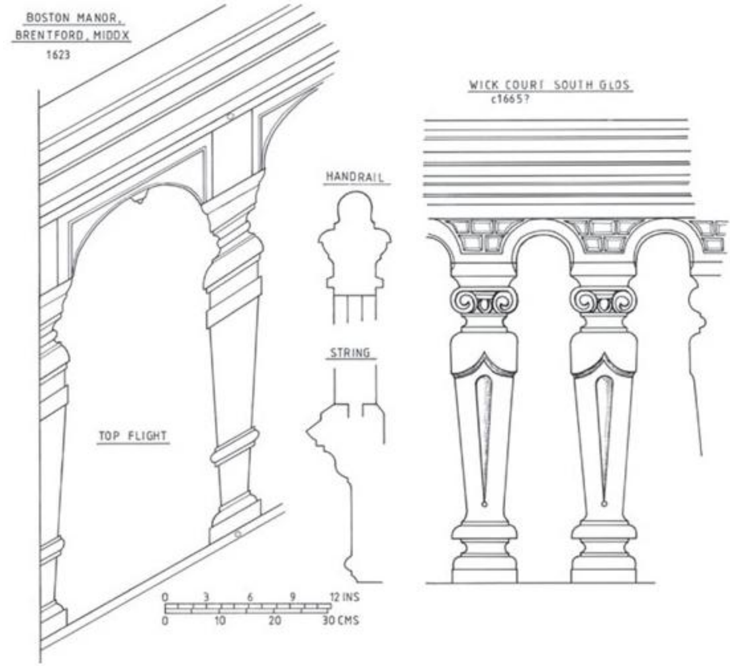
Splat balusters

Splat balusters consist of a simple outline cut from a flat plank. Their profiles often mimic those of turned balusters. Being cheaper to produce, they may be used for secondary stairs when the main stair has turned balusters. They differ from turned balusters in that symmetrical mirror balusters appear more popular in the later seventeenth century. However, many later mirror balusters, both turned and splat, are in Yorkshire, which may indicate regional preference; more research may pick up such regional variations in style or date. Splat balusters seem to be especially common in the western half of England and in Wales,[45] and are popular decorative features in wall framing in timber-framed houses in Staffordshire and Cheshire (1624 Staffs).[46]

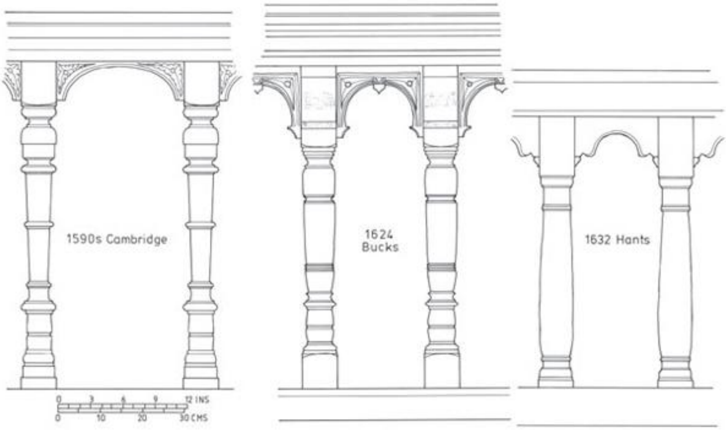
In the eighteenth century splat balusters were less common, but the wavy baluster became popular, its outline copying that of twisted balusters. It was sometimes used for staircases, but is more common in ventilation grilles. Splat balusters disappear altogether in the later eighteenth century, but reappear in the Victorian era with a great variety of designs, many of which bear little resemblance to those of the seventeenth century.


HATFIELD HOUSE, HERTFORDSHIRE
1608-11
NEWEL POST AT FOOT OF MAIN STAIR
DOG GATE
dog gate detail showing repair
moulding
BALUSTRADE DETAIL
handrail
tread end
string

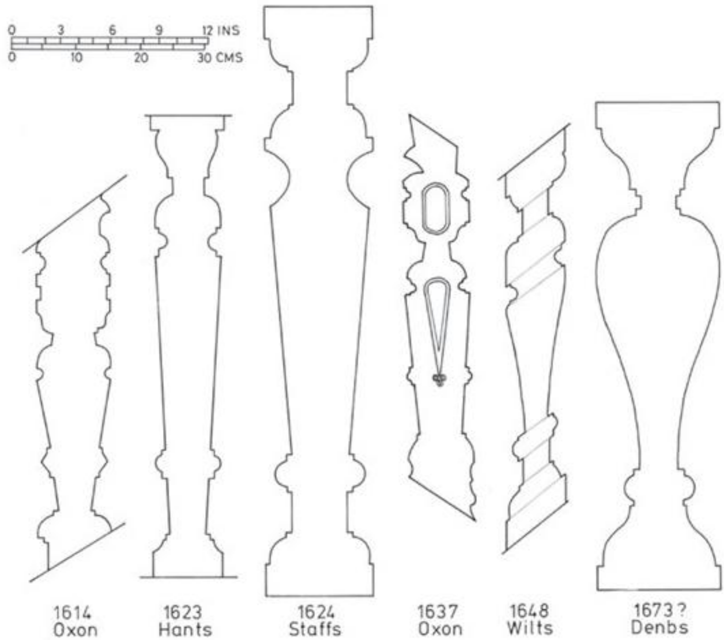
3.15 Hatfield House has carved balusters joined by arches; fluted balusters alternate with figure carvings. The arches have a central decorative block, echoing the keystone of a masonry arch, and carved spandrels. A band of pierced carving joins the balusters at the base.



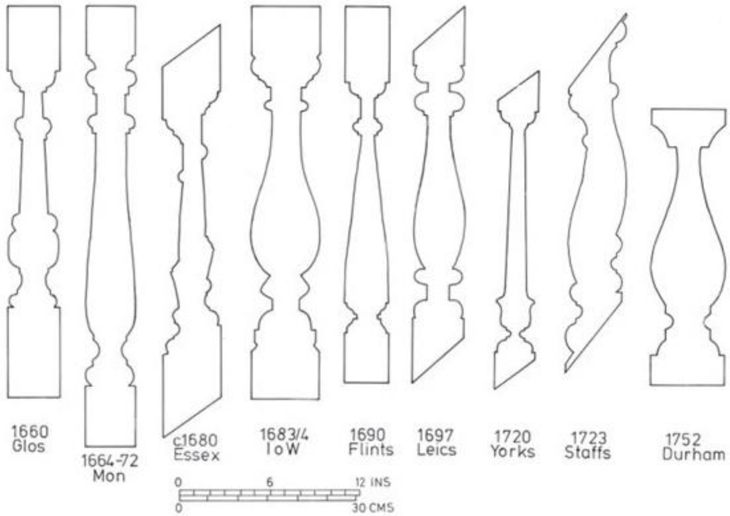
3.16 Carved balusters joined by arches. Like Hatfield, the stair at Boston Manor has arches of thin boards set into the thicker balusters and handrail. Wick Court, Wick, South Gloucestershire has a different method of construction, with arches carved in a secondary rail below the handrail; the carved balusters, which have Ionic capitals, are set below this rail.



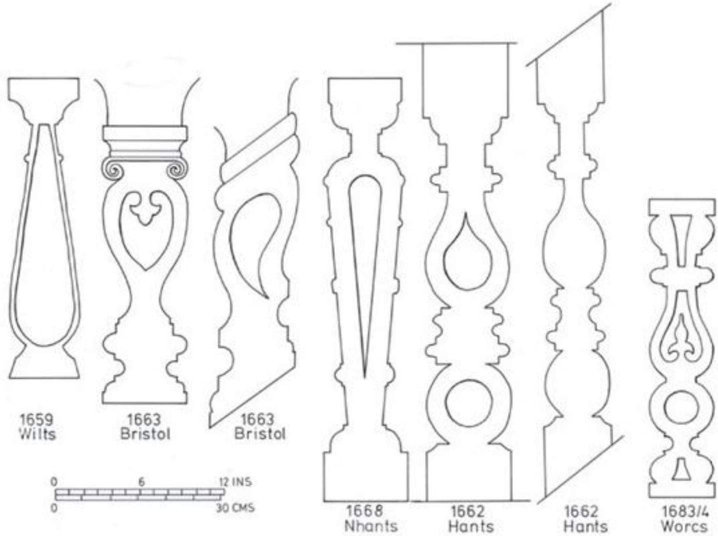
3.17 Three balustrades with arches have turned balusters; the Perne Library, Peterhouse College, Cambridge (*c*.1590), a Buckinghamshire manor house (1624) and the west gallery in All Saints' Church, Odiham, Hampshire (1632).



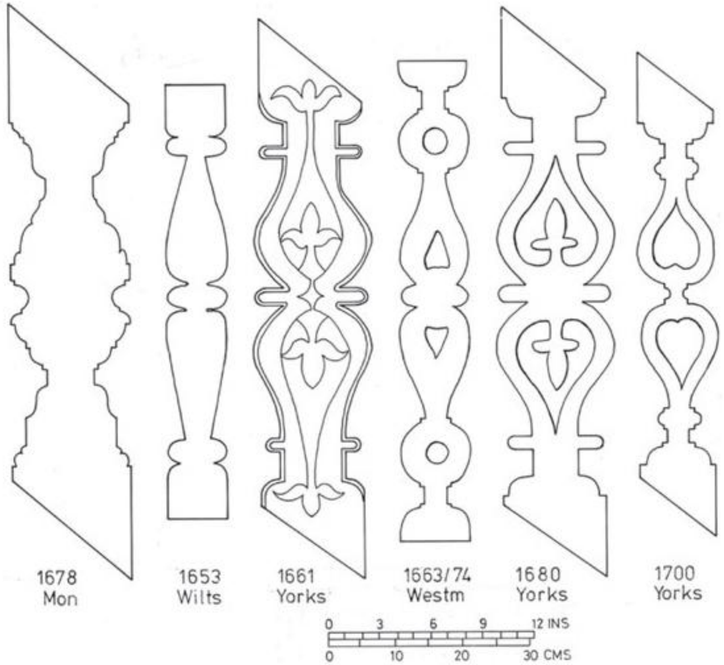
3.18 Splat balusters which taper from top to bottom. Like turned balusters, most date from the first half of the seventeenth century, except for the balusters in the attic flight at Gloddaeth, Penrhyn, Denbigh, in a wing believed to date from 1673. The 1637 Oxfordshire has incised decoration, also used in some undated examples from the mid-seventeenth century in Gloucestershire. Most of these early splats are cut from planks about an inch thick.



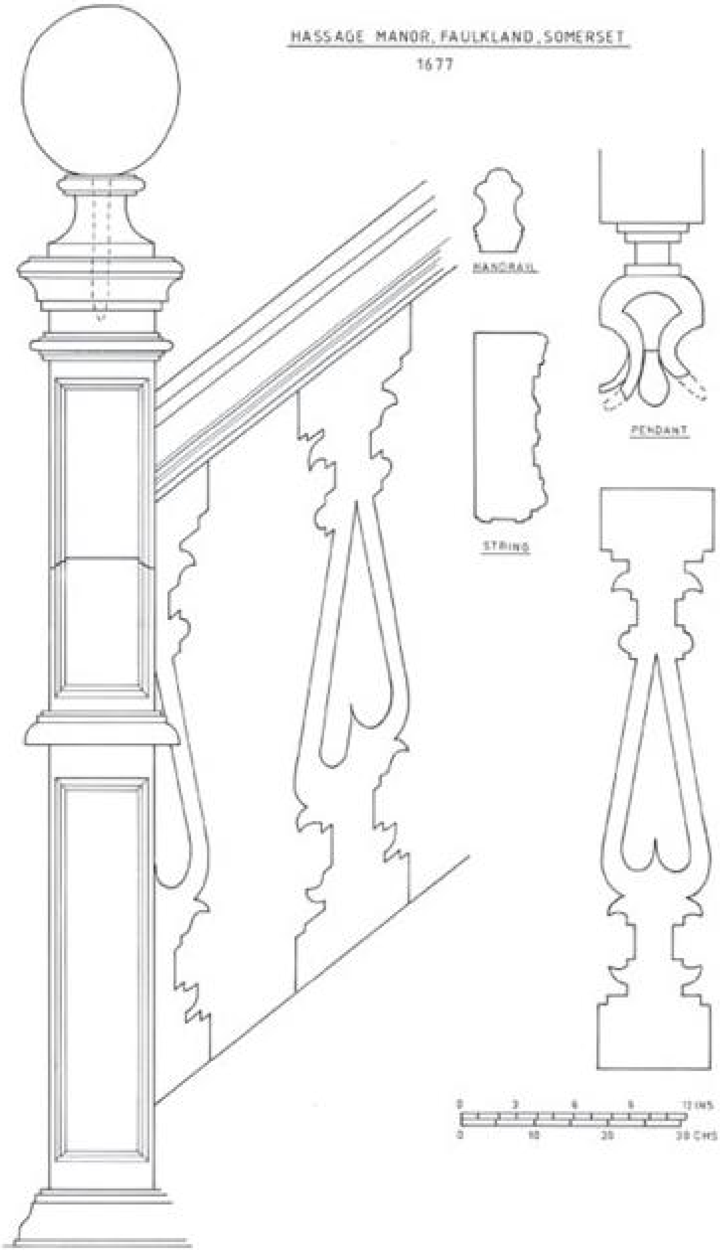
3.19 Splat balusters which taper from bottom to top; like turned balusters, most date from the second half of the seventeenth century. In County Durham they continued to be used as dresser legs until at least 1752. The balusters at 1660 Gloucestershire are over 1.5 inches thick, but many later splats are cut from thinner planks.



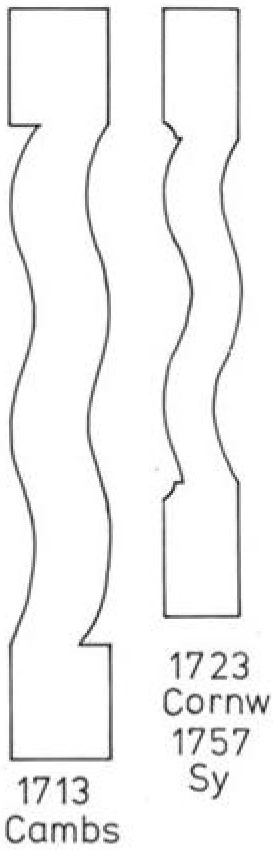
3.20 Pierced splat balusters. Splats can be pierced with circles, hearts and other designs; houses in Winchester Cathedral Close (1662) have splats for both stairs, but those on the back stairs are smaller and are not pierced.[47] Pierced balusters are also often seen in church altar rails, as at St Gregory, Castlemorton, Worcestershire, where they are inscribed with the dates 1683 and 1684.



3.21 Mirror splat balusters.


HASSAGE MANOR, FAULKLAND, SOMERSET
1677
HANDRAIL
STRING
PENDANT
0 3 6 9 12 INS
0 10 20 30 CMS

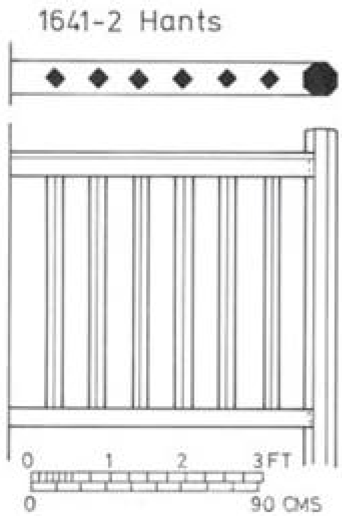
3.22 Splat balusters are not always an inferior type. Hassage Manor, Somerset (1677) has a dog-leg stair with unusually elaborate splat balusters over one inch thick, and the carving of the whole stair is of very high quality.



3.23 Wavy balusters.

Diamond Balusters

Diamond balusters are square in section and set diamond-wise, unlike the later stick balusters (p165) which are usually smaller in section and are set square. The few examples found so far date from the early seventeenth century. Crump House, Pucklechurch, South Gloucestershire (1624, dog-leg stair) and Eggar's Old School, Alton, Hampshire, (1641–1642, newel stair) have simple handrails, octagonal newels and diamond balusters.[48] The balustrade at Headstone Manor Farm, Middlesex is undated but alternates turned balusters of early seventeenth-century design, tenoned top and bottom, with much smaller diamond balusters.

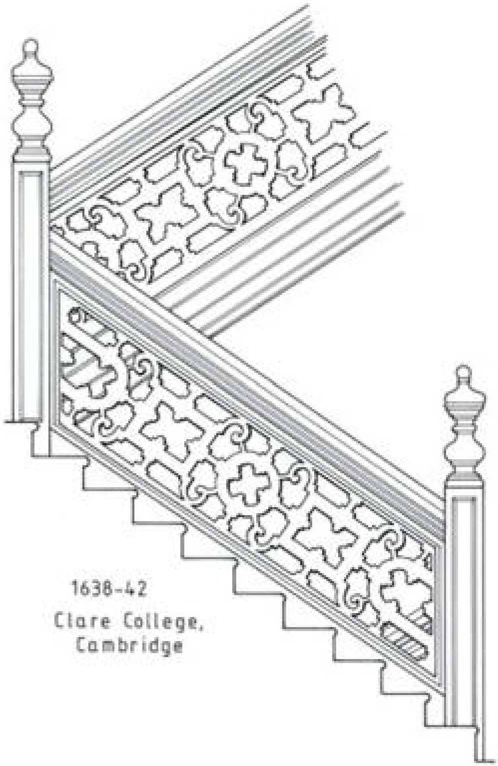


3.24 Diamond balusters

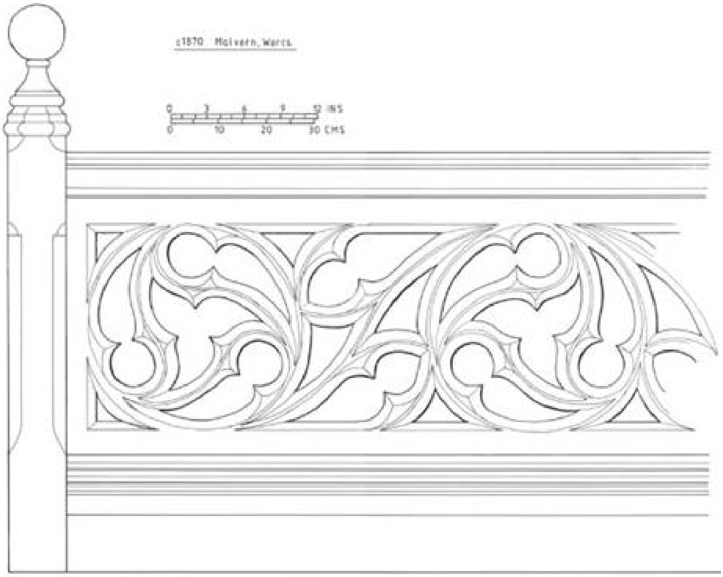
Pierced balustrades

There are two basic types of pierced balustrade, geometric designs based on squares, rectangles and circles in the early seventeenth century and more elaborate designs with naturalistic carving in the later seventeenth century. Most are in stately homes and other wealthy houses, with occasional examples in more modest buildings. Complex strapwork designs occur in some extravagant early-seventeenth-century staircases such as Rawdon House, Hoddesdon, Hertfordshire (1622) and Crewe Hall, Cheshire (1615–1636). Slyfield Manor, Surrey (*c*.1625–1640) has rusticated newel posts and a splat baluster dog gate[49] and Clare College, Cambridge (1640–1642) has an embellished strapwork design. Simpler designs were popular in smaller houses such as Radclive Manor, Buckinghamshire (1621) and Staircase House, Stockport, Cheshire (1618).[50]

The earliest examples of naturalistic carving are from the 1630s (Aldermaston *c*.1636, Ham House 1637–1638), but most date from the 1650s to the 1680s. The grand stair at Ham House, Surrey (1637–1638) has panels carved with military trophies, cannons, barrels of gunpowder and piles of cannon balls.[51] Documentary evidence shows that the wood was painted and veined to imitate walnut, with gilded details. Forde Abbey, near Chard, Somerset (1658) and Dunster Castle, Somerset (*c*.1680) have similar stairs;[52] at Dunster the grand stair is framed in oak but the carved foliage panels are of elm. Both have elaborate vase finials, with similar ones at Guildford House, Guildford (*c*.1660). Tredegar House, Newport, Monmouthshire (1664–1680) has lost its vase finials[53] but retains the elaborate pendants popular in earlier stairs. Pierced balustrades recur in the Victorian period, with a particularly fine one in the Headmaster's House in Malvern (*c*.1870).

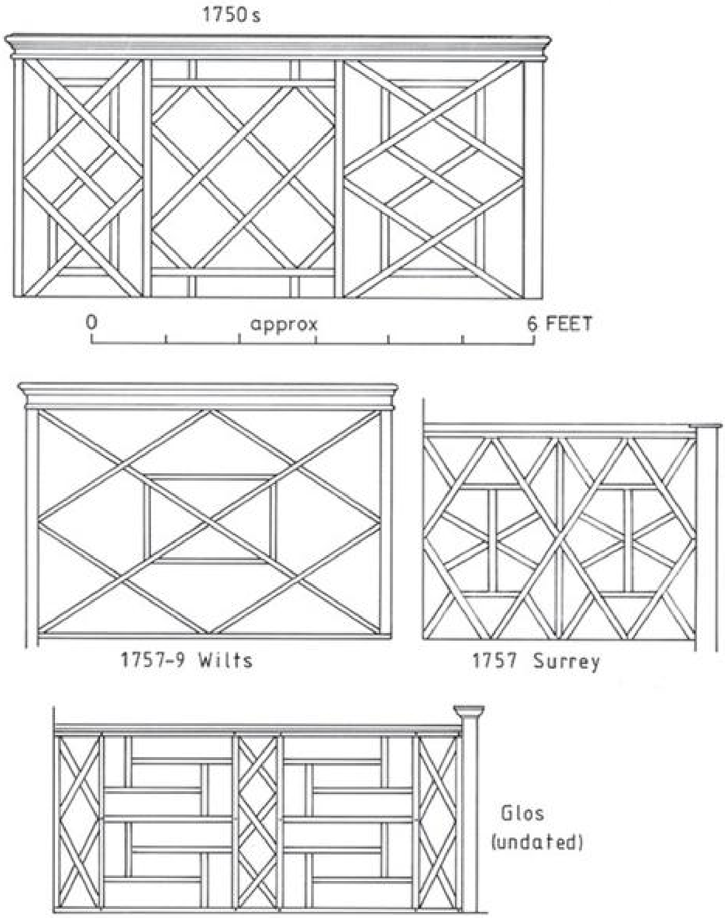


3.25 Pierced balustrade of staircase E at Clare College, Cambridge.



3.26 Pierced balustrade in a house of *c*.1870 in Malvern, Worcestershire.

A geometric style commonly called 'Chinese Chippendale' (Figure 3.27) became popular in the 1750s, but did not remain in favour for long. One example at 5 John Street, Bedford Row, London has an open-string stair with carved brackets and a Chinese Chippendale balustrade,[54] while a South Gloucestershire farmhouse has a standard eighteenth-century stair with turned balusters but a pair of Chinese Chippendale balustrades on the landing. The latest examples may be Freestone Hall, Carew 1768 and Treleddyn Uchaf, St David's 1778, both in Pembrokeshire.



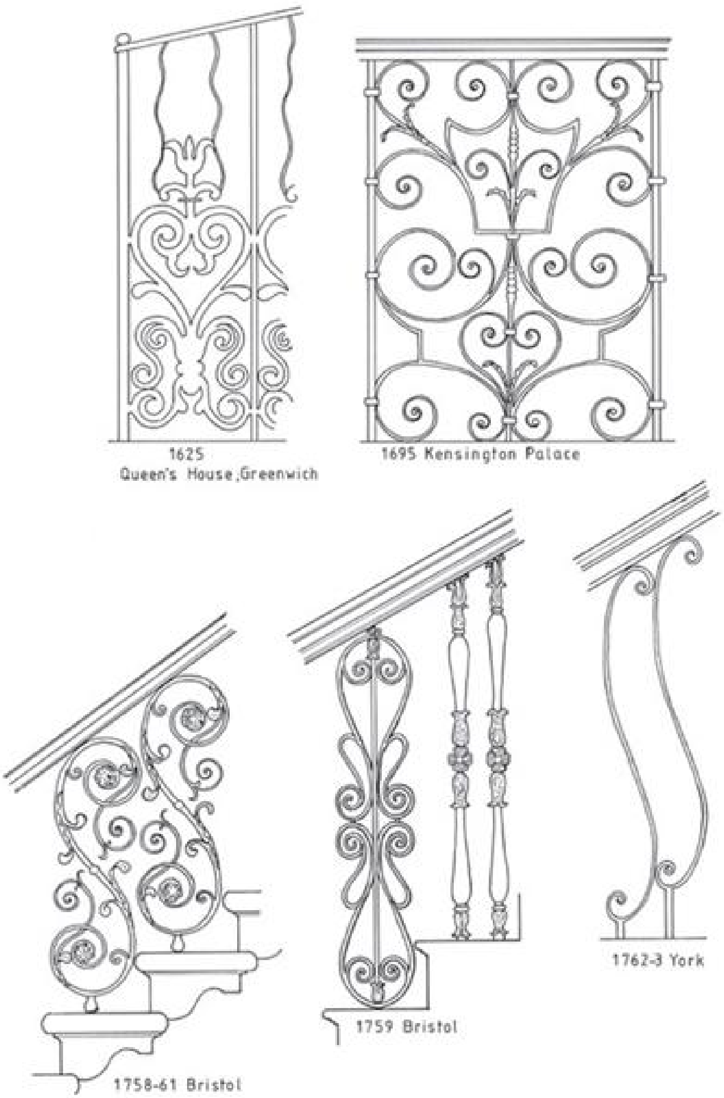
3.27 Chinese Chippendale balustrades.

Metal balustrades

Wrought iron, first used in 1625 for the balustrade at the Queen's House, Greenwich, was not used again until the late seventeenth-century. In 1685 the iron balustrade at Caroline Park, Granton, Scotland followed the design of wooden foliage balustrades, while in 1689–1690 Tijou installed wrought-iron balusters set into stone steps at Chatsworth. In 1695 the King's Stair at Kensington Palace was built, with a continuous wrought-iron balustrade, and shortly afterwards the King's Stair at Hampton Court followed a similar design. Other grand houses followed suit in the early eighteenth century (Eaton Neston, Northamptonshire, 1702–1711 and Towneley Hall, Burnley, Lancashire, 1725), but iron balusters only become popular in the second half of the eighteenth century. They were never used at the bottom end of the social scale and are far more common in town houses than in the country. A variety of geometric or floral patterns were used, with a sweeping scroll design becoming especially common in the later eighteenth century. Other metals such as lead and brass may form the more decorative elements and some balustrades were gilded. The use of pattern books meant that the same design could be found in houses all over the country.[55] Individuality was mostly lost as Victorian mass-production took over, although a doctor's house in York has the medical symbol of the serpent of Aescepulus worked into the balusters.[56]

Stick balusters

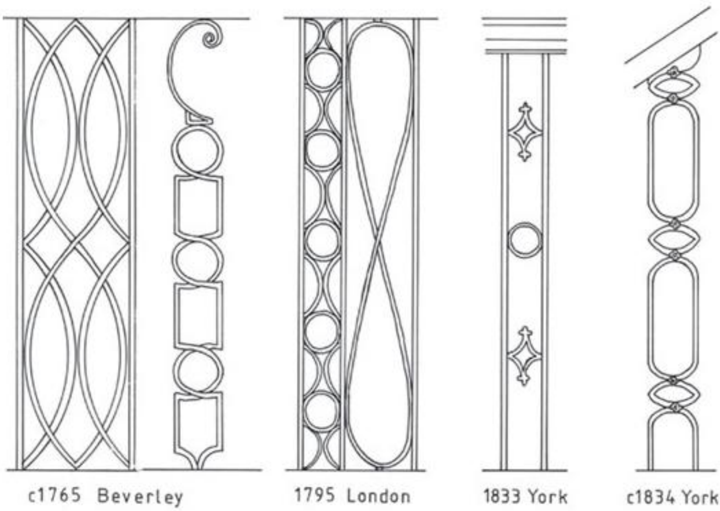
It used to be thought that the simple stick baluster staircase came in around 1800, but recent research and paint analysis have shown that stone stairs with stick balusters were created at Hampton Court in 1698–1700, and in the kitchen building at Kew Palace in 1736.[57] Here the main flights up to the living accommodation have turned balusters, but the lower flight to the service rooms in the semi-basement has original stick balusters. Stick balusters are made of pine one-inch square set under a mahogany handrail. The usual white paint enhanced the colour of the mahogany above, and disguised the fact that there were iron balusters at intervals to give strength to the balustrade. This type of stair became especially common from about 1800 and remained popular until the Victorians revived the turned baluster.[58]



3.28 Iron balustrades of the seventeenth and eighteenth centuries. The Royal Fort House, Bristol (1758–1761) has a particularly fine example of free-flowing scrolls, all gilded. The 1759 Bristol shows early use of cast-iron, which became increasingly popular in the later period.

Newel Posts

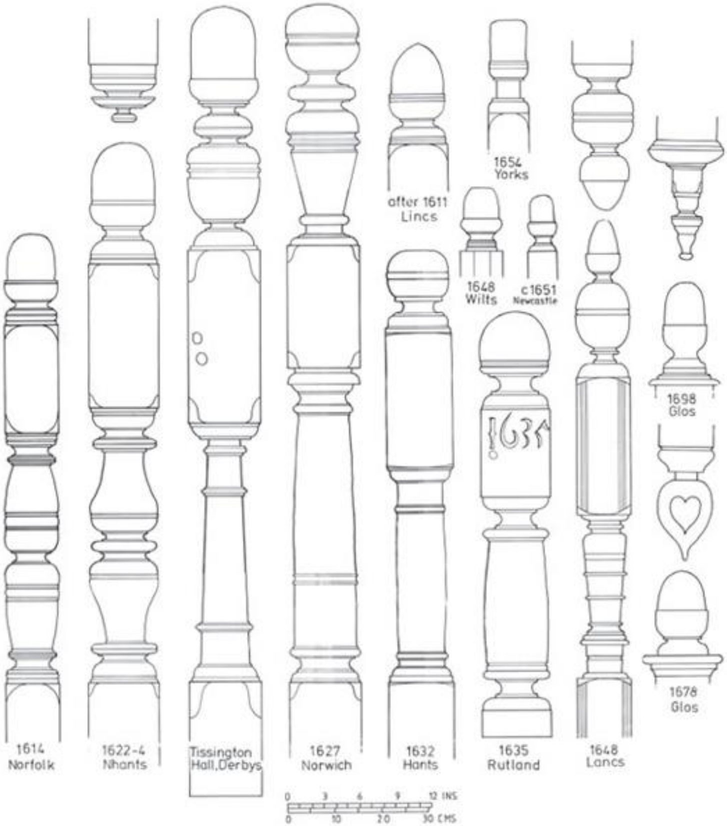
The newel post forms the end of the balustrade and varies from a plain post with no decoration to a hugely elaborate affair covered in carving and with large decorative finials, as at Hatfield House. Newel posts are usually square or rectangular, but may be chamfered and stopped. Their origin can be found in examples of the true newel stair, where the central newel supports a short balustrade at the very top. Most of these newels, whether circular (1627 Wiltshire) or octagonal (1624 Gloucestershire) are left plain, but some include finials (1628 Gloucestershire, a circular newel with a ball finial and Manor Farm, Ruislip, an octagonal newel with an elaborate faceted finial).



3.29 Iron balustrades of the later eighteenth and early nineteenth century. In York iron balusters were rare before 1800, but cast-iron balusters became increasingly popular from the 1830s and included both geometric designs and more elaborate patterns based on flowers and foliage.

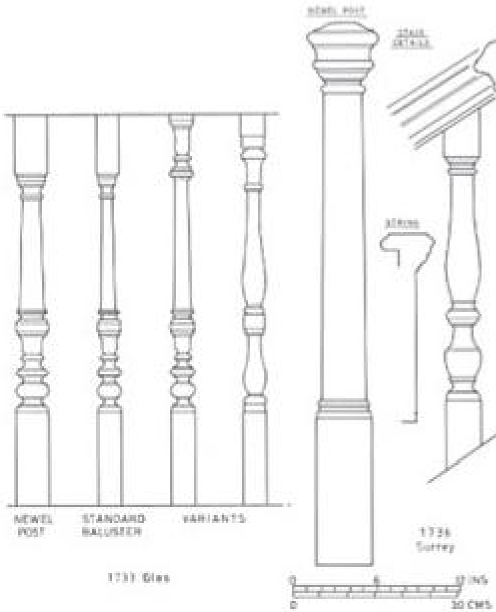
Turned newel posts

Newel posts turned to match the balusters were popular in the first half of the seventeenth century, and are usually surmounted by a substantial turned finial. Others do not match exactly as the turned section of the newel is shorter than the turned section of the baluster.[59] The large unturned blocks into which the handrail and string are tenoned may be decorated with carving or shadow mouldings. The secondary stair at Knole, Kent (1605–1608) has turned newels with vase finials, matched in the fictive balustrade, while other dated ones are Kirstead Hall, Norfolk (1614) and Apethorpe, Northamptonshire (1622–1624).[60] The undated example at Great Ellingham Hall, Norfolk, has unturned blocks decorated with strapwork carving.[61] Arreton Manor, Isle of Wight (1639) has turned newels with flattened ball finials and unusually slender turned balusters of a very plain design. Unusual variants at The Commandery, Worcester (probably *c*.1600) and Chetham's Hospital, Manchester (1653) have carved and splat balusters, respectively, with matching newel posts; Chetham's also has strapwork carving on the unturned blocks.[62]

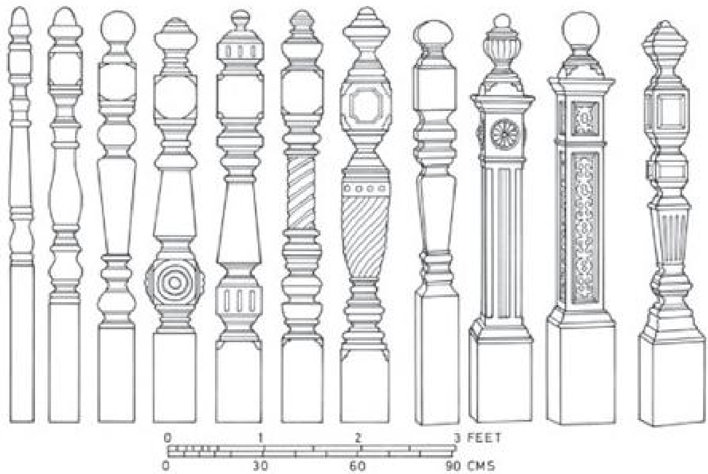


3.30 Turned newel posts and acorn finials. Newel posts turned to match the balusters often have acorn finials, which also occur in the later seventeenth century on square newel posts. Gun-barrel balusters often have matching turned newels; examples are Tissington Hall, Derbyshire (undated), Strangers' Hall, Norwich (1627), West Gallery stairs at Odiham, Hampshire (1632) and Bishop's Cleeve, Gloucestershire (1640? See note 35) and the altar rails at Lyddington, Rutland (1635).

Turned newels went out of use entirely *c*.1650, only to reappear in the early to mid-eighteenth century. Eighteenth-century turned newels did not
always match the balusters; the early eighteenth-century stair at No. 70 Walmgate, York has a columnar newel post of much simpler design than the balusters.[63] Turned newels were used in late eighteenth- to early nineteenth-century stairs with plain stick balusters and revived by the Victorians with an array of ever more bizarre designs.



3.31 Eighteenth-century turned newel posts. At 1733 Gloucestershire the turned newels match the balusters (which have a few variants in the upper flight), while in the 1736 kitchen block at Kew Palace, Surrey, the columnar newels have a much simpler design than the vase balusters.



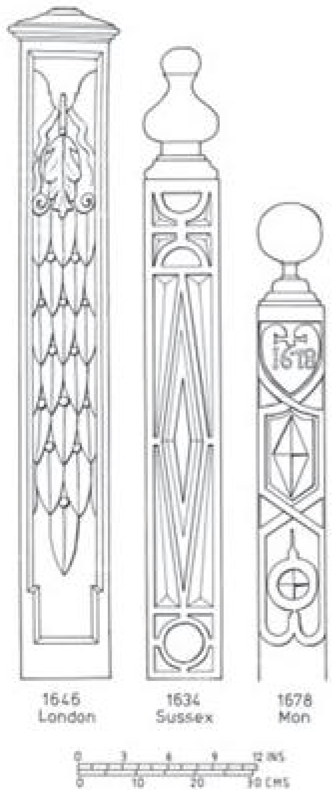
3.32 Victorian turned and carved newel posts with an array of fantastic forms.

Relief carving on newels

The finest Jacobean newel posts are covered in relief carving; at Hatfield (1607–1611) the carving is a mixture of mythical figures and realistic items (Figure 3.15). Elsewhere scroll patterns or embellished strapwork were popular (Beachampton Farm, *c*.1603; Charlton House, Kent, 1612–1615;[64] Dorfold Hall, Nantwich, Cheshire, 1616[65]). Most examples, with simpler designs based on strapwork, date from the first half of the seventeenth century.[66] The Commandery, Worcester, has an early stair with this feature;[67] two Sussex examples date from 1634 and 1641,[68] while a stair at Merton College, Oxford is dated *c*.1630–1640.[69] Park Hall, Oswestry, Shropshire had a more elaborate version, with tall tapered vase finials, and with further strapwork carving on the string.[70] Baildon Hall, West Yorkshire, is a multi-period house with a plaster fragment dated 1618 and a datestone of 1683; while the stair may belong to either or neither date, the mirror balusters and grip handrail make 1618 likely.[71] Knostrop Old Hall, Leeds, reputedly built in 1644 and demolished in 1960, was another example. Geometric carving is rare after 1650; the Scole Inn, Scole, Norfolk (1655)[72] and Artha, Tregare, Monmouthshire (1678) are late examples.[73]

Rusticated newel posts

A few grand stairs had rusticated newel posts carved to resemble masonry. Rawdon House, Hoddesdon, Hertfordshire (1622) is the only firmly dated one, but the nearby Conservative Club must be of similar date.[74] Holland House, Kensington had rusticated newels and balusters, the latter straight-sided columns with arches between, and tapered vase finials. The date of the stair is not clear; building began 1605–1607, and a wing was added 1638–1640.[75] Lymore Hall, Montgomery, was a Welsh example.[76]



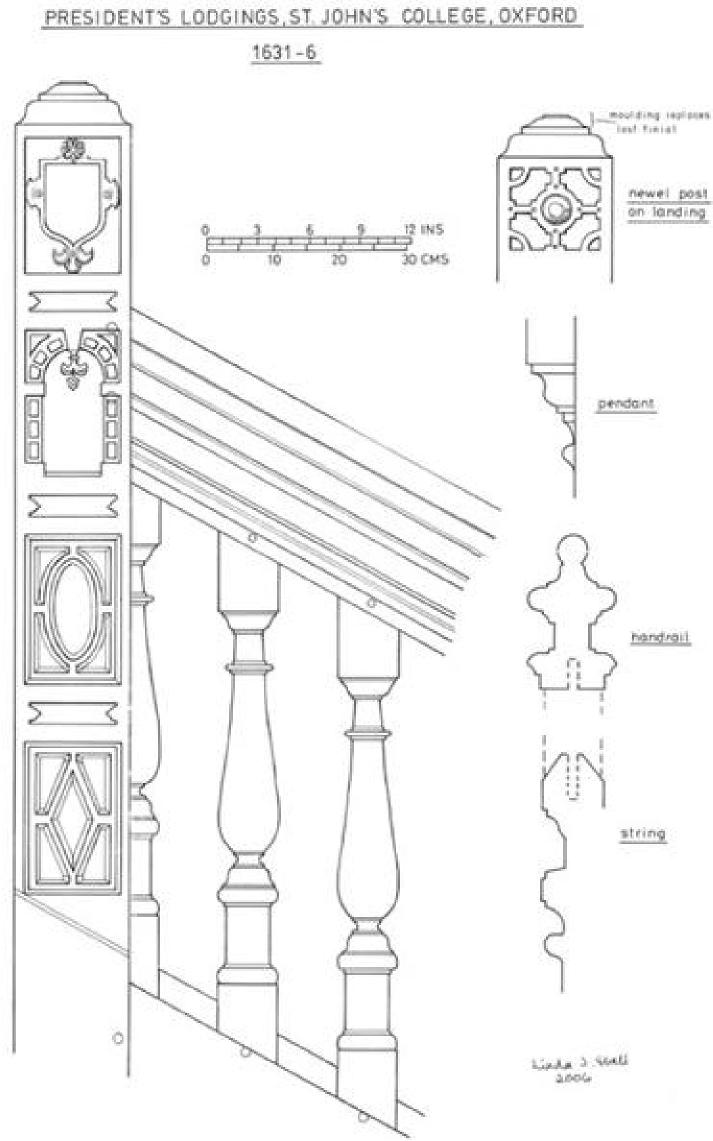
3.33 Carved newels. The 1646 London has an elaborate leaf design, while the others have the more common geometric designs based on Jacobean strapwork.

Panelled newel posts

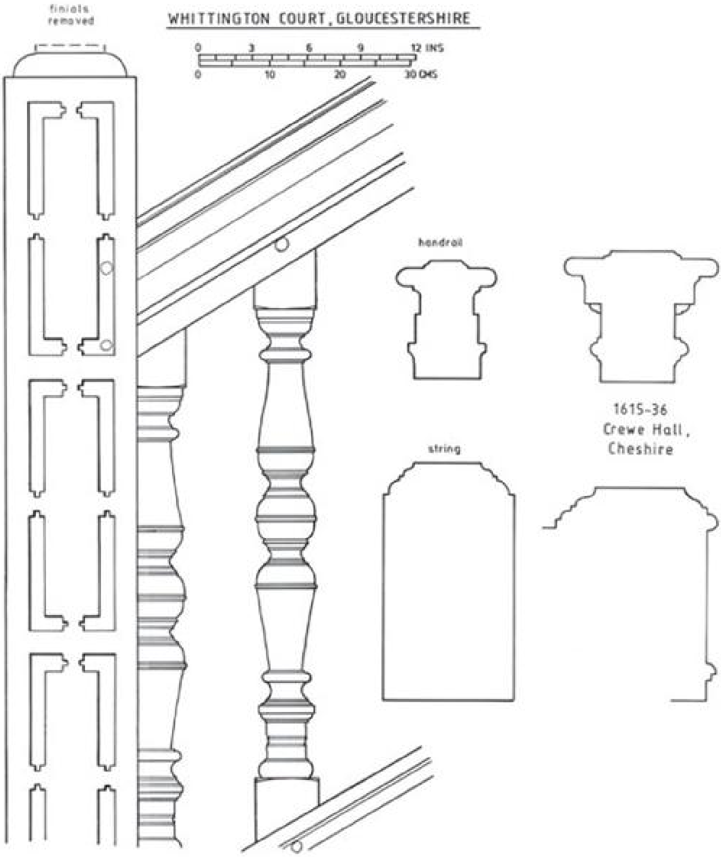
In the seventeenth and early eighteenth centuries square newel posts may have recessed moulded panels, a feature revived by the Victorians. The heavy chamfered newel post of the reused balustrade at Groombridge Place, Kent has plain recessed panels and may date from the late sixteenth century, while the 1590s stair at Peterhouse College, Cambridge has a simple hollow moulding. In earlier versions the moulding is integral to the post, while later seventeenth- and eighteenth-century examples often have applied mouldings nailed around the recessed panel. Sometimes the moulding has been lost but leaves tell-tale traces such as nail holes and discolouration of the wood. At Clare College, Cambridge staircases A (1638) and E (1638–1642) have square-headed panels with integral hollow mouldings, while G (1669–1676) and H (1683–1690) have round-topped panels with applied mouldings. G has an ogee moulding while H has the more prominent bolection moulding commonly used in panelling of this period.

Double newel posts on dog-leg stairs

Dog-leg stairs have some ingenious designs to cope with the junctions at the newels. Where the ceiling height is sufficient, the string of the upper flight is tenoned into the newel post immediately above the handrail of the lower flight, as at Groombridge Place, Kent. Alternatively, the lower handrail and the upper string cross over each other into a single newel post (Quebec House, Westerham, Kent, recently dendro-dated to *c*.1625[77] and Faber's Farm, Hambrook, South Gloucestershire, 1698[78]). If the handrail is relatively narrow both balustrades can be tenoned into a single newel post (Clare College, Cambridge, staircase E, 1638–1642 and staircases F and G, 1669–1676[79]). A wider handrail requires either two separate newel posts standing side by side (Knostrop Old Hall, Leeds, *c*.1644), or a double-width newel (Conservative Club, Hoddesdon, Hertfordshire).[80] Christ's College, Cambridge (1640–1643) has unusual double-width newels with single finials (Figure 3.40). More commonly the double newel has one half taller than the other, with a separate finial on each (Castle House, Monmouth, 1673;[81] Tredegar House, Newport, 1664–1672). In the later seventeenth century, when finials were replaced by moulded caps, some double newels have a large scroll joining the lower to the upper part of the newel.



3.34 The stair in the President's Lodging at St John's College, Oxford (1631–1636) closely resembles the painted version at Kew Palace of the same date, with early vase balusters and newel posts carved with geometric patterns. The shields at the top of the posts all have different designs and may have been painted with coats-of-arms. Large finials have been sawn off and the posts capped with a small moulding. Like many high-quality stairs, it has half balusters nailed onto the newel posts and the balusters are all tenoned and pegged.



3.35 Whittington Court, Gloucestershire has a large open-well stair with high-quality turned mirror balusters with unusually fine mouldings. Their design suggests a similar date to the stairs at Kew (1631) and St John's College (1631–1636), while its handrail is very similar to Crewe Hall, Cheshire (1615–1636). The newel posts have a simple geometric pattern carved on all four sides; half balusters nailed onto them suggest a change of plan. Large finials and pendants have been removed, shown in a drawing in the possession of the owners but so far not seen by the author.

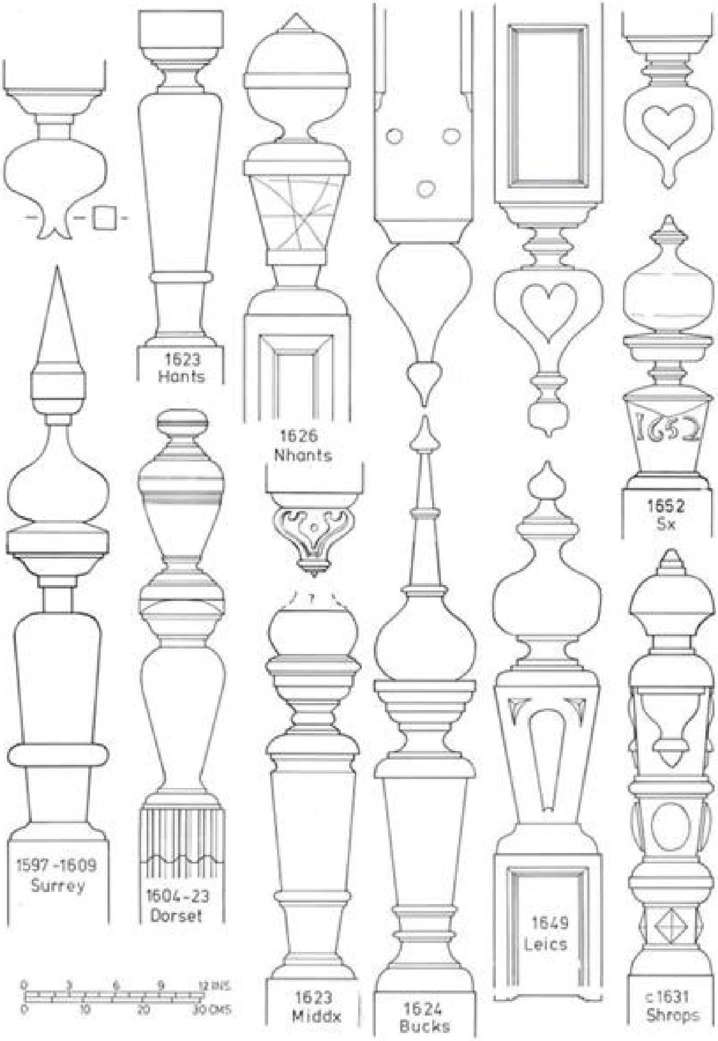
Finials and Pendants

Large finials and pendants, popular in the late sixteenth and early seventeenth centuries, have a variety of forms based on the tapered column, a bulbous vase shape and the ball. Acorns occur throughout the seventeenth century, often with turned newel posts. Pendants may match the finials in shape or be completely different. A popular shape was the
pierced heart, occurring from the 1620s to the later seventeenth century. The most elaborate early seventeenth century stairs had heraldic beasts and/or figures on top of tapered columns.[82] Others have a form of bulbous vase on top of the column, while a few columns have lost their top element (1623 Hampshire). The bulbous vase occurs on its own from the middle to the end of the seventeenth century, with some highly elaborate versions in the middle of the century. Smaller finials with ogee outlines were used in farmhouses, usually without accompanying pendants. Small faceted finials occur in modest houses from at least the end of

the sixteenth century, while polyhedrons were popular in the late seventeenth century. An undated house in Buckinghamshire has a polyhedron finial with twisted balusters, suggesting a late seventeenth-century date. Ball finials were popular throughout the seventeenth century in both large and small versions, some with incised lines around the centre (e.g. 1628 Gloucestershire[83]), and with or without pendants. Later ones are more likely to be truly spherical. Most have some sort of moulded base, but a few sit directly on top of the newel post (1682 Sussex, Tredegar House east stair, 1664–1672). Many are carved in the solid with the newel post, but others have a long dowel which goes into a hole in the newel (Figure 3.22) or a base which is nailed onto the newel post. It is not clear if there is any dating significance to the different methods. In the mid- to late seventeenth century the most elaborate stairs had finials in the form of vases of fruit and flowers.

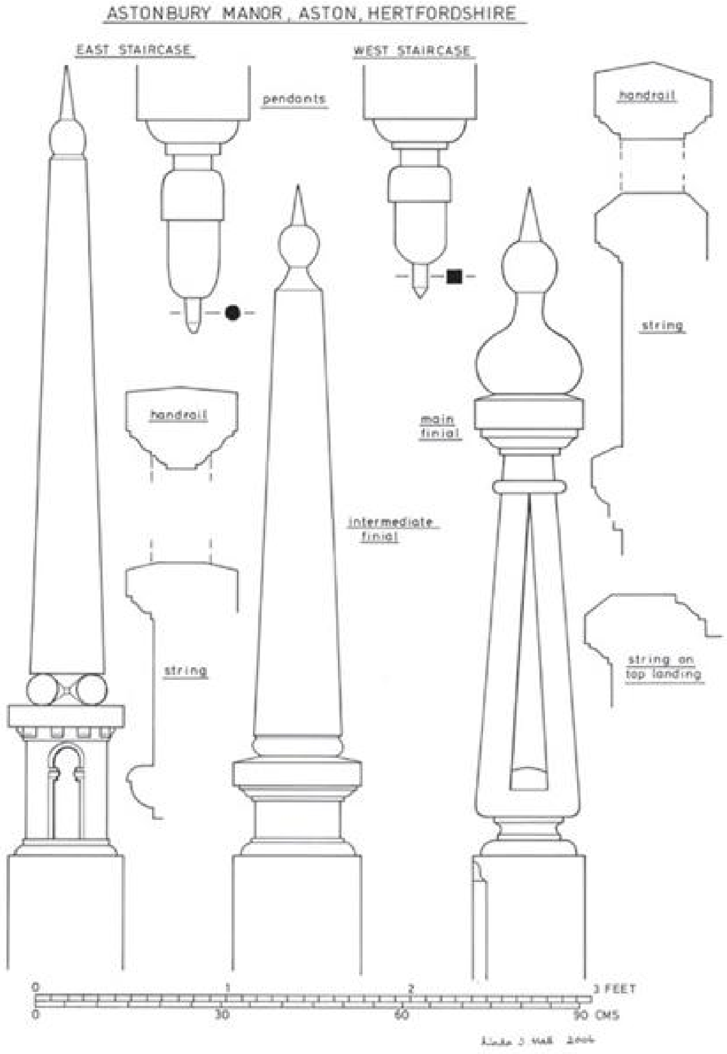
Ham House, Richmond, Surrey (1637–1638) has one of the earliest with baskets of fruit; vases occur at Tyttenhanger, Hertfordshire (*c*.1655), Forde Abbey, Dorset (1658), Thrumpton Hall, Nottinghamshire (*c*.1660),[84] Vintners' Hall, London (1671) and Dunster Castle, Somerset (1680s).

3.36 Dog-leg stairs may have double-width newel posts and some late seventeenth-century examples without finials have some form of curved bracket or console linking the two sections. The hall staircase at Clare College has two different designs, while a secondary stair at Kensington Palace (1691) has a simpler version.



