ADAPTING ADVANCES IN MEDICAL CLINICAL REASONING FOR THE CONTINUOUS LEARNING AND APPLICATION OF METHODS AND PROCEDURES FOR HOLISTIC BUILDING PATHOLOGY

by

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ABSTRACT

Purpose

Buildings are crucial for the survival of individuals and cultures, making the investigation and remediation of failures in the built environment essential, especially in a rapidly changing world and under the stress of climate change. Building Pathology, a relatively new subject, involves a holistic approach to diagnosing and addressing failures in buildings, viewing them as complex systems that evolve over time. However, since its inception in the 1980s, the understanding and application of Building Pathology has remained underdeveloped. This research tests the hypothesis that Building Pathology can be treated as a parallel to Medical Pathology, allowing the adaptation of recent advances in Medical Clinical Reasoning to improve the learning and application of holistic Building Pathology.

Research Methodology

This research, aiming to establish a holistic foundation for Building Pathology, began with a review of literature exploring the evolution of buildings as biologically generated systems and the origins of building pathologies. It draws parallels with medical pathology to support the hypothesis that these fields share similarities.

Building Pathology, which emerged in the 1980s, was further reviewed through literature and pilot interviews with experts. A key constraint identified was the lack of a holistic, evolutionary approach to the field, including the importance of case histories. To address this, methods for teaching and applying a holistic approach to Building Pathology were proposed, based on the researcher's 40 years of experience and recent advancements in clinical reasoning in medical pathology.

To support the research, current teaching practices in Building Pathology in the UK were compared to those in Clinical Reasoning, using semi-structured interviews with educators. Methods for diagnosing damp problems, a representative subset of Building Pathology, were developed through action research, informed by both the researcher's experience and developments in medical clinical reasoning.

Finally, Script Concordance Tests were created to teach and assess the metacognitive processes involved in diagnosing damp problems, based on best practices in medical clinical reasoning. These tests were beta-tested with experts and students, demonstrating the potential for parallel processes in learning and applying diagnoses in both fields.

Findings

This research presents key findings that advance the field of Building Pathology. It identifies the evolution of buildings and their associated pathologies, showing how these issues develop over time. The study also analyses barriers to the growth of Building Pathology as both a practical discipline and academic subject, including the lack of holistic understanding and approaches in training and practice.

A major contribution is the identification of parallels between Building Pathology and Medical Clinical Reasoning, suggesting that medical diagnostic principles can be applied to building failures. This comparison provides a framework for continuous learning in diagnosing and treating building pathologies.

The research also develops a comprehensive system for applying and continuously learning Holistic Building Pathology, integrating diagnostic tools to support both initial assessments and ongoing education, essential for addressing evolving challenges in the built environment.

The study further evaluates current best practices for teaching Building Pathology in the UK, identifying gaps in existing programs and highlighting the need for more structured, case-based, and holistic approaches. Additionally, the research creates metacognitive tools and frameworks to address "damp problems," a key subset within Building Pathology, improving diagnostic accuracy and decision-making.

Lastly, the research validates Script Concordance Tests (SCTs) as an effective method for assessing clinical reasoning in Building Pathology, ensuring practitioners have the necessary skills for accurate diagnosis and remediation.

Originality

The ‘new, original contributions to knowledge’ arising from this work is that Building Pathology and Medical Pathology are not just analogous but are similar and parallel subjects, and that recent advances in the teaching and continuous learning in the subject of Medical Clinical Reasoning can therefore be used to facilitate the continuous learning and application of the subject of Building Pathology. This research is also the first recorded use of Script Concordance Tests outside of education and certification in the medical professions, which serves as a practical illustration of a number of the theoretical aspects explored as part of this Thesis.

Keywords

Architecture, Building Failure, Building Pathology, Diagnosis, Script Concordance Test.

DEDICATION

This work is dedicated to my late father Geoffrey Hewland Hutton Esq. RIBA

He was a man of vision and a thinker who dedicated his life to the idea that knowledge and information were essential, and are resources that the more we use the more we have.

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LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CONTENTS PAGE

GLOSSARY OF TERMS

NB the definitions in this glossary are based on those provided by Google and Wikipedia online.

AI: Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems. Specific applications of AI include expert systems, natural language processing, speech recognition and machine vision.

Acanthus: is a stylised ornamentation in classical architecture and decorative arts, based on a characteristic Mediterranean plant with jagged leaves.

Anatomy: is a branch of natural science which deals with the structural organization of living things.

Anthropo-bio-geomorphology: is the study of interactions between human activity and the development of landform and environments.

Anthropogenic: refers to things that have been generated by human activity.

Anthropocene period: is a proposed epoch dating from the commencement of significant human impact on the Earth's geology and ecosystems.

Bayesian Statistics: interpretation of probability where probability expresses a degree of belief in an event, which can change as new information is gathered, rather than a fixed value based upon frequency or propensity.

Bio-geomorphology: is the study of interactions between biological organisms and the development of landforms and environments.

Bressummer: is a load bearing beam in the timber framing of a building.

Building Forensics: the study and evaluation of problematic conditions in a building and its many systems, to provide evidence for legal purposes.

Clinical Reasoning: is the process by which a clinician collects cues, process the information, come to an understanding of a patient problem or situation, plan and implement interventions, evaluate outcomes, and reflect on and learn from the process of critical thinking.

Cognitive Psychology: is the study of mental processes such as "attention, language use, memory, perception, problem solving, creativity, and thinking".

Commensalism: different species of plant or animal living in close association, such that one species benefits without harming the other.

Complexity: characterizes the behaviour of a system whose components interact in multiple ways and follow local rules, leading to non-linear or randomness, collective dynamics, hierarchy, and emergence. Complexity science is the study of the phenomena which emerge from a collection of interacting objects.

Continuous Professional Development (CPD): Continuing, or continuous, professional development (CPD), can be broadly defined as any type of learning you undertake which increases your knowledge, understanding and experiences of a subject area or role.

Cornice: this is generally any horizontal decorative moulding that crowns a building or furniture element. The function of the projecting cornice of a building is to throw rainwater free of the building's walls.

Craft: is an activity involving skill in making things by hand.

Decision Theory: is the study of strategies for optimal decision-making between options involving different risks or expectations of gain or loss depending on the outcome.

Defrassing: describes the removal of material from timber that has been structurally decayed by wood boring beetle larvae.

Diagnosis: is the identification of the nature and cause of a certain phenomenon.

End use: the ultimate use for which something is intended or to which it is put.

Entopic: occurring in its usual place.

Epigenetic: describes inheritable changes that do not involve alterations in the DNA sequence.

Evolution: is the gradual development and change of heritable characteristics over successive generations. Although commonly used to describe the Darwinian theory of evolution through natural selection of biological organisms, in this Thesis the term is used more generally to describe all systems that change progressively over time including biological, physical, and cultural systems.

Geophilic: means soil loving or preferring the soil.

Hardwood: comes from angiosperm, deciduous and broad-leaved trees. Trees that lose their leaves in the autumn, such as oak.

Hartwood: is wood nearer the pith of a stem or branch, different in colour from sapwood.

Holistic: Philosophically the parts of something are intimately interconnected and explicable only by reference to the whole. In Medicine, treatment considers the whole organism, and mental and social factors, rather than just the symptoms of a disease.

IT: Information technology (IT) is the use of computer systems to manage, process, protect, and exchange information.

Joist: is a length of timber or steel supporting part of the structure of a building, typically arranged in parallel series to support a floor or ceiling.

Latent defect period: the period when a Builder may be liable in law for a defect or flaw in building works which is hidden from knowledge or concealed from sight at completion pf the works.

Mimesis: is an idea that governed the creation of works of art with correspondence to the physical world understood as a model for beauty, truth, and the good.

Metacognitive: describes "cognition about cognition", "thinking about thinking", "knowing about knowing", becoming "aware of one's a*wareness*" and higher-order thinking skills.

Moribund: not active or successful and in terminal decline.

Negativity: a tendency to pessimism that always expects the worst.

Nocebo: is a detrimental effect on health produced by psychological or psychosomatic factors such as negative expectations of treatment or prognosis.

Parasitical: living off an organism of another species at the other's expense.

Pathology: is used broadly to refer to the study of disease in general, incorporating a wide range of bioscience research fields and medical practices.

Physiology: is the study of the normal functions of living organisms and their parts.

Placebo Effect: a beneficial effect produced by a treatment, which cannot be attributed to the properties of the treatment itself and must therefore be due to the subjects' belief in that treatment.

Probabilistic assessment: is a systematic and comprehensive methodology to evaluate risks associated with a complex engineered technological entity.

Prognosis: a forecast, based on experience, of the likely course of a condition and the likely outcome of a situation.

Prejudice: is a preconceived opinion that is not based on reason but may be based on previous experience.

Reductionist: attempting to analyse or describe a complex phenomenon in terms of its simple or fundamental constituents., or a philosophical position that interprets a complex system as the sum of its parts.

Relativism: is the doctrine that knowledge, and truth exist in relation to culture, society, or historical context, and are not absolute.

Remediation: the action of remedying something, of reversing or stopping environmental damage.

Sapwood: the soft outer layers of recently formed wood between the heartwood and the bark, containing the functioning vascular tissue.

Schema: in psychology this is a collection or network of previously gained knowledge that affects how new information is processed.

Scenario: in psychology is an adaptation of problem-based learning using hypothetical case studies that represent situations which might be typically encountered.

Script: in psychology this is the sequence of events expected in a specific setting.

Snagging: the process of checking for and identifying defects after building works, and bringing these defects to the attention of the Builder so that hey can be corrected.

Short termism: when individuals companies, or countries focus on short-term results to the detriment of long-term results.

Softwood: is a type of wood that is cut from trees belonging to gymnosperms, such as coniferous trees.

Speciation: is the formation of new and distinct species during evolution.

Status quo: the existing state of affairs, particularly with regard to social, economic, legal environmental, political, religious, or scientific issues.

System Engineering: is an interdisciplinary field of engineering management that focuses on how to design and manage complex systems over their life cycles.

Think-evil: a description of the process in Military or other planning processes where the planners consider what could possibly go wrong that could have a negative impact on their plan.

Treatment: care given to a subject for an illness or injury.

Value Engineering: is a systematic method to improve the "value" of goods or products and services by an examination of function, cost and benefit.

Vernacular Architecture: is an architectural style that is based on local needs, availability of construction materials and reflecting local traditions.

Waney: the outside of a cut timber with no square edge due to the natural shape of the original timber, the original bark being retained, and/or decay to the timber.

Zeitgeist: is a concept from 18th- to 19th-century German philosophy, translated as "spirit of the age" or "spirit of the times".

CHAPTER 1: INTRODUCTION

1.1 Background

Building Pathology as a concept first developed in the 1980s when the author and a number of other building professionals and academics with a cross-disciplinary background began looking at failures in buildings and the built environment in an 'holistic' way (Hutton, 1989a). This may have been part of the 'zeitgeist' of the time when holistic cross-disciplinary approaches were being applied to many subjects from Anthropology and Complexity-theory to Sociology and Zoology. At the same time the obvious limitations and failures in buildings designed and constructed in the second half of the 20th century was becoming abundantly clear, and older more 'historic' buildings were being increasingly valued and conserved (Harvey, 1972; Feilden, 2007; Earl and Saint, 2015). This was not just due to their cultural significance, but also because they were starting to be perceived as more desirable and 'fit for purpose' than many of the more recently built 'Modern' or 'Brutalist' structures of the 20th century (Frampton and Futagawa, 1983; Klotz and Donnell, 1988). It was also apparent that no single building profession or science was able to understand or effectively remedy the problems in buildings and built environments that were occurring. In particular, it was becoming clear that many remedial interventions generated unforeseen problems, which then required yet further remedial works.

The term 'Building Pathology' started to be used by the author and others to describe the study of this phenomena (Hutton, Lloyd and Singh, 1992a; Hutton and Dobson, 1993; Hutton and Lloyd, 1993). This was a development from the mid-20th century German concept of 'Baubiologie' or 'Building Biology' (Palm, 1992); where clothing was thought of as the second skin, and buildings were thought of as the 'third skin' of the organism inhabiting them. It was therefore perceived that buildings and the built environment were closely related to the organisms inhabiting them and might thus be studied and understood as such(Eastman, 1992; Gould and Gould, 2012). It was therefore conceived by the researcher that concepts in other disciplines such as 'survival of the fittest' and 'evolution' might usefully be used to help in understanding buildings as complex systems changing and evolving over time in response to their environments and occupancy; especially in a period of accelerating social and climate change. Similarly, it was conceived that the concepts and principles developed for Medicine and Medical Pathology for the investigation, diagnosis, prognosis and remediation of failures in biological systems might be usefully applied.

Since that time the term 'Building Pathology' and the description 'Building Pathologist' has gained some currency among building professionals involved in the investigation of building defects, and who have adopted some of the methods proposed in the past (Beukel, 1993). However, although there are now two internationally recognised peer-reviewed journals covering the subject of Building Pathology, and a number of textbooks on Building Pathology have been published (Harris, 2001; Watt, 2009; Douglas and Ransom, 2013); but a preliminary critical review of the literature on Building Pathology showed that a significant proportion of published material is of a relatively narrow technical nature and does not appear to have helped in the general understanding or development of the subject (see interviews with experts at Appendix A). Crucially the existing literature on Building Pathology includes little or no discussion of the importance of the evolution of processes over time, or the importance of a holistic appreciation of the interaction between processes which is crucial to the understanding and application of Medicine and Medical Pathology. It is also apparent that the role of Building Pathology has not been recognised or understood by other building professionals or academics. In particular, its role in allowing for risk identification, risk management and the remediation of perceived defects in buildings and the built environment (de Freitas and Delgado, 2016) has been overlooked. This has resulted in continuing failures in buildings and the built environment which could have been avoided (McKee, 2017). Similarly, the importance of Building Pathology in the cost-effective management of an aging building stock throughout the world, in a period of accelerated social and climate change, has not been generally understood (Reyna and Chester, 2015; Thomsen, van der Flier and Nieboer, 2015; Vardoulakis *et al.*, 2015).

From the above, it is evident that there is a need to carry out research into the subject of Building Pathology and its relationship to Medicine and Medical Pathology; to address the narrowly technical conception of Building Pathology that insufficiently acknowledges the evolution of buildings over time, and which is poorly understood by practitioners and therefore not used to mitigate future risks. In particular, further research is required in order to develop a clear and solid foundation to formulate a holistic understanding of Building Pathology and its relationship to Medicine, to allow its application, further development and teaching.

1.2 Rational for Research

Buildings and the built environment are essential for the survival of individuals and cultures. The effective and efficient investigation and remediation of failures in buildings and the built environment is therefore also essential. This is an increasing problem in a rapidly changing and increasingly complex world; especially under accelerated changes in the societies that occupy them, and under the stress of climate change.

Past research in building surveying has concentrated on investigation of causation of typical building defects, condition surveys, maintenance, management, building performance and building quality, using a combination of traditional monitoring techniques, and mathematical and statistical models. It has been the experience of the researcher and his colleagues over the last 40 years that these methods and techniques do not generally provide a holistic approach to the problems related to building pathologies and building failures which are generally complex in causation and effect. As a result, building failures and their associated risks are generally poorly understood by building professionals and their clients(Leaman and Bordass, 1993; Atkinson, 2002; Chong and Low, 2006; Hopkin *et al.*, 2017). This has led to a 'silo-mentality' in the investigation and attempted remediation of building failures; where one person's solution becomes the next person's problem; and where problems occur at the interfaces between areas of responsibility as well as at the interfaces between materials and structures. The Grenfell Towers disaster in the Uk was an extreme example of the result of this situation, but is the 'tip of an iceberg' of similar failures of buildings to meet the expectations of their owners and occupiers or the societies they serve (Dimka, 2023).

From a reductionist perspective, a building as initially designed or constructed might be thought to be a complicated but inanimate object at a fixed point in time, with no agency or ability allowing it to change or evolve. However, a soon as a building is subject to the effects of occupancy and the environment over time it becomes a complex system whose materials, components, and structures and occupancy evolve over time (Leaman and Bordass, 1993; Stock and Campbell, 2002; Pantazis and Gerber, 2019). Buildings therefore have many of the characteristics of superorganisms, and building failures have many of the characteristics of pathologies (Steadman, 2008). It is for these reasons that the subject of 'Pathologie du batiments' developed in France (Reygaerts, 1980), why the subject of 'Building Pathology' became a 'Core Discipline' for members of the Royal Institute of Chartered Surveyors in the UK (Hoxley and Wilkinson, 2006), and why the subject of 'Building Forensics' developed in the USA and the UK (Weizman, 2014). In these circumstances Building Pathology is conceived by the researcher as an holistic subject to allow the investigation, diagnosis, prognosis and remediation of failures in buildings and the built environment; based on the techniques of Medical Pathology, and on the understanding of buildings as complex systems evolving over time (Hutton, 1989b; Leaman and Bordass, 1993).

Empirical grounding to define the scope of the research project was provided by pilot interview of expert academics and practitioners of Building Pathology in the UK and abroad, to better understand the problems with the development and application of the subject since its inception. This background research found many areas that could and should be subject to further research but were beyond the time and resources available for this project. However, this did identify a perceived failure to establish an Academic grounding or background for the subject of Building Pathology that may have restricted research, and that may have restricted the ability to effectively teach and learn the metacognitive processes for diagnosis of the causes and effects of building pathologies. This allowed the clarification of the Aims of the research as described at 1.3 below ‘to test and develop the Hypothesis that Building Pathology can be usefully considered to be a parallel or sister subject to Medical Pathology’.

1.3 Aims and Objectives

The overall aim of this research project is to tests and develop the Hypothesis that Building Pathology can be usefully considered to be a parallel or sister subject to Medical Pathology; to allow the understanding, teaching, learning, application, and further development of the subject based on recent advances in the sister subject of Medical Pathology. Alternatively, the research question may be posed as; ‘can the subject of Building Pathology be understood as a parallel or sister subject to Medical Pathology; so as to allow the adaption of recent advances in the continuous learning of Medical Clinical Reasoning to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology’. Consequentially, the objectives for this research project were as described below:

1. To demonstrate that the parallels between the subject of Building Pathology and Medical Pathology are not just analogous but can be understood as the result of the co-evolution of Humans and the built environment.

2. To review the development of the subject of Building Pathology in the UK and compare this with the development of Medical Clinical Reasoning.

3. To critically evaluate procedures and methods for the application and continuous learning of Holistic Building Pathology based on recent developments in Medical Clinical Reasoning.

4. To determine current best practices for the learning and teaching of Building Pathology in the UK.

5. To develop tools to facilitate the learning of Schema for application to ‘damp problems’ as an exemplar subset of problems in Building Pathology.

6. To develop and test Script Concordance Tests on schema for application to ‘damp problems’ as an example of the potential utility of adapting recent advances in the continuous learning of Medical Clinical Reasoning to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology.

7. To analyse data from Script Concordance Tests to answer the research question, and to allow the further development of web-based tools and Schema for the continuous learning and development of Building Pathology.

1.4 An Overview of the Research Methodology

Based on the pilot scoping interviews prior to the research described above and recorded at Appendix A; this research project started with an extensive review of the literature on Building Pathology and related subjects to give empirical grounding the origins, background, and development of the subject of Building pathology since its conception. However, there was found to be only limited material available on the development of holistic approaches to Building Pathology; particularly with reference to the understanding of the root causes and evolution of building defects; on the understanding of the metacognitive processes involved in diagnosis and remediation; or on the understanding of the ways in which the investigation process mirrors closely those used in Medicine and Medical Pathology (de Freitas, 2013; Douglas and Ransom, 2013). This literature review also provided further empirical grounding for the relationship between Building Pathology and Medical Pathology, in support of the research Hypothesis discussed at 1.3 above.

Based on the background research above, it was decided to formally define the methodologies and protocols that have evolved to be used in the learning and application of Building Pathology by the researcher and their colleagues, and to compare this with current best practice in Medical Diagnosis or Clinical Reasoning, to further explore the relationship between these subjects and to test and develop the research Hypothesis. Further empirical evidence of the suggested relationship between the subjects of Clinical reasoning and Building

Pathology in support of the research Hypothesis was then sought by comparing current best practice in the teaching and learning the metacognitive process needed for Diagnosis in Building Pathology with current best practice in teaching and learning Clinical Reasoning. This was done by semi-structured interview of educators providing and delivering Building Pathology modules in the UK and by literature review.

Additional empirical evidence that the subjects of Building Pathology and Medical Clinical Reasoning could usefully be considered as parallel or 'sister subjects' was, then sought by developing a protocol for the investigation of 'damp problems in buildings' as a useful representative subset of problems in Building Pathology.

Finaly further evidence to support the research Hypothesis and triangulate an to answer the research question was sought by adapting and developing a Script Concordance Test, which is a methodology specifically developed for testing the metacognitive process of Diagnosis in Medical Clinical Reasoning; in order to test the metacognitive diagnostic processes of Students or Practitioners of Building Pathology in schema involving the investigation of 'damp problems in buildings' as a useful representative subset of problems in Building Pathology.

The researcher came from a Positivist background in science and medical science research, and Building Pathology is a practically based subject which has been generally studied and applied by professionals, rather than academics in the past. However, given the nature of the research aims and objectives, this research adopts a 'Pragmatist' and 'Mixed Methods' approach (see Chapter 4). The mixed methodology employed included literature reviews, qualitative data from the interviews, Action and Observational research, and quantitative data from of the Script Concordance Tests. These multiple methods of data collection and integrated analysis from different participant groups, allowed the triangulation of probable conclusions, and allowed probable observer and participant biases to be identified and critically analysed. Lacuna between existing datasets were equally revealing. However, further to the literature research, the research project included the following Phases and methodologies:

Phase 1: The metacognitive approach of the researcher and others to the investigation, diagnosis, prognosis, and remediation of building pathologies was reviewed based on Abductive and Action Research, so as to develop and test the research Hypothesis. Using this approach, an existing building or structure can be regarded as a continuing experiment over time; and its performance under the environmental conditions and occupancy to which it has been exposed accessed. Perceived or relative 'Building Pathologies' can then be identified affecting the functional 'Anatomy' and 'Physiology' of the building, and their causes diagnosed (Douglas and Ransom, 2013). This is a cyclical metacognitive process involving the continuous learning and development of 'Scripts' to allow a systematic and holistic understanding of the process of Building Pathology with experience. Best-practice and current developments in the diagnostic procedures and methods of Clinical Reasoning, in the 'parallel subject' of Medical Pathology were then reviewed so as to identify those that could be adapted for use in the subject of Building Pathology (Cooper *et al.*, 2016; Custers, 2018a).

Phase 2: In order to further develop and test the research Hypothesis, and to give empirical 'grounding' to any proposals to introduce and test Holistic Building Pathology Teaching or Learning interventions based on the work described in Phase 1 above; data was gathered from lecturers responsible for the preparation and delivery of teaching modules for Building Pathology at representative institutions in the UK, with both qualitative and semi-quantitative data by semi-structured online or telephone interviews. The data gathered was integrated and analysed using Thematic Coding; in order to try and triangulate an answer to the research question 'What are the perceived objectives and current best practice in the delivery of teaching and learning in 'Building Pathology modules' and Building Surveying courses in the UK?' (Husain *et al.*, 2020).

Phase 3: In order to further develop and test the research Hypothesis, Schema for the learning of the metacognitive processes used for the Diagnosis and management of 'Damp Problems' in buildings were develop and codified as an exemplar subset of problems in Building Pathology (Shelbourn *et al.*, 1998; Shelbourn, Aouad and Hoxley, 1999; Shelbourn *et al.*, 2000b; Shelbourn *et al.*, 2004); based on the results of research described as Phase 1 above,

Phase 4: Finaly to further test the research Hypothesis, web-based multiple choice Script Concordance Tests (SCT) were developed based on the Schema developed in Phase 3 above, in accordance with current best practice in testing Medical Clinical Reasoning (Charlin *et al.*, 2000; Charlin *et al.*, 2000a; Fournier *et al.*, 2008). This required collaboration with other experts in Building Pathology both to produce the SCTs, and to validate the SCTs produced. The SCTs developed was then submitted to representative groups of Experts and Students in Building Pathology to demonstrate their potential utility for the testing and learning of the metacognitive processes used in Diagnosis.

Phase 5: The quantitative data from the Script Concordance Tests (SCT) developed as in Phase 4 were analysed following current best practice for analyse of SCT in medical education (Fournier *et al.*, 2008) so as to adapt and improve the SCTs. Qualitative feedback was also gathered from participants with anonymised web-based questionnaires. Further cycles of testing and analysis as previously described were then undertaken to test the research Hypothesis and answer the research question.

1.5 Organisation of Thesis

This Thesis has been organised to highlight the epistemological background and foundations on which the Thesis was built. Each chapter has been cross-referenced and includes an Introduction and a Summary as an aid to the reader, and to allow each chapter to be read and understood on its own, and as part of the overall Thesis.

Chapter 1: Introduction

This Chapter describes the background, rational, aims and objectives of the research. It also introduces the methodologies used, describes the organisation of the thesis, and states the new and original contribution to knowledge that this work provides.

Chapter 2: Evolution of Construction Technology and Defects in Buildings

This Chapter describes the literature research undertaken to provide an empirical grounding on which to assert that the subject of Building Pathology can be understood as a parallel and 'sister subject' to Medical Pathology, in partial fulfilment of the research Objective 1 above.

Chapter 3: Critical Review of the Development of Building Pathology and Comparison with Medial Clinical Reasoning

This Chapter describes the literature research and other background research undertaken to understand the development of the subject of Building Pathology, and to provide further empirical grounding on which to assert that the subject of Building Pathology can be understood as a parallel and 'sister subject' to Medical Pathology, in fulfilment of the research Objective2 above.

Chapter 4: Research Methodology

This Chapter describes the methodologies used in gathering data to answer the research question and ensure the Thesis has a through empirical grounding.

Chapter 5: Procedures and Methods for the Application and Continuous Learning of Building Pathology Based on Recent Developments in Medical Clinical Reasoning

In this Chapter the metacognitive approach of the researcher and others to the investigation, diagnosis, prognosis and remediation of Building Pathologies from Action Research is described. Best-practice and current developments in the diagnostic procedures and methods of Clinical Reasoning, in the ‘parallel subject’ of Medical Pathology is also reviewed in order to identify those that can be adapted for use in the subject of Building Pathology, in fulfilment of the research Objective 3 above**.**

Chapter 6: Assessment of Current Best Practice for Teaching and Learning of Building Pathology in the UK

This Chapter describes an assessment of current best practice for the teaching and learning of Building Pathology in the UK. This was undertaken to give an academically valid empirical grounding to proposals to introduce and test procedures derived from medical Clinical Reasoning to Building Pathology, in fulfilment of research Objective 4 above.

Chapter 7: Development of Metacognitive Tools and Schema for Application to ‘Damp Problems’ as an Exemplar Subset of Problems in Building Pathology

In this Chapter the Metacognitive approach to Diagnosis described at Chapter 5 is further developed for ‘damp problems in buildings’, as a representative exemplar subset of problems in Building Pathology, in fulfilment of research Objective 5 above.

Chapter 8: Development and Application of Script Concordance Tests to Students and Experts in Building Pathology

This Chapter describes the development and testing of a Script Concordance Test (SCT) based on those developed for the learning and testing of Clinical Reasoning in Medical Pathology is described, in fulfilment of the research Objective 6 above.

Chapter 9: Analysis of Data from Script Concordance Tests to Test the Validity of the Hypothesis, and to Allow Further Development for the Continuous Learning of Building Pathology

This Chapter describes the analysis and interpretation of the results from the Script Concordance Tests in fulfilment of the research Objective 7.

Chapter 10: Conclusion

This Chapter provides a summary of the research objectives and findings, before discussing the practical and academic implications.

CHAPTER 2: THE EVOLUTION OF BUILDINGS AND BUILDING PATHOLOGIES

2.1 Introduction

Biological organisms have been using organic and inorganic materials and structures since the start of life on earth, indeed the earliest evidence of life on earth consists of the residues of these structures (Konhauser, 2009). Since that time, biological organisms and the structures that they create have evolved over time to adapt to the changing environments and purposes for which they were produced. In many situations the biological organisms and the structures that they create form super-organisms which evolve and adapt over time as complex systems (Csete and Doyle, 2002; Konhauser, 2009; Lenton *et al.*, 2018).

It should be self-evident that Humans are biological organisms and are subject to evolutionary change over time dependent on the environments and conditions we are exposed to. Huiman built structures and the occupants and cultures that create , occupy and maintain them may therefore also be considered as super-organisms or complex systems that are also subject to evolutionary changes dependent on our activities and the environments in which we live (Leaman and Bordass, 1993; Stock and Campbell, 2002; Pantazis and Gerber, 2019; Askar, Bragança and Gervásio, 2021). This has importance in what is now described as the Anthropocene and the resultant anthropogenic climate change(Lenton *et al.*, 2018). It might be argued that individual materials or structures in a building do not have autonomy or agency, except perhaps with the use of BMI and AI systems. However, the organic and inorganic, living, and dead components of buildings and the built environment interact and evolve independently and together over time resulting changes that may be perceived as Building Pathologies (VanderGoot, 2017; Della Torre, 2019; SONG, 2021; Zhao *et al.*, 2024). This chapter describes the results of the literature research undertaken on which this assertion is made, and to provide an academically and empirically based foundation for the further understanding and development of Building Pathology and support the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology; to allow the adaption of recent advances in the continuous learning of Medical Clinical Reasoning, to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology

Firstly, the evolution of biologically generated structures is described to demonstrate that these may be considered as complex systems evolving over time. The evolution of Human built structures is then reviewed to support the assertion that buildings may also be considered as complex systems evolving over time. Finally, the evolution of Building Pathologies is described to demonstrate that this is part of this process, and that there are clear relationships between the evolution of Building Pathologies and the evolution of pathologies in the organisms and superorganisms or cultures that use them. This discussion is subsequently used to support the argument that holistic methodologies and procedures developed or evolved for managing pathologies in biological organisms may be usefully used to help identify and manage Building Pathologies. The relationship between the parts of the literature research described in this chapter is shown in the flow chart in Figure 2.1 below.

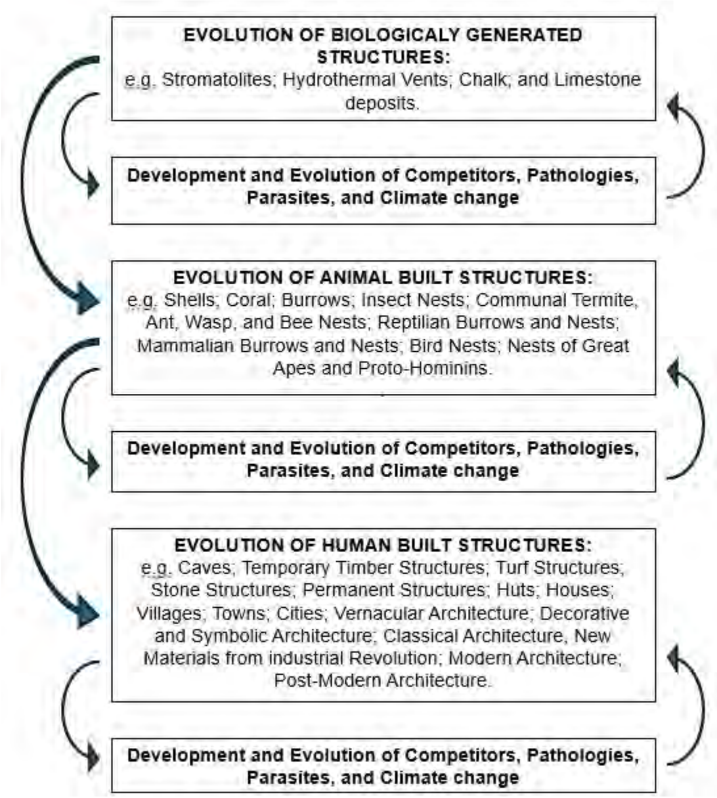

Figure 2.1: Evolution of Biological, Animal and Human Built Structures and Building Pathologies

This flow chart shows the Evolution of Biological, Animal and Human Built Structures since the start of life on Earth over 3.7 billion years ago, and the evolution of Building Pathologies as emergent phenomena evolving over time in these complex systems or superorganisms as described in Chapter 2.

2.2 The Evolution of Biologically Generated Structures

2.2.1 Background

Biologically generated structures develop over time to provide optimal solutions that respond to the external context and provide for their inhabitants' needs. As will be discussed in section 2.3 these natural processes also take place in relation to buildings. To have a holistic understanding of buildings and to support the hypothesis that is the subject of this research project, it is therefore first necessary to understand the development of biologically generated structures since the start of life on earth over 3.7 billion years ago (Dodd *et al.*, 2017).

2.2.2 The Evolution of Biologically Built Structures

Structures built by non-human organisms have been widely admired and studied throughout history (Steadman, 2008). These include the many simple and complicated burrows constructed by many species and genre from worms through reptiles to mammals (Mukherjee *et al.*, 2017), and extend through a wide variety of biological constructs: from the stromatolites and complex bacterial films that are some of the earliest evidence of living organisms on earth (Konhauser, 2009); the structures created by complex ecosystems of archaic bacteria, worms, molluscs and arthropods around deep sea hydrothermal vents(Martin *et al.*, 2008); the complex nests constructed by communal insects, such as ants, termites, bees and wasps (Mikheyev and Tschinkel, 2004; Korb, 2010); the wide variety and complexity of bird nests (Collias and Collias, 2014); to the more sophisticated structures built by some species of mammals such as beavers. (Butler and Malanson, 2005), and the simpler nests created by primates.

In this context, it is particularly interesting to consider the elegant and sophisticated structures created by many species of termite in order to create the environments required for these insects to breed and thrive. This is because, like many other structures evolved by non-human organisms, termite mounds have achieved a sophistication, complexity and even 'beauty' which is the envy of human architects and builders. Indeed, we often only come to appreciate the way that form has evolved to optimise function when we have belatedly 'discovered' the mechanism for ourselves. This includes the sophisticated 'air conditioning' systems within the mounds, and the energy efficiency of the construction and maintenance of such structures or 'buildings'. These structures built by communities of living organisms such as termites, bees and other organisms can reasonably be considered as part of 'superorganisms' competing and evolving over time (Noirot and Darlington, 2000; Moritz and Southwick, 2012; Turner, 2013).

Termites make a particularly interesting example in providing support to the Hypothesis that is the subject of this research, as they are also timber decay organisms that have more recently evolved to exploit Human built structures. For example, a number of species of termites are able to create tubes or tunnels from their subterranean nests through the ground in order to get access to building timbers; even across foundations specially constructed by Humans so as to prevent termite access (Su and Scheffrahn, 1998). These tunnels provide an air-conditioned internal environment protecting the insects, not only from the external environment, but also from observation and predation. This allows them to infest and consume timber elements used in building despite Human attempts to protect these timbers.

Although these impressive and fascinating structures generated by living organisms have been postulated as evidence of the work of a deity or 'great designer' in the past, they are now generally understood to be the result of evolution, and to have evolved in order to give the organisms that create them some competitive advantage. Buildings and their effect on internal and external environments can therefore be understood as part of 'Bio-geomorphology' or more specifically 'Anthropo-bio-geomorphology' (Butler, 1995). This is becoming increasingly apparent on a global scale with accelerated anthropogenic climate change.

However, buildings and the built environment can also be studied and understood in the context of the evolution of a wide range of structures produced by living organisms for many and multiple purposes both as part of the organisms that created them, as separate structures and as super-organisms. These include the shells of molluscs (Barthelat *et al.*, 2009); the calcareous structures produced by polyps forming coral reefs (Wood, 1995); the communal nests of insects such as bees, wasps, ants and termites; the nests produced by birds; and indeed, the nests constructed by some of our closer relatives such as chimpanzees (Fruth and Hohmann, 1996).

2.2.3 'Commensal' and 'Parasitical' Occupancy of Biologically Generated Structures

In nature, organisms do not live in isolation (Odling-Smee, Laland and Feldman, 2003), it is therefore necessary to consider the effect of other organisms on biologically generated structures, in order to understand the origins of Building Pathology. This is because these may be deleterious or sometimes advantageous for the organism originally generating the structure. Deleterious effects may be simple unintentional physical destruction, purposeful destruction in order to consume the organism within, or 'parasitical' in nature, when the organism entirely or partially displaces the organism that originally generated the structure for its own purposes. In all these cases, the processes become part of an evolving ecology in which the organisms may develop inheritable selective advantages in the relationship. In these cases, one or other of the organisms, or indeed, many organisms may become 'commensal' or even 'obligate commensals' and super-organisms, where their survival becomes entirely dependent on the other organism.

Coral reefs such as the Great Barrier Reef may be viewed in this way as each of the many species of corral that have built the reef over thousands of years are commensal partnerships of a corral polyp and an algae, and each corral and the whole reef of corrals, each supports many different ecosystems, including many different commensal partnerships of many diverse species (Wood, 1995). Similarly, smaller and less complex 'reef systems' such as those formed of the commensal organisms around oceanic hydrothermal vents can also be considered in this way (Martin *et al.*, 2008).

On a simpler level, there are many examples where organisms form burrows or other structures which they then allow or even encourage other organisms to inhabit to their mutual advantage (Mukherjee *et al.*, 2017). At the other end of the spectrum, there are many examples where organisms will parasitize, predate or displace other organisms from the structures they have created to their own advantage. The hermit crab is an example of such an organism (Chase, Weissburg and Dewitt, 1988). Although better examples are the many insects that parasitize the structures built by colonial insects such as termites, ants and bees, (Field, 1992; Hansell, 1993; Carrijo *et al.*, 2012). At the extreme end of this ecological spectrum, one organism may form the structure in which another organism lives, and these organisms may then continue to evolve together in an obligate symbiotic relationship (Goto and Kato, 2012).

However, it should be apparent from the above that 'pathology' may be considered as 'relative' to the organism under consideration; as what may be to one organism's advantage may be deleterious to another, or to an 'ecology' of organisms over time. In all cases, it should be noted that there is a crucial time component in the parallel evolutionary processes described. This is both in the time for the various effects to become manifest both in absolute time, and the number of 'lifecycles' necessary for the evolutionary processes involved to occur. This may have important implications for the holistic understanding of the development of Building Pathologies, as discussed below.

2.2.4 The Development of Building Pathologies in Non-Human Structures

Given the premise that some biologically generated structures may offer survival and/or competitive advantage to the organism that create them, it is apparent that some aspects of these structures or 'defects' in their construction must be less advantageous or deleterious to the survival and reproduction of the organisms concerned. Major failures or defects are likely to result in the swift destruction of the structure and associated organisms. However, it is possible that the organisms creating the structures might evolve methods for correcting or 'living with' less catastrophic and more subtle defects. At a basic level this can be seen in the repair to the 'exoskeletons' or shells of living organisms (Mayer, 2005), and in the repairs to the nests of insects and birds (Noirot and Darlington, 2000; Walsh *et al.*, 2011). When the information allowing the application of the repair mechanisms is inheritable, either genetically or epigenetically, these repair mechanisms will also be subject to evolutionary processes. This is also the case when the information allowing the application of the repair mechanisms is inheritable between and across generations as learned behaviours, or 'culturally'. However, where these give competitive advantage, they are the probable mechanism for the development and evolution of more complex and successful structures. This has obvious parallels with the evolution and development of Human built structures, and clear implications for the development and management of Building Pathologies in Human built structures, as described below.

2.3 The Evolution of Human Built Structures

2.3.1 Background

From the above, it is apparent that biologically generated structures are complex systems that are constructed, changed and evolve over time; in a way that may best be understood using evolutionary theory. It is also apparent that defects or disease in these organisms or super-organisms and the structures they create may be considered as part of the same complex systems evolving over time. Given that modern Humans and our ancestors are biological organisms; it is reasonable to assert that this will also apply to the structures we build or occupy and to perceived defects in these structures. The understanding their parallel evolution over time is therefore fundamental to the understanding of the subject of Building Pathology, and to the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology; to allow the adaption of recent advances in the continuous learning of Medical Clinical Reasoning, to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology, as described below.

2.3.2 The Early Evolution of Human Made Structures

Given the extensive evidence of the evolution of 'nests' constructed of branches and other vegetable matter and the adaptation of natural caves for occupancy, by both pre-Human species and our closest living relatives among the great apes described at 2.1 above (Sept *et al.*, 1992; Fruth and Hohmann, 1996; Kappeler, 1998; Barrett *et al.*, 2004; Karkanas *et al.*, 2007; Haslam *et al.*, 2009; Prasetyo *et al.*, 2017); there is clear evidence that our ancestors had evolved the use of both types of structures.

