THIRD EDITION BUILDING PATHOLOGY PRINCIPLES AND PRACTICE

DAVID S. WATT

WILEY Blackwell

Building Pathology

Building Pathology

Principles and Practice

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Third Edition

WILEY Blackwell

This edition first published 2025 © 2025 John Wiley & Sons Ltd.

Edition History

John Wiley & Sons Ltd (2e, 2008); Blackwell Science Ltd (1e, 1999)

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Library of Congress Cataloging-in-Publication Data Applied for:

Paberback ISBN: 9781119908258

Cover Design: Wiley Cover Image: Courtesy of the Author

Set in 9.5/12.5pt STIXTwoText by Straive, Chennai, India

To palliate the shortness of our lives, and to compensate our brief term in this world, it is fit to have such an understanding of times past that we may be considered to have dwelled in the same. In such a manner, answering the present with the past, we may live from the beginning and in a certain sense be as old as our country itself.

Peter Ackroyd (1992) English Music.

Contents

About the Author xi Preface to Third Edition xiii

1 Introduction 1

What is building pathology? 1 Why take a holistic approach to understanding buildings? 2 The relevance of building pathology 6 The principles and practice of building pathology 7 References 7

2 Understanding Buildings 9

What is a building? 9 Perceptions of buildings 13 Classification of buildings 16 Requirements of buildings 17 Our expectations of buildings 23 The way forward 27 Reference 28 Further reading 28

3 Building Performance 29

Why do buildings stand up? 29 Building structures 31 Building materials 36 Understanding building materials 37 Sources of building materials 39 Timber 42 Plant material 47 Stone 48 Ceramics 54 Binders and concrete 58 viii Contents

Metals 65 Glass 71 Bituminous products 73 Modern materials 74 Unusual materials 77 Building services 77 The building as a whole 82 Understanding buildings and building performance 83 Assessing building performance 83 How the construction industry needs to change 85 References 86 Further reading 87

4 Defects, Damage and Decay 89

What is a building defect? 89 Nature of building defects 90 Causes and effects of defects, damage and decay 95 Atmospheric and climatic action 98 Excess moisture 108 Chemical, physical and biological action 116 Movement 135 Fire 137 Human factors 139 References 142 Further reading 142

5 Survey and Assessment 145

Fault-finding 145 Building inspections and surveys 146 Assessment of defects 154 Severity of defects 155 Prioritising defects and remedial works 157 Unoccupied buildings and sites 158 Redundant and ruined buildings 159 Diagnosis and prognosis of defects 162 Non-destructive investigations 169 Monitoring defects 175 Environmental conditions 179 References 180 Further reading 180

6 Principles into Practice 183

Putting principles into practice 183 The changing fortunes of buildings 183 Looking forward by looking backwards 187

Cross-laminated timber buildings and their common defects 191 Understanding buildings: St Fagans National Museum of History 202 Relationship between fire and building pathology 208 Carrying out inspections and working at height 224 Conservation management plan for Marx Memorial Library 230 Training surveyors using script concordance testing 239 Scientific investigations at Hill House 243 Monitoring seismic movement at a church in Corfu 248 Diagnosing defects in a Martello tower 251 Using simple measurements to understand a problem 255 Bats in churches 258 Lincoln Cathedral's west front and Romanesque frieze 262 Planned preventative maintenance for Britten Pears Arts 270 Retrofit for rural National Trust buildings 279 New Court – a retrofit workflow by ArchiMetrics Ltd 285 Buildings on paper and in practice 292 Heritage, health and well-being 302 Dealing with chemical contamination in a building 306 Sustainable housing for the future 315 Lessons to be learned 319

7 Building Management and Aftercare 321

Planning the future 321 What can be done with buildings? 321 Managing building and change 324 Limitations of existing buildings 325 Finding the right use for a building 327 Making use of historic buildings and sites 328 Principles of conservation and building repairs 331 Principles of building maintenance 335 Planned preventive maintenance 337 Principles of retrofit 338 Climate resilience and mitigation 339 Planning for disasters and emergencies 341 Managing unoccupied buildings and sites 343 Heritage crime 346 Health and the built environment 347 Issues of sustainability and sustainable development 355 Stewardship and assessments of value 357 Buildings for the present and the future 359 References 360 Further reading 360