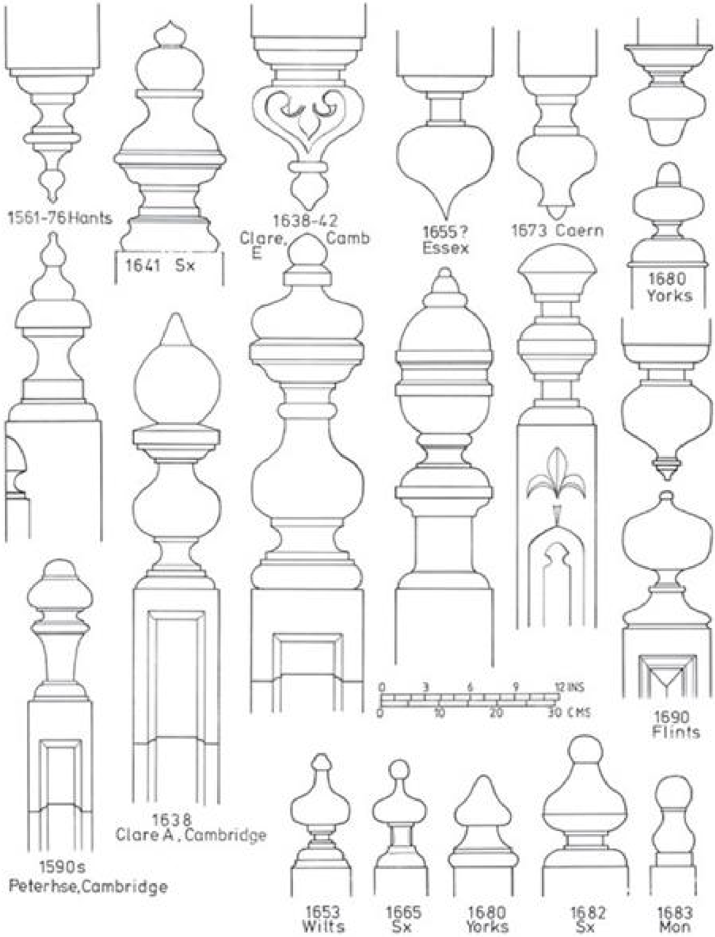
3.37 Tapered column finials. The tapered column was extremely popular in the first half of the seventeenth century and usually supports a further decorative element on top. The 1623 Hants is missing its top piece, but nail marks show that something was nailed onto the flat top, as at 1604–23 Dorset. The Mansion House, Shrewsbury, Shropshire (*c*.1631) is covered with relief carving and applied 'jewels' in the form of lozenges and ovals. The Talbot Hotel Oundle, Northants (1626) has scratched marks on one column of the type regarded as apotropaic or evil-averting marks.

Many finials and pendants were removed or altered when fashions changed. In the later seventeenth century the ball finials at Kew Palace were exchanged for newly fashionable vase finials, while Broughton Hall, Staffordshire had elaborate vases of fruit added on top of the already substantial finials of 1637.[85] Elsewhere finials and pendants were removed altogether.[86] Evidence may be a round mortise or nail marks in the top of the newel, or the characteristic base moulding either smoothed off or given a new capping. Painted balustrades may show finials removed from the actual stair, as at the Merchant's House, Marlborough[87] and 66 High St, Hadleigh, Suffolk.[88]

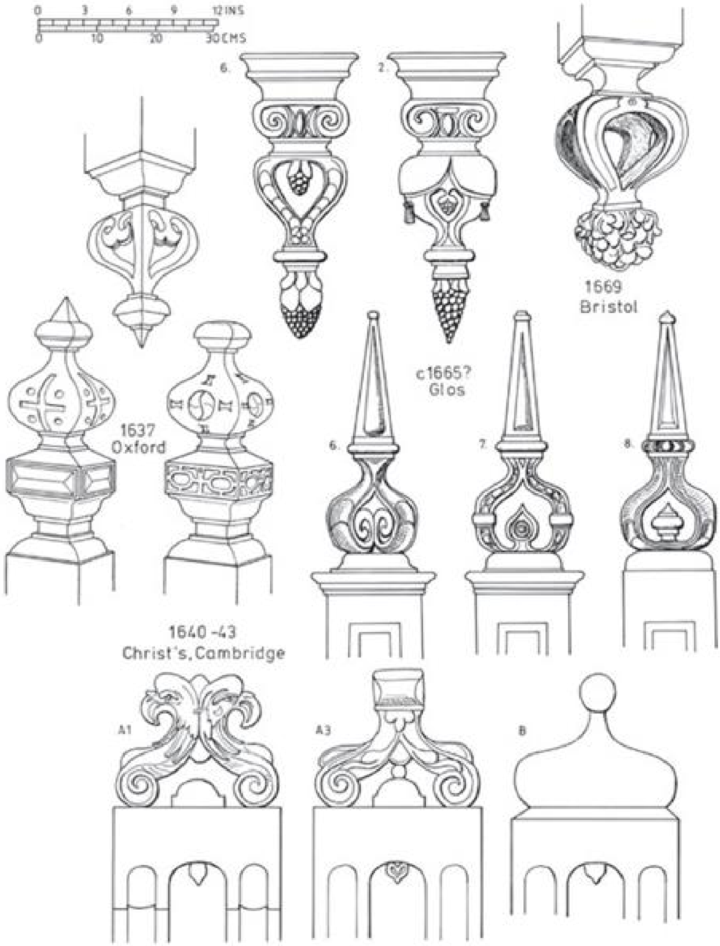


3.38 Aston Bury Manor, Hertfordshire has two large open-well stairs in matching turrets, with enormous tapered finials in the form of obelisks. The pendants have an acorn shape, while the handrail and string have very simple mouldings in contrast to all the other elements. The house is undated, but documentary evidence puts it before 1625.

From the 1690s finials went out of fashion for grander stairs; instead the moulded handrail was extended over the newel post to form a flat cap. Some continued to have pendants, however, giving a slightly odd contrast, and smaller houses continued to use finials. In the Victorian era large finials and pendants reappear, and although some are simple balls, many have new designs not seen in earlier periods.



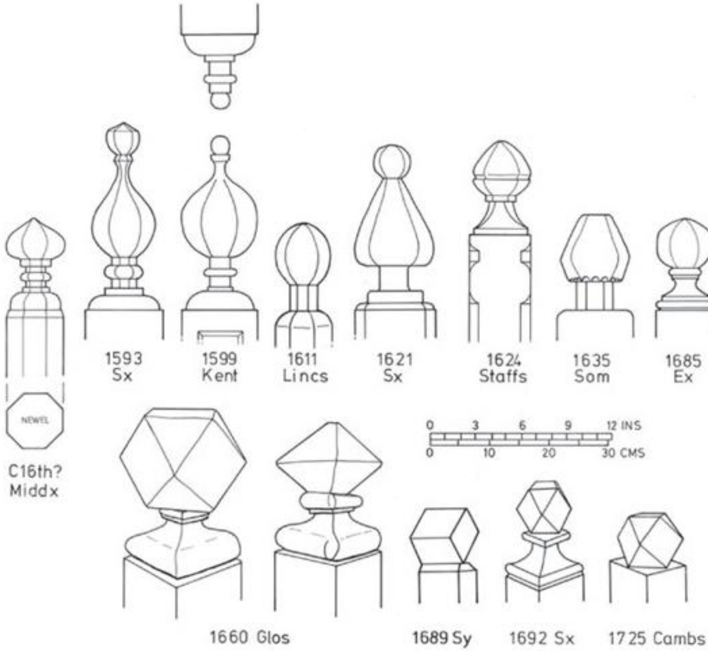
3.39 Vase finials. Many of these are based on an ogee shape, but are hard to categorise. Pendants may or may not match the finials.



3.40 Elaborate pendants and finials. These are based on the bulbous vase finials, but with the addition of relief carving. The 1637 Oxford and Wick Court near Bristol, Gloucestershire, probably dating from *c*.1665 but possibly earlier, both show the carver's art in its finest form, with different finials and pendants on every newel post. The Fellows' Building at Christ's College, Cambridge (1640–1643) has two dog-leg staircases, both with unusual double-width newels with a pierced centre panel and a single wide finial. Staircase A is more elaborate, with pierced finials based on a double scroll design. The scrolls of the bottom newel turn into the heads of fierce-looking birds of prey with large hooked beaks. The finials of staircase B are plain and unpierced. Both stairs have simple tiny pendants in the central panels of the newels; that on the first landing of staircase A is carved as a tiny heart.

Handrails and Strings

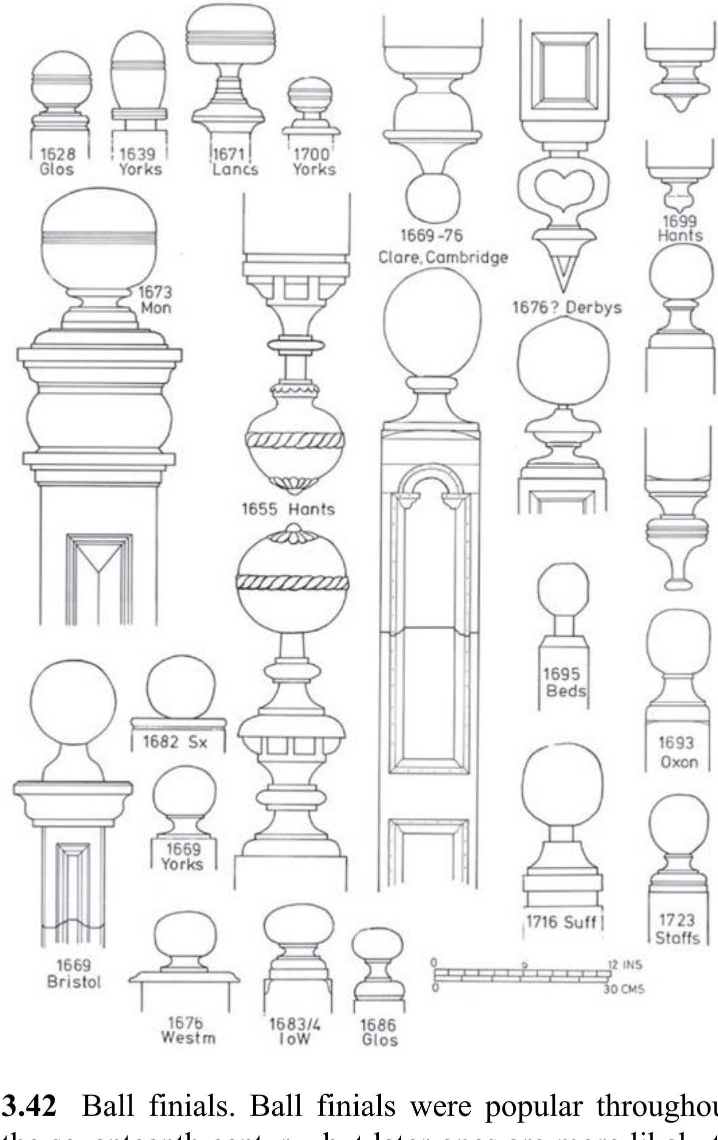
Handrails and strings vary considerably in both size and design and can be enormous in grand houses (Quenby Hall, Leicestershire, 1621). The earliest type of shaped handrail is the round-topped 'grip' handrail, common up to the 1650s; later examples include Clare College, Cambridge (1669–1676).[89] The simplest handrails are plain rectangular blocks, chamfered or with a rounded top and sometimes decorated with shadow mouldings. The landing handrail may differ from that on the flights, either in size (1590s Peterhouse, 1627 Norwich) or design.



3.41 Faceted and polyhedron finials. Faceted finials were popular in the late sixteenth and early seventeenth centuries; the example from Manor Farm, Ruislip, Middlesex may even date from the early sixteenth century. Polyhedrons are rare but the dated examples are from the late seventeenth and early eighteenth century.

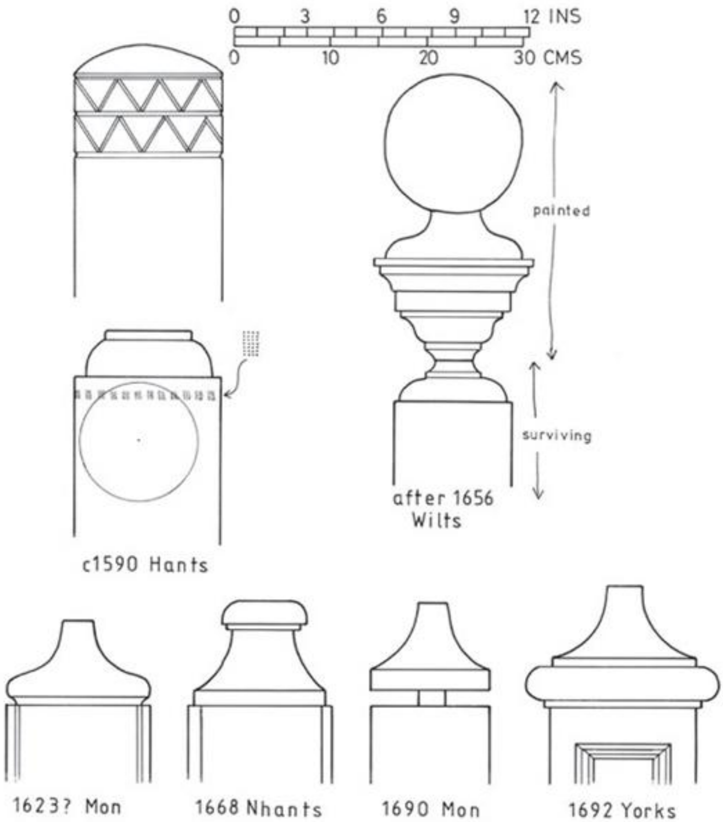
Many seventeenth-century handrails defy categorisation, suggesting a period of experimentation.[90] A miscellaneous variety of round-topped handrails occurs from about 1620 until the early eighteenth century. Some are relatively narrow but have elaborate mouldings. In the mid- to late seventeenth century broad flat-topped handrails were popular in grand stairs, such as the main stair at Tredegar House (1664–1672). In the late

seventeenth century designs settled down into two basic types, the curved top and the toad's back, which continued until the late eighteenth century. They may be carved from solid timber or consist of mouldings nailed to a rectangular block. Early examples of the toad's back date from the 1690s, and the style was revived in the second half of the nineteenth century. Often
associated with open-string stairs, it may be ramped, with the handrail curving up and over the newel posts. Forde Abbey (1658) and Dunster Castle (1680s) in Somerset have early ramped handrails; most date from the eighteenth century.

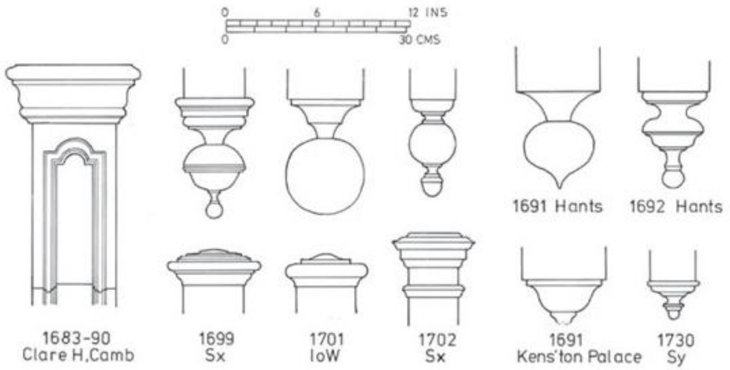


3.42 Ball finials. Ball finials were popular throughout the seventeenth century, but later ones are more likely to be truly spherical. The 1655 Hampshire is unusually elaborate, with cable moulding around the matching pendant and finial, a flower (possibly a marigold) carved at the top, and modillions around the base.

A change in baluster design brought a huge reduction in handrail size.
The King's Stair, Kensington Palace (1695) is an early example, where the wrought-iron balustrade has a very small but elaborate handrail. In the later eighteenth and early nineteenth century tiny handrails of simple curved designs were associated with slender stick balusters.



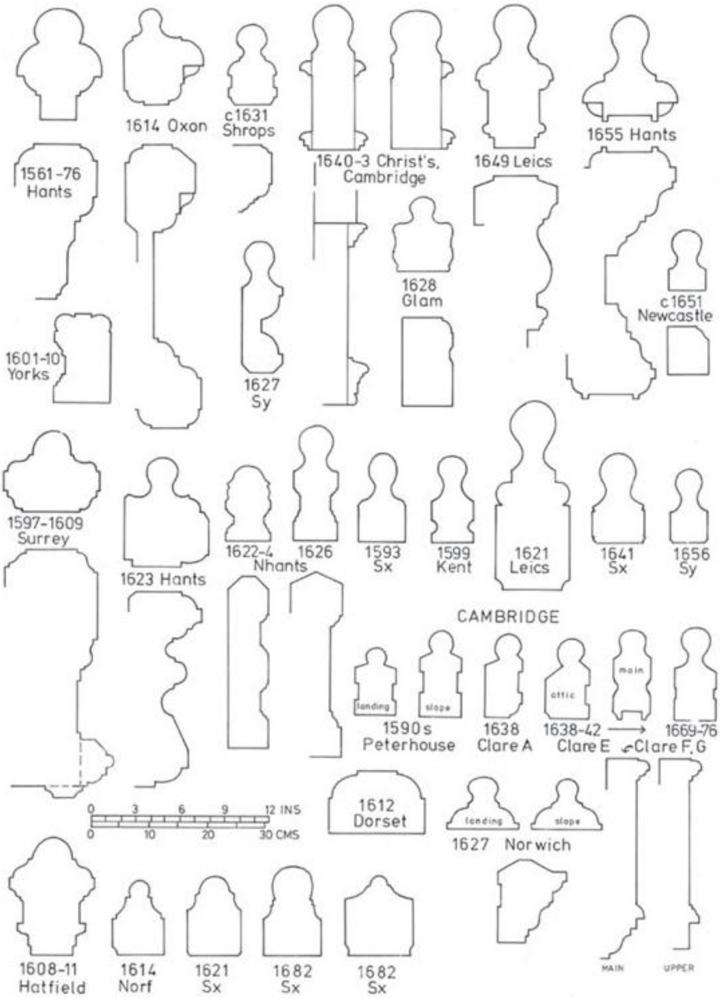
3.43 Incomplete finials. A cheap way of making a seventeenth-century staircase look less old-fashioned was to remove the finials and pendants that dominated the stair well. These were often sawn off, leaving a simple curved top to the newel post, as at Chawton House, Hampshire, where two newels from the 1590 stair were reused in a later stair. The four newels with concave curved tops all look incomplete as if ball finials have been sawn off, leaving just the bases. At the Merchant's House, Marlborough, Wiltshire (*c*.1656) they were removed altogether, surviving only in the painted version. See also Figures 3.34 and 3.35.



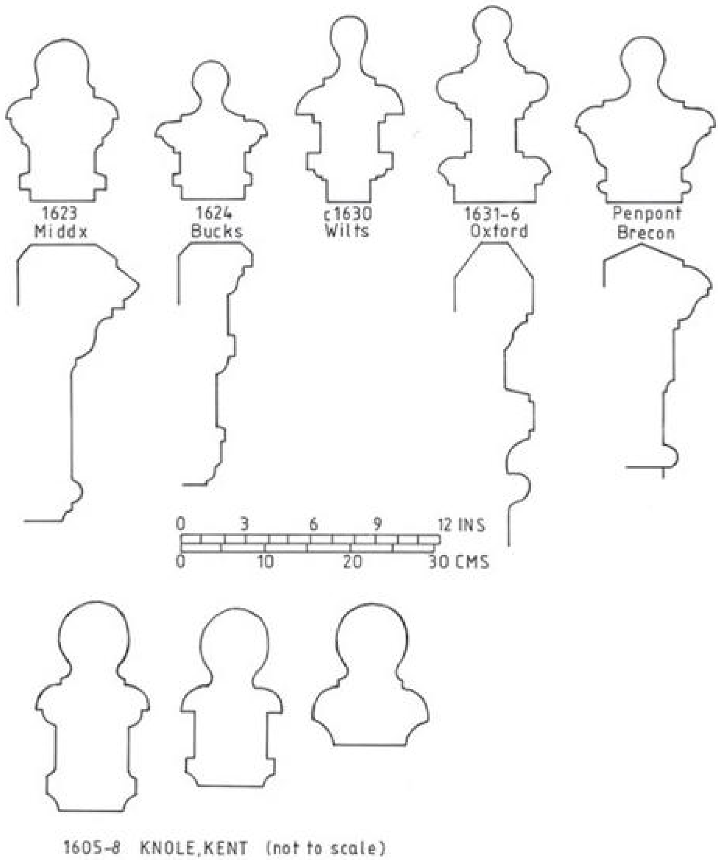
3.44 Newel posts with moulded caps and pendants.

Strings vary more than handrails in design, although earlier ones often have ovolo mouldings or chamfers at the top; later ones have a
projecting moulding. Chawton House, Hampshire (1655) is the latest with ovolo mouldings. Some early seventeenth-century strings have a pointed top, with the balusters shaped to fit over it (Apethorpe,

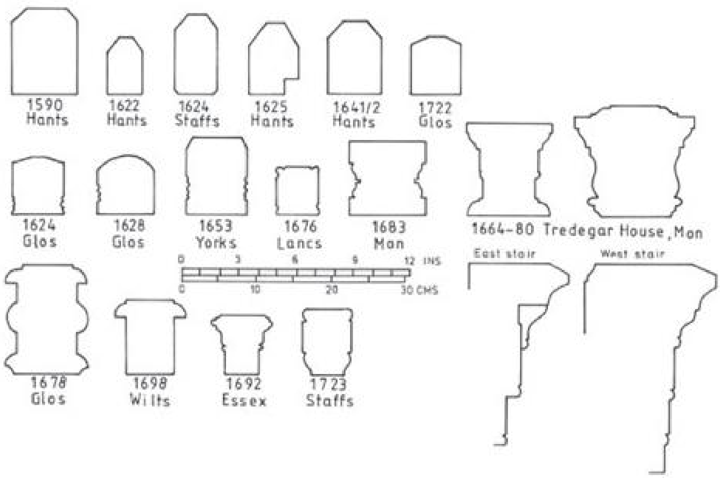
Northamptonshire, 1622–1624; Strangers' Hall, Norwich, 1627). This feature also occurs at Clare College, Cambridge (1683–1690), where it matches the handrail. Some early strings have a band of decorative carving, such as guilloche (1597–1608 Surrey, 1634 Sussex), strapwork (1648 Lancashire)[91] or a row of dentils (1614 Oxfordshire).[92] Others have more elaborate carving, as at Strangers' Hall and All Saints' Church, Odiham, Hampshire (1632).[93]



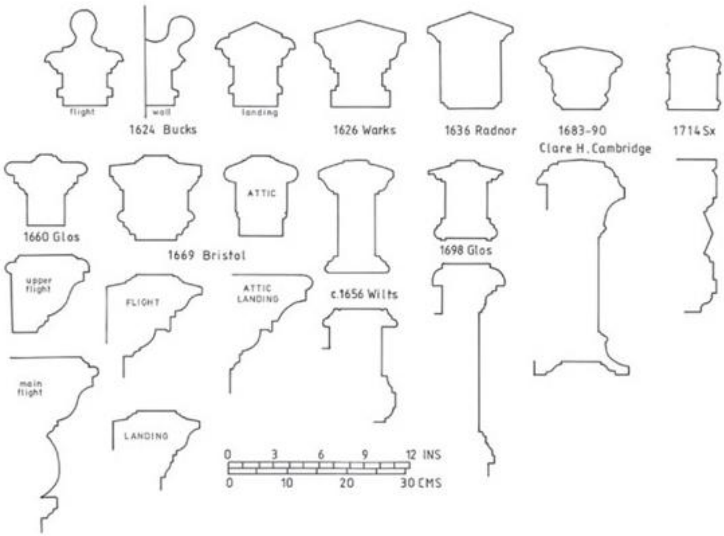
3.45 Grip handrails, some shown with string profiles. The three earliest examples are not true grip handrails, as they lack the characteristic indentations on each side (Grove Place, Nursling, Hampshire 1561–1576; Great Fosters, Egham, Surrey 1597–1609; and Hatfield House, Hertfordshire, 1608–1611). Simpler versions are 1614 Norfolk and 1621 and 1682 (twice) Sussex. Burton Agnes Hall, Yorkshire (1601–1610) has an unusual handrail with half round mouldings at the upper corners, while Cranborne Manor, Dorset (1612) has a very simple rail with ovolo mouldings. Most handrails are symmetrical, but a few are asymmetrical (Plas Teg, Flintshire, 1610; Denton House, Oxfordshire, 1614, St Margaret's Priory, Titchfield, Hampshire, 1623). Peterhouse and Clare Colleges, Cambridge have a characteristic angular variant from the 1590s and around 1640; more research may show if they are the work of the same carpenter or the same workshop.



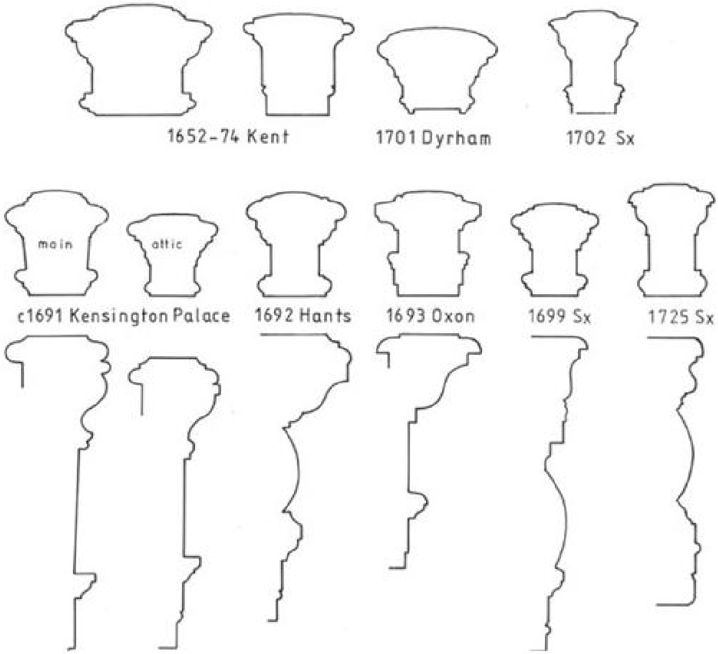
3.46 Grip handrail variants, some shown with string profiles. These elaborate variants of the grip handrail date from the 1620s and 1630s and have similar strings; they may indicate the date of Penpont, Brecon, at present undated, which has a similar handrail and string. At Knole, Kent (1605–1608) the handrails of the three main staircases vary according to their relative status.



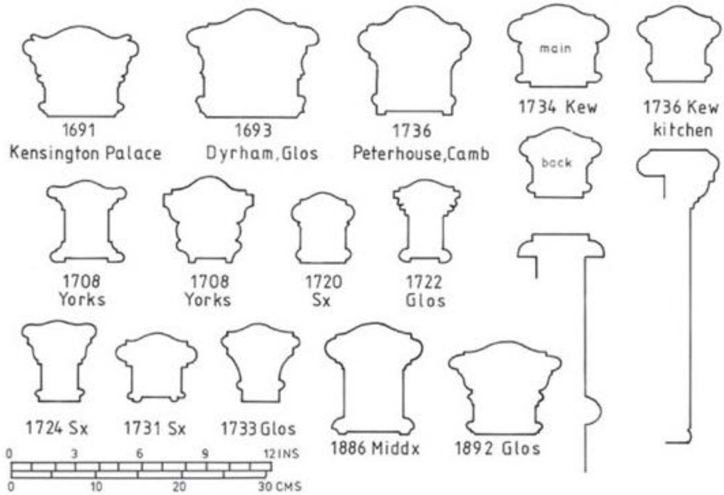
3.47 Flat-topped handrails. Simple handrails with chamfered tops are typical of smaller houses and can occur at any period; shadow mouldings are more common in the first half of the seventeenth century. A more elaborate type of flat-topped handrail is found in grander stairs in the later seventeenth century. Tredegar House, Newport, shown with string profiles. Recent tree-ring dating suggests the house was complete by about 1672.



3.48 Pointed-top handrails. The 1624 Bucks has a pointed-top handrail on the landing balustrades but grip handrails on the flights, with an asymmetrical version for the wall balustrades. Pointed-top handrails occur occasionally throughout the seventeenth century and into the eighteenth century. The Merchant's House, Marlborough, Wiltshire (*c*.1656) and 1698 Gloucestershire are variants with a central raised moulding covering the apex of the rail. The 1660 Gloucestershire has a similar moulding but with a flat top and is similar to Crewe Hall, Cheshire and Whittington Court, Gloucestershire (Figure 3.35). All are shown with string profiles except the first five in the top row.



3.49 Handrails with curved tops. Groombridge Place, Kent (1652–1674) has an early example of this type, which became popular from about 1690. The lower sections are string profiles.



3.50 Toad's back handrails. The Queen's Stair at Kensington Palace (1691) and Dyrham Park, Gloucestershire (1693) are among the earliest examples of a design which became universally popular throughout the eighteenth century. It was revived in the later nineteenth century in identical forms. The Kew Palace examples are with string profiles.

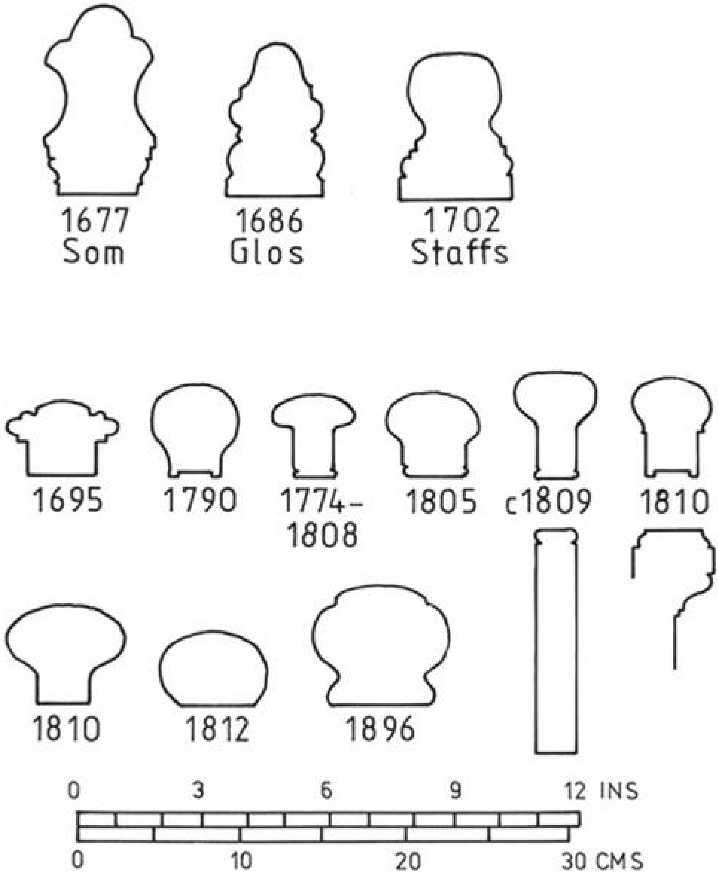
Open-String Stairs

The open-string stair, with balusters standing on each tread, came into fashion in the late seventeenth century, and remained popular well into the nineteenth century, especially in larger houses. The closed-string stair continued in general use in smaller houses and was often used for secondary stairs when the main stair had an open string. Chatsworth (1689–1690) and the King's Stair at Hampton Court (1697) with stone steps and the Queen's Stair at Kensington Palace (1691) with wooden

steps are among the earliest examples, although Gloddaeth, Penrhyn, Denbigh has an open-string stair which may date from 1673.[94] The balusters stand two or three to a tread,
although the Walnut Stair at Drayton House, Northamptonshire (*c*.1705) sweeps round in a tight curve with a single twisted baluster per tread.[95] The balusters are fitted under the handrail either by varying the length of the turned column or by varying the number of turned elements below it. Less commonly the length of the unturned bottom blocks varies. Many eighteenth- and nineteenth-century open-string stairs end in a curtail step, a wider bottom step with a curved end.[96] The handrail also curved around, sometimes with a cluster of balusters supporting it. The central baluster of the cluster was often of iron to provide sufficient strength.

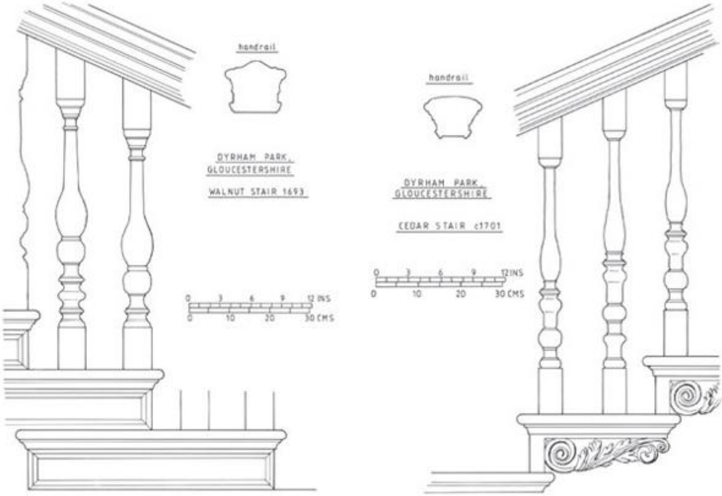
In the best early stairs (Chatsworth, Hampton Court, Drayton House) the moulding of the tread ends runs the full length of the tread, giving a richly moulded underside to the staircase. Alternatively, the exposed underside of
the stair may be panelled as at Dyrham. Most stairs have decorative brackets applied below the projecting tread ends. Elaborately carved spirals or scrolls with assorted foliage were common in the first half of the eighteenth century, while later stairs have simpler curved designs. Plain rectangular blocks were popular in York and Beverley; Beverley has dated examples from *c*.1708–1709 and the 1750s.[97] Both stairs at Redland Court, Bristol (1732–1735) have
unadorned blocks, while Sherborne House, Dorset (*c*.1720) has beautifully inlaid blocks with carved foliage

scrolls below, giving a particularly rich effect.[98] The plainer designs of *c*.1790–1840 sometimes omitted the brackets but had simple mouldings following the slope of the string.



3.51 Small handrails. The 1677 Somerset, 1686 Gloucestershire and 1702 Staffordshire are among a group of unusually small late seventeenth to early eighteenth century handrails. The first two have splat balusters, which do not require a wide handrail. The advent of slender wrought iron balustrades and small stick balusters brought simple rounded handrails which could be tiny.

3.52 Open-string stair at Gloddaeth, Penryhn, Denbigh. This stair, in a wing believed to date from 1673, is either an extremely early experimental example of an open-string stair or a later stair built by someone who had seen such a stair but not fully understood how it was constructed. The flush panels of incised carving below the tread ends can be seen either as a prototype for the eighteenth-century foliage scrolls, or as a provincial craftsman's attempt to copy this feature. The carved panels cut into the sloping string supporting the stair and on the upper flight the corners project slightly below the lower edge of the string. Stylistic evidence suggests that it is in fact an early example dating from 1673; the wide flat-topped handrail is similar to that at Tredegar House, Newport (1664–1672) and the end blocks of the balusters have long ogee mouldings at the corners, totally unlike eighteenth-century balusters. The mouldings of the twisted balusters follow the slope instead of being horizontal, a feature otherwise only known in the stair at Penpont, Brecon, which probably dates from the first half of the seventeenth century.



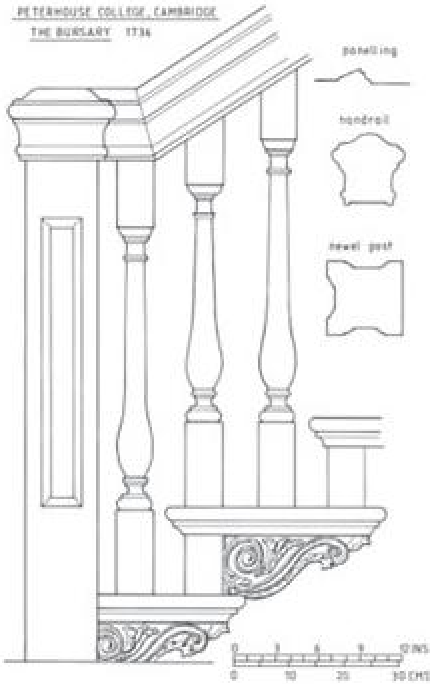
3.53 Open-string stairs at Dyrham Park, South Gloucestershire. The balusters of the Walnut Stair (1693) and the Cedar Stair (*c*.1701) have extra elements below the main shaft to give the required height.

The open-string stair remained popular in Victorian times, but often combined elements from varying periods. New designs were invented too; the balusters at an 1896 house in Hampstead (Figure 3.56b) are carried past the ends of the steps to terminate in little turned pendants. Slender balusters with multiple decorative elements remained popular well into the twentieth century, and many Edwardian houses show similar designs.

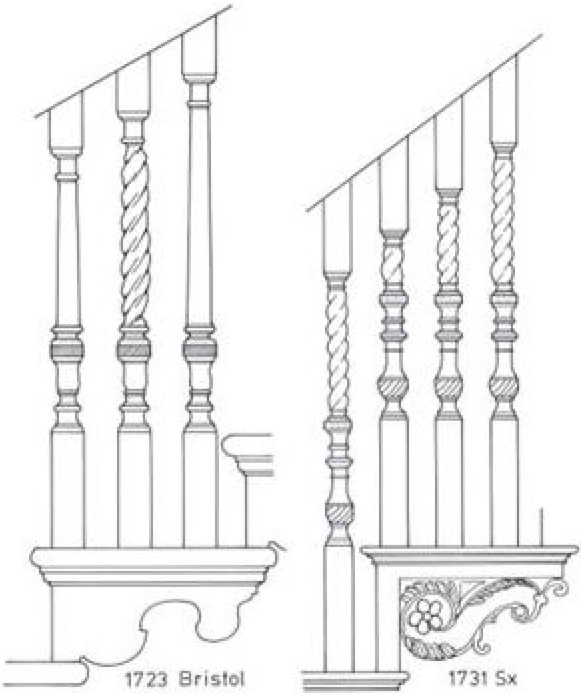
Types of wood: parquetry landings

Until the end of the seventeenth century most staircases were made of oak, with occasional use of elm; a secondary stair at Hatfield House, Hertfordshire

(1607–1611) has a pierced strapwork balustrade of elm, while the 1628 stair at Godinton, Ashford, Kent is made of chestnut. Dunster Castle, Somerset,
used oak and elm. Other woods were sometimes used in the late seventeenth century, but their rarity caused the stairs to be identified by their material (the Walnut Stair and the Cedar Stair, Dyrham; the Walnut Stair, Drayton House). High-quality oak was often chosen to produce fine figuring on the treads and the wall panelling. Parquetry motifs on the half landings take this a stage further, and use either the grain or a mix of different woods to achieve spectacular geometric patterns.[99] Although parquetry floors arrived in England in the mid-seventeenth century, the known landings all date from the end of the seventeenth and the early eighteenth century. Petworth House (1688–1694) had an inlaid stair (later rebuilt), and dated examples occur between 1693 and 1722.[100] The west stair at Redland Court, Bristol (1732–1735) has a simpler version of four small squares within a larger square. These all rely on the grain to create the effect. No. 68 The Close, Salisbury (1718–1722) has a more elaborate landing inlaid with different woods.[101]



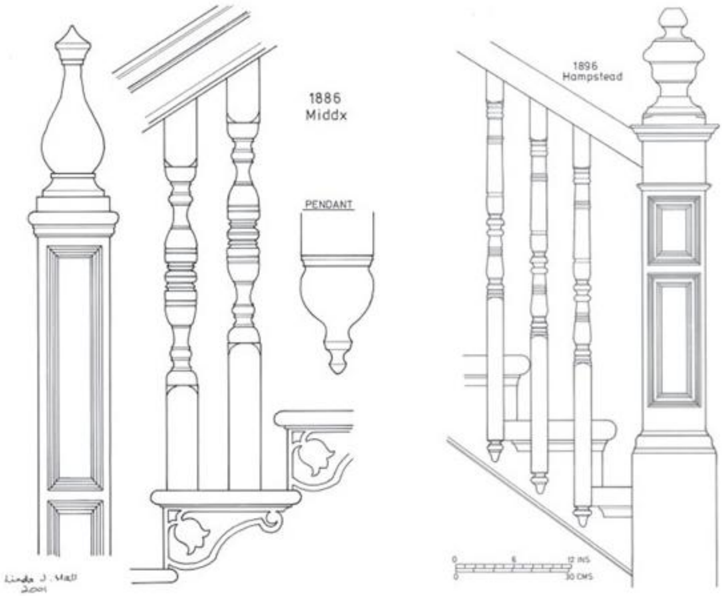
3.54 The Bursary, Peterhouse College, Cambridge. The 1736 stair has turned shafts of varying lengths, which is the usual method of obtaining balusters of the right length to fit between the horizontal tread and the sloping handrail.



3.55 Open-string stairs with twisted balusters. These two examples have shafts of varying lengths, and both have the square unturned blocks common in eighteenth-century balusters. The 1723 Bristol (Dowry Square) combines two tapered shaft balusters with one twisted, a combination found in better-quality stairs. (The square unturned blocks are shown cross-hatched in 1723 Bristol and dotted in 1731 Sussex, in an attempt at clarity.)

Dog Gates

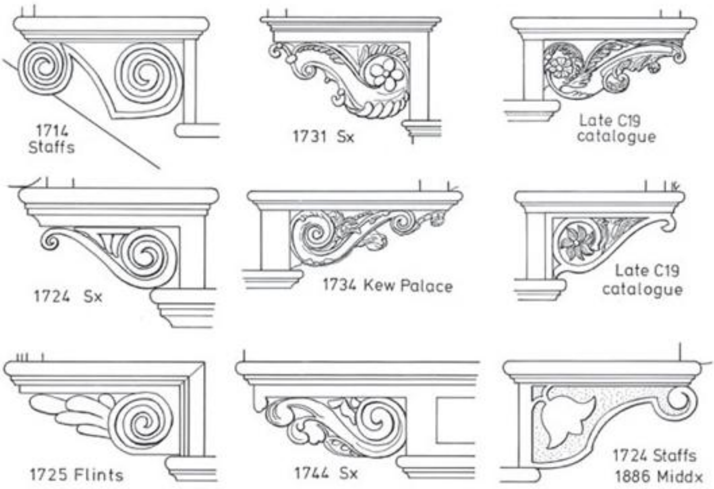
A number of houses, mainly grand but some more modest farmhouses, have dog gates at the bottom of the stairs. The great stair at Hatfield House (1607–1611) has a pair of gates (possibly later additions[102]) at the top of the first short flight, a position also favoured at Haddon Hall, Derbyshire[103] and Whittington Court, Gloucestershire. It has been suggested that large dogs would find it harder to jump over a gate in this position, but the open gate is also less likely to be in the way here. At Cold Overton Manor, Leicestershire (1649), the magnificent gate opens back against the wall on the first landing to form part of the wall balustrade. Collinfield Manor, Kendal, Westmorland (1663–1674) has a gate at the top of the stair, but it may have been moved from the bottom; both stair and gate have splat mirror balusters.[104]



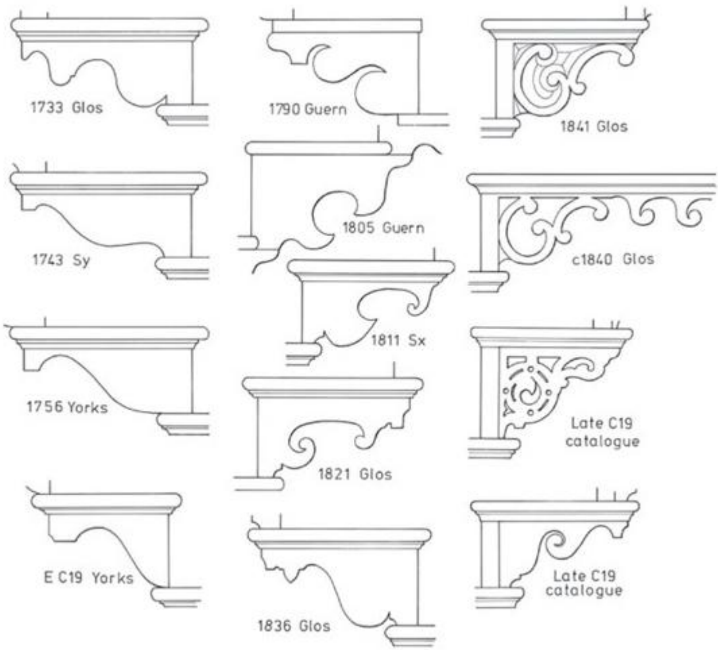
3.56 St. Saviour's Vicarage, Sunbury-on-Thames, Middlesex, designed by J.D. Sedding in 1886, has a fine stair which mixes elements of different periods. The turned section of the balusters is late sixteenth to early seventeenth century in style, but has the long unturned end blocks of a century later. The bottom blocks are different lengths to maintain a standard length for the turned shaft. The panelled newel post resembles late seventeenth-century designs, the finial is an elongated vase, while the toad's back handrail and the carved brackets are identical to early eighteenth-century designs. The newel at 1896 Middlesex (Hampstead) is similarly seventeenth century in feel.

The winder stair at Shelley Hall, Suffolk, has a lattice dog gate with small turned spindles in an open panel, claimed to be *c*.1600.[105] Many dog gates date from the second half of the seventeenth and the early eighteenth centuries. Some have balusters matching those of the staircase (Plox House, Bruton, Somerset, 1687, turned[106] and Manor Farm, Itteringham, Norfolk, 1707, twisted);[107] others have splat balusters when the stair has carved, turned or twisted balusters (Sheldon Manor, Chippenham, and Manor Farm, Yatton Keynell, 1659, both Wiltshire; Faenol Fawr, Bodelwyddan, Flintshire, 1690).[108] No. 15 Queen's Square, Bath (1727–30), Frampton Court, Frampton-on-Severn, Gloucestershire (1731) and Eastbach Court, English Bicknor, Gloucestershire (rebuilt after a fire in 1760) have ingenious gates which fold up like a trellis into a moulded housing on the wall.[109] Some late seventeenth- and early eighteenth-century gates are panelled and may have
ramped tops to match the handrail of the stair. Towneley Hall, Burnley, Lancashire (1725) has a wrought-iron

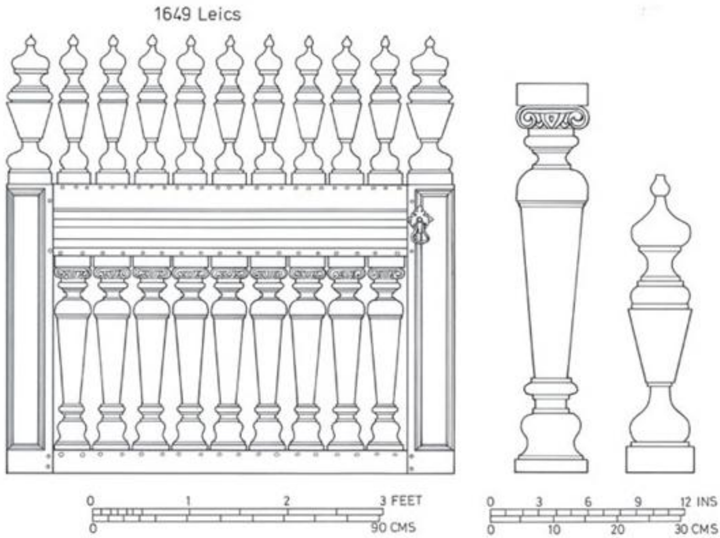
balustrade and a dog gate to match and is the latest known dated example. Dog gates are equally useful as toddler gates, and may always have had a dual function.



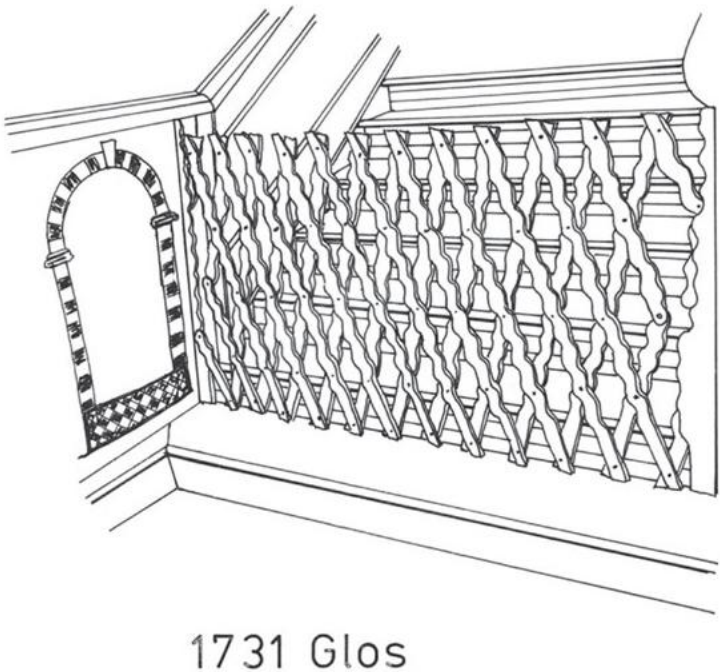
3.57 Early eighteenth-century tread end brackets. The foliage and scroll designs of the early eighteenth century reappear in the late nineteenth century, while identical tulip designs occur in two vicarages (1724, Leek, Staffordshire and 1886, St Saviour's, Sunbury-on-Thames, Middlesex. See also Figure 3.56a).



3.58 Late eighteenth- and nineteenth-century tread end brackets. Plainer designs were used in less elaborate stairs in the early eighteenth century and became universally popular in the later eighteenth and the nineteenth centuries.



3.59 Dog gate, Cold Overton Manor, Leicestershire.



3.60 Dog gate, Frampton Court, Gloucestershire.

Conclusion

This chapter has attempted to provide a broad overview of ways to date staircases through their details. There are, of course, pitfalls to this approach. Stairs may or may not be connected to the dates on inscribed stones or plaster ceilings, and the dendro-date for a roof does not necessarily date the staircase below it. Staircases can be partly or wholly relocated and are sometimes older than the buildings in which they now stand. They may be repaired or altered in later periods, and care should be taken to look for tell-tale signs of alteration or removal. Moreover, in every period staircases are subject to local trends and the whims of the individual craftsmen. Nonetheless, details provide crucial clues for dating staircases and their development shows the changes in fashion and aspirations of those who paid for and installed them.

Notes

1 Godfrey, Walter H., *The English Staircase*, Batsford, London, 1911, Plate II. Downholland Hall is now a farmhouse; it is not known if the stair survives (see Figure 2.12).

2 Key to county and other location abbreviations in illustrations are as follows:

Beds = Bedfordshire

Brecon = Breconshire or Brecknockshire (Wales)

Bucks = Buckinghamshire

Caern = Caernarfonshire (Wales)

Camb = Cambridgeshire

Cornw = Cornwall

Denbs = Denbighshire (Wales)

Derbys = Derbyshire

Durham = County Durham, can also mean City of Durham

Flints = Flintshire (Wales)

Glos = Gloucestershire

Guern = Guernsey

Hants = Hampshire

IoW = Isle of Wight

Kens'tn = Kensington (London)

Lancs = Lancashire

Leics = Leicestershire

Lincs = Lincolnshire

Mer = Merionethshire (Wales)

Merion = Merionethshire (Wales)

Middx = Middlesex (no longer an administrative area)

Mon = Monmouthshire (Wales)

NHants = Northamptonshire

Norf = Norfolk

Radnor = Radnorshire (Wales)

Oxon = Oxfordshire

Shrops = Shropshire

Som = Somerset

Staffs = Staffordshire

Suff = Suffolk

Sx = Sussex

Sy = Surrey

Warks = Warwickshire

Westm = City of Westminster (London)

Wilts = Wiltshire

Worcs = Worcestershire

Yorks = Yorkshire

3 Franklin, Geraint and Hall, Linda, *Manor Farm, Ruislip, London Borough of Hillingdon: Historic Buildings Report*, English Heritage Research Department Report Series no. 63-2008, Figs. 18 and 19, p36, and Figs. 58 and 59, p70.

4 Turner, T.H., *Some Account of Domestic Architecture in England from the Conquest to the End of the Thirteenth Century*, John Henry and James Parker, Oxford and London, 1851, p197.

5 Acton Court, Iron Acton, South Glos. Rodwell, Kirsty and Bell, Robert, *Acton Court: The Evolution of an Early Tudor Courtier's House*, English Heritage, London, 2004.

6 The Manor House, Cloatley, Hankerton. Slocombe, Pamela M., *Wiltshire Farmhouses & Cottages 1500–1850*, Wiltshire Buildings Record, Devizes, 1988, p48.

7 Allt-y-Bela and Trevella, both in Llangwm Uchaf parish. Fox, Sir Cyril and Raglan, Lord, *Monmouthshire Houses Vol. III*, National Museum of Wales, Cardiff, 1954, Fig. 1, p19 and Fig. 5, p24.

8 Great Lypiatt Farm, Corsham. Slocombe, Pamela, op. cit., Fig. 70, p48.

9 Street Farm, Alveston. Hall, Linda, *Rural Houses of North Avon and South Gloucestershire 1400–1720*, Bristol City Museum, Bristol, 1983, Fig. 22, p63.

10 Hall, Linda, *Period House Fixtures and Fittings 1300–1900*, Countryside Books, Newbury, 2007, Fig. 4.8, p103.

11 Cottles Barton, North Tawton, 1567, Wyld Court, Hawkchurch, 1593 and Walronds, Cullompton 1605; Cherry, Bridget and Pevsner, Nikolaus, *The Buildings of England: Devon*, Yale University Press, New Haven, 2004, pp292, 306, 476.