Although, it seems probable that conscious decisions would have been made in both adapting structures to their environment and in 'repairing' or 'refurbishing' the defects that arose; it is highly likely that 'trial and error' and the 'survival of the fittest' and 'stable state' solutions would have applied (Lenton *et al.*, 2018). This would have resulted in the evolution of ideas and information as it was passed from individual to individual and/or between generations. Evolution for 'survival of the fittest' and for 'stable systems' would also have applied to the individuals, families, extended families, tribes, and cultures utilising the structures (Laland *et al.,* 2011).

Unfortunately, only limited physical evidence is available of these early developments in Human-built structures due to climate change across the intervening years, resulting in scouring of the areas of probable occupation by ice, and/or their submersion below sea level in the intervening years. However, it is possible to look at the structures built by existing or recent indigenous societies; and to use these to interpolate the probable structures and the probable parallel evolution of structures and the Prehistoric Humans and cultures who built them in the past. This may be done by the study of Anthropology and Vernacular Architecture, as illustrated in Figure 2.2 and as discussed at 2.2.3 (Vellinga *et al.*, 2007).

Figure 2.2: The Evolution of Built Structures by Homo Sapiens and Our Ancestors

Anthropology and Archaeology show clear evidence of the development and evolution of built structures by Homo sapiens and our ancestors, to provide advantageous micro-environments, and to provide protection from adverse environments, predators or competitors, and to provide sexual and social advantages. This apparently simple but effective charcoal burner's hut is a direct descendant from these early structures and consists of timber elements, leaves, turf, and soil built off a foundation of stones. This provides effective insulation and protection. Although the materials used in this construction may have a limited service-life, they can be readily maintained and replaced allowing the hut to be re-built when necessary.

2.3.3 The Evolution of Vernacular Architecture

Until relatively recently, the materials, structures and details used in building have evolved to suite the local materials, environments and anticipated end use of the structures. This is the basis of Vernacular Architecture and has been extensively studied (Vellinga *et al.,* 2007). The use of the term Architecture implies conscious design; however, when Vernacular Architecture is considered from a historical perspective, it becomes clear that these buildings have evolved over time in parallel with the cultures that occupied them, so as to suit changing environmental conditions, available technologies, and use; in the same way that other biologically generated structures have evolved (Sheppard, 1966; Smith, 1970; Lawrence, 1983; Oliver, 2007).

This evolutionary process can be most easily seen in the evolution of detailing, with changes in available materials, for example, in early Greek architecture where details assumed to have originally developed for timber structures were replicated in masonry (Summerson, 1966; Lawrence and Tomlinson, 1996). This can then be seen to have evolved with details such as cornices being retained in order to discharge water clear of structures, and with details such as denticles, assumed to replicate the ends of timber joists, being retained for aesthetic reasons (Mulvin and Lewis, 1994).

Many similar examples can be found once historic or traditional buildings are analysed from this perspective. However, as in the evolution of living organisms, many apparent redundant or 'vestigial' features may appear to have been retained for no apparent practical reason, presumably because they did not have a negative impact on survival within the life cycle of the building or its builders. Indeed, it is probable that many such details have been conserved as part of 'cultural inheritance'; due to the positive survival advantages this can bring to both the group and the individual (Shennan, 2002; Atran and Henrich, 2010; Laland *et al.*, 2011).

In this context, it is interesting to speculate that the psychological comfort and wellbeing of occupants of buildings can be strongly affected not only by their own prior experience, especially as a child, but may also relate to inherited and even pre-Human preferences. In this way many buildings found to be especially desirable for occupancy may be found to contain characteristics which might be facsimiles of environments desirable to both our Human and pre-Human ancestors. This can be seen in buildings having apparent 'cave-like' characteristics, giving feelings of security (Fewkes, 1915), and in the many aspects of buildings having elements reminiscent of the arboreal environments of our pre-Human ancestors. For example, tree-like features; such as the classic 'acanthus' detail, pilasters and columns, tall windows, and 'calming' green colour schemes (Dauksta, 2011; Jalil *et al.*, 2012). This is a clear example of the parallel evolution of the interaction between the built environment and its occupants, as illustrated in Figure 2.3.

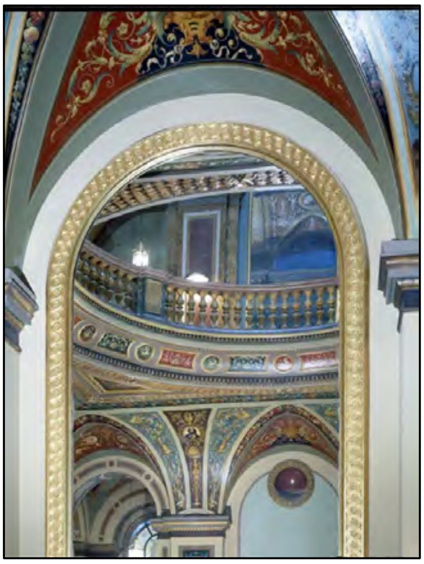

Figure 2.3: Modern Decoration Mimicking the Natural Environment and Structures of Our Ancestors

In this highly decorative interior of a mid-19th century building in London there are many decorative and design features which can be seen to relate back to the arboreal environment in which human beings original evolved. The designs and colour themes used were obviously considered to be attractive and to give a feeling of wellbeing to the occupants. This may be because they relate to our instincts inherited from our ancestors and evolved to encourage them to seek such environments for their wellbeing.

2.3.4 The Evolution of Architecture

Conscious design is an important part in the generation and eventual remediation of Building Pathologies, so the parallel evolution of Architecture over time has been an important component to this process. Anthropological studies suggest that some specialisation in building is likely to have developed as communities developed, especially as they became more settled, and structures became perceived as being more 'permanent' (King, 1984; Kerner, 2010). Although, it should be noted that mobile or even temporary structures will have evolved with the use of specialist materials, specialist detailing and special construction techniques.

However, although the evolution and development of individuals or groups with special skills in building for others suggests that some conscious design process may have started to evolve, so as to meet the requirements expressed by others, the concept of Vernacular Architecture and indeed Architects has been applied retrospectively (Rudofsky, 1964). In these circumstances it is more reasonable to try to understand the processes involved in terms of the development of specialist craft techniques, and the passing-on of craft traditions. Historically, these appeared to have taken on a wider cultural and even religious significance, as can be seen in the architecture of ancient civilisations such as Egypt, and in the role of the 'Master Mason' in Medieval Europe (Shelby, 1970; Clarke and Engelbach, 1990; Moorey, 2016).

It can be readily understood that the application of these specialist crafts would have developed with changing individual, social, economic and environmental conditions. However, what appears to have been less frequently considered is the evolutionary effect of failures to meet these requirements. This may be because such effects are likely to have been progressive rather than catastrophic, and are therefore less easy to discern over time (Gates, 2011). What can be more easily perceived is the way that vernacular building and Vernacular Architecture has evolved to suit the materials, environmental conditions, and end use within its environment. However, from and evolutionary point of view Human-built structures and communities can be seen as superorganisms competing and evolving over time (Stock and Campbell, 2002; Kesebir, 2012). It is therefore reasonable to consider that the inorganic built components of these superorganisms are subject to these same processes, providing further support to the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology

2.4 The Evolution of Building Pathologies

2.4.1 Background

From the above it is apparent that the efficacy of structures created by biological organisms to serve the purpose for which they may have been evolved and built, can be adversely affected by defects introduced by their creators, occupants and environment, and by other organisms. Organic materials used in their construction in particular are likely to be subject to decay, and all materials are likely to be subject to chemical corrosion and physical erosion over time.

Structures built by Humans can also highlight these processes. Indeed, these processes are likely to be more damaging a because the materials and structures used by Humans in their buildings are more likely to be subject to changing conditions and to conditions for which they have not yet effectively evolved to survive. Individual materials and components are therefore more likely to fail due to inadequate durability for the expected lifetime of the structure, resulting in an inadequate service life.

This is because Humans have spread across the world and encountered different environments both in space and time. The uses to which they have put their buildings has therefore developed relatively rapidly compared to that of structures built by other living organisms. This has resulted in acceleration of the processes of evolution by survival of the fittest combined with les opportunity to evolve to stable states. This similar to those processes that occur when other living organisms invade and adapt to new environments(Shennan, 2002).

The rapid evolution of diverse Human survival strategies and cultures since the last Ice Age has further accelerated these processes and resulted in the parallel evolution of Building Pathologies. An understanding of the history of this the evolution of Building pathologies is therefore crucial to a holistic understanding of the subject of Building Pathology. The evolution of the use of timber as a building material, and the adaption of its use in response to timber decay organisms discussed below, is a useful example of these processes to support the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology. However, it should be noted that similar processes can be found on analysing the use of other building materials over time.

2.4.2 The Effect of Decay on the Evolution of the Use of Timber as a Building Material

It appears likely that our ancestors used timber as a building material in a similar manner to the way that it is currently used by our closest primate relatives, with the branches of trees bent or broken to form a nest platform, and foliage used to provide comfort and protection.

Used in this way, these materials can provide good structural support in the short term, good ventilation and adequate protection from the environment. However, such timbers will generally retain their bark and have a high sapwood content. This leaves them very vulnerable to infestation and decay by wood boring beetle, and to consequential catastrophic failure if re-used (Hutton *et al.*, 1992b).

There is evidence that some plants with insecticidal properties may be incorporated in such nests and it has been argued that this is done in order to provide some protection against parasites, although they may also provide some protection against other insects (Baker, 1996; Lozano, 1998). By definition when such 'nests or huts are built at ground level they are in ground contact, and structural timber elements are likely to be exposed to the damper, more airless conditions, which promote both fungal and insect decay, especially to the sapwood band. This is because the sapwood of timber generally has a higher sugar and nitrogen content, making it suitable for consumption by decay organisms and also contains less of the chemicals produced by plants to protect their structural 'heartwood' elements from decay organisms (Wang and Wang, 2012).

There is therefore a tendency to use larger section timbers in ground contact, which will have a larger 'heartwood' component in proportion to their cross section, with the lighter, more sappy branches extending upwards and helping support other branches and foliage used as a weatherproof primitive thatch or cladding (Montgomery, 2008). Obviously, the larger broken end of the branch will be relatively sharp and is likely to have lost a significant proportion of its sapwood, especially if purposely cut. This not only aids the securing of the base of the branch into the soil but will also reduce the amount of bark and sapwood, which would otherwise make it vulnerable to infestation and decay.

These elements of a structure are therefore likely to remain in-situ for many months or even years, even if the lighter branches and covering thatch are lost due to decay and weathering. In these circumstances, it is highly likely that the primary elements would be re-used and re-covered, especially given a seasonal hunter gatherer lifestyle (Bettinger *et al.*, 2015) . On return to such structures, the decay or partial decay to the bark and sapwood band of the remaining elements, and the decay of the lighter elements would have been evident, and there would be a natural tendency to break away or remove decayed or partially decayed materials.

This de-barking and de-frassing process would have further exposed the more durable heartwood material; and the relative durability of different species would become evident. In these circumstances, it is not surprising that de-barked oak became the preferred structural material for timber buildings in northern Europe (Haneca, Čufar and Beeckman, 2009).

However, the ground bearing timber elements would remain very vulnerable to decay via wet rot and wood boring weevils and would eventually fail structurally; especially when buried within damp ground. In these circumstances, it is probable that the decayed or partially decayed bearing would be propped onto a masonry pad stone or foundation and would be found to be more durable as a consequence. In this way, such a timber structure is likely to have been eventually supported onto a masonry dwarf wall or damp-proof course. This would form a foundation to the building and help protect the timber frames above from damp and decay; especially if the exterior of the timber frame elements were provided with some form of cladding or weathering to drain water from wind driven rain clear of the structural elements (Liedgren and Bergman, 2009).

It can be seen that these represent the fundamental design features of timber frame buildings in the UK up until the late 17th Century (Brunskill and Crawley, 1994; Liedgren and Bergman, 2009). After this time, other species of timbers were increasingly used for a number of cultural, practical, and economic reasons. These were generally softwoods, which have a relatively high sapwood to heartwood ratio compared to oak and their heartwood is often significantly less durable; as they lack the protective chemicals generally found in the heartwood of hardwood timbers, as illustrated in Figure 2.4 (Zabel and Morrell, 2012).

Figure 2.4: The Evolution of Timber Framed Buildings

The construction of timber frame buildings has evolved in the UK and elsewhere throughout the World to use the relatively durable 'heartwood' of relatively durable species of timber. Here we can see durable oak elements, many of which have been salvaged from previous buildings and have been repaired or replaced on multiple occasions. The method of construction also minimises the effect of potential building pathologies such as water penetration providing conditions for decay within the joints between the timber elements.

However, at this time, other materials such as brick were being used to provide the primary structural support or walls of the buildings, rather than just the external cladding. At first, timber plates and bressummers were generally incorporated into the brickwork, to act as 'bonding timbers', plates, or levelling timbers during and after construction. This appears to have evolved from the way that oak timbers had been either incorporated in brick structures on original construction or incorporated in brickwork replacing original timber frame elements in the past.

Unfortunately, softwood timbers embedded in masonry subject to chronic damp conditions are very vulnerable to infection and decay by fungi; particularly fungi of the brown rot group, such as dry rot (*Serpula lacrymans*). This is a gyophilic fungus that naturally lives in calcareous soil with relatively high iron content, particularly in the Himalayas and some areas of the Rocky Mountains. In 'the wild' it lives within the soil for many years or even decades, forming 'mega fungi' that consume softwood timbers that become buried in the soil in which it lives, under damp airless conditions. In buildings, this fungus can decay large sections of softwood timber embedded in damp affected masonry in a period of 12 to 18 months, resulting in catastrophic structural failure (Hutton *et al.*, 1992b; Kauserud *et al.*, 2007).

A review of architectural texts and existing historic buildings shows a clear reduction in the use of softwood timbers in this way, with the preferred detailing increasingly supporting the structural timber elements separated from damp or potentially damp masonry throughout the 18th and 19th Century(Gwilt, 1854; Reid, 1986). Until by the end of the 19th Century, primary elements in contact with damp or potentially damp brickwork were generally constructed with masonry, cast iron or steel (McKay, 1945).

Obviously, these elements can also be adversely affected by moisture movement; and similar evolutionary processes can be seen in their use since that time, so as to help control structurally significant corrosion. However, many other examples of the evolution of the use of timber as a structural material can be seen both generally in the UK and abroad.

2.4.3 The Evolution of Timber Decay Organisms

It is important to understand the co-evolution or parallel evolution of timber decay organisms and their food sources both in trees and later in timber building structures, because this has had a fundamental effect on the evolution of the use of timber in buildings and the parallel evolution of associated Building Pathologies(Hutton *et al.* 1992a). Timber decay organisms have existed since the cellulose and lignin materials they consume were evolved to help support growing plants over 300 million years ago (Watt, 2015). This is because these energy rich materials represent a readily available source of food to other organisms. Since that time there has been a continuous evolutionary arms race in which the plants producing the timber evolve mechanisms to preserve their timber elements, and organisms which consume timber evolve mechanisms to bypass these protective systems (Despres *et al.*, 2007; Lieutier *et al.*, 2009).

As previously discussed, the sapwood layer is generally the most readily available and desirable food source, as it contains the sugars and other nutrients required for the growth of the plant and other organisms; while the heartwood is a structural element and is less readily available both physically and chemically. As this is more structurally important; it can be postulated that it is for this reason that plants have evolved mechanisms for depositing chemicals with fungicidal and insecticidal properties within their heartwood; and have developed protective barks and fast healing mechanisms such as fungicidal and insecticidal saps to protect their sapwood. The latter can be seen fossilised as amber and are often used by humans for their insecticidal and fungicidal properties; for example, the use of Pine essences (Nunes *et al.*, 2004).

However, most of these immediate defensive protective mechanisms rely on the plant to be alive. It may be for this reason that the majority of timber 'decay organisms', as opposed to organisms that consume living plants, have evolved to live in the conditions where dead timber is generally to be found. Although there may be some standing dead wood within a forest; this is generally on or in the forest floor, where conditions are relatively damp, airless and dark.

Conversely humans and our ancestors evolved for the light, airy, dry environments of the tree tops and savannah (Hutton *et al.*, 1992b). The structures we have evolved to provide a good living environment for ourselves therefore tend to provide these conditions, which fortuitously tend not to favour the growth of timber decay organisms. However, a number of timber decay organisms have evolved adaptations that make them able to tolerate and grow in these conditions; even if their growth and reproduction is sub optimal (Ridout, 2013; Querner, 2015).

2.4.4 The Evolution of Timber Decay Organisms in Buildings

In the UK examples of timber decay organisms evolved to inhabit buildings include wood boring beetles, such as woodworm (*Anobium punctatum*), death watch (*Xestobium* *rufovillosum*), and house longhorn beetle (*Hylotrupes bajulus*); and in more tropical climates many of the species of termite have adaptations that allow them to access and consume timbers; especially if in contact with the ground. Indeed, species of termite which form tunnels are able to build their own structures to allow them to access timbers lifted clear of the ground onto masonry foundations (Su and Scheffrahn, 1998; Noirot and Darlington, 2000).

To what extent these and similar organisms have spread across the world and into new environments due to their association with timbers used in building, and to what extent the organisms found in buildings have adapted away from their 'wild' ancestors is not clear. However, Woodworm (*Anobium punctatume*) is likely to have spread with European colonisation (Child, 2007; Diaz, 2009; Lukowsky, 2017), and, preliminary investigations of the genetics of the dry rot fungus (*Serpula lacrymans*) suggest that it may have moved from the Himalayas with the import of timbers used in the construction or repair of ships in to Europe (Kauserud *et al.*, 2007). The dry rot fungus is likely to have spread into the environment being created at that time in European cities with the embedding of softwood timbers in masonry with a high calcium content from lime mortar mixed with iron or steel, providing the higher iron content required for production of the enzymes that are used by the brown rot fungi for timber decay (Koenigs, 2007).

However, there is no doubt that many other organisms have adapted to living in structures built by humans and have spread throughout the world because of these adaptations. In particular, the house mouse, the Black and Norwegian rat, cockroaches, and more recently fire ants (Elton, 2000). There is also some evidence that species of tropical termite have become established in human built structures in temperate urban environments (Ghaly and Edwards, 2011). This may be due to the increased and rapid transport resulting from globalisation of trade, and it is probable that this process will continue, and indeed may accelerate because of climate change.

To what extent the adaptation and evolution of timber decay organisms to exploit the ecological niches provided by human-built structures has resulted in inheritable change or speciation is not clear. Aside from the example of dry rot (*Serpula lacrymans*) previously cited (Engh *et al.*, 2010). However, it has been noted by the author that the prevalence and distribution of house longhorn beetle as opposed to forest longhorn beetle appears to be associated with the construction and internal environments of buildings. Similarly, it has been noted that there appears to be differences between the preferred diet and probable physiology of death watch beetle (*Xestobium rufovillosum*) found in buildings in the UK, where they are generally found to consume the sapwood band of hardwood timbers; compared to those found in Europe, where they are often found consuming softwood timbers. It should be noted that this may be due to evolution of the commensal organisms in the guts of these wood boring beetle that allow them to digest the cellulose, rather than changes in the genetics of the beetles themselves (Harrow, Brewerton and McGrath, 1970).

Hence, there appears to be plenty of evidence of the widespread adaption of organisms evolved to decayed timber to allow them to exploit the timber used by humans in construction, or in structures built by non-human organisms.

2.4.5 The Evolution of Remedial Detailing and Design

As previously described, there is clear evidence of the evolution of remedial detailing to structures created by non-human builder using both inorganic and organic materials such as timber. Therefore, it is highly likely, that at least initially, most of the early detailing of structures built by humans using timber or other materials also evolved by 'trial and error'; rather than by conscious design. However, whether by conscious design or by random trial and error; there is clear evidence of the continued evolution of remedial detailing to human built structures over time; supporting the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology.

There is evidence of this in the earlier and perhaps more primitive built structures with the use of timber materials and their isolation from the ground as previously discussed. It is also probable that the smoke from fires without chimneys passing up through roof structures had a significant effect, in controlling infestation and decay of roof timbers and thatch, by wood boring beetles and other insects (Pyne, 2012). In this context, the author notes that the more general use of chimneys in domestic buildings appears to have become more prevalent with the use of secondary roof timbers with a higher heartwood content overlaid by slates or tiles, which are less susceptible to infestation by insects than reed, straw, heather or other thatches.

Detailing of provision for roof drainage also appears to have evolved over time from simple pitched roofs shedding water directly onto surfaces below, with or without some provision to drain water clear of the structures to prevent 'washing-out' of the foundations; to the installation of provision for eaves gutters and rainwater downpipes using timber and later lead, so as to minimise water shedding onto people and structures below and to allow the collection of rainwater for domestic use; especially in increasingly urban environments.

Early masonry structures also appear to have evolved from simple adapted caves and dry-stone wall structures; with the introduction of masonry courses laid to drain to the exterior face; and the use of earth or clay mortars and flashings; so as to drain water clear of the structure and stabilise masonry (Salzman, 1952). An example of this is illustrated in Figure 2.5. The eventual evolution of lime mortars, through the use of burnt shells from cooking fires, incorporated with ash as a pozzolanic, to stabilise earth and clays is speculative but seems probable (Malhotra and Mehta, 2014).

Figure 2.5: The Evolution of the Use of Masonry for Buildings

Buildings have evolved throughout the World to meet the requirements of local environments, occupancy, and the availability of materials. Stone has been used for construction purposes in many parts of the World with different stones found to have different properties and evolving different construction techniques. This has generally been combined with the use of other building materials. In this building, the roof is supported with softwood timbers which had been overlaid with heather thatching to provide waterproofing and insulation. Control of water penetration has been provided by the overhang of the thatched roof eaves, the coursing of the dry-stone walls, and by the sloping of the ground around the foundations. This is likely to have evolved by trial and error and by observation.

The evolution of building details within the built environment is never one of single cause and single effect but the interaction and balancing of relative advantages and disadvantages. For example, the evolution of the use of 'lime washes' and other surface coatings for interior surfaces not only increases available light and provides an aesthetically appealing finish; but is also a disinfectant that helps prevent the growth of potentially hazardous moulds, acts as a polities to prevent the buildup of potentially damaging hygroscopic salts, and may help prevent the spread of wood boring beetle (Schofield, 1991). This illustrates the complexity of the evolving system including the interaction of materials, details, structures and occupants and helps support the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology.

2.4.6 The Evolution of Classical Architecture

As in the study of classical Darwinian evolution, it can be useful to consider situations where a structure evolved to suit one environment is moved into another. In this context, an example of the evolution of detailing in human built structures is that of Classical Architecture; where structures such as cornice details thought originally to have formed part of the eaves of timber structures in a Mediterranean climate, were adapted with flashings and drip details to shed water clear of their masonry replacements (Lawrence and Tomlinson, 1996). These were then further adapted when these details were copied and transferred to a northern European climate as part of the classic revival in the 18th Century, where attempts were often made to replicate them with renders or plasters applied to brickwork and/or with timber (Gwilt, 1854; Curl, 1993).

This made them especially vulnerable to water penetration which results in accelerated erosion, corrosion and decay of the materials and finishes. This can also allow chronic water penetration into structures beneath, providing conditions for damp and decay; such as dry rot (*Serpula lacrymans*) infection and decay as previously described. Review of architectural literature and historic structures show that more effective flashings and drip details were introduced in order to minimise water penetration in this way; including over-flashing with lead sheeting (Gwilt, 1854).

It is probable that much of this remedial detailing over the millennia was the result of considered 'design' decisions, although these were probably made by craftsmen rather than specialist 'Architects'. This tendency to prioritise 'form' over 'function' has happened in the case of classical and neo-classical facades repeatedly in human history; resulting in building pathology and subsequent remedial detailing (Trebsche, 2009). This may have occurred with the roman adaptations of original Greek designs; and certainly, occurred with the classical revivals of the 16th, 17th and 18th Centuries. However, the same mistakes have been with the adoption of classical and neo-classical details for aesthetic purposes on modern buildings, where they have frequently resulted in problems with water penetration and consequential failures in finishes and underlying materials (Sizheng Fan, 2009; Summerson and Powers, 2023).

2.4.7 The Evolution of the Remediation of Timber Decay in Buildings

As discussed above, the evolution of the Timber decay in buildings involving the interaction between materials, decay organisms, occupancy, detailing and internal and external environments is a useful example of the complexity of the processes resulting in the evolution of Building Pathology supporting the Hypothesis. The evolution of measures to try and control timber decay by chemical treatment provides further evidence for this complex process. Structures built by humans appear not only to evolve structurally, but also to control the internal environment; as with some of the structures built by other organisms previously described. It is likely that details to provide protection from wind, rain and sun; while providing adequate fresh air and light for intended occupancy, were inherited from pre-human structures. It also seems increasingly likely that the use of fire for cooking and heating was also inherited from pre-human ancestors (Roebroeks and Villa, 2011). However, the regular use of fire in close proximity to human built structures and within these structures required the early adoption of fireproof materials, and through ventilation systems.

As previously noted, fire and resultant smoke may have also provided a remedy to some aspects of decay, both by keeping materials below the moisture content that allows timber decay to occur, but also by introducing chemicals toxic to fungal and insect decay organisms with the fumes and smoke. In this context, it should be noted that the fumes from the combustion of many hardwoods and other timbers are known to be very toxic, and to be effective insecticides and fungicides; and their use as such appears to have been evolved by many species of bird, some primates and other non-human organisms (Pausas and Keeley, 2009). The fumes of chemicals such as sulphur and arsenic, and plant products such as camphor, have been used in Europe for this purpose to control infestations; possibly since

Roman times, and may have been used in ancient Egypt even earlier (Chen, Vermaak and Viljoen, 2013).

The development of chemical remedial treatments including insecticides, and later fungicides, for use in buildings, especially in the 20th Century, can therefore be viewed as a recent round in the chemical arms race between living organisms. This includes the production of antibiotics and other chemicals by fungi and moulds in order to give competitive advantage against bacteria and other fungi or moulds (Durham, 2001), and the production of insecticides and fungicidal chemicals by plants to prevent their infestation and decay as previously discussed (Boulogne *et al.*, 2012)(Despres, David and Gallet, 2007). The failure of Chemical Remedial Treatment products to prevent decay unless the conditions for decay organisms to grow are eliminated is a clear example of the failure to effectively manage an apparent Building Pathology unless a more holistic approach to Diagnosis and remediation is taken based on those developed for Diagnosis and treatment in Medical Pathology (Hutton *et al.*, 1992a; Hutton and Lloyd, 1993; Ridout, 2013).

2.4.8 The Evolution of Timber Suspended Floor Structures

Another useful example of the evolution of the remedial detailing for damp and decay can be found in the ground floor structures of European buildings. These originally would have been of packed earth or 'bedrock', which were later overlaid; for example, with masonry slabs or bricks if required (Childe, 2009). In colder climates, sophisticated underfloor heating systems later evolved; especially with the roman hypocaust, where hot air was drawn through vents beneath the floor slabs from a remote fire or furnace (Ionescu *et al.*, 2015). However, this would have been relatively difficult and expensive to construct and maintain.

More generally, floor surfaces would have been found to be increasingly relatively cold; especially with the movement of the 'fire pit' from the centre of the floor into a fireplace and chimneystack (Shuffrey, 1912). This appears to have occurred in at different times in different regions of the UK. However, with this movement of the fire, it became necessary to provide a more thermally efficient floor surface which is likely to have been originally provided by laying timber directly onto the packed earth. This would have been relatively durable in areas with effective ground and surface drainage, or where durable materials such as oak heartwood could be used; especially where laid onto relatively well drained foundations (Smith, 1970).

However, these timbers would have become increasingly vulnerable to infestation and decay with wood decaying fungi and wood boring beetle; where subject to damp conditions. For example; as a result of defective and poorly controlled ground and surface drainage in urban environments, where the floor timbers were overlaid with other materials such as carpets preventing ventilation and drying, or where cheaper softwood timbers were used (Kostof, 1995).

A number of remedial details appeared to have evolved to reduce the resulting risk of decay. These include the separation of timber elements from the foundations with relatively damp-proof materials, such as slate; and the use of the more durable oak timber to form the joists or sleeper plates in contact with the damp materials beneath. However, this still allowed the accumulation of moisture beneath the floor surface, providing conditions for damp and decay. This could dissipate in the past through the gaps between floorboarding, which form naturally with the shrinkage of boards after original laying.

In this context it should be noted that floorboarding generally has moisture contents at or above 20 per cent weight for weight, when originally laid and is likely to shrink for 1 per cent of its radial diameter for every 3 per cent weight for weight drop in material moisture content. This is likely to result in gaps of, say, 3mm between 100mm wide boards with drying on occupancy. The gaps between boards as described above can provide significant through and cross ventilation beneath a timber floor structure. However, these would be effectively blocked with carpets and other floor surfaces, and would also become closed with expansion of floorboards with increased moisture content as a result of intermittent heating and ventilation to building interiors with occupancy.

Such loss of ventilation to the structures beneath timber floors is likely to have occurred increasingly in the 18th and 19th Century with changes in furnishing and occupancy. Evidence of this problem can be found in the infestation and decay, or partial decay of the sapwood band of floorboards and joists laid at ground floor level during this period.

It is in this period that remedial detailing to allow through and cross ventilation to sub-floor voids at ground floor level appears to have evolved; with the introduction of air vents to the exterior at the base of external walls, detailed so as to provide through and cross ventilation with fresh air (Foliente, 2000). This allowed long-term drying in case of water penetration, prevented the build-up of moisture laden air and ensured that timber elements remained too dry for infestation or decay by wood boring beetle or wood decaying fungi. Again, the evolution of the interaction between materials, decay organisms, occupancy, detailing and internal and external environments is a useful example of the complexity of the processes resulting in the evolution of Building Pathology; supporting the Hypothesis.

2.4.9 The Evolution of Background Ventilation

It is interesting to note that a similar process of evolution of remedial detailing was occurring to provide through and cross ventilation to occupied air spaces in much the same period as described above for the evolution of suspended floors (Awbi, 2002) (Gwilt, 1854). This may also be due to the introduction of fireplaces and chimneys in conjunction with the increasing availability of glazing for windows (Kostof, 1995). This appears to have resulted in the continuing evolution of detailing to both fireplaces, chimneys and windows to ensure adequate provision for background ventilation, as illustrated in Figure 2.6 bellow.

The requirement of this would be evident to occupants as smoke blowing back into an occupied air space soon becomes intolerable, and in the UK failure to provide adequate background ventilation soon results in superficial mould growth on building surfaces and contents. This would have been unacceptable to occupants who would have been familiar with the effects of fresh air and lack of fresh air on mould growth to foodstuffs and other materials.

The evolution and detailing to windows appear to be associated with the parallel requirements and potentially conflicting requirements for security and ventilation during a period of increasingly intermittent occupancy and heating. This resulted in the evolution of the simple casement window, and eventually to highly sophisticated sash window systems; which included provision for security, ventilation, lighting, and thermal and acoustic insulation; which have not been surpassed by modern purpose built specially designed triple glazed systems. Similarly, the evolution of fireplaces and stoves resulted in the energy efficient production of passive stack ventilation, radiant heat, and structural storage heating; and could also make provision for cooking, water heating, and central heating.

Figure 2.6: The Evolution of Complex Buildings and Building Systems over Time

The evolution of complex buildings and building systems over time never stops. In this case, an original stone building with a thatched roof, has been further adapted with the construction of chimneys, the laying of a slate roof and the installation of glazed windows. This has required the evolution of methods for managing water penetration, including roof drainage and ground and surface drainage, and for providing adequate background ventilation, purge ventilation and passive stack ventilation to prevent building pathologies.

It is probable that the relationship between human health and the health of buildings was recognised at an early stage (Hobday and Dancer, 2013), and indeed it can be postulated that some of the instinctive reactions that we are likely to have inherited from our pre-human ancestors allow us to make this association (Curtis, 2007). For example, humans appear to naturally avoid damp, dark, smelly environments, all of which appear to generate an immediate aversive response in most humans; especially with the presence of obvious bacterial mould and fungal growth (Miller, 2013).

This appears to have generally resulted in an acceptance that the removal of dust and debris, the introduction of fresh air and sunlight are good for human and building health. It is therefore interesting to note that increasing importance appears to have been given to the introduction of through and cross ventilation of occupied air space with fresh air in the 18th and 19th Century as described above in order to promote human health. This is likely to have been associated with a recognition that inadequate provision for fresh air provided the conditions for the spread of a number of debilitating and fatal diseases in crowded urban environments; especially tuberculosis (Bates and Stead, 1993).

This compares with previous Medieval theories where bad air or 'mal-aire' from the external environment was to be excluded, especially during the nighttime hours, as it was thought to be deleterious to human health. This fear of Malaria is likely to have been caused by the disease currently with that name; which was prevalent in the UK and other parts of Europe in the past (Bruce-Chwatt and De Zulueta, 1980). This example of an apparent Building Pathology and the associated complex interaction between the heath of occupants and structures over time, the evolution of remedial measures and their unintended consequences, provides further support to the Hypothesis.

2.5 The Evolution of Building Information and Information on Remediation

2.5.1 Introduction

An important component of any complex system evolving over time is the transfer of information (Nicolis, 2012).The majority of structures built by living organisms are created using information inherited genetically or epigenetically, and resulting in instinctive behaviours. However, there is evidence that some information used in construction by animals and birds is passed on by copying the actions of parents or relatives, in a way that might be considered cultural or mimetic (Mesoudi *et al.*, 2013). It is certainly probable that the majority of information used in human construction is past on in this way (Laland, *et al.* 2011).

It seems probable that information used by humans for building and remediation of building pathologies was initially by copying the actions of parents or close relatives. However, such information was then likely to have been increasingly passed on as a craft tradition from one specialist to the next. This eventually became highly systemised with equivalents to the Master-Craftsman and Apprentice system developing many times and in many cultures (Epstein, 1998). It was also probable that such specialisations and transmission of information would be valued and protected within families or within extended families, and possibly even a caste systems. Similarly, such information and knowledge appear to have been protected as part of the 'secret mysteries of priesthoods and crafts; as in ancient Egypt (Moorey, 2016).

This information and knowledge would certainly include information and knowledge on how 'not to do things' as well as how to do things successfully. It is also certain that as an individual learnt the craft and techniques involved in construction, they would have made mistakes and created sub-optimal structures. In this way Individuals would therefore soon develop first hand and hands-on experience of the materials they used and their limitations; in the same way that a child learns the limitations of sand when building castles on a beach. They would also have quickly learned remedial techniques in the same way.

Obviously as in all human social interactions, knowledge brings power, and such knowledge would have been protected. However, the ubiquitous process of evolution and survival of the fittest would have applied. This would result in inefficient and unsuccessful building techniques being eliminated over time, and successful and efficient techniques becoming the norm; given a stable environment.

2.5.2 The Evolution of Building Standards

With the invention of writing, some of the information disused above would have stated to have been recorded and passed on in written form. However, this is likely to have been originally for 'bureaucratic', legal and administrative purposes; rather than for passing on the knowledge on how to build, how not to build, and how to remedy defects that may have arisen. In this way it appears that systems of building codes and building regulations started to be written down and presumably applied in the early city states of the Middle East (Maine and Scala, 2017). However, until recently it appears that in most cultures and in most periods of history, reliance was placed on expert opinion based on craft experience; to provide the information necessary for the design and construction of the buildings; for the remediation of defects and maintenance; and for the resolution of any disputes over apparent failures (Shelby, 1970).

The recording of information in written or graphic form started to become more prevalent in the west in recent centuries due to the interest of gentleman amateurs, who were trying to copy and replicate the classical architectural forms (Skelton, 2009). This might be thought of as the birth of Architecture as a subject and profession in the west. However, at the same time the Industrial Revolution was resulting in an acceleration in the building of new structures, as well as an acceleration of the introduction of new materials, new end uses and environments (Williamson, 2002).

In these circumstances, there is evidence that the transfer of information by the 'traditional' crafts was put under strain; and that inadequate time was available for craft solutions to the problems generated by new materials and new uses to develop and be promulgated (Dyos, 1968; Stewart, 2009). An example of this is the problem with the changing use of hardwood and softwood timber species, iron and steel, as structural materials in the UK throughout the 18th and 19th centuries, previously described (Gwilt, 1854).

Similar problems developed with the accelerated use of steel and concrete in the early part of the 20th century (Broomfield, 2003), and the use of glass, aluminium and plastics in the second half of the 20th century; alongside the development of tower-blocks both for domestic and office use (Schwartz, 2001). In such rapidly changing environments evolutionary processes generally result in the rapid proliferation of possible solutions, followed by the equally rapid elimination of failing or sub-optimal systems. This can appear chaotic and catastrophic at the time and without the perspective possible when viewed on longer and geological time scales (Gould, 2002). However, the problem is one of information transfer; which in evolutionary terms generally relies on lifecycles, as the primary scaling factor; whether these are the lifecycles of a microbe which may be in minutes, or the lifecycle of a craftsman's professional career which may be 20-50 years.

In recent centuries attempts have been made to improve the transfer of information with pattern books, textbooks, regulations and Building Standards. In the 20th century there has been a tendency to regard such information as scientifically based, and indeed much good work has been done in Building Research Establishments. However, a cursory reading of the information held for example in the Building Regulations and relevant British Standards in the UK, suggests that most of the information that they contain has evolved from the knowledge gathered by those involved in practical building over many generations. This in turn evolved from lifetime experiences of the successful application of materials and details; and, perhaps more importantly, lifetime experiences of failures and their remediation.

2.5.3 Information and Building Pathology

Although information on failures in building materials, structures and environments has been increasingly accumulated and systemised in standards and regulations in the 20th century, and more recently has become more generally available with the development of information technology systems; their application does not appear to have kept pace with the information available (Van der Heijden, Visscher and Meijer, 2007; Van der Heijden and De Jong, 2009).

This appears to have become a particular problem in the second half of the 20th century, and may be due to a combination of deregulation in what might be described as free-market economies (Meijer and Visscher, 2006), and of corruption in centrally controlled or struggling economies. (May, 2003; Iwaro and Mwasha, 2010) This has resulted in many catastrophic and high-profile failures in buildings and structures; but perhaps more importantly, this has resulted in a chronic low-level failure of buildings and built environments to meet the perceived requirements of occupants or specifiers in a cost-effective and sustainable way, as illustrated in the example shown in Figure 2.7 bellow.

For example, buildings may have failed to have an expected service life (Lacasse and Sjöström, 2004), building environments may have adverse effects on the health of occupants (Yu and Kim, 2010), buildings may not be energy efficient (Iwaro and Mwasha, 2010), and buildings may have unexpectedly high maintenance and unsustainable maintenance costs (Seeley, 1987; Saghatforoush *et al.*, 2011).

Figure 2.7: Emergent pathologies in Heating and Ventilation

From the late 20th century reliance has been increasingly made on electrical and/or hot water heating and mechanical ventilation systems. These are often combined with mechanical air handling and air conditioning *systems. The rapid development and spread in the use of such systems has not allowed the evolution of failsafe design, construction, or maintenance systems. As a result, many of these systems are never properly commissioned, operated, or maintained, with resultant failure and secondary building pathologies. In this case, failure to properly install and maintain air conditioning was allowing water penetration into the structures beneath, providing, conditions for extensive interstitial mould growth and making the building unfit for human occupancy.*

These failures in the application and enforcement of standards and regulations, have also often resulted in failures to adequately investigate and analysis the building failures that occur. This has resulted in the failure to generate the information that might otherwise have resulted in the evolution of solutions to these building failures. Although integrated systems of monitoring have been proposed to provide automatic feedback on some areas of potential building failure (Volk *et al.*, 2014). This failure to investigate may be due to the same factors that result in failures in the first place as previously described. However, the situation has been particularly problematic where new materials, details and structures are being introduced at an increased rate, to meet new and changing uses. This was a component of the accelerated changes resulting from the Industrial Revolution in the UK and has continued to accelerate during the 20th century. Most recently with attempts to adapt to Climate Change (Green, 2023). The result has been an evolutionary process that has been relatively destructive and inefficient, due to a failure to transfer information in time to manage the risks (Hopkin *et al.*, 2017)to buildings and occupancy resulting in unnecessary and foreseeable Building Pathologies and Health problems for occupants and the environment (Rong, Clarke and Smith, 2007; Vardoulakis *et al.*, 2015; Hopkin *et al.*, 2017). However, the processes described illustrate the way that Building Pathologies relate and interact with the complex evolving system that tis the built environment, and relate to the Health of occupants.