Appendix A Requirements of Approved Documents Supporting Schedule 1 to Building Regulations 2010 365

 Contents
 Appendix B Hazard Identification Checklist 381
 Appendix C Useful Contacts 389
 Appendix D Warning Bells 395
 Glossary 399 Index 405

About the Author

David S. Watt is a chartered building surveyor and historic buildings consultant. He has worked in private practice, as conservation officer for Norfolk County Council and as a senior research fellow at De Montfort University. Since 2005 he has been an associate director with Hutton + Rostron Environmental Investigations Ltd (a SOCOTEC company) and in 2023 was appointed as a visiting professor at Oxford Brookes University. His particular interests relate to the influence of people and environmental conditions on historic buildings and the use of traditional building materials and practices.

Preface to Third Edition

In the quarter century since the publication of the first edition, significant events have changed the world in which we live. Each country has its own story, but in the UK the foot and mouth epidemics of 2001 and 2007, London bombings in 2005, financial crisis of 2008, Grenfell Tower fire in June 2017, withdrawal from the European Union (Brexit) on 31 January 2020, cost of living crisis starting in late 2021, death of Queen Elizabeth II in September 2022 and flooding across parts of the country in 2023/24 might be seen as some of the defining moments in the recent history of the nation. At a global level there have been natural and man-made disasters, war and the Covid-19 pandemic, as well as a range of emerging threats to public health (including antimicrobial resistance, mental health crises and environmental pollution), but perhaps the most pressing issue that will affect all of us is climate change. This is a book about building pathology, yet we cannot ignore how our world is changing when it comes to ways we choose to design, construct, manage and occupy our buildings.

Building pathology – both as a term and as a concept – has become widely used to define a holistic approach to understanding buildings. Such an approach requires a detailed knowledge of how buildings are constructed, used, occupied and maintained and the various mechanisms by which their structural, material and environmental conditions can be affected. It is, by necessity, an interdisciplinary approach and requires a wider recognition of the ways in which buildings and people react and respond to each other. It is not just about older or historic buildings, but all buildings.

Whilst the merits of building pathology have become more widely recognised (being a taught module on most building surveying courses and core skill for assessing professional competence), too often it is only the term, rather than the underlying principles, that has been adopted. In other professional training, such as for architects, little account appears to have been taken of the ethos for better understanding existing buildings and how they perform in time and place.

The purpose of this new edition is to put emphasis on the concept of building pathology and, with it, bridge the gap between current approaches to the surveying of buildings and the detailed – and often forensic – study of building performance and failures. It remains as a textbook for practitioners and students of built environment disciplines and will hopefully be of use to others who are responsible for managing buildings, structures and sites.

A criticism of books concerned with the survey, repair and maintenance of buildings is that no absolute answers are given, whether for the diagnosis of defects or recommendation

xiv Preface to Third Edition

for remediation. The reason is that such answers usually require more information than can be given in the pages of a book. It is partly in response that this current edition urges its readers to seek a greater awareness and comprehension of buildings to assist in the design and implementation of specific and appropriate remedial action.

This third edition includes case studies that demonstrate practical and often innovative approaches taken to address a range of issues and I am grateful to the respective authors and contributors.

Earlier editions of this book included thorough referencing of sources and lists of further reading, but increased use of the Internet and the increasing cost of publications mean this is no longer as important. Many of the suggested reference books have been around for several years, but the content remains relevant.

1

Introduction

What is building pathology?

The term *pathology* is defined as the systematic study of diseases with the aim of understanding their causes, symptoms and treatment. In a medical context, the person becomes the subject of detailed examination and investigation, with consideration given to age, health and lifestyle. A similar approach is relevant in the study of buildings, and it is this methodical and often forensic practice that has come to be termed *building pathology*.