12 Fox and Raglan, op. cit., pp29–34.

13 Cooper, Nicholas, *Houses of the Gentry 1485–1680*, Yale University Press, New Haven, 1999, p311.

14 Roberts, Edward, *Hampshire Houses 1250–1700*, Hampshire County Council, Hampshire, 2003, Figs. 5.59 and 5.60, p116.

15 Ibid., p117 (Grove Place, Nursling).

16 Clarke, Helen, Pearson, Sarah, Mate, Mavis and Parfitt, Keith, *Sandwich: The Completest Medieval town in England'*, Oxbow Books, Oxford, 2010, pp242–3.

17 Walter Godfrey describes one at Canonbury Tower, Islington, with a series of cupboards within the framed well. He attributes it to *c.* 1520, but the stair may belong to improvements made by Sir John Spencer after he

acquired the house in 1570. Godfrey, Walter H., op. cit., p24.

18 Cherry, Bridget and Pevsner, Nikolaus, *The Buildings of England: Devon*, Yale University Press, New Haven, 2004, p278.

19 Drury, Paul and Simpson, Richard, *Hill Hall: A Singular House Devised by a Tudor Intellectual*, Society of Antiquaries of London, London, 2009, Fig. 5, p7 and pp124–8.

20 Thorpe Hall, Northants, *c*.1650, has a free-standing newel stair from the top landing to the attic, with a continuous balustrade spiralling round it. Cescinsky, Herbert and Gribble, Ernest R., *Early English Furniture and Woodwork*, The Waverley Book Company Ltd, London, 1922, Fig. 249, p223. The Friars, Aylesford, Kent has a circular stair, also free-standing, with a tiny central well and a curving handrail, but has twisted balusters of late seventeenth-century type. Godfrey, Walter, H., op. cit., Plate XXXVIII.

21 Godfrey, Walter H., op cit, Plate IV. Pevsner does not mention the house so it may no longer exist.

22 Two late seventeenth-century examples at the Old Rectory and Shann House, both in Methley, are illustrated in Giles, Colum, *Rural Houses of West Yorkshire 1400–1830*, HMSO, London, 1986, Plates 118 and 119, p93.

23 Hollingthorpe Farm, Crigglestone (1725) has a dog-leg stair with winders; Giles, Colum, op. cit., Plate 263, p174.

24 Tipping, Henry Avray, *English Homes, Period III, Vol 1; Late Tudor & Early Stuart, 1558–1649*, Country Life, London, 1929, p42.

25 Cherry, Bridget and Pevsner, Nikolaus, *The Buildings of England: Devon*, Yale University Press, New Haven, 2004, p125.

26 Grove Place, Nursling. Roberts, Edward, op. cit., Fig. 5.62, p117.

27 Drury and Simpson, op. cit., pp128, 301.

28 Royal Commission on Historical Monuments (England), *York: Historic Buildings in the Central Area*, HMSO, London, 1981, Plate 189.

29 Denning, C.F.W., *Old Inns of Bristol*, John Wright and Sons Ltd, Bristol; Simpkin Marshall Ltd, London, 1949, p64. A drawing of a short section of balustrade at The Hatchet Inn, Bristol shows mirror balusters that may be turned for their whole length. The book has several detailed drawings of staircases, with measurements.

30 This is well illustrated by two Somerset buildings. Gray's Almshouses, Taunton (1635) has balusters which are wider at the top; Plox Farm, Bruton (1687) has elegantly tapered balusters which are wider at the base. Penoyre, Jane, *Traditional Houses of Somerset*, Somerset Books, Tiverton, 2005, Fig. 4.13, p71.

31 Quebec House, Westerham, Kent, dendro-dated to *c*. 1625 – Martin Bridge, pers. comm.

32 All Saints', Odiham, Hants (1632); Rug Chapel, Corwen, Denbigh (1637); St Michael and All Angels, Bishop's Cleeve, Glos (1640; see note 35).

33 Four-sided altar rails at St Andrew, Lyddington, Rutland (1635).

34 Godfrey, op. cit., Fig. 9, p14.

35 Cooper, op. cit., p196. See note 13.

36 Other examples, undated but with early seventeenth-century features, are Merton College and Oriel College, Oxford (Royal Commission on Historical Monuments (England), *An Inventory of the Historical Monuments in the City of Oxford*, HMSO, London, 1939, Plate 168); Baildon Hall, West Yorks (Giles, op. cit. p68); Tissington Hall, Derbyshire; Whittington Court, Glos; Wacton Hall, Norfolk (early seventeenth-century mirror balusters); Headstone Manor, Middx and Croydon Palace, Surrey. The west gallery stair in St Michael's Church, Bishop's Cleeve, Glos. also has tenoned balusters; Bond dates it to 1640. Bond, Francis Bligh, *Screens and Galleries in English Churches*, Henry Frowde, Oxford University Press, London, New York and Toronto, 1908, p143.

37 An example is illustrated in Smith, Peter, *Houses of the Welsh Countryside*, HMSO, London, 1975, Plate 90 (Glandolfan, Cilgerran, Pembs).

38 Cescinsky and Gribble, op. cit., Fig. 242, p217.

39 Accounts for the St John's College stair show that it was built by William Hudson, carpenter, and his son, David Woodfield, joiner ('for carving ye president's

staire case 20s') and Arts Stranguage, turner ('For turning 27 bannisters for ye half pace stairs at 6d a piece: 13s 6d' – the stair has 27 balusters, including those that were halved and fixed to the newel posts.)

40 The Master's Lodging, Pembroke College, and the Provost's Lodging and the north range of Front Quad at Oriel; Royal Commission on Historical Monuments (England), *City of Oxford*, HMSO, London, 1939, Plates 46 and 168.

41 Plox House, Bruton, Somerset. Penoyre, Jane, op. cit., Fig. 4.11, p68 and Fig. 4.13, p71.

42 Godfrey, op. cit., p34. Godfrey has many illustrations of stairs in this category.

43 Packington Old Hall, Great Packington, Warwicks, dated 1679 (rainwater head) and 1680 (internal plasterwork). It has a massive open-well stair with twisted balusters; a painted balustrade survives at attic level. Alcock, N. W., 'Innovation and conservatism: the development of Warwickshire houses in the late 17th and 18th centuries', *Birmingham & Warwickshire Archaeology Soc Trans 100*, 1996, pp133–154.

44 Andrews, H.C. and Reader, Francis W., 'Representations of staircase balustrades', *Trans East Herts Archaeology Soc* XI, 1940–4, pp150–3.

45 This may, however, reflect the areas where more fieldwork has been done rather than the true distribution of the feature. Examples from Ellesmere, Ludlow and Much Wenlock are illustrated in Moran, Madge,

Vernacular Buildings of Shropshire, Logaston Press, Logaston, 2003, pp189, 287, 297, 441.

46 Several splat balusters are illustrated in Jourdain, M., *English Decoration and Furniture of the Early Renaissance (1500–1650)*, Batsford, London, 1924, Fig. 256, p184.

47 Roberts, op. cit., Fig 5.66a, p121.

48 Ibid., Fig. 5.67 l, p123.

49 Nairn, Ian, Pevsner, Nikolaus and Cherry, Bridget, *Buildings of England: Surrey*, Penguin Books, Harmondsworth, 1971, Fig. 45.

50 The French Horn, Ware, Herts has a similar mid seventeenth-century stair with geometric balustrade and chunky finials; Smith, J.T., *English Houses 1200–1800*: *The Hertfordshire Evidence*, HMSO, London, 1992, Fig. 287, p173. Pevsner mentions another with 'open strapwork panels' at Tilley Manor House, West Harptree, Somerset (1659). The Brewery staircase, Norwich (Howard House) is illustrated in Jourdain, op. cit., Figs. 258 and 259, pp185–186.

51 Godfrey, op. cit., Plate XXIII.

52 Cescinsky and Gribble, op. cit., Fig. 250, p224; Godfrey, op. cit., Plate XXV.

53 Shown in Cescinsky and Gribble, op. cit., Fig. 251, p225.

54 Godfrey, op. cit., Plate LIII; Parissien, Steven, *The Georgian House*, Aurum Press, London, 1995, p152.

55 For example, local iron founder John Walker produced pattern books in York.

56 There are many illustrations of iron balustrades in Godfrey, op. cit., pp 59–69 and Plates LIV–LXIII.

57 Dr Lee Prosser, Historic Royal Palaces, pers. comm.

58 The change from simple stick baluster to fussy turned balusters is well illustrated by 94, The Mount, York (1821) and 127 The Mount (1833), Royal Commission on Historical Monuments (England), *York: Historic Buildings in the Central Area*, HMSO, London, 1981, Plate 89.

59 E.g Treowen, Wonastow, Mon (1627) and Hall i' th' Wood, Bolton, Lancs (1648); Hall, Linda and Alcock, N.W., *Fixtures and Fittings in Dated Houses 1567–1763*, Council for British Archaeology, York, 1994, Fig. 13.

60 A compact open-well stair added to Little Sodbury Manor, South Glos *c.* 1630–1640 has the usual combination of turned mirror balusters, matching turned newel posts with ball finials, and a grip handrail. Hussey, Christopher, 'Little Sodbury Manor, Gloucestershire', *Country Life*, 7 October 1922, Fig. 6, p443.

61 Godfrey, op. cit., Fig. 9, p14.

62 Ibid., Plate VII and Fig. 7, p11.

63 Royal Commission on Historical Monuments (England), *York: Historic Buildings in the Central Area*, HMSO, London, 1981, Plate 191.

64 Cescinsky and Gribble, op. cit., Figs. 242 and 244, pp217, 219.

65 Godfrey, op. cit., Fig. 25, p32 and Figs. 21 and 22, pp28–29.

66 Two are illustrated in Sandon, Eric, *Suffolk Houses: A Study of Domestic Architecture*, Baron Publishing, Woodbridge, 1977, Plates 120 and 121, p149; plates 140 and 141, p163. Hemingstone Hall is dated 1625; Baylham Hall is undated but of the same period, with carved balusters and tapered column finials.

67 Pevsner calls it Elizabethan but its exact date is not known.

68 Batemans, Burwash (1634) and Great Wigsell, Salehurst (1641); Martin, David and Martin, Barbara, *Historic Buildings in Eastern Sussex Vol 1, No 6: Timber Staircases*, 1980, Figs. 4 and 5, pp147–8. Also Old Marton Hall, Shropshire, Moran, op. cit., p441.

69 Royal Commission on Historical Monuments (England), *An Inventory of the Historical Monuments in the City of Oxford*, HMSO, London, 1939, Plate 168.

70 Godfrey, op. cit., Fig. 26, p33. Tragically the house burned down in 1918.

71 Giles, op. cit., Plate 69, p68; also Royal Commission on Historical Monuments (England), *City of York: Volume III: South-West of the Ouse*, HMSO, London, 1972, Plates 82 and 83; The Old Rectory, Tanner Row, *c.*1640 and 32 Micklegate, early seventeenth century. Both have strapwork of ovals and lozenges and the Old Rectory has tapered vase finials.

72 Godfrey, op. cit., Fig. 27, p34.

73 Fox, Sir Cyril and Lord Raglan, op. cit., Part III, Plate XVIIIB.

74 Ibid., Plates XII and XX.

75 Ibid., Fig. 23, p30.

76 Ibid., Plates X and XI. Lymore Hall (demolished 1931) had rusticated newel posts with huge tapered vase finials, carved balusters and a large grip handrail. Peter Smith dated it to 1675, but the Clwyd-Powys Archaeological Trust suggests the house was built in the late sixteenth/early seventeenth century and altered or enlarged in 1675. The stair would have been very old-fashioned for 1675 and the earlier date is more likely. It was moved to Aldborough Hall, Yorkshire after the house was demolished. http://education.gtj.org.uk/en/item1/20685

77 Martin Bridge (Oxford Dendro Lab), pers. comm.

78 Hall, 1983, op. cit., Plate XXVII, p67.

79 Royal Commission on the Historical Monuments of England, *An Inventory of the Historical Monuments in the City of Cambridge, Part I*, HMSO, London, 1959, pp37–47 and Plate 66.

80 Godfrey, op. cit., Plate XII. A Gloucestershire example is illustrated in Calloway, Stephen (ed.), *Elements of Style*, Mitchell Beazley International Ltd, London, 1991, p500.

81 Smith, Peter, op. cit., Plate 95.

82 Beachampton Farm, *c*.1603; Cescinsky and Gribble, op. cit., Figs. 242 and 243, pp217–218. Also Hatfield House 1607–1612; Crewe Hall, Cheshire 1615–1636; Rawdon House, Hoddesdon, Herts, 1622; Boston Manor, 1623, and The Bishop's Palace, Wells.

83 Hall, 1983, op. cit., Fig. 22, p63.

84 Cooper, op. cit., p312.

85 Tipping, Henry Avray, op. cit. Pevsner says the vases of fruit were brought from Holland.

86 The staircase at Sheldon Manor, Wilts 'was found covered with paint in 1911 and the dog gate and finials from the newel-posts had been removed. They were recovered and put back in position.' Cooke, Robert, *West Country Houses*, published by the author, Bristol, 1957, p21. He does not say where the finials were recovered from!

87 Hall, 2007, op. cit., Fig. 4.11, p105.

88 Andrea Kirkham, pers. comm.

89 Plox Farm, Bruton, Somerset (1687) has a variant. Penoyre, op. cit., Fig. 4.11, p68.

90 Hall, 2007, op. cit., Fig. 4.61, p126.

91 Hall, Linda and Alcock, N.W., op. cit., Fig. 7, p7; Old Marton Hall, Shropshire, Moran, op. cit., p441.

92 Hall, 2007, op. cit., Fig. 4.58, p125.

93 Roberts, Edward, op. cit., Fig. 5.28, p87.

94 Vernacular Architecture Group, *Spring Conference 2005: Snowdonia*, p22.

95 Tipping, op. cit. (Drayton House)

96 Celia Fiennes was clearly describing a curtail step in her journeys of 1701–1703 when she says ‘the lower step or two larger and the other end is in a turn’. Morris, Christopher (ed.), *The Journeys of Celia Fiennes*, Cresset Press, London, 1949, p345.

97 Hall, Ivan and Hall, Elisabeth, *Historic Beverley*, William Sessions Ltd, York, 1973.
This book has numerous photos of staircases in the town, many of them dated and by known craftsmen.

98 Bruce, Anthony, Sherborne House, *Somerset Archaeology and Natural History Soc Newsletter No 70*, Summer 2004 (www.sanhs.org/newsletter70.htm). The Master’s Lodge, Clare College, Cambridge (*c*.1710) also has decorative brackets below rectangular blocks. RCHME Cambridge, op. cit., Plate 67.

99 Celia Fiennes, writing on her travels between 1685 and 1696 refers to an inlaid stair at Broadlands near Romsey, Hants; ‘the halfe paces [ie the half landings] are inlaid with yew wood, which lookes a yellowish red, in squaires’, while on a later journey in 1701–1703 she mentioned two inlaid stairs. At Durdans, near Epsom ‘only the half paces inlaid’ and at the ‘house of Mr. Ruths … the half paces are strip’d, the wood put with the graine, the next slip against the graine, which makes it look pretty as if inlaid.’ Morris, op. cit., pp55, 344, 345.

100 The stair from St Mary Redcliffe Vicarage, Bristol, built in 1701, which was rebuilt in the nineteenth-century vicarage; when that was demolished it was installed in Taunton Castle Museum. A recent reordering of the museum has dismantled the stair yet again and it is currently seeking a new home. Other dated examples are the Walnut Stair (1693) and the Cedar Stair (*c*.1701) at Dyrham Park; Pallant House, Chichester (*c*.1712); Kings Weston House, Bristol (*c*.1710–1722); Gillingham Hall, Norfolk (*c*.1710–1720) and Beningbrough Hall, North Yorks (1716).

101 Royal Commission on Historical Monuments (England), *Salisbury: Houses of the Close*, The Stationery Office, London, 1993, Plate 177, p230.

102 The gates at Hatfield do not match the balustrades and are difficult to date. The same applies at Abbot's Hospital, Guildford (*c*.1619), which has a fine stair similar to Hatfield with arches joining carved balusters, but a very simple dog gate of splat balusters. Jourdain, op. cit., Fig. 251, p180. It is similar to Pound Farm, Dunsfold, Surrey (1687) except that Abbot's Hospital has long strap hinges and Pound Farm has H-hinges. Hall and Alcock, op. cit., Fig. 45.

103 Actually a pair of gates with panels in the lower half and turned mirror balusters above, illustrated in Jourdain, op. cit., Fig. 257, p185.

104 Ayres, James, *Domestic Interiors: The British Tradition 1500–1850*, Yale University Press, New Haven, 2003, Fig. 182, p121.

105 Sandon, op. cit., Plate 119, p149.

106 Penoyre, op. cit., Fig. 4.13, p71.

107 Wearing, Stanley J., *Beautiful Norfolk Buildings, Vol III*, Norwich, 1960, pp34–36. This has a detailed description of the stair including measurements, but no illustration.

108 See also Slocombe, Pamela M., op. cit., p49; a photo of Rowden Farm, Lacock shows an open-well stair with turned balusters and a dog gate with splat balusters.

109 Hall, 2007, op. cit., Fig. 4.74, p132.

4

London Staircases

Treve Rosoman

LONDON has always been the driving force for changes in fashion and technological change, driven by the fact that it is a centre for trade and finance. In the eighteenth century London was much smaller than its twenty-first-century size, and back then it consisted mainly of the City of London – the Square Mile – and the 'City and Liberty of Westminster'. However, it also included what were termed The Bills of Mortality, that is those neighbouring parishes all around such as Stepney and St Georges in the East and the Borough of Southwark, and St Mary, Lambeth, south of the river. These all returned weekly reports of deaths, thus enabling the authorities to keep some understanding of what was happening in the urban area. The high death rate required a constant influx of people and often the young men who came to be apprenticed to leading craftsmen were the younger sons of provincial gentry; this fact helped spread new fashions and taste as they kept contact with home.

Despite London leading the way in fashion, it was also quite conservative in many respects. Thus it is quite possible to find the latest designs alongside earlier patterns in the same house. This is especially true for staircases; on the ground and first floor the most decorative and latest designs will be found while on the second and third floors and above older, less fashionable patterns will be the norm. For example in 37 Craven Street, Charing Cross, a moderately expensive cut-string staircase with two balusters per tread ran from the entrance hall to the first floor, which was, of course, the principal social entertaining area of a London house. Upwards from there, on the second floor lay the family bedrooms, and so an older pattern closed-string stair design was used with only one, slightly different pattern baluster per tread (Figure 4.1).

4.1 No. 37 Craven Street, Charing Cross, *c*.1730. An unusual view taken during the substantial refurbishment in the late 1980s of almost the whole eastern row of houses. All the wall panelling has been removed thus revealing the usually hidden structure of the staircase from the first to second floor. The difference between a cut and open string stair is clearly illustrated. (Courtesy of English Heritage)

It is these rather anachronistic details that one must always bear in mind when examining houses, for they can skew the decisions one makes as to the age of the building as a whole; this is true, of course, for provincial houses as much as for the capital. It can be tempting to jump to easy conclusions.

4.2 No. 37 Craven Street, Charing Cross, *c*. 1730. Detail of the meeting point on a dog-leg staircase of cut-string type. Made of pine, the handrail is stained dark brown to imitate mahogany. While there are three turned balusters per tread they are of the same pattern; however, the turner has had to take into consideration the shrinking of shape to keep the design coherent, hence the short baluster in the angle. Note the thick paint layers covering the carved and turned details. (Courtesy of English Heritage)

As London was such a commercial focus it naturally became the place pattern books were written, printed and published and then sold either in town, elsewhere in the provinces or sent abroad to the new colonies, especially New England.

Pattern Books

Constructing a fancy staircase was an expensive undertaking; along with double-hung sash windows it was possibly the most expensive aspect of house-building. As with all complex ideas it became a useful aid to have a written guide. There had long been editions of Continental books such as Palladio, but they were all either in original Italian, French, or even Latin, or else they were translations of translations and so of limited use, although the illustrations of baluster shapes, for example, were useful.

Among the first to be published in England, which came out in 1678, was *Mechanick Exercises, or the Doctrine of Handy-Works* by Joseph Moxon (1627–1691). Although not exactly a pattern book as such, it does reveal much about the tools, the best timbers to use, and the work involved. It was originally published as a part-work, probably the very first of any in this way in England. It was reprinted as a single volume in 1703.

In the second quarter of the eighteenth century there were a number of important publications that were written in English by working tradesmen for their peers.

To name just a few there was William Halfpenny (d. 1755) *Practical Architecture*, 1724; Francis Price (1704?–1753) is an interesting case as much of his life was spent in and around Salisbury and Hampshire, but the book for which he is famous was a London publication. Originally published as *A Treaty on Carpentry* in 1733, an enlarged second edition came out in 1735 under the title *The British Carpenter*; with numerous plates it was the first book aimed directly at the instruction of craftsmen.[1]

Another important name, especially for staircase production, was Abraham Swan (*c*.1720–*c*.1765), who published *The Builder's Treasury of Staircases* in 1745. Like many of these pattern and guidebooks it had a long life and was republished after Swans death, with additional plates by the American John Norman (1748–1817) in Philadelphia in 1774.

4.3 No. 37 Craven Street, Charing Cross, *c*. 1730. A view of the underneath of the closed-string staircase with its usual covering removed during a major conservation programme. It shows very well the substantial timber bearers or carriage pieces that support the actual weight of the staircase structure and which are normally hidden from view. (Courtesy of English Heritage)

In the later eighteenth century, among the most influential, both in Britain and North America, were William Pain (1743–1794) and Peter Nicholson (1764–1844). Pain wrote a number of books but the one he is perhaps best known for was his first, *The Builder's Companion, and Workman's General Assistant*, 1758. Like many of these books they were co-published with printsellers, another London speciality. From *c*.1760 Pain wrote and published nearly a dozen books until his last in 1793, not including several editions of many of them. In Pain's little book of 1763, *The Builder's Pocket-Treasure*, he wrote that not only had he 20 years of experience of the building trade, but that he had 'executed almost every Part of the Book himself';[2] the book itself is only about five inches square and would easily fit in the generous eighteenth-century overcoat pocket.

The other major influence on late eighteenth- and early nineteenth-century staircase building was Peter Nicholson (1765–1844). Nicholson was a lowland Scot who had trained as a cabinet-maker and came down to London in 1788 to seek his fortune, or so he hoped. He had a considerable talent for mathematics and was also a skilled draughtsman. He could also write clearly, especially for his fellow tradesmen. Thus he combined these skills to write and illustrate a number of books of which the most influential was *Principles of Architecture* in 1798, and in 1823 *The New Practical Builder and Workman's Companion*, a book that remained in print in various editions long after his death. All of Nicholson's books were concerned with all aspects of building, but the extreme complexity of constructing the beautiful curving staircase that swept upwards from the entrance hall required a high degree of mathematical skill, and Nicholson's plates for these simple-looking stairs are a triumph. His books were not published in North America but were strongly influential on a number of architects, most notably Asher Benjamin (1773–1845).

Innovation vs. Tradition

All the books noted above and others like them were designed to inform the ambitious carpenter and joiner with entrepreneurial flair as to how best to create new styles. The design and manufacture of staircases required the input of not only the joiner, but also the skilled wood turner and carver; later in the eighteenth century the blacksmith was closely involved. The development of the staircase in London depended as much on technological understanding to make such things as cantilevered stairs and other flights of architectural fancy as the need to understand the latest fads and fashions such as rococo, Chinoiserie or Gothick.

Another great writer in the eighteenth century was the architect Isaac Ware (1704–1766), who had noted in *The Complete Body of Architecture*, 1756–1757, that 'A good house should always have two staircases, one for Shew – the other for domestics.' While much that Ware wrote referred to London houses, that is practically all he did write in the book concerning the stairs. It is interesting to note that, in common with other such high-status architects as James Gibbs (1682–1754) or Sir William Chambers (1753–1796) they wrote a great deal about chimneypieces and other decoration, but almost

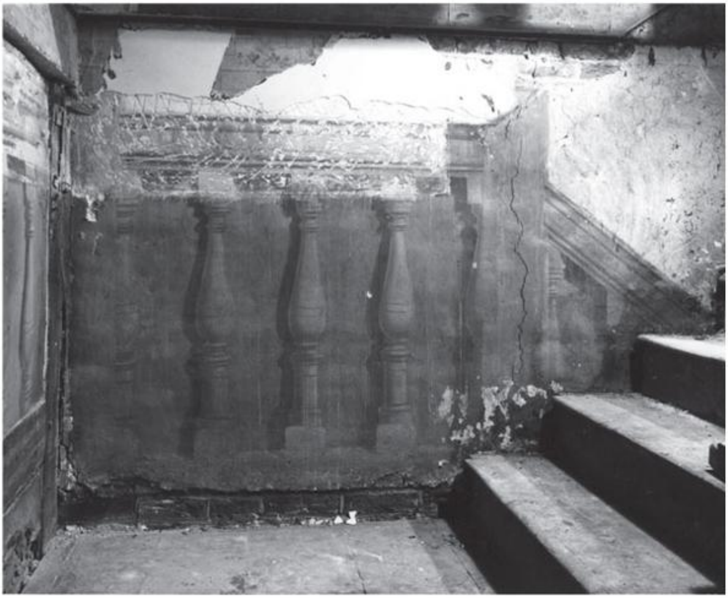
nothing about staircases. It would appear that such writing was
beneath them and it was left to the practical tradesman to write for his peers.

Although not always possible to have two staircases in the typical London terrace house for reasons of space, the differing types of stair described above, the open- and closed-string staircase, is not at all uncommon in early eighteenth-century London. What seems even stranger is the grand stair leading up from the entrance hall and no further; to reach the upper floors one must use a pokey, dull staircase. An example of this may be seen in many Mayfair houses, such as 39 Charles Street, built in 1750–1753.

The seventeenth-century staircase was the product of the carpenter, and so the structure was nailed and dowelled together with crude butt-joints rather than using the mitre or dovetails of the more skilled joiner. The decoration was planted on with glue and nails. The robust newel posts were either solid baulks of timber or built-up hollow constructions. The balusters were normally at least 2–3 inches square and produced by a turner, while the handrail ran in a straight line from newel to newel.

It was not at all uncommon in larger houses on the then outskirts of London to have a mirror image of the stair balustrade painted on the opposite wall using trompe-l'oeil paint effects to create the illusion. The faint remains of such a scheme were uncovered on the top floor of Kew Palace, a Dutch-style house of 1631 on the western outskirts of London. Also on the outer edges of eighteenth-century London on Highgate Hill is

Lauderdale House, built in 1582. When restoration work was being carried out after a fire the remains of the mirror-painted staircase was found running in the opposite direction to the staircase there now (Figure 4.4)



4.4 Lauderdale House, Highgate, *c*. 1650. Remains of the *trompe l'oeil* paint work imitating the turned wood balusters of a previous early seventeenth-century stair. Such schemes were popular and much cheaper than making it in timber. The photograph was taken during substantial repair work after a serious fire in the late 1960s. (Courtesy of English Heritage)

The great innovation in staircase design was the cut- or open-string stair (Figures 4.5–4.6). The cut-string staircase seems to have appeared in London by 1710. It may be argued that the cut-string stair could only be made with saws of sufficient quality to keep their edge, with chisels that could also stay sharp for carving and turning and planes that not only kept their edge but could be made small enough to get into the tight angles of the new design. London was a major centre for the manufacture of planes in the early eighteenth century as well as the making of all tools. The softwood that was used for the vast majority of London staircases was a beautiful material to work, being quite soft, but as it was slow-grown had close growth-rings that meant the wood took a sharp edge. The cut-string is a wasteful design, as substantial chunks of wood must be sawn off to make each step, but it provided the base for considerable embellishment.

4.5 No. 14 Fournier Street, Spitalfields, Tower Hamlets, London. A photograph taken in February 1909, a fine ramped, cut-string staircase of *c*.1726; with three balusters per tread and fluted Ionic column newel posts and a magnificent curving curtail where the handrail sweeps sharply round the clustered balusters on the first tread. It was built for and by the master carpenter William Taylor. (Courtesy of English Heritage)

4.6 No. 14 Fournier Street, Spitalfields, Tower Hamlets, *c*.1725. Detail at the half-landing showing the elaborate cut-string made from mahogany and dating from *c*.1726. Note the finely carved floral tread-ends, or stair brackets, which hide the construction slots into which the turned balusters are fitted. The staircase has had a relatively hard life as there are mismatched replacement balusters and there is an iron strap screwed into the handrail above the fluted Ionic column newel post. The photograph was taken in 1909. (Courtesy of English Heritage)

Quite advanced geometry was needed to lay out the new design, and it was usual for the joiner to assemble it 'dry' in the workshop as opposed to
the carpenter, who could make the closed string stair directly on site. The handrail was also of a completely different shape as it needed to be 'ramped', that is, the handrail had to rise up steeply as it came to the top newel post of the first flight of stairs in order to keep the balustrade at a constant height; it is a quite distinctive aspect of early eighteenth-century stairs (Figures 4.5, 4.7, 4.8). Thus, the joiner had to be in some considerable way of business to undertake such a project.

4.7 No. 2 Fournier Street, Spitalfields, Tower Hamlets; the house was formerly the rectory to the magnificent Christ Church Spitalfields, designed by Nicholas Hawksmoor, 1714–1729. As this house was built by the Church Commissioners it is unusually well documented by surviving accounts. Built in 1726–1728, the stair was made by Samuel Worrall at a cost of £40-10s-6d, with the 16 carved tread-ends measuring 9 inches by 4 inches, an extra £1-4s; to put this in perspective, a kitchen maid was probably paid around £3 per year, a clergyman about £40 and the very best French cook no more than £50–60. The photograph was taken in 1909. (Courtesy of English Heritage)

4.8 Detail of an early eighteenth-century handrail from a ramped staircase. Made from softwood imported from the Baltic, it is possible to see how such a sharply raked handrail was made; the short section fits into the newel post and is mitre-jointed to the curved section. This was then rub-jointed using glue and reinforced with nails onto the long straight section. (Courtesy of English Heritage)

The cut-string stair had a much-turned baluster, more so than earlier shapes, normally about 1 inch square and made up of a bulbous vase shape, confusingly also called a baluster, which was set below a version of a Doric column. It was a design capable of staggering variety. One of the best examples of such a London staircase is the Rectory, 2 Fournier St, Spitalfields (Figure 4.7). It was made from painted softwood and has three balusters per tread of three different patterns, two variations on spiral turning and a plainer column-and-vase pattern. As it was a church building the records survive for building this stair, which cost £41-0-0 in 1730.[3]

As each baluster was slotted into the tread via a dovetail, a cover was required to hide the join so a moulding, called a nosing, was nailed over. Immediately below was the mitre-joint of riser and tread that also needed to be masked. For this the carver was employed to make a roughly triangular-shaped tread-end, or stair-bracket; these were usually carved with a swirling floral motif and in the case of the Rectory cost 1s 6d each, which meant it took about half a working day to finish one.

The very architectural nature of these staircases underlines the link between trades in London, especially those of cabinet and furniture making, wood turning and wood carving; all very separate trades but all closely involved in the building expansion of London throughout the eighteenth century.

The final innovation, covered in more detail below, was the introduction of wrought and cast iron in staircase production.

Types of Staircase

The widespread adoption of the terrace house layout in London led in the long term to a fairly restricted range of staircase type. The earliest surviving terrace houses in the city are to be found at 52–55 Newington Green, near Islington, and they date from 1658. The staircases for these houses are sandwiched between the front and rear chimney stacks. It was eventually realised that this was an inefficient system. What evolved by the 1720s was a stout party wall into which the chimney stacks of the adjoining house were built; this added stiffness to the house structure, acted as a fire-wall – the great threat of all houses – and allowed the staircase to rise up from the entrance hall and have a halls-adjoining plan that gave greater privacy. The type of staircase used is called a dog-leg as it returns on itself to complete the rise to the next floor. Thus, one had a ‘pair’ of flights between each floor and this led to the common eighteenth-century description in letters and documents that somebody, for example, lived up ‘one pair of stairs’. That is, on the first floor.

During the transition to the ubiquitous dog-leg the most common was the open-well form as seen in the surviving houses in Albury Street, Deptford, South London, which were built *c.*1707–1710 (Figure 4.9).

4.9 Albury Street, Deptford. Originally known as Union Street, Albury Street was laid out and built 1707–1710. In this photograph it is possible to see what happens commonly in London with houses that have had a hard life. The first occupants were shipwrights for the Royal Dockyard at Deptford, but it then slipped down the social scale into multi-occupation. The staircase is of the closed-string variety and the twist-turned newel post and substantial handrail are of 1707, but all of the balusters have been replaced, *c*. 1880, with turned balusters of a very different profile to those originally fitted. While it is not at all unusual to find one or two replacements, this wholesale refitting is not common. (Courtesy of English Heritage)

Peter Nicholson wrote at length concerning what was called the 'geometrical' stair in which the intervening newel post was dispensed with and the handrail swept upwards, curving round to take the stair to the next floor. Often very severe with plain stick balusters and mahogany handrail, the decoration really lay in the quality of the workmanship.

There were few of the large grand houses in London such as those *hôtel particuliers* lived in by French aristocrats in Paris. Thus the sweeping staircases of 44 Berkeley Square of 1745 by William Kent, or Robert Adam's Home House, Portman Square, 1775, are somewhat of an exception. Larger houses were built in the nineteenth century with Imperial staircases, and large stone cantilevered stairs with cast-iron balusters that one can still see in many South Kensington houses.

4.10 No. 173 Hoxton Street, Shoreditch. A view of the stairwell of a mid-eighteenth-century terrace house just outside the City of London. In the early eighteenth century Hoxton was an area of fruit, vegetable and flower gardens supplying the city. However, as the century progressed so the fields were built over. No. 173 Hoxton Street was built *c*.1750–1760, a two-bay-wide three-storey house with a smart cut-string staircase and a first-floor front room with a plaster modillion cornice; a small garden lay between the house and the street. By the middle of the next century the whole area had declined, with considerably overcrowded housing; the gardens were built over to provide shops and the house subdivided. In this photograph taken in the 1970s a cast-iron spiral staircase has been inserted from the ground-floor shop – at this date a dry cleaners – up to the first floor where it is fixed to the original cut-string staircase with its silhouette tread-ends and turned balusters. Such architectural oddities are, or were, quite common in London, with the need to adapt houses to changing conditions. (Courtesy of English Heritage)

Materials

As elsewhere in the country, the earliest staircases in London were constructed of oak; Figure 4.4 of Lauderdale House shows what must have been a not uncommon late sixteenth-century stair. However, such was the city's expansion that there was insufficient oak and it was replaced by softwood imported from the Baltic, a change that was certainly underway by the mid-seventeenth century. Baltic timber was slow-growing due to the climate, but was easy to carve and turn, as it was quite soft. The slow growth meant the growth rings were close together and so any carved work was sharp and clean. The remains survive of a fine mid-seventeenth-century staircase from a house in Garret Lane, Wandsworth, South London, and it must have been made from some very large old trees, so substantial are the turnings and nailed-on mouldings (Figure 4.11). The trees would have been cut in winter when the sap was low and it was easy to slide them out over the snow or down the frozen rivers. The timber was loaded onto ships in ports all around the Baltic and brought down to the Thames around Wapping for unloading. Such softwood remained the building staple until the twentieth century, when there was a change in building styles and competition from North American wood.[4]

4.11 No. 14 Garrett Lane, Wandsworth, southwest London, *c*.1650–1660. Built in the mid-seventeenth century when the large house was surrounded by farmland, it was demolished in the early twentieth century. Whereas the picture of Lauderdale House (Figure 4.4) shows the design of the stair executed in paint, here the balusters, newel and handrail are replicated in softwood, a much more expensive option, especially as the turnings were made from substantial three-inch squares of Baltic softwood and the rest of the staircase made from similarly large scantlings. (Courtesy of English Heritage)

Oak was also imported from Northern Europe, mainly from Germany via Holland, where it was cut into planks. It was a much more expensive material than softwood and therefore used less commonly in London.

Next up the social scale was mahogany, imported from the Caribbean and Central and South America. The staircase in Marble Hill House, Twickenham, is quite possibly one of the first staircases made completely from mahogany (Figure 4.12). It is a beautiful wood capable of being crisply carved and taking a deep polish, but it was too expensive to be so used. The common use for mahogany was for handrails, especially in conjunction with wrought-iron balusters so popular in the last half of the eighteenth century. The use of mahogany became much more profligate in the nineteenth century, but the effect was also very rich.

4.12 Marble Hill House, Twickenham, West London. A mahogany closed-string staircase, *c*. 1730. This is a very old-fashioned design and reflects the taste of at least the 1670s and probably earlier, but it is made of the newly fashionable West Indian mahogany. Even the flooring of the *piano nobile* is all constructed of this expensive timber. (Courtesy of English Heritage)

Not only was London a centre of fashion, it was also a magnet to skilled craftsmen, among whom were specialist blacksmiths. One of the earliest staircases embellished with wrought-iron is in the Queens House, Greenwich, designed in 1616 by Inigo Jones (1573–1652). The Tulip Staircase is a magnificent stone spiral staircase with flat wrought-iron balusters decorated with tulip shapes. However, it was not really until the 1760s that interior stone staircases were fitted into London houses. Robert Adam (1728–1792) and his brother James, along with Sir William Chambers (1723–1796) and others made cantilevered stone staircases a very fashionable accessory. Stone treads required the use of wrought-iron balusters, and the ability to bend and flatten the iron into any shape made the material an ideal one for architectural design. There was also a use for wrought iron in the geometrical stairs as they were usually fitted with thin one-inch square section softwood balusters that gave little strength to the structure; thus every six treads or so an iron baluster was added. Kenwood House, Hampstead, has a fine example of such a stair where it is hard to tell which upright is iron and which wood as they have been painted to resemble bronze.

Cast iron came into use on London houses for both stone and wooden staircases in the nineteenth century. It was a product related to the manufacture of iron railings that were once so common all over London.

Bronze and lead were two unusual metals used to decorate iron balustrades. One of the very best examples of this may be seen in the imperial staircase of Home

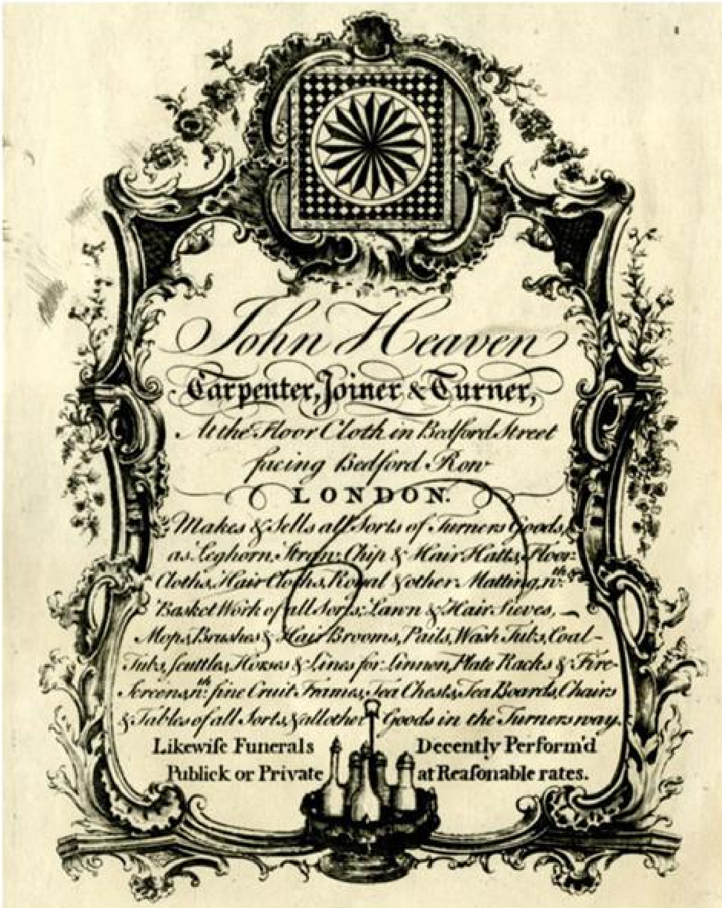
House, Portman Square. The wrought-iron newel post and balusters have fine gilt bronze ornaments attached, such as rams' heads, urns and stylised honeysuckle flowers. However, on ascending several treads of the first flight the expensive bronze changes to cast lead, a somewhat cheaper material. The use of lead for applied decoration was quite innovative. The fire welding of thin iron strips is highly skilled; to join two strips and encase them in a cast lead ornament was a much easier solution (Figure 4.13).

4.13 Cast lead decoration on a short section of staircase, *c*. 1780–1790. The ‘balusters’ are made up of two vertical wrought iron strips with an elongated X fire-welded to hold them together. Metal moulds, very similar to contemporary ice cream moulds, were placed around the iron strips and molten lead poured into the mould. (Courtesy of English Heritage)

Decorative Elements

Any of the decorative elements found in London will be found elsewhere; it is just that the quantity and variety in the city is greater. The money, taste and wish to show off, allied with highly skilled craftsmen were all more common than in the provinces.

As noted above, the staircase of the first half of the eighteenth century was very architectural in form, in fact very similar to much furniture of the period. For example, the newel posts were often shaped like fluted Corinthian columns similar to the pilasters on a building’s facade or on a grand walnut bureau-bookcase. The fielded panelling of the dado running up the wall parallel to the staircase balustrade reflected the same influence.



4.14 Trade card of John Heaven, Carpenter, Joiner & Turner, *c*.1760. Although staircases are not specifically mentioned, the card gives an excellent idea of the wide range of goods made by eighteenth-century woodworkers. (Courtesy of the British Museum)

Tread-ends, or stair brackets, were a splendid excuse for floral carved enrichment, much of it of fine quality, but even in London it could be extraordinarily crude in execution. Where it is sometimes possible to find similarly turned balusters in provincial towns simply because there were not many turners proficient enough, in London due to the sheer quantity of expert turners and carvers it is almost impossible to find two balusters that match in neighbouring houses, let alone anywhere else; without documentation it is impossible to determine particular craftsmen. Due to the complex nature of the way early eighteenth-century speculative building developed, such documentation is rare. In the nineteenth century, with the arrival of the large-scale contractors like Thomas Cubitt (1788–1855), and his industrial scale of building, the individual craftsman virtually disappears and only the name of the supplier may survive.

A final point concerning London staircase decoration where it probably differs from provincial examples is that in London virtually all staircases were painted, especially if they were made from softwood; it did not matter how fine the work was, it was painted, usually an off-white or stone colour. Even oak was sometimes stained, though not mahogany or walnut. Sadly, many staircases have had their splendour covered by too many layers of thick paint, obscuring the detail or covering the fine polished hardwood. Furthermore, the treads were always covered with some sort of floor covering; to understand this one only has to look at the state of the treads of any really old staircase and also note if there are stair-rod holders set into the angle of tread and riser, and also consider the width of the rods: the wider they are the more modern they are likely to be as early carpets were usually 21–23 inches in width.

Notes

1 J.W.P. Campbell ‘Price, Francis (bap.1704?, d.1753)’, *Oxford Dictionary of Biography*, Oxford University Press, 2004; online edn.

2 Gerald Beasley, ‘Pain, William (fl.1743 – 1794)’, *Oxford Dictionary of Biography*. Oxford University Press, 2004; online edn.

3 Dan Cruickshank and Neil Burton, *Life in the Georgian City*, Viking, London, 1990, pp220–235. To put this in context, an average skilled joiner of the mid-eighteenth century would have been paid no more than £10-0-0 per year, possibly less.

4 Until the American War of Independence the great majority of North American timber was reserved for Royal Navy use.

5

Survey and Analysis

Michael Heaton and Caroline Hardie

Introduction

Successful conservation of all historic structures requires understanding of their historical development, their structural and material characteristics and their significance.[1] A well-designed programme of recording and analysis is critical to this process, but there are particular challenges when dealing with stairs. As the architectural centrepiece, circulation node and one of the most heavily stressed elements of a building, stairs are subject to perennial modification, failure and refurbishment that creates a 3D ‘jack straw’ puzzle of differing ages, structural competence and significance. It is not always possible to unpick this 3D puzzle without invasive recording techniques, but more basic levels of recording can still throw light on the evolution of the stair and the parent building and can record changes in social dynamics and circulation patterns within the house. Archaeological recording is also an opportunity to record the staircase at a moment in time before further works are carried out and is therefore integral to the UK planning process. This planning process requires that the level of recording chosen should be proportionate to the significance of the stair and so it is important that the most suitable level of recording and analysis is chosen and that it is carried out by appropriately qualified personnel.

The proposition of this chapter is that historical stairs are often not quite as they seem and that detailed inspection and analysis along archaeological principles can often reveal a stair's history of construction, use and modification. This can help to ensure that decisions made about their future are based on an understanding of their significance and that this in turn can result in informed conservation. While several examples are referred to, the techniques and their potential are exemplified by the main stairs at
Whitestaunton Manor in Somerset, which is used as a 'worked example'. This is an architectural palimpsest of over 500 years of timber and masonry evolution, but the principles apply equally well to more recent stairs and to those of stone, metal or concrete construction.

The challenges of archaeological recording

The cultural status of staircases and their fundamental role in the circulation patterns of large buildings distinguishes them from most other building elements in two respects: first, they are prone to wholesale relocation and replication,[2] particularly during the early twentieth century, a good example being Barrington Court in Somerset, where the whole main staircase was imported from Scotland *c*.1913; second, the structural and functional development of the stair is inextricably tied to the development of the rest of the building, including non-adjoining areas, and so it is important that the analysis of the stair includes a wider understanding of the evolution of the parent building. Figure 5.1 shows the abnormal position and layout of the main stairs at Newton Surmaville in Somerset, which perplexed architectural historians for 50 years until its relationship to extensions of 1875 and 1907 was demonstrated.[3]

5.1 Newton House, Somerset. (Michael Heaton)

Further, because of the invariably enclosed situation of a staircase, 'indirect' or wholly instrument-based surveys often used in archaeological recording are likely to prove difficult and uneconomically time-consuming. Their shape and form also make the most popular building recording techniques such as rectified photography

unsuitable for all but the smallest details. All electronic, instrument-based measurements of a complex 3D structure such as a staircase will need to be augmented by close visual inspection of the structure and hand-measurement of details and arrangements not accessible to the instruments. This is primarily because such instruments, be they Total Station Theodolites (TSTs), scanning lasers or even the humble dumpy level, have to be mounted on secure immovable surfaces, which are virtually non-existent on timber staircases – the most common form of this structure. Even for stable masonry stairs, they have to be moved between intervisible 'back-sighted' stations because none can 'see' through the stair structure or around the corners of landings. This requires, additionally, that the end of a handrail, for instance, measured from one station be re-measured from the subsequent station, so that the 'drawing' can be extended: this is easily done at close quarters with a hand tape, but not so easy from several metres away with a laser of finite tolerance, especially when the surface being measured is irregular or curved. This
inherent imprecision requires a great deal of editing and adjustment during the creation of the finished drawings, especially if these are based on, or presented as, 3D CAD models. The methods of recording and surveying used will therefore often involve a mixture of techniques based on perceived significance, financial resources, potential threats to the stair's significance and the form of the staircase itself.

Archaeological features and dating techniques

Archaeological recording can help to interpret and record the evidence of change and residuality in the layout, structure and fabric of a building or element. The more obvious and superficial examples of features which might be recorded are modified openings and extensions. Less obvious, and invariably more significant, are wholesale historical rebuilds, salvaged materials or the replication of historical fixtures and fittings. The materials of associated structures (see below) can often be more instructive. Stairs are often supported by, or associated with, ancillary structures and details such as walls, door and window openings, floor structures or wall and ceiling finishes, may not have been intended to be seen, but may become apparent during invasive works and will be recorded. Such modifications are rarely identified in the 'list' descriptions and architectural histories, but affect the archaeological potential and historical significance of the stair and its associated building and, therefore, the degree of care appropriate to it.

Archaeological recording can also provide an opportunity to scientifically date a staircase. However, there are broad assumptions that might be made without recourse to such dating techniques. Building materials, and particularly their method of manufacture, can be chronologically specific and some, such as structural timbers, can be dated scientifically. This is a broad and complex subject, beyond the scope of this chapter, and is merely summarised here. Readers are referred to more authoritative and expansive analyses of the history of buildings materials.[4] In all cases the date of invention – as, for instance, in the case of Portland cement or steel

wire nails – is less important than their date of adoption in the locality of the building. Timber, as the most common constituent of historic stairs, exemplifies this. As a general rule – and away from London and major historical trading posts such as Poole, Liverpool or Hull – we would not expect softwoods to have been employed structurally before the nineteenth century and even elm not before the seventeenth century. Similarly, mechanical sawing would not generally have been employed until the later
nineteenth century. We would expect Medieval and early post-Medieval structures to be made of solid members, rather than of box-work composites. Nor would we expect, for instance, machine-made bricks to have been employed until the mid-nineteenth century and Fletton type bricks until the early twentieth century; cements and concretes, Portland or otherwise, to have been widely employed until the twentieth century, or ash-rich lime mortars much before the eighteenth century; Portland stone or Bath stone would not have been used as architectural details in associated structures distant from those sources until the eighteenth or nineteenth centuries, respectively.

Methods of connection are equally instructive. Mechanical fixings, such as bolts or nails, are rarely employed (in Britain) before the seventeenth or eighteenth century, while the type of nail or bolt can usually be dated more precisely.[5] Steel would not have been employed in those fixings until the twentieth century. Carpentry jointing, particularly, can also be chronologically specific.[6]

Modification, repair or refurbishment will result in changes in the fabric and layout. The latter will usually be self evident, such as an added flight in a slightly different style, but the former will often have been obscured by skilful joinery or paint, requiring careful comparison of timber types, conversion methods or wear marks. Structures built in one operation usually display homogeneity of material, craftsmanship and wear, and variations in either of those will indicate modification, whether the structure is of timber, masonry or concrete. Figure 5.2 demonstrates the insertion of a cantilevered staircase into the basement of an early nineteenth-century London terrace: the supporting wall is of hand-made stock bricks in an ash-rich lime mortar, but the treads are held in place by Fletton bricks in an OPC (Portland cement) mortar that have been cut to differing thicknesses to accommodate the different dimensions and rhythm of the new stair: it is, therefore, a replacement of the original stair.

5.2 Evidence of cantilevered stair. (Michael Heaton)

There is an increasingly broad range of off-site scientific analyses applicable to archaeology, building surveying and conservation, but four are of particular value to the analysis of staircases, albeit with important caveats: dendrochronology, carbon dating, timber species identification and stone source identification. A fifth technique – thermo-remnant magnetism – is used to date *in-situ* fired-clay structures such as hearths, kilns or fire-damaged brickwork, but is unlikely to be applicable to staircases. In these cases, their use is more likely to be applied where invasive works are proposed, although dendrochronologists are increasingly adept at securing a sample core without visual detriment to the structure being dated.

Dendrochronology is better known as ‘tree ring dating’. To all intents and purposes it works only on oak timbers large enough to retain sapwood that have been grown slowly enough for annual variations in weather to affect their growth rate, in areas where sufficient dating has been done to establish chronological ‘signatures’. Importantly, it dates the felling of the tree, not the building of the structure, which, in the case of salvaged timbers, can be decades or even centuries after felling. Effective use requires the identification of sufficient suitable and accessible primary timbers – i.e. timbers felled for the structure in question and not salvaged from elsewhere – to provide a representative sample of the structure, and that can usually be done only by the dendrochronologist and after some analysis of the structure. Most of the results for Britain and Ireland are published annually by the Vernacular Architecture Group[7] together with contact details of the contractors. A contractor would normally spend a day taking samples, and a draft report can be available within a few days, depending on their workload.

Carbon-14 dating is less applicable to buildings because of poor resolution, although the technique is being refined. This poor resolution can make the date given for a post-Medieval timber meaningless, and for that reason it is rarely used in building analysis. However, recent work on charcoal inclusions within mortar[8] have proved more promising as a method
of dating masonry and it is likely that, in the future, the technique might be used more widely.

Timber species and stone source identifications can date a structure in the broadest of terms, but are primarily used by archaeologists to understand the wider historical context of the sourcing and construction of a building. Neither material is inherently datable, but some imported species of softwood – such as pitch pine – were more common after a certain date and some sources of building stone ceased/began being worked after a certain date, so specialists familiar with the material can suggests a broad date range for the materials used at a given site. Identification is more useful when applied to understanding how a structure has been assembled and modified: a staircase built in a single operation will generally have a structural frame of one timber species or stone type and, perhaps, decorative detail in another. Broad identifications can, of course, be made by a competent surveyor on-site, but identification of softwoods to species and of stone to source quarry requires sample preparation and optical magnification. Most environmental archaeologists[9] can provide a timber sample identification service and most university geology departments have at least one research specialist willing to source stone samples on a commercial basis.