2.6 The Importance of Time

It will be apparent from the above that time is the essential component of all the evolutionary processes previously discussed. This should not be surprising as every physical phenomenon has a time component, and indeed time itself may only be defined by sequential physical phenomena. In particular, time is the main component in the study of Bio-geomorphology and Anthropo-bio-geomorphology; of which the creation of structures by both non-human and human agents is a part (Viles, 1988; Huggett, 2016).

As previously discussed, time is the crucial component of evolutionary processes both in terms of iterative 'lifecycles', and in transfer of information between lifecycles (Gould, 2002). It is obvious that any construction or building process is defined by time in that no macro structure pops into existence; rather it has a period of construction or building, which is continuous with the subsequent process of decay.

Although this is logically obvious and indeed obvious in daily life; there has been a tendency in modern western culture to ignore the time component; especially with regard to buildings. This may be caused by the apparent relative longevity of buildings, compared to the lifespan its occupants, or at least the usage of the building by its occupants; resulting in a lack of perspective. This may be reinforced by the fact that many of the buildings visible in a building stock at any one time may appear relatively old.

In the West it may be that an increasingly industrialised and 'consumer society' only perceives physical objects at the point of apparent completion or acquisition (Arnould and Thompson, 2005). The 'notional building' tends therefore to be conceived as perfect at a point in time with only slight consideration given to service life (Duling and Jacobus, 2006). This has profound effects on all those involved in the construction and maintenance of buildings, both professionally, contractually and financially. As a result, relatively little thought is given to the subject of maintenance (Feilden, 2007).

This is in stark comparison to the aerospace industry, the car industry or any other construction process; where service life, maintenance and life cycle are considered in detail in every part of the process (Ross *et al.*, 2008; Hawkins *et al.*, 2013). In fact, maintenance was and indeed still is a key aspect of buildings from the moment of their construction, and arguably even before construction is completed. This process of maintenance implies a recognition of the relative decay or degeneration of materials and structures over time. The necessary maintenance process also implies remediation of these emerging defects; whether in structures generated by humans or even non-human organisms.

This process of maintenance is a continuing source of information into the evolution of the building, and can allow structures to adapt to changing environments and use over time. This can be within the lifecycle of the building and can allow accelerated evolution to meet changing environments and usage (Brand, 1995). The Information from the process is not only available for this evolutionary process in real-time, but can also be made available by the retrospective analysis of past maintenance activity (Preiser, White and Rabinowitz, 2015).

This can be an informal process in the memory of the craftsman or occupant responsible for maintenance, or can be done by 'reading the building' as a physical embodiment of this information; in the same way that Archaeologists or Medical Diagnosticians will gather information. This information can then be used to inform the evolution of future maintenance activity, or future design and construction. This process of reviewing the history of the building and its failures is the process of Diagnosis, and the same as the proses of History taking in Medical Diagnosis.

2.7 Contextual Summary

The literature research discussed above was undertaken to provide the empirical and academic grounding for the assertion that Buildings and the built environment created and occupied by humans can usefully be considered as complex systems or super organisms evolving over time. From the above it can be seen that the evolutionary advantage of biologically generated structures may be by providing protection from predators, competitors or adverse external conditions; by providing improved environments for growth and reproduction; and by demonstrating social or sexual superiority, in competition with organisms of the same species (Davies, Krebs and West, 2012). In this way, these structures may be more than analogous to those created by humans.

However, the continuing development of the complexity and 'fitness for purpose of these often dead and inorganic structures has the same mechanisms as those affecting the development and evolution of the biological organisms that create them; that is the survival of the fittest in a competitive and changing environment (Gould, 2002; Pianka, 2011). Communities of living organisms and the structures they build may also be considered as superorganisms competing and evolving over time (Stock and Campbell, 2002; Moritz and Southwick, 2012).

In this context it should be noted that the information allowing the building of these structures is generally passed from one generation to the next of the biological organism that create them, as part of their genetic and epigenetic inheritance. There is also some evidence of cultural inheritance in some higher organisms affecting the construction and use of the structures they produce (Odling-Smee *et al.*, 2003).

It can also be seen that human-built structures have evolved over time under the influence of a number of evolutionary drivers in the same way driven by similar or the same mechanisms. These have included those that drove the evolution of structures built by non-human organisms; and include the availability of materials, protection form the environment and the creation of adventitious micro-environments, protection from predators or competitors, energy efficiency, and the demonstration of competitive advantage to social or sexual competitors. However, human built structures have also been subject to the proliferation of different and changing environments, materials, and uses as humans have spread and evolved. They have therefore had to evolve and adapt rapidly to these drivers over relatively short periods of time. This has resulted in more building defects developing in shorter time scales under more variable conditions, and in more limited time for effective remedial measures to evolve. Associated with this process the transfer of information allowing the evolution of human-built structures has also increasingly involved cultural inheritance rather than genetic or epigenetic mechanisms. Similarly, the increasing importance of competition between cultures, and their evolution, has also affected human built structures in ways that are not directly related to function. This may result in conflicting requirements for form and function generating more building pathologies, as illustrated ain Figure 2.8.

Figure 2.8: Building Pathology from Use of Impermeable Membranes and Insulation

In recent years in the UK, the introduction of plastics as membranes for moisture and vapour control and as insulation layers has often resulted in unintended pathologies and failures. This has been due to failure of the design, construction, and maintenance processes to evolve rapidly enough to deal with these emergent phenomena in the time available. In particular, the introduction of membranes and insulation into timber frame structures has resulted in severe problems during and after construction. This is a particular problem where form does not follow function, and where exterior claddings are used on top of the timber frame structure, to make them appear to have been built with brickwork and masonry, so as to give 'comfort' to naïve purchasers and facilitate marketing and sales.

From the above, it can be seen that building defects or building pathologies are an emergent phenomenon, that is part of the evolution of buildings as complex evolving systems over time.

CHAPTER 3: CRITICAL REVIEW OF DEVELOPMENT OF BUILDING PATHOLOGY AND COMPARISON WITH MEDICAL CLINICAL REASONING

3.1 Introduction

There has been a long history of the evolution of buildings and building pathologies, and of their study and remediation as described in Chapters 2 above. However, the term 'Building Pathology' and the subject it describes has a relatively short history in the UK. This chapter describes the history of the development of the subject of Building Pathology in the UK, and some of the factors that appear to have encouraged or restricted its development and understanding. A comparison is then made with the development of the subject of Building Pathology and of the related subject of Medical Pathology, specifically with medical Clinical Reasoning, in order to support the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology. Based on this, it is proposed that an understanding of the factors affecting the development of the subject of Building Pathology and of the resent advances in the parallel subject of medical Clinical Reasoning will help in formulating proposals for the further development and understanding of Building Pathology.

3.2 The Development of the Subject of Building Pathology in the UK

3.2.1 The Early Years

By the 1960s and 1970s an extensive body of knowledge covering the art and science of the construction, investigation, remediation, conservation and refurbishment of buildings and the built environment had developed and evolved (Benevolo, 1977). For example, in literature and supporting scientific references published over the years in the UK by the Building Research Establishment (BRE), the British Standard Institute (BSI), English Heritage and Historic Scotland; and by similar organisations in other countries, promoted by the International Council for Research and Innovation in Buildings and Construction (CIB) (Sjostrom and Bakens, 1999). Similarly, an increasing body of academic and practical knowledge on the interaction between buildings, the built environment and the building occupants, and on the perceived failures in these interactions, had developed (Rapoport, 1990). However, much of this knowledge was held in sciences, humanities and professional disciplines that did not regularly or easily work together; and as more academic research was undertaken this often led to frustration when the answers suggested were found to be impractical (Rapoport, 1990; Stone, 2004).

In the past, attempts had been made to achieve an overview and understanding of the knowledge available with the study of Architecture (Moffett, Fazio and Wodehouse, 2003). However, in the late 1970s and 1980s it was becoming apparent to many building professionals and academics that many of the designs and structures produced by architects and others working under the existing systems in the UK and abroad were resulting in what was perceived to be an unacceptable level of failure in buildings and the built environment. This was perceived to have socially and economically unacceptable implications for building occupants and for building stocks (Rowe, 2011; Murphy, 2012). In particular, those interested in the conservation and maintenance of historic building stocks were becoming increasingly aware that the remedial and refurbishment interventions that had been undertaken in the second half of the 20th century were often counterproductive, resulting in accelerated loss of original materials and structures (Forsyth, 2013).

About 50 years ago the more scientific approaches of Evolutionary Science and Ecology were applied to develop the concept of Building Biology and in the 1980s the author and other building professionals and academics in the UK and abroad with experience of Medical Pathology started to use the phrase ‘Building Pathology’; to describe the study of perceived failure in buildings and the built environment, so as to develop a scientific understanding of the processes involved, and so as to allow the diagnosis, treatment and prognosis of such failures (Harris, 2001; Douglas and Ransom, 2013). This cumulated in a series of annual conferences held from 1989 to1993 in Oxford and Cambridge; where academics and professionals from many different disciplines with an interest in buildings and the built environment or in related disciplines, came together to explore multidisciplinary approaches and solutions to these problems (Hutton, 1989b; Hutton, 1990). This was based on the concept that buildings were complex systems evolving over time, and that building failures could be understood using similar methodologies to those developed for Medical Pathology, as illustrated in Figure 3.1.

Figure 3.1: Medical Pathology

The subject of Medial Pathology has evolved over thousands of years to allow the understanding of the human body and other living organisms. This has generally been based on discovering function by investigation of failures in anatomy and physiology of the body. As buildings and other biologically generated structures can be considered as similar and parallel complex systems evolving over time, the methodologies and metacognitive processes evolved for Medical Pathology may be usefully applied to the understanding and remediation of Building Pathologies.

The term 'Pathology du Battements' or 'Building Pathology' also had some currency in France for describing building defects at this time (Reygaerts, 1980). Therefore, when in the 19090s the Royal Institute of Chartered Surveyors in the UK approached their colleagues in Europe (where the role of the 'Surveyor' was generally incorporated into the professions of 'Engineer' or 'Architect'), in order to have the UK profession of 'Surveyor' more internationally recognised; the phrase 'Building Pathology' was used to describe the core discipline of the identification of building defects; although this may not have been generally understood in the more holistic definition of the subject at its inception in the 1980s as described in personal communications during pilot interviews at the start of this research at Appendix A(Cassar *et al.*, 2018).However, in the 1980s it had become clear to the researcher and others that buildings and built environments were ‘complex evolved systems’, in which one person’s remedial intervention created another person’s problems. The concept of Building Pathology was therefore proposed at this time, so as to allow the study, application and development of methods for ‘diagnosis’, ‘epidemiology’, ‘treatment’ and ‘prognosis’ in this multidisciplinary area (Hutton, 1989a; Hutton, 1989b; Hutton, 1990).

3.2.2 The Development of the Subject of Building Pathology

The subject of Building Pathology has many roots as described above. These include subjects such as Evolutionary Science, Zoology, Anthropology, Ecology, Building Biology, Environmental Science, Material Science, Microbiology, Mycology, Medical Science, Pathology, Diagnostics, Epidemiology, Risk Management, Bayesian Statistics and Decision Theory, Archaeology, Architecture, Historic Building Conservation, Structural and Environmental Engineering, Pre-and Post-Occupancy Assessment, Surveying, and other related subjects; to name but a few. The subject of Building Pathology may also be conceived as branching into ‘sub-disciplines’ of these subjects, and/or branching into disciplines which may be perceived as ‘subsets’ of the subject of Building Pathology as illustrated in Fig.3.2, Fig.3.3 and Fig.3.4 below,. These include ‘Building Forensics’, ‘Building Biology’ and others. Since the inception of the subject of Building Pathology and the first uses of this term to describe the subject in the 1980s; the term ‘Building Pathology’ and the description’ Building Pathologists’ has gained some currency among professionals involved in the investigation of building defects, and who have taken on some of the methods proposed by the author and others in the past as described in personal communications during pilot interviews at the start of this research included at Appendix A(Cassar *et al.*, 2018).

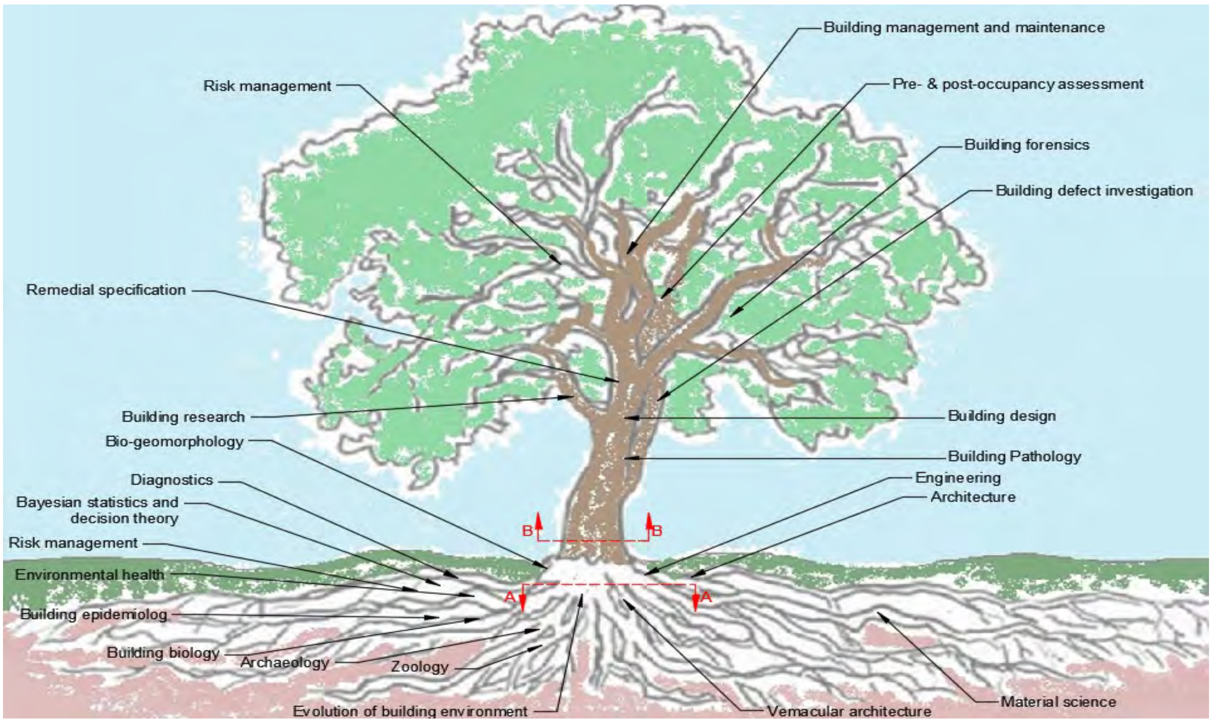

Figure 3.2: The Evolution and Growth of the Building Pathology ‘Tree of Knowledge’

This diagram depicts information flowing both up and down the roots and branches of a ‘Tree of Knowledge’ representing the subject of Building Pathology gas it grows and evolves, in the same way that buildings and the built environment have grown and evolved overtime.

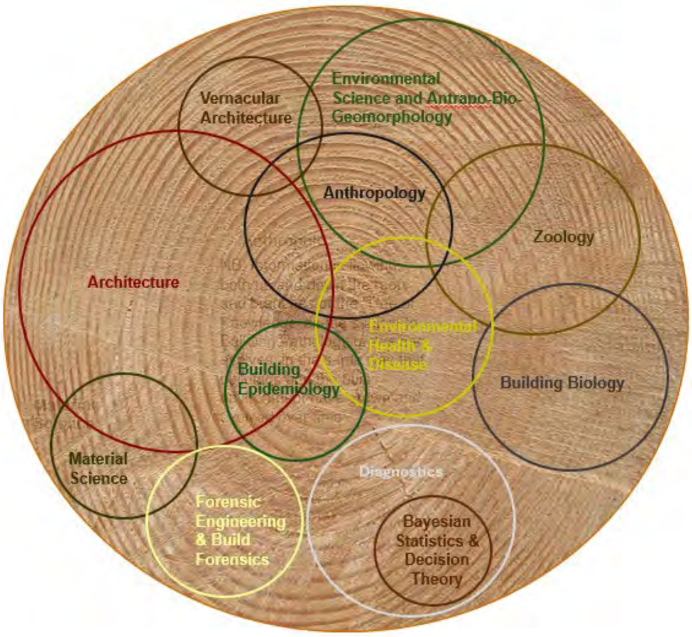

Figure 3.3: The Evolution and Growth of Building Pathology ‘Tree of Knowledge’ showing Venn diagram of source subjects or ‘Roots’ (Section A-A)

This diagram depicts information flowing both up and down the roots and branches of a ‘Tree of Knowledge’ representing the subject of Building Pathology gas it grows and evolves, in the same way that buildings and the built environment have grown and evolved overtime.

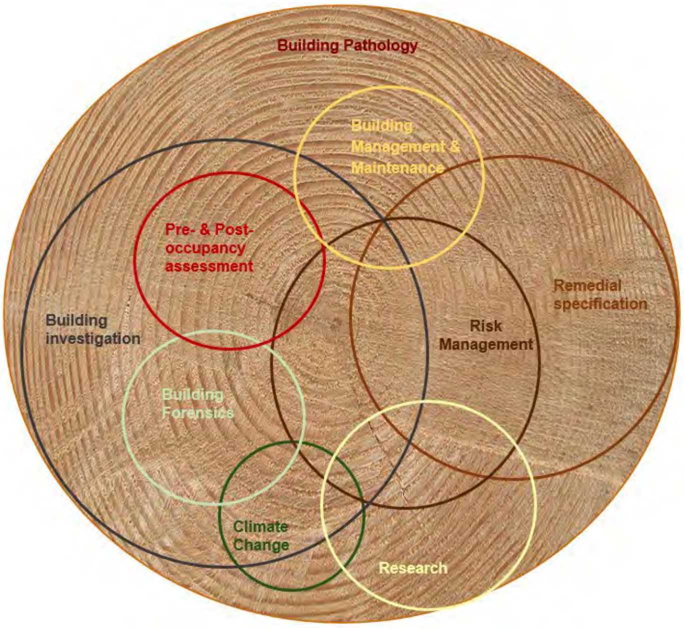

Figure 3.4: The Evolution and Growth of Building Pathology 'Tree of Knowledge' showing Venn diagram of development of subjects or 'Branches' (Section B-B)

NB Information is flowing both up and down the roots and branches of the 'Tree of Knowledge' as the subject of Building Pathology grows and evolves, in the same way that buildings and the built environment have grown and evolved overtime

Similarly, since that time there has been much progress in the related subjects and much knowledge and practical experience has been gathered on its application. In particular, a number of text books using the term 'Building Pathology' have been published(Harris, 2001; Macdonald, 2008; Watt, 2009; Douglas and Ransom, 2013) and two international peer reviewed journals have incorporated 'Building Pathology' in their titles. Indeed, the subject of 'Building Pathology' has been stated to be a 'core' discipline in the training of a number of building professionals; in particular, by the Royal Institute of Chartered Surveyors in the UK, and in the training of architects and engineers in Portugal as described in personal communications during pilot interviews at the start of this research project and included at Appendix A(Cassar *et al.*, 2018). The CIB started an international working group on the subject in the 1990s. However, it is generally felt by many specialist academics and building professionals who were involved in the original conception of the subject of Building

Pathology, that the development and general application of the subject over the intervening years has been less than might have been hoped for and expected at that time(Cassar *et al.*, 2018). In particular, there appears to have been a failure to get the subject of Building Pathology generally recognised and understood by other professionals and academics, or by the general public as described in personal communications during pilot interviews at the start of this research(Cassar *et al.*, 2018).

As might be expected, the subject has been taught and developed in countries and institutions where individual experts and groups are based, as described in personal communications during pilot interviews at the start of this research(Cassar *et al.*, 2018). As shown in the literature search for this project, and in the preliminary analysis at Appendix D; the term 'Building Pathology' and the subject of Building Pathology appears to have been relatively more frequently used in some parts of the world, and some areas of building science and practice than others. In particular, Building Pathology has been more frequently used in the study of concrete structures and concrete failures; possibly due to the fact that the term and concept of 'diseases of concrete' has been generally used in the past, and that the term 'Building Pathology' had been more generally used to describe defects in this material.

The subject of Building Pathology also appears to have been more readily understood and applied by those involved in Historic Buildings Conservation, both in the UK and around the World. This may be because those involved in Historic Building Conservation already understand the importance of time in the changes and evolution of building materials, structures and details over time. They are also more likely to be familiar with taking a holistic rather than a reductionist view of the varying requirements of building occupants and other 'stakeholders'; where all parts of a project are interconnected and can be explained only by reference to the whole.. They are also more likely to be familiar with considering remedial interventions as part of a cyclical maintenance process rather than a one off 'quick-fix'. Conversely, there appears to have been no development of a general understanding or even awareness of Building Pathology or its application among those involved in planning, finance or risk management.

3.2.3 Current Understanding of the Subject of Building Pathology

For those studying the subject of Building Pathology, its definition appears to remain that understood by the author and others back in the 1980s and 1990s described above. This is stated in the introduction to proceedings of the Building Pathology conferences in 1989-1992, in terms of reference of the CIB working group 86, and in the international peer reviewed journals and textbooks published since that time. The terms 'Building Pathology' and 'Building Pathologists' appears to have gained some currency in the last few years in the UK, based on preliminary Google searches using this term. However, in the experience of the researcher the term Building Pathology is generally not known, let alone understood or recognised by the majority of building professionals or academics working in the area of buildings and the built environment in the UK or abroad. Where the term Building Pathology is used, for example in the context of 'Core Disciplines' by the Royal Institute of Chartered Surveyors in the UK, or more generally in Europe, it is generally used to describe the simple reductionist identification of building defects; rather than in a more holistic way. Among those involved in Medical Pathology the term is unknown, or assumed to refer to human or animal diseases caused by the built environment.

Even among those studying and publishing in the field of Building Pathology, it is not clear that there is a general understanding of the holistic roots and application of the subject. In the UK a relatively small but growing number of building professionals and practitioners describe themselves as 'Building Pathologists', and offer the subject as a service to clients, but many of these individuals have been active since the inception of the subject in the 1990s. Similarly, a relatively small number of now very senior academics, who were involved in the inception of the subject of Building Pathology, have continued to promote it to colleagues and students as described in personal communications during pilot interviews at the start of this research(Cassar *et al.*, 2018).

Although there have been a number of reviews of the subject(Beukel, 1993; de Freitas, 2013; de Freitas and Delgado, 2016), little has been generally published that provides an overview of the subject; or that formulates methods to allow its further study, application and further development. Generally, much of the literature incorporating the term Building Pathology in text books(Harris, 2001; Macdonald, 2008; Watt, 2009; Douglas and Ransom, 2013), and in peer reviewed journals and technical journals(Beukel, 1993; de Freitas, 2013; de Freitas and Delgado, 2016) the term is generally used to describe defects to building materials or structures; rather than in its more holistic way, in the diagnosis of causation of these defects or in the holistic management and remediation of these defects. Indeed, much of the development in the subject of Building Pathology appears to have been in the development and improvement of techniques for identifying defects; or in the application and development of IT systems to the identification and statistical analysis of the occurrence of such defects(Beukel, 1993; de Freitas, 2013; de Freitas and Delgado, 2016).

It is instructive to review the main textbooks used by students studying building defects and Building Pathology in the UK. The first of these is 'Understanding Housing Defects' (Marshall, Worthing and Heath, 2008), which was first published in 1998, with the fourth edition published in 2014. This is generally about 'defects' not 'processes'. It therefore discusses the definition of a 'defect' and notes that this is subjective but has little or no discussion of the process resulting in defects or how they may be diagnosed in the introduction at Chapter 1. The text at Chapter 2 'Building History' is introduced, as is the significance of local environment and cultural needs over time. However, no attempt is made to relate this to defects or Building Pathology. Generally, the text may be a very useful reference for use in practice once a defect is identified; but does not discuss the evolution of defects over time, the probability of defects occurring, and how this relates to practical risk management. It is therefore not a useful introduction to the metacognitive processes required for the diagnosis of building defects in practice, or for identifying and considering alternative remediation or management strategies.

The first text book titled 'Building Pathology' was 'Building Pathology, Principles and Practice' (Watt, 2009). This was first published in 1999 and developed the ideas explored during the Building Pathology conferences previously discussed(Hutton, 1989b; Hutton, 1990). This therefore introduces the 'holistic approach to understanding buildings', the concept of 'failure over time', and the 'needs of a building'; based on the conservation background of the author. This implies the organic nature of buildings, but this is not further explored, and nor are the evolutionary processes applying to such complex systems. However, the author does introduce the concept of buildings with 'skin', and 'behaving' with a 'synergistic relationship with users' in Chapter 2. This also introduces the concept of the 'birth', 'life' and 'death' of a building. The introduction of 'Building Performance' at Chapter 4 implies adaption of buildings over time, and check lists for gathering information on different building types are proposed. However, the definition of faults as 'Defects, Damage and Decay' in Chapter 4 lacks a holistic view. 'Survey and Assessment' methods proposed at Chapter 5 include 'Background Research' for which a flow chart is proposed, and 'monitoring over time' is discussed. This leads into an introduction for the 'Concept of Building Management and 'After Care' and 'Preventative Conservation'. This and the second edition published in 2009 usefully introduced the time component and building defects as a process, based on the conservation background of the author. However, this book does not introduce or explore the evolutionary nature of these processes or the potentially useful parallels with 'Medical Pathology' previously discussed in this thesis.

The second main text book published with the title 'Building Pathology' was 'Building Pathology Deterioration, Diagnosis, and Intervention'(Harris, 2001). In the preface the author has a useful discussion of the development of the subject and the importance of understanding deterioration over time, but notes difficulties in teaching building professionals to think 'critically' or 'analytically'. He also discusses the analogy with the 'Medical Model' but appears to discount this as an analogy, and reports that he found the use of medical terminology in teaching was counterproductive. He does however clearly identify failings in the design process, especially in awards systems, which take no account of changes over time or with occupancy. In the introduction, the author discusses building conservation, and problems with acquiring and processing information on older buildings. He then introduces the 'Problem-Solving Process', and introduces the concept of a 'Search Pattern' to acquire and process this information. Despite his earlier rejection of medical terminology, the author does discuss 'Building Pathology and Diagnostics', and 'Deterioration as a Natural

Process'. However, the author discounts the Building Pathology and Medical Pathology analogy, as he states buildings are not biological but 'entopical' mechanisms. This fails to recognise that construction, occupancy and maintenance of buildings by living organisms is part of a biological process, and that the construction and occupancy of buildings is part of a wider process of 'Biogeomorphology'. The author does however introduce 'Deterioration Mechanisms' including the concept of life span driven by 'Thermodynamics' but appears to struggle with the complexity and dynamic mechanisms involved. The author proposes the 'Intervention -Matrix' including a component of cost-befit. However, this does not include evolutionary processes over time. Generally, the author proposes a 'system approach' and materials approach; while providing an analytical system that may not be practically applicable on site, or easily developed as a metacognitive process by practitioners or researchers to new or changing systems.

The text book 'Understanding Building Failures'(Douglas and Ransom, 2013) was first published in 1988 and did not identify itself as a text book of 'Building Pathology'. However, the latter editions included a useful 'introduction to Building Pathology', especially in the most recent edition published in 2013. This initially appears to regard the relationship between Building Pathology and Medical Pathology as one of 'metaphorical terminology' and has no recognition or review of processes over time, as introduced in the text books previously discussed above. The old process of enquiry of 'How What Where and When?' is introduced in the preface, and 'Evidence Based Practice' is proposed and criticised based on Medical Pathology. The medical practices of 'Person Based Practice' and 'Reflection' are also introduced. The author proposes building diagnostic 'Flow Charts' and introduces the subject of 'Heuristics'. He then proposes 'DENT' problem solving (Define, Explore, Narrow, and Test); and 'Critical Thinking', which in Medical Pathology has a probabilistic component. 'Scientific Method' related to medical problem solving to generate 'Hypothesis' is introduced. The author then suggests the use of historical information as part of the process. He then suggests 'Cost Benefit' as a test of proposed remedial actions and mentions the concept of 'Utility'. The author also introduces 'Decision Analysis' in Building Pathology, Medical Pathology and other professions. In particular, the concept of probabilities and 'Sensitivity Analysis'. This leads to an introduction to 'Risk in Building Diagnostics' and a discussion of 'Bias' and 'Failure

Patterns'. In the later editions, the author therefore appears to have provided a very useful introduction to the metacognitive processes required for the application of Building Pathology. However, despite this the authors appear to propose linear decision trees, and despite the discussion of the probabilistic components of diagnostics, he appears to consider tests to be definitive not probabilistic. There is also no review of processes over time, or how this might affect risk management in remediation. Generally, the author appears to have recognise and accepted the parallels between 'Building Pathology' and 'Medical Pathology', but does not appear to have understood that these subjects both have the same origins or causes, or to have understood their relationship to evolving complex systems naturally forming part of the general processes of bio-geomorphology. Readers may therefore be led to discount the relationship between Building Pathology and Medical Pathology as only an interesting analogy, and therefore not be able to readily accept or develop the metacognitive processes described. This may therefore be a useful reference book for students and practitioners, but does not appear to have facilitated the dissemination and training of the metacognitive processes required for a holistic Building Pathology as the late authors might have hoped and developed in further publications.

3.2.4 Reflective Review

It might be reasonable to expect to find a number of papers in peer reviewed journals that discus the nature and development of the subject of Building Pathology, but none have been identified for review by online search or on review of over 500 papers or other publications relevant to Building Pathology. This is interesting in itself; as it supports the proposition that a failure to adequately define and develop the subject since its inception, may have restricted its further development and understanding. However, the review of the main texts above indicates some recognition of the importance of changes over time, and some recognition of the similarities with Medical Pathology; but highlights a failure to fully understand or develop the importance of evolutionary changes over time, or the useful medical parallels to Building Pathology.

In this context it is interesting to note the results of a comparative study of flexible learning in construction education (Murray, Donohoe and Goodhew, 2004), where a case study in the teaching of surveying students found that practical interactive peer-group teaching sessions were found to be especially effective by both students and teachers, and similar findings were made on the development and testing of aids for learning Building Pathology using computers (Shelbourn *et al.*, 2000a). This is a similar finding to those in the extensive recent research into the teaching of Clinical Reasoning in Medical Pathology (Cooper *et al.*, 2016; Norris, 2017). However, it should be noted that apart from the references reviewed above, surprisingly little published work was found on the bases or understanding of the subject Building Pathology; despite extensive online search and the review of over 500 publications.

3.3 Constraints on the Understanding of Building Pathology

3.3.1 Background

Recent reviews of the subject as part of an international conference(Ferraz *et al.*, 2016a), and analysis of personal communications during pilot interviews at the start of this research and included at Appendix A, suggest that the subject is now relatively moribund(Cassar *et al.*, 2018). This appears to be due to a number of factors resulting in a lack of understanding of the subject by funders, specifiers or potential clients. This in turn appears to remove the perceived financial imperative to apply, study or teach the subject; as described below.

3.3.2 Vested Interest

In the UK and Europe, it appears that the constraints on the application, study or teaching of the subject of Building pathology are not just due to a lack of understanding; but are also due to the influence of organisations with a vested interest in the status quo; in particular, the manufacturers and suppliers of particular building products or systems of construction and remediation. Similarly, organisations with a short-term interest in the constant construction of new buildings appear to have a vested interest in avoiding the study of building failures, building maintenance and lifecycles. This appears to be a major constraint on the development of aspects of Building Pathology such as 'Housing Pathology'(Thomsen, 2014b; Thomsen, 2014a).

3.3.3 Psychological and Behavioural Constraints

There also appears to be a psychological constraint on the application of Building Pathology among building professionals, separate from the short termism inherent in most current systems of specification and contract. This appears to relate to the psychological and behavioural problem of the perceived negative implications of recognising defects, or even the possibility of defects, before, during and after the construction process.

Even when there appears to be a rational and conscious acceptance of the value of this process; there often appears to be an emotional or political feeling that such negativity is deleterious to the completion of the project or to the client's perception of the project. This is a well-known problem with activities such as snagging, and latent defect periods; and in sub-disciplines of Building Pathology such as Pre and Post Occupancy Assessment.

This psychological constraint on studying failures or the possibility of failures may be inherent in the basic human psyche. However, the situation is probably made worse by the current culture of blame; especially in a litigious environment. It should be noted that similar problems have arisen in medical Pathology, where again practitioners tended to try and avoid blame in a professionally competitive, and potentially very litigious environment.

These problems have started to be addressed by the application of procedures for 'risk identification', 'risk ownership' and 'risk management'(Cassar *et al.*, 2018). The author has noted that these appears to have come into the medical Professions from areas of human activity where the value of System Engineering is better understood and applied; such as air transport and the military. In these areas of activity, it can be more acceptable to 'think evil' in order to identify potential risks, and to go through the process of self and group analysis and criticism. In this environment, one area where the practice of Building Pathology has grown is in that of 'Building Forensics'; where the rigorous probabilistic investigation and analysis of the cause and effects of failures has obvious advantages to all concerned in potential and actual legal or insurance cases(Cassar *et al.*, 2018).

3.3.4 Cultural Influences

Generally, the presence or absence of a financial imperative appears to be the most significant factor affecting the application of Building Pathology, its study and teaching. However, there also appears to be other cultural factors affecting its understanding. For example, the author has noted that building professionals and academics from Asian cultures which may have an acceptance of the importance of time and cycles in time, have a more ready and instinctive understanding of the basis of the subject(Forster *et al.*, 2019).

Similarly, for example, those in Asia and the Indian subcontinent exposed to the more obvious evolution of buildings over time which occurs with the long lifecycles of historic buildings, or the more frenetic shorter lifecycles in self-regenerating slum neighbourhoods; may have a readier appreciation of the evolution of buildings and the built environment, and their management as part of everyday life(Milbert, 2006; Ni, Oyeyinka and Chen, 2014).

An area where the subject of Building Pathology is better understood and more commonly applied, is that of Historic Building Conservation. As previously discussed, this may be because of an easier acceptance of the importance of time related processes in the evolution of buildings and perceived building defects in this field. However, this may also be due to the more obvious financial imperative for providing cost effective and sustainable conservation(Watt, 2009; Watt, 2015). It is for this reason that the appointment of practitioners with understandings of the application of Building Pathology may be more routinely specified by funders, clients and their advisers, when involved with Historic Building Conservation both in the UK, and elsewhere in Europe and North American(Forsyth, 2013).

3.3.5 Risk Management

Although there is a general lack of understanding or even awareness of the subject of Building Pathology, there does however appear to be an increasing awareness of the requirement for a more rigorous and holistic approach for identifying defects and potential defects in buildings and the built environment. This has become particularly relevant in recent years in the UK and elsewhere, because of high profile failures in the UK such as the Grenville Tower disaster, and the results of subsequent investigations of these failures resulting in the recent Building Safety Act 2022 and Building Regulations 2023(Frame, 2022; Vagtholm *et al.*, 2023) These impose responsibilities and hence liabilities on 'duty holders' and the 'principle designer' in all construction and refurbishment projects in the UK, and make it necessary for building professional weather members of the RICS the RIBA or other organisations to have adequate competency to identify and manage the risk of building failures. Failure to do so can now result in criminal prosecution, substantial fines, and custodial sentences. Similarly, there is currently an increased awareness of the importance of existing building stocks for a sustainable economic future (Liao, Ren and Li, 2023). It is therefore likely that increased political and economic importance will be given to maintenance and management of these building stocks, rather than their constant demolition and rebuilding with new.

When looked at from an evolutionary perspective over time; this is in fact just a reversion to the status quo ante, that existed prior to the second half of the 20th century in most parts of the world. There is now also an increasing awareness and acceptance of the political and economic implications of Climate Change, and the need to understand its probable implications for buildings and the built environment. This is clearly a subject to be addressed by the holistic appreciation of buildings and built environments as part of Anthropo-bio-geomorphology, as illustrated at Figure 3.5. This is the subject of Building Pathology.

Figure 3.5: The Evolution of the Use of Timber as a Construction Material

The use of timber as a construction material has evolved over thousands of years to provide increasingly sophisticated structures. This typical timber frame building in the UK has been reconstructed at least 3 times over a service life of over 500 years and has even been moved from one location to another on at least one occasion. The evolution, development, and reuse of building materials and structures in this way is typical of the sustainable buildings that have survived 'the test or time'. In this context it should be noted that there is really no such thing as an old building, just a successful building that has been able to evolve to meet changing requirements of environments and occupancy.

3.3.6 Reflective Review

Many of the constraints on the development and application of the subject of Building Pathology described above, are beyond the scope of this research project. However, the drafting and presentation of a coherent view of the basis of the subject; and the presentation of practical methods and procedures for the holistic learning and application of the subject should be possible. This could facilitate the teaching, application, and further development of the subject. It is apparent that although the RICS took a lead in making Building Pathology a core 'Competency' this has not developed as might have been expected in the UK. However, it is of special concern that although the RIBA took and early interest in the subject of Building Pathology, it is not taught to Architects in the UK. This is despite the urgent requirements for a clear understanding Building Pathology and appropriate risk management and mitigation resulting from the developments in the Construction Design and Management Regulations (CDM) and the recent Building Safety Act 2022 in the UK, which impose a clear duty and hence liabilities on designers and project managers as ‘duty holders’ to prevent building defects on construction and refurbishment projects. Indeed, it is arguable that all those involved in building and the building Professionals should have at least a basic understanding of Building pathology; in the same way that they are expected to have at least a basic understanding of First Aid, Health & Safety, and risk management. It is to be hoped that the better understanding and application of the subject of Building Pathology, along with developments in AI and other modern technologies from medicine and other disciplines will help manage the problems and risks inherent in this situation.

3.4 Parallels Between the Evolution and Development of the Subjects of Medical Pathology and Building Pathology

3.4.1 Background

In the literature research discussed in Chapter 2 above, it was demonstrated that organic and inorganic structures created by humans and other organisms formed ecosystems or even super organisms that could be considered as complex systems evolving over time (Fischer, 1998; Dekker, 2012). It was then demonstrated that perceived failures in these systems or Building Pathologies could be considered as emergent phenomenon evolving over time (Leaman and Bordass, 1993; Lachhab *et al.*, 2017). Given that buildings and the bult environment are complex evolving systems as described above; it is probable that methods and procedures that have been developed or evolved to investigate similar systems may be used or adapted to help investigate and understand buildings and the built environment. In particular, it is probable that building defects and pathologies may be investigated and understood using the methods and procedures developed for the ‘Art and the Science’ of Medicine and Pathology (Ackerknecht, 2016). This is because these subjects have been developed and evolved to investigate complex evolving systems which also change with time; and for which it is never possible to have full information(Benton *et al.*, 2021; Montefusco and Angeli, 2024). This is demonstrated below.

3.4.2 History

There has long been a recognition and acceptance of a relationship between the health and disease of humans and animals, to the buildings and built environments that they occupy (Ackerknecht, 2016). In the past this was often perceived as having supernatural causes and agencies, and supernatural remedies were often sought(Ackerknecht and Haushofer, 2016). Recent understanding of the scientific basis of the 'placebo' and 'nocebo' effect may show the basis of the efficacy of some of these solutions(Benson, 1997), and some of these more ancient systems of understanding embodied in subjects such as Feng Shui still have currency in the modern world (Mak and Ng, 2005). However, the progressive development and evolution of the Art and the Science of the subject of Pathology over the millennia has slowly supplanted these supernatural systems (Malterud, 2001).

More recently pathology has been progressively seen as having a scientific basis, with logical mechanisms such as Koch's Postulates, where one disease is perceived as only being able to have one cause being applied(Byrd and Segre, 2016). However, the history of the subject shows that many apparently logical models have been applied through history, all of which eventually become supplanted by new models based on new information. For example, few pathologists nowadays would subscribe to the system of 'humours' where all diseases were perceived to be caused by imbalances between the humours of blood, black bile, yellow bile and phlegm. Irrespective of the systems or mental models applied to try and understand pathology; the subject has always relied on the 'art' of observing the apparent causes and effects of perceived failures in the complex biological systems of the human body; or of other living organisms such as animals or plants (Ainsworth, 1981; Kelly, 2007).

The evolution of more effective techniques and methods for observation have allowed the development of the subject. However, this was generally based on the understanding of the primary subjects of the 'Physical Anatomy' of the organisms; and the 'Physiology' or dynamic, chemical, and physical processes within that anatomy. This has developed into a process of 'Diagnosis', 'Prognosis' and 'Treatment' or remediation; with sub-disciplines such as

‘Epidemiology’ for the study of populations and subjects such as ‘Medicine’ and ‘Surgery’ as options for remediation.