1

Building pathology, both as a term and as an overall concept, has become more widely used to define the holistic approach to understanding buildings. Such an approach requires a detailed knowledge of how buildings are designed, constructed, used and changed, and the various mechanisms by which their material and environmental conditions can be affected. It is, by necessity, an interdisciplinary approach and requires a wider recognition of the ways in which buildings and people react and respond to each other.

The definition of building pathology given by the Association of European Experts in Building and Construction (AEEBC) draws attention to three separate, though interrelated, areas of concern:

- · identification, investigation and diagnosis of defects in existing buildings
- prognosis of defects diagnosed and recommendations for the most appropriate course of action having regard to the building, its future and resources available
- design, specification, implementation and supervision of appropriate programmes of remedial works and monitoring and evaluation of remedial works in terms of their functional, technical and economic performance in use

Other definitions include:

- study of failures in the interrelationship of building structures and materials with their environments, occupants and contents (Hutton + Rostron)
- study of failures over time in building materials and components (Groák)
- systematic treatment of building defects, their causes, their consequences and their remedies (CIB W86 Building Pathology Commission)

2 1 Introduction

- scientific study of abnormalities in the structure and functioning of the building envelope and its parts; it seeks to study the interrelationships of building materials, construction, services and spatial arrangement with their environments, occupants and contents (Singh)
- forensic approach to inspecting, investigating and problem-solving in buildings and finding solutions (CIOB Academy)
- holistic approach to studying and understanding buildings and, in particular, building defects and associated remedial action. In a medical context, pathology is the study of diseases in order to determine their causes and prescribe treatment. Similarly, building pathology involves the methodical study of buildings, their components and their environment to address failures (Designing Buildings)
- process by which the history and condition of a building, and its suitability for improvement, are analysed systematically as part of its assessment for retrofit (PAS 2035). The whole-dwelling approach described in this publicly available specification considers a building to be a system of elements, interfaces and occupants that interact, rather than a set of elements that are independent of each other or of the practices or lifestyles of the occupants

The International Council for Research and Innovation in Building and Construction (CIB; formerly International Council for Building) was established in 1953 to stimulate and facilitate international cooperation and information exchange. It has since developed into a worldwide network whose members are active in over 30 working commissions covering all fields in building and construction-related research and innovation. The objectives of the Building Pathology Commission (W86) are to conduct basic and applied research; promote meetings and webinars about the application of building pathology; disseminate information to those involved in the design, construction and management of buildings; participate in creating international and national standardisation or technical notes and strengthen connections with relevant CIB commissions and other organisations.

Although each definition places a slightly different emphasis on aspects of the discipline – in particular the link to retrofit given in PAS 2035 – it is clear that building pathology, in its widest sense, is concerned principally with performance, defects and associated remedial action. The lessons that can be learnt from such a structured approach can also be brought into play when altering existing buildings or in the design of new buildings. The purpose of this book is therefore to expand the range of investigation normally undertaken in the surveying of buildings and to draw together various categories of information that are required to make informed decisions about how buildings might be adapted, repaired and best utilised now and in the future.

Why take a holistic approach to understanding buildings?

Buildings do not exist in isolation, but instead represent various levels of action and interaction between people and their surroundings – on the one hand, they can be expressions of creative impulse and, on the other, simple statements of functional need. Put another way, they are complex systems of materials and environments evolving over time. In whichever form the building exists, it is a physical response to people, place and environment. Shifts in the balance between these three factors are responsible for many of the decisions around which buildings are built, occupied, adapted and ultimately destroyed. Why take a holistic approach to understanding buildings? **3**



Buildings in context, reflecting intersecting systems and highlighting the importance of adopting an inclusive holistic approach to understanding performance and failure.

In order to understand a building, it must first be considered in context, from when it was designed and built, through changes over time, to its present use today. This progression takes into account various actions, some significant and others more mundane, but all giving information that may have relevance to understanding the building in the context of the present. Such an approach has much in common with archaeology, combining aspects of discovery, scientific analysis and creative imagination, but with the wider objective of informing decisions that will affect the present and the future.



Archaeological investigation that helps understand the history and development of buildings.