Levels of Survey

Surveying historic buildings can become an expensive end in itself. It is therefore very important that the purpose of such surveys and, more importantly, the nature and scale of works likely to be informed by them are identified before instructions are given. The 'Brief' is fundamental and would normally be prepared by a conservation officer or archaeologist after an initial site appraisal.[10] The brief would be designed to help inform the future management and present understanding of the significance of the structure and its parent building. The principle of proportionality is explicit in the UK planning guidance and the level and extent of survey will also relate to whether the work is part of a conservation management plan where no invasive works are proposed to the stair, or whether it is designed to inform major works to a designated historic building. The analysis of the building should be carried out by an experienced historic buildings specialist or buildings archaeologist, and any subsequent surveys by experienced archaeological buildings surveyors who have developed methodologies which combine the need to include features often excluded by architectural surveyors as irrelevant and which deal with the lack of straight edges and lines in historic buildings, with the need to deliver surveys rapidly and economically as part of the planning process. A staged approach is likely to be necessary, starting with mainly desk-based assessment, evaluation and mitigation as set out in the National Planning Policy Framework.[11] English Heritage have also adopted the former RCHME four ‘levels’ of inspection and survey, reflecting the significance of the structure and the resources it warrants.[12] These ‘levels 1–4’ should be used with caution because they relate to the perceived significance of the building or structure, not the questions asked of it. It is therefore important to try to determine the significance of the stair and gaps in our knowledge before prescribing the level of survey and analysis. This is, of course, fraught with difficulty because much of the evidence which will help to throw light on the significance of the stair may only be accessible through invasive techniques.

The desk-based assessment and statement of significance

The starting point for most recording and analysis is a desk-based assessment or Statement of Significance which will inform future management (including the need for further survey) tailored to the needs and potential significance of the staircase. More specifically, it should explain the nature, extent and level of significance[13] of the stair and its associated structures; it is unlikely that the significance of the staircase can be understood without an assessment of the wider building. Importantly, the structure does not have to be designated in order to justify such a Statement; this is a process that can be used on the most modest Victorian terrace or the grandest country house, although the latter is more likely to have a broad range of archival material requiring examination. The first phase in such a Statement, or indeed in any form of archaeological recording, is an analysis of accessible source material and a rapid visual inspection of the structure and its context by a knowledgeable person. Few historic buildings are accompanied by comprehensive sets of primary historical documents,[14] and those that do survive are frequently disparate and difficult to interpret.

Where should one start? Historical sources can be divided into three types: tertiary, secondary and primary. Tertiary sources are popular publications such as village histories and guide books, often published privately by amateur local historians, increasingly on the internet and available from bookshops and libraries close to the site.

They are not wholly reliable as a source of facts, but they will give a good idea of the chronological framework of a building's history and the people associated with it. They often include historic photographs which can provide valuable information relating to the form of the building or its interiors in the nineteenth and early twentieth centuries. Equally importantly, they will usually cite the 'secondary' sources they have used. For this reason it is useful to start with tertiary sources in order to obtain an overview of the building and to target more detailed research from other sources.

Secondary sources are authoritative historical analyses published by recognised historians and organisations. They are held by the main reference libraries and county records offices, some university libraries and the National Monuments Record Centre at Swindon, while academics can access many through internet 'portals' such as JSTOR.[15]

Primary sources are the original documents on which all subsequent analysis is based, be they Medieval charters, seventeenth-century household accounts, fire insurance maps, property deeds or estate maps. They are immensely variable in quality, completeness and scope and many will be illegible or unintelligible to the inexperienced eye. Depending on the status of the building, the principal repositories are likely to be: the local county records office and/or museum, the RIBA collections, the National Monuments Record Centre and the Public Records Office in London, the catalogues for which are now available online. The older universities also hold archives pertaining to their current and former estates, particularly Oxford and Cambridge colleges and, of course, many of the larger country houses and civic buildings maintain their own archives – Longleat and Christchurch Priory (Dorset) being good examples. Other resources are increasingly available online, such as the British Newspaper Archive, and here local notices of works and lettings can be found which provide descriptions of interior layouts and significant periods of alteration or decoration of country houses.

Visual inspection

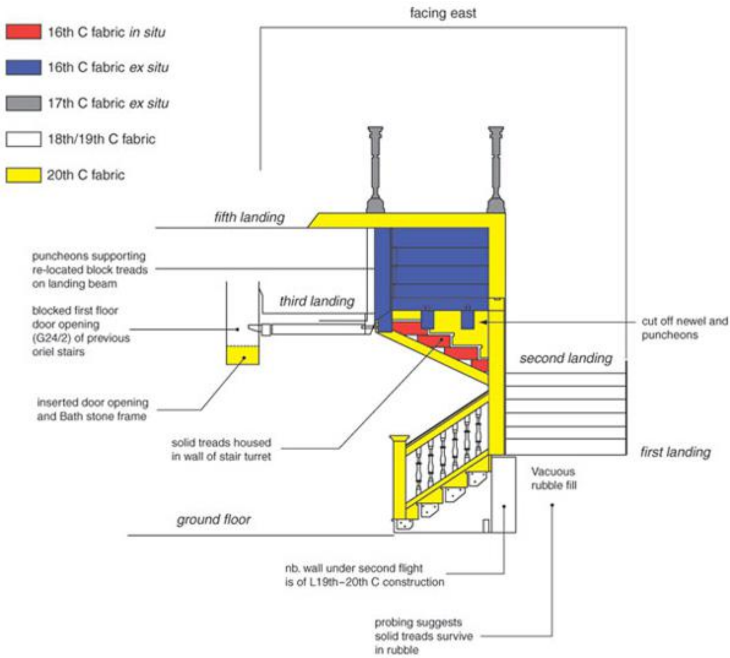
The preliminary visual inspection associated with the Statement of Significance should include a basic photographic record with a scale, sufficient to illustrate the significance of the stair and to justify the report's recommendations. This might include an overall view of its form, details of decorative elements and stair lights. There may be no further requirement for survey work and so any photographs taken could be the only contemporary record of the stair. The author of the brief will need to consider whether these images should be of archival quality and fully catalogued, or whether digital images within the content of the report will suffice.

The resulting Statement of Significance should be presented as an
illustrated report set out along the lines recommended by the Heritage Lottery Fund,[16] starting with a section on 'Understanding the Asset' which explains the evolution of the structure as evidenced from the desk-based research and the preliminary visual inspection. A subsequent section covering gaps in our knowledge will help to justify any further work as mitigation or the need

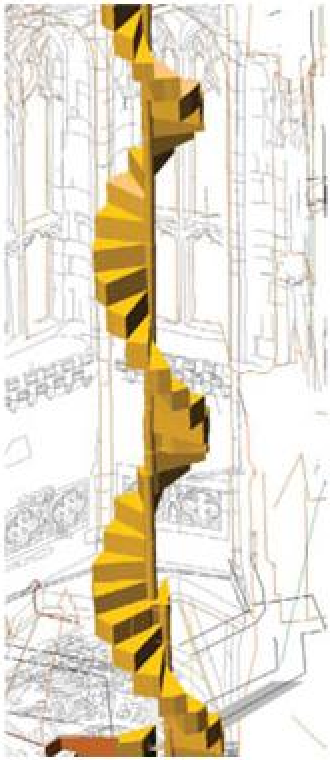
for more information obtained through an evaluation before management decisions are made. Where there is sufficient information, the report should then discuss the stair's significance by exploring its architectural, archaeological, historic or artistic interest in relation to its associated structure. The impact of any future proposed works to the stair is likely to be measured against these interests.

Archaeological evaluation

'Evaluation' is more intrusive and, for that reason, should be undertaken only where there is insufficient information to make judgements regarding the future management of the stair based on desk-based research and visual inspection alone. Evaluation will invariably involve partial dismantling and opening-up for the purposes of fabric examination and for that reason, in the case of listed buildings, will require Listed Building Consent. An example might be where substantial structural modifications or wholesale re-location or demolition are proposed; the desk-based research and visual inspection might have suggested that the stairs were structurally refurbished in the early twentieth century, but was the work indicated by the archive sources actually completed as specified? Evaluation is similar to an excavation and so will require an accurate method for presenting the results, which will include a survey, although this must be limited to gaining an understanding of the significance of the stair. The degree of resolution of any survey – i.e. the accuracy and scale – is determined by the purpose of the survey and the dimensions of the individual components: it may be necessary to distinguish individual fillets and mouldings, so an appropriate scale for a staircase might be 1:20 or possibly a combination of 1:20 and 1:50. A metric survey will show plans at landing and/or floor levels, elevations and representative cross-sections to help explain significance. Figure 5.3 is an extract from a very detailed 1:20 survey of the stairs at Whitestaunton Manor, colour-coded to illustrate chronologically indicative qualitative variations in the materials. Data capture in three dimensions – even if only the principal structural elements – for analysis and presentation in a 3D CAD package, though time-consuming and expensive, can be essential in the analysis of complex 3D structures, and might prove invaluable to the presentation and justification of modification proposals (see Figure 5.4). It is also at this stage that scientific dating techniques such as dendrochronology might be used in order to provide an absolute chronology rather than a relative one. However, it should be borne in mind that the evaluation is simply a form of testing the archaeological significance of the stair and that more detailed survey work can come at a later stage once a programme of mitigation is designed to complement any future works. The results of an evaluation will be used to update any earlier Statement of Significance and will be illustrated by detailed annotated line drawings and photographs.



5.3 Elevational analysis of the stair fabric. (Michael Heaton)



5.4 A 3D Solid CAD model of the spiral stair at Greyfriars Tower, Kings Lynn, Norfolk. The model was built up from wireframe measured by reflectorless TST using real-time CAD site capture. Infill to the wire-frame was from notes logged in table form with additional sketches of variation in detail by tread number. (Drawing by Bill Blake, Heritage Documentation)

Survey as mitigation

'Mitigation' is a response to modification proposals, rather than an informant of them, and is analogous to the archaeological excavations that property developers are required to fund as conditions of planning permission. In the case of a staircase or other building element, especially in a listed building or structure falling within the remit of the National Planning Policy Framework, the local authority or English Heritage is likely to require a detailed record to be created before and during modification works. Such ‘building recording’ would employ the same techniques as an evaluation survey and would result in a formal report, but would be aimed primarily at an academic audience. The detail and consequently the resources required will vary depending on the level of significance of the stair and the impact of any proposed changes on that significance. If the mitigation is a result of a planning application or listed building consent, it will need to be specified, normally by the local authority conservation officer or the archaeologist. The specification should clearly state what the research objectives are of the recording exercise.

Measured Surveys

The panoply of survey techniques available to record the staircase is explained in, among others, English Heritage’s *Measured and Drawn* (2009) – a freely available download. It ranges from hand measurement with tape measures, through photogrammetry to ‘point cloud’ laser scanning. Because of the invariably enclosed situation of a staircase, ‘indirect’ or wholly instrument-based surveys (see below) are likely to prove difficult and uneconomically time-consuming. In reality, the survey of most staircases is likely to be a combination of methods, and guidance on the procurement of surveys and analysis of historic buildings is given in *Measured and Drawn*, along with links to specifications that can be purchased or downloaded for adapting and reuse.[17]

The basic survey record

Detailed hand drawings, annotated by manual measuring, is the most common method for recording staircases. However, it is unlikely to be suitable for the most complex staircases undergoing refurbishment because the drawings quickly become cluttered and illegible. To avoid this,
archaeologists have developed recording systems based on pro forma record sheets on which observations are recorded, together with cross-references to drawings and photographs. Each recorded element is assigned a unique reference code and its position indicated on small-scale (e.g. 1:50) layout drawings such as floor plans or elevations. This restricts annotation of those drawings to no more than a few numbers. The author uses an alphanumeric code referring to floor, room and detail: e.g. 0B/3 is a detail in Room ‘B’ on the lowest floor, while 0B/3/2 is a component of it. This makes it relatively easy to discern the structural and spatial relationships of recorded details in the reference codes, especially in large buildings where several hundred details might be recorded. The record sheets are used to record written observations of those characteristics that cannot be drawn or photographed satisfactorily such as: stone type or timber species; tool marks, especially saw or chisel types; finishes, such as render and paint schemes; wear marks and their likely cause; structural

relationships and evidence of residuality and modification. Complementary records such as detailed large-scale drawings and photographs are assigned separate references, which are recorded on the pro forma sheets. This might seem onerous, but it is actually no more time-consuming than annotating a drawing, and the results will be far easier to analyse and curate, while a demonstrably systematic recording method will carry more weight at a planning appeal, should that be necessary.

In most cases, measurement using hand-held tapes or ‘disto’ type hand-held electronic distance meters (EDMs), fitted into a ‘control’ framework measured using an instrument, is likely to prove the most cost-effective. Distos can capture more difficult measurements with ease, such as floor-to-floor heights, landing levels and half-landing levels and can capture cross-bracing dimensions of stairwells where a vertical line would otherwise be out of reach by standard tape methods. If detailed positional and dimensional information on, for instance, balusters is not required, these details could be ‘captured’ instead by rectified photography and pasted onto elevational drawings prepared in CAD or manually. How the measurement is done is determined, finally, by the presentation method: drawings prepared in 3D CAD will require fewer measurements than the same plans, elevations and sections presented traditionally; but more discipline, accuracy and time in their preparation. In either case, measurement should be accompanied by copious ‘narrative’ photography for use as a double-check in the drawing office.

A hand-drawn survey of a staircase would present each elevation, plan and cross-section as a separate drawing, possibly on the same drawing
sheet, but nonetheless as separate graphical entities. Measurement for each of those drawings should proceed in the following order and should, ideally, be transcribed on-site onto a scaled draft (the author uses gridded polyester drawing sheets for this purpose):

1. Control measurements of the structural space occupied by the stair – i.e. the walls, floors and ceilings – taking as many diagonals as possible, transcription of which, on-site, will require use of a compass. At least one vertical and horizontal plane (wall face or floor/landing) should be checked against a plumb line or a spirit level, preferably the first of these measured. These measurements, especially the diagonals, are best taken with a 'disto' type hand-held EDM or with a fixed instrument such as a TST (see below). This fixes the outer limits of the stair structure. Distos are now available which capture 3D points in space from a central axis similar to a TST, thus producing a high level of accuracy in digital form with relatively low levels of cost.
2. The outer edges of the principal structural elements relative to the control frame. This is likely to be the string(s), the newels and the handrails. Deflection of, for instance, strings and hand rails between their end points, should be checked by one of two methods: a string line (as in bricklaying) stretched taut between two fixed points and the deflections along it measured in the 'X' and 'Y' axes using

two hand-tapes; or the same deflection measurements taken relative to a horizontal datum using a plumb line, usually to the floor. If the construction of the stair is to be fully understood, some dismantling or opening-up will be necessary. This fixes the principal structural elements relative to the control frame.

3. The outer edges of the treads and risers relative to the string. Do not assume that these are of a common dimension or level and plumb. For the purposes of flat, hand-drawn sections, a nominal 'cutting plane' will have to be chosen, along which all measurements are taken. The easiest is the face of the string/wall itself, but the more informative is the centre-line of the flight.
4. The balustrading relative to the string and handrails. This is undoubtedly the most tedious and the task that lends itself readily to photographic techniques such as rectified photography or photogrammetry that also avoid the danger of assumptions – that the balusters are all the same: in a historic staircase they undoubtedly will not be the same. Essential equipment: a camera, 30 m tape, hand tape, bricklayer's
spirit level, plumb line, string line; A3 drawing sheets and lightweight drawing board, hard pencils and an eraser.

More complex instrument-based techniques

Where more detailed survey is required, normally because invasive works are proposed to the staircase, there are three main survey types which can be used:

reflectorless TST, photogrammetry and rectified photography/orthophotography. Increasingly, laser scanning is also being used as it offers a relatively quick recording process with equipment which is now sufficiently mobile to be used in confined spaces. As with all instrument-based techniques, it is important that the person commissioning the work has the necessary means to view the results. If the output is simply a paper-based report, that will not be a problem, but with an output which is 3D, appropriate hardware and software will be required to view and manipulate the survey data. All techniques are described in detail in *Measured and Drawn*[18] and are merely summarised here.

A TST is a computerised theodolite that uses a laser beam fired at a portable prismatic mirror to measure or calculate distances and can store measured co-ordinate data for transfer to graphics software. A 'reflectorless' TST dispenses with the prismatic mirror, relying instead on reflection of the laser by the object surface. Either is particularly useful for measurement of remote objects and 3D spaces, especially when combined with software such as TheoLt™, which that provides a 'real-time' interface with graphics software such as AutoCAD™. When used in this manner, the TST becomes the mouse/cursor and the drawing is generated on-site with the object in front of the surveyor and, as such, is a form of 'direct plotting' that allows errors and assumptions to be checked as they are made. This form of digital recording requires a reasonable level of specialist knowledge to operate and the costs are higher than more basic techniques. It is particularly useful for establishing 3D control frameworks around or within complex 3D structures. It would normally be used to create 3D models, from which 2D drawings could be extracted, if necessary, but it is not suitable for the measurement of intricate decorative detail.

Photogrammetry and rectified photography or orthophotography, on the other hand, are suitable for the measurement and recording of intricate decorative detail. Both can be done using ordinary hand-held cameras, but professional reliability requires they be done by specialist contractors using specialist cameras designed to eliminate distortion at the edges of the image. The former involves the tracing of detail from a scaled photograph

to create a line drawing; the latter is simply the creation of a dimensionally accurate scaled photograph. Both can be imported into drawings, especially if generated in CAD, as a quick way of representing fine detail, such as baluster profiles, in 2D.

Laser scanning is the fastest way of collecting large amounts of very detailed 3D data which can then be used to display the results in a 3D format. There are many types of terrestrial laser scanners and each type records hundreds of thousands of 3D points from a known position of orientation, with the result being a data set known as a 'point cloud'. These data sets are merged together to form a 3D image which can be selectively sliced and manipulated in AutoCAD packages to provide highly detailed orthogonal views both in plan and sectional elevation form, which can then be digitised (see Figure 5.5).[19] However, with staircases there are limitations. The laser cannot see around corners or

through objects, so the scanning equipment will need to be moved and set up frequently, so the advantages of speed are diminished. Further, some laser scanning equipment can have trouble with reflective materials such as marble or gilded surfaces[20] It is, however, invaluable where 3D results are required for display or where detailed monitoring of condition is required over time. It will not necessarily improve the understanding of the staircase; that still requires a specialist archaeologist or buildings historian who will also need to ensure that the right data are being captured. This method of data capture is a highly specialised form of data recording with a very high initial outlay of cost and associated training required. However, the resulting point cloud data sets are becoming ever more usable in common drawing interface packages, and confidence in the integrity and accuracy of the data set
would be exceptionally high. English Heritage maintains a list of specialist contractors who carry out laser scanning and have also published guidance on this technique.[21]

5.5 3D point cloud data set taken with a terrestrial laser scanner. (Image courtesy of Greenhatch Group)

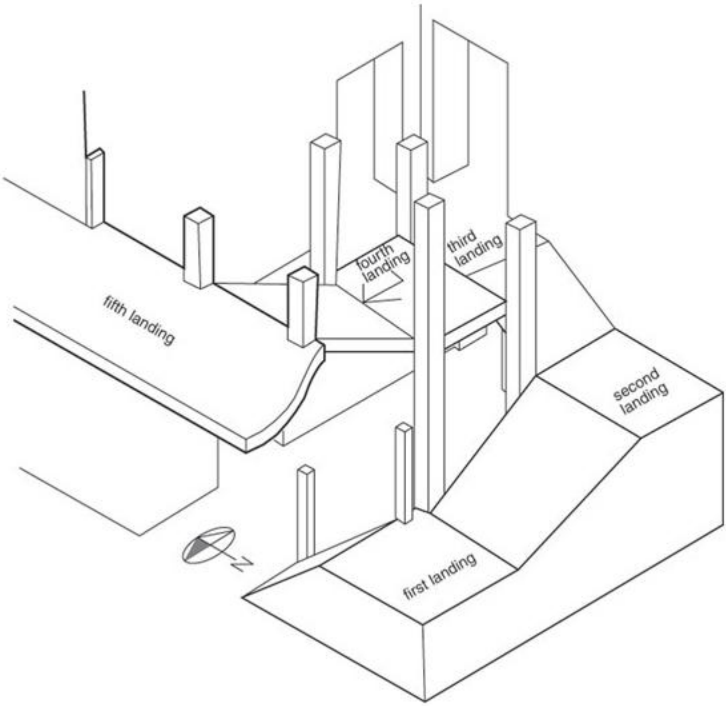
The resulting survey may enter into the public domain if it is part of a planning application or a listed building consent. However, some conservation management plans may remain in private ownership. Whatever the motivation is for the survey and recording of the staircase, the resulting report and supporting documentation should be lodged with the local authority Historic Environment Record or the records office, and an entry logged with OASIS, a digital archive of grey literature reports hosted by the Archaeology Data Service.[22] If English Heritage has been involved, they may also require the archive to be lodged with the National Monuments Record in Swindon. This ensures the work can continue to inform the future understanding and management of the staircase and its associated structures long past the initial survey date.

Conclusion

It is clear that there is a wide range of recording techniques available from simple photography and sketch plans to highly accurate laser scanning. The choice will be based on available budgets, the accuracy required and the access constraints. Whether the survey is carried out by a professional surveyor or an interested enthusiast, there is no substitute for adequate thinking time and research to help inform the level and objective of the survey and the resulting management decisions which will arise.

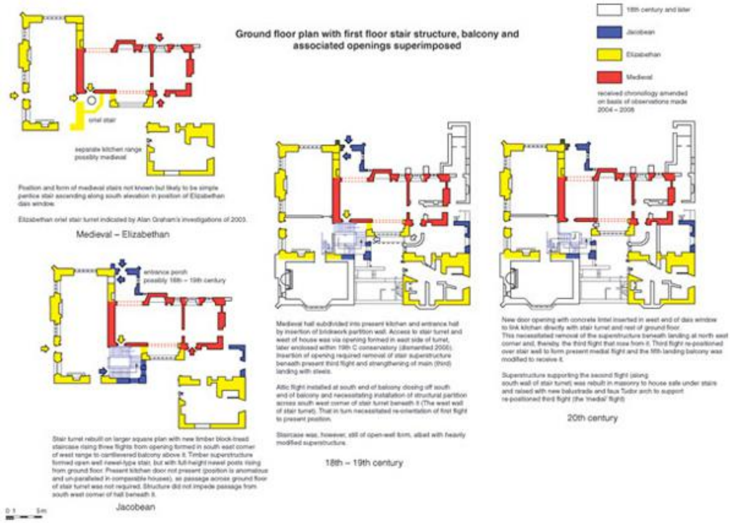
Case Study: Whitestaunton Manor

Whitestaunton Manor house is an architectural and archaeological palimpsest of fifteenth to early twentieth century construction that contains, *inter alia*, one of the finest decorated Medieval roofs in Somerset, dated by dendrochronology to 1446–1478. It is a Grade I listed building. However, its chronological development is not clear, not least because the interiors were homogenised during extensive restorations in the late nineteenth and early twentieth centuries. Ongoing archaeological investigation commissioned by the owners has indicated that many of the structural relationships contradict received histories and that much of the decorative detail is of an early twentieth-century date. The extensive and comprehensive nature of the refurbishment works at Whitestaunton and the owners' retention of an archaeologist throughout its seven years has facilitated a level of observation and recording not available to most surveys. Nonetheless, the results are relevant here because they demonstrate the nature of evidence and the circumstances of its discovery. Despite being described as a 'good C17 stair' by the list description, the staircase is atypical for a house of this age and status in having a fourth landing and upper flight supported over the stair well, blocking off all natural light to the ground floor of the stair hall (see Figure 5.6). The owners wished to re-locate those details to re-create an open well staircase.



5.6 Structural layout. (Michael Heaton)

The stair occupies a masonry turret formed in the angle of the west and north wings, with windows in its south and east sides (Figure 5.7d). Its Escher-esque form is illustrated in simplified form in Figure 5.6, viewed from the southwest corner of the upper first floor. The uppermost flight, rising from the fifth landing, was not affected by the owner's proposals
and has been omitted from the isometric drawing and is not referred to further here.



5.7 Plan form analysis of the house. (a) Medieval–Elizabethan; (b) Jacobean; (c) eighteenth–nineteenth century; (d) twentieth century. (Michael Heaton)

Analysis of the stairs proceeded along the staged approach advocated above, against a background of intermittent archaeological investigations and recording by the author and others. Alan Graham's investigations at the base of the staircase revealed an octagonal or hexagonal masonry plinth, extrapolation of which suggested an oriel-shaped structure in the corner formed by the medieval hall and the early baroque west wing, which he interpreted as an oriel stair turret predating the present stair turret. Its position is indicated in Figure 5.7a. Subsequent removal of render from the north wall of the stair hall has revealed the moulded frame of a blocked door opening of late Medieval form slightly below current first-floor levels, apparently confirming

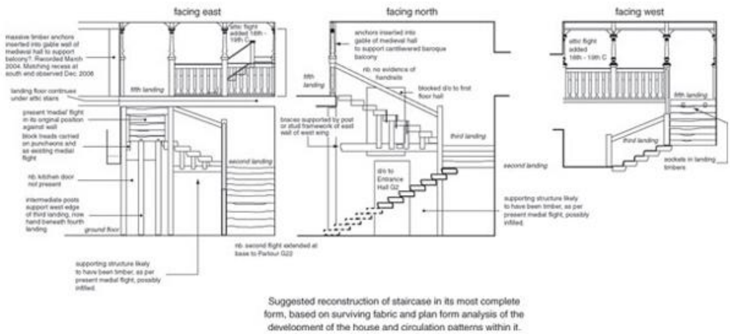
Graham’s interpretations. An initial inspection of the stairs by Hugh Harrison established it was of at least two and possibly
three phases of construction, with the earliest members being coeval with the construction of the stair turret in the late sixteenth to early seventeenth century (see below), and that several aspects of the stair’s fabric and construction were atypical for one of that date range.

5.8 The good, the bad and the ugly. This baluster could not have been chewed *in situ*. (Michael Heaton)

More detailed research as part of a conservation management plan confirmed, *inter alia*, that the house had been subject to two major refurbishments in *c*.1875 and *c*.1925, both involving the installation of salvaged and replica historical details throughout the house. Individual applications for Listed Building Consent were then submitted for each of the owners' proposals, supported by detailed 'evaluation' of the affected fabric informed by ongoing observations throughout the house. In the case of the stairs, two stages of evaluation were commissioned, the second involving partial dismantling with the consent of the local authority and English Heritage. The evaluation report confirmed, unequivocally, Hugh Harrison's analysis and explained the atypical characteristics of the stair by reference to demonstrable changes in the layout and use of the rest of the house *c*.1925.

Contrary to appearances, therefore, the stair was found not to be of timber newel construction: the 'newels' are mainly hollow box-work tubes of machine-sawn oak that perform no structural function other than to support the handrails. Solid oak newels survive only at ground-floor levels,

but provide no support to other members and are themselves all of salvaged timber and supported wholly by twentieth-century masonry. The second and third flights are of solid oak block treads housed in the outer walls of the stair turret and supported at their inner ends by twentieth-century masonry (see Figure 5.10) and a rough carcass frame of band-sawn softwood of twentieth-century date, and at their upper end by the full-length first-floor landing (third landing on Figure 5.9). The structure is therefore a quasi-cantilevered stair supported by twentieth-century masonry and a full-length first-floor landing, on which all other members bear. Examination of the first-floor landing revealed it to be constructed of salvaged timber and built against finished internal wall faces, the whitewashed lime renders of which were trapped behind the pole plates. The stair's decorative fabric consists of a mix of machine-sawn oak veneers and deals of nineteenth- and twentieth-century date; salvaged balusters, handrails and pillars of, probably, seventeenth-century manufacture; and nineteenth-century imitations of these in machine sawn or machine-turned oak, all fixed with screws and wire nails. These phases of joinery are visibly distinct, not least through the differential wear evident on them and are mixed randomly about the structure. That much was evident from superficial visual examination and limited dismantling.



5.9 Graphic reconstruction of staircase in its 'original' form. (Michael Heaton)

5.10 Second flight at Whitestaunton, showing the complete structural history. (Michael Heaton)

But what perplexed all investigators was the position of the fourth landing, the flight rising from it and its abnormal horizontal handrails. It made the structure unnecessarily complex and blocked all natural light into the ground-floor stair hall. Plan form analysis of the whole building,

based on ancillary observations (Figure 5.7) and Alan Graham's excavations, revealed the timber stair must have been appended to the rear (south) wall of the Medieval range, but without any form of structural connection to it, and that the ground-floor door in the northeast corner of the stair turret was an early twentieth-century insertion (OPC *in-situ* concrete lintel). Had a weight-bearing third landing and fourth flight been positioned over this corner, as received models suggest, supported on posts or masonry as would have been necessary, insertion of the doorway in the early twentieth century would have necessitated its removal. Re-positioning it over the stairwell allowed half its load to be borne indirectly by the masonry walls supporting the lower flights, via a visually complex structure of salvaged members that was probably meant to be hidden above a plaster soffit. Of the horizontal handrails, only two were substantially seventeenth century and neither was *in situ*, but their lengths were exactly one-third that of the fifth landing (allowing for uprights): it is likely they originally formed a landing balustrade to an open gallery overlooking the stairwell from the west that provided morning light into the baroque west range.

In conclusion, contrary to the assertion of the list description, the main stair at Whitestaunton was neither 'good' nor 'C17'. Based on this new understanding of significance, consent was granted for the proposed modifications. Subsequent repair, restoration and modifications have been based on a sound, verifiable understanding of the subject and its significance.

Neither dendrochronology nor radiocarbon dating were required because other dating evidence was available, but detailed inspection of fabric, metric survey and the plan form analysis of the house's chronological development was able to provide the necessary information to make informed decisions regarding its future management.

Notes

1 Association of Local Government Archaeological Officers, *Analysis and Recording for the Conservation and Control of Works to Historic Buildings*, 1997; Clark,

K., *Informed Conservation*, 2001; English Heritage, *Understanding Historic Buildings: A Guide to Good Recording Practice*, 2006; Worthing, D. and Bond, S., *Managing Built Heritage: The Role of Cultural Significance*, 2008.

2 Harris, J., *Moving Rooms: The Trade in Architectural Salvage*, 2007.

3 Heaton, M.J., 'Building palaeopathology: practical applications of archaeological building analysis', *Structural Survey*, 27, No. 2, 2009.

4 In, for instance, Stanier, P., *Stone Quarry Landscapes: The Industrial Archaeology of Quarrying*, 2000; Parsons, D. (ed.), *Stone: Quarrying and Building in England AD43–1525*, 1990; Yeomans, D.T., *Construction Since 1900: Materials*, 1997; Yeomans, D.T. (ed.), 'The development of timber as a structural material', *Studies in the History of Civil Engineering*, Vol. 8, 1999; Goodburn, D., 'Woods and woodland: carpenters and carpentry', in Gustav Milne, *Timber Building Techniques in London c. 900–1400*, 1992; Lynch, G., *Brickwork: History, Technology and Practice*, 1994; and the many papers in the *Proceedings of the International Congresses on Construction History* and introductory texts on dating historic buildings.

5 Priess, P.,'Wire nails in North America', *Bulletin of the Association for Preservation Technology*, 5, No. 4, 1973; Yeomans, D., *The Trussed Roof: Its History and Development*, 1992; How, C. and Lewis, M., 'The Ewbank Nail', in *Proceedings of the Third International*

Congress on Construction History, Cottbus, Germany, May 2009.

6 Hewett, C.A., *English Historic Carpentry*, 1980.

7 www.vag.org.uk

8 Ringbom, A., Hale, J., Heinemeier, J., Lindroos, A. and Brock, F., 'The use of mortar dating in archaeological studies of Classical and Medieval structures', *Proceedings of the Second International Congress on Construction History*, Vol. 3, 2006.

9 www.archaeologists.net

10 Local authority archaeologists have a longer track record of preparing briefs and specifications for survey work than their conservation officer colleagues, arising from planning guidance published in 1990. It may therefore assist conservation officers to make use of their expertise when commissioning building recording.

11 National Planning Policy Framework, Department of Communities and Local Government, 2012, section 12, 'Conserving and enhancing the historic environment', paragraphs 128 and 141, UK government document.

12 English Heritage, *Understanding Historic Buildings: A Guide to Good Recording Practice*, 2006.

13 The Planning Practice Guide published by English Heritage and originally
published with Planning Policy Statement 5, 2010, will continue to be used to inform what should be in a

Statement of Significance until it is updated by English Heritage.

14 Wilson, R.G. and Mackley, A.L., ‘How much did the English country house cost to build, 1660–1880?’, *The Economic History Review*, New Series, 52, No. 3, 1999.

15 www.jstor.org

16 Heritage Lottery Fund, 2008, 15 and Appendix A.

17 English Heritage, *Measured and Drawn: Techniques and Practice for the Metric Survey of Historic Buildings*, 2nd edition, 2009.

18 Ibid., pp31–33.

19 With thanks to Andrew Dodson of Greenhatch Group Ltd for advice on laser scanning.

20 English Heritage, *3dLaser Scanning for Heritage*, 2nd edition, 2011.

21 Ibid

22 http://archaeologydataservice.ac.uk

Part Two

Designing the Staircase

6

The Geometry of Staircases: Their Comfort, Safety and Setting Out

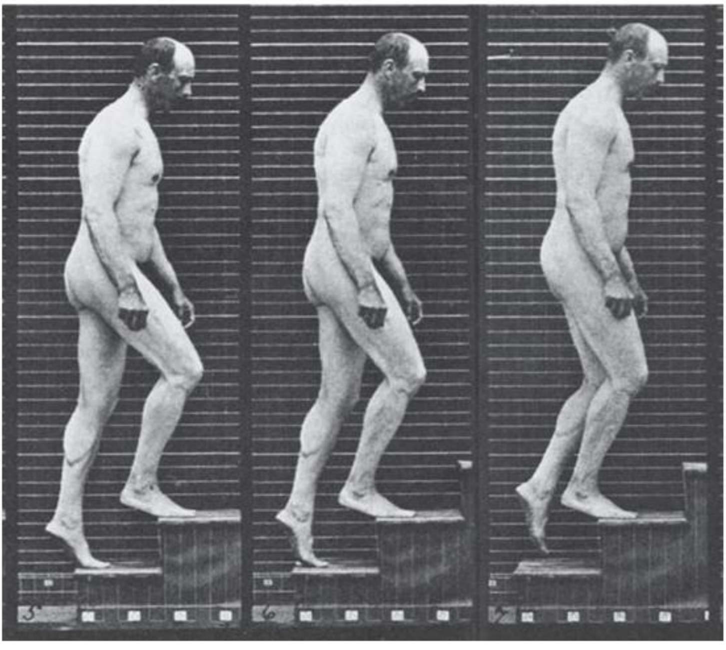
James W.P. Campbell

STAIRCASES are a frequent cause of accidents, and because of this a great deal of research has been carried out into their design. All architects and interior designers should be familiar with the local Building Regulations that they operate under. It is, however, much more difficult for them to find out about or keep up to date with scientific research, particularly as this is rarely reported on by the architectural press and has not been widely written about in books on stairs.

This chapter aims to provide the designer with a brief overview of the research that has been carried out into staircase design and to show where this agrees with, or contradicts, the regulations. Regulations are often based on research, but they change slowly and in some cases they are a deliberate attempt to find a middle ground between the ideal and the most common solution.

There are two critical considerations in staircase design: comfort and safety. They are connected, but not identical. Comfort aims to provide the user with a staircase that is as easy to walk up or down as possible. It is about dimensions. Dimensions do play a part in safety. The poor dimensioning of stairs might contribute to accidents, making a trip or fall more likely, but anyone can fall on a stair, even a perfectly designed one. The question of safety is different and can be divided into two problems: the first is how to minimise the chance of falling on a stair in the first place, and

the second, when a fall does occur, is how to make sure no serious injury results. Both have been the subject of considerable research, which this chapter will attempt to summarise. Lastly, the chapter will discuss aspects of the geometry of staircases, and more particularly their handrails and balustrades which, although they have little to do with comfort or safety and are rarely included in regulations and books on construction, are the frequent causes of errors in design.



6.1 Muybridge, *Man Ascending a Staircase*, 1870.

These, then, are the issues that this chapter will seek to explore. Each has an extensive literature of its own. The object here will merely be to provide the briefest introduction to each subject, summarising the conclusions without going through all the working, and directing the reader through the references to further reading should they so desire.

Accidents and Deaths on Stairs

One of the reasons for research into staircase design is that stairs are a significant cause of injury and death. In 1990 a staggering 998,871 people in
the US received hospital treatment for injuries resulting from stair accidents. This suggests that 1 in every 250 people in the US went to accident and emergency that year because they slipped or fell on a stair.[1] In the UK between 1992 and 1996 as many people died in the home as died in traffic accidents, and half of those deaths in the home were due to falls on stairs. It has been calculated that a serious accident in the UK happens on a staircase every 2.5 minutes.[2] Studies of deaths in the US and the UK both show that stair fatalities are reassuringly rare, but they are tragically more common in the elderly, who are prone to falls on all surfaces and run a much higher risk of coming to serious harm when they fall (elderly people suffer 70 per cent of fatal accidents in the UK;[3] 84 per cent of fatal accidents in the US happen to those over 65[4]). In fact, so high is the risk to the very elderly of serious injury or death due to falls on stairs that the only sensible conclusion is that care units and houses for the elderly should avoid stairs altogether. Children, by comparison, very rarely die from

falls on stairs, although they are frequently injured (20 per cent of all domestic accidents happen to children under four on stairs).[5] Studies have shown that everyone is much more likely to fall when they are going down stairs rather than when they are going up.[6]

Injuries from Treads and Obstacles

Many people who fall on stairs do so without any injury whatsoever. They slip, then regain their footing and carry on their way, perhaps with a minor twist of the ankle or a slight bruise. Some 80 per cent of serious accidents on stairs – those that result in hospital visits – involve falling backwards or forwards onto the steps, and research has shown it is the resulting collision with the treads and the edges of one or more step nosings that makes accidents on stairs more dangerous than slipping on a flat floor.[7] Researchers have shown that stairs with soft, rounded edges covered in carpet, rubber or similar are much less likely to cause an injury than hard and angular edges of glass, stone, concrete or steel.[8] The attachment of separate rubberised nosings on top of the treads is a popular solution, but creates a potential trip hazard unless the nosings are flush with the surface of the tread, which is possible to achieve on new-build staircases, but must be carefully addressed where the nosings are being added to existing ones.[9]

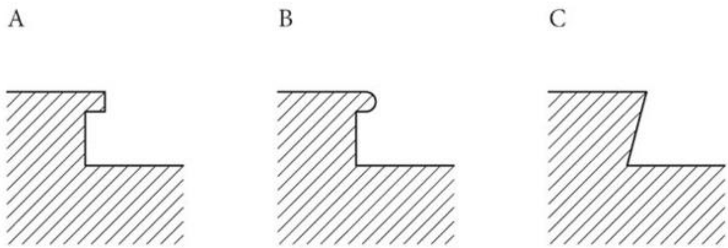
As already mentioned, 80 per cent of injuries result from falling onto the steps themselves. The remaining 20 per cent of accidents involve collision with the walls, handrails or balustrades.[10] Again, research has concluded that designers need to pay particular attention to the design of these elements and remove all angular projections and sharp edges that might cause injury in a fall. We increasingly live in a world of hard edges and concrete and steel stairs, but all the research suggests that we need to think more carefully about the surfaces used in staircases to help protect everyone in the event of falls.[11]

Causes of Falls

Research has shown that many falls are caused by poor maintenance of stairs (loose nosing strips, badly eroded treads, lights not working, handrails loose or missing, etc).[12] These are easily rectified. Other causes are more a function of the design of the stair itself. Distraction has been found to be a significant factor,[13] leading to the unfortunate conclusion that the safest stair is a rather boring one, featuring blank walls on either side, well lit, properly maintained with a handrail on either side and no view to distract a person using it. This is unnecessarily cautious, but obvious and powerful distractions on stairs should be avoided. In a similar vein, it is essential that the position of the edge of the step or nosing is clearly visible. Highly-patterned carpets which conceal the position of the edge of the tread should be avoided and the stair should be lit in such a way that the edges of the treads are easy to see. Colour is also an issue: black treads are a particular problem, but so too are brightly coloured treads, if they are uniformly so. In all cases it is the edge that needs to be easily differentiated from the main part of the tread.[14]

Nosings

Nosings, the projecting leading edges of stairs, pose a significant design problem. Studies of accidents show that catching the heel of the shoe on descent or the toe on ascent on a nosing is a significant cause of accidents.[15] On steeper stairs, however, other research has shown that nosings are very helpful in ascending a stair. The conclusion is that they should be used, but that their shape should be carefully considered. Research has concluded that the projection should not be greater than 20 mm, although Building Regulations are often less restrictive (UK regs: 25 mm).[16] Research has also shown that large, rounded nosings are better than narrow, square ones. Backward-sloping risers are better still. Counter-intuitively, the common addition of abrasive strips on nosings has been shown to actively cause accidents. If required, the whole step should be equally treated and the nosing should be clearly marked so the user can easily see it.[17]



6.2 Nosings: (a) abrupt; (b) curved (better); (c) inclined/backward sloping (best)

Open Risers

Open risers have been popular with designers since the beginning of the twentieth century, but from a safety point of view they are a very bad idea. Research has shown that many users rely on the back of the step to indicate that their shoe is correctly positioned on ascent. The absence of this crucial cue can throw a user off-balance.[18] Open steps are also much more difficult for visually impaired people to see. Finally, they present significant problems for people suffering from vertigo to the point that people may be unable to ascend the stair at all.[19] Most Building Regulations restrict the size of the opening (in the UK to no more than 100 mm)[20] to avoid children falling through. The latest revision of UK Building Regulations advises against the use of open stairs.[21]

Stair Layouts

Many old stairs, particularly those in grand public buildings, have very long uninterrupted straight flights; flights of 20 steps or more are not uncommon. These clearly contravene modern Building Regulations. In the UK the limit is 12 risers for normal stairs and 16 for utility stairs. The limit on number of risers is somewhat illogical: it is the height of the fall that matters. A more logical regulation is used in the US, where landings must be provided every 3.6 m of rise in height. In such litigious times it is not uncommon for the owners of the historic buildings which are open to the public which have staircases that do not meet these modern guidelines to ask whether their existing historic staircases are safe or should be closed in case someone falls or trips and sues the owner. The answer, of course, depends on the stair.

The need for a landing has been understood at least since the Renaissance. Alberti says ‘the best architects almost always avoided having an unbroken flight of more than seven steps or nine steps … they wisely provided a landing to give the weary or infirm a place to rest … and, should anyone happen to stumble … to offer a place to check his fall’.[22] These comments were echoed by Palladio.[23]

Detailed studies have shown that most accidents happen on the top three steps or the bottom three steps of a flight, and that there is no direct correlation between the number of steps and the occurrence of accidents.[24] Indeed, short flights are just as dangerous and very short flights (1–3 steps) are particularly so. Most Building Regulations forbid these. The danger from long flights is that if an accident does occur it can be more serious. The elderly also find long flights difficult to ascend or descend without a pause. For this reason, flights of more than ten risers should be avoided.

It is easy to suppose that helical stairs and dog-leg stairs with winders are more dangerous than straight flights.[25] Counter-intuitively, research has shown that the reverse is the case: significantly more accidents happen on straight flights of stairs than spiral stairs, dog-leg stairs or those with winders, and more serious injuries also result.[26] It appears that the more difficult stairs are to climb (such as spiral stairs with their varying widths of winders) the more people pay attention to what they are doing and the less likely they are to trip. Furthermore, when people do trip on spiral or dog-leg stairs they are more likely to be able to break their fall against the walls or the balustrade before they have fallen very far. Conversely, on straight flights they tend to fall further, increasing the risk of serious injury. The length of the fall is strongly dependent on the length of the flight, the pitch of the stair and, most importantly, the direction of travel. People tripping on the way up usually fall forwards and catch themselves. In descent people are more likely to pitch down the entire length of the flight.

To return to the question posed, of whether to close historic stairs with long flights, the answer is that the length of flight is not in itself a reason for closure, provided due attention is paid to the other factors. The question is what measures can be taken to reduce the severity of an accident should one happen? Such measures could be applied equally to all stairs, old or new. Shallow-pitched flights with soft surfaces, clearly marked and well-maintained treads are probably perfectly safe. Simple measures such as warning signs, a ban on unsuitable footwear (high heels, etc.) or *in extremis* imposing an 'up-only' policy may be all that is required. Unless a stair has a history of accidents, research and common sense suggests that there is no reason to close a stair simply because it has more than the arbitrary 12 or 16 steps in a flight required by the current Building Regulations. However, research also shows that those designing new stairs should listen to Palladio and Alberti, breaking long steep flights wherever possible with wide, well-lit landings. The result will be stairs that are easier to climb and safer to descend.

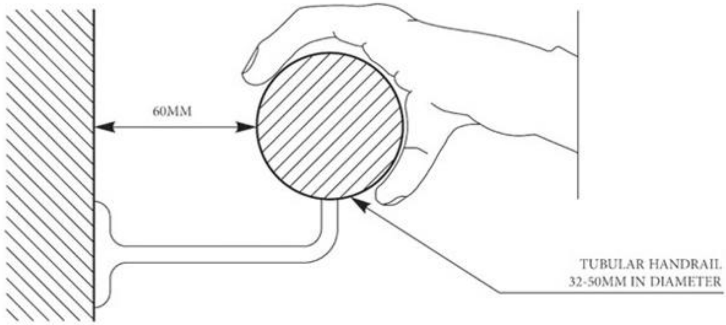
Handrails, Guard Rails and Balustrades

Handrails, guardrails and balustrades fulfil three different functions. Surprisingly few designers are taught at school the difference and almost all architects think guardrails and handrails are the same thing. *Handrails* give the stair user something to hold onto when ascending or descending the stair. They help the user to keep their balance and to avoid falling. The correct height of a handrail varies according to the height of the person and can be found out by research. It is surprisingly low. A *guardrail* stops the user pitching over the edge and falling down an open well or off the edge of a landing. A guardrail should ideally be high, much higher than a handrail, to avoid the risk of tipping over the edge. Often handrails are used as guardrails, but this is far from ideal as they have entirely contradictory requirements, as we shall see. Building Regulations accept this is going to be the case and set an arbitrary height for handrails doing both functions. A *balustrade* stops the user slipping under the handrail or guardrail. It may also hold the handrail, but that is not its primary purpose.

Handrails

Handrails are important in preventing accidents where they enable a person to recover in the event of a trip. The perfect height for a handrail will differ with the height of the user. It also differs whether ascending or descending, so the height is necessarily a matter of compromise unless a whole series of handrails is going to be provided. Research has shown that the most comfortable height for an average man for ascent is 838 mm (33

inches) at the nosing, while the ideal for descent was a height of
777 mm (30.5 inches). Studies on avoiding falls suggest a higher handrail height of 927 mm was better[27] The result of all this research supports the requirement in UK regulations for handrails to be between 900 mm and 1,000 mm high, measured from the top of the handrail to the line of pitch (nosings).[28] Handrails for children, if provided, should be set about 600–700 mm high.[29]



6.3 Ideal handrail configuration, showing clearance from the wall.

The perfect shape of the handrail also depends partly on the size of the user's hands. The great wide stone handrails of classical staircases, graceful as they are, are almost entirely useless as handrails, providing nothing to hold onto or grab in an emergency. Detailed research into handrails has concluded that the ideal handrail is tubular, 32–50 mm in diameter and set 60 mm from the wall.[30] The material is also important. Hard handrails do not afford the best grip and may be particularly difficult to grip for those with disabilities. Rails should be smooth enough to be comfortable, but provide enough grip to aid recovery in a slip or fall. They should also have good colour contrast against the surroundings. Soft coverings like leather or rubber are to be preferred as they provide protection from impact in a fall and are easier to grasp.[31] It is not normally acceptable or desirable to add a handrail on top of a stone balustrade in a historic building, but it may be possible to produce a more user-friendly one discreetly on the wall side of the stair. Handrails should continue beyond the lowest step wherever possible. Elderly and infirm people may benefit from handrails on both sides of a stair, in which case they should be set 800–1000 mm apart.

Guardrails

Guardrails stop people pitching down wells and off landings. The physics of falls lead to some rather surprising results: most people who fall less than 20 feet (6 metres) will land on their heads. Short falls are thus disproportionately likely to be lethal. Even for a fall of as little as 4 feet (1.2 metres) 14 per cent of falls are fatal. However, above 20 feet people tend to land feet-first, increasing the chances of survival, albeit with very serious injury.[32] Building Regulations vary from country to country. Many do not require any form of guardrail around a drop of 600 mm or less and also allow the handrails on a stair to act as a guardrail. However, a significant number of fatalities on stairs involve the participant tripping and pitching over the edge of the handrail. The statistics on injuries suggest that in many cases the Building Regulations are too lax and that guardrails should probably be required in addition to handrails and should be provided at all changes in level, however slight.

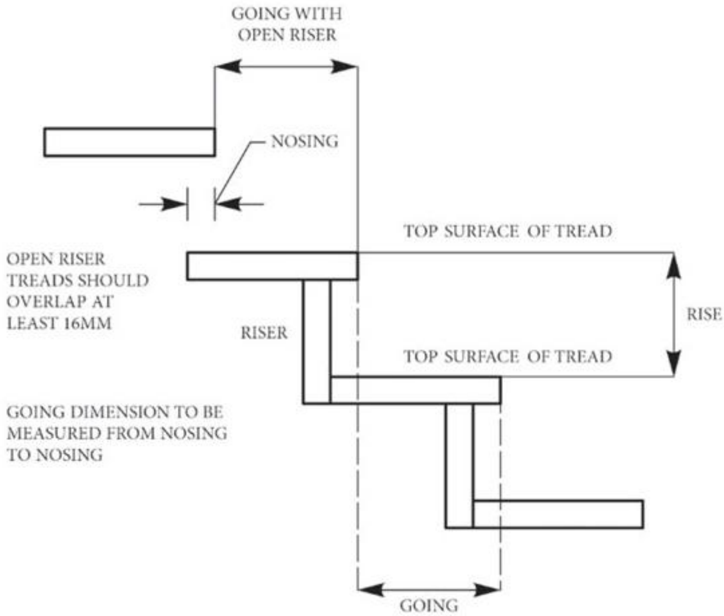
Comprehensive research has been carried out into the appropriate height for guardrails. The general conclusions are that all guardrails on landings and balconies should be as high as possible, but at least 1.1 m high. There is a relaxation in the UK Building Regulations for landings in single-family dwellings of 900 mm,[33] but this is not to be recommended. It has also been shown that increasing the width of the guardrail significantly reduces the risk of toppling over.[34] This may be an important factor in considering whether historic balustrades or guardrails on landings are fit for purpose and safe for public use. A stone parapet 300 mm wide would act as a guardrail that was considerably higher and thus would not need to be 1,100 mm high to be safe. In cases where the parapet is low, either a rail should be added on top, or (where this would obviously be undesirable), other ways of keeping the public away from the edge should be used (ropes, placement of furniture, sculptures, etc). In so doing it is of course important to avoid placing objects where they might be knocked over and drop off the edge. The shape of the top of a guardrail is not significant as the user will not be holding onto it while moving unless it also acts as a handrail.

Balustrades

Both guardrails and handrails on stairs require balustrades. Balustrades usually also support the handrail, but that is not their primary purpose, which is always the same: to prevent people falling under the guardrail in the event of a slip. There are certain basic considerations to be taken into account in designing a balustrade. First, the balustrade must not have openings that a child could crawl through, or catch their head in during a fall. This is usually encoded in regulations as a ban on all gaps larger than 100 mm.[35] Next, the balustrade should not have any sharp or projecting surfaces. Although rarely mentioned in regulations, these are a cause of injury in falls and thus should be avoided. Lastly, horizontal rails or other features which make it easy or tempting for children to climb should be avoided. This is particularly true of guardrails on landings, where such rails look like the ladders in a playground. It is surprising how such an apparently obvious design mistake is so commonly found in public buildings and shopping centres.

Treads and Risers

Although seemingly straightforward, the relative sizes of treads and risers has occupied more pages of discussion in sections on staircases in architectural treatises than any other aspect. The earliest recommendations we have are from Vitruvius. He suggests that stairs should follow the proportions of Pythagoras's 3, 4, 5 triangle (with three being the riser and four the going, giving a pitch of 37°), which is surely based more on geometrical neatness and mathematical perfection rather than any study of comfort.[36] Elsewhere, when discussing the correct size of steps for the front of a temple, Vitruvius gives the first recommendations for maximum and minimum step sizes, suggesting the size for risers should be in the range of 9–10 inches (228–254 mm) and treads of 18–24 inches (457–610 mm).[37]



6.4 Definitions: goings and risers.

The late seventeenth century saw a different approach to describing stair sizes, this time using equations. The first use of a mathematical relationship linking the height of the riser to the going (although expressed in words rather than algebra) is found in Blondel.[38] Thereafter explicit equations of varying complexity become increasingly common (Table 6.1). All of these formulations only work for a narrow range of dimensions of risers and goings, outside of which they yield absurd results. Later researchers often used tables to get around this problem.

Table 6.1 Historic equations for calculating rise (R) and going (G)

Date	*Author*	*Recommendation*
39 BC?	Vitruvius	G/R = 3/4, 228 mm < R < 254 mm, 457 mm < T < 610 mm
1698	Blondel	2R + G = 24 inches (approx. 600 mm)
1840	Viollet Le Duc	Pitch of 22°
1865	Newlands	R × G = 66 (in inches)
2000	BS 5395	2R + G is in range 550 (min.) to 700 (max.)

In the twentieth century researchers began to carry out more systematic research into the sizing of steps. They looked at the energy expended and the problems of gait. The results all focus on minimum dimensions for going.