The methods and procedures for analysing perceived failures in complex systems developed in the general subject of Pathology are directly applicable to diseases and perceived defects affecting the structures formed organically by living organisms; even when the materials used are not or are no longer alive. For example, the woody stems of plants, and for example the shells or exoskeletons of molluscs and arthropods.

The subject of Pathology is also applied to diseases in populations and superorganisms such as communal insects. In these cases, diseases and perceived defects in the structures they build and inhabit form an integral part of the pathology of the superorganism; e.g. diseases of honey bees such as ‘Foul Brood’ or parasitism such as ‘Comb Moth’(Williams, 2000). From the above it can be concluded that failures or defects in structures built by non-humans and humans have been clearly understood as sources of pathology and disease of their occupants in the past, and the remediation of these defects or other interventions in the structure or built environment have been considered as part of treatment (Tillon and Madec, 1985).

Figure 3.6: Relationship between Building Pathology and the Health of Occupants

The relationship between the health of buildings and the occupants of built environments has been recognised for thousands of years This became a particular social and political issue in the UK in the 19th century, with cholera epidemics identified as the result of inadequate provision for foul water drainage within and around *buildings, and with the recognition that epidemic and endemic respiratory diseases such as typhus and tuberculosis could be directly associated with inadequate provision for ventilation within buildings.*

The relationship between pathologies in the built structures and the organisms by which they are constructed or occupied has therefore been long recognised, as illustrated in Figure 3.6 and the application of the methods and procedures evolved in the subject of Pathology is therefore self-evident to those with experience of the subject (Zinsstag *et al.*, 2011). Similarly, it appears to the author that it is self-evident that perceived defects and latent defects in the built environment, and their remediation, may be understood using the methods and procedures evolved in the development of the subject of Pathology.

3.4.3 Diagnosis of Pathologies

Diagnosis which is defined as the process of identifying perceived pathologies and their causes is of primary importance in the subject of Pathology, and in the subject of Building Pathology, as described above. Although this process may have been masked by supposed supernatural processes, divinations or auguries in the past, and may still be hidden behind a scientific or pseudo-scientific process; this generally involves the mental processes and decisions of an individual diagnostician (Gilhooly, 1990).

These mental processes can be understood using the methods and procedures of the subject of 'Decision Theory' which has its basis in the mathematical subject of 'Basian Statistics' (Slovic, Fischhoff and Lichtenstein, 1977; Takemura, 2014). Here it is postulated that logical or rational decisions are arrived at based on a 'prejudice' or 'prior probability' based on previous experience, which is then modified by further information, which changes a probabilistic assessment of the facts on which the decision is to be based. The key aspects of this process are the basis and validity of the prior probability, and that the decision is eventually based on a probabilistic assessment. It can be argued that all modern science is based on this statistical approach, and that all science is therefore probabilistic. There is therefore no absolute certainty that cannot be reassessed and changed by further information.

This statistical approach can form the basis of very useful diagnostic procedures and tools; especially when applied to large numbers of cases or populations. This has been increasingly used for the production of AI systems, to allow the cost-effective diagnosis of human disease (Horvitz, Breese and Henrion, 1988; Elstein and Schwarz, 2002). Many of these algorithms and machine learning systems have been found to be statistically more reliable than even the best human diagnosticians. However, this is generally for defined areas of pathology, and from the point of view of the 'population', rather than the individual (Doi, 2007; Soni *et al.*, 2011). In particular, such AI systems have difficulty allowing for unexpected information, and often have to rely on input such as 'senior nurses opinion' to cope with this information; especially when based on 'Decision Trees' (Liao, 2005).

Other useful approaches to the mental process of diagnosis and prognosis developed in recent years, are those based on current understandings of psychology and neuroscience. These have increasingly shown that decision processes are not in fact rational but may be usefully categorised into conscious and sub-conscious processes. These have been described as 'Type 1' and 'Type 2' thinking where 'Type 1' thinking results in an immediate and apparently thoughtless response to information based on prejudice and previous experience (Meadows, 2008). In contrast 'Type 2' thinking is supposed to be characterised by a slower conscious though process, where each available fact is considered and weighed against previous experience and prejudice before coming to a decision. It is suggested that the relatively large amount of time and energy required for this 'Type 2' thinking means that it is avoided where possible, and that 'Type 1' thinking is preferred in most situations.

This has profound implications for any scientist or professional intending to make a correct diagnosis and prognosis. In particular, it implies that the mind of the individual making the decisions must be carefully trained and programmed to make the correct diagnosis or prognosis. This training or programming must be a continuous process, if inappropriate prejudices are not to cause incorrect diagnosis, resulting in incorrect decisions (Ericsson, 2004).

This appears to concur with the history of the development of the subject of Pathology in medicine; with the teaching of excepted facts and principals, followed by guided practical learning and experience. Obviously, the development and evolution of this and other subjects can be severely constrained by the unthinking application of such 'accepted facts and principals'. This may account for the relatively slow evolution of the subject of medical Pathology in the past, where 'accepted facts and principals' may have been rigorously enforced over centuries or even millennia. For example, the enforcement of the doctrines of Aristotle and Galen by the Catholic church. However, it may also be that the evolution and teaching of scientific and other subjects continue to be restricted by the accepted facts of one generation of academics being imposed on the next generation, over the professional ifetime of a senior academic of approximately 20-30 years.

In medical Pathology there is obviously an increasingly strong economic drive for improvement; especially with the centrally controlled and publicly funded delivery of medical care. This has resulted in increased interest in the process of diagnosis in recent years and much research(Eva, 2005; Bowen, 2006; Higgs *et al.*, 2018). However, the result of previous experience and recent research appears to optimise around a system of 2-3 years academic learning of accepted facts and principals, followed by or concurrent with a minimum of 750 hours of practical experience of applying this knowledge.

Importantly it is accepted that crucial knowledge needs to be imparted by appropriately experienced mentors during this period of practical application. There is then an accepted need for continuing education and professional development; especially if there is an aspiration to further specialisation or expertise. This appears to be expected to take at least 2-6 years.

While there appears to be a clear parallel and indeed a clear relationship between the subject of Pathology and Building Pathology, no similar process of training or formal education has developed for Building Pathology. Rather the study of Diagnosis, Prognosis and Remediations in Building Pathology appears to have remained with interested individuals, whether these are craftsman, builders, building professionals, or academics. As a result, the subject has not been able to develop in a holistic, multidisciplinary, and progressive way; and the information inherent in the knowledge and experience of individuals, is lost. This limits the effective evolution of the subject across professional and academic generations.

3.4.4 Psychology and Relativism in Pathology and Building Pathology

Psychology and relativism are important in Pathology, both in terms of the objective and subjective perception of disease or disability (Chapman and Gavrin, 1999). In human medicine this is well understood because of the phenomena of the placebo affect and the less well studied nocebo effect (Benson, 1997). It is very relevant in individual and population medicine, especially about the perception of pain. This is because what is perceived as an intolerable disease or disability by one individual or in one culture, may be accepted as normai by another individual or culture.

Similarly, in Building Pathology the concept of a building defect may also be relative to individuals, to cultures, and in space or time. For example, the ‘waney’ appearance of partially decayed oak timbers in an historic building may be a desirable characteristic for one generation, but may be unacceptable in another place or time (Lowenthal, 2015). Generally, the ‘patina’ of age which is the result of erosion, corrosion, and decay to building materials may be more or less desirable or undesirable (Jokilehto, 2007).

In more practical terms, the perceived end use of the structure affects the relative perception of defects or latent defects. For example, cold damp conditions may be desirable in a cellar intended to be used for storing wine; but may become undesirable when new occupants wish to convert the use of the same cellar to a bedroom, kitchen or office space. Indeed, in some cellar spaces mould growth is actually felt to be desirable, for example, for the production of specialist food stuffs such as cheeses and hams, while it would be generally thought to be undesirable elsewhere.

Taking an even more holistic relativistic view of the built environment; the relatively dry and well-ventilated conditions desirable for human occupancy, might be undesirable from the point of view of other organisms occupying the structure. For example, the conditions promoting the growth of wood boring beetle may be desirable to the wood boring beetle, but undesirable to the human occupants (Hutton *et al.*, 1992a).

This may appear facetious. However, this can become very important. For example, when considering legal and planning requirements to retain or promote the environments required by protected species, such as bats and birds, within a building; or for example, to allow the continued growth of plants felt to be desirable, such as creepers, mosses or planting around the base of walls.

This can be a contentious problem when there is a difference in perception about the relative importance of a building as a structure for occupancy; when set against its relative importance as an historical artefact, or as an aesthetic feature as part of landscaping or gardening. In all the above situations it is interesting to note that even without the conscious understanding of the process or its application, sophisticated solutions will generally evolve over space and time. This is usually by cyclical processes of trial and failure, and by both technical and social compromises.

3.4.5 Teaching and Learning of the Subject of Building Pathology

In the literature review undertaken for the research project, it was found that the concept and title of the subject 'Building Pathology' and the definition of the subject developed, was subsequently adopted by the Royal Institute of Chartered Surveyors (RICS) in the UK in the late 80s and early 90s (Watt, 2009; Cassar *et al.*, 2018). As a result, the RICS, which is the relevant professional and body in the UK, made 'Building Pathology' a 'core discipline' to be learnt and demonstrated by those applying to act as professional Surveyors in the UK under its auspices ('RICS Requirements and Competencies guid', Version 1.2, March 2018, RICS, London). Unfortunately, no published literature further defining the subjects to be learnt under this heading is generally available (Price.J, Pers. Com., June 2021). However, many eminent academic institutions have provided courses in Surveying including modules on 'Building Pathology' since the 1990s. It is assumed that these are likely to have been based on the text books published on the subject since that time (Harris, 2001; Marshall, Worthing and Heath, 2008; Watt, 2009; Douglas and Ransom, 2013). However, as noted in the previous critical review on this project, these give differing interpretations to the subject of Building

Pathology and its application. In particular, there appears to be differing understanding of the nature of Diagnosis and the metacognitive processes involved. These appeared to have been explored in most detail by the late James Douglas (Douglas and Ransom, 2013).

It appears that educators with a professional practical experience of the application of Building Pathology have generally recognised the importance of practical experience and/or case studies to learn the application of the subject as discussed at Chapter 6 below. It also appears that this aspect of learning the understanding and application of Building Pathology, and particularly the process of diagnosis, has relied on the inclusion of presentations by experienced and eminent practitioners as part of the courses for students, and/or reliance has been placed on students gaining 'practical experience' when working with Surveying practices as part of their course. Over the years it has become apparent this may not always have given students of Surveying in the UK the knowledge and/or confidence to effectively diagnose problems in practice; especially in the areas of damp and decay ((Edwards, 2016; Cassar *et al.*, 2018; Husain *et al.*, 2020). As a result, some research has been done on the introduction of teaching and learning aids to facilitate the learning of the subject of Building Pathology (Murray *et al.*, 2004; Wilkinson and Hoxley, 2005). In particular, useful work has been done on the use of computer based and audio-visual presentations to replicate and/or augment case studies in the field (Shelbourn *et al.*, 2000a; Smith *et al.*, 2006). More recently and during the period of the research project; a number of eminent practitioners who had recognised the requirement for better teaching and learning resources, have produced very useful text books and learning packages (Burkinshaw and Parrett, 2003; Parrett, 2016; Hoxley, 2019; Burkinshaw, 2020; Edward 2021; Parrett,;2021; Piplica, 2021) These have generally been based on working through the technical aspects of the cause and remediation of building defects, and on case studies.

At least some of these interventions appear to have been increasingly incorporated into the Building Pathology modules in courses provided by many academic institutions in the UK. However, there appears to be little or no published literature on the efficacy of these interventions or on the learning of the metacognitive processes involved in diagnosis in Building Pathology. In comparison, for the Medical Professions there is an extensive literature on the requirements for the learning and application of 'Diagnosis' and the metacognitive processes required, which is described as 'Clinical Reasoning'.

3.5 Summary

From the above there are clear parallels between the problems inherent in the investigation and understanding of the processes leading to pathologies in buildings and in the living organisms that build or inhabit them. In particular, there are clear parallels in the requirements for 'Diagnosis', 'Prognosis', and treatment. It might therefor be reasonably asserted that the subjects of medical Pathology and Building Pathology are not only analogous but are parallel or 'sister subjects'. It is therefore probable that procedures and methods developed and evolved in medical Pathology may be useful in understanding and developing methods for the diagnosis of building pathologies; especially given the time and recourses that have been made available to develop the subject of Diagnostics and Clinical Reasoning in human and veterinary Medical Pathology. Further empirical grounding for this assertion can be obtained by comparing the methods and procedures used in current best practice for the application and learning of the metacognitive process used in Building Pathology and medical Clinical Reasoning; using the methodologies described in Chapter 4 below. In particular by the characterising of a system of procedures and methods for the application and continuous learning of holistic Building Pathology based on recent developments in medical Clinical Reasoning described at Chapter 5, by the assessment of current best practice for the teaching and learning of Building Pathology in the UK described at Chapter 6, by the development of metacognitive tools and schema for application to 'damp problems' as an exemplar subset of problems in Building Pathology described at Chapter 7, and by the demonstration that methodologies developed for the testing and learning of medical Clinical Reasoning can be adapted for use in the testing and learning in this subset of exemplar problems in Building Pathology by the development of a Script Concordance Tests described in Chapter 8 and Chapter 9.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

This research is based on the Hypothesis that Building Pathology can be considered as a parallel or 'sister subject' to Medical Pathology, especially with regard to the learning and application of the metacognitive processes required for Diagnosis in these subjects. These subjects and this research project therefore come from the researchers Positivist epistemological background in the medical sciences. As Building Pathology is a relatively new practically based subject which has been generally studied and applied by professionals, rather than academics in the past, Postpositivist Action research and Observational research might therefore be expected. However, given the research question and aims described below, this research project as it has developed, has become more Interpretivist with what might be considered a semi-conceptual approach to developing the Hypothesis, after which some more Postpositivist empirical testing of the Hypothesis is done, in order to help answer the research question. Generally, an approach based on Pragmatism and Mixed Methods was found necessary to answer the research question given the limited time and resources available. The research Methodologies used, and the rational for their use were therefore as described below.

4.2 Research Purpose

4.2.1 Research question

The overall aim of this research project is to establish methods, and procedures for holistic Building Pathology based on the Hypothesis that it can be considered to be a parallel or 'sister subject' to Medical Pathology; to allow the understanding, teaching, learning, application, and further development of the subject based on recent advances in the sister subject of Medical Pathology. Alternatively, the research question may be posed as 'Can the subject of Building Pathology be understood as a parallel subject to Medical Pathology; to allow the adaption of recent advances in the continuous learning of Medical Clinical Reasoning, to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology.

4.2.2 Research Paradigms

The subject of Building Pathology is a relatively new practical subject that has evolved from the work of professionals and practitioners with academic backgrounds in both the sciences and social sciences. It might therefore be expected to be considered as an 'Art and a Science' and may therefore be expected to have similar Paradigms as the 'Art and Science' of medicine. Although some building failures that are the subject of Building Pathology may have aspects that may be considered as subjective, most building failures are considered to be objective. For example, a building is either wet or dry, and safe to occupy or not. In the same way that a patient's leg is either broken or not, and the patient is alive or dead! A strong tendency towards Positivism might therefore be expected given the background of the subject and the researcher. However, the metacognitive processes involved in Diagnosis and Building Pathology generally depend on a 'Bazian' approach to prior probabilistic assessments by a Diagnostician, which are by their nature based on Post-positivism and Interpretivism; and might even sometimes be considered to tend towards 'Critical Theory'. The research Paradigms for this project have therefore been based on Post-positivism and Interpretivism, with the epistemological background to this project being based on Postpositivist Action and Observational research during the career of the researcher as a practising Building Pathologist and Medical professional(Walliman, 2017b)

4.2.3 Research approaches

Scientific research is a methodical and systematic investigation or inquiry undertaken to address specific problems or questions, to generate new knowledge, or to test existing theories or hypothesis. This research project and research generally has the following stages (Walliman, 2017b):

1. Formulate a Research Question
2. Review Existing Literature
3. Design a Research Methodology

4. Data Collection
5. Analysis and Interpretation of Data
6. Drawing and Discussions of Conclusions
7. Communicate Results

Research is intended to advance scientific knowledge, to promote innovation, and to promote the understanding of natural phenomena, social processes, and human behaviour. Scientific research should be committed to systematic inquiry, empirical evidence, and the rigorous application of methods and principles to ensure the validity and reliability of the findings. To achieve these objectives scientific research can be approached using different perspectives and methodologies. However, the selection of these is depends on the characteristics of the research question, on the discipline, and on the resources available for the research project. Common approaches to scientific research and their strengths and limitations are described below:

1. **Experimental research:**

   Experimental Research involves observing the effects of manipulating variables in a controlled environment to establish cause and effect. Control of extraneous variables is used to enhance the internal validity of observations and results so they can be generalised to a broader population if the sample is representative. However, a limitation of Experimental Research is the requirement for high levels of control of variables and/or the random assignment of participants to different groups with differently controlled variables. The resultant artificial or 'laboratory settings' may then limit the generalisability of findings in real world contexts. Necessary control variables also impose practical constraints due to the availability of time and resources, and due to the necessity for complex experimental designs so as to 'confound' variables (Walliman, 2021). Despite these constraints, Experimental Research was chosen for use in part of this research project so as to provide empirical data to provide Post Positivist testing of the Hypothesis. This was practical because of the 'Script Concordance Test' methodology used allowed variables to be 'confounded' using relatively small sample sizes.

2. **Observational Research:**

Observational Research involves the observation and systematic recording of behaviour, events or phenomena as they occur in their natural environment. Observational Research is therefore useful in real world settings and allows the study of complex processes and interactions that may be difficult or impossible to manipulate with experimental design. Observational Research can therefore produce in depth qualitative data and context to research. However, lack of control of variables may reduce internal validity, making it difficult to establish causality and limit the ability to generalise findings beyond a specific population or context under observation. Observational Research is also especially vulnerable to observer bias influencing data collection and interpretation(Walliman, 2021). Despite these limitations Observational Research was fundamental in establishing the background to this research project. In particular the gathering of data by Observational Research through the professional life of the researcher as a practising Building Pathologist was essential in developing, defining and testing the Hypothesis that is the subject of this research project

3. **Survey Research:**

Survey Research describes the collection of data from individuals through standardised questionnaires and/or interviews, and is the basis of much research in the Social Sciences and Psychology; where it is used to gather data about behaviours, beliefs, attitudes and demographic characteristics of the samples of individuals subject to survey. This can be an efficient way of gathering data from large representative samples allowing generalisation of research findings. This can also be done in a relatively short timeframe and standardisation of questionnaires and methodologies can allow comparisons across studies and populations. However, reliance on 'self-reported' data makes the results subject to 'response bias', such as 'recall errors' and 'social desirability'. The generalisability of findings may also be significantly compromised by sampling bias and low response rates making the samples unrepresentative of more general populations(Walliman, 2021). However, Survey Research using Qualitative Research techniques as described at 4 below was used in preliminary 'pilot interviews' of Experts in Building Pathology at the start of this research project in order to determine the practicality and scope of the proposed research. Survey Research with Qualitative Research and Quantitative Research as described at 4 and 5 below was used during the subsequent research to provide empirical grounding to the research project, and to help test the research Hypothesis

4. Qualitative Research:

Qualitative Research uses techniques such as interviews, focus groups and participant observation to gather data that can be analysed 'Thematically' or through 'Grounded Theory' approaches, so as to understand complex phenomena through the subjective experience and perspectives of individuals. This can allow adaptable data collection and analysis as research questions and context develops. However, findings may be of limited value due to the small non-random samples often used in Qualitative Research and 'researcher bias' and subjectivity may adversely affect data collection, analysis and interpretation. Analysis of data therefore requires care to ensure reliability and rigour; which can be time consuming and labour intensive despite the development of computer programmes to assist in this (Walliman, 2017a). This may be significantly improved by the use of AI in future. Qualitative Research combined with Survey Research described at 3 above and Quantitative Research as described at 5 below was used in this research so as to provide empirical grounding for this research project and to help in testing the research Hypothesis

5. Quantitative Research:

Quantitative Research is the collection and analysis of numerical data in a systematic way to test hypothesis in a way that allows them to be generalised to larger populations. This generally requires statistical analysis of data so that the probability of inferences drawn about the relationship between variables to be quantified and analysed. 'Semi-Quantitative' data may sometimes be collected. This is 'Qualitative' data that is ranked based on numbers but there is no exact measurement of the numbers. Quantitative Research is often favoured by Positivist and Post-Positivist researchers as it can provide apparently precise data that can be analysed statistically for the testing of Hypothesis and the identification of patterns allowing apparent generalisation of research findings if sampling is representative. It may also facilitate replication of research and research finding. However, this is vulnerable to 'Reductionism' where complex phenomena may be reduced to quantifiable variables oversimplifying complexity of real life phenomena (Walliman, 2021). Quantitative and Semi-Quantitative Research methodologies were therefore used in this research using the Script Concordance Test methodology that has been well tested and tried by other researchers over the last twenty years so as to give Post-Positivist support to the testing of the research Hypothesis.

6. Mixed-Methods for Research:

Qualitative and Quantitative approaches may be combined in Mixed-Method research so as to allow for more comprehensive data gathering and analysis. This allows researchers to benefit from the strengths of each approach, and to 'Triangulate' research findings to enhance validity and reliability. This allows a more comprehensive understanding of research questions and allows research to explore complex phenomena from different perspectives. However, this necessitates the careful integration of different data sources requiring more time and resources than simple single method approaches(Walliman, 2021). For this research project it was necessary to use Mixed-Methods because of the many factors contributing to the research question and research Hypothesis, and the relative lack of previous research. It was therefore not possible to design an experiment or simple test that would answer the research question or adequately test the Hypothesis.

7. Action research:

Action Research describes collaborative enquiry by stakeholders and/or practitioners in a particular context to improve practice or resolve practical problems. Action Research is generally an iterative process involving observation, planning, action and reflection so as to generate practical knowledge and promote positive change (Walliman, 2021). Action Research by the researcher and colleagues acting as practising Building

Pathologist was an essential part in providing data to develop and test the research question and research Hypothesis.

8. **Case Study Research:**

Case Study Research is the investigation of specific phenomena and/or organisations in real life by researchers gathering and analysing data from multiple sources to provide a holistic understanding of the case under investigation (Walliman, 2021). Case Study Research is the basis of practical Building Pathology investigations and is inherent in the diagnostic process undertaken by Medical Pathologists and Clinicians (Cooper and Frain, 2023). Case Studies undertaken by the researcher forming part of the Observational Research and Action Research as described above were therefore the fundamental basis for the development of the research question and the development and testing of the research Hypothesis for this research project. The investigation of the methodologies used for Case Study Research in diagnosis in Building Pathology and Clinical Reasoning in Medical Pathology was also fundamental in developing and testing the research Hypothesis as described below.

4.2.4 Adopted Approach

Building Pathology is a relatively new practically based subject with little peer reviewed literature or other empirical data with which to help answer the research question or achieve the aims of this research project. The purpose of the Research Methodology used was therefore to provide at least some empirically grounded foundations on which this and further research into the subject can be built, using the time and recourses available.

A Mixed Method was therefore adopted to triangulate an answer to the research question and test the research Hypothesis; as no single methodology described at 4.2.3 above could meet the research aims. Indeed, non were rejected and all were used in some way during the research project as described at 4.3 below. This included preliminary background Literature research and reviews described in Chapter 2, preliminary scoping of the research project by Qualitative semi-structured Interviews in the pilot Survey research reported in Chapter 3, Action and Observational research as described in chapter 5, Qualitative and Semi-quantitative Survey research and Thematic Analysis as described at Chapter 6. Action and Observational research as described in Chapter 7, and Quantitative and Qualitative Experimental research and Survey research in the development and testing of the Script Concordance Test described at Chapter 8 and Chapter 9. These are discussed in further detail in 4.3 below.

4.3 Research Framework

4.3.1 Background to the Development of Building Pathology

An extensive preliminary literature review discussed in Chapter 2 above was undertaken to provide a conceptual or semi-conceptual theoretical grounding to the assertion that Building Pathology may reasonably be considered as a similar, parallel or 'sister subject' to Medical Pathology. This has not been clearly asserted by previous researchers or authorities. The provision of academically acceptable empirical grounding to this assertion is there for essential to this research project and might reasonably be considered to be a significant contribution to knowledge.

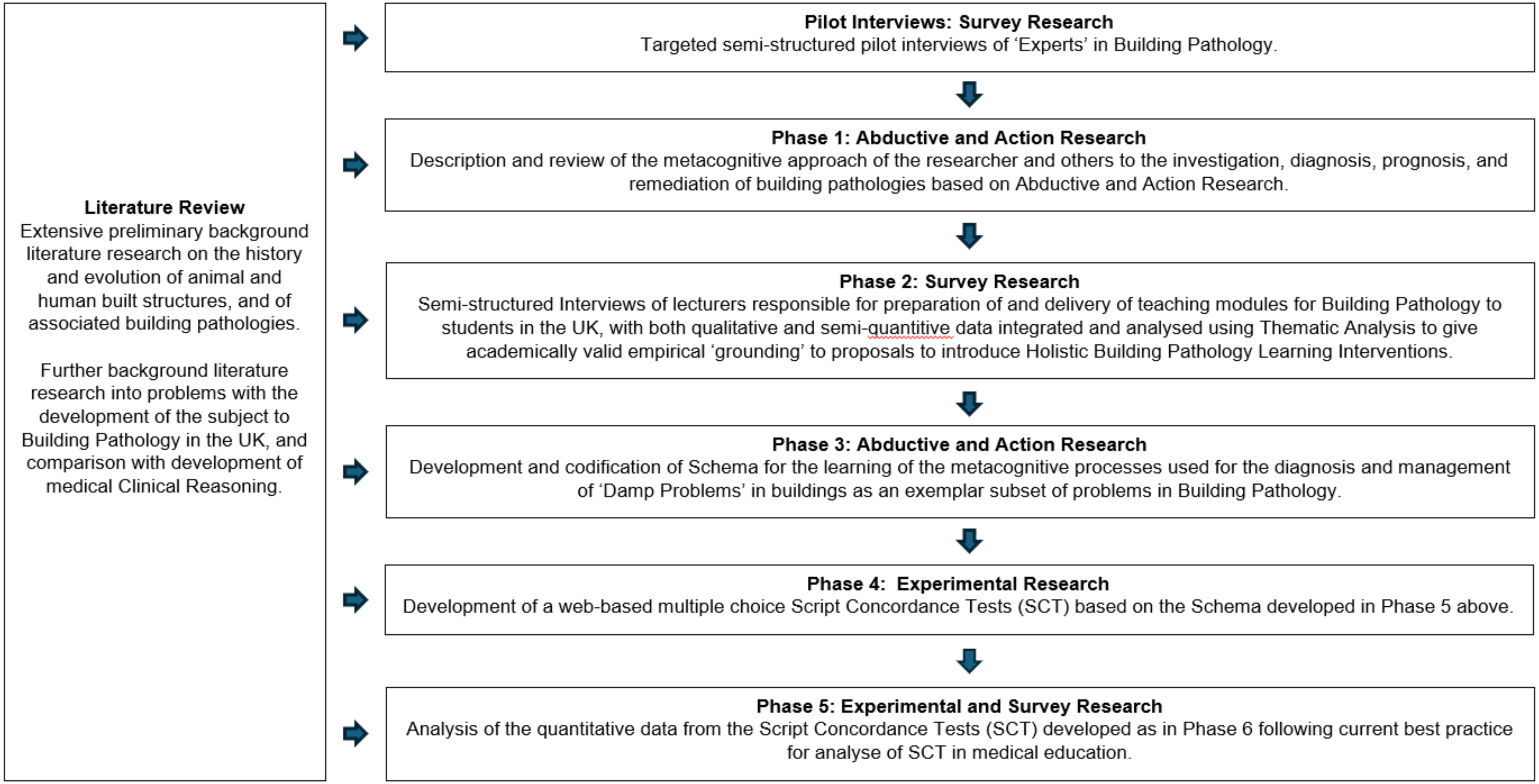

Figure 4.1: Overview of Research Methodology

The research activities to achieve the objective described above were undertaken in parallel rather than as a sequential program. This allowed the mixed methodology used to be refined throughout the research project and for the objectives to be achieved. The arrows in this flowchart show the cyclical and iterative flow of information between the phases of the research project.

4.3.2 Background to the development of the subject of Building Pathology in the UK

To understand the subject of Building Pathology there is a need to review the basis of the subject, to review its development since its conception, and to review the current state of the subject. The research framework for this project therefor included background research into problems with the development of the subject to Building Pathology; in particular its learning and general application both practically and academically. In addition to reviewing the available literature, this was explored by targeted semi-structured Piolet interviews of 'Experts' in the subject; to help focus the research and scope of the project beyond the individual subjective 'Action Research' inherent in the researcher's work as a practitioner over the last 40 years. To do this 30 eminent academic and building professionals who have been active in developing the subject of Building Pathology since the beginning of the 1990s were contacted by email, with a request for an interview as part of the piolet scoping and background research prior to the research project. This was to discus and record their views on how the subject has developed, how it is understood, and how it may develop in the future. Of those contacted 16no. agreed to be interviewed by the researcher in person or by tele conference. These interviewees were asked 'What is Building Pathology?', 'How has Building Pathology developed?', 'How well is Building Pathology understood and applied?', and 'How can the understanding and application of Building Pathology be improved?'. The results of these interviews were recorded and summarised by the author in the written notes attached at Appendix A and are referenced in the review of Building Pathology described in Chapter 3 above. These were preliminary or scoping interviews intended to help define the scope of the research; and had obvious limitations due to time and recourses available and to the potential for bias in the selection and/or self-selection of the interviewees, and in the selection of questions inherent in most Qualitative Survey research of this type. This had to be accounted for in the interpretation of the results, as described at Chapter 3(Walliman, 2017b; Walliman, 2017a).

4.3.3 Review of Pear reviewed papers published in the *International Journal of Building Pathology and Adaption*

Data held by Emerald Group Publishing on the pear reviewed papers published in the International Journal of Building Pathology and Adaption in the period January 2016 to April 2017 was analyse by the publishers, on behalf of the researcher; to determine who is contributing to this journal, the subjects they are covering, and who is reading their contributions. The results of this analysis are shown in the tables at Appendix D and are included in the meta-review discussed in Chapter 3 above. These appear to show Australia, Malaysia and Portugal as disproportionately active; presumably due to local academic and professional conditions. The results also appear to show the USA as relatively inactive; presumably due to the general use of the related term 'Building Forensics' to cover activity in this field. This semi quantitative Survey research by a third party and the semi-quantitative analysis by the researcher was likely to have provided limited and potentially biased data which had to be allowed for in the analysis and resultant preliminary conclusions described in Chapter 3(Walliman, 2021).

4.3.4 Procedures and methods for the application and continuous learning of holistic Building Pathology based on recent developments in Medical Clinical Reasoning

A system of procedures and methods for the application and continuous learning of holistic Building Pathology based on recent developments in Medical Clinical Reasoning was characterised based on literature review and based on Observational and Action research during the work of the researcher as a professional Building Pathologist, as a Veterinary Pathologist, and as an Emergency Medical Technician. Parallels in current best practice in the teaching and learning of Building Pathology and Clinical Reasoning identified as previously described in Chapter 3, were also used to draft proposals for learning interventions to help with possible deficiencies noted when comparing with the literature reviewed and 'Current Best Practice' as described in Chapter 5.

4.3.5 Interviews to gather data from Educators providing Teaching and Learning for Building Pathology

1. Introduction to the Qualitative approach: Review of the available published literature failed to identify previous research with the same or similar objective of this research project to gather empirically valid data to answer the research question "What are the perceived objectives and current best practice in the delivery of teaching and learning in 'Building Pathology modules' and Building Pathology courses in the UK"**.** As discussed at 4.2.3 above Qualitative Research methodologies have many advantages for such research. It was therefore proposed to do this following current best practice in a Mixed-method Study with a Multi-strategy Design (Bryman, 2016; Morse, 2016; Robson and McCartan, 2016).

2. Description of data collection methods: data was gathered from Educators or Teachers responsible for preparing, delivering and/or assessing modules currently providing teaching or learning of the subject described as Building Pathology. Both qualitative and semi-quantitative data was gathered by semi-structured online or telephone Interviews. This was so as to optimise the chance of reaching the subjects, given the expected problems with making appointments for interviews in the COVID19 restrictions at the time of the research, and the expected problems associated with the Academic year(Tierney and Dilley, 2002; Hopf, 2004; Harris and Brown, 2010; Janghorban *et al.*, 2014; Oltmann, 2016; Łątkowski, 2021). Current best practise reported by the literature above, and previous experience interviewing Academics teaching Building Pathology in the earlier stages of this research described at Appendix A(Cassar *et al.*, 2018), indicated that interviews of between 30 and 90 minutes might reasonably be expected. It was therefore intended to gather qualitative data my interview using Microsoft Teams, prompted by the semi-quantitative data, in the pre-submitted questions in the draft questionnaire shown at Attachment C. It was hoped that this would act as a script to help keep the interviews focused on the research question in the limited time available, and assist in the 'bench-making' and in the coding of the data gathered when analysed. These questions and semi-structured interview were trailed with 2 no. subjects; prior to submitting the questions and subsequently interviewing, 10 no. representative educators or teachers providing 'Building Pathology Modules' or Building Pathology courses in the UK; in order to provide an empirically valid sample in accordance with current best practice (Tierney and Dilley, 2002; Desimone and Le Floch, 2004; Hopf, 2004; Harris and Brown, 2010; Baker and Edwards, 2012; Bryman, 2016). Audio recording and verbatim text recording of the interviews was made using Microsoft Teams. The subjects for interview were those who agreed to be interviewed after approaching all those identified by the researcher as providing or delivering courses in Building Pathology in the UK. This was likely to result in some selection and self-selection bias as discussed in Chapter 6.

3. Explanation of data analysis procedures: Audio recording and verbatim text recordings of the interviews described at 3. above were made using Microsoft Teams. The qualitative and semi-quantitative data gathered was then be integrated and analysed using Thematic Analysis in accordance with current best practice (Bazeley, 2009; Harris and Brown, 2010; Zohrabi, 2013; Campbell and Stanley, 2015; Bryman, 2016; Morse, 2016; Robson and McCartan, 2016; Josephsen, 2017). This was done by reading and re-reading to identify Codes, Nodes and Themes in the data from the interviews, and the results subject to further Coding and Thematic Analysis based on the initial questionnaire as shown at Appendix C and as shown at Appendix D. This was done in order to try and 'Triangulate' an answer to the research question described a 1. above and to test and develop the research Hypothesis.

4. Justification for the chosen methods: The limitations and potential bias in the Qualitative and Semi-quantitative data gathered and its subsequent Thematic Analysis in this Mixed Method Survey research are discussed at Chapter 6. However, these include potential selection/self-selection bias in the subjects, and bias in the selection, delivery and subsequent Thematic Analysis of the answers to the questions used in the semi-structured interviews. These had to be allowed for in the analysis and conclusions, as discussed at Chapter 6. However, the Qualitative Research and Survey research methodologies used allowed for the practical and relatively resource efficient gathering of data during a period when COVID 19 and its aftermath was having severe effects on many aspects of research and Academia generally. The data gathered and its subsequent analysis therefor provided useful support to this Mixed Method research project in testing and developing the research Hypothesis, and provided potentially useful insights for the further development of methods for the Teaching and Learning of Building Pathology, as discussed at Chapter 6.

4.3.6 Script Concordance Test

1. **Definition and purpose of the Script Concordance Test:**

   The Script Concordance Test (SCT) was originally designed to measure the degree of 'concordance' between the examinee's scripts and the scripts of a panel of experts. The SCT has been described as having three key design features as described by Lubarsk, Dory, Duggan, Gagnon and Charlin in 2013 (Lubarsky *et al.*, 2011): *'(1) Respondents are faced with ill-defined clinical situations and must choose between several realistic options, (2) Response that reflects the way in which information is processed in challenging problems/solving situations, (3) Scoring takes into account the variability of responses of experts to clinical situations*' . To do this the SCT relies on statistical analysis of multiple-choice answers scored in a Likert scale (Charlin *et al.*, 2000; Brailovsky *et al.*, 2001; Karila *et al.*, 2018). For example, Scenarios may be followed by a series of questions presented in three parts. The first part 'if you were thinking of' contains a relevant diagnostic or management option. The second part 'and then you were to find' presents a new clinical finding such as an observation or result of a test. The third part 'this option would become' is a five-point Likert scale that captures examinees decisions. The task of the examinees is to decide what effect the new finding has on the status of the option in direction (positive/negative or neutral), and intensity. This effect is captured with the Likert scale because Script theory assumes that clinical reasoning is composed of a series of qualitative judgements. Research has suggested that a 5-anchor Likert-type scale is most conveniently used for this purpose (Lubarsky *et al.*, 2011).

2. Rationale for choosing Script Concordance Test:

The rapid expansion of the scope and complexity of modern medicine in the 20th century and continuing into the 21st century, resulted in the requirement to train increasing numbers of medical practitioners of all sorts, in increasing numbers of speciality areas of medicine. This resulted in the need for educators and regulators to develop objective, reproducible, quantifiable and statistically valid methods to ensure that students of different medical subjects and professions met agreed standards, and had adequate levels of expertise and competency to provide safe and cost-effective medical services to patients(Ackerknecht, 2016; Stirling, 2023). The subject now described as 'Clinical Reasoning' developed during this period to study and develop the metacognitive process required in Diagnosis and Treatment, and several methodologies for providing such tests were proposed. These were generally based on Multiple-Choice tests so as to facilitate efficient delivery and marking of the tests, and in recent decades were increasingly delivered in electronic and eventually web based platforms; so as to allow efficient delivery and marking(Charlin, Tardif and Boshuizen, 2000b; Brailovsky *et al.*, 2001; Eva, 2005; Norman, 2005; Bowen, 2006; Eva *et al.*, 2007; Kassirer, 2010; Pelaccia *et al.*, 2011; Rencic, 2011; Linn *et al.*, 2012; Marcum, 2012; van Bruggen *et al.*, 2012; Cooper and Frain, 2016; Houchens *et al.*, 2017; Custers, 2018a; Custers, 2018b; Higgs *et al.*, 2018; Duca *et al.*, 2020). The Script Concordance Test (SCT) proposed by Charlin, Roy, Brailovsky, Goulet and Van der Vleuten in 2000 was '*designed to prove whether knowledge of examinees is efficiently organised for clinical actions'*. The methodology used and hence the name of the test was based on 'Script Theory' which proposes that knowledge is held and used based on prior experience, and the SCT aimed to present examinees with information based on authentic clinical situations which data must be interpreted to make decisions (Charlin *et al.*, 2000; Brailovsky *et al.*, 2001). The research previously described in 4.4 above provided empirical justification for the development of a sample 'Script Concordance Test' (SCT) for the learning and testing of the metacognitive processes involved in diagnosis of a subset of problems in Building Pathology; based on current best practice in the use of Script Concordance Tests in the learning and testing of Clinical Reasoning (Charlin *et al.*, 2000; Fournier *et al.*, 2008).

This was submitted to representative 'Experts' and 'Students' in the subject of Building Pathology to demonstrate the possible utility of the parallels between teaching and learning in Building Pathology and Clinical Reasoning, using a statistically valid post-positive research methodology developed for use in medical education.