4 1 Introduction

Taking a wider view of a building thus requires a level of understanding that, apart from simple examples, will often require the knowledge and experience of various disciplines. Those who might commonly be called upon to offer advice or an opinion as part of an interdisciplinary team may include:

- · administrators and asset, building or facilities managers
- archaeologists
- architects and designers
- art and architectural historians
- building control approver or building inspector
- building services engineers
- building surveyors
- conservation officers
- disaster/emergency managers
- ecologists
- environmental and material scientists
- fire safety engineers
- garden and landscape consultants
- · general practice and investment surveyors
- insurers and loss adjusters
- interior designers
- quantity surveyors
- town and urban planners
- structural and civil engineers

Additional advice, information or comment may also be received from:

- · amenity societies and community groups
- governmental departments and organisations
- non-governmental organisations
- owners and occupiers
- public utilities (e.g. communications, electricity, gas, water)
- service staff (e.g. caretakers, cleaners, ground staff, security)
- local authorities (e.g. building control, environmental health, planning, transportation)

More specialised information may additionally be required from other groups or individuals when dealing with particular building types or situations. Those who might contribute to an understanding of historic buildings may, for instance, include conservators, curators and craftworkers. Other sources of information may have to be sought and examined for each specific need.

The needs required to form an understanding of a building must consider the building in context with its location and use. Consideration of one without the others is a common fault that may ultimately lead to dissatisfaction, unnecessary expense or unjustifiable change.

Whilst it has become the norm to specialise, there is merit in retaining a wider set of interests and learning through a variety of means. Static learning solely from books can take one so far, but experience gained through dynamic learning – by watching, discussing and attempting a particular task – will provide a better grounding. Specialisation can also

stifle the skills of problem-solving and cause one to miss synergies (combined actions or operations) that might exist between one set of conditions and another. Far better to have several areas of interest or expertise and recognise that a task, such as understanding a building defect, can be better done by thinking in terms of systems rather than a more common reductionist view of seeing only a set of separate parts. This is at the core of what building pathology is about.

Needs of the building

Buildings, together with their contents, present a complex assembly of materials and parts. Each material, whether it forms an identifiable element or component of the construction or part of the internal fabric, has its own characteristics and requirements. Traditional buildings, which are essentially a collection of natural materials, rely on soft mortars, sacrificial renders, moisture–vapour permeable plaster and finishes and natural ventilation to retain their integrity and cohesion. This is in contrast to more modern buildings that make use of cement and concrete, plastics, composites and other artificial or human-made materials to fulfil the requirements of client, designer and statutory authority.

The needs of the building, of whatever age or construction, must be understood, respected and responded to if it is to function to an acceptable standard. It is these needs, and the question of what is 'acceptable', that will be considered in later parts of this book.



The design, construction and use of contemporary buildings differ in many ways from those of previous generations.

6 1 Introduction

Needs of the building user

The use and function of buildings change over time, and with each change comes a different, and often conflicting, set of requirements. These user requirements will typically leave evidence in the form of physical changes to the structure, fabric and services of the building; personal recollections and remembrances and associated documentation. Each of these levels of evidence will provide potentially useful information to be collected and considered when attempting to understand a building or collection of buildings. The question to ask is, 'How have we arrived at the point we are now?'

The relevance of building pathology

The relevance of building pathology to practitioners and students of built environment disciplines, and others who are responsible for managing buildings and their sites, lies principally in the need for more accurate and appropriate information on which to base decisions. This need may arise for a variety of reasons:

- determine financial security against an intended loan or mortgage, or change of ownership
- provide confidence on acquisition for occupation or investment by way of a report commissioned by a purchaser or vendor wishing to confirm or disclose material facts (technical due diligence survey)
- determine stability and risk of failure following natural or man-made disasters
- establish liability for disrepair (dilapidations)
- · diagnose defects when symptoms appear to occupiers
- determine the effectiveness of past repairs or maintenance
- assess levels of disrepair in advance of legal proceedings
- acquire information about a building including design, construction, occupation, refurbishment and ongoing management (e.g. knowledge acquisition survey, golden thread)
- understand key aspects of buildings and facilities to inform strategies and manage risk (six-facet survey)
- ensure compliance with legal requirements
- understand and document factors affecting condition
- provide a basis for planned work (repair, maintenance, retrofit)
- provide a basis for physical change (adaptation, change of use)
- inform post-occupancy evaluations
- provide opinion in court (Part 35 compliant expert witness report)