The UK Building Regulations set minimum and maximum riser heights and goings as follows:

Table 6.2 UK building regulations (2013) on staircases; recommended risers and going

	Min. rise (mm)	*Max. rise (mm)*	*Min. going (mm)*	*Max going (mm)*
Private stair (max. pitch 42°)	150	220	220	300
Utility stair	150	190	250	400
General access stair	150	190	250	400

Table 6.3 Recommended risers and goings from BS 5395-1 (2000) (all dimensions in mm)

	Rise, r		*Going, g*		*Sum of g + 2r*		*Pitch*	*Stair clear width*		*Handrail Height*	
Stair category	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Max.*	*Min.*	*Reduced min. where limited use*	*Min.*	*Max.*
Private stair	100	220	225	350	550	700	41.5	800	600	900	900
Public stair	100	190	250	350	550	700	38	1000	800	900	1000
Assembly stair	100	190	280	350	550	700	33	1000		900	1000

Risers of less than 100 mm are acknowledged to be dangerous.[39] It is interesting to note that the UK Building Regulations differ from the figures given in the British Standard.

Small treads (small goings) have been shown to be particularly dangerous, leading researchers to recently suggest revised minimums as shown in Table 6.4.

Table 6.4 Recommended minimum going based on research into accident research.

	Min. going
Private stair	250 mm
Semi-private stair	300 mm
Public stairs	350 mm

Source: M. Loo-Morrey, K. Hallas and S.Thorpe, 'Minimum going requirements and friction demands during stair descent', *Contemporary Ergonomics*, 2004, pp8–12.

Many early books on staircases recommended a *wash* or *kilt*, which is a downward slope to the treads. This was meant to aid both ascent and descent. The earliest written known description of this is in Henry Wotton's *Elements of Architecture* (1624), which reports that this had been commonly used in Italian stairs. The UK Building Regulations rule out this measure, specifically requiring that all treads are horizontal, but washes and kilts are commonly found in stairs from the seventeenth to the nineteenth centuries.

Simple Setting Out

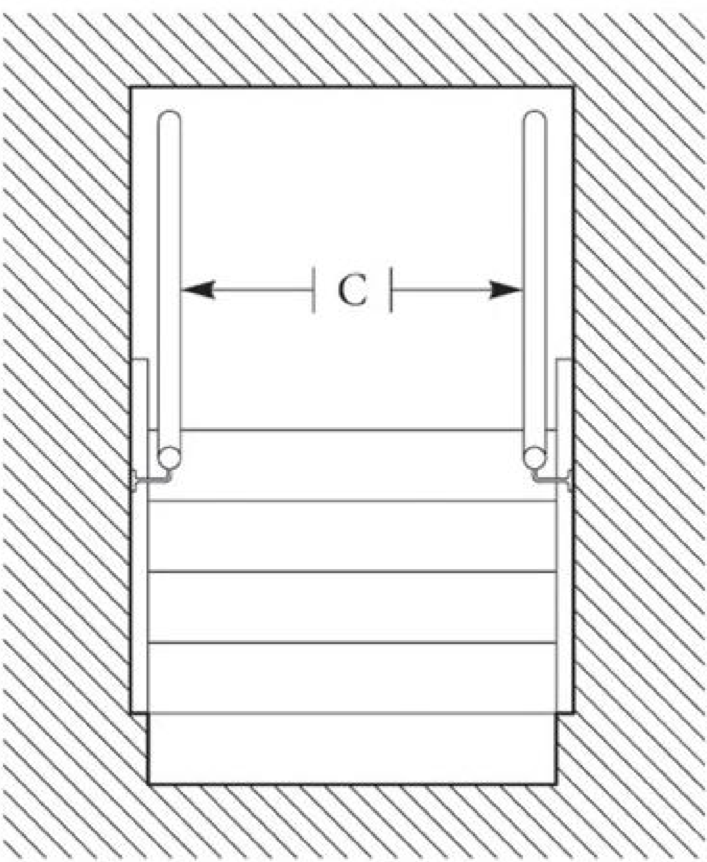
The setting out of most staircases is not complicated, but does require some basic skills in geometry and arithmetic. The easiest staircases to set out are straight flights. The first element to determine is the height of the riser. To set out a staircase, simply take the floor-to-floor height and divide it by the required riser height to get an approximate number of risers. Round this down to the nearest riser to get the actual number and divide it again into the floor-to-floor height to find the actual riser height. In the UK the maximum number of steps in a straight line is 12 (16 in a utility stair, defined as one not for day-to-day access but only for escape or maintenance),[40] so if more than 12 risers are required then a landing will have to be introduced. The landing must be as long as the staircase is wide.

The actual space taken up with a staircase will vary according to going and to plan layout. Winders should be avoided if possible. Despite this, the layout of a straight flight turning through 90° top and bottom, with winders, is particularly economical and commonly used in commercial housing, as is the floor-to-floor height of 2,640 mm, which is exactly 12 risers at 220 mm. Unfortunately, 2,640 mm can lead to a rather mean floor-to-ceiling height.

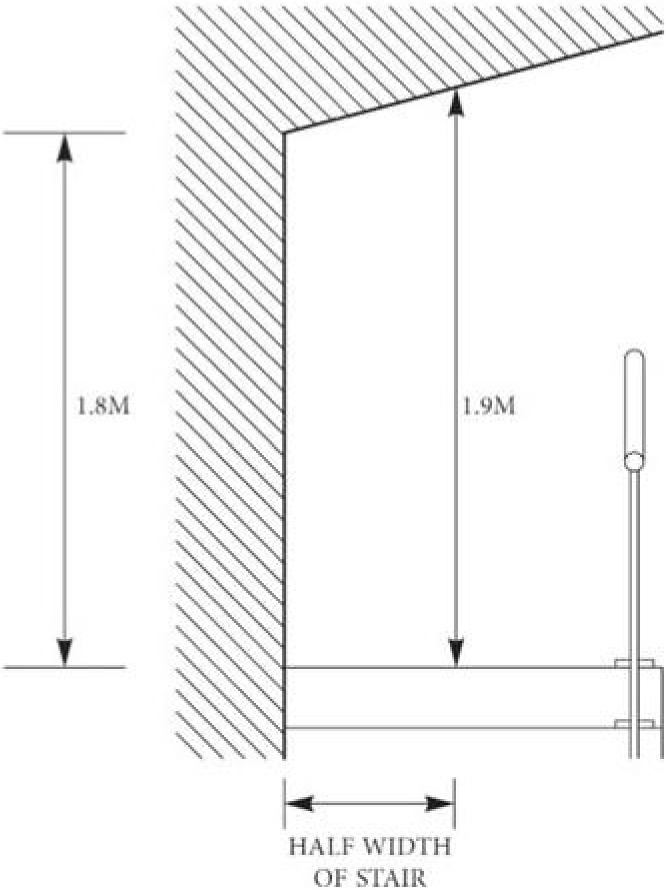
Width

The UK Building Regulations used to require a minimum clear width of 800 mm. This width was measured between the handrails or at the narrowest point, although minor projections such as skirting or a slight narrowing at the newel post at the top could be ignored. Narrower staircases (min. 600 mm) were permitted, provided they only gave access to a single room, which was not a living room or kitchen. These restrictions have been lifted and staircases can now be any width. The question remains: what is the optimum width for a staircase?

Research into staircase dimensions has shown that for people within the 99th percentile 530 mm clear space is required just for the width of the shoulders. Clothing can add another 38 mm. Thus, the absolute minimum clear width for a staircase is 568 mm. However, if other elements are added such as arm swing (102 mm), lateral movement (200 mm), wall clearance (50 mm) and tracking errors (50 mm), a more comfortable distance for a staircase enclosed within walls for one person going in a single direction would be 980 mm. A stair of 780 mm would accommodate a person in the 95th percentile. This supports the idea that domestic staircases, designed for one-way traffic, should be 900 mm wide. This also allows for the easy movement of furniture up and down.[41]



6.5 Clear width (C).



6.6 Minimum headroom for staircase at eaves. (UK building regs diagram 1.4)

The situation is slightly more complicated for staircases which seek to allow passing or side-by-side ascent. Here, similar research suggests that 1,200 mm is the minimum and something closer to 1,750 mm the ideal.[42] UK Building Regulations set a minimum width on non-domestic stairs not forming part of a means of escape of 1,200 mm (1,000 mm between handrails) and require that staircases should not be wider than 2,000 mm unless an intermediate handrail is provided.[43] This seems sensible as 2,000 mm allows people to pass in opposite directions with ease.

Headroom

Headroom for a straight stair is relatively easy to calculate. The UK Building Regulations require a minimum headroom of two metres, but where staircases are ascending to a loft 1.9 metres in the middle of the staircase and 1.8 m minimum at one edge are deemed acceptable. A schoolboy error, still disappointingly common, occurs when adding flights to an existing staircase to ascend into an attic. It is easy to draw a staircase on plan that
is completely impossible to ascend because it runs out of headroom. The answer, in such cases, is to draw sections.

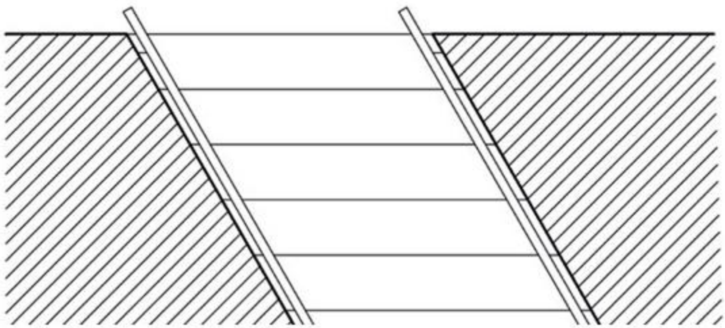
The junction of wall and step

A common pitfall among inexperienced designers is the diagonal tread between parallel walls. This simple device produces a stair that is incredibly difficult to ascend or descend. The handrail set at an angle to line of ascent is unpleasant to use, yet curiously common in modern design. With the exception of winders at the corner of a rectangular well, steps should always follow the simple rule of meeting the wall at a right angle. Curving treads of the type so beautifully seen at the vestibule to the

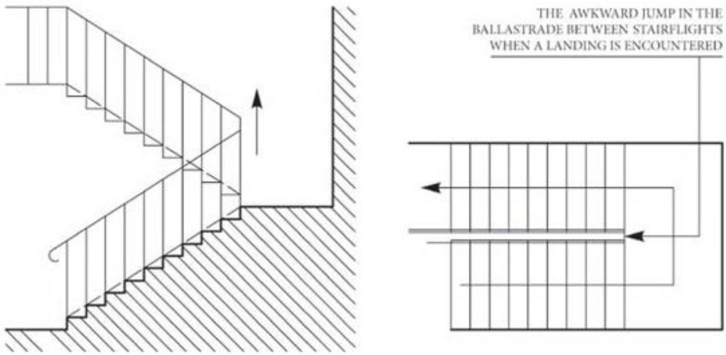
Laurentian Library should likewise always meet the edge at a right angle (see Figure 1.58, Chapter 1).

The Balustrade/Guardrail and Landing Problem

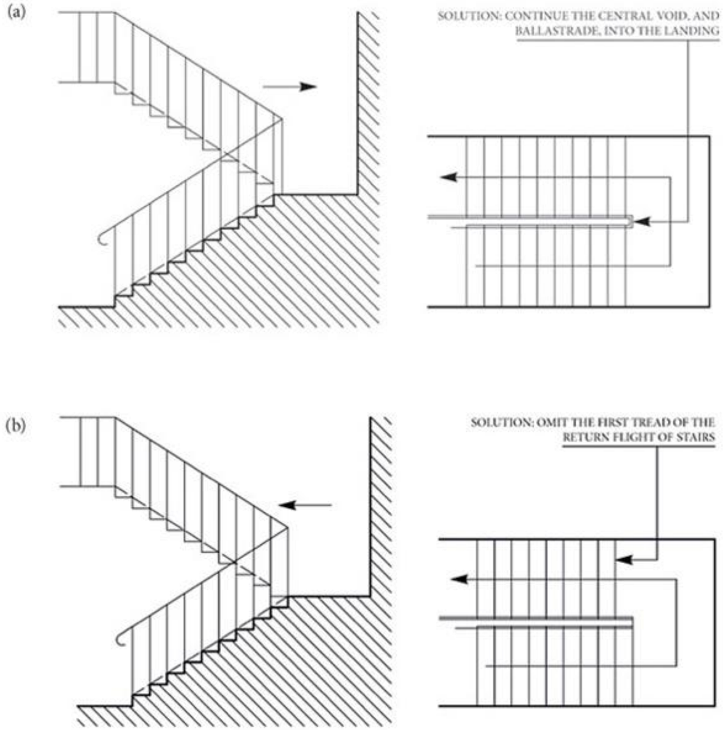
The most common design mistake in staircase design is perhaps the most difficult to visualise. It occurs at the landing of dog-leg staircases. These are commonly drawn on plan by designers (Figure 6.8). The handrail rises up the first stair at the normal height. When it reaches the landing it then needs to turn through 180 degrees and set off at the correct height of the next flight. However, the designer has failed to take into account the riser of the next flight, and the handrail thus has to twist and rise vertically. This configuration will be difficult to build and very difficult for the user. There are two common solutions to this problem: (1) move the riser of the upper flight back one tread or (2) project the well into the landing, which effectively achieves the same effect.



6.7 The common error of the diagonal stair on plan. If constructed, this stair is very difficult to both ascend and descend.



6.8 The handrail problem. The plan of the staircase on the right. The elevation on the left shows the problem. At the landing the handrail has to lift vertically



6.9 The handrail problem: (a) solution 1; (b) solution 2

A similar geometric problem arises at the top of the stair where the handrail has to join the guardrail of the landing, which will inevitably be higher. The traditional solution to this problem was the ramped handrail.

Curved Handrails

Nineteenth-century books on handrailing explain some of the key problems that faced joiners trying to build staircases. They give step-by-step explanations of how to set out and how to cut curved timbers for the handrails and strings of circular and oval spiral stairs. These books

– Nicholson's *Practical Stairbuilder* or Hasluck's *Practical Staircase Joinery* – remain as valid now as the day they were written. The problems exist because designs were always communicated on paper, which meant that the three dimensions of the stair needed to be reduced to two dimensions in the drawing. The architect would provide a plan and perhaps an elevation or section showing the balustrade, but the contractor was left with the problem of translating these drawings into a 3D form.

Some of these problems can be solved by computer-aided design. Now the designer can 'build' a 3D computer model, which can then be measured to provide the relevant dimensions; books on handrailing may no longer be required. There are, however, still pieces of geometry that the designer has to understand, whether drawing in 2D or 3D, to avoid the risk of producing an unbuildable or unworkable design.

Spiral and Helical Staircases

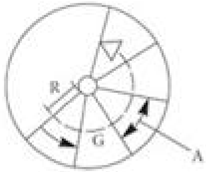
Many spiral staircases are purchased direct from the manufacturer and are available off-the-shelf. If this is the case, guidance on size and layout can be found in the manufacturer's literature. Non-standard designs require more calculation. Details of how to calculate the size of spiral and helical staircases can be found in BS 5395-2 and the UK Building Regulations.

There are a number of problems to be solved in designing a spiral staircase. They are interrelated and belong in no particular order. The risers and going of a spiral or helical stair need to be determined. Risers are simple enough and are measured in the same way as they would be on a straight staircase; however, the determination of their correct height is not just a matter of finding the correct number to rise from floor to floor, but also making sure that there is sufficient headroom. Headroom can be quite complicated to determine because it is particularly constricted at the landings. Landings may take up one-quarter of the stair (90°), but must be no less than 60° if they open onto a floor.

In all helical and spiral stairs the tread width at the inside edge should not be less than 50 mm and preferably no less than 70 mm. In stairs with a low riser this may lead to a large drum or void. To determine whether the stair meets regulations it is necessary to measure the going. In narrow stairs (below 1 m) this is done at the centreline, while in wide stairs it is done at the centreline and 270 mm from both the outer and inner edges, measured from the handrails. The going at any point may be determined using the equations in Figure 6.10.

G=2R (SIN A/2)

WHERE G= GOING
R= RADIUS FROM THE CENTRE AT WHICH THE GOING IS TO BE MEASURED
A= ANGLE OF TREAD

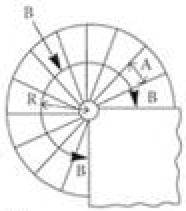


THE MATHEMATICAL EQUATION FOR DETERMINING HEADROOM IS:

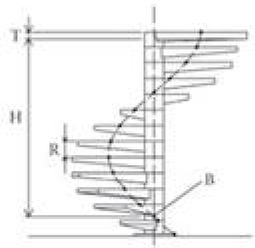
H=R(B/A)-T

WHERE THE DEFINITIONS ARE AS FOLLOWS:

H= HEADROOM (IN MM)
R= RISER (IN MM)
B= ANGLE OF ROTATION BETWEEN EDGES OF LANDING AT PITCH LINE
A= ANGLE OF TREAD
T= THICKNESS OF LANDING (IN MM)



PLAN



PLAN (TOP) AND ELEVATION (BOTTOM) SHOWING
KEY DIMENSIONS FOR CALCULATIONS OF HEADROOM

6.10 Plan (top) and elevation (bottom) showing key dimensions for calculation of headroom. The results of these equations for width of spiral staircases and the correct goings and risers are summarised in Table 6.5.

Table 6.5 Sizes of spiral staircases from BS 5395-2 (1984).

Stair category	*Riser, r (mm)*	*Going, g (mm)*			*2r + g (mm)*		*Clear width (mm)*
		Inner min. g	*Centre min. g*	*Max. outer g*	*Min.*	*Max.*	*Min.*
Small private stair intended to be used by a limited number of people, familiar with the stair. Typical diameter **1,300–1,800 mm**	170–220	120	145	350	480	800	600
Private stair similar to above, but also providing the main access to upper floor. Typical outside diameter **1,800–2,250 mm**	170–220	120	190	350	480	800	800
Small semi-public stair used by fewer than 50 people, suitable for a small office or common stair to more than one dwelling. Typical outside diameter **2,000–2,250 mm**	170–220	150	230	350	480	800	800
Semi-public stair intended to be used by larger numbers of people, e.g. large floor area in factory. Typical outside diameter **2,150–2,550 mm**	150–190	150	250	450	480	800	900
Public stair intended to be used by large numbers of people at one time. Typical outside diameter **2,500–3,500 mm**	150–190	150	250	450	480	800	1,000

Summary

This chapter has attempted to give a brief introduction to the problems involved in setting out stairs. Further information on designing staircases can be found in

Templar, *The Staircase: Studies of Hazards, Falls and Safer Design* (1992) and in BS 5395-1(2000) and BS 5395-2 (1984). Hopefully this chapter has given an introduction to the problems commonly encountered in staircase design and its possible pitfalls. Staircases give designers an opportunity to demonstrate their imagination, but they remain firmly rooted in the dimensions of the human body and are one of the most difficult aspects of architectural design to master. It is easy to design a staircase that looks stunning and meets the building regulations, but less easy to design one that is also safe and comfortable to climb.

Notes

1 Anita Scott, *Falls on Stairways*, Report by UK Health and Safety Laboratory, 2005, accessed July 2012, www.hse.gov.uk/research/hsl_pdf/2005/hsl0510.pdf; J. Templar, *The Staircase: Studies of Hazards, Falls, and Safer Design* (MIT, Cambridge, MA, 1992), pp3–5.

2 BS 5395-1 (2000), para. 6.1.

3 Ibid.

4 Templar, op. cit. p5.

5 Ibid.; BS 5395-1 (2000), para. 6.1.

6 L. Svanstrom, *Falls on Stairs: An Epidemiological Study* (Lund Institute of Technology, Lund, Sweden, 1973), cited in Templar, op. cit., p16.

7 Svanstrom, op. cit., cited in Templar, op. cit., pp19–20.

8 Templar, op. cit., p178; J. Coutts, D. Lockett and N. Edwards, *Steps to Safer Stairs* (University of Ottawa, Ottawa, n.d), accessed July 2012, http://aix1.uottawa.ca/~nedwards/chru/english/pdf/SafeStairsOct5.pdf

9 Templar, op. cit., p57; Scott, op. cit., pp22–23.

10 Templar, op. cit., p23.

11 Templar, op. cit., p78.

12 Scott, op. cit., p18.

13 Templar, op. cit., pp140–141.

14 Templar, op. cit., pp141–144; Scott, op. cit., p18.

15 Templar, op. cit., p148.

16 UK Building Regs. Approved Document K 2013, 1.7b.

17 Templar, op. cit., pp147–149; UK Building Regs. Approved Document K 2013, 1.7a.

18 Coutts *et al*., op. cit., p3.

19 BS 5395-1:2000, para. 7.2.

20 UK Building Regs. Approved Document K 2013, 1.9a.

21 UK Building Regs. Approved Document K 2013, 1.6.

22 L.B. Alberti, *On the Art of Building on Ten books*, trans. J. Rykwert, N. Leach and R. Tavernor (MIT, Cambridge, MA, 1988), p31.

23 A. Palladio, *The Four Books on Architecture*, trans. R. Tavernor and R. Schofield (MIT, Cambridge, MA, 1997), p66.

24 Templar, op. cit., p140.

25 Templar, op. cit., p138.

26 L. Svanstrom, op. cit., cited in Templar, op. cit., p138.

27 Templar, op. cit., p120.

28 UK Building Regs. Approved Document K 2013, diagram 3.1.

29 Templar, op. cit., p122.

30 Templar, op. cit., pp123–126; Scott, op. cit., p8.

31 Templar, op. cit., pp126–127.

32 Templar, op. cit., p132.

33 UK Building Regs. Approved Document K 2013, diagram 3.1.

34 Templar, op. cit., p133.

35 UK Building Regs. Approved Document K 2013, 3.3a.

36 Vitruvius, Bk. 9, preface pt.8 (p108).

37 Vitruvius. Bk. 3, ch. 4, pt. 4.

38 Blondel, *Cours d'architecture*, 2nd edition, 1698, vol. II, p693.

39 BS 5395-1 (2000) para.7.2.

40 UK Building Regs. Approved Document K 2013, 1.18b.

41 Templar, op. cit., pp61–62.

42 Templar, op. cit., p62.

43 UK Building Regs. Approved Document K 2013, 1.15 and diagram 1.5.

7

The Engineering of Staircases

Robert Bowles

Historical Background to the Involvement of Engineers

Structural engineers emerged as a separate profession during the late nineteenth and early twentieth centuries. Before that the geometry of stairs and ways of supporting them had evolved based on the dimensions of the human body, and experience. The structure was determined by traditional methods of employing timber, brick and stone, which were the commonly used structural materials. The nineteenth century saw the development of new and stronger structural materials, and the pace of change gave no opportunity for designs in these materials to be developed by trial and error. That led directly to the involvement of engineers in stair design, since their skills provided a means of designing stairs economically in new materials using mathematical calculations, which was quicker and cheaper than allowing new designs to evolve by rule of thumb. Sometimes these new materials were used simply as a direct substitute for timber or stone in a traditional structure, but they also offered all sorts of opportunities for new forms and scales of structures, including stairs.

Design Procurement: New Stairs

Today the design will normally be undertaken by one engineer working with the architect up to the point where there is a co-ordinated overall scheme. During this phase the materials and general layout of the stair are fixed, together with the way it works as a structure – i.e. how the loads are transferred to the ground. This will identify which elements are structural (i.e. supporting more than just their own self-weight) and which are not. Once that phase is complete, the design is developed in detail and turned into a set of instructions (normally in the form of drawings) for the manufacture and construction of the stair. Where the stair is an integral part of the rest of the structure – for example, an *in-situ* reinforced concrete stair in a building with *in-situ* concrete floors – the details will generally be produced by the engineer responsible for the rest of the structure. Where the stair is manufactured separately and brought to site for installation, the details are normally produced by the specialist manufacturer.

Materials and Design Constraints: New Stairs and Existing Stairs

Stairs are built in a great variety of materials – timber, natural stone, cast iron, mild steel, reinforced concrete and aluminium. In recent years glass has been used structurally. Sometimes the structure is exposed; sometimes it is covered up by non-structural finishes. The constraints of building regulations and health and safety mean that the basic geometry of many individual stair flights are very similar and the way they are engineered does not have to be worked out from first principles. These constraints set out minimum and maximum dimensions for the treads and risers and minimum widths for the stairs and landings. They set an upper limit on the number of risers between landings and define the loads for which the stairs and handrails are to be designed. The constraints on stair geometry vary according to the use of the stair. Private stairs used only for access and maintenance are the least constrained, while escape stairs from places of public assembly are the most constrained. Stairs and their enclosures that form part of the means of escape from a building are more constrained than accommodation stairs (which are not used in emergencies). Over the years the geometrical constraints have become progressively more onerous, particularly in places of assembly, in response to experience from accidents where people have been trapped or crushed during the evacuation of premises.

In existing buildings, staircases may not comply with the latest regulations, and designers are often called upon to make decisions about whether they can remain unchanged or must be upgraded. In new buildings there is normally a requirement for stairs and their enclosures to occupy as little area as possible, to minimise the construction cost of the stair and maximise the area of floor outside the stair enclosure. The exception to this is the ‘feature stair’, where the stair, and the space around it, are designed to be seen. Feature stairs provide more opportunities for creative architecture and engineering, sometimes becoming more like artwork that you can walk up. Nevertheless, the basic geometrical constraints of local building regulations must be adhered to.

Associated structural issues

As with other elements of structure, stairs and handrails must satisfy basic requirements for strength, durability and serviceability. In this context serviceability usually refers to the stiffness of the structure. Stiffness is usually not an issue if the stair is compact and built of heavy materials. It can become an issue in lightweight stairs, particularly those with long spans, where both static deflections and vibrations need to be checked. Deflections also need to be considered in stairs where the structure is hidden by cladding. Either the cladding must include joints to accommodate deflections in the structure, or the stair must be stiffened so it is stiffer than the cladding. In most stairs there are four aspects apart from the flights themselves that require engineering input, and these are often where the engineering interest really lies:

1. How to form the holes in the floors through which the stair is to pass.
2. How to construct the walls enclosing the stair.
3. How to support the landings and half-landings.
4. How to fix the handrails.

Summary of Engineering Involvement in the Twenty-First Century

At the beginning of the twenty-first century engineers are involved with stairs in the following circumstances:

1. To design new stairs in new buildings in modern materials.

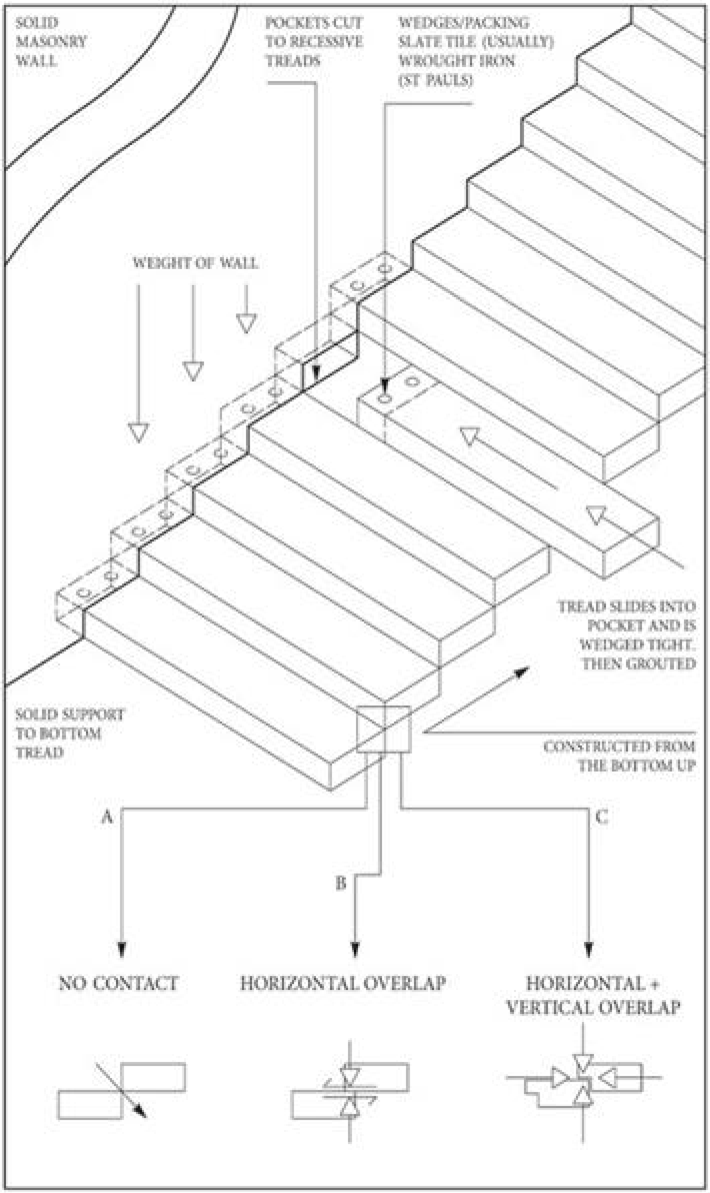
2. To justify the use of traditional materials in non-traditional ways.
3. To justify a change of use and loading, where the change is sufficiently great for the stair's continued justification by precedent to be in doubt.
4. To design alterations that fall outside traditional practice.
5. To assess the structural significance of damage.
6. To design structural repairs.
7. To investigate and set out the lessons to be learned from failures and collapses.
8. To repair and conserve historic stairs.

How this Involvement Works Out in Practice

The vast majority of stairs in old buildings are made of timber. These stairs can and do have structural defects, but they are generally easy to understand as structures, they give warning of impending problems by deflecting, and mitigating the defects does not always need to involve engineers. Stone is a brittle material, and defects in stone stairs often manifest themselves without warning. Building owners tend to involve engineers more readily when there are doubts about stone stairs, which leads to a disproportionately high percentage of enquiries to engineers relating to stone stairs.

Cantilevered stairs have been described in the previous chapters. They provide an excellent example of the variety of ways that engineers become involved, whether the stairs are traditional in form and materials, or are modern feature stairs built in new materials. The way these stairs 'work' structurally has been the subject of much debate between engineers for many years. The answer is that the structural action is highly dependent on the degree of contact between one tread and another, and how rigidly fixed the treads are into the supporting wall.

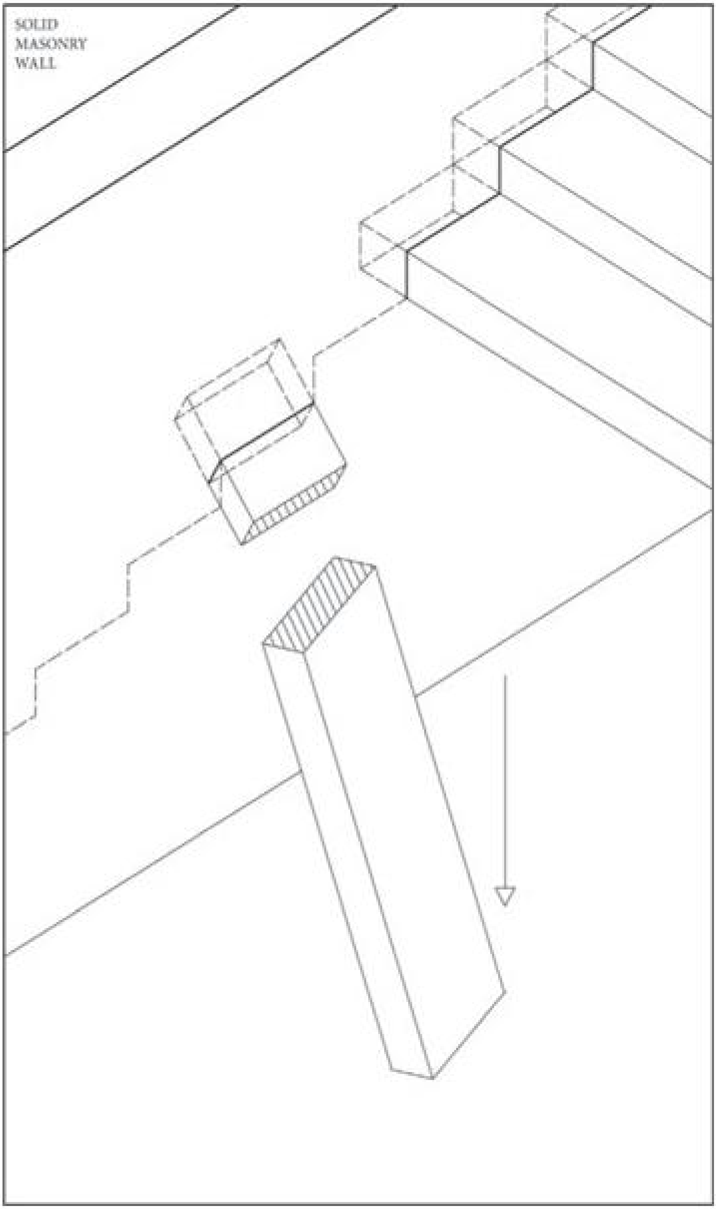
Cantilevered stone stairs can either be constructed at the same time as the walls which support them or inserted after the completion of the main structure (see Figure 7.1). Historically, the benefits of inserting the treads later were that that the walls could have time for the mortar to harden and the foundations could settle and consolidate, and the treads could be inserted much more precisely In new work foundations are not expected to settle and mortars gain strength rapidly, so it is more common to build the treads in as the walls are built.



SOLID MASONRY WALL
POCKETS CUT TO RECESSIVE TREADS
WEDGES/PACKING SLATE TILE (USUALLY) WROUGHT IRON (ST PAULS)
WEIGHT OF WALL
TREAD SLIDES INTO POCKET AND IS WEDGED TIGHT, THEN GROUTED
SOLID SUPPORT TO BOTTOM TREAD
CONSTRUCTED FROM THE BOTTOM UP
A
B
C
NO CONTACT
HORIZONTAL OVERLAP
HORIZONTAL + VERTICAL OVERLAP

7.1 Stone 'cantilever' stair. The rings denote the approximate location of packing. These would have been slate, tile, shell, or, very exceptionally, iron, as at St Paul's.

In the simplest case the only contact that the treads have with the structure is through the connection into the wall, and they can only work in pure bending as true cantilevers – like the individual teeth in a comb. In this case there is no contact between one tread and another (Figure 7.1a). If there is even a small overlap with contact between the treads, then that provides the opportunity for loads to be transferred down the stair from one tread to another (Figures 7.1b–c). However, such stairs are not robust, and if there is a problem there is no opportunity for a tread to shed its load to adjacent treads, and a complete failure of an individual tread could ensue (Figures 7.2–7.3).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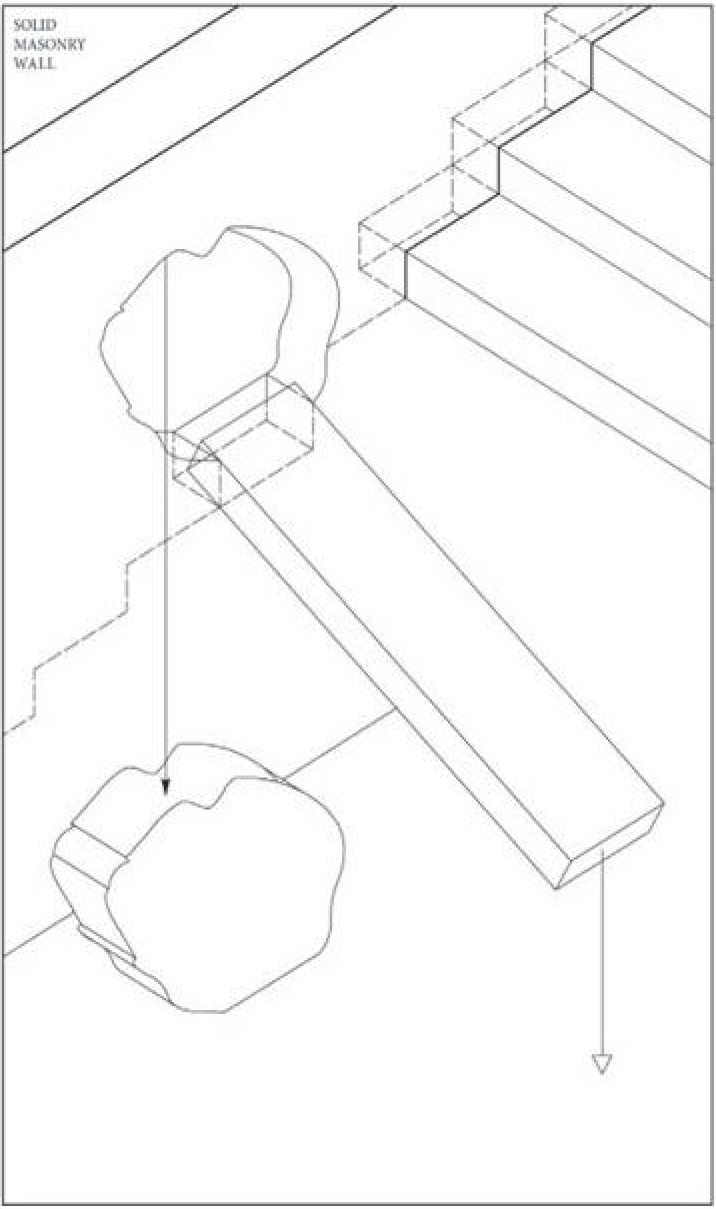
7.2 Pure cantilever – bending failure.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7.3 Embedment failure.

The true cantilever case is simple to calculate, but once one introduces a load path from one tread to another it becomes much more complex. Until quite recently engineering appraisals were usually based on the simple cantilever model, even if in reality there was contact between the treads that significantly increases the strength and robustness of the structure. This load path from one tread to another was regarded as an additional bonus, or factor of safety, which was not quantified.

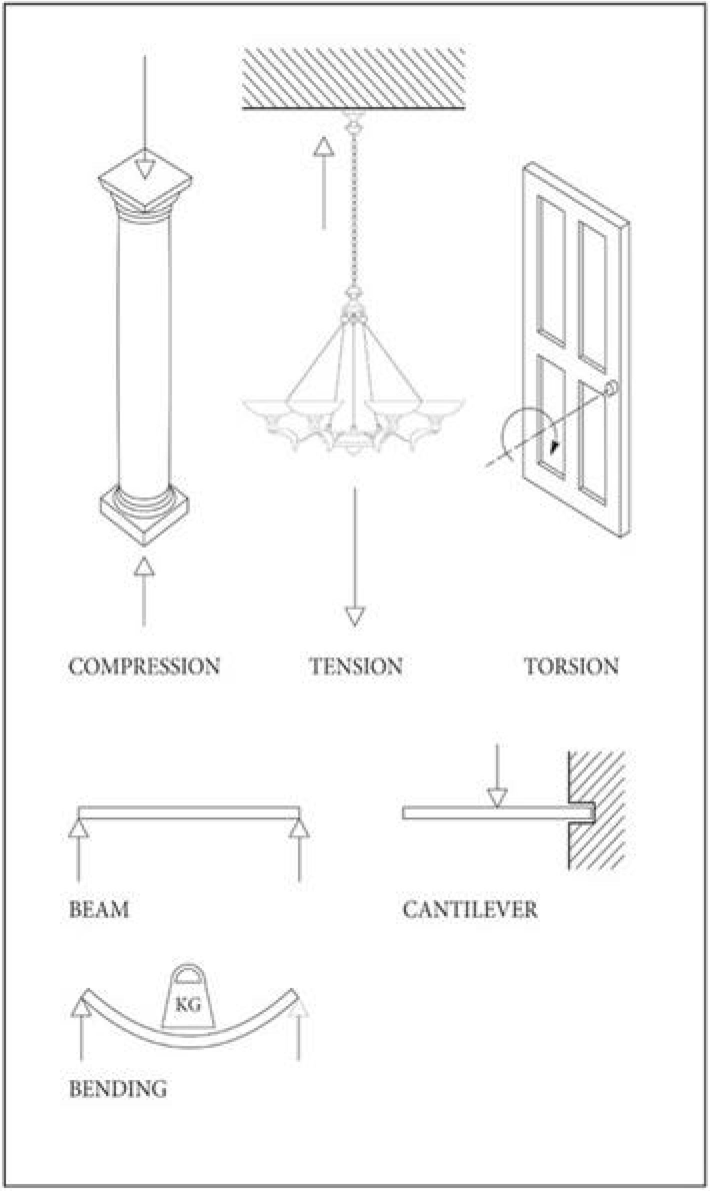
The unfortunate aspect is that when treated as pure cantilevers, virtually all existing cantilever stairs cannot be justified by calculation. Usually the depth of the embedment in the wall appears insufficient. Yet many of these stairs have stood firm for centuries, so the challenge for the modern engineer
is to find a way of modelling the structure that more closely reflects the real situation and allows for the safety of the stair to be assessed. The answer lies in more accurately assessing the tread-to-tread load transfer and its effect. In recent years the challenge of analysing how the tread-to-tread load transfer really works has started to be addressed,

Sam Price has demonstrated that where treads overlap each other and are in contact, loads are transferred into the supporting wall in torsion. The explanation is set out in various papers and reports, the most informative of which followed investigations into the disastrous failure of a flight of the main staircase in the Natural History Museum in Dublin in 2007.[1] The investigations concluded that the treads had failed in torsion, the evidence for that being in the shape of the fracture plane in the stub of stair left in the wall. It was evident that the treads had been severely weakened after the top surface had got worn down and new nosings had been inserted. This involved cutting out a significant proportion of the original solid treads, but the inserted stone was not structurally connected to the original, so in structural terms the cross-section of the treads had been permanently reduced. After these repairs were done the stair was subject to very light use, and the problem did not come to light until the stair collapsed when a group of people happened to use it. The profile of the fracture surfaces left no doubt that the mode of failure had been torsional. Torsion calculations based on the reduced cross-section would have predicted failure, but these were not done as the implications of inserting new nosings were not appreciated at the time. Further calculations, based on the original dimensions of the solid treads, showed that they would have had a more than adequate factor of safety against torsional failure.

The Problem of Torsion

Generally, the best structures are the simplest, and simplicity comes at two levels – in the concept of the structure as a whole and the way that individual components in the structure work. Simplicity in the design of structural elements is generally achieved by arranging for them to act wholly or largely in compression or in tension or in bending, and for the forces to act in one direction only (Figure 7.4). These simple modes of action are easily recognised and understood by most people simply by observing the

world around them. Columns and pillars are clearly compression members, and the chain suspending a chandelier is clearly in tension. A diving board supporting a diver about to launch himself into the air is clearly a
cantilevered beam subject to bending in one direction. In mathematical terms the calculations necessary to assess whether a given piece of structure working in one of these simple ways is adequate are quite simple.

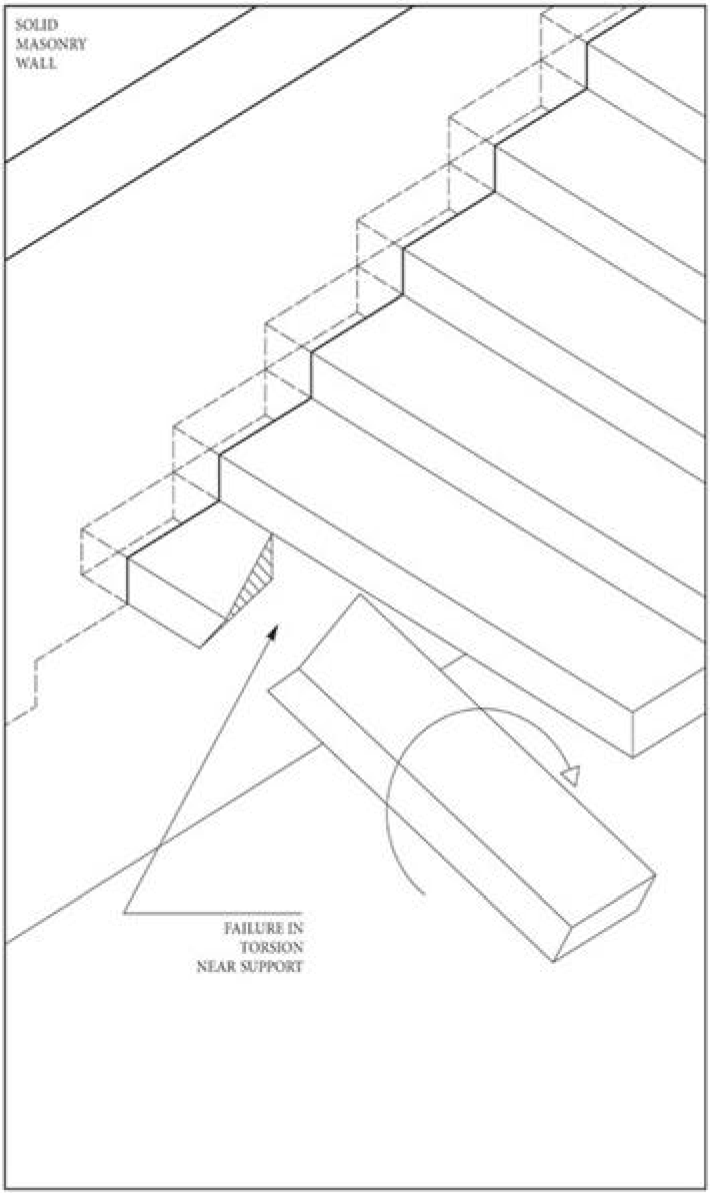


7.4 Simple modes of structural action.

There are other modes of structural action which occur in practice, but which are more complex to analyse. These include plate action, membrane action and torsion. Plate action involves bending in various directions simultaneously, and membrane action involves tension in various directions simultaneously. Torsion involves twisting, and in the world of machines and mechanical engineering it is commonplace, and not regarded as being particularly special. Every time we turn a key in a lock we are applying a torsional force to the key, and when the key breaks off in the lock we experience torsional failure.

However, in the field of structural engineering, torsional action is special, and in the interests of keeping designs simple and therefore economical, torsion is to be avoided where possible. In most cases it is possible to arrange for a structure to be made up of walls and columns loaded in compression, ties in tension and beams and floor plates in bending. The analysis of these types of structural elements is covered in detail in the most basic of university courses on structural engineering, but at university level torsion is often only dealt with in outline, with the message that if you can avoid it you don't have to know how to deal with it. It is then dealt with in detail in modules for students who are particularly interested and able to deal with the complicated mathematics involved. The concept is not difficult to appreciate, but a lot of calculations are required to work out the section properties, the internal stresses and therefore the factor of safety of such structures. The time and cost of that have been greatly reduced since the development of finite element computer programs, but the need to rely on torsional action remains something which engineers would normally seek to avoid.

Structural engineers’ caution when dealing with torsion and brittle materials such as stone and glass is deeply ingrained, and this may explain their readiness in the past to accept the very conservative pure cantilever model as the basis for appraising cantilevered stone stairs. Returning to our Dublin example, investigations showed that the load capacity of the stairs is considerably increased if the contact between treads is achieved via a rebated joint capable of transferring both vertical and horizontal loads. The lesson from all of this is that the detailing of the contact point between treads has a profound effect on the robustness of the stair and how it works as a structure, and any loss of contact due to settlement or movement will adversely affect its performance.



7.5 Cantilever stair: failure in torsion.

Specific Problems in 'Cantilever' Stairs

Complete collapse of unmodified 'cantilevered' stone stairs is extremely rare, but they can be susceptible to damage in ways that conventional calculations would not predict. In one example, in a grand public building dating from the mid-nineteenth century, the bottom two treads of a straight flight were found to have fractured near the face of the supporting wall. The proportions of the treads were not unusual, and the quality of the stone was good. The problem was that the support to the bottom tread was a timber beam that was not stiff. The defect was mitigated by inserting a stiff steel beam under the bottom tread. The original omission of an adequately stiff support for the bottom tread when the building was constructed was very puzzling, as it was a high-quality building, both in terms of its design and its construction. However, the original building accounts showed that the construction was undertaken in two separate contracts, one to build the structure and the other to fit out the completed shell. The stair formed part of the fit-out contract. It appears that those who installed the stair did not quite understand the unusual floor construction, and there was some evidence that the stair may have been intended to be constructed in timber until very late in the design process. In any event, the origins lay in a lack of detailed co-ordination in the design at the point where two contracts met.

In another example, a terrace of late eighteenth-century houses, the top treads of a cantilever stone stair exhibited a pronounced deflection. There was no cracking in the treads, and the general state of the decoration of the walls suggested that the deformations had occurred a long time ago. The wall into which the treads were built was a solid brick wall of quite adequate proportions. However, about a metre or so above the top floor the wall construction changed to timber stud, which is a much lighter form of construction than brickwork. This provided less dead weight and clamping action than was desirable to hold down the ends of the top treads, particularly if several treads were loaded simultaneously, and the treads had deflected so that much of the load passed directly down the flight rather than into the wall at each tread. In this case the explanation for the defect appeared to be that the flight in question had been added to extend the original stair when attic rooms were created. The attic construction was entirely of timber, including the walls enclosing the stairs. The new stone treads were all built into the top of the original masonry walls enclosing the original stair, but nobody realised that they should extend the walls in brick to provide something to hold down stair treads, or take other measures to ensure that the ends were firmly embedded and clamped in the brickwork.

In a third example a cantilevered stair had been strengthened midway between one floor and another by the insertion of iron columns with cantilevered brackets (Figure 7.6).

7.6 Stair with later iron column inserted, which the client wished to remove.

The building concerned was originally a terraced house built in the eighteenth century, but it had been converted for use as offices since the mid-nineteenth century. It was to be converted back to a family house, and the strengthening columns were considered intrusive. The proportions of the stair generally were not unusual, so it should have been able to work without the strengthening. A feasibility study was commissioned to determine what defects had led to it being strengthened and whether there was an alternative and less visible way of achieving the same result. The design of the existing stair was much plainer than would have been typical of the eighteenth century, and plainer than the corresponding stair in the adjacent house.

The investigations showed that the wall into which the stair was built had a history of settlement problems due to the house having been built on marshy ground. Most of the settlement occurred in the first years of the building's life, and it was sufficient for the treads in the original stone stair to have lost contact with each other. The original stair would have been severely disrupted, and the existing stair was clearly a mid-nineteenth-century replacement, installed when the building was converted to offices. The embedment of the nineteenth-century treads into the wall was examined, and the brickwork around the treads was found to be quite loose, with many cut bricks, some of which were little more than rubble. It seemed that this, combined with a small amount of further settlement, had led to the insertion of the strengthening columns at about the same time. The wall had been underpinned at some time in the early twentieth century, so settlement was no longer a problem, and the only reason for retaining the props was the poor-quality brickwork around the embedded ends of the treads. Proposals were developed to work in short lengths and cut out this defective masonry, replacing it with sound brickwork which provided the necessary torsional restraint for the treads to work without the props.

Problems of Diagnosis: The Case of the Geometrical Stair at St Paul's

The Geometrical Stair in the southwest tower of St Paul's Cathedral provides a stunning example of a feature stair, built at the end of the seventeenth century. Its 88 treads spiral up round the circumference of a vast cylindrical chamber. However, the proportions of the individual treads are generous in comparison to later eighteenth-century designs, and it is built from high-quality Portland stone, so it is surprising that so many of the treads are cracked. There have been several attempts to repair them, but only in the most recent work has the reason for the cracks been identified. The cracks are most unusual. They emerge from the wall at right angles and then progress diagonally to a free edge. None of the modes of failure predicted by different ways of modelling the treads mathematically will generate that pattern of cracking. The hidden construction in the thickness of the wall was a mystery as there were no drawings, and the building accounts did not describe it in detail. A small amount of stone was therefore removed to investigate the origin of one of the cracks. A small wedge of corroded iron was found in the mortar bed on top of the tread. A metal detector then showed that there were typically two such wedges on each tread. These wedges were the origin, and were the clue which led to the full explanation of the mystery cracks.

The cylindrical chamber had been completed some two years before the
stair was installed. The upper part of the tower was completed several years after the stair was installed. The stair treads had been inserted into pockets cut into the wall. The underside of each pocket was accurately positioned for a stone bedded on it to be in the required position, but for practical reasons the top of the pockets was set slightly high, making it easier to insert the treads into the wall. The treads were inserted from the bottom up, and each tread had to be firmly installed before the

next tread could be inserted without risk of disturbing the one below it. Instantly hardening liquid grout had yet to be invented, and the traditional method of instantly locking the treads in place was to hammer in pieces of slate or tile. Someone at St Paul's, was taking an innovative approach when they used iron instead of slate, and they did not realise it would corrode and expand. The weight of the tower above the stairs should have been distributed evenly over the whole of the masonry below, but the wedges attracted ever more load into themselves as they expanded and tried to jack up the entire construction above. The huge concentrated load arriving on the top of each tread via the wedges was sufficient to crush the stone locally and cause it to crack.

Fortunately there was sufficient un-cracked stone in each tread for overall structural stability to be maintained, Nowadays the environment in the staircase is not allowed to get damp enough for there to be much risk of further corrosion, so further intervention was not required. The integrity of the individual stones was restored by a combination of pinning and careful vacuum insertion of resin grout, and the stair is back in use free from concerns as to its structural stability.