3. Implementation of Script Concordance Tests in research project:

The development and Implementation of the Script Concordance Tests (SCTs) for this research project is described in detail in Chapter 8 and Chapter 9 below because the demonstration of the feasibility and utility of this process was the main reason for this part of the research project, rather than the gathering of the raw data from the SCTs, as discussed at 2. above. However, two preliminary SCTs were developed based on twenty Schema or Cases Studies representing the range of damp problems commonly found affecting buildings of a range of different types from his experience as a practicing Building Pathologist over the last 20 years that were representative examples of particular damp problems in buildings, and include a range of the different types of construction, date, and occupancy found in the UK as shown at Appendix F. These had approximately 100 no. questions in each SCT designed to take a total of approximately 1 hour for the subjects to answer as an online interactive multiple-choice test on the JISC on-line survey platform These were then 'Beta tested', in accordance with current best practice for developing SCTs and following the methodology of Charlin et al of 2000, and Fournier et al of 2008(Charlin *et al.*, 2000; Charlin *et al.*, 2000a; Charlin *et al.*, 2000b; Charlin *et al.*, 2007; Fournier *et al.*, 2008),and as discussed in detail in Chapter 8 below. The efficacy of these questions in differentiating between Experts and Student subjects was then determined by analysing the results of the SCTs in accordance with the methodology described by Charlin et al of 2000, and Fournier et al of 2008(Charlin *et al.*, 2000; Charlin, Tardif and Boshuizen, 2000a; Charlin *et al.*, 2000b; Charlin *et al.*, 2007; Fournier, Demeester and Charlin, 2008) and as shown in Tables 8.1, 8.2 and 8.3, and in the spreadsheets at Appendix G. This is discussed in detail at Chapter 8. A third optimised SCT was then developed based on the 100 no. questions found to be best at distinguishing Expert from Student subjects as shown at Appendix F. This was then submitted to Experts and Students as previously described for the two preliminary SCTs, and the results were then analysed as shown in the spreadsheets at Appendix G and discussed in detail in Chapter 9. There are obvious risks of bias and limitations to the use of Script Concordance tests in this way from potential bias in the selection and/or self-selection of Experts and Students or subjects. There is also the possibility of bias in the design of the questionnaire. This must therefore be recognised in the analysis and the use of the resultant data, as discussed in detail at Chapter 9 below.

4. Qualitative Survey data gathered during Script Concordance Test:

The questionnaires on the JISC on-line survey platform delivering the Script Concordance Tests (SCTs) described above and shown at Appendix F included a field that allowed the Expert and Student subjects taking the SCTs to record comments and other qualitative data on Academic or professional background if they wished. This was not subject to formal Thematic Analysis as not all subjects chose to volunteer further information. However, the comments that were recorded were used to illustrate the results of the quantitative results of the SCTs on analysis, as discussed in Chapter 9.

4.4 Summary

The research methodology described above may appear to be eclectic to many academically based scientists and social scientists. However, an approach based on Pragmatism and Mixed Methods was found necessary to answer the research question given the limited time and resources available. The mixture of methodologies described was also necessary due to the relatively wide variety of objectives that had to be met to achieve the Aim of the research project. This inevitably resulted in potential limitations and possible sources of biases, However, analysis of the results of the various strands of the research project indicated that it was possible and even informative to allow for the possible limitations and potentials for bias in the methodologies used, as described in proceeding chapters.

CHAPTER 5: CHARACTERISING A SYSTEM OF PROCEDURES AND METHODS FOR THE APPLICATION AND CONTINUOUS LEARNING OF HOLISTIC BUILDING PATHOLOGY BASED ON RECENT DEVELOPMENTS IN MEDICAL CLINICAL REASONING

5.1 Introduction

The previous Chapters 2 and Chapter 3 reviewed how the subject of Building Pathology came to be considered by the researcher to have evolved as a parallel and 'sister subject' to Medical Pathology. It might therefor be reasonably expected that the systems, procedures and methods for the application and continuous learning of the subject of Building Pathology can be informed and improved by those developed and applied in Medical Pathology. Over the past 35 years there has been many advances on 'Clinical Reasoning' and developments in the metacognitive processes needed for Diagnosis. These developments may therefore be used to characterise a system of procedures and methods for the application and continuous learning of Holistic Building Pathology.

5.2 Diagnostic Methods and Procedures for Building Pathology by Previous Authors

The diagnostic methods and procedures proposed for Building Pathology by previous authors have been reviewed in Chapter 3 above, to determine to what extent they allow for the understanding of the evolution of the complex systems of Building Pathology over time. In particular to determine; to what extent they allow an holistic overview of the prior-probabilities in complex systems; and to what extent they include time and evolution of complex systems over time as key factors in the diagnostic process. The 'decision-trees' and 'check- lists' previously proposed, were also reviewed; to determine to what extent they allow an holistic overview of the prior-probabilities in complex systems, and to what extent they include time and evolution of complex systems as key factors in the diagnostic process. This review included the proposals in the current core text books on Building Pathology (Harris, 2001; Broomfield, 2003; Watt, 2009; Douglas and Ransom, 2013), and those in the **more** recent literature (Atkinson, 2002; Lacasse and Sjostrom, 2005; Macdonald, 2008; Neils-Jogen

Aacaard, 2014; Ferraz *et al.*, 2016b). This showed that it will be necessary to develop procedures with due regard to current understanding of the limitations and advantages of decision-trees in Diagnostics for complex systems over time(Murthy *et al.*, 1994; Podgorelec *et al.*, 2002; Osman, 2011; Higgs *et al.*, 2018). These are currently best understood in Diagnostics for Medical Pathology, where methods and procedures have been studied and developed under the subject of 'Clinical Reasoning;' as discussed at 5.4 below.

5.3 Comparative Review of the Methods Used by the Researcher Over the Last 35 Years

The researcher has been a pioneer in the professional application of the subject of Building Pathology for over 35 years. The diagnostic methods and procedures used in practice for Building Pathology by the researcher and his professional colleagues have been based on his training as a statistician, Comparative Pathologist and Veterinary Surgeon, and his further experience working as a part time Emergency Medical Technician. This is based on a probabilistic assessment of a buildings 'Anatomy'; consisting of its structure, its component materials, and their characteristics. This is followed by the assessment of the buildings 'Physiology'; the most significant components of which generally involves the controlled or uncontrolled movement of moisture, air and energy through the structure and materials. Again, this is initially based on a probabilistic assessment, which is then refined by further investigations and 'tests'; in order to narrow the probabilities; as necessary to allow a value-engineered prognosis, management and/or remediation. Integral to this process is the recognition of the importance of the flow of time and evolutionary processes. As in Clinical Reasoning and Diagnosis in Medical Pathology, this is formalised in the taking of a 'Case History'. Using this approach, an existing building or structure can be regarded as a continuing experiment over time; and its performance under the environmental conditions and occupancy it has been exposed to accessed. Perceived or relative 'Building Pathologies' can then be identified affecting the functional 'Anatomy' and 'Physiology' of the building, and their causes Diagnosed. This is a cyclical metacognitive process involving the continuous learning and development of procedures and methods to allow a systematic and holistic understanding of the process of Building Pathology with experience. Because of the medical training of the researcher, metacognitive protocols such as ‘common things occur commonly’, and the ‘art and the science of diagnosis’ are routinely applied. These emphasise the probabilistic and ‘Bayesian’ nature of the metacognitive processes employed(Warner *et al.*, 1972). The differences between the standard methods generally applied in the building industry for the investigation of building defects and the more holistic methods developed by the researcher and his colleagues working as Building Pathologists were reviewed by the researcher based on the investigations of building failures while working as a practicing Building Pathologist in the UK and abroad for over 35 year. These are summarised at table 5.1 below.

Table 5.1: Comparison of Building Industry Standard Investigation of Building Defects and Holistic Building Pathology Diagnostic Methodology Based on the Investigations of Building Failures Undertaken by the Researcher Working as a Building Pathologist in the UK and Abroad for over 35 Years

Building Industry Standard Investigation of Building Defects	**Holistic Building Pathology Diagnostic Methodology** •
1. Assumes Building Defect is caused by the simple failure of a single building material, component, detail, or structure: Single specialist Investigator/investigation results in 'tunnel-vision' and 'silo-mentality'. Tends to favor marketing of product lead rather than design or management lead remediations.	**1. Assumes that apparent Building Pathologies are emergent phenomena in complex systems evolving over time:** Holistic investigations aim to identify all probable causes and possible remedial options. Tends to favor management of problems, and/or 'building-out' potential problems with 'fail-safe' details and materials.
2. Assumes Building Defect is the result of one cause resulting in one effect: Silo-mentality from investigation as in **1** above result in failure to resolve problems in complex systems and remedial interventions result in further problems; especially over time and at interfaces between materials or 'areas of responsibility'.	**2. Assumes that apparent Building Pathologies are emergent phenomena in complex systems evolving over time:** Holistic investigations focus on the 'History' of the emergence of the problems, and of any subsequent remediation and/or management measures. Tends to favor sustainable remediation as in **1** above.
3. Assumes building defect occurs at a point in time and can be resolved by a single intervention at a point in time: Fails to identify or resolve failures occurring progressively over time as in **1** and **2** above.	**3. Assumes that apparent Building pathologies are emergent phenomena in complex systems evolving over time:** Allows sustainable remediation of building failures over time, and for building to 'evolve' to meet changing requirements of occupancy or environment.
4. Fails to recognize probabilistic nature of causation, testing, and diagnosis, and of remedial interventions occurring over time: Results in unnecessary and ineffective remedial interventions, and/or does not provide information allowing Risks to be cost-effectively managed in accordance with the requirements of CDM 2015, or BSA 2022. Encourages marketing of 'insurance-backed' warranties for products and workmanship' which do not cover the real risks from building defects.	**4. Recognizes probabilistic nature of causation, testing, and diagnosis, and of remedial interventions occurring over time:** Allows for avoidance of unnecessary or ineffective remedial interventions. Provides information suitable for managing safety and financial risks from current or future building failures in accordance with the requirements of CDM 2015, or BSA 2022; with robust 'Risk-identification', Risk-management', and 'Risk-ownership'.

5.4 Basics of Medical Diagnosis and Prognosis

Building Pathology as conceived by the researcher and their colleagues in the 1980s and 1990s included the metacognitive processes of Diagnosis used in medical pathology, and practical Building Pathology has been practiced by the researcher and his colleagues using these metacognitive processes since that time. However, since that time the basics of medical diagnosis and prognosis have been further studied and developed under the subject of Clinical

Reasoning(Cooper and Frain, 2016). This may be considered as a development of the basic mental process of problem solving and inference applied by everyone in their daily lives, involving pattern recognition, Type 1 and Type 2 Thinking, and basic inference(Meadows, 2008). Generally, these activities are probabilistic in nature as developed and studied in Basic Inference and Decision Theory in Finance and Economics. However, in Medical Diagnosis and Clinic Reasoning; this has developed as a practical subject, with protocols and procedures applied in all levels of experience and expertise; for training Nurses, Emergency Medical Technicians, Paramedics, and Senior Practitioners in all areas of Medicine(Bowen, 2006; Cooper and Frain, 2023). The principals and protocols applied are clearly formalised in the protocols for Emergency Medical Technicians and Paramedics in First Aid and Pre-Hospital care where a 'preliminary assessment' is made following the mnemonic DR ABCDE(Singletary *et al.*, 2015). Here the first action is a risk assessment under the heading 'Danger' and 'Risk' to the Medical Professionals or 'First Aiders' and patients. This is followed by a preliminary assessment of risk factors affecting critical aspects for the survival of the patient and the headings 'Airways', 'Breathing', 'Circulation', 'Deviation and disability', and 'Environment and exposure.' These may have obvious co-relations to the risk assessment and investigation of problems affecting buildings and their occupants. The protocols and procedures developed in medical diagnosis and Clinical Reasoning have also come to reflect the metacognitive processes involved in the process of Diagnosis, Patient Management and Prognosis(Bossuyt *et al.*, 2003). These protocols and procedures have been systemized in Patient Report or Record Forms or PRFs, which are used in all aspects of assessment of patients in pre-hospital and Accident and Emergency (A&E) for assessing and recording diagnosis and treatment of patients (McKenzie, Pap and Hardcastle, 2022). These were initially paper based forms produced and copied to all interested parties and stakeholders, both for management and for recorded purposes; but they are increasingly IT and web based, and a typical example of a PRF is included at Appendix C However, these PRFs have a common theme following the process of assessment, diagnosis, and patient management as follows:

1. **Presenting Complaint:**

   The Presenting Complaint is the description of the problem for which medical assistance has been sought. This is often very different to the description of the actual medical problem suffered by the patient. For example, a patient complaining of a 'chest pain' may be suffering from an acute heart attack, a minor muscular skeletal problem; or a psychosomatic problem described in the past as 'hypochondria' in an attempt to seek attention and help for other psychological, social or physical problems. The medical practitioner will make preliminary risk assessments and probabilistic judgements based on this 'Presenting Complaint' but must allocate resources and response times based on this. However, it is important not to 'pre-judge' and 'prejudice' any future diagnosis and treatment prior to a proper holistic assessment of the case, as described below.

2. On Arrival:

On arrival the medical diagnostician will be presented with further data, both visually in terms of the appearance of the patient and their environment, and in verbal reports of 'symptoms' from both the patient and their carers of family. For example, the patient may be found lying in the road next to a motor vehicle with blood on the pavement. Alternatively, the patient may be found unconscious in the lavatory of a restaurant with a party or celebration taking place outside. This data will enable the medical diagnostician to make a further 'rolling risk assessment' of both the safety and condition of the patient, and of the attending medical practitioners; for both 'Health and Safety', medical, diagnostic, and legal purposes.

3. History of Presenting Complaint:

Although observations made under headings of Presenting Complaint and 'On Arrival' will have started to provide data on the history or timeline of the problem to be diagnosed and managed; it is crucial to gather further date on the history of the presenting complaint in order to effectively diagnose and manage the patient. In particular, when did the signs of symptoms complained of first appear, what the signs and symptoms are, where the signs and symptoms occurred or are occurring, and how they occur, and who they affect, what the signs and symptoms are and what they are affecting. It is to be noted that this is the same as the classic tenants of enquiry described for all areas of human activity Who, What, Why, When, How and Where. This 'History' is the fundamental basis on which the first probabilistic assessment of the diagnosis management or prognosis is made; which is clarified by further enquiry and investigation as described below. However, it should be noted that as in all aspects of the diagnostic process, it should be cyclical or iterative in nature; with further history being sort based on the results of a more detailed enquiry, after the initial recording of the History of the Presenting Complaint.

4. Medical History and Surgical History:

The key part of History taking, for Medical Diagnosis is the previous Medical History and Surgical History of the patient; not least because the Presenting Complaint is likely to have been subject to recent previous remedial interventions and may have been subject to treatments in the past. The results of these interventions are therefore very useful in the probabilistic assessment of the diagnosis and efficacy of proposed interventions. It is also common for conditions to be recurrent or progressive in nature and to have been subject to previous treatments and interventions, whether these are Medical (chemical or physiological) or Surgical (physical and anatomical) in nature. These may have been helpful in managing the Presenting Complaint in the past, or may have exacerbated or caused the current Presenting Complaint. Information on the Medical History and Surgical History can therefore be crucial in reaching a probabilistic diagnosis, and in providing effective future management and prognosis both for the short, medium and long term.

5. Social History:

The 'Social History' of the Patient and their Presenting Complaint can be crucial in providing a probabilistic diagnosis in conjunction with the histories described above. This includes the history of the environment in which the patient has suffered the presenting complaint; whether this be their domestic conditions, their exposure to potentially harmful materials or conditions at work, or the effect of social or sporting activities. These are likely to have significant physical and potentially physiological and chemical effects on the patient. For example, trauma or over exertion in sporting activities, or exposure to excessive consumption of foods, alcohol or recreational drugs.

Social History may also provide useful data on the reliability of information provided by the patient themselves, or on their physical and mental care and wellbeing.

6. Observations:

In Medical Diagnosis a standard protocol of preliminary Observations has been developed covering critical aspects of the physiology and anatomy critical to the health and survival of the patient as described above; these generally cover Airway, Breathing, Circulation, Disability and Disfunction. This is done by visual observation and the use of simple diagnostic aids, for example to determine pulse or heart rate and body temperature. These observations are generally a combination of visual and tactile impressions of the patient and are taken in a regular protocol to avoid missing any important aspect of Physiology and Anatomy due to 'tunnel vision' as a result of assumptions made too early in the diagnostic process based on incomplete information. For example, it is usual to expose all parts of the patient as far as is practical, and to make observations from head to toe or 'top to bottom', so as to minimize the risk of missing a crucial anatomic or physiological observation which may significantly change the probabilistic diagnosis or 'Presumptive Diagnosis'. For example, it is possible for a practitioner to become focused on a heavily bleeding head injury and miss a potentially fatal stab wound in the perinium form a stiletto or screwdriver. Similarly, this is intended to avoid a medical practitioner becoming totally focused on an obviously infected wound on the leg potentially resulting in Septicemia and resultant disorientation; but missing the fact that the pupils of the eyes are of different sizes and that there are other indications of a cerebral vascular stroke.

7. Impressions:

Based on the history and observations described above, the Diagnostician generally records their Impressions or Presumptive Diagnosis. This is important for record purposes, but also allows the Diagnostician to review their impressions; which promotes the cyclical or re-iterative metacognitive process required to refine the probabilistic nature of diagnosis, and possible Differential Diagnosis of causes of the Presenting Complaint.

8. Treatment:

It is usual for some Treatments or physiological interventions to have been undertaken by the medical practitioner by this stage of the diagnostic process based on the information available; so as to manage the risk of further deterioration of the condition of the patient and/or to promote their recovery. These are usually recorded for record or legal purposes. However, the response of the patient to these treatments of interventions are crucial in the further diagnosis and management. For example, if the differential diagnosis includes a probable respiratory problem, the provision of supplementary oxygen to the patient results in a reduction of some of the symptoms and an increase in the blood oxygen levels detected as part of the preliminary observations, this diagnosis may be supported. Again, the iterative and cyclical nature of the diagnostic and differential diagnostic process is reinforced, in that the basic observations are repeated after interventions, and these further observations increases or decrease the probability of the diagnosis or differential diagnosis made on which they were based.

9. Management:

The protocols developed in medical diagnosis and generally formalized in the PRFs (Patient Report Forms) also include formal proposals and records of the future Management of the patient. This is likely to include furthermore specialist or specific investigations or tests such as x-rays or other medical imaging, analysis of blood chemistry, and tests for evidence of bacterial or viral infections; in support of a probabilistic Presumptive Diagnosis. However, this also records who will be responsible for the further investigation, management and care of the patient. For example, will the patient be transported by ambulance service and handed over to the Accident Emergency department (A&E) or a hospital, will the patient be referred to their own doctor acting as a General Practitioner (GP), will the patient be transferred from the responsibility of the Accident or Emergency department (A&E) to a specialist Intensive Care Unit (ICU), or a Surgical Department. This is not only important for the diagnosis and treatment of the patient but is also important for purposes of risk management and risk ownership. This is an important part of what is often described as 'Handover' by medical practitioners, and describes the handing over of responsibility for the patients care and wellbeing between the professionals involved.

Although the protocols described above and summarized in Table 5.2 below generally refer to those applied for diagnosis and management in pre-hospital and emergency care; these protocols and the associated metacognitive processes involved developed over the last 20 years are now routinely applied for diagnosis throughout medical practice (Yazdani *et al.*, 2017). For example, the patient report forms and formats in PRFs that are described above are used on transfer or 'Handover' of patients between medical practitioners and departments within and outside hospitals (Xu *et al.*, 2021). Similarly, protocols such as the 'Surgical Sieve' using mnemonics such as 'VITAMIN C DEF' (Vascular, Infection/Inflammatory, Trauma, Autoimmune, Metabolic, Iatrogenic, Neoplastic, Congenital, Degenerative, Endocrine/Environment, Functional), or the Compass Medicine' approach are used (Chai, Evans and Hughes, 2017). This promotes further review and revisiting of the diagnostic process at each stage, allowing new diagnosis to be made and/or misdiagnosis identified. This has obvious parallels and applications to Building Pathology. The investigation and further development of the learning and application of the associated metacognitive process under the subject of Clinical Reasoning may therefore be usefully applied, as discussed at 5.4 below.

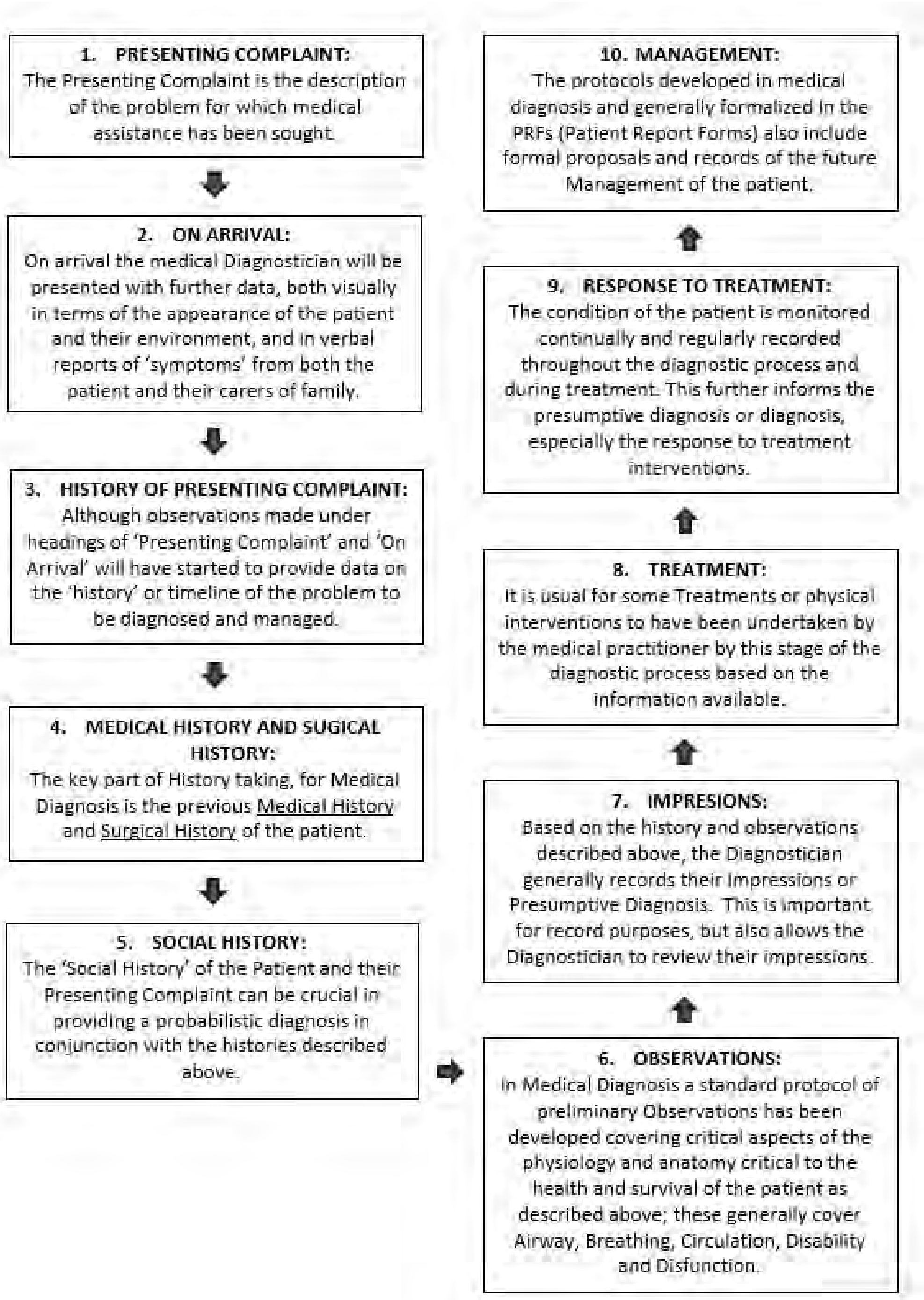

Figure 5.1: Flowchart Showing Basics of History Taking for Medical Diagnosis and Prognosis Based on Standard Patient report Forms (PFRs) used by Ambulance Services Throughout the UK(Bossuyt *et al.*, 2003; Xu *et al.*, 2021; McKenzie *et al.*, 2022)

NOTE: *Before any Diagnosis or Treatment*, *the first action is always a Health and Safety Risk Assessment of potential hazards to the medical Professionals, the Patient, and the Public.*

5.5 Review and adaptation of best-practice and current developments in the learning of Clinical Reasoning for Building Pathology

Traditionally, the Art and Science of medicine and of medical diagnosis has been learnt as a practical subject by exposing the student practitioner to situations requiring diagnosis and remediation of patients' complaints and pathologies in real life (Ackerknecht, 2016; O'Malley, 2023; Stirling, 2023). These are generally referred to as 'cases', and their investigation as 'case studies'. In modern Medicine, actively engaging with patients or their care in this way is described as 'clinical experience'. This approach to learning practical as opposed to theoretical Medicine has evolved over millennia and in many cultures (Hampton *et al.*, 1975), and it is generally recognised that exposure to working through practical case studies is a fundamental requirement for developing the Diagnostic and other skills required for effective Medical Practice. Similarly, different levels of expertise are generally recognised as requiring different levels of experience, and with Specialists requiring specialist experience. Historically a student practitioner may have worked as an apprentice or assistant to an experienced and 'qualified' practitioner for many years, slowly developing their skills and expertise. In particular it was necessary for them to have had adequate experience of the sort of cases that they intended to diagnose and treat when qualified (McLean, 2016). This appears very similar to the current situation for those involved with the teaching and learning of Building pathology. However, the rapid expansion of the scope and complexity of modern medicine in the 20th century has resulted in the requirement to train increasing numbers of medical practitioners of all sorts in increasing numbers of specialist areas of medicine (Xu *et al.*, 2021). This has resulted in the need for educators and regulators to ensure that students of practical medical diagnosis receive sufficient training, including exposure to appropriate cases to develop appropriate levels diagnostic skills. The subject of 'Clinical Reasoning' has therefor been studied and developed by those concerned with the teaching and learning of diagnosis in modern Medicine since the 1950s (Cooper and Frain, 2016). This has resulted in extensive research, and in an extensive literature on the academic or scientific basis of the subject, and its practical application. Generally Cognitive Psychology' concepts such as 'Scripts', 'Schema', and 'Type1 and Type 2 Thinking', have been used in current developments in Clinical Reasoning, and these appear to have parallel applications for metacognition in Building

Pathology (Charlin et al., 2007, Charlin et al., 2000b, Kahneman, 2000, Kahneman and Klein, 2009, Osman, 2011). Research has also repeatedly shown that appropriate exposure to relevant case studies is the most important factor in the learning of Clinical Reasoning(McLean, 2016). A Google search of information provided by UK and US medical professional institutions and educational organisations show that it is currently generally expected that qualification as an Emergency Medical Technician or Paramedic will require at least 750 hours of practical experience diagnosing and treating cases, that qualification as a Nurse will require at least 2,000 hours of clinical experience, that qualification as a Midwife will require at least 4,000 hours of clinical experience, and that qualification as Doctor will require at least 3000 hours of clinical experience over a minimum of 3 years, while a Junior Doctor will require at least 6-8 years of further clinical experience before having sufficient expertise to qualify as a Consultant. In this context it is interesting to note that this is similar to the experience of the researcher in training building professionals to work as professional Building Pathologist; in that it has generally been found by the researcher in their professional practice to take at least 6 months practical experience as a Building Pathologist for a basic level of competency to be achieved, and 1 to 2 years of experience before they can reliably to act as the leading investigator on a Building Pathology case. However, the teaching and learning of Clinical Reasoning is dependent on exposing the student to appropriate case studies in conjunction with appropriate Mentoring for Practice Based Learning, effective cognitive and metacognitive reflective reasoning on 'clinical problem solving', and diagnostic decision making (Elstein and Schwarz, 2002; Norman, 2005; Marcum, 2012). Recent developments in the subjects of 'Reflective Reasoning 'and 'Reflective Practice', also show useful parallel process for development in the understanding of Building Pathology (Kuiper and Pesut, 2004; Mann, Gordon and MacLeod, 2009). Near Pear Mentoring has been found to be more effective that Expert mentoring in some studies. This effect may be partially due to the extra motivation of participants in studies of new learning interventions (Dickman *et al.*, 2017; Hundertmark *et al.*, 2019). However, the researcher has observed that Students may often find it easier to understand the explanations and advice provided by near pears, than that provided my experts in Medicine or Building Pathology who may be charismatic or enthusiastic but may not be experts in teaching. Because of the increasing problems in modern medicine of ensuring the exposure of students to suitable patient case studies; those teaching and learning Clinical Reasoning have made increasing use of the presentation of virtual case studies or 'Schema' for the students work through (Charlin *et al.*, 2000b; Charlin *et al.*, 2007; Dreicer *et al.*, 2023). These are now often presented on electronic media directly to the student via the internet, rather than being presented in a lecture theatre. These virtual cases may also be presented as a self-administered multiple-choice test for learning purposes, or as part of a test for professional or academic assessment. This use of individual IT based for self-teaching has been part of a profound change in the way that students of the medical professions are taught and learn, which has accelerated over the COVID 19 epidemic (Stirling, 2023). In the medical professions, as in other professions, it is now generally recognised that the process of learning must continue in practice; in order to maintain and continually develop skills such as Clinical Reasoning. This generally requires the continued exposure of the student and practitioner to appropriate Cases or Case Studies, followed by Reflective Study, and mentoring as previously described (Grant, 2017). This is especially important in professions such as Medicine and Building Pathology; where their subjects and the conditions that they are exposed to may be rapidly changing and evolving over time (Pantazis and Gerber, 2019).

5.6 Review of Differences Between Medical Pathology and Building Pathology

The similarities or parallels between complex living organisms and the structures they create has been recognised both by Architects and Biologists, who have recognised the convergence of their subjects (Mitchell and Hansell, 2008; Ireland and Garnier, 2018), and the ways that this has resulted in the evolution of building pathologies and the subject of Building Pathology have been discussed in Chapter 2 and Chapter 3 above. However, there are some apparent differences between Medical Pathology and Building Pathology to be considered. Primarily this is the apparent difference between the investigation of mostly living organic systems in Medical Pathology with the investigation of mostly dead inorganic systems in Building Pathology. This leads to the apparent difference between self-replicating, and self-repairing or healing of living organic systems, and the necessity for the intervention of living humas or animals to allow replication, maintenance and repair of buildings and building failures over time. There is also the apparent differences resulting from the perception of people and animals as being self-aware or having emotions that affect diseases and their management (Benson, 1997). However, these may be considered as problems of scale or relative preparation, in that a living organisms may be considered as complex systems and include inorganic components which can be the subject of Medical Pathology, such as prosthetics (Burnard *et al.*, 2020). Similarly, buildings and the built environment may be considered as complex systems including their occupants (Pantazis and Gerber, 2019). This also applies to the role of perceived disease or disability in Medical Pathology, which is similar to the role of the building occupant in defining and managing what is a perceived building failure in Building Pathology (Leaman and Bordass, 1993). In this context it is interesting to note the similarity between the expected service lives of buildings with the expected lifespan of its occupants of between 20 and 100 years, suggesting a link between the complex systems they represent. Certainly, the differences appear to be related to scale in that the study of Epidemiology in Medical Pathology has many of the characteristics of studies of building stocks (Bahramian and Yetilmezsoy, 2020; Geraldi and Ghisi, 2020). However, review of the practical experience of the researcher and his colleagues in the application of Building Pathology for over 35 years in the UK and abroad have resulted in the evolution of a diagnostic methodology with differences and similarities to those applied in Medical Pathology, as described above and summarised in Table 5.3.

Table 5.2: Comparison of Methodologies Used for Diagnosis in Medical Pathology and Building Pathology Methodology Evolved in the Practical application of Building Pathology by the Researcher over 35 years (Bossuyt *et al.*, 2003; Xu *et al.*, 2021; McKenzie *et al.*, 2022)

Medical Pathology	**Building Pathology**
1. Presenting Complaint: This is the description of the problem for which medical assistance has been sought.	**Assessments prior to site visit:** Including Presenting Complaint; History of presenting complaint; potential Health and Safety hazards or concerns; and probable building structures and materials affected.
2. On Arrival: The medical diagnostician will be presented with further data, both visually in terms of the appearance of the patient and their environment, and in verbal reports of 'symptoms' from both the patient and their carers of family.	**2. On Arrival:** On arrival on site information can generally be obtained by a visual assessment prior to entering the building or site. This includes information on Health and Safety, verbal History by interview, written information, and inferred History from visual inspection.
3. History of Presenting Complaint: It is crucial to gather further date on the history and timeline of the presenting complaint in order to effectively diagnose and manage patient's complaints.	**3. History of Presenting Complaint:** It is crucial to gather further date on the history and timeline of the presenting complaint in order to effectively diagnose and manage building failure.
4. Medical History and Surgical History: The Presenting Complaint is likely to have been subject to previous remedial interventions. The results of these interventions are therefore very useful in the probabilistic assessment of the diagnosis and efficacy of proposed interventions.	**3. History of remedial interventions and/or refurbishments**: by verbal enquiry, reference to written or printed information, and by visual inspection.
5. Social History: The 'Social History' of the Patient and their Presenting Complaint can be crucial in providing a probabilistic diagnosis in conjunction with the histories described above. This includes the history of the environment in which the patient has suffered the presenting complaint; whether this be their domestic conditions, their exposure to potentially harmful materials or conditions at work, or the effect of social or sporting activities.	**5.** Social History or Occupancy: History of current and past occupancy including domestic use, industrial use or other occupancy; and whether the building is intermittently or continuously occupied. This includes the History of heating and ventilation, and inspection and maintenance.
6. Observations: In Medical Diagnosis a standard protocol of preliminary Observations has been developed covering critical aspects of the physiology and anatomy critical to the health and survival of the patient as described above; these generally cover Airway, Breathing, Circulation, Disability and Disfunction. This is done by visual and tactile observation and the use of simple diagnostic aids.	**6. Observations:** Observations and investigations are undertaken on site or by taking samples for testing elsewhere; to provide more data or information to clarify the data and information already gathered as described above, and to clarify the probabilities of the various diagnoses and differential diagnoses resulting from this information
7. Impressions: Based on the history and observations described above, the Diagnostician generally records their Impressions or Presumptive Diagnosis.	**7. Impression or Diagnosis and Differential Diagnosis:** The process of observation and the interpretation of the data and information gained is a cyclical process; in which the Diagnosis and the probabilities of Differential Diagnoses are refined by further observation.

8. Treatment: It is usual for some Treatments or physiological interventions to have been undertaken by the medical practitioner by this stage of the diagnostic process based on the information available; so as to manage the risk of further deterioration of the condition of the patient and/or to promote their recovery.	**8. Treatment or remedial actions:** Remedial actions are proposed by the investigator based on the Diagnosis and Differential Diagnosis described at 5 above. These remedial actions may include further investigations and management measures.
9. Management: The protocols developed in medical diagnosis and generally formalized in the PRFs (Patient Report Forms) also include formal proposals and records of the future Management of the patient. This is likely to include furthermore specialist or specific investigations or tests.	**9. Risk management:** Each stage of the diagnostic process described above is probabilistic in nature, and the decisions based on any Diagnosis will be consciously or unconsciously based on a probabilistic assessment by those making any decisions. This is true for both the probabilistic assessment of the cost-benefit or 'Utility' of the intervention described at 7 above; or the probabilistic assessment of the hazards or 'Risks'. These perceived risks will therefore need to be owned, managed, or eliminated as necessary for each interested party.

5.7 Summary

As described above, the experience of the researcher and others in using the basic principles and protocols of medical Diagnosis, to develop and practically apply the principles of Building Pathology, may be further developed by reference to the extensive research and literature on the teaching, continuous learning and application of the subject of Clinical Reasoning in Medicine. In particular it is clear that the use of Case Studies, History Taking, Reflective Learning, and Near Pear Mentoring are generally important for the student and practitioner developing the metacognitive skills required for Diagnosis in both the Medical Professions and in the parallel subject of Building Pathology; as summarised below:

1. **Case Studies:**

   It is clear that adequate exposure to suitable case studies is essential for the student and practitioner learning the metacognitive skills required for diagnosis I for both Clinical Reasoning and Building Pathology. These case studies need to be an adequate representative sample of the sorts of cases that the diagnostician will be required to investigate and remediate in practice. However, appropriate case studies may be presented to the student either in real life, or as 'Schema' using photographs and written text, or virtually using information technology. However, adequate and continuing exposure to relevant case studies is essential for developing and maintaining the expertise required for diagnosis, and demonstration of adequate exposure to case studies is an essential part of qualification to practice in the medical professions. Arguably, this should be an essential part of qualification to practice Building Pathology professionally.

2. **History taking:**

The necessity of developing effective protocols and metacognitive process for recording and analysing the 'History' of a case is recognised as fundamental in Diagnosis and Differential Diagnosis is clearly fundamental in medical Clinical Reasoning. This has been recognised by the researcher and others for the practical application of Building Pathology.

3. **Reflective learning:**

An essential part of understanding and internalizing the lessons learnt from case studies in the medical professions is Reflective Learning(Kuiper and Pesut, 2004; Mann *et al.*, 2009; Branch Jr, 2010). The habit of informal Reflective Learning is encouraged in students in all the medical professions, and formal demonstration of reflective learning is often required as part of qualification for practice in the medical professions.

4. **Near Pear Mentoring:**

An important part of understanding and learning from case studies is their presentation and/or interpretation by mentors. This may be during investigation or presentation of a case study, or part of subsequent Reflective Learning as described at 1 and 2 above. This has been the case for hundreds if not thousands of years in the medical professions. Recent studies on students of medicine have indicated that near peer mentoring may be more effective than mentoring by experts, and practical experience by the researcher and others suggests that this may be the case for students of Building Pathology. However, more recent studies suggest that this effect may be associated with the enthusiasm and resources brought to bear during the trialing of 'new' learning intervention, and may not persist when this enthusiasm cannot be maintained in the absence of charismatic educators and motivated students (Dickman *et al.*, 2017).

5. Continuous Professional Development (CPD):

In all the medical professions there is a professional and indeed legal requirement to undertake regular and adequate CPD. This is also true of professions in the Building Industry. Although this may often be understood as the introduction to new knowledge and techniques; there is generally at least an implied requirement for practitioners to be exposed to adequate case studies within their field of activity in order to maintain and develop the expertise necessary for practice (Grant, 2017).

CHAPTER 6: ASSESSMENT OF CURRENT BEST PRACTICE FOR THE TEACHING AND LEARNING OF BUILDING PATHOLOGY IN THE UK

6.1 Introduction

The recognition that buildings and Building Pathology are emergent phenomenon in complex systems evolving over time, and the relationship between the subjects of Building Pathology and medical Pathology has been described in Chapter 2 and Chapter 3 above. The resulting relationship between the development or evolution of the metacognitive processes needed for effective Diagnosis in the subjects of Building Pathology and medical Pathology or Clinical Reasoning has then been demonstrated in Chapter 3 and Chapter 5, in support of the Hypothesis. An assessment of current best practice for the teaching and learning of Building pathology was then undertaken to give further Academically valid empirical grounding to the relationship between these subjects This was because it was expected that current best practice in teaching Surveyors in the UK includes elements that have evolved to allow the learning of the methods and procedures needed to Diagnose problems in buildings and the built environment; but it is not clear how the metacognitive processes involved are generally understood, how they are currently prioritised and presented in courses, or how their learning by students is currently assessed. It was there for proposed to undertake research to answer the question "What are the perceived objectives and current best practice in the delivery of teaching and learning in 'Building Pathology modules' and Building Pathology courses in the UK. As discussed at Chapter 4 above; review of the available published literature failed to identify previous research with the same or similar objectives as the currently proposed research project to gather empirically valid data to answer the research question "What are the perceived objectives and current best practice in the delivery of teaching and learning in 'Building Pathology modules' and Building Pathology courses in the UK"**.** It was therefore proposed to do this following current best practice in a Mixed-method Study with a Multi-strategy Design with both qualitative and semi-quantitative data gathered by questionnaires and semi-structured online or telephone Interviews from ten educators or teachers responsible for preparing, delivering and/or assessing modules currently providing teaching or learning of the subject described as Building Pathology(Bryman, 2016; Morse, 2016; Robson and McCartan, 2016).

6.2 Findings and Discussion of Analysis of Qualitative and Semi-Quantitative Data from Interviews and Questionaries

6.2.1 Qualitative and Semi-Quantitative Data from Interviews and Questionaries

Qualitative data was gathered by questionnaire and interview using Microsoft Teams, prompted by the semi-quantitative data, in the pre-submitting questions based on the draft questionnaire at Attachment D, as discussed in Chapter 4 above. It was hoped that this would act as a script and would help keep the interviews focused on answering the research questions in the limited time available and assist in ‘bench-making’ and coding of the data gathered when analysed. These questions and semi-structured interview were trailed with 2 no. subjects; prior to submitting the questionnaire and subsequently interviewing, 11 no. representative educators or teachers providing ‘Building Pathology Modules’ or Building Pathology courses in the UK; in order to provide an empirically valid sample in accordance with current best practice (Tierney and Dilley, 2002; Desimone and Le Floch, 2004; Hopf, 2004; Harris and Brown, 2010; Baker and Edwards, 2012; Bryman, 2016). Audio recording and verbatim text recording of the interviews was made using Microsoft Teams.