Whatever the reason, this need for accurate and appropriate information, acquired at a cost that is acceptable to the client, will require a change in the ways in which buildings are perceived and dealt with. The acceptance and practice of building pathology – providing a holistic approach to understanding buildings – will add an extra dimension to what many professional advisers already offer. As such, its relevance needs to be acknowledged and understood, and its principles more fully adopted.

The principles and practice of building pathology

The principles upon which building pathology is based rely on a detailed knowledge of how a building is designed, constructed, used and changed and the various mechanisms by which its structural, material and environmental conditions can be affected. It is more than just a detailed building survey, for it acknowledges the relative importance of people, place and environment. Such a comprehensive approach to understanding buildings offers potential for developing a deeper understanding and providing more useful information.

It is often said that every art benefits from a little science and every science benefits from a little art. Building pathology is very much an art and a science. Whilst the diagnosis of building failures may require detailed investigation, which could include testing, analysis and monitoring, it also requires imagination to ask questions, reflect on events and causes and conceive appropriate courses of action.

The following chapters are laid out to provide a logical progression, with consideration of buildings, building performance, causes and effects of problems, survey and assessment, remediation in practice and principles of building management and aftercare.

What is building pathology?

Building pathology offers a holistic approach to understanding the built environment by recognising relationships between people, buildings, environments, uses and contents. This requires critical thinking. It encourages collaboration between different professional groups and embraces a wider set of interests.

> This includes legislation (fire, safety, planning, environment), history (art, architecture, social, political), health and well-being, building services, sustainability, ecology, technology, construction, engineering, archaeology and cultural studies, design (architecture, interiors, furnishings) and sciences (biology, chemistry, physics, geology, environment, materials).

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8 1 Introduction

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2

Understanding Buildings

What is a building?

What is a building? Although this might at first sight appear to be a relatively straightforward question, it can nevertheless be answered in a variety of ways. To most people who live and work in buildings, they are merely containers for activities that require shelter from the external environment. Such containers may vary in complexity from simple bus shelters to elaborate cathedrals or from traditional forms of construction to those that rely on sophisticated building services in order to create and maintain specified environmental conditions.

The image that a building acts as a container or envelope, which buffers or filters the external environment for internal needs, is one that is widely used in understanding how buildings work. An analogy of a building acting like a skin, which surrounds the occupants and modifies environmental conditions, is similarly useful in that it indicates how it must be strong, resilient and able to adapt to changing conditions if it is to succeed and survive. Self-healing, both as a natural ability of the skin and inspiration for futuristic surface materials, takes this concept still further.

This image of a building behaving as a skin has been advanced with the notion that there is no such thing as a building at all! Instead, there is a series of layers or boundaries – *shell, services, scenery* and *set* proposed by Duffy and *site, structure, skin, services, space plan* and *stuff* offered by Brand – which tear or shear due to different rates of change. This is again useful in emphasising that buildings are more than just bricks and mortar. Taken together, a building might be considered to be an experiment in time from which lessons can be learnt and attitudes changed.

Whether buildings are *more* than the sum of their component parts, representing a synergistic relationship between building and user, is a matter of personal opinion and debate. This is not to suggest the existence of a built 'superorganism', similar to that of James Lovelock's *Gaia*, but the concept that a building has a birth, life and death is, however, known in various parts of the world and is acknowledged in the temple building of the ancient Mayan civilisation of Central America.



Buildings may be seen as a collection of different layers that react and respond to one another, but ultimately have to fit together, as with this Russian matryoshka nesting doll, in order to work.