Landings in 'Cantilever' Stairs

These examples all relate to the stair treads, but stairs have to start and end somewhere, and the flat areas of floor at the top and bottom often take the form of landings built in the same material as the treads. In an engineering appraisal of real staircases it is the landings, rather than the treads, which are usually found to be the least robust and weakest part of the structure. Where there are problems with the treads this is normally due to accidental impact damage, previous repairs, previous alterations or some shortcomings in the workmanship when the treads were installed. Where a stair is enclosed on all sides by masonry walls, and the landings are short, flagstones in the corners of landings can be supported on two sides and they can also provide support to other slabs by means of 'joggle joints', so none of the slabs is required to act as a pure cantilever.

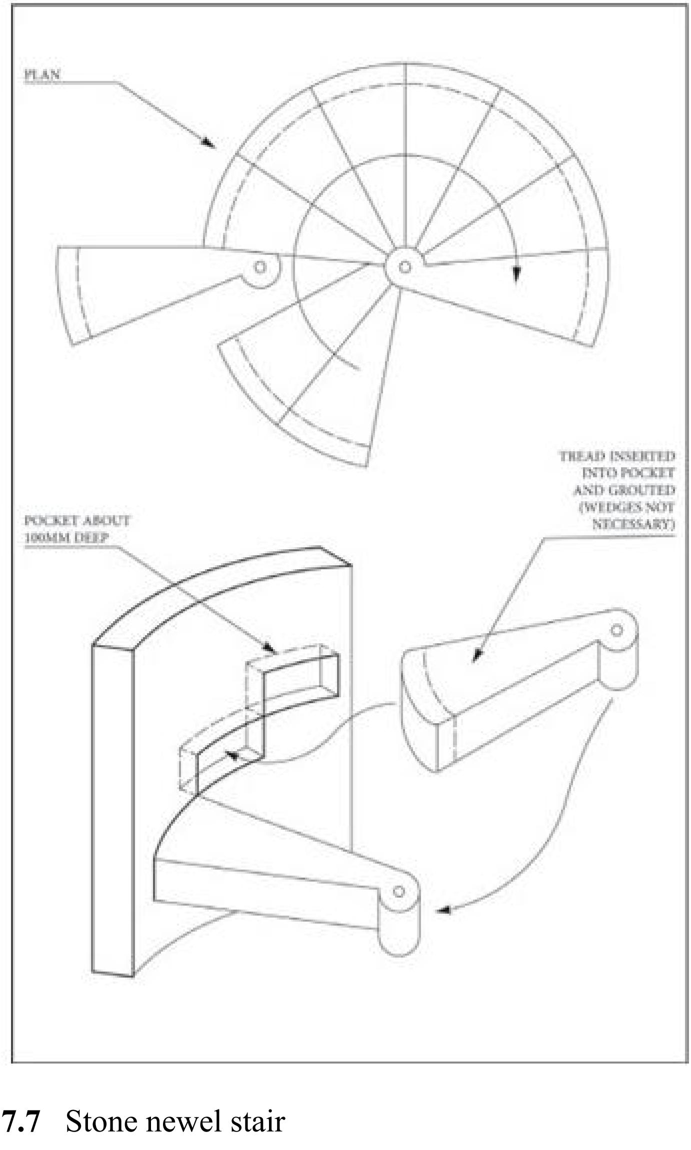
A set of mystery cracks was observed on the very long cantilevered landings of the Great Stair at Keddleston Hall.[2] The landings were too long for the stones in the centre to benefit much from support from the end stones, so they were acting as more or less pure cantilevers. The cracks were perpendicular to the supporting wall and parallel to and close to the joints between adjacent stones, in positions where conventional theory would have predicted no stress in the stones at all. After extensive investigations of the original building accounts and the construction on site, it was evident that there had been a late design change, and when the walls of the stair were constructed the stair had been intended to run from ground to first floor only. The stair from first to second floors and the second floor landing had been cut into the wall after it was completed. As a result the landing slabs were far less firmly embedded in the wall than they would have been if they had been built into the brickwork in the first place. Each landing stone had deflected by a different amount, reflecting the variation in fixity, but the stones were interlocked along the joints between them by joggle joints. There should have been no differential deflection between stones, and the joggles were not designed to cope with it. The joggle joints had to fracture to allow the stones to deflect. In the light of that explanation it was apparent that the cracks themselves were not a particular cause for concern, but the shortcomings in the anchorage of the slabs into the wall needed to be improved, especially where there were doorways in the wall. Mitigation methods included steel angles let into the door thresholds and steel ties between slabs to restore some capacity for load sharing following the cracking of the joggle joints. Loads on the stair were limited by ensuring that all heavy loads were taken up a much more robust back stair. Together these mitigation measures avoided the need to insert intrusive steel beams under the ends of the slender cantilevered landing slabs.

These examples are all very different, but there are some common characteristics. Real problems in cantilevered stone stairs are rare if the stair was properly built in the first place from good-quality materials and has not been altered or repaired inappropriately. The key to appraising such stairs is to closely examine the construction details and the history of the stair and spot abnormalities. That is usually where the problems lie.

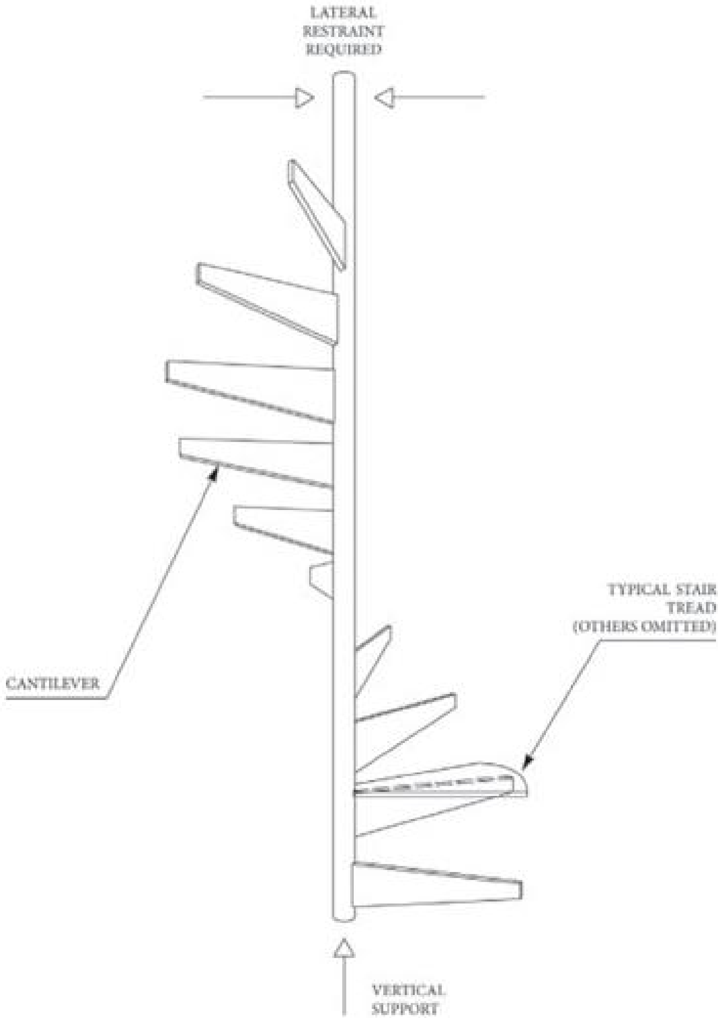
Newel and Spiral Stairs

The simplest stone stairs are in massive self-stable masonry structures such as castles or churches, where the top surfaces of the stones have been set out
so it is easy to walk up them. They can be found in the thickness of massive walls, or in turrets attached to massive walls or towers. In the earliest examples, prior to the early thirteenth century, the stone treads were not built into the walls but were laid on a rubble base,

supported on a rubble vault. After the early thirteenth century the vault and rubble were often omitted and stairs were constructed as a series of tapered individual treads stacked on top of each other (Figure 7.7) In both cases the average stresses in the stone are very low and the structure does not require justification by calculation. In metal spiral stairs the treads commonly cantilever from a central post (Figure 7.8).



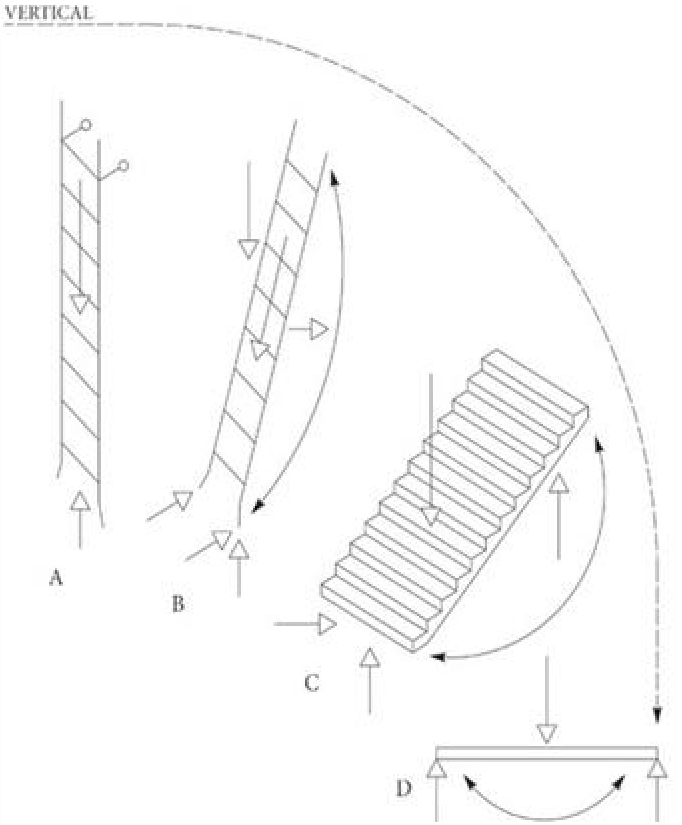
7.7 Stone newel stair



7.8 Metal spiral stair.

Carriage Beams and Stringers

A vast variety of different architectural forms and many different materials are used in these stairs, but they all rely on the same basic structural beam principle, and there are practical and regulation-based limits on the geometry so that people can use them safely and comfortably, and the choice of materials may be limited by consideration of combustibility and fire resistance.



A - VERTICAL LADDER (RESTRAINED LATERALLY)
ACTS AS A COLUMN OR STRUT.

B - INCLINED LADDER
ACTS MOSTLY AS A COLUMN - BUT WITH SOME BENDING

C - TYPICAL STAIR AT 30-45 DEGREES TO HORIZONTAL
SOME STRUT ACTION (USUALLY IGNORED) MOSTLY BENDING

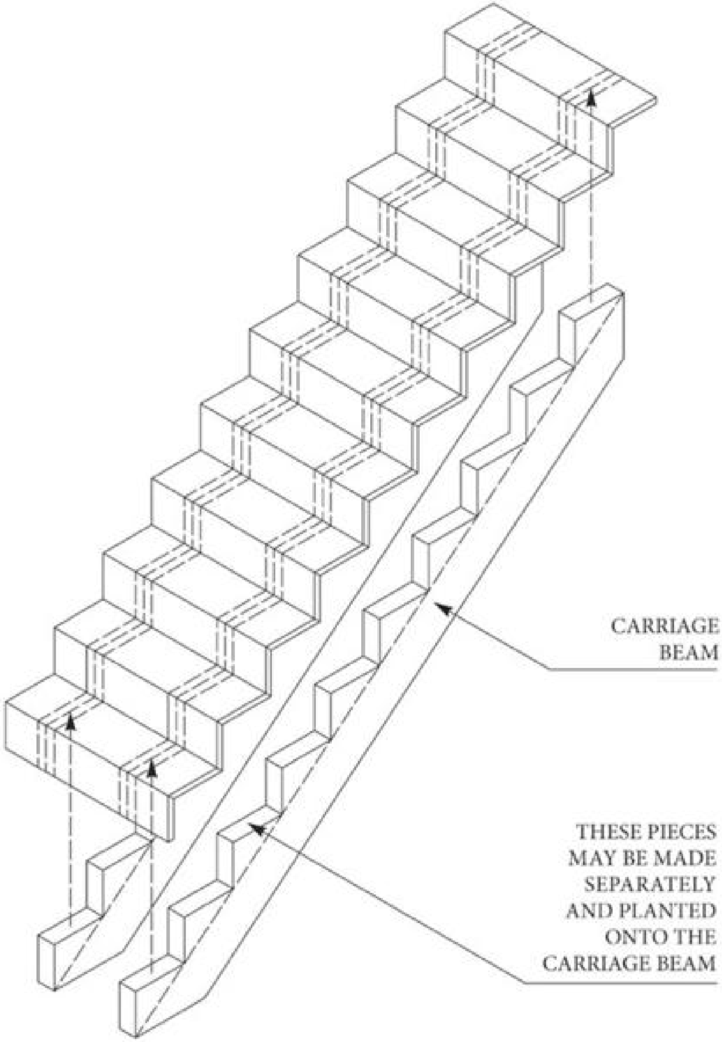
D- HORIZONTAL BEAM - ALL BENDING

7.9 Structural action of a stair compared to a ladder and beam.

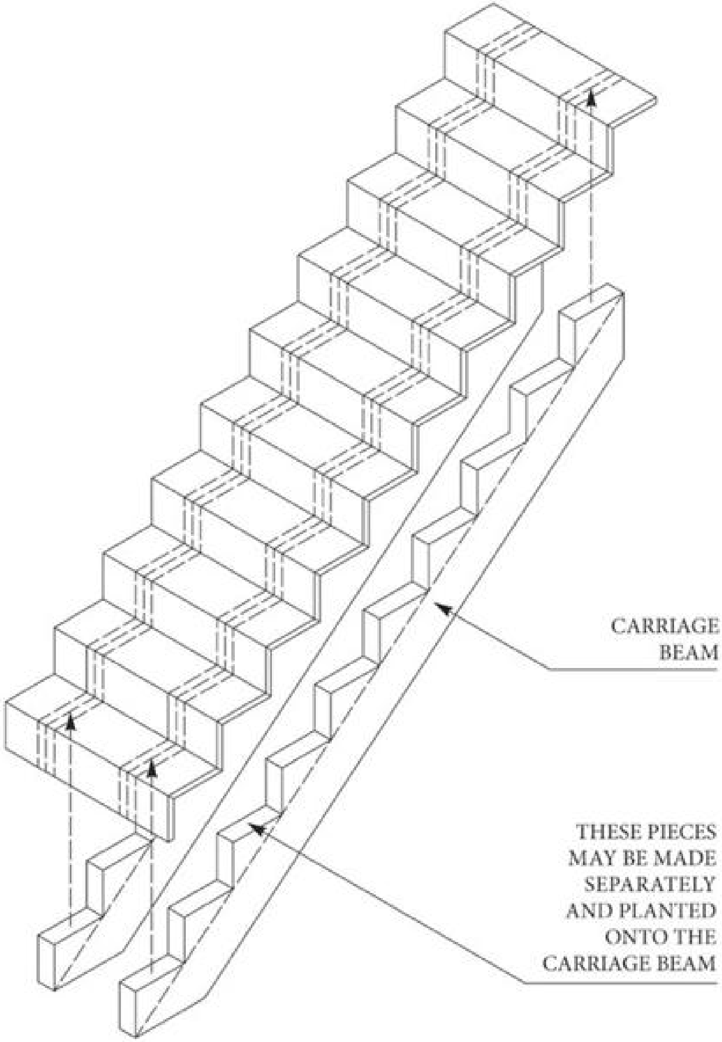
The influence that engineering has on the appearance of stairs therefore derives from the properties of the materials and the manner in which structural joints are made in different materials. An *in-situ* reinforced concrete stair is completely jointless, whereas a timber stair will have many different components joined together. The degree of influence that engineering considerations have on the appearance of a stair will also depend on whether the structure is to be exposed or hidden behind some applied cladding. The cladding may be made of the same material as the structure, but if it is not required to carry loads its details can be determined by purely aesthetic considerations.

The difference between a stair whose structure is exposed and one

whose structure is hidden is evident in even the simplest of cases. Consider a straight stair with, say, eight steps and spanning about 1.6 metres. There are two ways this can be structured. Figures 7.10–7.11 show timber stairs, but the same principles can be applied if the structure is steel, cast iron or aluminium.



7.10 Stringer stair.



7.11 Carriage stair.

One way relies on the stringers to do the work, spanning between the end supports (Figure 7.10). The treads and risers are structurally connected to the stringers. The proportions of the stringers will be governed by the need to make them strong enough and stiff enough to perform their task, even when part of them is cut away to make the joints for the treads and risers. The other way relies on carriage beams under the treads and risers (Figure 7.11). In visually important situations in historic buildings these are normally hidden behind the sloping soffit of the stair, and their appearance is not of any significance. In other cases where appearance was not important – in church towers, for example, the carriage beams were often little more than tree trunks very crudely carpentered to carry stair treads. There are types of aesthetic in more modern buildings where exposed carriage beams are a feature of the design, and great attention is paid to the aesthetics of the details.

Winders and Open Newels

Stairs with winders and open newel stairs have more complex geometry, and it is often physically impossible for the stringers or the carriage beams to be continuous from one wall to another or from one landing to another. In small-scale domestic timber stairs the newel post may extend down and act as a prop around which the winders wind. In open newel stairs the stringers or carriage beams tend to act as props as well as beams, but timber tends not to be fully seasoned when it is incorporated into a building and subsequent shrinkage can lead to deflections which cause concern to the building's occupants. Often, where all the joints are in compression, these concerns are not justified, as the intended load paths are maintained and timber gets stiffer and stronger as it dries out. However, the causes of all such deflections should be investigated.

Reinforced Concrete

Reinforced concrete stairs do not need to have separate stringers or carriage beams, and they work as sloping beams or slabs. They can be clad in other materials, or exposed, and they may be cast *in situ* or precast elsewhere and installed into the building as large components as the work proceeds. Where the concrete is to be exposed and when there are several flights all the same there are advantages in precasting the stair, since the quality of the shuttering (moulds) can be higher and the cost of it can be spread across several re-uses. The surface finish can be better than in *in-situ* work. Careful consideration has to be given to how and when precast stairs are fitted into a building under construction, since they tend to be heavy components that must be craned into position, and clear access to the working area must be available for the crane when the time comes to install them. Concrete stairs are inherently much heavier than steel or timber stairs, though in any given situation there will not be much difference between *in situ* and precast as far as dimensions are concerned. The design of the supporting structure will need to take this into consideration, but in most new buildings and where the stairs are of compact proportions (not feature stairs) the weight of concrete is not normally a factor in determining the material from which the stair is made.

Glass

All the materials discussed so far have characteristics which make them obviously suitable for use in structures, including staircases. The same cannot be said of glass. In its basic form it has a tendency to fracture unpredictably and in a brittle manner when loaded, which is quite the opposite of what makes a good structural material. Yet perhaps because of this, and certainly because of its transparency and sparkling finish, the idea of using it structurally has an appeal which is difficult to resist. Staircases can be gloomy places when all the components are impervious to light, and the use of glass offers ways to lighten things. There are two engineering challenges. One is to produce a material whose behaviour is consistent and is capable of mass production in sizes that are useful. The second is to develop a means of connecting components together so that loads can be transferred from one to another.

Developments in the last 30 years or so mean that glass is available with more predictable physical characteristics than ever before, and there have been developments in the field of adhesives. Nevertheless, these have not yet reached a point where durable structures can be produced made only of sheets of glass glued together. Until that happens mechanical connections are required, usually of metal, and the transfer of loads by that means inevitably involves concentrating load at the connections. Glass is rather better at coping with distributed loads than concentrated loads, and mechanical connections need to be detailed so as to provide a degree of flexibility and resilience, as well as being capable of transferring the required loads (Figure 7.11) For all these reasons, the detailed design and manufacture of ‘glass’ stairs is a matter for specialists rather than engineers in general practice. It is a rapidly evolving subject, and to understand current developments the reader is recommended to search the internet.

Deflections and Vibration

All structures deflect under loads of any sort and vibrate under repeated impact loads. Stairs are subject to repeated impact loads from the footfalls of people using them. However, the natural frequency of staircases usually turns out to be high enough for resonance to not be a problem. Deflection under static loads is also not normally an issue. That is because the sizes of the structural members of a stair tend to be determined by the geometry of the stair, and there are lots of opportunities for secondary structural actions which stiffen the whole structure. Thus stair flights designed as sloping beams will in practice also act as props between one support and the next. Architectural components such as handrails and cladding can also have a damping effect on vibrations in the main structural elements.

Unclad, lightweight, free-standing steel stairs such as escape stairs can sometimes have a ‘lively’ feel to them, but this is accepted because they are rarely used, and people’s expectations are less demanding over something that is for emergency use rather than everyday use. Heavier, long-span structures can have resonant frequencies as low as 4 Hz, which is the level at which problems can arise. These problems are not of an engineering nature; the vibrations do not threaten the stability or integrity of the structure, but are to do with the human response to them. That is partly because people associate flexibility in structures with weakness, and partly because vibrations in that frequency range can induce nausea.

Long-span stairs, including dog-leg feature stairs without propped landings, need to be checked to see that their natural frequency is high enough. If it is not, the natural frequency can be raised by stiffening the structure, either by increasing the member sizes or by introducing further supports which act as dampers but are not part of the overall structural system. Another approach to dealing with resonance is to increase the inertia of the structure by increasing its weight, so that the energy from the footfalls of humans is no longer sufficient to induce motion. This does add a layer of complexity to the design and analysis of the stair, but the types of structures where it is likely to be necessary are those that are special and will require a higher level of engineering input to their design for reasons other than vibration.

7.12 Composite glass and stainless steel staircase, Apple Store, Glasgow. (Michael Tutton)

If a stair structure is to be clad in material that is stiffer than the stair itself, the detailing of the cladding needs to include joints that will allow structural deflections to occur without loading up the cladding. In any piece of construction the load will, in practice, take the stiffest path available – whatever the engineer has written in his calculations.

Stair Wells and Surrounding Walls

Stair flights cannot exist in isolation, and they are always associated with other elements of construction that may require some engineering input. Where the stair passes through a floor the opening needs to be properly formed with a clear structural relationship between the floor and the walls enclosing the stair. In modern framed buildings the normal arrangement is for the holes in the floor to be trimmed with beams that form part of the main frame, and the enclosing walls serve no structural purpose and are supported floor by floor. Sometimes columns forming part of the frame may be incorporated into the surrounding walls. Where the building does not have a separate frame the walls around the stair will normally be loadbearing. Occasionally, in framed structures, the arrangement is less clear-cut. The floor trimmers may be sized only to carry the floors themselves, and the walls are built so that they sandwich the floor beams but do not rely on them for support. The self-weight of the wall is transferred to the foundations via the wall itself. Such an arrangement is quite satisfactory until someone decides to remove a large section of wall towards the bottom of the building and assumes, having seen the beams, that no additional support is required. The options in that case are to design out the need to make the openings, or arrange for posts to transfer the vertical loads through the zone where walls are to be removed.

Handrails

Handrails are not normally seen as major structural items, and where they are simply fixed by brackets to a surrounding wall there is no need
for engineering input. In other cases, where the handrails are supported on balusters, some engineering input is necessary, if only to establish the structural principles behind how they work. On stairs and landings that are subject to crowd loading a full engineering input is usually required.

The structural principles available to the handrail designer are:

1. The handrail is fixed to walls at both ends, and spans horizontally between fixings. The balusters serve merely to hold the rail at the right height.
2. The balusters act as individual vertical cantilevers, and the handrail serves only to link them together so that individual balusters do not undergo gross deflections when someone leans on the handrail.
3. Some of the balusters are designed to cantilever, and the handrail spans horizontally between them. The remaining balusters just hold the handrail in position. This could lead to some of the balusters being substantially larger than others, but the principle can be achieved with balusters of the

same section, if console brackets are installed on the outside to act compositely with the balusters.

Conclusion

The constraints on geometry imposed by the dimensions of the human body and safety considerations limit the opportunities for innovation. Future developments in the engineering of stairs are likely to involve the use of new structural materials developed for other purposes, and the timing of that is unpredictable. What is certain is that the requirement for staircases is not going to go away: the world is not big enough for everything to happen on one level.

Further Reading

The design of staircases is far less of a challenge for engineers than it is for architects, unless the stair is to be made of special materials (e.g. glass) or is a feature stair deliberately conceived to involve daring structural devices. For that reason there are no books exclusively devoted to the subject. However, the reader will find in the bibliography reference to a number of published papers, mostly on cantilevered staircases.

Notes

1 Natural History Museum Dublin, unpublished structural report into the collapse of a flight of the main staircase, December 2007, ref 16829, Price and Myers.

2 For a full and illustrated account of how the mystery was solved, see the *Journal of Architectural Conservation* March 2012 “The Great Stair at Keddleston Hall” by Paul Ragsdale.

Part Three

Conservation and Repair

8

Curating Staircases: Cleaning and Maintenance

Lee Prosser

Introduction

This chapter is designed to provide basic advice to owners of historic staircases who are not fortunate enough to have conservators to hand, by illustrating the range of materials found in staircases and offering advice for the proper care and maintenance of historic fabric. It can only act as a brief outline, and further reading is strongly recommended. By far the most useful aid will be the National Trust's Manual of Housekeeping, a compendious and meticulously considered work, which now runs to 1,000 pages in the latest edition.[1]

Like any historic interior, the staircase is vulnerable to damage, but the threat is particularly strong when houses are open to the public, as the staircase is a point of concentrated footfall and greater pressure is brought to bear on fragile materials. In any house, the staircase is a focus of traffic which, in the course of everyday use, serves as the main means of transport for food and drink, people and heavy furniture. Lying as it often does near external doorways, it is exposed to fluctuations in temperature, humidity and airborne particles, which can affect historic materials. Modern demands of comfort often require central heating. Alternating and sudden warming and cooling dries timber joinery and can cause

splits to appear. Wood rots, warps and bleaches; metal corrodes and stone can crack, delaminate or flake under a host of conditions, while all materials can become filthy and unsightly through benign or deliberate neglect. The first are natural processes, which
are often accelerated by heavy use or inappropriate treatment, but can be slowed or halted by judicious preventive measures. The second, that of dirt, is mitigated by cleaning. Safety is another concern, as nowadays there is a greater need to provide for level access or additional means of support. In the absence of lifts, which are expensive and not always practical to install, the staircase often then becomes the target for potentially damaging modification in order to conform to regulations.

Understanding the Materials

All risk is lessened by understanding the materials, and by knowing how they are affected by the natural processes described above. As we saw in an earlier chapter, the oldest surviving staircases were mostly of masonry and stone, but from the late sixteenth century, timber became popular and many thousands of elaborately carved staircases from this period survive. Almost all combine oak with elm, both of which are hard-wearing with good resistance to decay. During the eighteenth century, variation was introduced with new exotic timbers such as mahogany, walnut and cedar,[2] and a fashion grew for stone treads and wrought-iron balustrades. Softwood was also extensively employed due to its availability and cheapness and was, in turn, almost universally disguised with paint. In the nineteenth century even greater diversity appeared; new timber sources such as hard-wearing teak or close-grained pitch-pine were exploited, and monumental structures of highly polished decorative marble appeared in many institutional buildings as a mark of Victorian confidence and a display of wealth.[3] The finish on a staircase would also vary, with timber left 'naked' or untreated, or fed with oils, painted, grained, varnished or polished to a high gloss using shellac and other materials. In the twentieth century, more experimental staircases of composite stone or terrazzo with fittings of brass and bronze were introduced. It is rare to find these finishes unaltered, usually due to changes in fashion or because tried and tested materials were superseded by cheaper, modern finishes. Where they do survive, they should be cherished and preserved.

What is Grime and How does it Get there?

Dust is the most visible manifestation of dirt. It is a ubiquitous by-product of human and natural activity and one component of several 'agents of decay',
including chemical and biological agents, light and even custodial neglect. Like any surface in the house, the staircase is constantly under attack from a host of foreign bodies, exacerbated by its position and heavy use. Dirt and dust arise principally from clothing fibres, skin flakes and hair, which humans and their pets shed at a bewildering rate. Dust may seem harmless, but cumulatively it is acidic, and if not removed can become permanently cemented to the material on which it settles. It can also form a food source for biological pests which can do damage in their own right. Other materials are

constantly present in the air, such as soot, mould spores and other particulates. Footwear is also a potential danger, with shoe treads carrying mud and pebbles, mineral salts such as winter road grit and animal waste into houses, where they are deposited and can cause scratches and be driven into historic surfaces. This is exacerbated by deep treads on modern trainer shoes and a propensity to employ dusty gravels near historic buildings for aesthetic reasons.

Humans are also fairly oily creatures, and on heavily used stairs the handrail can develop a build-up of sticky acidic residue, deposited from the oils and sweat secreted through skin. Food, drink and oily deposits from cooking can find their way onto surfaces by accidental spillage or the condensation of airborne vapour, acting in turn as a magnet on which dust may settle and bond. Other agents of decay include light, which can bleach or darken timber, and fluctuations in temperature and relative humidity, which also cause problems of their own, but these are often symptomatic of specific problems which fall beyond the scope of this chapter.[4]

How We Cleaned in the Past

In the past, the build-up of dirt was more rapid and visible than today, with open fires and higher concentrations of soot and pollution in the atmosphere. In addition to the house-maid flicking around with a feather duster, both timber and stone staircases were treated in the same manner as floors and liberally swabbed down with a mop and bucket, supplemented by scrubbing with detergents or abrasives such as sand. Oils, wax and polishes were subsequently applied, most

recently augmented by mechanical buffing as a labour-saving device. Proprietary polishes were also used liberally for details such as brass decoration, and extensive residues from careless cleaning may still be seen on many staircases.[5] Over time, a staircase might be repainted repeatedly, usually without much careful preparation, leading to a build-up of paint layers and the loss of definition on mouldings. Attempts to save
time and money spent on frequent and time-consuming preparation can also be seen in the application of varnishes to timber surfaces. In our more conservation-minded world, most of these techniques are now understood to be highly damaging to old materials, but if undertaken sensitively, considered carefully and employed correctly, with the right tools and materials, cleaning still plays a vital role in the maintenance of historic fabric.

Cleaning

Cleaning should be balanced with the need for the staircase to continue in active use. Dirt may occasionally form part of the patina, and hence charm, of the staircase, and so over-zealous and frequent cleaning may do more harm than good, and should be avoided. In order to find a balance, some form of monitoring should be put in place to assess the effectiveness of a cleaning regime and allow owners to become aware of any other underlying problems at the earliest opportunity. This can be rolled into a general maintenance regime, which could highlight any damage or potential problems before they become serious. This is discussed further below. For dirt as for problems of accidental damage, prevention is better than cure. Simple precautions such as the provision of doormats can capture a great deal of grit and dirt which might otherwise make its way onto historic surfaces, and limiting or policing risky movement of liquids, food or heavy items on the staircase can off-set a great deal of risk. Many historic houses employ rigid housekeeping guidelines to control movement of food and even the type of flowers which may be employed for displays, both to lessen the possibility of water spillage, and pre-empt substances such as pollen or fleshy, staining petals from finding their way onto the historic surfaces.[6] These are measures which apply equally to the rest of the house as to the staircase. In a smaller, private house with a good, historic staircase, tight guidelines need not apply, but understanding the risks, identifying the potential damage and knowing the best solution for resolution remains as valid as for larger buildings.

Dusting

Dusting should form the basis of all good housekeeping. Dust can abrade or scratch vulnerable surfaces if it is simply wiped away, and so should rather be lifted with gentle vacuum suction, or blown.[7] Vacuuming can be followed by occasional buffing with a lint-free duster or chamois. Conversely,
over-dusting can be damaging. It should be perfectly acceptable to allow a modest build-up of dust over the course of a week or two, rather than attempting to keep surfaces free of dust at all times, as this could contribute to cumulative wear and tear.

Wet cleaning

Cleaning by liberal wetting and mopping in the old-fashioned way is likely to drive dirt into crevices, and simply moves dirt around, often leaving unsightly tide-marks, and so should be avoided completely. Many of the chemicals found in cleaning fluids can be detrimental to stone, as some contain bleaches, caustic soda and acids. Sodium can introduce soluble salts into stonework, leading to future problems. For ingrained dirt, a gentle hogs-hair bristle brush may give a beneficial effect, but expert conservation advice should be sought for deep stains, as specialist gel poultices have proved effective in some cases.[8] A more immediate need for some form of wet cleaning will occur with spillages. Whatever the material, these should be cleaned up at the earliest available opportunity. Wood is easily stained and many types of stone are surprisingly porous, allowing oils or fluids to soak into the structure. Even innocuous liquids such as sparkling wines can be very acidic, and attack surfaces within a short while, while splashes of coffee can prove difficult to remove. Blotting the affected area with absorbent paper towels (preferably undyed or colourless) followed by localised cleaning with cotton wool and damp cloths ensures that only small areas are cleaned at any one time, and dried almost immediately afterwards. Small amounts of clean tap-water with a few drops of detergent may help if required. If any form of wet cleaning is required, then it is better to use a damp method rather than a wet one.

Waxing and polishing

Waxing is a tried and tested method of protection, setting off timber with a pleasing sheen and offering a sacrificial layer, but can accumulate if applied too frequently, progressively trapping dirt and grime with unsightly effect if the treated areas are not cleaned before re-application. If waxing is already part of an established regime, then it makes sense to continue, but care and judgement should be exercised if deciding whether to wax for the first time. Timber or surfaces traditionally dry cleaned should not be waxed just as a means of making maintenance cheaper or quicker. Wax builds up, especially in crevices, but can also be rubbed off at particular points of heavy wear.

It can be removed, or at least should be thinned periodically, with white spirit, but this is a time-consuming process and should respond to particular needs, such as unsightly build-up or visible pockets of dirt. Localised reapplication to areas where the wood has been exposed is preferable to re-waxing large areas. Traditional, uncoloured beeswax is the least harmful and most sympathetic. This is preferable to modern proprietary aerosol polishes – which are often synthetic, containing chemicals which can be incompatible with the material and can leave residues.[9] Spray polishes also tend to cover large areas indiscriminately. Beeswax, by contrast, can be applied to small areas with a pad or sponge, and gently worked into the surface with a gentle, circular motion.

What to wax

Waxing may depend on past usage. On many staircases, the handrail is often found waxed, as this provides a sacrificial layer against oily residues, where continuous cleaning of the underlying material may prove detrimental. However, oily grime can be removed direct from the wood safely with mineral spirit in some cases. A mahogany handrail, for example, is more durable than softwood, and would stand up better to dry cleaning. Metal balustrades can also be waxed and cloth-cleaned, but care should be taken because of the likelihood of trapping isolated pockets of corrosion, especially in crevices. Metal polishes, by contrast, are no longer advisable because they are abrasive and will, in time, have a detrimental effect on any surface. Polishable marbles (i.e. those already polished to a high gloss), have been waxed in the past, but continuing this may require specialist advice. Unpolished stone should never be waxed.

Mechanical buffers, once often employed on landings, are rarely allowed in historic houses today. The machinery is often heavy and cumbersome, and a piece of grit trapped in the cleaning brushes can do untold damage.

Painted surfaces

In recent times a worrying trend has been the fashion for removing historic paint surfaces in order to reveal the natural wood on internal joinery. Paint is an important characteristic of the historic staircase, and its presence is integral to a wider understanding of historic décor. Several important painted staircases survive from the early seventeenth century. Perhaps the most magnificent is at Knole in Kent, which preserves its vibrant colours in imitation of expensive and exotic marble. At Kensington Palace in 1807, James Wyatt created an iron balustrade which was intended from the outset to be painted in imitation of bronze, and innumerable Georgian staircases were painted in differing colours, both in the prevailing fashions of the day but also in imitation of more expensive woods. The cavalier stripping of paintwork is, from a conservation perspective, unjustifiable and damaging. Often harsh chemicals are used, which if insufficiently neutralised can continue to affect the underlying material, while exposed timber is usually left dry, and splits as a result. Even worse is the use of sand-blasting on historic timber, which could be considered as pure vandalism and causes irreparable damage. Using hot-guns to remove lead paint is extremely hazardous.[10] More importantly, historic layers, which inform our understanding of the staircase and its evolution, are removed. Any desire to strip paint may require listed building consent and should only be considered for good conservation reasons, and in discussion with professionals in the conservation field.[11]

Historically, paint varied in composition over time. Many early paints contained lead and were bound in oils such as linseed. Modern white tones in particular have been achieved by the addition of zinc or titanium dioxide, with the result that historic paintwork behaves differently over time, becoming discoloured or failing, dependent on age, composition and local conditions of light, temperature and other factors. Only in rare instances are historic paint layers exposed to view, such as at Kew Palace,
where the eighteenth-century back stair has not been painted since *c.*1810 (Figure 8.1) The paintwork here is

particularly grimy and peeling, but is only infrequently dusted, as any form of cleaning is likely to detract from its charm and leave an unsatisfying finish. Some cleaning of painted surfaces is possible, but risks include the dissolving of soluble salts and the development of 'blooms' on varnishes. For bad stains, cleaning with sponges or erasers is an option.[12] A general rule, however, is to conduct small-scale cleaning tests with spirit, pure water or water with detergents in varying concentrations in order to establish any visual and physical effects.[13] For ancillary decorative surfaces such as painted walls or wallpapers, specialist advice should be sought.

8.1 Surviving eighteenth-century paint on the back stairs at Kew Palace, London. To preserve its patina, the staircase is lightly dusted at infrequent intervals. (Lee Prosser)

Good Maintenance and Damage Limitation

Decay is a natural process which should be accepted to a tolerable degree, but wear and tear, though often a slow process, can be cumulative. The greatest danger is posed by casual knocks and bumps, vibration and excessive flexing of the structure through over-use, which can dislodge plaster, loosen nails or pegged elements or even cause structural failure. Timber tread-ends or nosings are often the first elements to split or break, and suffer the greatest stress from footfall. On stone stairs, chipping of treads or erosion by constant traffic is similarly cumulative. This may be due in part to the nature of the stone, which can delaminate naturally, but carelessness is often a contributing cause. Monitoring can help offset damage, but some preventive measures can be employed to lessen impact. Some faults are noticed casually, but setting up some form of regular monitoring, perhaps incorporated as part of a wider survey of the house, can pick up any problems long before they become serious. This need not be time-consuming and could be undertaken on a monthly or even yearly basis. Keeping an ongoing checklist and noting any defects or visual changes would pick up potential problems before they become serious. These include loosening, splitting, cracking and breaking of any timber or stone elements; deflection or bending, signs of rust or corrosion in metal, abrasion or general loss of fabric; the appearance of unsightly marks, white 'blooms' on timber which might be caused by moisture, chips, dents, frass (or woody 'dust' gathering at a single point, usually a sign of beetle attack) or anything out of the ordinary. Remember that not all problems are serious, and may not need any drastic response. For example, the appearance of beetle flight-holes is often met with panic and a standard response to spray or treat timber with chemicals, which might be wholly inappropriate for historic fabric. It is far better to weigh up possible solutions carefully and take expert advice for the best outcome, both financially and to benefit historic fabric. At Kensington Palace, small splits in the heavy decorative panelling of the Queen's Staircase were noticed. The cause was thought to have been the frequent movement of heavy objects like pianos from the ground floor to the State Apartments for functions and events. Before any remedial action was undertaken, the soffit panels were removed with the necessary permissions, and a structural engineer observed the exposed carriage beams with a piano being carried up and down. Normally a failed carriage beam might require strengthening with steel at considerable cost, but in this case it was concluded that the beams were flexing within normal tolerance, suggesting that the splits were natural, or caused by some other agency such as excessive central heating and dry air. In the event, the problem was not serious, but nevertheless, guidelines were modified, the heating turned down slightly and the movement of heavy items is now more closely supervised than before (Figure 8.2).

8.2 Kensington Palace, the Queen's Staircase; investigations to assess the structural integrity of this late seventeenth-century staircase. (Lee Prosser)

Protective measures

A simple housekeeping regime with rules or guidelines lessens many risks and can be augmented with other practical measures. At a wider level, control of humidity and heat can be beneficial. This is easy to over-exaggerate. As heating is now a necessary requirement for many houses, the problem is very common, but simple measures such as positioning radiators away from staircases during installation, and also reducing the heat to a lower but consistent level could also provide benefits. In protecting the actual fabric, carpets, for example, are often considered to form a good protective barrier, providing a sacrificial layer against hazards and also cushioning the stair against vibration. There is also good historic precedent from the eighteenth century onwards for carpeted stairs; an early sign of affluence. However, carpets should be chosen and laid with care. Many have impermeable synthetic foam backing layers, which could cause ‘sweating’ and the trapping of moisture, and in time disintegrate, releasing chemicals which may react with the underlying surface. Similarly, more natural fibrous carpets or rugs can abrade stone and wood alike if not backed with a sympathetic, natural material. The method of fixing a carpet should also be chosen carefully. Stair-rods may require new and intrusive fixings, but modern adhesives are also unpredictable over time. On less important or service stairs, metal nosings and linoleum or synthetic coverings are often employed to prevent slipping and provide a protective cover, allowing more extensive wet cleaning where stairs are exposed to heavier use. These can be damaging, especially when metal strips need to be nailed or screwed into the treads, and modern glues are used, but less damaging alternatives are available. A thin protective carpet laid on the 1770s staircase at Queen Charlotte’s Cottage in the 1960s was stuck with modern synthetic glue which has failed in its original purpose, but also defied recent attempts to remove the residues. This illustrates the need for an assessment of reversibility in advance of any new or replacement measure (Figure 8.3).

8.3 Mid-1970s carpet and nosings to a staircase of 1771, though originally installed in order to protect the timber, have proved irreversible due to the use of synthetic adhesives. (Lee Prosser)

A notable failure to provide protective measures is commonly found during redecoration or renovation works, when the staircase is particularly at risk from dust, abrasive grit, paint splashes and careless working practices. Too often these hazards are ignored and cleaned up with the completion of the job. Protective measures which should be considered include the use of a thin material such as ‘correx’, laid and taped over vulnerable elements such as balustrades, foam wrapping around the handrail and some form of protection applied to both the treads and risers of the stair, to protect against steel-capped boots (Figure 8.4).

8.4 Protection in place during building works. This included pre-cut foam, applied to the handrail with cable-ties, ‘correx’ sheeting on the balustrade and a waterproof, plastic-coated textile, similar to carpet protector, applied over a floor fleece, itself held in place by low-tack tape for maximum reversibility. (Lee Prosser)

Accessibility

The modification of a staircase to give extra support, or to make it comply with current Disability Discrimination Legislation, is an issue which is still in the process of evolution with regard to historic buildings. Legislation changes over time, and measures put in place now with enthusiasm and considerable physical intervention may in a few years be superseded and require upgrading or alteration, with yet more damaging consequences. Similarly, mechanical equipment of any sort has a limited life before needing replacement, invariably with a different specification, size and requirement. Listed buildings currently have some exemption if the damage caused by installing such measures can be considered to outweigh the benefits, but this is a difficult philosophical line to define, and many owners would prefer to make such modifications for practical reasons, or on principle.

Modifications include the addition of some form of visual distinction on the treads to assist visually impaired people, to prevent the likelihood of tripping, and extra handrail measures (Figure 8.5). Many historic staircases have balustrades which are considered too low by modern building standards, or are fragile by nature, especially if the traffic on a staircase is high, leading to a greater risk of accidents.

8.5 Kensington Palace, a secondary, reversible handrail added to a stair of 1807. The new balusters rest on the stone treads, and no other fixings are used. New is distinguished from the old by the use of different materials. (Lee Prosser)

There are no firm and fast solutions to these problems, as each staircase presents its own problems and the many aspects of safety are beyond the scope and competence of this chapter. Owners should apprise themselves of any legal obligations with professional advice, and consult a conservation surveyor to consider options and alternatives. In almost all cases there are usually sympathetic, reversible alternatives which can achieve the same effect without the need to intervene in the historic fabric. Two examples from Kensington Palace illustrate the dilemma. The Red Stair is an early nineteenth-century domestic back stair, constructed by the architect John Nash in 1819, which was brought into general use as a convenient way to allow visitors to climb through three floors to follow the public route. The staircase is elegant and steeply ramped, but also fairly insubstantial, and within a short while sheer numbers had loosened many elements of the timber balustrade and caused cracks in the plasterwork to the underside, suggesting some form of structural stress or even failure. Possible solutions were examined, and remedial measures, such as the addition of balustrade brackets, the insertion of steel supports and a secondary handrail, were recommended. However, these interventions were considered too damaging and were rejected; instead the staircase was taken out of the public route and returned to its earlier occasional use by staff who were aware of its fragility and limitations (Figure 8.6).

8.6 The steepness and flimsy construction of this staircase of 1819 created hazards, but its importance ruled out excessive strengthening measures. (Lee Prosser)

Luckily, this could easily be accommodated, but the monumental 1690s King's Staircase was another matter, which could not be solved so easily. It has black marble treads, combined with low levels of natural light in order to protect extremely important wall paintings by William Kent. Several accidental falls and the use of the important ironwork balustrade for two-way traffic demanded a reassessment of safety measures which would respect the historic importance of the staircase while protecting and facilitating visitor safety. Monitoring and a full study of the historic fabric ruled out any intervention of the stair treads themselves, but showed that the dado panelling against the wall was probably of nineteenth-century date, and so considered of less historic importance than other elements. Consequently, a secondary handrail was bolted through the panelling to the underlying brickwork. Light levels were raised on one flight by modifying artificial light from a chandelier, while the darkest flight was illuminated from a small track of LCD lights beneath the new handrail. In this way, a sacrificial element – in this case the new handrail – could be modified in future when repairs or improved technology demanded further intervention, leaving the historic elements untouched. Monitoring continues, both to assess the effectiveness of the new measures, but also the additional pressure on the staircase, and possible extra cleaning or protection which may need reassessment (Figure 8.7).

8.7 Kensington Palace, the King's Staircase. A secondary handrail, added for safety, accommodates an adjustable LED lighting system, though in such a sensitive space, the light levels need to be policed closely. (Lee Prosser)

Conclusion

The range of materials found on historic staircases is wide, and invariably each example will differ from another by reason of these materials, past use and prevailing environmental conditions. The subject of cleaning and maintenance is similarly broad, limiting what can be said here to a basic outline and general guidance on the best approaches, as well as what not to do, while also highlighting a few of the problems and dilemmas which might be encountered. However, it

hopefully serves to illustrate, as part of a wider, informative book on the subject, that the staircase needs careful consideration for its adequate maintenance and protection, as a special and valuable component of any old house worthy of proper attention. Owners are invariably engaged in a balancing act; continuing to use the staircase for the
practical purposes for which it was designed and keeping it polished, clean, or brightly painted, as they would wish to do without too many limitations. Ultimately the best approach is to remain vigilant, pre-empt problems with monitoring, and when introducing new regimes or new ideas, conduct tests before initiating full-scale changes. Finally, if in doubt, leave matters to a specialist conservator.

Notes

1 The National Trust, 2006, *Manual of Housekeeping: The Care of Collections in Historic Houses Open to the Public*, Amsterdam and London, Elsevier Butterworth Heinemann. Hereinafter referred to as *The Manual*.

2 The staircase at Dyrham Park, Gloucestershire, has walnut and cedar staircases, introduced around 1693 using imported North American timber as a symbol of status.

3 The staircase at the old King Edward VII Sanatorium at Midhurst, constructed in 1906, was of Moulmein teak, which was believed to have antiseptic properties, but was also hardwearing and has withstood a century of hard cleaning with remarkably little effect.

4 Reference should be made to *The Manual* (see note 1) when thinking about protection from these other natural hazards.

5 See *The Manual*, p256, for more information on removing these, and the use of templates and suggestions for cleaning.

6 Most usually banned flowers include peonies, while lilies are normally 'emasculated' by removal of pollen-bearing stamens.

7 *The Manual*, p205, has a fuller section on dust.

8 In these cases, advice from a specialist should always be sought.

9 *The Manual*, p145. For waxed floors, see p218. Methods of applying wax are covered on p221.

10 The effect should, however, be reiterated, as burning vaporises the lead bound within it, which can then be inhaled.

11 There are a number of useful works on historic interiors. These include: James Ayres, *Domestic Interiors*; Ian Bristow, *Architectural Colour in British Interiors 1615–840*; Charles Saumarez Smith, *Eighteenth Century Decoration* and Michael Forsyth and Lisa White, *Interior Finishes and Fittings for Historic Building Conservation*. Fuller details will be found in the bibliography.

12 *The Manual*, p180 gives more detail.

13 This method of small-scale testing is equally valid for all methods of cleaning.

9

Repair and Conservation of Timber Staircases

Donal Channer

Introduction

The timber staircase is one of the great triumphs of the craft tradition. The methods of construction – and the design developments these allowed – were evolved by the craftsmen who made the stairs and their knowledge was passed from master to apprentice through the centuries. Staircases have always been individually made to fit the buildings they are in, and although there may be great similarities of design, each situation is different. It is crucial to know how something is constructed and how the parts work together in order to formulate a plan for its repair and conservation.

Planning the Work

Confronted with a staircase requiring repair and attention, it can be very difficult to work out exactly what is wrong, as the underside is often concealed by decorative plasterwork or panelling. While it may be apparent that part of the stair is sinking or deforming, it may not be possible to decide whether this is due to the timber stair itself, or what it rests on, without unsightly investigations, or even partial dismantling. A video endoscope can be inserted into a hole to inspect the interior, and a long, sharp probe may give some idea of the condition of the timber inside. Rot and beetle damage can be rife inside the structure and may not be noticeable at the surface until it is fairly advanced.

Safety and access

The primary consideration with stairs is always safety. While it may be necessary to take a stair out of day-to-day use because its decorative elements are fragile, it must be strong enough for emergency use unless access can be prevented totally. Loads can be very heavy and localised, and any weakness in the structure can be dangerous. Techniques of conservation which may be appropriate to other forms of woodwork will not be appropriate for use on stairs as they will not give sufficient structural strength. Inserting props and reinforcing parts with steel can upset the forces at work in the structure and lead to undue loads bearing where they are not designed to. This may not show up until the structure has absorbed the change. This means that conservation work for stairs, particularly those that are to remain in constant and general use, is usually replacement of parts, and much of the work will involve careful copying of elements which are no longer serviceable.

Assessing the major issues

It is not unusual to find that old stairs have been altered to suit changes in the house or that they have been brought in from elsewhere. John Harris in *Moving Rooms*[1] records many instances of the reuse of joinery items. Changes in width of flights, slight awkwardness of dimensions, quarter-landings which are rectangular instead of square, uneven rises at the top or bottom can all suggest the stair started life elsewhere.[2] Awkwardness in the run of the handrail and banisters of unusual proportions will almost certainly mean they are not in their original position. In such cases it will be essential to work out how all the parts have been adapted to their new situations, and deformation may be due to the alterations coming apart. Sometimes the work has not been well done, the parts do not fit properly and sorting out the muddle can be time consuming.

Dismantling and temporarily removing the stairs may be required. This will allow the supporting and ancillary structure to also be repaired. Damage to the original fabric may be caused in the process, but this must be weighed against the necessity of repair. One of the most difficult situations is where parts of the stair have deformed due to shifting of the building or decay of the structural elements and rebuilding can be the best or only way of dealing with this. In a stair which has sagged badly, all of the joints will have been disturbed, nails will have bent, tongues slid in grooves, and tenons in mortises, as joints have twisted. Jacking it up so that all is level again will not close all the joints and these will need to be checked as they may well have opened up in the process. Dirt will need to be removed from open joints and mouldings and strips that have been added to cover them will need to be removed.

Repair

Worn treads

Treads may be worn, but their unevenness gives old stairs charm and interest. There will come a stage when the treads are so thin they are not strong enough. The area of wear will centre on the walking line, about 450 mm from the handrail, and will not reach quite to the back of the tread. It may be possible to reinforce from below, but this is not always feasible. In many stair designs it is possible to extract the treads and replace them, but this will cause considerable disruption. It is possible to recess worn areas with a router. The banisters and the next riser up will restrict the area which can be reached, but a good flat area can be produced and a patch glued in place. Care must be taken to ensure that the recessed area is perfectly flat so as to achieve good adhesion. Heavy weights should be used to hold the patch firmly in place while the adhesive sets. When all is set, the patch can be brought level with the surrounding surface, which may not be flat, and the front rounded to match the nose.

If the nose has broken away, the broken area may be squared up and a close-fitting repair glued and pinned in place. The riser may have a tongue and this should be removed so that the repair piece will have a greater area of contact with the tread for the glue to work on. When the nose repair has set, it may be levelled and the repair shaped into the main area. The mouldings under tread noses give considerable support to the noses and should always be glued as well as pinned in position.

Copying details

Removed items will have layers of paint or other finishes on them which will change the profiles. It is better to

match the stripped profile and then clog it with paint to match the rest. If replaced parts are to blend in, they must
match exactly in profile. This requires careful measurement and preparation of cutters. Modern spindle moulder and router cutters are ground to profiles adapted for continuous machine use and have broader grooves and blunter points to avoid overheating. Moulding planes have narrower grooves and sharper corners. Generally only the use of the correct tools will produce the correct surface finish.

The traditional scratch-stock, for instance, is just a piece of steel ground or filed to the required profile fixed to a handle. This is dragged along a piece of wood and while seemingly very crude is capable of producing fine results and is suitable for short lengths of moulding. Repetitive carved decoration under paint often turns out to be cast from 'compo', which is a paste made of animal glue and finely powdered chalk, or even papier mache; if this is the case, an impression can be taken of a thoroughly cleaned example and further examples cast using traditional or modern materials. Impressions can be taken of hand-carved work, but re-entrant shapes will usually prevent a full cast being taken. Copying carvings is exacting work as the aim is to reproduce another craftsman's style and not to have your own work noticed.