The qualitative and semi-quantitative data gathered was integrated and analysed using Thematic Analysis to identify Nodes and Themes in the data from the interviews, and the results subject to further Thematic Analysis(TA); in order to try and ‘Triangulate’ an answer to the research question “What are the perceived objectives and current best practice in the delivery of teaching and learning in ‘Building Pathology modules’ and Building Pathology courses in the UK”**.** Initial coding was based on the questions used and shown at Appendix D. This coding was then refined on further TA shown in Table 6.2 and Table 6.3.

6.2.2 Assumptions and Researcher Biases

It is recognised by the researcher that the analysis of the data gathered from interviews and questionnaires is likely to have been affected by the prior expectations inherent from 40 years of practical experience as a Building Pathologist and from the results of the extensive literature review undertaken in the earlier parts of this research project. In particular, there was a prior expectation that practical experience, case studies or 'Schema', case history, and other aspects common in the teaching and learning of medical pathology were likely to be reported by Interviewees. However, there was also an expectation that a Didactive Approach was likely to predominate, with some Practical Based Learning and Practice Based Learning. This is likely to have affected and guided the questions used during the interviews and guided subsequent conversations and eventual Thematic Analysis (TA). It is also recognised that the data collected by interview represents the reported objectives and opinions of the interviewees, not objective facts about the actual teaching and learning activities on the Building Pathology modules that they were reporting on.

6.2.3 Selection of interviewees

Those identified by the researcher to be preparing and delivering modules on Building Pathology as part of Surveying or other courses at institutions in the UK were contacted by email and telephone to try and achieve a representative sample to answer the research question described above. It should be noted that the only Universities currently providing courses on Building Pathology in the UK are those teaching the subject as an RICS Core Discipline for Students studying for a degree in Surveying. Most interviewees were there for providing Building Pathology modules on Surveying courses.

It is recognised that the selection of Interviewees described above is likely to have resulted in some selection bias. It is also possible that a potentially more significant self-selection bias was introduced by only the ten interviewees responding having the motivation and time to participate in the research project. However, it might be reasonably argued that those with the motivation to participate are likely to be those at the forefront of developing 'current and future best practice'. The data gathered from the interviews as described below may therefore still be regarded as useful in answering the research question and the preliminary findings from analysis of the data on the Interviewees are discussed below.

1. **Age of interviewees:** The age of interviewees was reported to range between approximately 46 and 72 years with the average being above 55 years old. This suggests there may be a significant selection and retention biases at work in the employment of those providing teaching to Surveyors in institutions in the UK. This may be due to a perceived need for the experience and qualifications described below; especially in the absence of any formal professional or academic qualification in the subject.
2. **Academic qualification:** All the interviewees had Bachelor's Degrees and over 50% had Masters Degrees. However, only 18% had PhDs. This suggests that the subject of surveying and Building Pathology in particular, is generally not regarded as an academic subject within the UK. This may have affected research and publication of peer referenced literature on the subjects in the past.
3. **Professional affiliation:** The majority of the interviewees were reported to be members of the Royal Institute of Chartered Surveyors (RICS), but 20% were not members of the RICS but were members of the Chartered Institute of Building (CIOB) instead. However, only two of the interviewees were Fellows of either organisation, and none of the interviewees had affiliations to the Royal institute of British Architects (RIBA) or other architectural professional bodies. This suggests that teaching and research in the subjects of Surveying, and in particular Building Pathology, are not generally recognised as routes for advancement in these professions, and their importance within the professions is not generally recognised.
4. **Experience:** Interviewees reported professional experience of between 21 and 36 years with an average of 26 year; and reported academic experience of between 2 and 24 years, with an average of 13 years. This represented approximately 65% of years in professional practice and 35% of years in academic research and/or teaching. This appears to be an extraordinary and remarkable depth of experience on which to base

their opinions; and suggests that a high level of professional experience has been a key factor in the appointment of those involved with the preparation and delivery of Building Pathology modules in institutions in the UK. It was also reported that many of the interviewees had practical experience outside the profession of Surveying in the UK. At least three interviewees reported working in practical trades in the Building Industry or elsewhere, and at least half reported being involved in sandwich courses or apprenticeships as part of their training. This is likely to have provided a relatively broad holistic and practical approach to the subject.

5. **Expertise:** Only two of the interviewees claimed any special expertise in the subject of Building Pathology, while others claimed to base any expertise, they had on their experience in general surveying practice as discussed above. In this context, preliminary search using Google Scholar indicated that four interviewees had produced between 1 and 19 publications in which the subject of Building Pathology was discussed. Although all the interviewees expressed interest in research in the subject of Building Pathology, a number reported workload as the factor preventing research and publication. Academic professional publications of all sorts reported varied between none and 55, with five. of the interviewees having produced less than two publications. This appears to emphasise the lack of research and academic recognition of the subject of Building Pathology and Surveying generally, or perhaps the lack of time available to the interviewees given their teaching commitments.

6. **Job titles:** The majority of interviewees reported job titles of Senior Lecturer and/or Course Director with only one. retired interviewee having been titled Professor, only one being tilted Visiting Professor and only one being described as Associate Professor. This again appeared to indicate the lack of recognition of the subject of Surveying and Building Pathology, within academic institutions in the UK.

7. **Character of interviewees:** The researcher's impression of the character of the interviewees was that they were generally extraordinarily experienced, capable, and motivated individuals with a passion for their subject; that expected to deliver the majority of the course material to their students either directly or indirectly. It was

therefore probable that the courses delivered may have been affected by the individualistic and charismatic nature of the interviewees. This may have a positive effect on Student motivation and learning. However, it may also constrain the more general understanding and development of the teaching and learning methodologies employed; especially given the reported restricted time and resources for research and publication previously discussed.

8. **Demographic of Interviewees**: Given the age profile of the interviewees described above and the demographic of the Building Industry in the UK thirty years ago, it is perhaps unsurprising that they were generally White British and Male. It might also be hoped that the changes in the Building Industry in the UK since that time may result in a broader demographic spectrum in future. This might be especially useful in making a wider Academic and Professional understanding of Building Pathology available to students. However, the lack of Academic recognition and time for research previously discussed may discourage those from other backgrounds who might otherwise teach Building Pathology. The demographic background of the ten interviewees who agreed to participate in the research project is summarised in Table 6.1 below.

Table 6.1: The Demographic Background of Interviewees Preparing and Delivering Modules on Building Pathology as Part of Surveying or Other Courses for Institutions in the UK

Interviewee	Institution for which Building Pathology Module provided	Highest Academic Qualification	Professional affiliations	Time in Building Industry, Academic teaching or Research	Practical Trade Experience in Building or Other Industry	Age	Ethnicity and Gender
1	University providing RICS accredited Surveying BSc.	MSc.	RICS	35 years	Non reported	55+ years	White British male
2	RICS CPD	MSc.	RICS	36 years	Non reported	55+ years	White British male
3	University providing RICS accredited Surveying BSc.	MSc.	RICS	20 + years	Non reported	55+ years	White British male
4	University providing RICS accredited Surveying BSc.	MSc.	RICS	23 years	7 years	46 -55 years	White British male
5	University providing RICS accredited Surveying BSc.	MSc.	RICS	20 + years	5 years	55 + years	White British male
6	University providing RICS accredited Surveying BSc.	MSc	RICS	37 years	5 years	55 + years	White British female
7	University providing RICS accredited Surveying BSc.	PhD	RICS	37 + years	2 years	55 + years	White British male
8	University providing RICS accredited Surveying BSc.	MSc.	RICS, CIOB, CABE	20 + years	8 years	46 - 55 years	White British male
9	University providing RICS accredited Surveying BSc.	PhD	CIOB	40 years	5 years	46 - 55 years	White British male
10	CIOB CPD	MA.	RICS, CIOB, IHBC	20 + years	Non reported	55 + years	White British male

6.3 Thematic Analysis (TA) of Interviews and Questionnaires

6.3.1 Introduction

The interview scripts and questionnaires obtained using the methodologies described above were initially coded based on the questions in the Questionnaire shown at Appendix D. This data was then subject to first stage reflective immersive reading and Reflective Thematic Analysis (TA) following the methodologies described by Brawn and Clark(Clarke and Braun, 2017; Braun and Clarke, 2020). Initial repeated reflective immersive reading of the transcripts and questionnaires was used to allow preliminary deductive and inductive coding, a described in Table 6.2 below.

Table 6.2: INITIAL CODING AND CONCEPTUAL THEMES FOR ASSESSMENT OF
CURRENT BEST PRACTICE FOR THE TEACHING AND LEARNING OF BUILDING PATHOLOGY IN THE UK

The Initial Coding and Conceptual Themes used on Thematic Analysis of Questionnaires and Interviews from ten educators or teachers responsible for preparing, delivering and/or assessing modules currently providing teaching or learning of the subject described as Building Pathology are listed below:

1. INTERVIEWEES
1.1 Job title
1.2 Age
1.3 Training
1.4 Qualifications
1.5 Affiliations
1.6 Experience
2. PRIORITY OF TEACHING ACTIVITIES (UNPROMPTED) AND SCORE 1-5
3. TEACHING ACTIVITIES (PROMPTED) AND SCOR 1-5
3.1 Defects and their causes
3.2 Common defects and remedial measures
3.3 Talking through cases with more experienced senior colleagues (on course or on placement).
3.4 Near-pier mentoring (talking with colleagues of similar or slightly more experience on course or on placement)
3.5 Site visits and investigations
3.6 Reflective learning (thinking through site investigations you have been involved with)
3.7 Reference to textbooks or articles
3.8 Online or DVD based learning packages

3.9 Case studies on audio visual media (talking through case studies on PowerPoint or other audio-visual media)

3.10 Lectures from staff

3.11 Lectures form guest experts (lectures from specialist guest speakers online, or at university or college)
3.12 History (introduction to the importance of investigating the history of a defect and of previous remedial interventions)

3.13 Diagnostic test and their limitations

3.14 Probabilistic diagnosis (introduction to prior probability or expectations refined by further tests to give probabilistic diagnosis and risk-management)

3.15 Building pathology as evolutionary process (introduction to building pathology as a process in the evolution of buildings as complex systems)

3.16 Building pathology as holistic subject (introduction to building pathology as a holistic subject where defects do not occur in isolation)

3.17 Report production

4. TIME AND RECOURSES IMPROVEMENTS SUGESTED

5. USEFUL INFORMATION FOR PREPERATION

5.1 From RICS

5.2 other sources

6. ASSESSING EFFICACY OF TEACHING

6.1 Student feedback

6.2 Exams

6.3 External examiners

6.4 Continuous assessment

6.5 Employer feedback

6.6 RICS feedback

Iterative reading and re-coding allowed descriptive and conceptual Themes to be identified as described at Table 6.3, and as discussed at 6.3.2 below. Semantic Analysis was not undertaken initially due to problems with the quality of the transcripts from Microsoft Teams, but some Semantic Analysis was undertaken to clarify the research question towards the end of the analysis. Observer Bias is therefore likely to have occurred in the selection of questions, coding and analysis. However, the possible implications of this bias will be discussed for each finding in the TA based on the final coding and conceptual themes shown in Table 6.3 and described at 6.3.2 below.

Table 6.3: FINAL CODING AND CONCEPTUAL THEMES FOR
ASSESSMENT OF CURRENT BEST PRACTICE FOR THE TEACHING AND LEARNING OF BUILDING PATHOLOGY IN THE UK

The final Coding and Conceptual Themes after review and definition on Thematic Analysis of Questionnaires and Interviews from ten educators or teachers responsible for preparing, delivering and/or assessing modules currently providing teaching or learning of the subject described as Building Pathology are listed below:

1. INTERVIEWEES

1.1 Age of interviewees

1.2 Academic qualification

1.3 Professional affiliation

1.4 Experience

1.5 Expertise

1.6 Job titles

1.7 Character of interviewees

2. THE MOST IMPORTANT TEACHING AND LEARNING INTERVENTIONS FOR BUILDING PATHOLOGY MODULES

2.1 Case studies or 'Schema'

2.2 Information management and report writing

2.3 Material delivered by Experts

2.4 Lectures and Seminars

2.5 History of buildings and Building Pathologies

2.6 Textbooks and reading

2.7 Challenging Students opinions and teaching Students 'how to think'

2.8 Use of specialist tests and equipment

2.9 Holistic Building pathology

2.10 Building defects

2.11 Material Science

2.12 Motivation of students.

3. TEACHING AND LEARNING ACTIVITIES DISCUSSED ON PROMPTING DURING INTERVIEW

3.1 Practical site experience

3.2 Experience in practice

3.3 Commentative Enquiry', Directed 'Flipped learning' and Practical Based learning

3.4 Probability and risk management

3.5 'Reflective Learning' and 'Near Pier Mentoring'

4. INFORMATION USED IN PREPARATION OF BUILDING PATHOLOGY MODULES

5. ASSESSING EFFICACY OF TEACHING AND LEARNING

5.1 Student Feedback

5.2 External Examiners

5.3 Continuous Assessment

5.4 Exams

5.5 Employer Feedback

5.6 Feedback from the Royal Institute of Chartered Surveyors (RICS)

6. SUGGESTED IMPROVEMENTS IN TIME AND RESOURCES

6.3.2 The most important teaching and learning interventions for Building Pathology modules

The interviewees were asked by questionnaire and on interview to list their five most important teaching and learning interventions for Building Pathology modules. They were also asked to score these 1-5 with 1 being the least important and 5 the most important. This scoring did not provide useful semi-quantitative data but acted as a useful talking point in order to explore their selection on interview. The interviewees all made different selections and simple comments.in the questionnaires prior to interview. However, exploration of their answers on interview and subsequent Thematic Analysis (TA) revealed what appeared to be several common themes. These are described in their order of apparent importance on TA as described below. However, there also appeared to be an apparent common theme in support of Practice Base Learning and what might be considered to be Flipped Lecturing techniques. However, it is possible that these may currently be common themes in Higher Education, especially in professional and practical subjects.

1. **Case studies or 'Schema':** All the interviewees stressed the importance of working through case studies of Building Pathology with Students; and over half reported that this was the most important teaching and learning intervention on the Building Pathology module at their institution and almost half. reported it was the second most important. Some of the interviewees believed this was best achieved with conducted site visits. However, the majority relied on virtual media, including photographs on Power Point presentations or videos. Many of the interviewees were exploring the

possibility of virtual online presentation of case studies. Several interviewees felt that virtual presentation had advantages over face-to-face and site visits, based on their experience of teaching during the Covid 19 pandemic; where it was reported that as good, if not better results were achieved using these methodologies. The majority of the interviewees provided this teaching themselves either face-to-face on site, in seminars, or online. For example, quoting Interviewee 10:" *I use case studies which also link into guidance. So, to actually illustrate how you can feed in what other people learn from buildings into our thought process, emphasizing the need. Don't think you know it all. I don't know it all. I will look at different research papers. I will look at different guidance notes to actually see what instructs me. So that will be through examples of work*".

2. **Information management and report writing:** Report writing, and information management was reported by over half of the interviewees to be one of the five most important teaching and learning activities in the Building Pathology modules at their institutions. On prompting the majority of interviewees believed that report writing as part of the production of course work, making presentations of information from investigations, and preparing reports as part of continuous assessment or examination were very important as teaching and learning activities for Building Pathology modules. Quoting Interviewee 3:" *It's very much about report writing*". And quoting Interviewee 4:" *You know you try and get students to always think about best practice and always thinking about a systematic approach. The report writing is really important for me for undergraduates because it's asking them to take ownership and responsibility of their opinion*".

3. **Material delivered by Experts:** The majority of the interviewees believed in the importance of at least part of the Building Pathology modules at their institutions being delivered by invited 'Experts', and over half the interviewees reported this as among the five most important teaching and learning interventions at their institutions. Some

of the interviewees reported using outside 'Experts' to provide technical background to Building Pathology, while others reported inviting 'Experts' from professional practice to give a more professionally based background and motivation to the course. However, the impression from all the interviewees was that they were the main point of delivery of teaching to the Students on the Building Pathology modules and other parts of the Surveying courses at their institutions. This was likely to result in a varying Student experience between institutions; especially as Student numbers reported by interviewees varied between 15 and 150. For example quoting Interviewee3:" *Lectures by outside Experts are important, and these now need to be recorded, and we actually make these available to the students after the event to dip into for revision purposes. Subsequent face to face tutorials are probably more important than the actual lecture. I think students buy into it better if students can get a grasp of a conversation you're having with an Expert colleague in the class, then trying to get the students to sort of, you know, ask their opinion of what do you think of this? What should we do? What's the best to deal with this problem*?". And quoting Interviewee 7:" *I bring in guest lectures as extras as well, surveyors from industry. We then talked about particular issues*".

4. **Lectures and Seminars:** All the interviewees believed that lecturing remained a key part of teaching and learning of Building Pathology modules, and half reported that lecturing was one of the five most important teaching and learning activities in the Building Pathology modules at their institutions. All the interviewees had had experience of preparation and delivery of online lectures and seminars during recent years because of the Covid 19 pandemic; and a number reported advantages in the online and virtual delivery of lecture material. However, several interviewees believed that there was still and important role for face-to-face lecturing. This was reported to be due to improved student motivation and engagement. There appeared to be variation in a way that different interviewees perceived 'lectures' and 'seminars'. However, even formal lectures on set factual subjects appeared to include significant interaction with the students than might have been expected with the 'chalk and talk' or 'death by Power

Point' lectures in the past. For example quoting Interviewee 8: "*We've got our own sort of set of videos which cover, you know, defects in materials. We also utilize material from the web. We've got independent snippets where we've done a damp survey which has some an interactive pack where you can put a video in. You can have a set of questions or quiz you can have hot spots where they can pick the areas which are wrong. In the future I'm looking to get a full 3D model of a property which we can then do a virtual walkthrough of a property finding defects."* Quoting Interviewee 1:*" I did try an experiment, on Building Pathology with what's called, 'flipped lecturing' where you give the materials to the students in advance. And then they're meant to come to the session. And that that didn't work, as 3/4 of the class hadn't done the work so you can't have a valuable session. So face to face delivery supported with PowerPoint or whatever is it is an absolute fundamental requirement*. Quoting Interviewee 6:" *Partly because of the interactive technology that we've now got that's come through COVID really is what I call interactive, I don't stand up and do chalk and talk anymore. I create a series of Videos, I collate that with a whole load of technical resources, with things like from the RICS S building research digests. And I then I ask the students to work together to watch these things. Read these things in the class., and then answer a series of questions relating to what they've learned. And I'm a floating resource*". And quoting Interviewee 9: "*Yeah, you know they say, lectures should be minimized, and we should be all this fun stuff. But you know lecture still have a massive part to play. You know it's in part in that basic knowledge and without that you've got nowhere to go. The lectures by the lecturer should be important, and if they're not important, something is badly wrong. But I do think it's about that delivery and I understand why lectures get a bad press because there's a lot of boring lecturers out there that just drone on in this monotone with the death by PowerPoint, you know so many points on one slide. Yeah, real bad practice"*.

5. **History of buildings and Building Pathologies:** The History of buildings Building Pathologies was reported as one of the most or second most important subjects in the teaching and learning of Building Pathology modules at their institutions by two of the

interviewees. On prompting, interviewees generally reported recognising the importance of 'history' in diagnosis of Building Pathology, and on further prompting, claimed to have an understanding of the evolutionary nature of buildings and Building Pathologies over time. However, several interviewees appeared to be confused over the difference between the 'history' of a 'Building Pathology', as opposed to the investigation of a Building Pathology in what might be conceived as an 'Historic Building'. Several interviewees reported that 'History' was covered in separate modules or courses to Building Pathology; although they agreed that there was 'cross over' between the subjects taught. None of the interviewees reported providing special training within taking 'case histories' in Building Pathology modules, but on prompting, claimed that this was covered in case studies, seminars and lectures as described above. However, only the two interviewees previously mentioned reported any special teaching or learning activities for Students regarding the progression of Building Pathologies over time; except as part of the instruction inherent in the 'case studies', 'seminars' and 'lectures' previously described. For example Interviewee 4 reported:" *You have to introduce the ability to kind of softly interrogate your client, you're building owner, your tenant on what might have happened in the history of a defect and when did they notice it and what would the symptoms, and is it at this time of year? Is it all year? All these sort of things you'd like to find out. A bit like a medical perspective*". And quoting Interviewee 6:" *It's important to understand that a lot of what our students are taught is how we build now, and that's irrelevant if you're looking at a Victorian building. So I teach them the history of how buildings have got to this; from the Mud Hut to today. So I teach them the evolution of buildings"*.

6. **Textbooks and reading:** The reading of textbooks and other technical reading were reported by two of the interviewees to be one of the five most important teaching and learning activities on the Building Pathology modules at their institutions. All the interviewees reported using textbooks and other technical reading material either printed or online as part of the Building Pathology modules that they presented.

However, interviewees reported variable opinions on the adequacy of available textbooks and the technical literature available as described below. In particular, there appeared to be variable opinions on the usefulness of online teaching materials. Many of the interviewees reported using 'flipped learning' or 'flipped lecturing' techniques in conjunction with workbooks and course work. Several interviewees reported that the teaching materials available from the University of West England and the RICS 'Isurv' online information service were particularly useful in this way. However, several said that there was a ned for a better textbook. For example, quoting Interviewee 10:" *I think you get more information from heritage bodies to be honest that in terms of the older building stock, but you can use that for modern building stock as well to some degree. But from the from the profession institutions, no, not much information at all to be honest".* And quoting Interviewee 1: "*The problem I have with resourcing on building pathology for an undergraduate course is that, Academic papers that are written are too complicated for undergraduates, and there's not enough In terms of a textbook at undergraduate level and so RICS serve is quite important. An awful lot of what is written about building pathology is written from an historic building perspective, understandably. I would like to see more about failures and diagnosis and remediation of more complex modern buildings"*. While Interviewee 4 reports:" *There are some very good textbooks, very good publications and you tend to lecture from that*".

7. **Challenging Students opinions and teaching Students 'how to think':** None of the interviewees reported any special teaching or learning interventions intended to introduce Students to the 'metacognitive' processes involved in diagnosis in Building Pathology. However, all the interviewees reported encouraging students to think for themselves and several interviewees reported 'trying to get their students to 'think like I do'. Two of the interviewees put 'challenging students' opinion' as one of the most important parts of their teaching. However, the general impression on TA of the interviewee's responses suggested that they generally expected students to develop the metacognitive processes required as a by-product of the case studies, presented as

described above, and/or by reflective learning, and pier group mentoring undertaken in conjunction with course work and the filling of workbooks. For example quoting Interviewee 2:" *Challenging them in a very in a very, very uncomfortable way. Making them think and making them uncomfortable. For example I would ask why haven't we fallen into the basement? And say well, let's think about who knows the answer to that? Architects would know the answer. Surveys should know the answer. Good contractors would know the answer*!", and "*With all of this, it is trying to get them to think, in the same way that I think"*.

8. **Use of specialist tests and equipment:** The use of technology and test equipment was reported to be one of the most important teaching and learning activities on the of the Building Pathology modules at their institutions by two. interviewees. On prompting during interviews, all interviewees agreed on the importance of practical experience in using specialist test equipment and to teaching its limitations. This generally appeared to apply to the use and limitations to 'electronic moisture meters'; although some interviewees mentioned other equipment such as infra-red thermal cameras and drones in investigation of Building Pathology. Generally, interviewees reported only limited 'hands on' experience with test equipment for students in the modules they delivered, and it appeared that the majority of this experience was likely to be classroom based. Generally, interviewees reported on relying on students obtaining practical experience outside the course for example on 'placement'. However, no formal system for recording such experience or for 'qualifying' students in the use of specialist test equipment was reported; as might be expected in other courses for professional or practical qualifications. For example, quoting Interviewee 1:" *I try to get the students to use the equipment as a tool, but to understand the range of false positives and negatives that they can get from those tools and then to form and a proper professional analysis of those results rather than simply saying it's in the red"*. And quoting Interviewee 4:" *the best way to teach the basics is to have experience. So to get*

out there a Protimeter measuring, and looking at buildings. You know, seeing is believing from that perspective and then trying to understand, you know, building failure".

9. **Holistic Building pathology:** One of the interviewees reported that the teaching of Holistic Building Pathology was the most important teaching and learning intervention in the Building Pathology module at their institution. On prompting, the interviewees generally agreed that teaching the importance of Building Pathology as a holistic subject was important, and the courses they reported delivering appeared to tend to be holistic in nature, rather than divided into unrelated subjects or 'silos'. For example quoting Interviewee 1 "T*he first thing as a holistic approach to building performance. Buildings are more than the sum of parts. That's what I think is the key outcome, that I want the students to appreciate*".

10. **Building defects:** One interviewee reported that the visual and 'hands-on' introduction of students to building defects was the most important teaching and learning intervention in the Building Pathology module at their institution. On prompting other interviewees generally reported covering Building Defects as part of the modules at their institutions. This generally appeared to be as part of case studies, and/or in the lectures delivered by the interviewees or other experts. For example quoting Interviewee 8:" *We've got our own sort of set of videos which cover, you know, defects in materials*. *We also utilize material from the web. We've got independent snippets where we've done a damp survey which has some an interactive pack where you can put a video in. You can have a set of questions or quiz you can have hot spots where they can pick the areas which are wrong. In the future I'm looking to get a full 3D model of a property which we can then do a virtual walkthrough of a property finding defects*". And quoting Interviewee 2:" *You know Students are so focused on the defect, and I'm saying to them, understand the form of construction and the architectural age of the building, and things start falling into place".*

11. **Material Science:** One interviewee reported that the teaching of material science in a laboratory setting was the second most important teaching and learning intervention in the Building Pathology modules at their institution. On prompting, other interviewees reported teaching material science by other methods including lectures by the interviewees or other Experts, reading, and coarse workbooks. For example, quoting Interviewee 6:" *Where they actually get their hands on the technology and can have a play with it In real life building. Actually, seeing what this equipment is and what it does and how you use it. For me it's really important"*.

12. **Motivation of students:** One interviewee reported that Student engagement was one of the five most important teaching and learning interventions on the Building Pathology module at their institution; and many of the interviewees emphasised the importance of student motivation in the effective teaching and learning of Building Pathology modules and other aspects of Surveying courses in the UK. Obviously the apparent 'Charismatic' and inspirational nature of the interviewees described above was likely to be key in promoting the success of student learning on the course that they delivered. However, all interviewees noted improved motivation and learning of students associated with work experience before or during the course; especially with 'mature students', sandwich course and apprenticeships. Interviewees also reported clear improvements in motivation and learning after 'placements' during courses. For example, quoting Interviewee 1: "*Students these days are quite transactional on a module modular course, though they look and say what is the coursework? What do I need in order to pass this course work? And it's quite difficult. Only a few of them will go and say, well, I'm doing reading for reading sake. So if you just say, well, here's the book and read it, not many of them will do it*". Similarly quoting Interviewee 3: "*I think students certainly know what they want to learn. And they sort of know what is irrelevant? I think they sort of more or less think for themselves; 'Yeah, this is important, I have to go to this lecture*", and "*The really big difference we see in our students is*

coming back after year three after placement for year four. They are coming back with a grown up mentally, and certainly have a lot more of the skills, and see the relevance of what they have done probably in year one and year two, well prepared to embark upon year four. With a proper mindset. This is my profession. This is what I want to learn. And these are the things that we need to learn and progress. Without this Students just simply switch off!". Similarly, Interviewee 9 reported:" *If you've got a majority or a significant minority that are disengaged, it can sort of effect the rest of the class*".

6.3.3 Teaching and learning activities discussed on prompting during interview

As discussed above, interviewees were prompted where possible during discussion of their selection of the most important teaching and learning activities for Building Pathology modules as described above, in order to try and elicit their views on teaching and learning activities under the headings listed at Appendix D. Although this might be considered to have introduced significant observer bias, it allowed the interviewee the opportunity to clarify their understanding of their original statements in questionnaires and subsequent interview. It also allowed the researcher to clarify points to answer the research question. Subsequent Thematic Analysis (TA) highlighted several Themes or issues believed to be important by the interviewees in preparation and delivery of Building Pathology modules further to or in addition to the perceived priorities discussed at 6.3.2 above. Observer Bias is likely to have occurred in both coding and analysis; especially given the researchers special interest in the subject. However, the possible implications of this bias have been discussed for each finding described below. Data sampling was also irregular; given the variable opportunities for presenting questions inherent in a semi structured online interview. However, these Themes are discussed below.

1. **Practical site experience:** The majority of interviewees believed that practical site experience was very important in the teaching and learning of Building Pathology modules. Although some believed that virtual site visits in conjunction with case studies as described above were as useful or if not more useful; there was a general opinion

that hands-on experience of using equipment and inspecting buildings was an essential part of teaching and learning the subject. The majority of interviewees reported having special access to buildings owned by their institutions for this purpose. However, the interviewees generally appeared to believe that visits to actual building sites or investigations was less practical or useful. This was because of health and safety and security concerns, the practicality of large numbers of students visiting a site, and problems associated with students becoming distracted from productive learning activities when in an unfamiliar environment. Fort example quoting Interviewee 6:" *On both of the building pathology modules I teach, the most important part of that and the best teaching is when we actually physically go and do a survey or a case study. Effectively, it's a practical application of the theory that has been learned*". While Interviewee 7 reported:" *When I was teaching I tried to take students out on site and to do actual surveys, but I found it very difficult with Such big numbers and I in the end I found that using videos of other people doing surveys and explaining what they were doing and why they were looking thing was more useful than taking them out on site and not being able to speak to all of them at same time*". And Interviewee 2 reported:" *Taking Students to site is crucial, but it's so difficult because if there was an incident or an accident you're in for a criminal prosecution. So the concept of taking people to a building site is much, much more problematic than it's ever been*".

2. **Experience in practice:** On prompting, their appeared to be a general recognition by interviewees that practical experience in surveying was crucial in developing the skills required for learning in Building Pathology and other aspects of Surveying. This could be from work experience prior to, during or after the formal taught course; and could be via previous work, sandwich courses, placements, or apprenticeships. All interviewees reported that at least some of their students benefited from the learning possible with practical experience. However, organisation and provision of this experience appeared to vary widely within and between institutions. In particular, no formal requirement appeared to be recognised requiring that this should be delivered

as part of RICS recognised courses in the UK. This was surprising given the apparent perceived importance of this aspect of teaching and learning of Building Pathology and other subjects in Surveying; and contrasted sharply with the acceptance of the importance of 'Practice based Learning' for teaching and learning in all the Medical professions; where Practice Based Learning is generally recognised as the basis for most courses ,and appropriate practical experience must be formally recorded and proved in order to obtain qualifications from academic and other institutions. For example, quoting Interviewee 3: "*The really big difference we see in our students is coming back after year three after placement for year four. They are coming back with a grown up mentally, and certainly have a lot more of the skills, and see the relevance of what they have done probably in year one and year two, well prepared to embark upon year four. With a proper mindset. This is my profession. This is what I want to learn*". Similarly, Interviewee 1 reported: *"Placement is a mandatory part of our course, so it is a learning activity rather than a year out. And we find that when they come back from placements, they're much better!".*

3. **Commentative Enquiry', Directed 'Flipped learning' and Practical Based learning:** The majority of interviewees appeared to apply the principals described in educational science in recent years as 'Commutative Enquiry', 'Practical Based learning' and directed 'Flipped Learning', and most appeared to recognise these terms. However, there did not appear to be a general interest in the application of modern trends in higher education pedagogy, and there appeared to be a degree of cynicism regarding this subject by at least some of the interviewees. This may reflect the individualistic character of the interviewees and the courses that they provided, as described above; and may also partially explain the lack of research and published papers on the subject of teaching and learning in Surveying generally and Building Pathology in particular. For example, quoting Interviewee 1:" *I did try an experiment, not on building pathology with what's called, flipped, lecturing where you give the materials to the students in advance.*

And then they're meant to come to the session. And that that didn't work, as 3/4 of the class hadn't done the work so you can't have a valuable session".

4. **Probability and risk management:** On prompting, many of the interviewees reported recognising the importance of getting Students to understand the probabilistic nature of Building Pathology investigations, although this generally appeared to be restricted to the problems with using electronic moisture meters for diagnosing 'damp problems'. None of the interviewees reported giving special instruction on the probabilistic nature of investigation and diagnosis, prognosis, or remediation. However, a number of interviewees reported concerns with getting Students to understand the importance of 'risk management'; in particular, with regard to preparation of reports and professional opinions. For example, quoting Interviewee 10*:" I would like to think that with Grenfell; that one of the lessons we can learn from that, is that everybody needs to understand the implications are not constructing a building property of not repairing and maintaining a building property. They could be disastrous; and that's where Building Pathology comes in"*.

5. **'Reflective Learning' and 'Near Pier Mentoring':** On prompting, all interviewees reported using 'Reflective Learning' and 'Pier or Near Pier Mentoring' techniques as part of their Building Pathology modules. This was reported to be encouraged on site visits, in workshops, and by coarse workbooks. However, there was some variation of the perceived importance of these teaching and learning techniques. For example, quoting Interviewee 2:" *Reflecting on what you do is really important and actually one of the things that's come out from my own research is that Surveyors generally don't find enough time to reflect*". And quoting Interviewee 4:" *We try to have seminars in smaller groups where we talk about the knowledge that we have, and then we look at that in applied situations which we try to get them to discuss. You know what might be the cause and you know the pathology on face value seems quite straightforward to them, but that actually the more you learn about it, the harder it is!*". And quoting Interviewee

5:" *You could be taught AutoCAD but you can't be taught how to be a good Surveyor. You can learn how to be a good Surveyor"*.

6. **Information used in preparation of Building Pathology modules:** Interviewees reported using a large range of materials in preparation of the Building Pathology modules at their institutions. In particular, the information available from the Royal Institute of Chartered Surveyors (RICS) through their online portal 'Iserve' was reported to be useful in both preparation and delivery of Building Pathology modules by all of the interviewees. However, some interviewees believed that the information available from the RICS from this and other sources was no longer very useful, and/or was less useful than in the past in preparing and/or delivering teaching and learning. Many of the interviewees mentioned information available from the Building Research Establishment (BRE) was very useful in preparing and delivering Building Pathology modules. A number of interviewees were also finding information available from the Chartered Institute of Buildings (CIOB) to be useful, and one interviewee reported finding information available from the Chartered Association of Building Engineers (CABE) to be especially useful. All interviewees reported using the standards published by the RICS for accreditation of courses in Building Surveying. However, interviewees reported that these were prescriptive rather than descriptive. Some interviewees referred to their own experience in higher education learning to be a Surveyor in reference to the Building Pathology modules that they prepared and presented. However, the extent to which interviewees had relied on courses delivered by their institutions in the past in preparing their current Building Pathology modules was not investigated. This is recognised by the research as an oversight and a possible area for future research. The majority of interviewees reported using textbooks on the subject to Building Pathology in preparing and delivering their modules on Building Pathology

6.3.4 Assessing efficacy of teaching and learning

The interviewees were asked for their opinions on the best ways of assessing the efficacy of teaching and learning in the questionnaire and during the interview. Their answers were then subject to Thematic Analysis (TA) as previously described. This revealed the Themes discussed below.

1. **Student Feedback:** All interviewees reported that Student Feedback was the most important method of assessing the efficacy of teaching and learning on the Building Pathology modules that they provided at their institutions. There appeared to be some variation of opinion of the usefulness of the formal Student Feedback provided to and via their institutions as part of National schemes. However, less formal Student Feedback during or after the courses they provided was generally thought to be very useful. For example quoting Interviewee 9:" *Yeah, so there's a horrible thing called the National Student Survey that rules my life. We get feedback from that*!".

2. **External Examiners:** Several interviewees reported receiving useful feedback from External Examiners in accessing the efficacy of teaching and learning, although many appeared to regard this to have less to do with the content and delivery of the course than in trying to ensure compliance, and in maintenance of standards

3. **Continuous Assessment:** All interviewees reported using Continuous Assessment as an important part of assessing the efficacy of teaching and learning in their Building Pathology modules, both for individual Students and for the course in general. However, the methodology of continuous assessment used appeared to vary widely between interviewees; including course work, exams, workbooks, participation in case studies and/or seminars, and employer feedback.

4. **Exams:** The performance of students in exams was reported by a number of interviewees as one of the most important methods of assessing the efficacy of teaching and learning on Building Pathology modules. However, a number of interviewees noted the difference between the ability of individual students to perform well in exams, and their actual ability in understanding principals and practice and applying the

methodologies of Building Pathology. In particular, it was noted by a number of interviewees that students direct from school and higher education were more likely to perform well in exams than more mature students on sandwich courses or apprenticeships, while the latter were more likely to be better at applying Building Pathology in a professional or practical environment.

5. **Employer Feedback:** Several interviewees reported that Employer Feedback was very useful in assessing the efficacy of teaching and learning of Building Pathology. However, only a few interviewees reported having a formal system for obtaining this feedback and most appeared to rely on informal methods. This may limit its general effectiveness.

6. **Feedback from the Royal Institute of Chartered Surveyors (RICS):** Interviewees reported receiving formal feedback from the RICS on a quinquennial assessment and validation of their surveying courses for professional qualification. Some interviewees believed this was crucial in assessing the efficacy of the teaching provided. However, the majority of interviewees did not report receiving regular useful feedback from the RICS enabling them to improve the teaching and learning provided on their Building Pathology modules.

6.3.5 Suggested improvements in time and resources

The interviewees were asked for their suggestions for improvements for the delivery of modules for teaching Building pathology in the questionnaire and on interview. Thematic analysis (TA) of the interviews and questionnaires showed that there was a general recognition among all interviewees that the time available for Building Pathology modules on Surveying courses was a limiting factor, but that the 'teaching time' available could not be practically increased given the other pressures on the courses. Interviewees appeared to believe that improved resources should therefore be provided; in particular, several interviewees suggested that access to buildings for teaching and training would be especially useful, and many proposed that improved interactive audio-visual presentation of case studies or ‘Schema’ would be particularly advantageous. There also appeared to be a general recognition by interviewees that more practical experience before or during the courses via ‘placements’, ‘sandwich courses’ or ‘apprenticeship schemes’ would be advantageous. Several interviewees suggested that a new textbook on Building Pathology was required; especially one focused on the requirements of students, rather than for example specialists in historic buildings.

6.4 Summary

This chapter reviewed the current practices in the preparation and the delivery of teaching and learning in Building Pathology modules in the UK; and these have evolved similar methodologies to those found to be useful in the teaching and learning of Clinical Reasoning in the medical professions. Although it is recognised that this is likely to have resulted in Observer Bias; the data gathered, and the subsequent Thematic Analysis (TA) described above appears to support this. In particular, there appears to be a general recognition of the importance of the use of ‘case studies or ‘Schema’ in teaching and learning, and a general recognition and use of techniques such as ‘Pier Mentoring’ or ‘Near Pier Mentoring’, ‘Reflective Learning’ and Practice Based Learning. However, the introduction to, and the learning of the metacognitive processes involved in diagnosis, prognosis, and remediation, do not generally appear to be specifically recognised or taught. In particular, although the importance of understanding the probabilistic nature of investigations and resulting information, and the probabilistic nature of diagnosis and prognosis was recognised on further questioning and prompting; this did not appear to be specifically taught. Similarly, the importance of ‘case histories’ and the general significance of time and the evolution of building structures and Building Pathologies; even in new buildings or buildings under construction, did not appear to be generally recognised, without prompting.

Based on these research findings it is suggested that teaching and learning interventions on the specific areas of the subject discussed at above may help in the continuous learning and application of holistic Building Pathology by students. In particular the researcher and a number of the interviewees believed that an introduction to these subjects could be usefully given at an early stage in the teaching of all Surveying courses, and more generally to any course for the teaching of other Building Professionals. It is proposed by the researcher that the early understanding of these processes would allow Students to optimise all the learning opportunities available to them from the start of their studies and throughout their career. This appears to be particularly likely to improve the continuous learning of Building Pathology if combined with improved systems for the presentation of and learning from case studies or 'Schema'; and with a more formal integration into a system of Practice Based Learning(Barrows, 1994), with formal Student and Employer feedback. This might be done via more formal systems of placement, sandwich courses, and/or apprenticeships, to manage and record the student's practical experience(Murray *et al.*, 2004; Wilkinson and Hoxley, 2005; Hoxley and Wilkinson, 2006; Yung, Lam and Yu, 2015; Hoxley, 2016). It is therefore proposed that students should be introduced to the metacognitive processes of diagnosis, prognosis, and remediation at an early stage during their training, introduced to the concept and methodologies of history taking; and any improvement in their understanding and application of holistic Building Pathology assessed. A draft synopsis for a Building Pathology course based on the findings described above was also prepared as shown in Table 6.2 and Appendix F.