The success of a building in fulfilling its basic duties of containment and shelter depends on a series of related and interrelated issues. Much has been written on design theory and practice, and whilst it is not the purpose of this book to comment on how new buildings are procured, designed and built, it is useful to consider some guiding views on the subject:

In Architecture as in all other Operative Arts, the end must direct the Operation. The end is to build well. Well building hath three Conditions. Commodity [user satisfaction], Firmness [structurally sound], and Delight [aesthetically pleasing].

(Sir Henry Wotton)

When we build, let us think that we build forever. Let it not be for present delight nor for present use alone. Let it be such work as our descendants will thank us for. (John Ruskin)

We start with the ground. This is rock and humus. A building is planted to survive the elements – the ground already has form. Why not begin by accepting that? Is the ground a prairie, square, flat? Is the ground sunny or the shaded slope of some hill, high or low, bare or wooded, triangular or square? Has the site features, trees, rocks, streams or a visible trend of some kind? Has it some fault or a special virtue or several? So essentially the site is the starting point of design.

(Frank Lloyd Wright)

Man puts available materials together to form shelter in such a way as to modify the indigenous climate in order to provide a satisfactory climate of comfort and convenience within. If the climate concept includes the cultural, social, political, aesthetic climates in addition to the physical one it suggests three kinds of information are needed [pattern of activities, available site with its indigenous climate and building technology]. Without satisfaction, an individual may be unhappy, inefficient and uncomfortable.

(Geoffrey Broadbent)

The reason for architecture is to encourage ... people ... to behave, mentally and physically, in ways they had previously thought impossible.

(Cedric Price)

What should we ask of a new shelter? We should ask for protection from the elements, an adequate level of comfort and a pleasurable environment that enhances our life. These features should be supplied economically, simply, reliably. Shelter should not dominate our lives but rather make minimum impact upon us. Ideally, a shelter should make us aware of the beauties and delights of nature rather than remove us from them.

(Rodale)

All buildings give their owners opportunities to recondition visitors' expectations and to lay down rules of conduct specific to them.

(Alain de Botton)

Each building is a box built not just of bricks and mortar, but of a series of practices, associations and taboos, the designation of what is acceptable, the design of normality Third Space is the place where real life occurs amid its theoretical design.

(Nick Hayes)

Buildings are also expressions of the people and society that built them – this forms part of the national identity. Changes in society are thus reflected in how and when buildings are designed, constructed, utilised, adapted and ultimately destroyed. Some of the most important concerns to have shifted building design and construction throughout history have been those of comfort and security – each has forced change that today represents history, whether it be architectural or social, political or economic. Chapter 6 case study *The changing fortunes of buildings* considers what has happened to two particular buildings over the past 400 years.

These changes, and the changing demands of modern lifestyles, continue to this day with the development of building automation and management systems that can control heating, ventilation, lighting, security and other facets of building use to allow simple and efficient management with greater comfort and reduced energy consumption and costs. The goal of a smart building is to self-manage, learn, anticipate and adapt without intervention. Such changes, and corresponding shifts in attitude, will continue for as long as there is freedom of choice and action.

Although change is evident in how we use our buildings, there are nevertheless reminders of the past embedded in the buildings of the present. Such symbols of fashion or sentiment represent a visible link to earlier principles and practices, albeit often misunderstood and misapplied. This preoccupation with the past, driven by a growing awareness and interest in a nation's cultural heritage, also creates a tension between old and new, witnessed by buildings that are out of harmony with their surroundings in place and time.



The Dugald Stewart Monument on Calton Hill overlooking the capital city of Scotland, with Edinburgh Castle, Balmoral Clock Tower and the Scott Monument on the skyline. Edinburgh was inscribed as a UNESCO world heritage site in 1995 for its outstanding universal value reflected in the striking contrast and quality of architecture between the medieval Old Town and the Georgian New Town.



The Odeon on Alderney (Channel Islands) was built in 1943 using forced labour as a naval range-finding tower to observe enemy ships and form part of a network with five other similar towers around the island. It is open to the public.