Resin repairs

Non-structural parts may have damage and small areas missing. These can be filled with a two-part filler, levelled and coloured with artists' paints to match or painted over, depending on the proposed finish. Deep holes should have pins knocked in, with heads below the finished surface to help the filler grip. Glue mixed with sawdust is not reliable. Fragile parts not subject to wear or stress can be consolidated by brushing resins onto them. The resins are formulated to be very thin and to penetrate the wood easily, however, they do not penetrate very far and they do not make the wood very hard. The best results are achieved by injection, but the main problem is access to backs and the hollows of carvings. The resin is not usable for long, so the work needs to be carefully planned and done in short sessions.

Glues

Traditionally stairs were made using hot collagen or animal glues, if adhesives were used, which needed to be applied hot.[3] These are quick to form an initial bond and have the advantage for conservators of being reversible, as they may be softened by heat, moisture or methylated spirits. Their major drawbacks are that if their consistency is not correct, or if they are boiled before use, they lose strength. The surface chills and forms a skin which can prevent adequate contact and adhesion with the timber, which ideally should be heated before the application of the glue. Because the glue does not set, hard joints which are under continuous tension in their length can creep or slide, particularly in warm or moist situations. Traditional joinery is designed using wedged through-tenons, dovetail housings and other similar techniques so that adhesives are not necessary. Modern PVA glues are easy to apply and are used widely, but they are also subject to creep and, depending on formulation, have varying resistance to water. Urea formaldehyde, epoxy and resorcinol glues are irreversible and resistant to both moisture and heat.

Beetle infestation

Evidence of beetle attack will be seen as a yellowish, slightly gritty-feeling powder (frass) in undisturbed areas or in flight holes. Furniture beetle holes are about 2 mm diameter; death watch holes are 3–3.5 mm. The timber will be soft and friable. These can only be eliminated by the application of chemicals in the form of liquids to spray, or gels to be wiped onto surfaces. The grubs of these beetles live inside the timber, sometimes for years in the case of death watch beetles, and eat the fibres. In order to be effective the chemicals need to be in contact with the insects and penetration of the timber is very limited. Some parts of stairs can be very thick and there will inevitably be grubs left in the middle which are unaffected. Access is very problematical and there is no point in treating only the bits which are easy to access. Squirting through small holes can help, but there is no way of knowing how well the timber inside is covered and it is in the interstices around the converging parts where the spray most needs to go which are most difficult to get at. Treating chemically for beetles cannot be relied on to completely eradicate them, and a return visit will almost certainly be necessary in a few years.

Chemicals that are suitable are controlled under the Pesticides Regulations 2009 and should be applied in accordance with the manufacturer's instructions. The British Wood Preserving and Damp-proofing

Association, the Timber Research and Development Association, the Health and Safety Executive and Natural England all have recommendations. The latest advice should be sought.[4] Beetle infestation is less likely to occur where the relative humidity is kept within the 50–65 per cent range. This should be the level throughout the house, but the internal enclosed parts of the
stairs may have a higher level if moist air is trapped. Appropriate means of allowing adequate ventilation should be investigated.

Timber that has suffered beetle attack has no strength and cannot be relied on. Many old timbers were used in much larger sizes than is required, but the beetles may have removed more than half the material. Beetle attack is often localised as the grubs work out from their hatching area, so damage may be very serious in one end of a board but not the other. Insect attack, if found in stairs, is unlikely to be confined locally. All surrounding woodwork should be inspected and treated. Any untreated timber acts as a reservoir for future infestation. The beetles are particularly attracted to traditional hot animal glues. Replacement timber should be preservative treated, ensuring that newly exposed surfaces are treated on-site before they are fixed. However, it is better to select timber which is resistant. There are cheap tropical hardwoods available from sustainable sources which can be used where not seen and will have the advantage of indicating which elements have been replaced.

Wet and dry rots

These will be seen as softening of the timber, cracking along or across the grain, sagging and bouncing of the structure. If diagnosed in the early stages it may be possible to remove the rotted parts and splice in new material using resistant timber. There is usually little alternative to replacement of affected material as it has no strength and will have deformed. Both wet and dry rots are associated with dampness and poor air circulation. The enclosed areas under stairs are particularly prone. It can happen that the main part of a ground floor has been concreted but the area below the stairs has not because it is awkward to access. This will result in that area becoming particularly damp as moisture will migrate there from the main floor area. All means such as grills in the panelling below the stairs, or even small holes in the bottom riser, should be used to promote airflow. Reducing the moisture content of the timber by preventing water penetration directly or by seeping or condensation will be the first priority. Chemical treatments can hinder or prevent infections but will not make the timber strong again. Squirting through holes can help access difficult areas, but good penetration is important and a thorough drenching should be given. Advice should be sought from an expert as to currently recommended treatments and chemicals. Whatever is done to the stairs will inevitably be required on the nearby woodwork, so a general plan will need to be made.[5]

Types of Stairs: Specific Problems

Stairs in a cupboard or cottage stairs

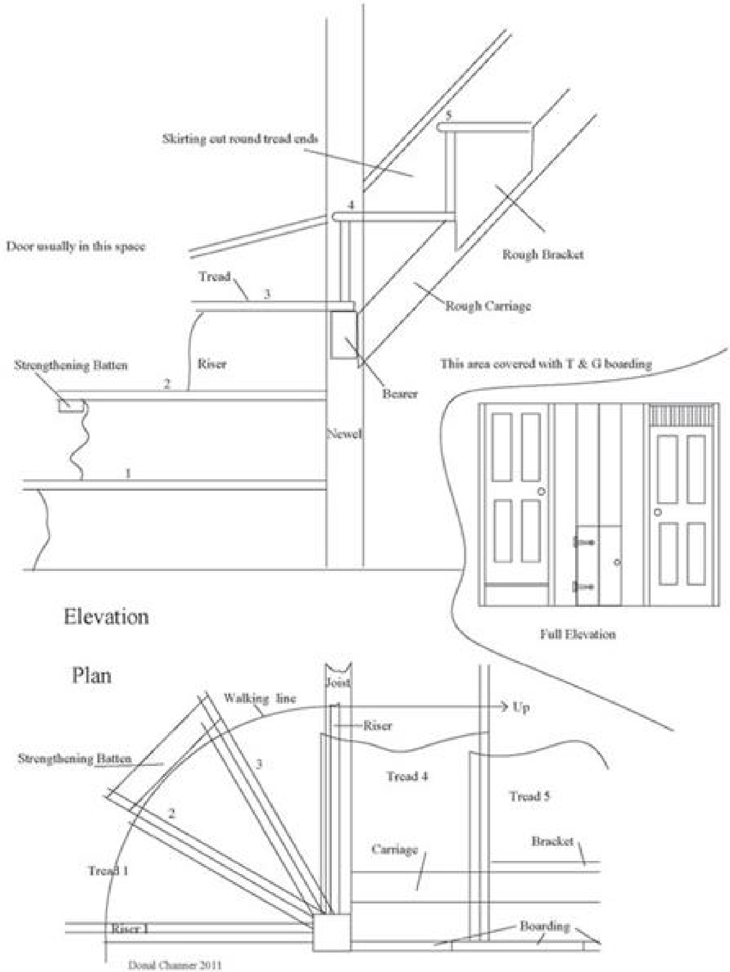
This type of stair is found throughout the country from the earliest time to the end of the nineteenth century. The door keeps the heat downstairs in the only heated part of the house. They are built on-site using only nails and can be made of oak or pine and quite often elm. It is quite usual to find elm used for the winders in pine stairs as it is very strong across the grain.

The winders radiate around the newel and are nailed to it. It is unusual to find more than three winders. The winders rest on ledges nailed to the walls and are also nailed to the newel. Sometimes they have a batten to strengthen them housed into the top of the back of the riser below and nailed up into the riser above. The pitch is usually very steep, sometimes as much as 47°. The flyers (the steps of the straight flight) are supported on brackets nailed to carriage pieces and these rest at the bottom on a joist or bearer mortised into the newel and let into the wall and a floor joist from the floor above. The grain of the brackets which support the steps may run horizontally or vertically; they are nailed to the carriages and the treads and risers are nailed to them. The wall skirting is cut to fit around the steps, usually by cutting the shape out of a single board, but sometimes made by building up horizontal elements and nailing them all to a batten on the wall. The vertical boarding enclosing the stairs usually has a door below, giving access to a cupboard.

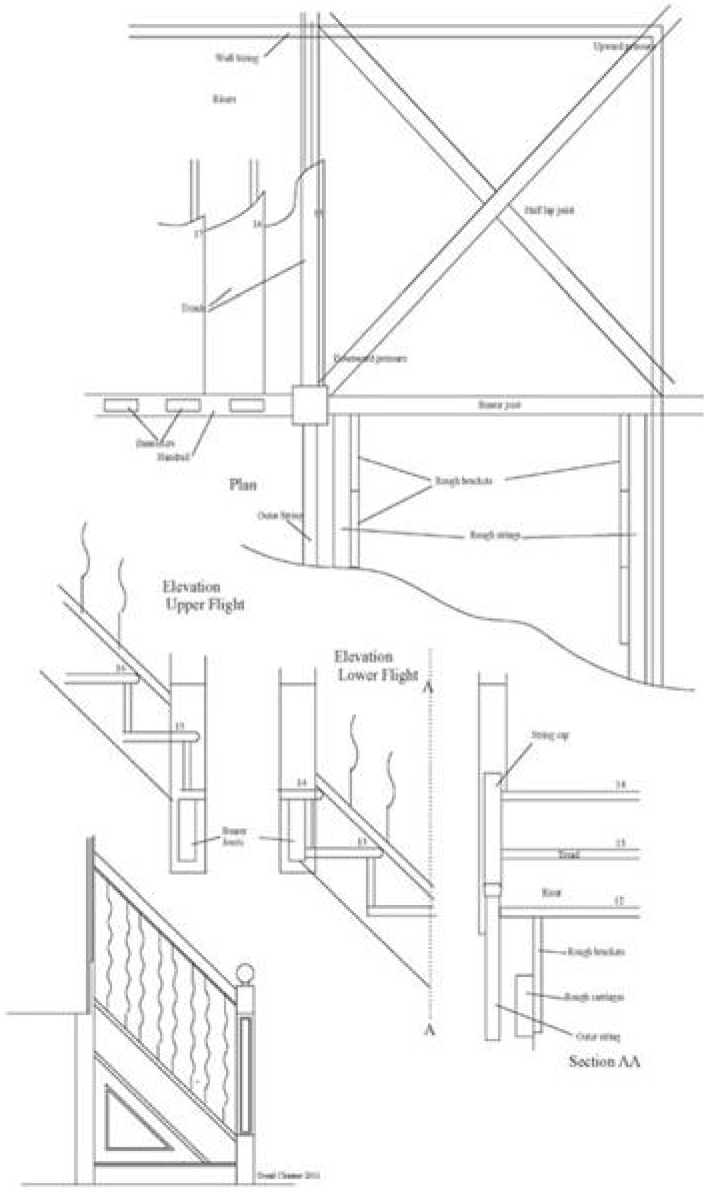
All the parts in contact with the walls and floor should be checked for decay and beetle attack and any affected parts replaced. Treads will be worn and may need attention. The carriage pieces can sometimes pull away from the lower joist and can be reattached with screws. Since the boarding is independent of the steps it is possible to replace treads, risers and carriages without disturbing them; this is often done. Extra carriages can be inserted to add rigidity and strength. It is important to ensure free ventilation under the stairs as modern damp-proofing measures can send moisture to parts of walls and floors which have not been sealed by those measures. Any mustiness suggests wet or dry rot and must be investigated.

Quarter landing and closed-string stairs

This is the most popular type of stair. It can be narrow with two rough carriages or very grand indeed, with three or four carriages. The outer strings support the newels, the handrail balustrade and the bearers at the landings. The bearers support the rough strings, which support the
treads and risers. The treads and risers are structurally independent of the outer string, although they may be nailed to them, and it is possible to replace them without disturbing the outer string and handrail. The landing sometimes has two diagonals and the one across the corner supports the one from the corner to the newel by means of a half-lap joint. The downward pressure at the newel end produces an upward pressure at the corner end. In a first flight the upper newel often extends to the ground and the triangular space is panelled and encloses a cupboard or stairs to a basement with access under the landing.

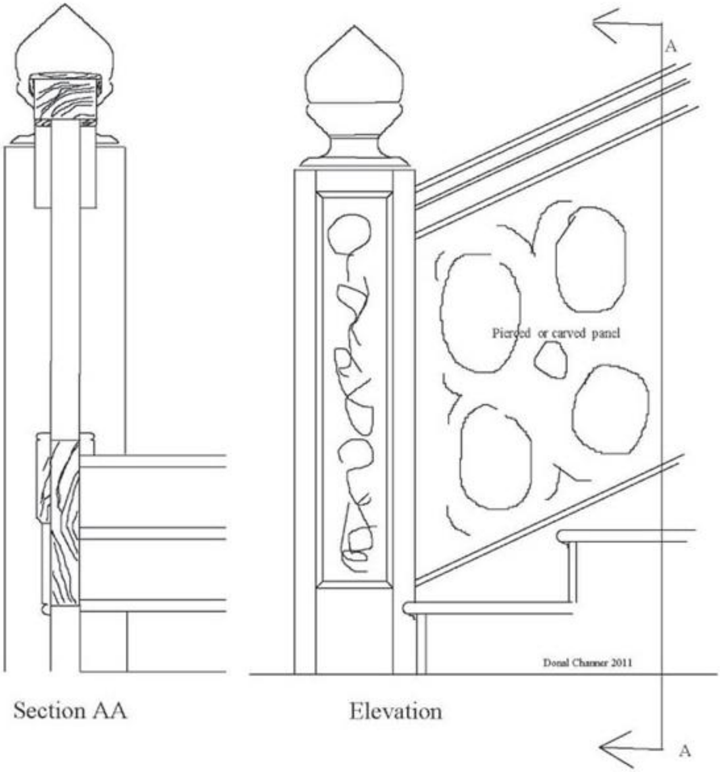


9.1 Cottage stair full elevation and details.



9.2 Quarter-landing closed-string elevation and details.

The outer string and handrail are mortised into the newel. The tenons are held in position by dowels, which in fine work are inserted from inside the stairs and do not show on the outside. They will need to be drilled out if the stair is to be dismantled. The wall string is cut round the steps and
may consist of a moulding above and thinner board below shaped to fit. Handrails are straight and often very broad. Banisters are usually held by spigots below and nailed into the handrail at the top. In stairs with solid panel balustrading the handrail and string are very large and usually built up of several sections with the panels sitting in grooves formed by the sections (Figure 9.3). The sections are nailed together and occasionally the nails will rust. Rather than trying to remove the rusted nails which will cause damage, it would be better to drive in new ones and fill over them. Carved panels may need pieces refixing or bits replacing. Panels with longitudinal splits may have been unable to shrink naturally as their edges are stuck in the string and handrail because they have been painted. If the paint is to be stripped it will be possible to free the panel and, after cleaning the joint, glue it together if the panels are still flat and have not warped. If the paint surface is to be preserved the split may be filled with softwood and painted to match.



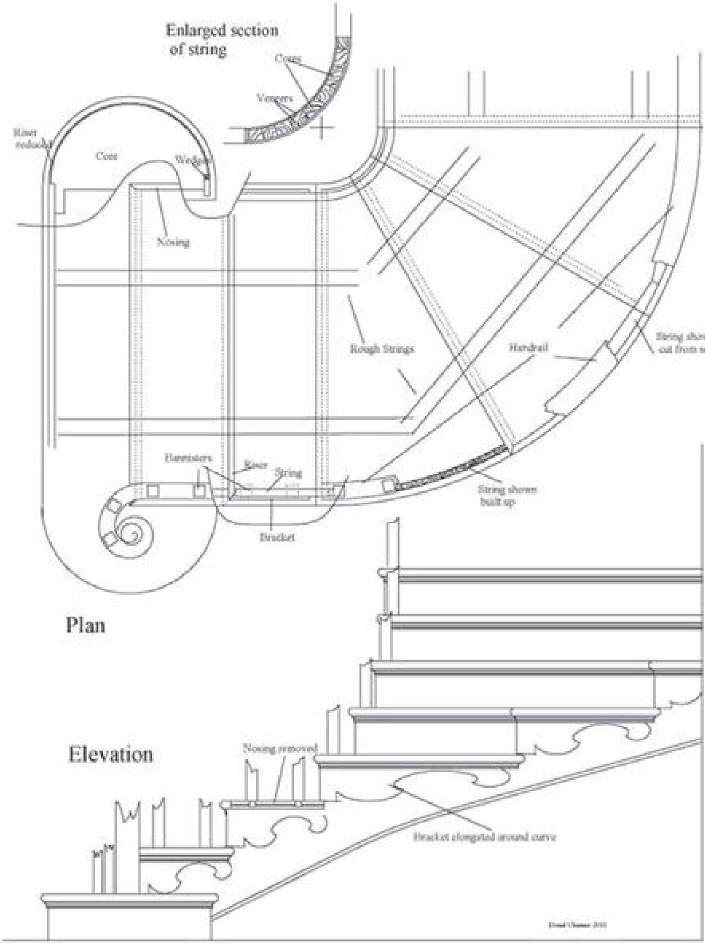
9.3 Pierced panel balustrade.

Cut and curved string stairs

In this form of stair, the treads and risers are supported by carriage pieces, and so is the outer string, which is too narrow to have any structural significance. They are assembled on-site from previously prepared parts. The riser is either mitred to the string itself or passes in front of the string and is mitred to a shaped bracket on the outside of the string, which may be carved. The tread has a return nosing mitred into the end located with a tongue and groove. Frequently a concave moulding runs below the front of the nose and across the end below the tread. This moulding is not merely decorative: it helps to support the nose where the greatest pressure is placed, ensure that it is intact and firmly pinned and glued in position. Differential shrinkage between the tread and the return nosing can loosen the nosing and it may need to be refixed. The banisters are dovetailed into the end of the tread before the nosing return is fitted and are nailed at the top. The wear on the tread can only be repaired by routing out and letting in a board.

The well string is made up by gluing strips together around a former, using animal glue and veneering across the strips. The animal glue attracts beetles and is softened by damp. The straight strings pass outside the curved well string and behind it meet a rough winder string which gives added strength. Deformation at the well will suggest that the glue has softened and that the string is coming apart. Drying out the glue may harden it somewhat but the elements will not be in close contact, so it will not regain its original strength. A replacement string may be made using thick veneers and modern glues wrapped around a former. The internal spaces below the treads will be filled with as many blocks and rough strings as the stair builder could fit in, and all of these will need to be checked to see that they are performing correctly. Space is usually very restricted, there is little room for extra bracing and it may be more desirable to reinforce the stairs with a steel frame from below. The outer strings are flatter and are sometimes cut out of solid boards and joined with dowels and bolts.

These can separate and the bolts will need tightening to correct this; glue blocks can then be fitted inside.



9.4 Cut-string stairs curved on plan.

Handrails are narrower and often made of three sections of mahogany around a pine core. They are continuous over curved cut strings, but on straight cut strings are often ramped and they pass over the tops of the newels, sitting on spigots. The cut strings are mortised into the newels at the landings. The riser for a rounded step is made by reducing the thickness of the riser to 4 mm and wrapping it around a core. The core is screwed to the thick, straight section of the riser and the other end of the riser is held in place by a pair of wedges. Cracks in the curved part of the riser may be due to the shrinkage of the riser, which may have been soaked or boiled before assembly. This has no structural implications as the core behind the riser takes the stresses and the cracks can be filled. The newel will continue through the tread into the riser core, which is in turn fixed to the floor below.

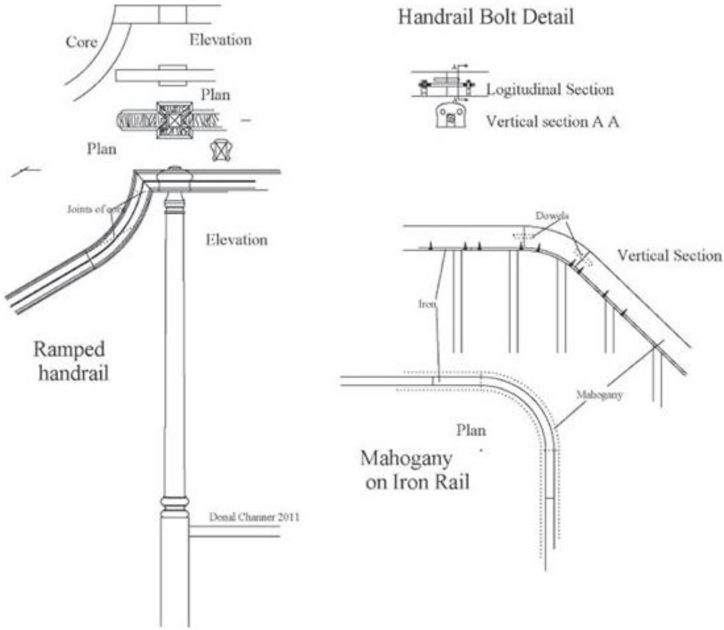
Housed string stairs

In these more modern stairs the strings and risers are housed in both the inner and outer strings and held in place by wedges. These stairs are made off-site and brought in and fixed. The outer strings have a cap to which the banisters are nailed or, in later examples, it has a groove in which the banisters sit while being held in position by thin strips between them. The outer strings are mortised into the newels, as are the handrails. Wider stairs have a rough string or carriage piece in the middle. The wall strings are nailed to the wall. The treads may be withdrawn and replaced. If the wedges have come loose they may be driven in again or replaced. It is important that the wedges should run the whole length of the tread housing and they should be glued in position. It is possible that the strings will have moved apart and that the treads no longer enter their housings by the full amount. If the strings cannot be pushed together screw blocks may be fitted under the treads at each end, but it is important that the blocks span the wedge grooves and run the full width of the tread. The treads and risers of each step are often tongue-and-grooved and glued together before assembly. The backs of the treads are screwed up into the risers from below.

Handrails

Handrails can be solid or built up as two sides and a cap around a core, or even more complicated assemblies in very large rails. If they are built around a core, the top section is sometimes made up of short sections of wood running across the rail. These short-grained cap sections can come loose
due to glue failure, differential shrinkage of the core and cap, or sometimes warping of the cap sections if they are wide across the grain. Loose pieces can be re-glued using modern adhesives, but often will have shrunk or been reduced when refitting, and an uneven surface results and a certain amount of filling will be required at the joints. If this unevenness is extensive, it may be desirable to smooth it, but doing so will expose new wood which will be of a different colour. Where new timber has to be let in to fill gaps it can be shaped to the correct profile and polished before gluing in place if the existing finish is considered valuable.

Handrails are joined by special bolts that are threaded rods with a square nut at one end, which is held steady in a close-fitting mortise in one section of rail and a toothed nut at the other end in the other rail. The bolt is accessed from below and tightened by turning the toothed nut with a screwdriver and mallet. The rails are prevented from twisting by dowels. The joint relies on the ends of the rails being quite flat, or even slightly hollow, and the bolt being as tight as possible. The mortises which give access to the nuts are often filled and can be difficult to locate – they may be concealed by the top of a banister. If a joint has come loose, ensure that the ends of rails have not been rounded. Level curves and vertical curves can be worked in the solid and joined with handrail bolts to the straight rails. If they are built up around a core the joints of the core and covering parts will be staggered so as to strengthen one another. Wreaths, where the rail curves horizontally as well as rising or falling, are always worked from the solid and joined with handrail bolts. Wreaths twist in their length, sometimes quite sharply over small wells, and this means their profiles are distorted and sometimes they can look inelegant, even when they take the only possible shape.



9.5 Handrail details.

Banisters can be turned or plain and can sit on dowels or have spigots at the base, but they have to be cut at an angle to fit the rail at the top. If they are nailed to the rail frequently the wedge effect of inserting the nails lifts the rail and can disturb the joint between the newel and rail. This is usually associated with carelessly executed repairs and may require refixing some or all of the banisters of that flight. Banisters break at their thinnest and weakest points, usually where the grain runs at an angle to the axis. Repair can be achieved by inserting steel dowels, but requires accurate centring and is best done on a lathe or a drill press. If it is possible, replace the repaired banister by exchanging it with one where it is less likely to be struck, such as towards the top of a flight or next to a newel.

Long stretches of straight rails are often strengthened with iron banisters screwed up into the rail and carried down into the main landing joist or outer string. These are usually found in rectangular banisters, but they may be made of iron bars with added rings and corners to imitate those of turned wood. They are blacksmith-made, and fixings vary widely to suit the stair. Screws may become loose and should be tightened or replaced with slightly longer and fatter ones. Wrought iron rails that have a mahogany handrail have a trench in the underneath of the mahogany which covers the iron rail. Fixing is with screws which sometimes come loose or rust away. It is usually easier to drill a new hole in the iron and put in a new screw than to extract a broken one. Joints in the iron and timber will be staggered and the joints in the timber rail are dowelled.

Scrolls often have inlays at their centre and these can fall out. Ready-made replacements are available from veneer merchants and a match may be found or a copy made. The recess will need careful cleaning out so as to have a flat bottom to which the veneer will stick. The veneer will be thin and the hole may need to be filled slightly. If no veneer replacement is available the recess may be filled level with hard filler and stained or painted with a suitable pattern. Inlays also occur in treads and risers and sometimes in tread end brackets; these are made of thicker veneer than is usually available today so it may be necessary to plane some suitable wood to the right thickness.

Always ensure that the bottom of the recess is smooth, flat and clean. The new veneer can be held in place with heavy weights while the glue dries on horizontal surfaces, but may need to be pinned on vertical ones; the pins should be very fine and only partly driven in so they can be withdrawn later.

Conclusion

In view of the great variety of design and construction and the individual history of each staircase an attentive approach will be required to take account of the unexpected throughout the conservation process. Recording the processes and treatments will enable future maintenance and repair of the stairs and the surrounding structure. The staircase usually occupies a major central part of the design of the house and it has an important unifying function, both visually and as a crucial part of the circulation plan: when the stair is repaired the house is repaired.

Case Studies: Adaptation and Reproduction

Dauntsey Park, Wiltshire

The plan of this stair had been altered during a previous rearrangement of the circulation of the house at some point in the 1960s. The large open well had been filled in and floored over at the main landing level and the bottom flight turned through 90 degrees and inserted in the archway (Figure 9.6).

9.6 Dauntsey Park staircase before intervention. (Donal Channer)

On examination it was found that the walls were stud partitions and that what appeared to be a wall string was in fact a skirting fixed to the stud wall with no structural implications. The newels and banisters had been removed and some of them arranged to form a balustrade around the new enlarged main landing. The bottom flight was intact except that the right-hand spandrel had been removed and its space filled up with breeze blocks. The flight was slightly narrower than the archway and the gaps had been filled with plaster. The handrails and newels were in their correct positions relative to the flight. A breeze-block wall had been built under the top of the flight where it met the new section of landing.

When the stud partition was demolished it was discovered that the tread end brackets had been removed and the studs were right up against the outer string and the ends of the treads had been sawn off. The banisters are usually dovetailed into the end of the tread and the joint is covered by the
nose return, but so much had been removed that the banisters would now sit entirely on the extensions. The new banisters would have to sit on dowels on the new tread extensions which would be dowelled onto the treads for strength. A new stud wall was built below the second flight. A short section of the original fascia to the main landing had been left exposed and this was copied and fixed around the well. Two new newels had to be turned, as well as two mahogany newel caps. The client decided to replace the plain rectangular section banisters with turned ones.

The breeze-block wall at the back of the bottom flight was demolished, with the landing behind it and the flight held up with temporary supports. The filling at the side was removed and the breeze blocks below the right spandrel taken away. It was discovered that the flight was not fixed to the floor. The flight was lifted forward and, once free of the arch, turned on its side and carried back through the arch, turned upright and put in its original position. It was undamaged except that an old crack in the left curtail step had opened up.

A new spandrel panel was made for the right side and a pair of cupboard doors to go below the bottom landing. New tread end brackets were made and fitted for the second and third flights, with the new tread extensions and under nose mouldings. New sections of ramped handrail were made to the correct profile and the balustrade erected. The longest section of the main landing balustrade had a newel in the middle, but the shorter section did not and the client felt this was too wobbly, so two steel banisters were made by building up layers of epoxy on a steel tube in imitation of the turned parts of the other banisters. The centre of the scrolls and newel caps had an inlaid pattern, only one of which survived. Copies were made and fitted in all of the newel caps after the recesses had been clean up and filled enough to bring the inlays level.

15 Queen Square, Bath

These stairs were well known and illustrated in many books on interiors written before 1930.[6] The house was built by John Wood the elder in 1730 and retained by him for his own use for some time – perhaps as a show house. The hall has elaborate plaster decoration with a tableau of St Cecilia at the organ on the main wall, with figures playing musical instruments on either side, another in a niche between the window and another one facing it in the other wall. The shutters were once richly decorated with carving and the door to the main first-floor room had a very elaborate carved and moulded doorcase. The fireplaces and shutters of the double rooms were also

carved and moulded. The stairs served only the first floor as there is another stair at the back of the house which serves the full height of the house. The house was bought in the 1920s by Colonel Mallet, a member of the family of auctioneers, and the front stairs, doorcases, fireplaces and shutters were removed and the house was given to the Salvation Army. The whereabouts of the shutters and fireplaces is not known, but the stairs were first installed in a house in Bristol and are now at Norcott Hall at Berkhamsted, with a different plan and altered construction, and three steps removed. In 1986 the house belonged to Bath City Council, who wished to reinstate the stairs, but the owners of Norcott Hall did not want to sell their stairs so it was decided to replicate them

9.7 Dauntsey Park staircase, first floor with well infilled. (Donal Channer)

9.8 Dauntsey Park staircase at completion of adaptation works with open well. (Donal Channer)

An old photograph shows a three-flight cut-string stair with finely carved tread end brackets, an extended curtail step and a bottom flight enclosed with a spandrel panel and a cupboard (Figure 9.9). In the second and third flights the profile of the underside of the steps was that of the carved tread
ends, looking like cantilevered stone stairs. Other contemporary stairs have this shaped soffit but they have a panel at the end of the step with a bracket behind, which means that there is room between the steps and soffit for a carriage to support the treads and risers, but in the Queen Square stairs there was not enough space for a carriage. Inspection of the remains showed that the soffit was hollow but a string had been added below which provided the necessary structure. It also showed

that the stairs were much more elaborate than appeared in the photograph: the treads, risers and soffit were oak with mahogany inlays, while the handrail, banisters and wall panelling were of mahogany. The landings had a pattern of mahogany and oak squares and the soffit of the quarter-landing was veneered with a mahogany star and lunettes on an oak ground.

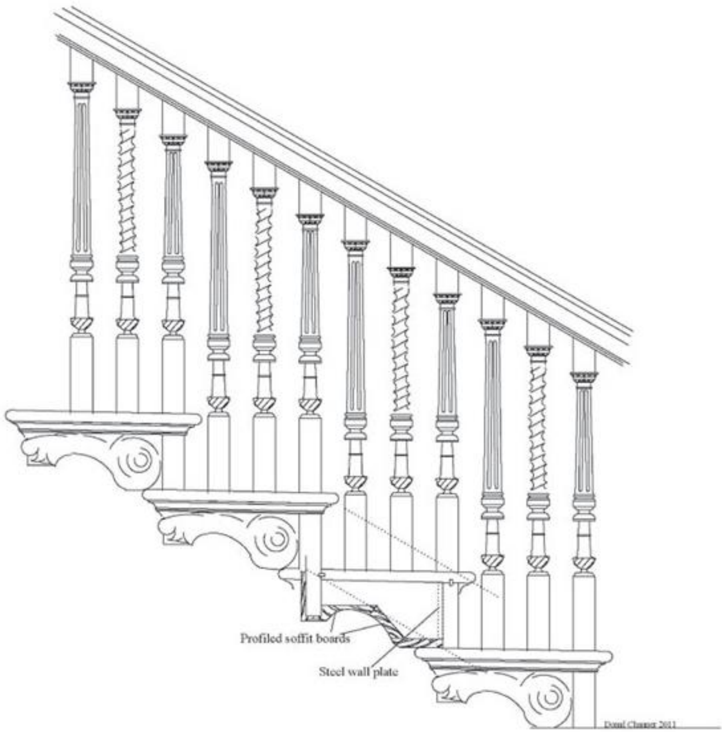
9.9 Pre-1920 photograph of the staircase at Queen Square. (Arthur Stratton, 1920, *The English Interior*)

The Norcott stairs gave no indication of the construction of the steps and investigations in the wall at Queen Square did not show any signs of cavities that may have held the risers. It was decided to fix a steel plate to the wall at the pitch of the stairs with plates at right angles which could be screwed to the backs of the risers. The steps would also have wooden brackets (which was probably the original method of construction), a steel strap at the outside edge behind the tread end bracket, and the banisters would not only be dovetailed into the treads but the deep handrail core would be screwed down into the tops of the banisters.

Measurement of the Norcott stairs showed the rise to be 6.25 inches and this was confirmed by measuring the plaster moulding which extended around the hall at Queen Square and also the timber moulding across the landing. However, by measuring floor to floor at Queen Square the rise needed to be 6.5 inches, an overall difference of almost a whole step. A return visit to Norcott Hall showed that the treads were all level and the risers vertical and the rise at the nose was indeed 6.25 inches; however, when leaving and glancing back at the stairs it was noticed that all of the banisters were slightly bent: they were joined to the treads at an angle of about 93°. Examination of other staircases in Queen Square showed that all the painted ones had level treads and the two mahogany ones had a slope across the step. The stairs at No. 15 had sloped by 0.25 inch from back to nose, which increased the apparent rise of 6.25 inches to an actual one of 6.5 inches. When they had been installed at Norcott Hall with the treads level the banisters had to bend in order for their tops to be vertically above their bases.

Each banister has four sections: a square base the same height as the step; a mid section with a fluted vase and a

square knop; an upper section which varies; and a square top section of uniform height with an applied carved moulding around it, as well as one carved into it. Each step has
three different upper sections: a short fluted taper, a spiral turned taper, and a tall fluted taper (Figure 9.10). A jig was devised to allow the straight fluting to be carried out on a lathe and the gearing of the lathe was reversed to enable the spiral fluting to be done as well. The handrail is built up of two sides and a top around a core. The newels are fluted and have carved Corinthian capitals.



9.10 15 Queen Square stairs, details of flight.

By taking very careful measurements of the extended curtail step and the positions and heights of the banisters it was possible to reproduce the exact shape of the step and also the fall and sweep of the open scrolled handrail above it. The shaped soffits for the steps were made up of four sections of profiled oak and assembled and then inlaid with a strip of broad mahogany featherbanding. The bottom flight was assembled in the workshop with its rough carriages and cut strings. The handrail with its ramps and scrolls was fitted and then removed. The bottom flight was transported and installed in one piece. At the bottom of the stairs is a dog gate which has a wavy
criss-cross pattern when open and which folds up to form a flat panel in the wall. The wall panelling is shaped to follow the angle and curves of the handrail. The dado rail has the same profile as the handrail.

The aim was to make the stairs exactly as they were originally so they were not stained or coloured, but waxed and left to fade and darken naturally, which they have done in the 25 years since they were made and installed. Gratifyingly, the landings have small cracks where the original has cracks. (Figures 9.11–13)

9.11 The Queen Square staircase under construction. (Donal Channer)

9.12 Queen Square, the completed staircase showing the soffit of the second quarter-landing. (Donal Channer)

9.13 Queen Square, the completed staircase; compare with Figure 9.9. (Donal Channer)

Notes

1 John Harris, *Moving Rooms: The Trade in Architectural Salvages*, 2007, Yale University Press, New Haven and London.

2 However, not all inconsistencies and quirks point to this type of change. For instance, treads which slope down from back to front may actually be correct as there was a brief fashion for this in the early eighteenth century.

3 The glues were based on animal hides and had to be prepared in double boilers so that the actual glue did not boil. They had to be used hot in order to obtain liquidity.

4 See, for instance, Health and Safety Executive guidance, *In-situ Timber Treatment Using Timber Preservatives*, available as a free download from: www.hse.gov.uk/pubns/books/gs46.htm

5 The standard works are, Iain McCaig and Brian Ridout, eds, *Timber*, 2012, Ashgate; Brian Ridout, *Timber Decay in Buildings: The Conservation Approach to Treatment*, 2000, E & FN Spon, London; A.F. Bravery, R.W. Berry, J.K. Carey and D.E. Cooper, *Recognising Wood Rot and Insect Damage in Buildings*, 1987, Building Research Establishment, Watford.

6 Such as Walter Godfrey, *The English Staircase*, 1930, Batsford, London; Arthur Stratton, *The English Interior*, 1920, Batsford, London; and George Ellis, *Modern Practical Stairbuilder*, 1911, Batsford, London.

10

The Repair of Stone Staircases

Tom Flemons

THE repair of stone stairs shares similarities with the repair of other elements of a building; there are also idiosyncrasies which mean that repairs differ. The main difference is that although they may form part of a traditional structure where repairs generally follow the principle of repairing using soft and flexible materials, by contrast repairs to stairs aim for achieving a rigid structure. This can lead to a more engineer-led approach, with the structure of paramount importance followed by the aesthetic and other concerns. The key factors, however, as with any repair, are the analysis, the thought process and the quality and craftsmanship used in execution of the repair. A multidisciplinary team may be required to tackle a complex repair; this could include the building owner and their professional team – architect, engineer, possibly geologist, masons, conservators and perhaps other specialist contractors.

When approaching the repair of a stone staircase there are a number of questions that need to be addressed. These include:

- Why do we need to carry out this repair/what has led to the need to repair?
- Have the cause or causes of failure been addressed or is the problem ongoing?

- How is the staircase constructed, and from which materials?
- What is the history of the structure within which the staircase is built?

If satisfactory answers to the majority of these questions can be made then one can move forward to addressing how best to undertake any repairs deemed necessary.

Why do we need to carry out this repair?

Has there been a significant structural failure? What is the cause of this? Is the repair necessary due to wear? Is the volume of traffic responsible for this wear continuing? Have the use patterns altered, e.g. is the stair now open to the public? Is the repair due to a reaction between materials, e.g. the corrosion of ferrous banister rails? Another potentially damaging intervention is the inappropriate insertion of services. This has in some instances taken the form of large-diameter conduit drilled through a cantilevered tread adjacent to the wall line, thus reducing the amount of stone and the strength of that tread.

Has the cause of failure been addressed?

If you have been brought in to address repairs to any building or structure with which you are not fully familiar, the first task must be to build an understanding of the structure. If cracking has been noted, for example, is this a recent phenomenon? Is any movement ongoing? Does it stem from a significant episode? Is the fracture moving? Is the movement linked with movement elsewhere in the building, or seasonal fluctuations? Could the cracking be the result of design or failure based on the original construction? If, rather than 'cracking', the reason for the repair is based on wear, does the wear truly justify the intervention? Can we negate repair by re-routing traffic or are the stairs the only route up the church tower? Non-invasive testing can also be used to determine the extent and spread of any cracking. Techniques such as impulse radar and dynamic impedance can be used to map unseen fractures and faults within the stone.

Answering these questions will require an information-gathering exercise. This should involve utilising any inspection records, quinquennial reports and discussion with the building owners or tenants. It should extend to other craftspeople involved with the building, building professionals, surveyors or architects, documentary records, either written or photographic – this could include incidental visual images, perhaps from periodical magazines such as *Country Life* records.

How is the staircase constructed?

Is the stair supported independently of the building fabric? This may include construction on sleeper walls. Or is it an integral part of the structure, e.g. the spiral stair within a stair turret or a cantilevered flight apparently suspended within the staircase hall of a country house. Whichever scenario one is addressing, it is the understanding of the construction which is of paramount importance before one begins any repair. If the stair is cantilevered, can the depth of the 'tails' of the stairs be determined? If supported from below, is access available to view the support structure?

What are the steps made of?

The stone used could come from a range of types with their own specific characteristics and intrinsic decay mechanisms. The stone type could be almost any stone, dependent upon the location of the building, the affluence of the original owner and the style of staircase.

Marble is used either in structural form or as a decorative veneer, generally in high-status buildings. Another metamorphic stone is granite, whose strength and weathering capability generally means it is less often the subject of repairs. Another stone employed perhaps in a similar way to marble is slate, often used in relatively thin section as treads and risers. Sedimentary stones, sandstone and limestone, are more pre-eminent as their characteristics and workability make them ideal.

If the repair is likely to involve the replacement of elements of the stair or use of 'pieced repair', (the careful removal and replacement of small sections of stone), accurate identification of the original material is of high importance. In order to identify the stone type a suitable match may be determined by the practitioner or specifier through personal knowledge and experience. Alternatively, analytical assistance may be required. Should it prove possible, a suitably qualified geologist or petrographer with knowledge of building stones may be able to visit and assess the stone *in situ*. Alternatively, it may be necessary to take a sample for analysis off-site. This may be possible if stone is to be removed during replacement; however, removal of stone from a highly decorative internal staircase may not be appropriate.

Wherever possible compatible materials should be used – stone that closely replicates the original in its appearance, chemical, physical and mineralogical properties, strength and durability. The aim should be to retain the maximum amount of original stone wherever this does not compromise the integrity of the building.[1]

Many stones of which historic structures were created may have been 'quarried out' or are no longer available. It would therefore be an opportunity to commission geological advice to identify the most compatible stone to use for repairs, from its visual compatibility and, perhaps more importantly, its geological, strength and physical characteristics.

What is the history of the structure within which the staircase is built?

Study should be undertaken into the construction details combined with the history of the building or structure. Is much known regarding the construction, the plans and any records? Gathering such information where possible could assist the understanding and design of any repair philosophy.

Types of Stone Staircase

Staircases can be differentiated from one another with regard to their construction detailing. There are a number of principal designs which are discussed in far greater depth elsewhere in this volume.

The simplest form that can be adopted is to build steps into walls at either end if space was not required below; the profile of the steps will often be rectangular.[2]

A flying or geometric stair is ‘cantilevered’ from the stairwall without a newel. They can be built in straight flights or on either a circular or elliptical plan. Repairs to these staircases, also known as hanging or pencheck stairs, must be treated with the utmost care. The structure of such staircases relies upon the integrity of the design: ‘Part of the load is carried by the wall, with the rest being transferred down the flight from tread to tread.’[3] Such stairs don’t hang or cantilever, nor receive support from the handrail; the treads, however, bear on one another and rely on torsion where they are built into the wall.[4]

There are three common reasons why such stairs will require repair.

1. Wear through a history of pedestrian traffic forming indentation and loss, particularly to the central area of the tread (see Figure 10.15).
2. Structural movement causing vertical fractures within the tread (see Figure 10.8).
3. Expansion of the tails of ferrous baluster spindles (Figure 10.1).

10.15 Worn treads. (Cliveden Conservation)

10.8 Structural movement resulting in fractured treads. (Cliveden Conservation)

10.1 Expanding ferrous spindle tail, Sharpham House, Devon. See Figure 10.3 for the finished repair. (Cliveden Conservation)

Rectifying worn treads

The structural issues regarding the repair of cantilever stairs are explored in depth in Chapter 7 and in the article by Ian Hume cited earlier.[5] The conclusion of this article from the viewpoint of the engineer is that any significant cutting into a tread in order to insert new stone could have a dramatically detrimental structural impact upon the staircase. The resultant advice is therefore that in the case of rectifying wear, alternative solutions should be explored. Dependent upon the appearance of the staircase and without cutting away worn stone, the options may be limited. Solutions that have been propounded include building up the weathered surface with either a hard cement-bound mortar or a resin-based mortar. Neither solution sits comfortably within a conservation context with regard to compatibility of materials, such as their hardness and weathering characteristics. There may, however, be a strong argument for carrying out such a repair if all other options have been explored. If this style of repair is to be undertaken the execution and choice of materials should once more be of paramount importance. The mortar used in such a circumstance would have to be carefully designed to mimic the strength and appearance of the stone using graded aggregates perhaps of both sand and stone dust. This option may also be appropriate if the stairs are to be covered by a carpet or similar. The infill material must have sufficient independent integrity to allow it to perform in even shallow depths at the outer edges of the repair; ideally the outer edges of the repair should be 'cut in' to prevent the creation of feather edges. Discussion with an engineer should precede any such intervention.

An alternative, and one which has been used historically, is to apply a stair over the stair (see the case study, below). Timber has traditionally been used to create a conservative repair that removes no original material and reinstates a safe, regular flight of stairs, thus satisfying health and safety guidelines. This does, however, create a significant visual impact which may preclude it as a solution in certain circumstances. Other, more modern materials could achieve the same effect. Steel and glass can create a more transparent alternative; however, the materials are perhaps less sympathetic to the historic context but form an honest intervention.

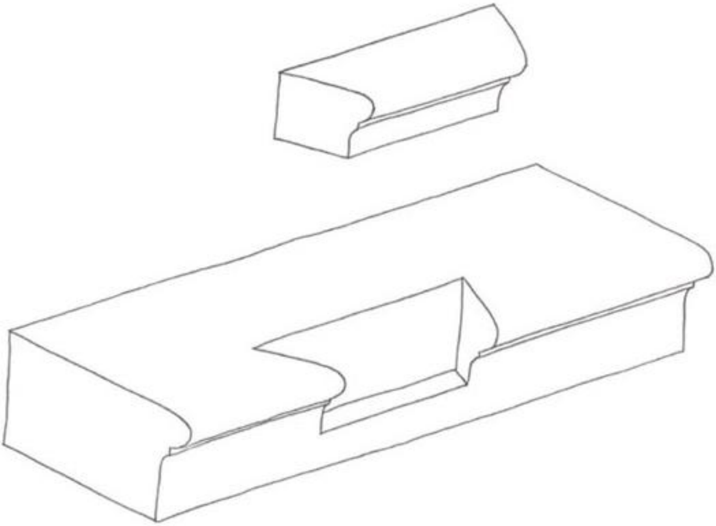
A radical idea, and one which would almost certainly only ever be considered as a last resort, is the insertion of whole new treads. This option is the least conservative and removes the most historical material. The issue of worn treads is something which would generally affect multiple, if not all treads of a staircase, and such a radical solution would not generally be considered. The technical complexities of replacing a cantilevered tread at all but the lower level also make it a difficult proposition. The disruption to other elements of the building – plasterwork, for example – also counts against this approach.

If this direction is taken, initial measuring up and template making would be followed by the creation of temporary support for the adjacent treads, to include lifting capacity for raising new treads into position. In preparing scaffold design, appropriate engineering advice should also be sought as it is inadvisable to place any scaffold onto treads, even if supported from below the corresponding stone. The release of any balustrade would then be required, during which the assistance of a conservation-aware blacksmith or conservation metalwork contractor should be sought to work alongside the stone team. The worn step could then be carefully cut out and removed. Cutting out should be undertaken using techniques to minimise vibration, such as non-percussion drilling or the use of oscillating plunge cutting saws. With the old stone removed and the pocket prepared, the new stone tread would then need to be slid into place with sufficient tail entering the supporting wall. The tail and all joints should then be packed and thoroughly pointed to re-create a rigid structure. The selection of a suitable mortar for such a circumstance would be based upon the strength of the stone being used, compatibility with historic material and depth of mortar required. Where the tail of a new tread enters the wall the mortar may be placed in an area where no air movement is going to allow carbonation of a 'fat lime' mortar. In such a situation a hydraulic lime mortar would be required, whether achieved through the mixing of fat lime with pozzolans or through the use of a natural hydraulic lime (NHL). The characteristics of the mortar should be appropriate to the situation. 'Stone cantilever staircases are one of the few parts of traditional buildings that do not benefit from being flexible: treads must be rigid, tight to their neighbours and firmly embedded into the supporting wall.'[6]

Localised Mechanical Damage

The option of 'pieced repair' may be considered in situations when the treads are fully supported from below or are narrow and supported at either end. Mechanical damage may be the result of the corrosion and expansion of ferrous balusters/spindles or an incident of fracture caused by accidental striking of the stone edge, e.g. scaffold tube, lawn mower! In such a circumstance the selection of a suitable stone for carrying out the repair, as described above, is imperative. The minimum of material should then be removed. A traditional technique which offers both a neat and strong repair is to form the indent to receive the new stone in a key or dovetail shape. The new stone is then cut to fit this form as accurately as possible, retaining minimum joints. Cutting out should be undertaken using sharp mason's chisels with both the bed joint and the vertical at the rear of the repair being maintained as near horizontal and vertical as possible. To reduce vibration when cutting out, a drill may be used to relieve some of the waste; equally, in skilled hands, and if site circumstances permit, the use of small grinders or oscillating cutters may be appropriate. Although often a cause for concern in many eyes, in skilled hands the use of power tools will provide not only a labour-saving solution but, more importantly, one which limits potentially damaging shocks and vibration of any structure.

The carefully cut and prepared 'key-shaped' section of new stone should then be set in place, often with the initial fixing using spots of adhesive
resin, e.g. polyester or epoxy. It may also be desirable to secure the new stone using small additional hidden stainless steel dowels. Once any adhesive has set, the joint can then be grouted. The thin joints should first be thoroughly dusted and then flushed using water with industrial methylated spirits (this acts to break down the surface tension). Subsequently, a thin mortar based on a hydraulic lime binder can be poured or injected into the joints. Final pointing can be undertaken to the outer edges of the joint using small spatulas or 'small tools'; ideally, due to the small amount of mortar being placed, it should be undertaken while there is still moisture in the grout but after the initial set/de-watering has occurred (see Figure 10.3). Re-setting of the spindle can involve the use of poured resin or cold packing with lead wool.



10.2 Sketch showing a key-shaped pieced repair. (Tom Flemons)

10.3 Pieced repair to nosing, Sharpham House, Devon. See Figure 10.1 for the damage before repair. (Cliveden Conservation)

Where mechanical damage has occurred recently, the fragments have been retained and the break edges are 'clean', it may be possible to re-set the pieces. The techniques used will be dependent upon the size of the damaged fragments and the level of traffic anticipated upon the stairs. In order to re-set a nosing, some form of resin adhesive will be required. If the stairs are external, re-setting of fragments should not include a full layer of adhesive which will form an impermeable barrier preventing free movement of moisture. A repair undertaken in this way could result, during the winter, in water becoming trapped at the resin interface, and when frost occurs the fragment can be forced clear of the body of the tread. The answer is to 'spot glue' the fragment; however, one must not rely solely on a bonded solution – such a repair should be augmented through the use of non-ferrous dowels, either stainless steel or phosphor bronze.

If the size of fragment permits, then the dowelling should be set within the fragment. This is a skilled operation and requires proficiency and experience. Both the fragment and the tread are initially dry cleaned to remove any dust or particles which may prevent the two sections being brought cleanly together. A minimum of two dowels will be required, of a minimum diameter. To mark their position, first establish their desired position and direction. On the break surface one can then apply a small spot of acrylic paint or similar, as the two surfaces

are brought together the paint is transferred, giving corresponding marks on each surface. Pencil lines or low-tack tape should be used on both sections to describe the direction and orientation of the new dowels. The holes can then be drilled and the
dowels cut to size. The dowels should be set using either a polyester or epoxy resin dependent upon the situation and circumstance (remembering that polyester resin is more reversible but more susceptible to ultraviolet light and moisture). Any excess resin should be removed prior to curing using an appropriate solvent. The surface should be clamped or retained in the correct position until the resin has cured. If fine fissures or cracks remain, these should be filled using a matching mortar of an appropriate strength and colour, where possible basing the mortar on a lime-based binder. With small fills the binder:aggregate ratio may have to be increased.

Structural movement

This may manifest itself as cracking, which at worst can endanger the integrity of a staircase. The cause of such cracking is most likely to be the result of movement within the building itself. The rotting out of timbers which may have been set within the wall may have led to movement. Another possible, but less likely, explanation would be the overloading of a staircase. This could be caused by a change in use of the building, e.g. from country house to visitor attraction and the ensuing increase in traffic. Equally, within a building the change in pedestrian routing could cause similar issues. This is, however, highly unlikely as proved through an experiment undertaken by the English Heritage

Engineering Team, who attempted to test a cantilever staircase to destruction but failed,[7] proving that cantilever staircases are much stronger than their appearance might suggest.

Prior to embarking on a campaign of repair, one needs to establish whether equilibrium has been reached, and to determine whether the structure is still moving. It will then be possible to map the fractures and try to establish the most likely cause and solution. Fracturing often occurs towards the tail of a stair, running parallel with the wall line. This can be caused by an inherent weakness in the stone, movement in the supporting structure or through weakening caused by misguided 'cutting in' of pieced nosing repairs.

With regard to cantilever staircases, there are thought to be only three possible causes of failure:

1. accidental damage to an individual stone tread or group of treads;
2. a loss of rigidity either in the wall or between the treads;
3. weakening by the cutting in of new nosings.[8]

The solutions to structural failures will involve many of the techniques covered elsewhere in this chapter. Where the cracking is deemed irreparable, replacement of an individual tread may be the only option, as described above. It is most likely, however, that if failure of one tread has occurred then the fault will have affected other stones, thus necessitating a more extensive repair programme.