CHAPTER 7: DEVELOPMENT OF METACOGNATIVE TOOLS AND SCHEMA FOR APPLICATION TO 'DAMP PROBLEMS' AS AN EXEMPLAR SUBSET OF PROBLEMS IN BUILDING PATHOLOGY

7.1 Introduction

Given the clear relationship between the subjects of Building Pathology and medical Pathology described at Chapter 2 and Chapter 3 above, and the apparent parallel evolution or development of methods for teaching and learning of the metacognitive processes needed for effective diagnosis in the subjects of Building pathology and medical Clinical Reasoning described at Chapter 5 and Chapter 6; it was decided to further explore the utility of exploiting this relationship; so as to provide further support to the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology; to allow the adaption of recent advances in the continuous learning of Medical Clinical Reasoning, to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology'.

Given the practically infinite number of ways that materials, structures, and environments can interact and fail to meet the changing requirements of occupancy over time in the built environment, that may then be the subject of diagnosis in Building Pathology; this was done by development of metacognitive tools and schema for application to 'damp problems' as an exemplar subset of problems in Building pathology. However, this Thesis is not all about 'dam problem', but it is intended to enable a more general understanding of the learning and application the diagnosis in Building Pathology. The approach of the researcher and others for the investigation, diagnosis, prognosis, and remediation of building pathologies, that has been evolving over 35 years in practice and described in Chapter 5 above, is based on a probabilistic assessment of a buildings 'Anatomy'; consisting of its structure, its component materials, and their characteristics. This is followed by the assessment of the buildings 'Physiology'; the most significant components of which generally involves the controlled or uncontrolled movement of moisture, air and energy through the structure and materials. Again, this is generally first based on a probabilistic assessment, which is then refined by further investigations and 'tests'; to narrow the probabilities, as necessary to allow the prognosis, and value-engineered management and/or remediation of the problem under investigation. Integral to this process is the recognition of the importance of the flow of time and evolutionary processes. As in the parallel or 'sister subject' of Clinical Reasoning and Diagnosis for the medical professions, this is formalised in the taking of a 'Case History' as described at Chapter 5 above.

Using this approach, an existing building or structure can be regarded as a continuing experiment over time; and its performance under the environmental conditions and occupancy it has been exposed to accessed. Perceived or relative 'Building Pathologies' can then be identified affecting the functional 'Anatomy' and 'Physiology' of the building, and their causes Diagnosed. This is a cyclical metacognitive process involving the continuous learning and development of procedures and schema to allow a systematic and holistic understanding of the process of Building Pathology with experience. Obviously this a very extensive and complex subject for investigation; but the principals involved may be investigated by reference to 'damp problems' in buildings as a subset of problems in Building pathology, as described below.

7.2 'Damp problems' as a subset of problems for investigation and remediation in Building Pathology

The investigation of 'damp problems and their remediation is a useful exemplar subset of problems in the subject of Building Pathology as in the real world it is not practical or even possible to keep moisture out of buildings especially when occupied, or in the majority of the parts of the world where natural precipitation is to be expected. It has been noted by the researcher and others that the majority of perceived problems in buildings and the built environment are associated with moisture movement within buildings and building materials. This is the case with historic buildings, older building stocks, buildings being repurposed, and new buildings or buildings under construction(Hutton, Lloyd and Singh, 1992b; Burkinshaw, 2003.; Hutton, Timothy and Charles, 2004; Hutton, Timothy and Charles, 2012; Wang and Wang, 2012; Parrett, 2016; Burkinshaw, 2020). For this reason, it can be argued that a significant proportion of the cost of construction, maintenance and remediation in buildings is directly or indirectly related to 'damp problems'. This may appear to be an extraordinary assertion. However, it could be considered that in the natural world generally the majority of physical erosion, chemical corrosion or biological effects understood under the subject of Biogeomorphology (Viles, 1988; Naylor *et al.*, 2002), and that effect everything from the materials in the natural environment to the built environment are related to moisture movement. For example, the erosion of mountains, the creation of river valleys, the shaping of continents, or on a smaller scale the deposition of geological strata such as sandstone, limestone and chalk are the result of moisture movement. Similarly, the deposition of geological strata based on biological organisms such as limestone and chalk, the formation and decay of biologically based materials such as the decay of timber and the formation of petrochemicals are moisture dependent. It should therefore be expected that structures created by biological organisms including human society would be subject to similar processes as understood in the subject of 'anthropogeomorphology' (Goudie and Viles, 2016), and discussed in Chapter 2 above. However, those involved in the investigation and remediation of problems in Building Pathology in the UK and elsewhere have generally recognised the significance of the proper diagnosis and remediation of damp problems in resolving building pathologies (De Fino and Scioti; Harris, 2001; Macdonald, 2008; Watt, 2009; Neils-Jogen Aacaard, 2014; Delgado, 2016a).

It is apparent that this was implicitly if not explicitly understood in the past, when our ancestors evolved many building details, processes and maintenance methodologies so as to control and manage moisture movement through buildings and through building materials; as discussed at Chapter 2 above. More recently those involved in the investigation and remediation of building problems in the UK have recognised the importance of the effective diagnosis and remediation of damp related problems and a number of technical articles and books have been published on this subject (Hutton and Lloyd, 1993; Hutton, 2004; Hutton, 2012; Parrett, 2016; Burkinshaw, 2020). Current best practice in the investigation and remediation of damp problems in Building Pathology can therefore be combined with current best practice in diagnosis and remediation in Clinical Reasoning in the medical professions to create a schema or methods for the investigation and remediation of damp problems as an exemplar subset of problems in Building Pathology as described at 7.3 below.

7.3 Schema or methods for investigation of 'damp problems' based on current best practice in medical clinical reasoning and practical Building Pathology

7.3.1 Moisture movement as the fundamental component of 'damp problems' in buildings

The term 'damp problems' in buildings is generally used to refer to any perceived problem in the building or built environment thought to be associated with water or moisture. As described above water or moisture is an essential part of physical erosion, chemical corrosion and/or biological decay. None of these are static but are dynamic and evolving processes over time. It is therefore important to understand moisture or water movement over and through buildings, their component structures, or materials in order to have any practical understanding for diagnosis or remediation of these perceived problems. For this reason, the researcher and others have developed a metacognitive mental model of these processes that can be constructed, developed, and interrogated as part of the process of diagnosis and remediation in Building Pathology. In particular, the mental model and if necessary, the virtual drawn or electronically developed model of the building structure or 'anatomy' is overlaid with the known or suspected 'moisture sources', 'moisture sinks' and 'moisture reservoirs' (Hutton *et al.,* 1992a). This is illustrated in the diagrams in Figures 7.1, 7.2, and 7.3.

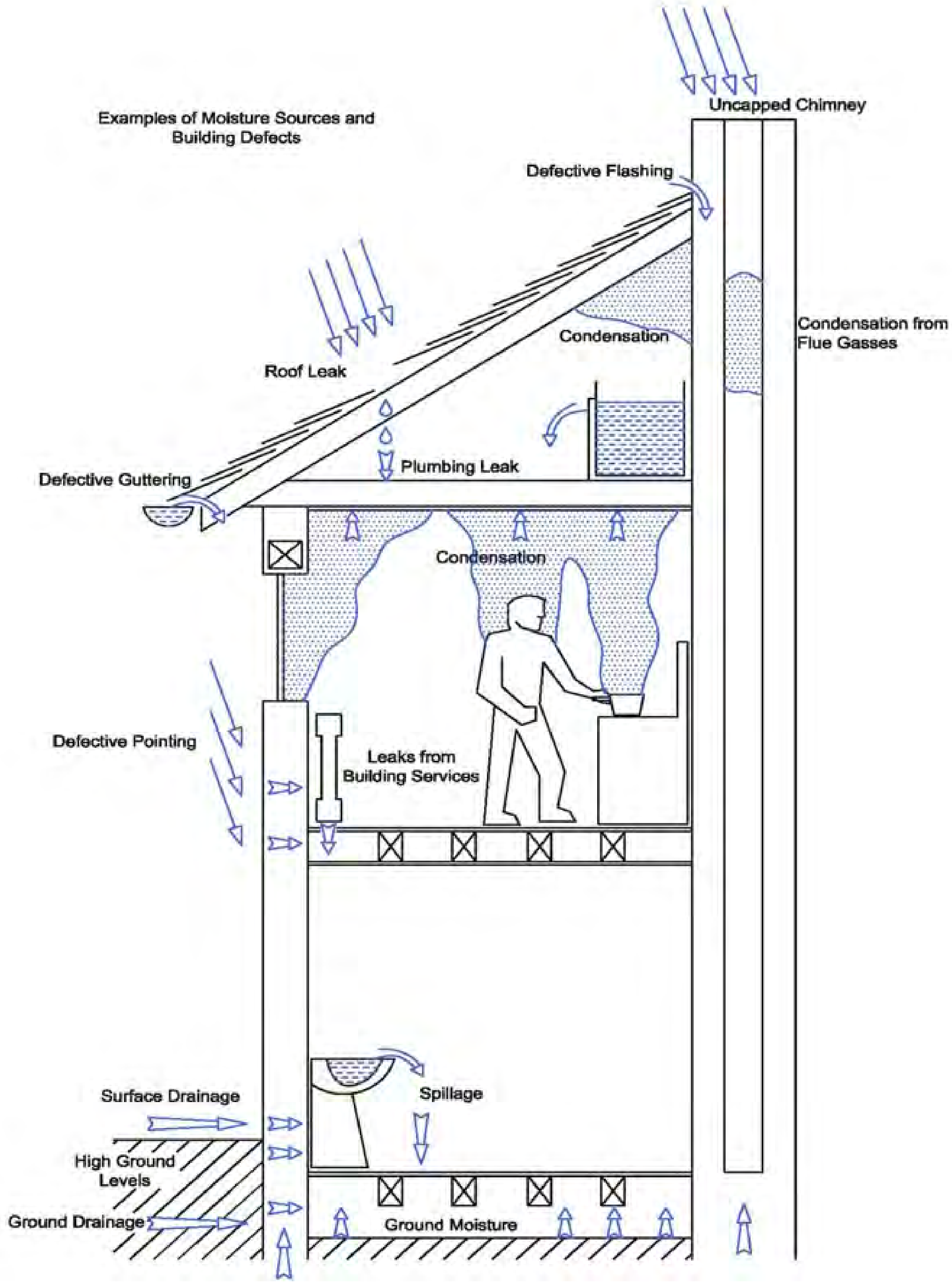

Figure 7.1: 'Physiology' of Buildings Showing Moisture Movement: 'Moisture Sources' (Hutton *et al.*, 1992a)

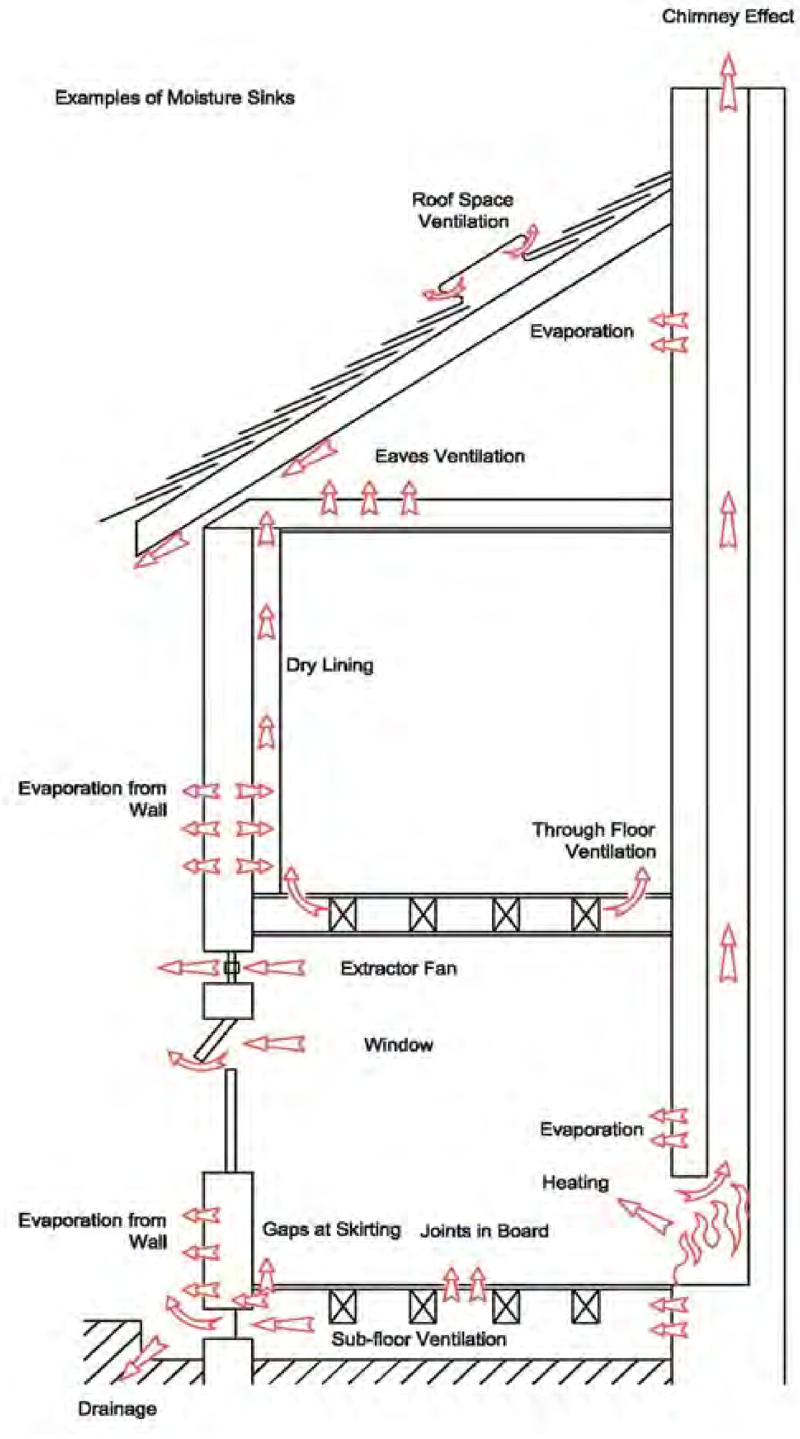

Figure 7.2: ‘Physiology’ of Buildings showing moisture movement: ‘Moisture Sinks’
(Hutton et al., 1992)

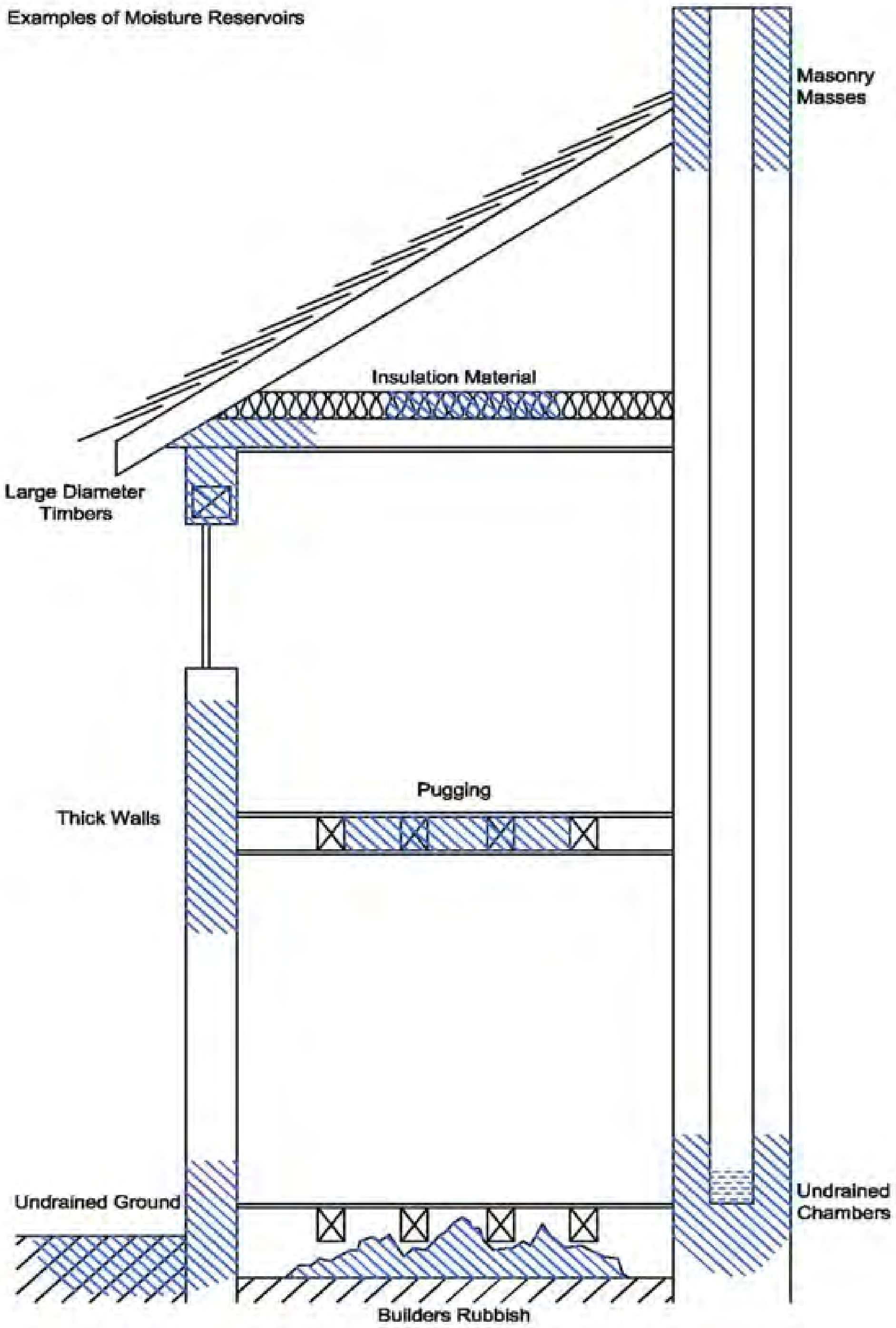

Figure 7.3: 'Physiology' of Buildings showing moisture movement: 'Moisture Reservoirs'

(Hutton et al., 1992)

It will be understood that if a moisture source in a building as shown in Figure 7.1 above is not balanced by an appropriate moisture sink as shown in Figure 7.2 above, moisture or even liquid water is likely to accumulate resulting in a moisture reservoir as shown in Figure 7.3 above. The identification and probabilistic assessment of these moisture sinks, and moisture reservoirs are therefore an important part of enquiry for both history taking and further investigation in any Building Pathology case or case study as described in Figure 7.4. This schematic diagram illustrates an example of the cyclical metacognitive processes used by the researcher and others for the continuous learning and development of procedures and methods to allow a systematic and holistic understanding of the process of Building Pathology with experience in practice, using the example of apparent 'damp problems' in buildings. It should be noted that these are filled out and developed with individual experience, and that similar metacognitive processes will be followed for other aspects of building 'Anatomy' and Physiology'. It should also be noted that that these will form a metacognitive network of interconnected probabilistic assessment processes, adapting and evolving to circumstances over time, rather than linear decision-trees identifying defects in materials or details at a moment in time.

7.3.2 Metacognitive protocols and 'check lists' for investigating 'damp problems' in buildings

A number of authors have proposed protocols or 'check lists' for the metacognitive processes for investigating damp problems in buildings (Burkinshaw, 2003.; Douglas and Ransom, 2013; Burkinshaw, 2020). Such check lists were first introduced in aviation and associated engineering professions, and in the military and emergency services; where critical decisions had to be made under stressful circumstances and with limited timeframes. These therefore have relevance in identifying and managing risks in diagnosis and remediate in emergency medical situations. Such check lists may also be used in the process of clinical reasoning in the review of differential diagnoses as described at Chapter 5 above. Although it is now generally recognised in medical Clinical Reasoning that they do not adequately represent the actual metacognitive processes required for actual differential diagnosis and remediation, these may form the basic scaffolding on which the information can be

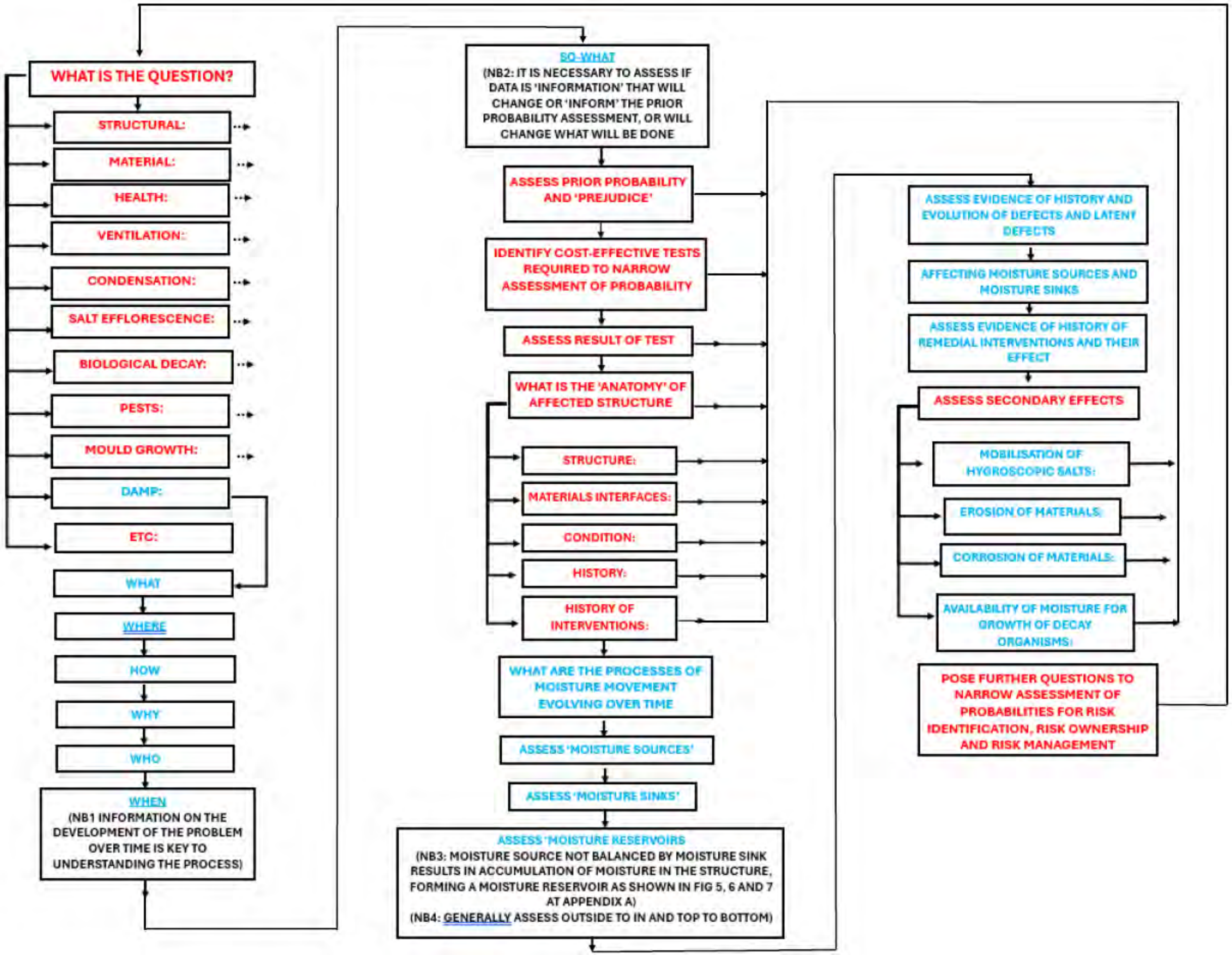

Figure 7.4 Diagram Showing example of Metacognitive Process for Investigating Damp Problems in Building Pathology

Note that considerations that may be generic to the metacognitive process are highlighted in red and considerations specific to the assessment of 'damp in buildings' are highlighted in blue, while notes and links are marked in black.

gathered and the metacognitive process of diagnosis may be learnt (Bosk *et al.*, 2009; Thomassen *et al.*, 2014; Chai *et al.*, 2017; McKenzie, 2022). This has been incorporated in many standard methodologies for gathering information on a patient's condition and medical problem or 'Case History' in a standardised written Patient Report Form (PRF). These are increasingly in electronic format and web-based, and are generally similar to the example shown at Appendix F (Kuisma *et al.*, 2009; Bellary *et al.*, 2014; Altuwaijri *et al.*, 2019). In this context it can be noted that the learning of standard report righting formats or templates can aid in the metacognitive processes needed to gather information during a Survey or other investigation, and can help in the production of useful recommendations in reports. This has been noted over many years of professional practice by the researcher and by others, as noted in Chapter 6.

7.3.3 Proposed protocol, methodology or schema for taking and reviewing a Case History for damp problems in Building Pathology

As described in Chapter 5, the effective gathering and review of data and information forming the 'Case History' for medical diagnosis and remediation has evolved over many years, and has been more recently studied as part of medial Clinical Reasoning(Warner *et al.*, 1972; Hampton *et al.*, 1975; Keifenheim *et al.*, 2015). These protocols and methodologies have been incorporated into standard 'patient report forms' (PRFs) which have been paper based in the past, but which are increasingly electronic and on web-based intranets, as described in section 7.3.2 . This current best practice in Clinical Reasoning can be adapted for the diagnosis and remediation of 'damp problems' or other problems in Building Pathology in accordance with the 'step-by-step guide' or protocol for diagnosis, proposed in Chapter 5 and summarised in Table 5.3 in Chapter 5. This is described for 'damp problems' under the headings and sub-headings listed at 7.3.4. However, it should be recognised that all data and information gathered in the diagnostic process will be probabilistic in nature and will be changing over time. Any inferences or conclusions drawn will therefore also include a component assessing its probability. This generally requires a specialist medical or building professional to explain the probabilities to the non-specialist client. This may be referred to as a 'health warning'; so as to allow them to properly appreciate and manage the risks associated with the case and its remediation (Timmermans, 1999; Dahm and Crock, 2022). This is discussed further below.

7.3.4 Proposal for Case History Taking for 'damp problems' in buildings

1. **Assessments prior to site visit:**

   i) **Presenting complaint:** What are the client's complaints or questions (note this is often not the actual problem on site).

   ii) **History of presenting complaint:** How long has the presenting complaint been a known problem and history of any previous investigations, reports and remedial interventions (a 'timeline' and sequence for these may be important).

   iii) **Potential health and safety hazards or concerns:** This includes potential hazards to the general public, building occupiers, and the investigators (for example structural failures, asbestos or other potentially hazardous materials, electrical hazards, water hazards and environmental hazards such as mould growth or even potentially dangerous animals occupying the building or adjacent areas.

   iv) **Probable building structures and materials affected:** This may be inferred by the reported original purpose and location of the building, its date of construction, the reported history of previous refurbishments or remodelling, and the date or level of completion of a new building or building under construction.

2. **On arrival:**

   On arrival on site information can generally be obtained by a visual assessment prior to entering the building or site.

i) **Health and safety:** The potential hazards to the public, occupants and investigators should be reviewed. This may be done by observation of activities or lack of activities on site, health and safety signage, preliminary questioning of other people on site or other methods.

ii) **Review of inferred history**: Review inferred history from information provided from assessments prior to site visit at 1 above with regards to probable structure and history**.**

iii) **Interview:** Interview of client's representative, occupants, tenants, landlords, workman, facility managers and other building professionals on site often elicit information that is different to that provided prior to the site visit as described at 1 above. This helps a probabilistic assessment to be made of the accuracy of the information provided. It is also found by experienced investigators that someone often knows the contributory causes of the presenting complaint but have been ignored, or have been reluctant to give what information they have prior to the investigation.

iv) **Written information:** Written or printed information is often available on site which has not been available prior to the site visit. This may include written records, photographs, and drawings.

v) **Visual inspection:** Visual inspection of the exteriors and interiors of the building from 'top to bottom' as previously described will often find indications of the history of the presenting complaint. For example, green algal or plant growth on the exterior masonry of the building indicates current damp conditions affecting the masonry for months or even years depending on the species and nature of the algal or plant growth; while visible evidence of salt efflorescence indicates that the affected surface was wet or damp in the past but has since dried.

3. **History of remedial interventions and/or refurbishments:**

   i) **Verbal enquiry:** Verbal enquiry will often elicit useful information on the history of previous remedial interventions and refurbishments from client's representatives, occupants, tenants, or others.

   ii) **Written or printed information:** Written or printed information recording previous remedial interventions and/or refurbishments may be found on site or obtained during or after the site investigation, and the relative success or failure of these interventions can be important in obtaining the probability of any diagnosis or differential diagnosis.

   iii) **Visual inspection:** Visual evidence of previous remedial treatments, refurbishment, and re-modelling both externally and internally will give useful information on the development and evolution of the building pathologies on site. Similarly, visual inspection may reveal evidence of previous remedial treatments and re-modelling on similar or adjacent structures on site or in the area which may be used to inform the probabilistic assessment of the diagnosis and remediation of the problem under investigation. This can be especially useful where there are rows of buildings or structures of similar date and construction which can be interpreted as repeat experiments or controls.

4. **Social history:**

   i) **Occupancy:** Current and past occupancy including domestic use, industrial use or other occupancy; and whether the building is intermittently or continuously occupied.

   ii) **Heating and ventilation:** Current and past history of heating and ventilation.

iii) Inspection and maintenance: Current and past history of inspection and maintenance.

5. Observations:

Observations and investigations are undertaken on site or by taking samples for testing elsewhere; to provide more data or information to clarify the data and information already gathered as described above, and to clarify the probabilities of the various diagnoses and differential diagnoses resulting from this information. It is generally understood in science including the medical sciences that all observations and data have a probabilistic component and will vary with time and the observer. This is therefore also true for observations made as part of diagnosis in Building Pathology, including the investigation of damp problems. In such investigations several techniques are generally used as part of good practice. Further to the preliminary observations described above. All of these will give variable readings and results, but this is often poorly understood by most investigators. However, the following techniques are often used (Hutton, 2012; Parrett, 2016; Burkinshaw, 2020).

i) Electronic resistance-based timber moisture meter: These may give a useful indication of the moisture content of timber elements between approximately 6 and 30 per cent moisture content weight for weight (w/w). However, over approximately 33 per cent timber moisture content w/w most species of timber reach ‘fibre saturation’ and results become difficult to interpret and are often meaningless. The calibration of these meters should vary with different species of timber, and readings may vary widely due to contamination by for example chemical remedial treatments or hygroscopic salts. Adhesives used in plywood and other composite timbers often result in erroneous results, and electronic resistance-based moisture meters are often inappropriately used to try and determine the moisture content of other materials other than timber. This results in erroneous results. For these reasons it is generally good practice to use electronic resistance based moisture meters and other techniques to compare and contrast readings from different parts of the structure under investigation, to compare and contrast readings over time, the ability of an investigator to do this is very dependent on their prior experience with the technique, or even the individual instrument being used, and their ability to effectively 'self-calibrate' and interpret the readings they are obtaining. It should be note that resistance-based meter readings from a particular piece of timber will vary widely on the depth at which the reading is taken. This may be due to actual changes in moisture distribution through the material or to differences in for example surface contamination or treatment of the surfaces of timber compared to the deeper parts of the fabric. As previously mentioned, electronic resistance-based moisture meters are commonly used to take readings from plaster or masonry surfaces. Resistance based moisture meters may only be used in this way as a quick preliminary way of identifying possible problems with moisture and salts on surface of materials by very experienced operator. These readings are often misinterpreted either due to ignorance or fraudulently.

ii) **Capacitance and radiofrequency electronic material moisture content meters:** Electronic capacitance and/or radiofrequency electronic meters may be used to assess the possible moisture content of materials. However, these electronic readings are widely variable due to many factors other than the gravimetric moisture content. For this reason, it is rarely practical or even possible to calibrate such meters to achieve useful precision and accuracy for their readings, and they are therefore often used as only a preliminary method of identifying possible areas or materials for further investigation as described below.

iii) **Gravimetric analysis of material moisture content:** Gravimetric analysis of representative samples of materials taken from buildings is generally the most reliable reproducible, and scientifically valid method of determining the probable moisture content and distribution of moisture in buildings. In the UK, this is generally done following the methodology described in BRE Digest DG 245:2007 (Trotman and Peter, 2007) and is most efficiently done by waying and oven drying in a Laboratory to allow the calculation of the weight for weight (w/w) gravimetric moisture content of the sample. Because many building materials are hygroscopic and/or become contaminated with hygroscopic salts; it is generally also necessary to determine the hygroscopic moisture content following the recommendations in the BRE Digest DG 245. The w/w hygroscopic moisture content can then be subtracted from the w/w total moisture content and the 'available' moisture content calculated. This is a useful indicator of the moisture available to decay organisms, or able to readily migrate into adjoining materials. Hundreds of samples can be taken and processed in this way; allowing gravimetric, hygroscopic salt, and available moisture profiles and distributions to be assessed in the structures under investigation. Similarly repeated sampling over time can allow the monitoring moisture penetration or drying of the materials under investigation.

iv) **Infra-red thermography:** Infra-red thermography has been increasingly used as an aid to investigate damp problems associated with condensation and drying; as it represents a practical way of measuring surface temperatures of potentially affected structures. Infra-red thermography may also be used to identify current or recent water penetration due to the differential temperature resulting from relative cold water penetrating the structure and/or evaporating from affected surfaces. Infra-red thermal cameras may also be used for identifying leaks from water pipes; especially from underfloor heating systems. However, the proper calibration and operation of the infra-red cameras used is critical in the accuracy of the results; and the interpretation of the images obtained is dependent on the experience of the investigator.

v) **Computer modelling:** Computer modelling has been increasingly employed so as to determine the probable risk of interstitial or superficial condensation within designed or as-built structures. This has become a particular problem in the UK with the introduction of Building Regulations Parts E and L (Government, 2023) and a number of computer packages such as WUFI are available (Karagiozis, Künzel and Holm, 2001). However, the inputting of data into the computer model and the interpretation of the results are critically dependent on the knowledge and experience of the investigator.

vi) **Monitoring:** Because damp problems and other problems in Building Pathology evolve and vary over space and time it can be necessary to 'monitor' parameters such as moisture content, water level, temperature, and relative humidity over time. Many electronic, wired and radio-telemetric systems are now available that can be usefully deployed for this purpose(Hutton and Lloyd, 1993; Hutton *et al.*, 1995). However, the location of sensors, and the interpretation of resultant readings is very dependent on the experience and expertise of the investigator. It is for this reason, that in his professional live, the researcher has found the majority of the 'data' from such systems is often not properly gathered or interpreted in a useful time frame, or not even gathered; and that 'monitoring systems' installed in buildings in the UK in the past have often been of little of no practical use for diagnosis or for risk-management.

6. **Impression or Diagnosis and Differential Diagnosis:** From the above it will be apparent that data or information obtained from one set of observations will generally require review and reinterpretation by taking further observations either taking the same or a different technique. The process of observation and the interpretation of the data and information gained is therefore always a cyclical process; in which the Diagnosis and the probabilities of Differential Diagnoses are refined by further observation. Similarly, the results of remedial interventions must be reviewed by reference to further observations. A probable Diagnosis is then identified by the investigator based on their impression of the information or evidence available, on which proposals for remedial actions or 'treatments' can be

based; as described at 7 below (Andrade *et al.*, 1968; Warner *et al.*, 1972; García-Morales and Palomo, 1998; Lanzinha, Freitas and Castro-Gomes, 2002; Delgado, 2016b).

7. **Treatment or remedial actions:** Remedial actions are proposed by the investigator based on the Diagnosis and Differential Diagnosis described at 6 above. These remedial actions may include further investigations and management measures. A number of options may be proposed by the investigator for consideration by the building owners, building occupiers, and other interested parties. These will generally be reviewed and decided on, based on the preserved cost-befit of the proposed remedial actions; as advised by the Investigator based on the information gathered as described above. Factors such as short-term and longer-term monetary costs, the effect on occupants and occupancy, the effect on the capital value and service-life of the property, the time required for remediation, the conservation or loss of original materials, and the perceived risk and the risk appetite of the interested parties involved are generally implicitly or explicitly considered. Obviously, the perceived cost-benefit of remedial measures may vary widely for the different interested parties, and are likely to vary over time. In these circumstances the perceived most cost-effective options may also vary wildly between interested parties; for example, from the demolition and re-building of the damp effected structure, to doing nothing and continuing to live with the perceived damp problem (Atkinson, 2002; Chong and Low, 2006; Hopkin *et al.*, 2017; Denman *et al.*, 2024).

8. **Risk management:** Each stage of the diagnostic process described above is probabilistic in nature, and the decisions based on any Diagnosis will be consciously or unconsciously based on a probabilistic assessment by those making any decisions. This is true for both the probabilistic assessment of the cost-benefit or 'Utility' of the intervention described at 7 above; or the probabilistic assessment of the hazards or 'Risks'. Obviously, the perceived Risks and the 'risk-appetite' will be different for the different interested parties (Flüeler and Seiler, 2003; Edwards, 2017; Denman *et al.*, 2024). These perceived risks will therefor need to be owned, managed, or

eliminated as necessary for each interested party. Generally, the factors described below need to be assessed before and during the investigation, and remediation of damp problems in buildings:

i) **Health and safety:** Measures necessary to manage any risks to the Health and Safety of any occupants, to the public, to any workers or managers, to any visitors, and to Investigators and Surveyors, should be considered.

ii) **Structures and materials subject to investigation and remediation:** Measures necessary to manage the risks of further damp related problems or other problems effecting the structures and materials subject to investigation and remediation, should be considered.

iii) **Effect on other structures and materials:** Measures necessary to manage the risks to other structures and materials should be considered. For example, in structures adjacent to the structures and materials subject to investigation and remediation.

iv) **Liability**: Measures necessary to manage the liability of those involved in the causation, investigation, and remediation of the problems investigated, should be c considered. For example, liability under the current Construction Design and Management Regulations in the UK, and liability failures to any works or materials covered by Guarantees or Warranties.

v) **Environment:** Measures necessary to protect the Environment from hazards resulting from the problems under investigation and their remediation, should be considered.

vi) Insurance: Measures necessary to ensure adequate provision or continuation of insurance cover for any risk management measures.

Current best practice in medical Clinical Reasoning can be adapted for the diagnosis and remediation of 'damp problems' in accordance with current best practice in Building Pathology as described at Chapter 5 above under the headings and sub-headings listed below.

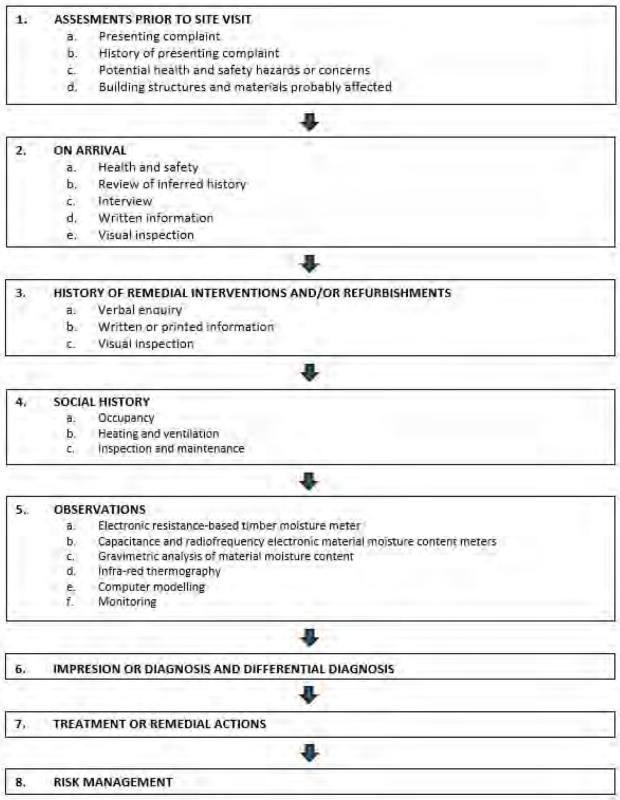

Figure 7.5: Flowchart Showing Methodology for Taking Case History for Diagnosis of Damp Problems in Building Pathology

7.4 Summary

It has been shown in Chapter 7 above that it is possible to combine current best practice in the practical application of medical Clinical Reasoning and in practical Building Pathology, to develop metacognitive tools and schema for application to the diagnosis and remediation of 'damp problems' as an exemplar subset of problems in Building Pathology. This might reasonably be expected, given the background research and findings described in the previous Chapters of this Thesis. Similarly, it can reasonably be expected that this and other recent developments from the continuous learning and application in the subject of medical Clinical Reasoning could be used to help in the learning and application of the metacognitive process required for Building Pathology. However, the objective assessment of the effect of learning interventions is notoriously difficult. This has been a particular problem in assessing learning interventions in medical Clinical Reasoning, where the financial, organisational, and social stakes are very high (Oskamp, 1962; Hatala and Guyatt, 2002; Reed *et al.*, 2005; Steinert *et al.*, 2006; Keifenheim *et al.*, 2015; McLean, 2016). It might therefor be reasonably expected that the methods of assessment developed for assessing interventions in medical Clinical Reasoning could be usefully adapted for assessing the metacognitive process used in diagnosis in Building Pathology as described in Chapter 8.