There is also a growing need to develop better ways of planning, designing, constructing and maintaining buildings to improve the sustainability of the built environment. The UK Green Building Council (UKGBC) has highlighted the importance of a built environment, which enables people to thrive by mitigating and adapting to climate change, eliminating waste and maximising resource efficiency, embracing and restoring nature and promoting biodiversity, optimising the health and well-being of people and creating long-term value for society and improving quality of life. This set of goals provides the challenge that will ultimately take buildings and their construction into the coming decades.

Perceptions of buildings

Since people first began to think of buildings as commonplace (probably with the advent of mass housing in the twentieth century), rather than essential for their survival, our perception of and regard for the built environment has progressively diminished. Buildings might thus be many things to many people, yet for much of the time their presence and purpose are ignored.

Whether one likes a building or not depends on personal preference and refinement. This is derived from a host of conscious and subconscious judgements, including personal values, beliefs and meanings; knowledge and experience of a building or space; and mental or visual stimuli based on prompts such as books, films and childhood memories. These personal, and often intimate, perceptions or sensations – many acting as dualisms – include:

- light and dark (e.g. visible, hidden)
- hot and cold (e.g. comfort, discomfort)
- dry and humid (e.g. airless, clammy)
- sunshine and shadow (e.g. glare, movement)
- colour and texture (e.g. cold/warm, rough/smooth)
- smells and odours (e.g. musty cellar)
- sound and silence (e.g. echoes, music, stillness)
- location and situation (e.g. hilltop, valley)
- size and scale (e.g. intimate, intimidating)
- context and use (e.g. recognition, confusion)
- character and association (e.g. 'haunted house')
- people and contents (e.g. familiarity, caution)
- private and public (e.g. boundary layer)
- contemplation and pilgrimage (e.g. labyrinth)
- disenchantment and wonder (e.g. mystery, rationalism, ordinary/fantastic)
- disguise and deceit (e.g. camouflage, trickery)

As well as such palpable observations, buildings – as with pictures and sculptures – are able to cause the user or observer to experience their surroundings in less apparent ways. Cognitive perception and sensory responses that might be experienced when in and around buildings may thus indicate a latent awareness or 'feeling' of what is 'good' and 'bad'. These feelings have been used by designers throughout history to bring about differing emotions, sensations or behaviours that reflect the nature and use of the

14 2 Understanding Buildings

building. Such stimulation or arousal is one of the essential elements of good architecture. Architecture may not be intentional, but rather accidental, and develops through various individual design decisions – often based on a single consideration – rather than a unified design.



Left: Rushton Triangular Lodge (Northamptonshire). In plan, this building is an equilateral triangle, with three storeys having three windows on each side and on each floor. Each side has three gables, rising to three tapering pinnacles. At the intersection of the roof is a three-sided chimney stack. Below the gables is a frieze with a continuous inscription carried round the three sides, each side (33 ft long) bearing 33 letters. The Lodge, built by Sir Thomas Tresham in 1593–97, is symbolic of the Holy Trinity and linked to the doctrine of the Mass and contains allusion to both religious literature and personal imagery. *Right*: The Mausoleum in Blickling Park (Norfolk) was built in 1793 to a design by Joseph Bonomi and erected in memory of John Hobart, Earl of Buckingham (d.1793). The regular pyramidal structure was modelled on the pyramid of Cestius in Rome and represents one of the best examples of the influence of ancient Egyptian culture on the Roman Empire and an early example of Egyptian Revival architecture.

Various feelings generated by architecture			
'Good feelings'		'Bad feelings'	
• homely	• welcoming	 claustrophobic 	 lonely
• peaceful	• comfortable	 intimidating 	• morbid
 spiritual 	 spacious 	 overwhelming 	• isolated
• restful	 uplifting 	 demoralising 	• uncomfortable
• atmospheric	• exciting	• cramped	 impoverished
 inspiring 	• breathtaking	 oppressive 	• squalid

These judgements are, however, essentially subjective in nature and may only partly answer the question of whether a building is really 'good' or 'bad'. Objectivity comes from acknowledging the various requirements of the building and assessing it against accepted criteria. These might include:

• fitness for purpose (e.g. needs, expectations, functionality)