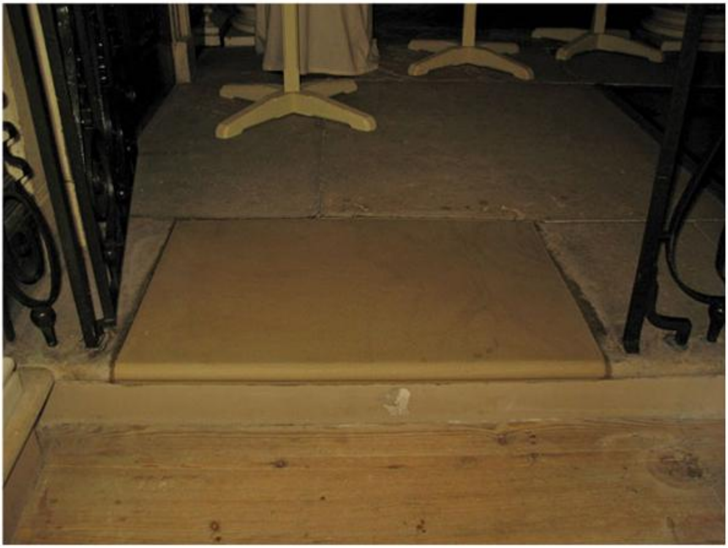
A less dramatic solution which may be possible in cases involving less movement is the insertion of dowels into the individual treads (see the case study, below). This will involve the advice of a structural engineer regarding the most appropriate direction, angles, diameter and length of dowels. They will usually be drilled across the fracture at opposing angles, thus acting against one another. It is important in such repairs that the resin is placed into the holes using either a low-viscosity resin to penetrate the holes when gravity is 'on your side', or an injection system to ensure the resin is injected up a hole. With the resin injected into the holes, it is then 'riddled' into place using 'placement rods' to ensure adhesion of the resin to stone
and elimination of air pockets prior to insertion of the dowel. It may be necessary to temporarily hold or wedge the dowel in place until curing has taken place; excess resin should be cleared using appropriate solvents while the resin is still uncured. The entry holes for the dowels should then be plugged to reduce the visual impact using an appropriately coloured mortar of sufficient strength. When carrying out such a repair, which may become almost invisible, particularly when drill holes enter from the underside of the stair, accurate records must be kept detailing what, where and how it was done.

10.4 Worn top tread, Attingham House, Shropshire. (Cliveden Conservation)

10.5 Central section of top tread released through stitch drilling. (Cliveden Conservation)

Where a tread in a structurally well-supported ‘tread and riser’ stair has been worn or mechanically damaged, pieced repair may be appropriate. In order to cut away the damaged section the use of a ‘grinder’ may not be possible due to dust, or may be deemed inappropriate. The relieving of new joints may therefore be undertaken by ‘stitch drilling’. This involves drilling multiple holes in a line which are joined, allowing the damaged section to be

removed. The new joints can then be trimmed using hand chisels. The new stone can be prepared ensuring the original profile is accurately re-created. If the new stone is to blend seamlessly with adjacent worn flooring (as in the example below describing replacement of a top tread), it may be necessary to trim the surface to mimic the adjoining stones. With the stone prepared a full mortar bed can be prepared of a mortar appropriate to the location and situation. The stone and substrate should be thoroughly pre-wetted prior to setting. The joints, dependent on their size, should then either be grouted or pointed, with the surface cleaned before the mortar has a chance to set and leave unsightly smearing or staining.



10.6 New Grinshill sandstone tread fitted, grouted and pointed. (Cliveden Conservation)

Another intervention that has been explored as an answer to the structural cracking is injection of resin with additional vacuum suction. This approach was used in combination with other solutions to solve problems with both the great and blue staircases at Kedleston Hall, Derbyshire. Full details of the work undertaken are covered in an article published in the *Journal of Architectural Conservation*.[9] The major structural support in this instance was created through the addition of a new steel beam below the landing area. Low-viscosity polyester resin was introduced into the fine fractures, with vacuum suction running. On reflection, the results of the project were that the resin even under high pressure did not always penetrate the cracks as desired, in one case finding a route through a porous area of the Hopton Wood limestone. The results meant that localised drilling and pinning was used along with the beams and strapwork; however, this approach was only possible due to managing use of the stairs and altering routing and usage. The key is the ability to plan and create a solution through the interrelationship between management of use and the degree of intervention required.

Expanding ferrous material

Ferrous dowels or straps may be found associated with stonework of almost any age and in many situations – stairs are no exception. It is possible that ferrous reinforcement may have been included in a misguided attempt to provide additional strength. Although initially beneficial and perhaps protected on installation by the alkalinity of surrounding lime mortar or indeed encasement in lead, once breached corrosion may lead to damage. As iron oxidises it expands; the volume ratio between iron and rust can be as high as 1:7. The resultant expansion and damage can therefore cause significant disruption, jacking and spalling of stone. Expanding fixings in bed joints even at ground level have been seen to lift whole courses of stonework, opening the joints and allowing the ingress of additional moisture, thus exacerbating corrosion. The other source of ferrous material is in historic repairs: dowels, cramps and supporting strapwork or brackets formed to alleviate structural movement can in the longer term become the cause of damage to stairs.

Dependent upon the position of the fitting, fixture or fixing, the options for amelioration will vary. In the simplest scenario an externally secured strap or fixing could be removed and replaced. Should it be deemed to have historic merit it may be possible to remove the strap, treat it, perhaps replace bolts or similar with non-ferrous alternatives (care being taken to ensure that one isn't creating a potentially damaging galvanic reaction). Alternatively, fixings built in or embedded within the structure may require 'surgery'. Any intervention may first require the input of a structural engineer to avoid potential destabilisation of the structure. Temporary support may be necessary; any 'opening-up' should be undertaken with an approach of minimum intervention. Following removal, an assessment regarding the replacement of the fixing should be made and action taken accordingly.

The third approach, cathodic protection, is not a new process: in 1824 Sir Humphrey Davy presented a series of papers to the Royal Society describing how cathodic protection could be used to prevent the corrosion of copper sheathing in the wooden hulls of British naval vessels.[10] This technique has the ability to treat corroding ferrous materials *in situ* without the costly and disruptive action caused by opening up and removal. The protection is created through the application of a small negative charge to the iron or steel. Joints can be raked out to allow the insertion of the thin connecting ribbon to the cramp or fixing. Further details of these systems can be found in articles referenced.[11] This technique, although slightly more unusual and technical, provides the potential for a less invasive solution.

Removal of surface coatings

A staircase may have been coated or covered at some point during its lifetime. Removal of coatings may be necessary due to change of use, to allow structural assessment or on purely aesthetic grounds. The first approach to a coated surface should be to understand what the coating or coatings are, their historical importance and the composition of the material. Following a decision to remove a coating, and ensuring that relevant consents and permissions have, where necessary, been sought, a trial should be undertaken. It may be necessary to remove a sample for analysis to allow composition of the coating to be determined and thence the best method or materials to be used for its removal. Coatings may be in many forms, from multiple layers of limewash, through oil-bound paints to modern paints and possibly including adhesive coatings used to adhere linoleum or similar surface finishes. Allied to analysis of the coating should be an understanding of the stone substrate, such that any techniques or methods used do not result in either short- or longer-term damage to the stone. Potential problems could be caused by acidic-based cleaners on limestone, leading in the worst-case scenario to dissolution of the stone. Caustic alkaline cleaners could lead to build up of salts, efflorescence and potential damage.

If coatings are thick, mechanical removal may be considered, this should be a last resort and should only be undertaken using skilled operatives with proven skills, following completion of a carefully monitored trial area. Scraping often forms part of coating removal – this may be the case whether using a chemical treatment or mechanical removal – and care should always be taken to avoid any tool ‘digging in’ where the surface undulates or does not conform to the tool in use. The tools selected should therefore be chosen to follow the topography and nature of the stone surface, which may, below the coating, be worn and undulating.

Coating removal may involve the use of chemical treatments. As described above, their selection should follow trials and an understanding of the coating, the substrate and also take into account health and safety concerns. Consideration of the operatives may have a significant influence on techniques due to the sometimes confined nature of staircases and the potential for poor airflow. Solvent systems may be in the form of liquids, pastes or poultice-based products. When removing proprietary paint-removal systems another common temptation is to use wire brushes to remove residue. Dependent upon the strength and nature of the stone, allied with the nature of the brush, this can be a further source of damage to historic surfaces. The use of wire brushes should not be entirely dismissed as, in the right hands and with the correct selection of brush, this can be the most effective means of removing residual paint and ‘stripper’. At no stage should ‘ferrous’ brushes be used as these are often too coarse and also have the potential to leave behind steel bristles which, while not immediately apparent, can lead to rust marking and staining. Soft phosphor bronze-bristled brushes can be used, but must be carefully monitored for the potential for cupreous staining. The final alternative is soft stainless steel-bristled brushes, which of all the alternatives probably offer the best option if deemed necessary.

It is possible that an abrasive system based on low-pressure air, or possibly water, could be used to remove coatings; again, trials would be required and control levels set. Considerations for such techniques would include placement of equipment, maintaining clear vision during cleaning, and maintaining a tidy site and controlling the residue generated.

Upon completion of cleaning, the reason for application of the coating may become apparent. Perhaps it had been applied to mask defects or unify previous repairs. Following the cleaning it may be necessary to undertake a full review of the structural condition of the staircase and refer back to the issues covered elsewhere in this chapter.

With all repairs it is imperative that accurate records are made of the work undertaken. This should take the form of a written document describing the techniques, materials and details of the intervention. This should be supported by drawn records and/or photographs. The completed report should be retained by the contractor and specifier and, most importantly, supplied to the client. This ensures the record is accessible in the future should further repairs be required; informing those who may once more be faced by problems with the staircase when perhaps the 'human' link has been lost. In parallel with the record, continual monitoring should be undertaken to determine the success of the intervention. Freshly pointed and filled joints thus become a very prominent and easy-to-read visual sign for future movement.

In conclusion, intervention should only be considered once there is full understanding of the construction, the problems and the impact any intervention may have on the staircase.

Case Study: Sharpham House, Devon[12]

Sharpham House is a Palladian villa overlooking the river Dart in Devon, dating back to the 1770s. The house has been expanded and redeveloped throughout the centuries. Captain Philemon Pownoll, a high-seas adventurer, a captain in the Royal Navy, engaged Sir Robert Taylor to incorporate Sharpham's existing Tudor mansion into a new villa.

It was Sir Robert's love of mathematics and geometry that helped him create this outstanding example of English Palladian architecture. His genius is most evident in the house's optically floating, elliptical cantilevered staircase – one of the most dramatic in England. The staircase is worked from fine-grained Portland limestone. The treads have a leading astragal nosing and a beautifully detailed ogee profile to their underside/ soffit. The first flight leads to a 'hanging' landing and the principal rooms, from which a further flight of reduced width ascends to a higher landing.

10.7 The grand elliptical staircase at Sharpham House. (Cliveden Conservation)

Concern was raised primarily with regard to cracking which followed the outer wall line, to the lower treads of the lower flight of stairs. There were
also a number of open 'bed joints' which exceeded the ideal. Following an initial stone survey that identified the defects, a structural assessment was undertaken which, following discussion with the stone conservation team, produced the specification and principles for repair.

10.9 After works undertaken with surface fills completed. (Cliveden Conservation)

It was determined that the stairs were structurally sound and thought that the movement represented historic settlement; therefore a series of localised repairs were specified. These took the form of ‘cross pinning’ of the fractured treads through drilling from both below the soffit and at opposing angles from the riser. The dowels used were threaded stainless steel of differing lengths and diameters (6 mm and 4 mm). The holes were cleared using ‘bottle brushes’, residue was cleaned using a volatile organic solvent, acetone. The dowels were then set in place using an injection system of epoxy resin, which was ‘riddled’ into place using placement rods to ensure adhesion of the resin to stone and elimination of air pockets.

In conjunction with this action, the fractures were grouted. Prior to this
they were thoroughly cleaned and dusted. The fissures were then flushed, initially with a solution of water and industrial methylated spirits (which acts to break the surface tension); this was followed by further water to ensure the surface did not rapidly ‘de-water’ the grout. A hydraulic lime-bound grout, based on NHL 3.5, with Portland stone dust sieved to <500 µm, run initially to a ‘thin cream’ consistency, was injected into the joints using a large-gauge veterinary syringe. Once the grout began to penetrate, the joints were stopped and packed using cotton wadding. The grout was then topped up as the material shrank back within the fissures, until this ceased.

10.10 Beautifully worked soffit to stair treads, showing previous resin patch repairs. (Cliveden Conservation)

10.11 Insertion of stainless steel cross dowels. (Cliveden Conservation)

Due to the shallow nature of the subsequent fills required and the need for the repairs to withstand visitor traffic, the binder chosen was white cement, which was used in a ‘weak’ mix with carefully selected sands and Portland stone dust. Due to the surrounding patina and appearance of the building the surface of the mortar was toned during curing with small quantities of ‘lime fast’ earth pigments to minimise the visual impact of the repairs.

10.12 Indication of placement of dowels at risers. (Cliveden Conservation)

Case Study: The Night Stair, Bristol Cathedral

The night stair at Bristol Cathedral formed the principal passageway for the monks from the Augustinian abbey to enter the cathedral from their dormitory to carry out their prayers. Over the centuries the stone treads had become extremely worn, and the level of wear had made them unsuitable for use by the public. The intention was, once the stonework had been consolidated, to construct a stairway over the stairs to open up access to the range of buildings on this side of the cathedral.

The stair connects the range of abbey dwelling on the south side of the cathedral to the main body of the building via the south transept. Although both the transept and the dorter passage to which the stairs lead are Norman in origin, much of the construction of each is of a later date. Pevsner ascribes the majority of the construction of the transept to the late fifteenth and early sixteenth century, and identifies much nineteenth-century work in the range of buildings into which the dorter passage is incorporated.

The stairs are accessed through a gate at the base of the stairs in the east corner of the south transept. The gate threshold is formed from Medieval tiles laid three to four rows deep. A low step with a limestone kerb gives onto a pennant sandstone half-landing, forming the base of the stairs. The remainder of the steps themselves are of Oolitic limestone.

The construction of the stairs appears largely to belong to the original phase of building, which is reflected in the generally even wear pattern. Despite this pronounced wear to the stairs, the treads remain well secured and it was only the fill material to the treads and pointing to the risers that required attention.

The topography of the steps illustrated the level of traffic to which it had been subject over its lifetime. The pattern of wear was, as one would expect, principally down the centre and along the leading edge of each step.

The principal areas of concern regarding the condition of the stairs as a whole related to the widespread and general loss of mortar from joints between the stonework. Although heavily worn, the underlying structural stability of the stairway was sound.

Following a full condition survey and recording of the condition of the stairs, a phase of conservative repairs were undertaken to point open joints using lime mortar and consolidate the structure through an approach of minimal intervention. In order to allow public access the decision was made to construct a secondary set of timber stairs which would sit over the historic originals.

The oak stair was designed with treads supported on two strings, which
were carefully scribed to fit the profile of the stair, with a minimal number of fixings into the stonework. A layer of inert padding, Plastazote©, was used to separate the oak from the stone and to take up undulations. The treads were kept clear of the walls so that they float over, rather than cover the stonework, which remains visible,

and can be vacuumed. The timber stair is designed in such a way that it can be taken away with only the fixing holes to be made good.

10.13 Base of stair before intervention. (Cliveden Conservation)

10.14 New stair in place. (Seymour & Bainbridge)

The much worn stone stair wasn't safe to use but the timber stair over provides even treads.[13]

10.16 New stair. (Seymour & Bainbridge)

Notes

1 English Heritage, 2006, *Identifying and Sourcing Stone for Historic Building Repair*, Technical Advice Note.

2 Warland, E.G., *Modern Practical Masonry*, 1929, London, Batsford. Reprinted, 2006, Shaftesbury, Donhead Publishing.

3 Ragsdale, P, 'The great stair at Kedleston Hall', *Journal of Architectural Conservation*, Vol. 16, No. 1, 2010, pp39–54.

4 Hume, I., 'Cantilever, hanging or pencheck stairs', *Journal of Architectural Conservation*, Vol. 15, No. 2, pp79–90.

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8 Taylor, R., 'Stone cantilever stairs', in *Building Conservation Directory*, 2006, Tisbury, Cathedral Communications, pp32–34.

9 Ragsdale, op. cit.

10 Hunt, C. and Farrell, D., *Cathodic Protection of Tie Bars & Ring Beams in Church Towers*, 2010, Manchester, Rowan Technologies Ltd.

11 Ibid.; McCaig, I., Davies, K. and Farrell, D., 'Cathodic protection of iron and steel' *Context*, Vol. 17, 2001.

12 The building is owned by, and the works were commissioned by, the Sharpham Trust. Survey and works undertaken by Cliveden Conservation; engineering survey and advice by Paul Carpenter Associates

13 There were no objections to the work, which received Fabric Advisory Committee approval in accordance with advice from the Cathedral Fabric

Commission for England. An English Heritage grant aided the work, together with the initial report and conservation of the stonework, mortar repairs, etc., which were done before the timber stair was fitted. The work was designed and overseen by Louise Bainbridge of Seymour & Bainbridge, Architect to the Chapter of Bristol Cathedral; Condition Survey, Advisory Report and Specification by Cliveden Conservation; stone conservation by Nimbus Conservation; new timber stairs by Ellis & Co.

11

Repair of Iron and Steel Staircases

Geoff Wallis

Introduction

Historically, cast iron, wrought iron and steel offered a number of advantages over other structural materials traditionally used for the construction of staircases. Long staircases could be designed with relatively few support points that enabled more slender and more elegant designs and also saved space. Castings for strings and balustrades could be made decorative at relatively low cost, enabling the staircase itself to act as an architectural feature as well as being functional (Figure 11.1). The fire resistance of iron was also important, exploited first in textile mills, then in buildings for public, industrial and military uses.

11.1 Switzers Store, Grafton Street, Dublin. A fine example of a decorative staircase, apparently unsupported, which can only be constructed by using the strength and malleability of an iron or steel core. (James Sutherland)

Metal staircases could be erected quickly on-site, components having been prepared and sometimes pre-assembled off-site. Open treads enabled staircases to be constructed to steep angles while remaining comfortable to use, and spiral designs were easily constructed, allowing restricted spaces to be used for access between floors. In industrial applications such as engine-houses, where heavy loads may be placed or carried on stairs, iron and steel could accommodate high loadings without visual impairment, and the materials were resistant to spilt lubricants and solvents.

Balustrades are both highly visible and highly stressed, so it is here that the strength and decorative properties of cast iron, wrought iron and steel were particularly important and exploited to the full in a vast range of designs, sometimes incorporating other metals as decorative elements.

Materials, Properties and Recognition

Before the processes required for the manufacture of steel were perfected in the late nineteenth century, metal staircases were made from cast and wrought iron. These two materials have very different but complementary properties, so they were often used together to great effect.

Cast iron contains 1.8–5 per cent carbon and has a crystalline structure. It is formed, as the name suggests, by casting into a mould when molten. It is strong in compression but relatively weak in tension and is brittle, so it fractures without warning, rather than stretching or yielding as with wrought iron and steel. Cast iron was commonly used to form compressive members such as supporting columns and pillars, but was also widely used to make landing-beams and staircase strings. It is difficult to weld.

11.2 David and Sampson blowing engines, Ironbridge Gorge Museum. An exceptionally long cast-iron staircase giving access to the upper floors of blowing engines manufactured by the Lilleshall Company Ltd in 1851. (Geoff Wallis)

By contrast, wrought iron and steel are ductile and malleable forms of
iron, wrought iron being the more so. Wrought iron is almost pure iron with less than 0.1 per cent carbon. It has a fibrous, wood-like structure. It is readily forged and hammered to shape and was also rolled to form angles, tees, flats, plates and other sections. Larger beams and stair strings were fabricated from angles and plates fixed together by multiple rivets set hot, usually riveted up in a workshop and joined together on-site by means of bolted joints. Wrought iron was also used traditionally by the blacksmith to make balustrading where the malleability

of the material allowed highly decorative elements to be produced, often showcasing both the skill of the smith and the fashionable taste and wealth of the owner.

Cast iron has good damping properties, so tends to absorb vibrations and noise, which can be both practical and an aesthetic advantage in a staircase. By contrast, wrought iron and steel tend to be ‘livelier’ and vibrate in use, transmitting and even amplifying noise by ringing.

Iron castings were formed by pouring molten iron metal into sand-moulds containing voids formed by patterns. These patterns were traditionally made of wood, so could be carved or built up to form decorative shapes. Cast iron components were therefore often ornate, an art which reached its peak in Victorian times when balusters, treads, risers, floor gratings, columns, brackets and other components of staircases were often extensively moulded or decorated. To reduce weight, castings were usually made hollow, fretted or pierced, and on large castings shaped cores were used so that the inside of a hollow casting followed the shape of the outside, reducing the overall thicknesses of walls. The strength of cast iron is influenced by several factors, including carbon content, rate of cooling in the mould and size and shape of the cast element. Thick cast-iron sections are less strong than thin sections, which can chill (cool quickly) and become very hard. Chilled thin sections can be too hard to drill, making repair difficult.

Wrought iron is a pure form of iron made by converting it from cast iron in a chafery and finery or puddling furnace. The carbon in the brittle cast iron is burned out, leaving almost pure iron which is repeatedly hammered or ‘wrought’ to consolidate it and drive out slags and other impurities. The hammering and rolling of wrought iron during its manufacture developed a marked wood-like grain, so its strength is directional. By contrast, steel has a granular matrix, is almost homogeneous, and has an ultimate tensile strength approximately 50 per cent greater than wrought iron. Wrought iron is no longer manufactured commercially anywhere in the world, so is of historic importance and must be retained wherever possible.

Identification of cast iron, wrought iron and steel

It is important to distinguish cast and wrought iron and steel by inspection and testing. The three materials were often used together, but have significantly differing properties, so it is vital to establish which materials are used at each location in the staircase. The following provide qualitative indications.

Shape and design

Iron castings were often heavier and coarser than wrought iron or steel sections, and may form recognisable components such as columns, beams, monolithic panels, etc. Profiles that are ornate and vary along their length are likely to be cast iron. Wrought iron and steel were typically made by rolling and so are of constant cross-section. Cast iron is used in compression for columns (typically of hollow circular or cruciform section), for beams and stair strings, usually with a larger bottom tension flange than the top compression flange, in view of its relative weakness in tension. Wrought iron and steel are found in I-beams, angles, tees, channels, tie-rods and as girders built up from plates or beams and angles, riveted together and often with additional flange plates over their middle section. For a given strength, wrought iron and steel sections were thinner than cast iron. Cast iron sections have mould or ‘flash’ lines and misalignment may be visible, particularly as diametrically opposite lines on hollow circular columns, cast horizontally, where the upper and lower halves of the mould met.

Surface appearance

A sandy or rough surface, blowholes, porosity and inclusions[1] all indicate cast iron, whereas a hammered or incised surface is probably wrought iron. The smooth surface with sharp outside corners and rounded internal corners produced by relatively modern rolling techniques are often indicative of late nineteenth-century wrought iron or steel, or twentieth-century steel. A founder’s name in raised lettering and perhaps a logo were often cast onto the surfaces of castings, and the name of the mill rolled in raised lettering on the webs of steel sections, but wrought iron plates rarely carried raised lettering.

Connections

Cast iron is often joined using bolts or leaded sockets, whereas riveting indicates either wrought iron or steel. Riveting was rarely used on cast ironwork as the driving and contraction of hot rivets risked fracturing the casting. Fire- or forge-welded joints which are heated white hot and hammered together usually indicate wrought iron and are often found on decorative balustrading. Arc-welds indicate steel unless subsequently applied to earlier wrought iron, as the technique was not available when wrought iron was in widespread use.

Date of original construction

The date of original construction, if known, can be a valuable aid to identification, particularly for distinguishing between wrought iron and steel, but later alterations can mislead. Cast iron was in structural use from the late eighteenth century until the early twentieth century, although decorative castings for railings are made to the present day. Wrought iron was in structural use from *c*.1840 to the end of the nineteenth century, and steel in structural use from *c*.1880 onwards, so there are about two decades when the two metals were both in use, and may need to be distinguished by testing.

Testing

Testing can be carried out in a laboratory.[2] Various methods of site testing are also available from qualified metalworkers. A sliver of wrought iron cut with a cold chisel gives a curled shaving, whereas cast iron breaks in chips. Being tougher, it is difficult to cut a shaving in steel with a cold chisel, and it does not produce such a curled shaving. When partially cut and then bent, cast iron breaks with a crystalline fracture, whereas wrought iron bends, showing a fibrous wood-like structure. When a sample is placed against a power grinder, cast iron gives ragged reddish sparks, wrought iron narrow white sparks, and steel gives straw-coloured sparks with stars.

Construction

Individual flights of a metal staircase resemble bridge spans in that they were usually designed to be supported only at their ends. All three traditional
forms of iron were used in the construction of staircases for both structural and decorative purposes, but have very different properties, as set out above. Metal staircases were often designed on the basis of a ‘permissible stress’ which was not to be exceeded in service under certain applied loads.[3] The different metals were chosen for their particular properties, and deteriorate in differing ways at different rates so their identification is a fundamental pre-requisite to conservation.

Once the materials in the staircase and balustrading have been identified, an assessment can be made as to how they are used structurally. How is the staircase put together? Which members are primary, and critical in load-bearing. Which are secondary? And which are purely decorative? Which members are subject to tensile, compressive and compound stresses? If the structure has moved, how has this been accommodated?

Balustrades

The non-ferrous metals such as copper, lead, zinc and, later, aluminium are weaker than the ferrous metals, so were usually used only decoratively on balustrading. Gilding was also an important decorative element on balustrades (Figure 11.3).

11.3 Castle Howard, York. The most decorative balustrades were commissioned by the nobility and gentry as a sign of status and wealth. These early eighteenth-century balustrades are forged by a master blacksmith using only wrought iron. Scrolls, water-leaves, beading and acanthus leaves are riveted or fire-welded together or secured by decorative collars. Panels are assembled into frames secured between the stair treads and an iron core-rail, which carries a moulded mahogany capping or handrail. Much early paint and gilding survives, which is of the same historic significance as the ironwork itself. (Geoff Wallis)

The primary purpose of balustrading was to provide containment for the users of the staircase, and it was not generally expected to contribute significantly to the structural strength of the stairs. Cast- and wrought-iron balustrading was traditionally regarded as adequate if it was high enough to prevent users feeling exposed on the edge of the stairs and provided a comfortable height for the handrail. Lateral stability was often provided by multiple fixing-points, and the use of back-stays. The bottom sections of balustrades adjacent to the stair treads are subject to the highest bending forces so here the metal sections were usually thicker. Slender sections of cast iron were liable to fracture from repeated flexing in use.

Metal balustrades were often provided on masonry and concrete stairs where fixings may be into the top faces or ends of treads. These fixings, too, were highly stressed and were liable to break out of masonry, or themselves fail, particularly in external locations (Figure 11.4). Early balustrades were not made to comply with any minimum height or maximum gap regulations, nor to provide a quantified lateral load-resisting capability. They may therefore not comply with modern legislation and require modification, which should be unobtrusive and reversible (Figure 11.5).

11.4 Damage to stonework. Typical failure of a stone tread due to rusting of outdoor wrought-iron balusters. After the ironwork has been removed, a new piece of stone may be doweled to the end of the tread. If additional strength is required, recycled wrought-iron extensions may be welded to the balusters. After cleaning and painting, ironwork is re-fixed in new holes, secured by molten lead poured in and dressed tight. (Geoff Wallis)

11.5 St. Pancras Chambers, Kings Cross, London. Historic balustrading may fall below the safety standards reasonably expected on staircases nowadays, but upgrading can be difficult and obtrusive. Here, a traditional woven mesh has been added to reduce the size of voids, and a secondary handrail clamped on to raise handrail height, both being reversible additions. (Michael Bussell)

Surveying Iron and Steel Staircases

Components of iron staircases and landings may be complex and highly loaded, and conservation work on iron can be intrusive, non-reversible and costly. It is therefore important that metalwork is surveyed expertly before conservation work starts, so as to determine the construction method and materials; establish fully the nature and extent of defects and deterioration; facilitate strength assessment; and allow the least intrusive and most economical conservation options to be planned.

The primary structural elements of a staircase may be exposed, particularly in industrial applications, but if not visible, selective opening up will be required to reveal the size, construction and condition of key elements and the joints between them. To minimise intervention, a range of equipment is available for viewing internal spaces such as optical endoscopes and CCTV, which require access holes of 12 mm or less. Floor coverings should be lifted and skirtings may need to be eased away, but extensive dismantling of the metalwork itself should not be necessary. Old coatings on iron and steel can be useful indicators of past movement, corrosion in joints and impacts, so their general removal should be unnecessary, unless they are exceptionally thick.

Structural engineering checks may be needed to establish the overall stability and load-bearing capability of the structures, including cast-iron columns which may need specialist testing and measurement of their wall thickness to assess stability.

Paint

All historic ferrous metalwork was originally painted, and evidence of past priming, undercoating and finish coats often survives. The survey should
sample these and original colours should be identified where possible and re-used. Even if paintwork has failed generally, remnants can often be found intact in crevices and protected areas. A full-depth sample from each area of the structure should be dislodged by scalpel or chisel, and inspected on edge under a microscope. Layers of paint and dirt should be sketched to scale and photo-micrographed. Samples should be retained and archived. Ideally pigments should be laboratory-analysed and their formulation used to mix new paint. It should be noted that binders usually darken on drying, and some colours change dramatically with age. Analysis is best carried out by a specialist paint conservator.

Condition survey: what to look for

Evidence should be sought for general and localised defects, including:

- settlement, overloading and other movements
- mechanical shock

- thermal shock
- original material or manufacturing defects
- badly executed alterations and repairs
- corrosion
- defective fastenings
- vulnerable areas.

A survey of levels may assist in identifying settlement, overloading and other movements. but original misalignments may exist and mislead. Movement of cast-iron staircase strings can be particularly destructive of the strings themselves, treads and risers. Staircase handrails, especially spirals, tend to be pulled down the stairs with repeated use, causing balusters to lean and core-rail joints to be strained. Cast-iron treads may have cracked from repeated deformation in use or over-loading. In cast iron, lugs, flanges and changes of section are particularly vulnerable to cracking if the structure moves.

Slender cast-iron balusters and fretted treads are particularly vulnerable to mechanical shocks resulting from impacts. Thermal shocks typically result from fires, the effects of quenching during fire-fighting, and from past electric-weld repairs. Original material or manufacturing defects include voids, inclusions and cracks in cast iron, and de-lamination or cracks along the grain in wrought iron. Badly executed alterations and repairs can damage metal stairs. Holes drilled to secure plates generally weaken
the original material, and if poorly bedded the plates may trap moisture, promoting rusting of original iron- or steelwork. Corrosion typically occurs in joints, areas of

poor drainage or ventilation, splash zones and around dissimilar metals. Rust-swell in and around cast-iron components can cause bending and cracking, especially around lugs, flanges and at changes of section. Defective fastenings include wasted bolts, missing or loose nuts and corroded or broken rivets. Bolts threaded (tapped) into cast iron are liable to strip their threads and pull out if overloaded. Particular attention should be paid to vulnerable areas, such as fastenings. Hidden shanks may be wasted or broken, heads or nuts may have reduced section and threads may have stripped. Holes and changes of section in castings concentrate stresses and increase the risk of cracking. Other vulnerable features include thin castings (especially in treads, risers and balusters), crevices, joints, interlocking parts, imperfections in castings (such as porosity, voids, inclusions and cracks) and associated materials which may attack iron electro-chemically in damp conditions.

Non-destructive investigation techniques

Non-destructive testing (NDT) techniques are available for inspecting metals on-site, to expose small or internal defects on highly stressed parts. Surfaces must be blast-cleaned first. Techniques include:

- dye penetrants
- magnetic-particle penetrants.
- ultrasonic probes.

Dye penetrants involve a low-viscosity coloured liquid which is sprayed onto the surface and allowed to enter cracks by capillary action. The excess is removed and a white ‘developer’ powder applied generally. This draws out penetrant from cracks, revealing their positions, particularly useful for castings. Magnetic-particle penetrants are similar to dye penetrants, but here the penetrant is a magnetic-particle ink, drawn out of the crack by application of a hand-held magnet. Penetrant techniques can be confused by porosity in castings. Ultrasonic probes use a reflected beam of ultrasound which indicates the presence of internal flaws. The process can be confused by rust on the rear face, slag-stringers in wrought iron and porosity or inclusions in castings.

Survey report quick checklist

The survey report should ideally include:

- a description of the structure, identifying its materials;
- the causes, nature, extent and location of defects and deterioration;
- a record of active deterioration and estimate of its rate of progression;
- an analysis of structural adequacy;
- paint sample analysis;
- a schedule of recommended repairs;
- general and, where necessary, particular specifications for conservation works.

Conservation Strategy

General conservation principles and options

The general guiding principles in the treatment of historically important buildings are minimal intervention and minimal loss of evidence. A lightness of touch should be adopted, preserving as much extant evidence as possible for future generations.

11.6 Muckross House, County Kerry, Ireland. Rust staining is unsightly but not damaging, and does not require metalwork to be dismantled, which should be confined to situations where components or their joints are structurally unsound and cannot be treated *in situ*. (Rupert Harris Conservation)

If a staircase is stable, or has achieved equilibrium, it may only require cleaning and painting to prevent further deterioration. Settlement, distortion, corrosion and cracking do not necessarily justify intrusive treatment, provided they are not structurally significant and provided that further deterioration can be prevented by surface treatments such as filling and painting. If the strength of the staircase has to be increased, additional components can be introduced either to share the load (for example, by introducing additional beams into a landing to span alongside the existing beams), or to increase the strength of the existing elements. This is preferable to removal and replacement of the existing structure, but lateral thinking may be needed to avoid strengthening measures being obtrusive.

Dismantling and reassembly

Dismantling clearly offers the advantages of allowing repairs to be undertaken in the controlled conditions of a workshop, the components to be cleaned as necessary and fully painted all round, and new elements and fastenings to be fitted. However, dismantling can be destructive of brittle or rusted components, and there is a risk of parts becoming lost, damaged or reassembled incorrectly.

Riveted metalwork is particularly vulnerable to damage when the rivets are removed. The original rivets will be lost as they cannot be re-used. The decorative infill panels and handrail cappings of balustrades were fitted after erection of the primary structure of the stairs and can often be dismantled with relative ease. However, wooden handrail cappings were often pre-assembled using hidden double-ended handrail bolts, and then fitted to a core rail mounted on the balustrade in lengths and glued. Joints were usually then dressed by small single-handed moulding and smoothing planes, called 'palm-planes'. On high-quality work locating the joints can be difficult, disturbing them is usually destructive and neat reassembly of joints often impossible. It is therefore advisable not to disturb timber handrail cappings unless their joints are readily visible and loose, and there is no other course of action available.

Bronze, brass, and cast-iron cappings were usually bolted up from underneath a wrought iron core-rail (Figure 11.7) and can often be removed relatively easily if the fastenings are not corroded. However, joints in metal cappings were often finished to a high standard, and can rarely be removed and refitted without some loss of fineness in alignment, appearance or finish when reassembled.

11.7 Ryde Pavilion, Isle of Wight. Broken cast-iron balusters can be reproduced by unbolting an original, preparing it as a pattern and recasting at a foundry. New castings should be fettled (dressed to remove imperfections), painted and bolted in place. Materials added to improve strength or stiffness must not trap water and should be sympathetic to the historic structure. (Geoff Wallis)

Seriously corroded decorative wrought-iron panels are best removed carefully from site and repaired in a conservation forge where traditional blacksmith's techniques and hot repair processes can be used.

Lead used in fixings for baluster-feet, sockets, etc., can usually be removed by chain-drilling and carefully wriggling the component until the spigots are loose enough to pull out, taking great care not to snap cast ironwork. Attempts to melt out lead are not recommended as they usually result in failure or spoiled surrounding materials, and are dangerous in a historic building.

Dismantling should be adopted only as a last resort, carefully planned, and undertaken by specialists experienced in the conservation of cast iron, wrought iron or steel. Parts should be double-tagged with metal labels wired on before removal, and re-erected without delay as soon as any necessary work has been carried out. Detailed records should be kept at all stages, including drawings during and after repairs. New materials should be distinguishable from old, being date-stamped or embossed.

Repairs

Hot repair techniques

Hot processes are used in forming, joining and cutting iron and steel, but are usually prohibited in historic buildings due to the potential fire risk, or are allowed only on the basis of a daily 'hot works permit' where no other process can be substituted. In general hot repair processes should be restricted to a conservation workshop.

Coke-fired hearths were the traditional means of heating for manufacture and repairs. On building sites, small portable hearths were employed for heating rivets, etc., and hearths are still widely used in workshops for general forge-work. More modern methods of heating include:

- fuel gas and air
- fuel gas and oxygen
- electric arc.

Fuel gas and air uses butane or propane stored in portable bottles mixed with air at a torch to provide a flame of several hundred degrees centigrade.
It is used for low-temperature operations such as heating components to separate them, softening paint, and soft soldering (see below). Fuel gas and oxygen uses propane or acetylene and oxygen, stored in heavy bottles, mixed at the nozzle of a blowpipe to produce a flame around 3000°C. It is used for shaping metals, separating components, flame cleaning, silver-soldering, brazing and fusion welding (see below). These gases can also be used for cutting thick sections of wrought iron and steel where excess oxygen is used to blow away white-hot metal (flame cutting). Electric arc welding employs the low-voltage/high-current output from a transformer to provide a continuous spark or arc between the work-piece and an electrode, instantly producing a localised molten pool. It is used mainly for welding processes, principally MMA & MIG (see below).

Electric arc welding is not recommended for repairs to cast iron due to the risk of thermal-shock damage to the brittle material.

Soldering and welding processes

Iron oxidises when heated, which prevents joining, or reduces the strength of the joint. A flux or inert gas shield must therefore be introduced to prevent oxidation by providing reducing conditions. Common ‘hot’ techniques applicable to iron and steel repair include:

- brazing or hard soldering
- gas fusion welding
- manual metal arc welding (MMA or ‘stick’ welding)
- metal inert gas (MIG) welding
- fire or forge welding.

11.8 Repair to a wrought-iron balustrade component. Decorative wrought ironwork subject to severe corrosion can be repaired by use of gas or electric welding techniques. Components should be renewed only as a last resort, using the original material. (Chris Topp)

In brazing or hard soldering, the surfaces to be joined are cleaned, fluxed and heated by oxy-propane flame to around 600°C. A bronze filler wire (spelter) is melted into the joint, being drawn in by capillary action. Spelter containing silver (silver solder) melts at a lower temperature, providing a weaker joint. Suitable for non-structural applications on thin cast- and wrought-iron sections, the technique can be applied to thicker cast iron if heated and cooled slowly to minimise the risk of cracking. Gas fusion welding involves heating components using an oxy-acetylene flame to their melting temperature, creating a localised weld-pool into which a filler rod of the same metal is melted; it is suitable for the structural repair of cast iron, which must be pre- and post-heated to minimise thermal shock. In MMA welding an electric arc is formed between a consumable electrode and the work-piece, creating a small weld pool in which the components fuse. Oxidation is prevented by the vaporisation of a flux coating around the electrode. It is widely used for jointing wrought iron and steel on-site and in the workshop, but is not recommended for cast iron due to the risk of thermal shock causing cracks around the weld. Wrought iron should preferably be welded with a full or partial penetration butt weld over its cross-section, as the alternative of fillet-welding to the metal’s surface can be ineffective due to the laminar nature of wrought iron.

MIG welding is similar to MMA welding, but the weld pool is protected by a shield of argon, and the filler-wire electrode is automatically fed into it by a current-sensed servo-system; it is suitable for welding wrought iron, and also for cast iron if pre- and post-heated to reduce thermal shock. In fire or forge welding two pieces of wrought iron are fuse together by being heated in a hearth to white heat and then hammered together. A well-executed forge weld should achieve about 80 per cent of the original metal strength, and is recommended as an appropriate traditional process for repairing wrought ironwork.

Hot-set riveting

Riveting is the most common traditional method of joining wrought-iron components in structural and decorative applications, and should not be replaced by welding. A rivet is entered red-hot into a prepared hole, the rivet head is retained by a hand-held gun or jack (a 'holder-up') and the shank is
then forged down to form a second head, fill the hole in the plates and grip them together. The grip is further tightened as the rivet cools and shrinks, resulting in a strong, watertight joint. Rivet heads are commonly spherical (round-head), conical (snap-head) or flush with the surface (counter-sunk). Small rivets are set by hand, larger ones by pneumatic or hydraulic tools that allow large numbers of rivets to be set quickly.

Removal of rivets must be undertaken with care to avoid damaging plates and holes. Heads may be ground off, shanks drilled and the rivet punched out. Where a large number of rivets is to be removed, a quicker traditional method is to shear off the head with a rivet-buster, a long pneumatic gun operated by two persons. Its chisel is placed under the rivet-head to shear it off, and a punch in the same gun is used to drive out the shank. Appropriate safety precautions are essential.

Cold repair techniques

Cold repairs avoid the thermal stresses and the fire and fume hazards of hot processes, and so are safer and particularly suitable for use in historic buildings. Cold processes generally employ simpler and cheaper equipment than hot techniques, so should be adopted where possible. All the techniques described are commonly used for repairing cast iron, which contains flakes of graphite that lubricate cutting operations such as drilling and tapping (threading) holes.

Plating

A strong and discreet repair can often be achieved by bolting a steel or brass plate across a cracked cast-iron component on a hidden face (Figure 11.9). Plates must be bedded on red lead or on a two-pack epoxy putty to exclude water, and can be secured with countersunk screws flush with the surface for a neat appearance. Repair plates can often be sited on the insides of staircase strings, on the back faces of risers, and under treads. Pierced risers and treads can be plated unobtrusively by use of a thin plate containing holes cut out on an automatic gas or laser profiler.

11.9 Regent's Quarter, Kings Cross, London. As part of a major refurbishment, cast-iron staircase treads needed to be strengthened and cracks repaired unobtrusively. The outline of the original tread was traced and followed by an automatic laser-profiler to cut strengthening plates from 3 mm steel exactly matching the originals. These were painted and bonded to the underside of treads, secured by small countersunk machine screws. The sizing and siting of fastenings drilled into small sections of cast iron must be chosen carefully to minimise the weakening of the component being strengthened. (Geoff Wallis)

If stainless steel plates or fastenings are used on outdoor metalwork, they must be physically and electrically isolated from the casting to prevent bimetallic corrosion. Stainless steel bolts and nuts can be isolated by plastic washers or by painting with a two-pack epoxy primer and assembled before the paint cures.

Studding

Broken rod-shaped components can be repaired by drilling and tapping both parts and screwing together onto a threaded bar (studding) bedded on red lead or two-pack epoxy putty. If components cannot be rotated, the studding can be screwed into one part and secured by epoxy putty into the other. Studding is particularly applicable to the repair of broken cast-iron balusters.

Carbon or glass-fibre repair and strengthening

In some situations strips with filaments of carbon or glass-fibre bonded with two-pack epoxy resin onto a blast-cleaned surface can repair a crack or strengthen a component. Pre-formed pre-tensioned plates may also be used to upgrade structural strength, and have been used on a number of cast-iron bridges and beams. As this is a relatively new technique, long-term performance has yet to be proved, but the technique has merit for conservation work, being reversible, water-resistant, potentially discreet and allowing all existing fabric to be retained.

Stitching

Stitching is a modern version of a traditional technique for repairing cracked cast iron. Holes are drilled across the crack and slotted, and then a ferrous
lock or ‘stitch’ is driven into the slot to tie the sections together. Further slots and stitches are installed across the crack, which is then sealed with interlocking studs screwed in (Figure 11.10).

11.10 Example of metal stitching. This is not part of a staircase but shows repairs to the dome of the US Capitol building, Washington, DC, which clearly shows the process. ('Architect of the Capitol' US government work, www.flickr.com/photos/uscapitol/7203655282/in/photostream)

The process offers the advantage of requiring only portable hand tools, so is safe to use on historic sites. The repair is hermetically tight without the use of sealants, is heat-resistant and is invisible on completion, all stitches and studs being set within the thickness of the repaired metal.

The disadvantages are that the process is not suitable for thin sections and cannot be applied near edges and corners.

Coatings

Ironwork was coated for decoration and protection. Internally, staircases and balustrades were usually finished by painting, surface-colouring or, later, plating. Externally protection was paramount, so painting was usual or, from the late nineteenth century, cathodic metal coatings.

Surface colouring/patination and electro-plating

Traditionally the simplest form of decoration was colouring of the surface of components by heating and dipping in various liquids to create a range of colours, principally dark blues or light/dark browns.

An improved level of protection was achieved by electro-plating iron with a more corrosion-resistant metal, often chosen for its decorative qualities, e.g. copper, brass, chromium. These processes are cosmetic and were generally limited to indoor balustrading.

Traditional paint coatings

Paint is composed of a powdered solid pigment providing colour mixed into a fluid which cures or dries and bonds it to the surface. A solvent or 'thinner' is used to regulate viscosity and ease of application.

Traditional pigments used on ironwork include raw or burnt earth colours (e.g. ochres, umbers, siennas) and the products of chemical processes, especially the corrosion of metals, such as white lead (lead carbonate). Less stable colours were obtained from vegetable and animal sources. Black was obtained from soot or lamp-black, but was not commonly used on outdoor metalwork until the advent of alkyd oil paints in the early twentieth century.

On outdoor metalwork the most common pigments were white lead or light colours based on white lead, red lead or minium orange (lead tetroxide) and red oxide, a cheap, hard-wearing paint used for priming and finishing.

Finish paints again incorporated white lead or more exotic colours such as ‘invisible’ or Brunswick green, and bronze greens, particularly in park or garden settings. Smalt (cobalt glass blue) and other rare and costly pigments were occasionally used by the wealthy for prestige balustrading on prominent facades from the seventeenth century. Paint with rare pigments must be conserved if found.

Traditionally, varnish, a clear or pale yellow resinous lacquer, was used as a gloss finish coat, and gilding was commonly applied on fine ornamental ironwork indoors and out. On more prosaic outdoor structures coal tar and natural bitumen, often mixed with solvents, were used as thick, protective coatings in functional applications.

For external use the sacrificial metal zinc was used for coating (‘galvanising’) from the mid-nineteenth century. Wrought iron and steel was chemically cleaned, dipped in a bath of molten zinc and hung to drain. Early examples of ‘hot-dip’ galvanising are now rare and must be preserved.

Where traditional coatings are present and serviceable they should be retained. On indoor metalwork either traditional or modern paints may be used, but lead-based paints may only be used on Grade I and II* listed buildings after authorisation by English Heritage.

Modern paints

On outdoor metalwork the longevity of modern paints is often of paramount importance, particularly where access for maintenance is difficult. Modern coatings are formulated to perform efficiently: as primers to adhere to the metal; provide chemical protection; provide a sound substrate for subsequent coats to provide opacity and protection, and as finish coats to provide colour, sheen and toughness. A range of synthetic single and two-pack binders is available, including alkyd oil, epoxy and polyurethane resin, acrylic and water-based paints. The advice and recommendation of a specialist manufacturer of paints for metalwork should be sought in selecting a coating system, and their specification for preparing surfaces and applying coatings followed carefully. Coatings must be uniform and of adequate thickness, so must be applied by skilled painters. For outdoor metalwork a minimum dry film thickness of 250 microns is often specified, measured by a magnetic dry-film-thickness meter.

Conclusion

The repair of metal staircases offers a number of challenges and should be approached with appropriate caution. Dismantling can in certain circumstances be advantageous but should not be undertaken before a detailed report has been carried out. The same rules apply to the conservation of metal staircases as other structures: start with analysis, prepare a plan of work, proceed with caution and if in doubt consult.

Notes

1 Blowholes and porosity are air bubbles, the former large and the latter tiny. An inclusion is a metal contamination of dross, sand or slag.

2 Laboratory tests may be used to distinguish the metals and establish likely properties. Metallurgical tests will analyse element content and microstructure, and mechanical properties such as yield and ultimate tensile strength and percentage elongation may be determined by stretching a test-piece to destruction.

3 Typically, this stress was based on the ultimate strength divided by a factor of safety – commonly four, although a higher factor was often recommended for cast iron, allowing for variations in material strength and quality as well as providing an adequate margin of comfort. The first 'official' figures for permissible stresses appeared in the London (General Powers) Act of 1909, by which time cast iron was in minimal use for structural purposes. Typical figures given are (tons per square inch and Newtons per square millimetre in brackets: *cast iron*: tension: 1.5 (23): compression: 8.0 (124): shear 1.5 (23); *wrought iron*: 4.0 (62); 5.0 (77); 4.0 (62); *mild steel*: 7.7 (116); 7.5 (116); 5.5 (85). The last British Standard for wrought iron, BS 51 of 1939 (now withdrawn), specifies test procedures and properties. The lower strength across the grain compared with strength parallel to the grain, rather as in wood,

should be noted. This has implications where recycled material is used in structural repairs.

Baluster The individual upright members supporting a handrail.

Balustrade A series of balusters together with a handrail.

Cantilevered A term generally adopted (but technically inaccurate) to describe a stone staircase without external outer support, newels or otherwise. They can be spiral or elliptical (geometric) or in straight flights with landings or winders. Other terms include flying; hanging; pencheck (Scotland).

Carriage In timber stairs a length of timber inserted beneath the treads and risers to further support them, they are often notched out to receive their inner bottom angle, also known as bearers. They are generally hidden from view within the soffit.

Curtail steps The curved and enlarged bottom steps where a flight meets the floor.

Dog-leg A staircase in two flights with a half-landing where the second flight continues parallel to the first without an open well. The outer strings of each flight are housed into a common single newel.

Flight A series of steps between floors or landings, or a combination of the two.

Geometric A poorly defined term, normally used to mean a spiral or elliptical cantilevered staircase with a continuous (i.e. unramped) handrail, but the term is often used to describe any 'cantilevered' staircase.

Going The depth of a stair tread from its leading edge to the vertical element between the treads (riser).

Guardrail A rail to prevent a user falling down a well. Often a handrail does this, but in some stairs a separate higher guardrail is provided behind.

Handrail The component gripped to aid ascent and descent.

Imperial A staircase in an open hall commencing with a single straight flight to a wide landing where two branches either side return at 180°. Occasionally the reverse is seen, with the staircase starting with two flights with a single returning.

Landing (1) A platform between flights. A half-landing is between flights where the stair turns through 180° and the following flight continues parallel to the first. It will be at least twice the width of one flight. A quarter-landing is where a stair turns through 90° and continues at a right-angle.

A quarter-landing is usually square in plan. (2) Where a flight reaches a principal floor the area immediately adjacent to the stair is known as the landing.

Newel (1) The central drum or pier of a spiral stair. (2) The leading or end post (newel post) of a balustrade into which are set or fixed the handrail and the outer string.

Newel stair A stone staircase where the tread and newel are made out of a single piece of stone.

Nosing The leading edge of a tread which projects and overhangs the riser below. They are often rounded (bullnose), but can be square.

Ramped A handrail that suddenly steepens drastically in pitch at a landing to turn and ascend the next flight. If it does so in a continuous curve it is called a ‘swan’s neck’.

Rise The vertical distance between treads.

Riser The vertical element between two treads, or between floor and/or landing level and the first tread at the start of a flight, or the final tread and floor or landing level at the end of a flight.

Step The combination of tread and riser.

Soffit The underside of a stair flight. May be plastered, boarded or left open.

Spandrel The triangular space between the string and floor level. In domestic situations often forming an under-stairs cupboard.

Spindle A term used to describe a turned baluster.

Spiral A circular, helical or elliptical staircase. Other terms synonymous and in general usage include: vice; vis (French); winding; geometrical (when ‘cantilevered’); cockle.

Staircase The whole ensemble including stair, balustrade and supporting newels, framework and any other integral structure.

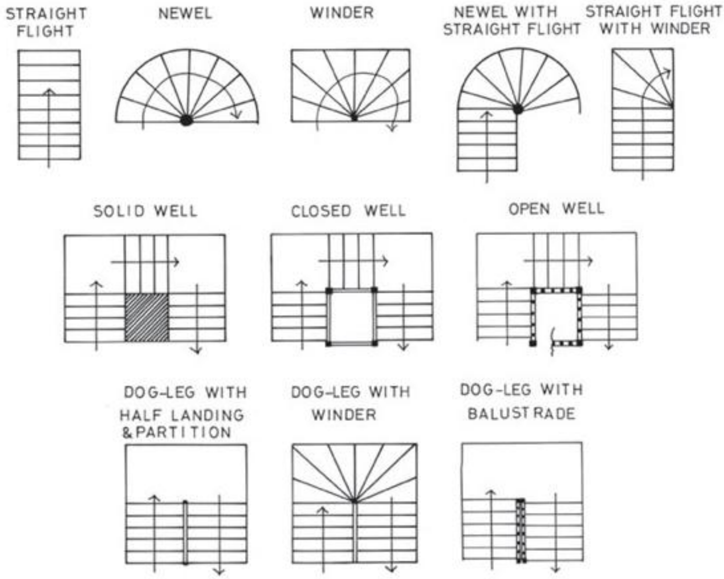
String The inclined side of a stair, usually composed of a board which supports the treads and risers. A closed-string will rise at the same angle and parallel to the handrail and hides the ends of the treads and risers. An open- or cut-string is cut to expose the tread and riser ends, and requires balusters of differing heights per tread.

Tread The flat or horizontal element of a stair which one treads on.

Well The void or area enclosed by a staircase.

Winder Describes the triangular steps (winders) where a stair changes direction without landings.

TYPES OF STAIRCASE



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