CHAPTER 8: TESTING THE LEARNING OF EFFECTIVE SCHEMA FOR APPLICATION TO 'DAMP PROBLEMS' BY THE DEVELOPMENT AND APPLICATION OF SCRIPT CONCORDANCE TESTS TO STUDENTS, PRACTITIONERS AND EXPERTS IN BUILDING PATHOLOGY

8.1 Introduction

The research described above has identified the parallel development of the metacognitive process for diagnosis and remediation or 'treatment' in Medical Clinical Reasoning and Building Pathology. In particular, this research identified the importance of developing diagnostic Scripts or Schema by working through real Case Studies and/or virtual Case Studies or Scenarios, for learning and developing the metacognitive skills required. Research into recent advances in the teaching, and continuous learning of Medical Clinical Reasoning described in Chapter 5, and current best practice in the teaching and learning of Building Pathology described in Chapter 6; has also identified several other learning interventions that may be useful in the teaching and continuous learning of diagnostic reasoning for Building Pathology. However, no objective, reproducible, quantifiable and statistically valid methodology to assess any such learning interventions are currently generally available. Therefore to further test the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology; to allow the adaption of recent advances in the continuous learning of Medical Clinical Reasoning, to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology' it was decided to test if a methodology developed for testing clinical Reasoning could be adapted for this purpose. Similar problems were identified during the development of the subject of medical Clinical Reasoning over 20 years ago, and several methodologies for this purpose were developed and tested. The most widely used test developed for this purpose in medical Clinic Reasoning has been the methodology called the Script Concordance Test (SCT) (Charlin *et al.*, 2000; Charlin *et al.*, 2000a; Cobb *et al.*, 2015). These are multiple-choice tests with questions based on relevant virtual Case

Studies or Scenarios covering Diagnosis and treatment in a particular medical discipline. In these Script Concordance Tests the examinee or Student is presented with a question based on the Scenario, and is invited to select a multiple-choice answer based on their perception of the probability of the correctness of the suggested answer to the question. The statistical 'Concordance' of the multiple-chois answers selected by the examinee or Student with those selected by a panel of 'Experts' in diagnosis and treatment in a particular medical discipline, can then be used to assess the relative expertise of students of a subject compared with these Experts, with their peers, or against the acceptable levels of expertise for professional practice. These Script Concordance Tests have also been found to be useful teaching and learning tools, when students repeatedly work through the virtual Case Studies or Scenarios in the tests (Cobb *et al.*, 2015; Tayce and Saunders, 2022). Given the parallels between Medical Clinical Reasoning and Building Pathology; it was decided by the researcher to develop and trial a Script Concordance Test for testing and learning expertise in diagnosis and remediation in the subject of damp problems in buildings, as an exemplar subset of the subject of Building Pathology as described below.

8.2 The Development and Use of Script Concordance Tests for Medical Clinical Reasoning

The rapid expansion of the scope and complexity of modern medicine in the 20th century and continuing into the 21st century discussed at Chapter 5 above, resulted in the requirement to train increasing numbers of medical practitioners of all sorts, in increasing numbers of speciality areas of medicine. This resulted in the need for educators and regulators to develop objective, reproducible, quantifiable and statistically valid methods to ensure that students of different medical subjects and professions met agreed standards, and had adequate levels of expertise and competency to provide safe and cost-effective medical services to patients (Ackerknecht, 2016; Stirling, 2023). The subject now described as 'Clinical Reasoning' developed during this period to study and develop the metacognitive process required in Diagnosis and Treatment, and several methodologies for providing such tests were proposed.

These were generally based on Multiple-Choice tests so as to facilitate efficient delivery and marking of the tests, and in recent decades were increasingly delivered in electronic and eventually web based platforms; so as to allow efficient delivery and marking (Charlin *et al.*, 2000b; Brailovsky *et al.*, 2001; Eva, 2005; Norman, 2005; Bowen, 2006; Eva *et al.*, 2007; Kassirer, 2010; Pelaccia *et al.*, 2011; Rencic, 2011; Linn *et al.*, 2012; Marcum, 2012; van Bruggen *et al.*, 2012; Cooper and Frain, 2016; Houchens *et al.*, 2017; Custers, 2018a; Custers, 2018b; Higgs *et al.*, 2018; Duca *et al.*, 2020). The Script Concordance Test (SCT) proposed by Charlin, Roy, Brailovsky, Goulet and Van der Vleuten in 2000 was '*designed to prove whether knowledge of examinees is efficiently organised for clinical actions'*. The methodology used and hence the name of the test was based on 'Script Theory' which proposes that knowledge is held and used based on prior experience, and the SCT aimed to present examinees with information based on authentic clinical situations which data must be interpreted to make decisions (Charlin *et al.*, 2000; Brailovsky *et al.*, 2001).

The SCT was originally designed to measure the degree of 'concordance' between the examinee's scripts and the scripts of a panel of experts. The SCT has been described as having three key design features as described by Lubarsk, Dory, Duggan, Gagnon and Charlin in 2013 (Lubarsky *et al.*, 2011): *'(1) Respondents are faced with ill-defined clinical situations and must choose between several realistic options, (2) Response that reflects the way in which information is processed in challenging problems/solving situations, (3) Scoring takes into account the variability of responses of experts to clinical situations*' . To do this the SCT relies on statistical analysis of multiple-choice answers scored in a Likert scale (Charlin *et al.*, 2000; Brailovsky *et al.*, 2001; Karila *et al.*, 2018). For example, Scenarios may be followed by a series of questions presented in three parts. The first part 'if you were thinking of' contains a relevant diagnostic or management option. The second part 'and then you were to find' presents a new clinical finding such as an observation or result of a test. The third part 'this option would become' is a five-point Likert scale that captures examinees decisions. The task of the examinees is to decide what effect the new finding has on the status of the option in direction (positive/negative or neutral), and intensity. This effect is captured with the Likert scale because Script theory assumes that clinical reasoning is composed of a series of qualitative judgements. Research has suggested that a 5-anchor Likert-type scale is most conveniently used for this purpose (Lubarsky *et al.*, 2011). However, it has been suggested that care should be taken in framing the questions to avoid situations where the null value might be used by examinees as a statistically safe choice in order to 'cheat' the objective of the examination (Wan, 2015; Wan, Tor and Hudson, 2018b; Wan, Tor and Hudson, 2020). Much research has been carried out on the use and validity of Script Concordance Tests since their inception in 2000, and there is an extensive literature on their statistical validity and practical utility. There is therefore a large body of research supporting the validity, reliability and feasibility of Script Concordance Tests across many health science disciplines and across the spectrum of education for health professions; from preclinical training to continuing professional development (Ramaekers *et al.*, 2010; Deschênes *et al.*, 2011; Dufour *et al.*, 2012; Cobb *et al.*, 2015; Vital *et al.*, 2021; Naylor *et al.*, 2024). Other test methodologies are widely used in Medicine, where Script Concordance Tests (SCT) may be used to assess clinical reasoning, and where they may be used alongside Multiple Choice Questions (MCQ) and Progressive Clinical Case tests (PCC) which test knowledge (Aljarallah, 2011; Aubart *et al.*, 2021a).

8.3 The Design and Development of a Script Concordance Test for Assessing Expertise in Diagnosis and Remediation of Damp Problems in Buildings

Because of the parallels between medical Clinical Reasoning and Building Pathology described above, the researcher decided to develop and trial Script Concordance Tests for testing and learning the expertise in diagnostics and remediation for the subject of damp problems in buildings; as an exemplar subset of the subject of Building Pathology; based on current good practice in the design of Script Concordance Tests in medical clinical reasoning. In particular reference was made to the seminal work by Charlin et al of 2000, and Fournier et al of 2008(Charlin *et al.*, 2000; Charlin *et al.*, 2000a; Charlin *et al.*, 2000b; Charlin *et al.*, 2007; Fournier *et al.*, 2008). To do this the researcher selected twenty representative cases representing the range of damp problems commonly found affecting buildings of a range of different types from his experience as a practicing Building Pathologist over the last 20 years.

Cases were selected as representative examples of particular damp problems in buildings, and were selected to include a range of the different types of construction, date and occupancy found in the UK. The written and photographic records from these cases were then used to draft Case Histories or Scenarios; to highlight the points within the case that decisions had to be made on investigation, diagnosis, remediation, and management where the knowledge and experience of a Building Pathologist was required, as shown at Appendix F. These case studies or scenarios were laid out so as to include at least one photograph which included information pertinent to the diagnosis; and diagnostic, remediation and decision points were laid out in accordance with the metacognitive protocols developed as current best practice in the application of practical Building Pathology, as described at Chapter 7 above. The Script Concordance Test is case based, with cases described as short scenarios which always incorporate uncertainty. The questions used are therefore formulated to be relevant to solve the diagnosis or management of the problems proposed by the Scenario, following best practice for Script Concordance Test construction, reflecting the place of uncertainty and the limitations of test material production (Dory *et al.*, 2012).

At each potential decision point in the case study or scenario; a question was posed on the diagnosis, remediation, or management of the case to test the knowledge and experience of the person working their way through the Script Concordance Tests (SCTs). This was done by offering further information from the case and asking for an answer based on the examinees probabilistic assessment of how this affected their opinion. This was done by presenting possible answers as a multiple choice 5-anchor Link to Scale as recommended as best practice for designing Script Concordance Tests in medical clinical reasoning. These draft test scenarios were then submitted to a panel of experienced Building Pathologists for review and comment and edited as necessary so as to optimise the quality of the drafting of the scenarios and questions. The resultant twenty scenarios and questions were then used to draft preliminary Script Concordance Tests as documents in Microsoft Word format. These were then loaded onto the JISC on-line survey platform as two on-line surveys or SCTs, each containing ten of these scenarios and associated questions, as shown at Appendix F. Expert practitioners in the subject of Building Pathology were then invited to undertake the on-line survey including the preliminary SCTs, and students studying for an MSc in Historic Building Conservation at Oxford Brooks University, or a BSc in Building Surveying at Nottingham Trent University were subsequently invited to complete these surveys and SCTs. The answers from the surveys and SCT tests on the JISC on-line platform were then downloaded as Excel files and processed to calculate the statistical concordance between the answers from 10 no. Experts, and from ?? no. Students who agreed to take the SCT tests. This was done by scoring based on the divergence between the answers provided by the reference panel of Experts and the Students following the methodology described by Charlin et al of 2000, and Fournier et al of 2008 (Charlin *et al.*, 2000; Charlin *et al.,*2000a; Charlin *et al.*, 2000b; Charlin *et al.*, 2007; Fournier *et al.*, 2008).

The way that the answers on the Likert Scale are converted to numerical data is best described by Fournier et al of 2008 "*Credits for each question are derived from the answers given by the reference panel. For each answer, the credit is the number of members that chose that answer, divided by the modal value for the question. If, for a given question, fifteen panel members chose "-2," two chose "-1" and one chose "0" credit for the "-2" is 1 (15/15), credit for the "-1" is 0.13 (2/15), and credit for the "0" is 0.06 (1/15). For the non-chosen options, "+1" and "+2," the credit is 0. With this method, all questions have the same maximum (1) and minimum (0) value. Scores obtained on each question are added to obtain a total score for the test. This number is then divided by the number of questions and multiplied by 100 to get a percentage score."*(Fournier, *et al.*, 2008). The necessary spread sheet calculations are summarised in Table 8.1 below.

Table 8.1: Summary of the calculation of Concordance between answers to Questions between Experts and Students taking Script Concordance Tests based on the methodology described by Charlin et al of 2000, and Fournier et al of 2008

Step 1 Survey responses are split into 2 no. classifications ‘**Expert**’ or ‘**Student**’ on an Xcel Spread Sheet.
Step 2 Answers are converted to numerical values by splitting each question into as many columns as there were answers using the Linklater Scale and assigning a ‘**1’** value for the answer option column equivalent to the answer option selected by the individual (**Numerical Answer Value).** This was repeated for each question and the results recorded in 2 tables on tabs ‘**Expert results’** and ‘**Student results’**.
Step 3 For each Expert their Total Score is calculated by summing the ‘**Individual Score for agreement with Experts**’ for all questions as follows: · Each answer column is then summed to calculate the value ‘**A’**. · For the Experts, using the summed values of each answer column for a question, the largest value of **‘A’** or the ‘**B’** value is identified. This is the answer option for a question with the greatest agreement amongst the Experts. · For each answer column to a question, the ‘**Sub-Q Score Value’** is then calculated: **A** / **B**. · Each Experts’ **Numerical Value Answer** is divided by the equivalent **Sub-Q Score Value** from the equivalent answer column. (**Individual Sub-Q Score Value**). · For each Expert their **Total Score** is calculated by summing the **Individual Sub-Q Score v**alue" for all questions. · The **Average Expert Score** or arithmetic mean of the Expert scores is then calculated. · Each Expert’s percentage of the **Maximum Possible Score** is then calculated.
Step 4 Each Student's **Numerical Value Answer** is divided by the equivalent **Sub-Q Score Value** from the equivalent answer column from the **Expert** results to determine the Individual Score for agreement or concordance with the **Average Expert Scores**. · Each answer column in the ‘**Students – scores’** tab is summed to calculate the value **C** · For the Students, using the summed values of each answer column for a question, the largest value of **C** or

the ‘**D**’ value is identified,. This is the answer option for a question with the greatest agreement or concordance with the Students answer with the Experts.
Step 5 For each Student their Total Score is calculated by summing the ‘**Individual Score for agreement with Experts**’ for all questions. · The Sum of all **D** Values is calculated. · Each Student's percentage of the Maximum score for agreement with the Experts is calculated, and the Students’ percentage of the **Average Expert Score**.
Step 6 The **Student D Value** row from the tab ‘**Student – scores’** was transferred to tab ‘**Top 50 Qs – Sub Data**’ along with the question and scenario numbers (Table 8.2 and Table 8.3). · The data was pivoted and filtered so only the **D** values were visible (Table 8.4). · Table 8.4 is sorted 'Smallest to Largest' for the **D** values. · This sorting identifies those questions the Student’s answers least agreed with those of the Experts.
Step 7 · Table 8.4 was transferred to tab ‘**Top 50 Qs – Results’** with the Top 50 Qs sorted by Scenario number. · On tab ‘**Top 50 Qs - Results**" an Effectiveness of Each Scenario to differentiate between Experts and Students table was created (Table 8.5). · A **VLOOKUP** formula was used to identify the number of questions in each Scenario from the tab ‘**Tracker - # of Q's**" or ’**E’** values. · A **COUNTIF** formula was used to identify the number of questions in each Scenario that also had been identified as being in the Top 50 questions to differentiate between Professionals and Students or **F** values. · Value **E** was divided by value **F** for each Scenario to identify an Effectiveness value ‘**G’** for each Scenario. · The closer Value **G** is to ‘1’, the more effective the Scenario was at differentiating between Students and Experts.

In order to optimize the two preliminary tests the fifty questions giving the highest divergence between the Experts and Students for each of the groups of ten case studies or scenarios from each of the preliminary SCTs on the JISC on-line survey platform were then identified as shown in Appendix G and in Table 8.2 below.

Table 8.2: Effectiveness of Questions in each Scenario to differentiate between Professionals and Students to determine the top 100 Questions From 20 Scenarios in the preliminary Script Concordance Tests

Scenario	**Number of Questions in Scenario (A)**	**Number of Questions in the Top 100 Questions (B)**	**Effectiveness of Scenario (B/A=C)**
1	11	4	0.36
2	12	4	0.33
3	15	3	0.20
4	16	7	0.44
5	12	6	0.50
6	13	6	0.46
7	16	8	0.50
8	14	9	0.64
9	15	8	0.53
10	13	9	0.69
11	14	5	0.36
12	13	1	0.08
13	11	1	0.09
14	11	5	0.45
15	16	5	0.31
16	16	5	0.31
17	14	4	0.29
18	17	5	0.29
19	16	4	0.25
20	18	1	0.06
		100	

The text of the draft scenarios and questions used in these preliminary SCTs were then edited to include these questions and to eliminate the other questions, while maintaining the information and technical validity of the draft scenarios, so as to have five questions for each scenario. These were then redrafted into the combined Full Script Concordance Test for Beta testing as shown at Appendix F. This consisted of twenty Scenarios with five Questions each, and a hundred questions in total in accordance with the recommendations of Lubarsky et al 2013 and Dory et al 2012(Lubarsky *et al.*, 2011; Dory *et al.*, 2012). Expert practitioners in the subject of Building Pathology were then invited to undertake the on-line survey, and students studying for an MSc in Historic Building Conservation at Oxford Brooks University, or a BSc in Building Surveying at Nottingham Trent University were subsequently invited to complete this survey and SCT test. The answers from the test on the JISC on-line platform were then downloaded as Excel files and processed a previously described to calculate the statistical concordance between the answers from the 10 no. Experts, and from 17 no. Students who agreed to undertake the full SCT test. The results are shown at Appendix G and summarised in Table 8.3 and Table 8.4 below:

Table 8.3: Expert Scores from Trial of Full Script Concordance Test

Number Assigned to Expert	**Total Score**	**Percentage of the Maximum Score**
675	93.53	80.6%
676	97.25	83.8%
677	91.42	78.8%
679	88.38	76.2%
680	98.11	84.6%
697	87.41	75.4%
699	88.37	76.2%
700	95.06	81.9%
701	94.14	81.2%
702	86.90	74.9%
704	89.53	77.2%
Maximum score	116	
Average Expert Score	91.83	79.2%

Table 8.4: Student Scores from Trial of Full Script Concordance Test

Number Assigned to Student	Total Score	Percentage of Maximum Score	Percentage of Average Expert Score
698	63.24	54.5%	68.9%
703	81.90	70.6%	89.2%
705	75.40	65.0%	82.1%
706	63.42	54.7%	69.1%
706	58.44	50.4%	63.6%
707	49.93	43.0%	54.4%
708	79.29	68.4%	86.4%
709	75.57	65.1%	82.3%
710	76.31	65.8%	83.1%
711	70.06	60.4%	76.3%
711	79.54	68.6%	86.6%
712	59.98	51.7%	65.3%
Maximum score	116		
Average Student Score	69.42	59.8%	75.6%

These results were then further analysed as shown at Appendix G and as described at Chapter 9 below.

8.4 Discussion

The problems with recruiting both Experts and Students to take the Script Concordance Tests (SCTs) without any financial, academic or professional inducements was to be expected given the time constraints of modern Professional and Academic life; especially during and after the COVID 19 epidemic. However, the strength of the SCT is that provided adequate numbers of Experts and Questions are used in preparing the test following the methodology described by Charlin et al of 2000, and Fournier et al of 2008 (Charlin *et al.*, 2000; Charlin *et al.*, 2000a; Charlin *et al.*, 2000b; Charlin *et al.*, 2007; Fournier *et al.*, 2008); a statistically valid assessment of the concordance of even an individual Student's answers with those of the Experts can be made. Similarly, if numbers of Student test subjects are at least over 5 and preferably over 30 statistically valid inferences can be made on the efficacy of the test, as discussed at Chapter 9 below. The research described at 8.1 to 8.3 above therefor demonstrates that it is possible to take the methodology developed for designing and delivering Script Concordance Tests (SCTs) which was specifically developed for testing the metacognitive processes and knowledge required for Diagnosis in the Medical Professions and adapt this methodology for testing the metacognitive processes and knowledge required for Diagnosis Building pathology. Although this was for an exemplar subset of 'damp-problems in Building pathology, and only preliminary SCTs were Beta tested as part of this research; it should therefore be reasonable to expect that this methodology could be extended to other areas of Diagnosis in Building Pathology. Similarly, it is reasonable to expect that the methodology could be refined with more resources and larger groups of test subjects to allow more detail analysis than described at Chapter 9 below. However, it is clear from the preliminary and Beta testing described above, that SCTs developed for testing Medical Clinical Reasoning can be adapted to test diagnosis in Building Pathology. This further supports the hypothesis that the diagnostic process for Building Pathology and Clinical reasoning are likely to be similar if not identical, and that developments in the teaching and learning of Medical Pathology can usefully be used for the teaching, learning and application of Building pathology.

8.5 Summary

It has proved possible to design, develop and apply an effective Script Concordance Test to students, practitioners and experts in Building Pathology using scenarios and questions covering the exemplar subset of damp problems in buildings, as described at 8.1 to 8.3 above. This was possible by reference to the extensive literature on the design and application of Script Concordance Tests which were first developed in the late 1990s for use in medical Clinical Reasoning. This might reasonably be considered as a useful teaching and learning tool for Building Pathology, but also demonstrates that it is possible to develop useful teaching and learning interventions for the subject of Building Pathology by reference to research and current good practice in the parallel subject of medical Clinical Reasoning. This may be considered as a new and original contribution to knowledge, as no recorded use of Script Concordance Tests outside the teaching and learning of medical related subjects have been found during this research. However, a preliminary analysis and discussion of the results of the Script Concordance test developed as part of the research project on the exemplar subject of damp problems in Building Pathology is described in Chapter 9.

CHAPTER 9: ANALYSES OF AND DISCUSSION OF THE DEVELOPMENT OF THE SCRIPT CONCORDANCE TESTS AND OF THE DATA FROM THE SCRIPT CONCORDANCE TESTS

9.1 Introduction

As described in Chapter 8 above it was found to be possible to design, develop and apply effective Script Concordance Tests (SCTs) to students, practitioners and experts in Building Pathology using scenarios and questions covering the exemplar subset of damp problems in buildings. This supported the Hypothesis that the subject of Building Pathology can be understood as a parallel subject to Medical Pathology; to allow the adaption of recent advances in the continuous learning of Medical Clinical Reasoning, to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology However, analysis of findings during the development of the SCTs and the data gathered from the preliminary and Beta testing of these tests was found to provide information that could be useful for the further development of SCTs for the learning and testing of the metacognitive process needed for diagnosis and remediation in Building Pathology, as shown in the tables of results at Appendix G, and as described below.

9.2 Results from the development of Script Concordance Test Scenarios and questions

9.2.1 Selection of Scenarios

It was found to be relatively easy to select scenarios for inclusion in a Script Concordance Test (SCT) covering the subset of damp problems in Building Pathology, given the detailed records of the hundreds of cases including damp problems investigated as part of the researchers work as a practicing Building Pathologist. Scenarios were therefore created using the records of relatively recent cases including a representative range of building types, structures, materials, and ages. It was also possible to select cases and scenarios which demonstrated common subsets of problems found when investigating damp related problems in buildings. However, this was restricted by the number of scenarios that could be included in a practical SCT as described at 9.2.2 below (Lineberry *et al.*, 2019).

9.2.2 Number of scenarios

Research on the development and application of Script Concordance Tests (SCTs) in Medical Clinical Reasoning had found that the practicality and efficacy of these tests was reduced if too many scenarios were included in an individual test (Charlin *et al.*, 2000; Fournier *et. al.*, 2008; Cobb *et al.*, 2015; Kün-Darbois *et al.*, 2022). This was reported to be due to limits on the ability of the student or subject of the test to concentrate on the test for a period of over an hour, and due to suspected problems with students or subjects tending to link the scenarios and their responses consciously or subconsciously during the test, which might compromise their responses and subsequent analysis (Lineberry, Kreiter and Bordage, 2013). For this reason, 10 No. case studies and scenarios were developed for each of two preliminary SCTs covering the Building Pathology of damp problems in buildings. These were then combined to provide 20 No. scenarios in the full Script Concordance Test for Beta testing, as this was reported as an optimum maximum number of scenarios for SCTs developed for Medical Clinical Reasoning (Fournier *et a*l., 2008).

9.2.3 Drafting of questions

The information recorded from investigation of each case study or scenario selected was reviewed following the methodology and protocols developed in the practical application of Building Pathology and current best practice in Clinical Reasoning as described at Chapter 5 and Chapter 7 above. The relevant information to the expert diagnosis and remediation of the problem described in each Scenario was provided in written format at each decision point in the diagnostic and the remedial process, and a script of a set of expert opinions or actions framed with questions in multiple choice format. The participant were then asked to determine the appropriateness of the given scripts in the context of the presented information, following the methodology described for best practice in SCTs in Medical Clinical Reasoning (Charlin *et al.*, 2000; Fournier *et al*., 2008; Lubarsky *et al.*, 2011b;

Lineberry *et al.*, 2019). Information was also provided at the start of each scenario using one or two photographs from the case which included visual clues to the Building Pathologist on the age, structure, materials and condition of the building under investigation. It could be argued that there is a significant risk of 'Expert Bias', 'Clinical Bias' and 'Confirmation Bias' in the drafting process described (Frederiksen, 1984; Worster and Carpenter, 2008; Mizrahi, 2018; Kung *et al.*, 2023), as has been studied in the drafting of SCTs in Medical Clinical Reasoning where procedures have been recommended to control for such bias (Fournier et.al., 2008; Lubarsky *et al.*, 2011b; Lineberry *et al.*, 2019). These includes 'Diverse Expert Panels', Extensive Pilot Testing', 'Regular review and Updates', and 'Transparency' to minimise bias in drafting of the SCTs, and to enhance the validity and reliability of assessments. However, given the limited time and resources available to this research project a significant risk of bias must be accepted in the analysis of the results of the tests. However, attempts were made to limit 'Expert Bias' and 'Clinical Bias' when drafting the test by submission of the draft scenarios and questions to experienced colleagues and other members of the panel of experts in Building Pathology and incorporating their comments during the drafting process.

9.2.4 Number of questions

As described in Chapter 8 above the drafting of the two preliminary Script Concordance Tests (SCTs) included 10 No. scenarios or case studies. Each scenario was drafted with questions at each of the perceived decision points for an 'Expert Building Pathologist' found on review as described at 9.2.3 above. This resulted in multiple questions with variable numbers for each scenario. However, research into the drafting and application of SCTs for Medical Clinical Reasoning has shown that the optimum maximum number of questions in a scenario was likely to be 5 No. and the maximum number of questions for a full test was likely to be 100 No (Fournier *et al.*, 2008; Lineberry *et al.*, 2013; Wan *et al.*, 2018; Aubart *et al.*, 2021; Kün-Darbois *et al.*, 2022). This was reported to be due to the practicality of delivering and taking such tests within a time frame acceptable to the subjects or students taking the test. The questions found to show the most marked difference between responses of 'Experts' and 'Students' were therefore selected for inclusion in drafting of the

‘Full Script Concordance Test’ for Beta testing, after analysis of the results of the preliminary SCTs as described at 9.3.2 below.

9.2.5 Recruitment of panel of experts

Research into the drafting of Script Concordance Tests (SCTs) in Medical Clinical Reasoning has reported that the optimum size for the panel of experts used providing the basis for the test and subsequent analysis is between 10 and 30 experts in the area of clinical expertise being assessed(Charlin *et al.*, 2000; Fournier *et al.*, 2008). However, it was found to be very difficult to recruit experts in Building Pathology for this research project. This appeared to be due to a lack of time or willingness to undertake the test by those with sufficient experience and expertise to act as experts, and as a result many of the Academics and Practitioners approached could not be persuaded to spend the time to complete the test. It was also possible that many of the practitioners and academics approached were concerned that the results of the test might be used to assess and comment on their expertise, despite written and verbal assertions to the contrary. However, 8 No. Experts in the practical application of diagnosis and remediation of a subset of damp problems in Building Pathology completed the preliminary SCTs. This is at the lower range of the numbers recommended for the Expert panel for designing SCTs for Clinical Reasoning, as lower numbers lower than this can affect the reliability of the tests as assessed by the Cronbach Alpha Coefficient. This can be affected by panel size and other factors, but Cronbach alpha Coefficients of from 0.35 to 0.85 have been reported as acceptable in the literature, although a Coefficient of over 0.75 has been recommended for tests needing a high level of reliability. For example, for professional qualification. It was noted that one of the experts approached did not complete the SCT because they found that they required more graphic information for investigation and diagnosis than was presented in the scenarios within the test. This may have implications for the future design and delivery of SCTs and other interventions for the learning of Building Pathology as discussed at 9.5 below. It might be argued that the recruitment of the Panel of Experts may be a source of bias affecting the validity and reliability of assessments, due to the limited number of Experts prepared to participate in the research project (Frederiksen, 1984; Worster and Carpenter, 2008;

Mizrahi, 2018). This must be accepted and allowed for in any analysis or interpretation of results. However, it could be argued that useful analysis can still be undertaken in that the results of the test show the concordance of the responses form subjects or students with the opinions of the particular subset of experts used, and further measures can be taken on future drafting and application of SCTs in Building Pathology to control this bias following the continuing developments in the drafting and application of SCTs in Medical Clinical Reasoning (Peyrony *et al.*, 2020; Steinberg *et al.*, 2020; Kün-Darbois *et al.*, 2022; Tayce and Saunders, 2022).

9.2.6 Recruitment of subjects for preliminary and Beta testing

The constraints on the recruitment of subjects or students for the research project included the effects and aftermath of the Covid-19 epidemic on student teaching and academia generally, and included the constraints on student time and motivation, particularly on BSc surveying course, that was reported during the research described at Chapter 6 above. Similarly, it was not possible to recruit significant numbers of Building Professionals to take the SCTs during the research project due to similar constraints. Consideration was given to further incentivising participation, but this was decided against on the advice of the Supervisors of the research project, and of those controlling access to Students for the research. In these circumstances the SCTs were undertaken on a voluntary basis by students on an MSc conservation course and students on a BSc surveying course who were incentivised by the prospect of the learning opportunity represented by taking the SCT, subsequent to a lecture introducing the subject of Building Pathology and the SCT by the researcher. Although this resulted in a relatively low number of subjects or Students taking the test, these were found to come from a wide cross section of backgrounds and previous academic or professional experience, as shown in results at Appendix G. It was therefore unsurprising that these produced a wide range of results for the test, but also suggests many areas of further research as discussed at 9.3.3 and 9.5 below. It was thought by those supervising the research that it would not be possible to recruit adequate numbers of subjects or students to provide for the further statistically valid analysis of any results obtained from subsets of Students. However, the statistical basis of SCTs dose allow for the statistically valid comparison of individual test subjects or relatively small subsets of subjects with the panel of Experts (Peyrony *et al.*, 2020; Steinberg *et al.*, 2020; Kün-Darbois *et al.*, 2022), and although the difficulties in recruiting Students discussed and the restricted time and recourses available restricted further analysis of the data from the SCTs, this did not affect their efficacy in answering the research question as concluded in Chapter 8 .

9.3 Results from the Preliminary Testing of First Draft of Script Concordance Test Scenarios and Questions

9.3.1 Acceptance of Script Concordance Tests and Feedback from Subjects

It was found to be difficult to recruit Experts or Student subjects for the Script Concordance Tests (SCTs) in this research project as described in 9.2 above. However, this is likely to have been due to other problems other than acceptance of the testing format. However, similar problems of acceptance by students have been reported on the use of SCTs in Clinical Reasoning. Unfortunately, it was not possible to record how many prospective subjects to the online tests on the JSCA platform did not decide to take or complete the test after accessing these online, and it appeared possible that prospective subjects may have completed or partially completed a test without effectively 'Saving' their tests because there was no automatic save function on the web-based platform used for the research. However, the test included a 'Comments' field at the end of the test in which subjects were asked to record any feedback or comments they had on the SCT that they had just taken. Unfortunately, only a small proportion of subjects recorded any comments either negative or positive. However, the few comments left showed subjects were generally intrigued and interested by the test. Negative comments generally referred to typographical errors, the length of the Script Concordance Test and problems with interpreting the information provided in the scenarios. Some subjects also noted that they would have liked more graphic information showing the structures described in the scenarios. In particular, one of the proposed members for the Expert panel reported that he was unable to do the SCTs as he generally relied on visual information as described at 9.2 above.

9.3.2 Analysis of Data from Script Concordance Tests and Separation of Students from Experts

The data from the preliminary Script Concordance Tests (SCTs) hosted on the JIC platform was anonymised and downloaded as Excel files. The data was then processed following the methodology recommended for current best practice for SCTs in Medical Clinical Reasoning as shown in the spreadsheets at Appendix G to assess the script concordance of the answers from the Student subjects with the subset of results from the Expert Panel. This showed a clear differential between the answers provided by the panel of Experts across the scenarios and questions used in the preliminary SCTs, as shown on the spreadsheet at Appendix G. This demonstrated the efficacy of the SCTs in testing the concordance of the results from Experts and Student subjects, proving that this methodology developed for Medical Clinical Reasoning can be effectively developed for use in the teaching and learning of Building Pathology. However, some questions were found to show a clearer difference in the concordance of the responses given between the panel of Experts and the Student subjects, as shown on the tables at Chapter 8 above and in the spreadsheets at Appendix G. This apparent variability in the efficacy of the questions and scenarios found on analysis of the data from the preliminary SCTs indicated that these could be further refined to draft a more effective test as described at 9.2 above and 9.3.3 below.

9.3.3 Preliminary observations on results from subsets of Students

It is probable that there were inadequate numbers of subjects taking the Script Concordance tests and resultant data in this research project to allow any statistically significant results to be drawn from more detailed analysis, except that there is a clear difference between the amortised results from the Expert panel and the Student subjects as described at 9.3.2 above. However, preliminary review of the data gathered during the SCTs and shown in the spreadsheets at Appendix G suggested a number of areas of future investigation and research. In particular, there appeared to be differences between subjects based on their previous professional background and experience. There also appeared to be differences in results based on academic background and their associated previous teaching and learning opportunities. This could be an especially useful area of research, especially when associated with the findings described from investigations into current best practice in the teaching of Building Pathology modules in the UK described at Chapter 6 above. However, it was unfortunately not possible to persuade the institutions involved in the investigation of current best practice described at Chapter 6 to participate further in the development and application of the SCTs during the period of the research project. Similarly, it was not possible to persuade professional institutions such as the RICS, RIBA or CIOB to encourage their members to participate during the period of the research project.

9.4 Results from the Beta Testing of Second Drafts of Schema and Questions as part of a Full Script Concordance Test

9.4.1 Acceptance of SCTs and Feedback from Subjects

It was found to be difficult to recruit subjects for the Script Concordance Tests (SCTs) in this research project as described in 9.2 and 9.3 above. However, the test included a 'Comments' field at the end of the test in which subjects were asked to record any feedback or comments they had on the SCT that they had just taken. As described at 9.3 above, only a small proportion of subjects recorded any comments either negative or positive, and the few comments left showed subjects were generally intrigued and interested by the test. As described at 9.3 above, negative comments generally referred to the length of the Script Concordance Test and problems with interpreting the information provided in the scenarios. This was similar to the responses reported by researchers subjecting of medical subjects to SCTs, further supporting the Hypothesis that learning Diagnosis in Building Pathology is a similar subject to learning Clinical Reasoning in the Medical Professions (Cobb *et al.*, 2015; Peyrony *et al.*, 2020; Kün-Darbois *et al.*, 2022). The requirement for further visual information for the subject to reach as satisfactory Diagnosis was also raised by at least two other subjects, who interestingly had some experience of practical surveying of building defects. This could be a useful area of further research as discussed at 9.5 below.

9.4.2 Analysis of Data from Script Concordance Tests and Separation of Students from Experts

The data from the Full Script Concordance Test (SCT) hosted on the JIC platform as described at Chapter 8 and at 9.2 above was anonymised and downloaded as Excel files. The data was then processed as described at 9.3 above to assess the script concordance of the answers from the Student subjects with the subset of results from the Expert panel. This again showed a clear differential between the answers provided by the panel of Experts across the scenarios and questions used in the Full SCT as shown on the spreadsheet at Appendix G. This was found to be more marked than in the Preliminary SCTs described at 9.3 above, but the sample size available was not large enough to allow further useful statistical analysis during this research project. However, this again demonstrated the efficacy of the SCTs in testing the concordance of the results from Experts and Student subjects, despite relatively small sample sizes. This further showed that this methodology developed for Medical Clinical Reasoning can be effectively developed for use in the teaching and learning of Building Pathology.

9.4.3 Statistical validity of the Preliminary and Combined Script Concordance tests

The statistical validity of the preliminary and the combined Script Concordance Tests (SCTs) was calculated following the methodology described in at Chapter 8 above and shown at Appendix G(Fournier *et al*., 2008; Lineberry *et. al.*, 2013; Wan *et al.*, 2018; Aubart *et al.*, 2021; Kün-Darbois *et al.*, 2022). The results of this preliminary analysis are shown in Table 9.1 bellow. This analysis confirmed that the difference between the Expert and Student subjects scores for SCT1, SCT2, and the optimised and combined SCT are very significant with P-values of < 0.001 when calculated using a 2-tailed t-test for Equality of Means. More significantly, calculation of the Cronbach's alpha Coefficients for the SCTs showed that the construct validity of Script Concordance Tests was very good. These indicate very good internal consistency and reliability, but also showed an improvement in the already high construct validity and reliability with the optimisation of the preliminary SCTs to create the final Combined SCT; as shown in Table 9.1. In this context it should be noted that in the literature it is reported that, Cronbach's alpha values of over 0.65 are generally considered to be good and values of over 0.75 are generally reported as being acceptable for the purposes of national professional qualifications or accreditation(Lubarsky *et al.*, 2011a; Lineberry *et al.*, 2019; Wan *et al.*, 2019; Aubart *et al.*, 2021). Preliminary statistical analysis indicted that further optimisations of the Scenarios and questions could still improve the Script Concordance Test, but this is likely to require multiple iterations and more subjects and time than were available during this research project.

Table 9.1: Preliminary statistical analysis of results from Script Concordance Tests

Script Concordance Tests	P-value	Cronbach's alpha Coefficient
Test 1-Scenarios 1 to 10	<0.001	0.86
Test 2-Scenarios 11 to 20	<0.001	0.93
Test3- Scenarios 1 to 20 Optimised and Combined	<0.001	0.96

9.4.4 Preliminary observations on results from subsets of Students

As previously discussed, it is possible that there were inadequate numbers of subjects and resultant data from the Script Concordance Tests (SCTs) in this research project to allow any statistically significant results to be drawn on differences between subsets of the Expert or Student subjects; except that there is a clear difference between the amortised results from the Expert panel and the Student subjects as described at 9.4.2 above. However, preliminary review of the data gathered during the SCT and shown in the spreadsheets at Appendix G suggested a number of areas of future investigation and research. In particular, there appeared to be differences between subjects based on their previous professional background and experience. There also appeared to be differences in results based on academic background and their associated previous teaching and learning opportunities. These could be an especially useful areas of further research.

9.5 Implications for the Further Development of Script Concordance Tests and Other Web Based Tools and Schema for the Continuous Learning and Development of Building Pathology

9.5.1 Script Concordance Tests for Other Subsets of Building Pathology

The development and testing of a Script Concordance Test (SCT) for the metacognitive process needed for diagnosis and remediation of the subset of damp problems in buildings in Building Pathology reported above, indicates that similar SCTs could be developed and applied for other subsets of problems in Building Pathology. In particular, it is likely to be practical and useful to develop similar SCTs for problems associated with timber decay, problems associated with ventilation and condensation, problems associated with mould growth in buildings, and on the effects of hygroscopic salts, as well as many other subsets of problems in Building Pathology. Preliminary analysis of the results of the Script Concordance Tests (SCTs) undertaken as described above, indicated that further work could be done to consider what it was about Scenarios 1 to 10 that made them more effective than 11 – 20 in these SCTs, and why Scenarios 11 - 20 didn't differentiate as well between Experts and Students.

9.5.2 Use of Script Concordance Tests for Teaching and Learning Building Pathology

Script Concordance Tests (SCTs) have been used in Medical Clinical Reasoning and the professions relating to medical subjects for teaching and learning as well as for testing the abilities of students of their subjects (Charlin *et al.*, 2000; Deschênes *et al.*, 2011; Cobb *et al.*, 2015; Karila *et al.*, 2018; Kün-Darbois *et al.*, 2022). This is because the process of working through tests and examination questions has become an accepted way of efficiently learning these and other professional and academic subjects. This is because the re-use of examinations or other tests in this way allows individual or group learning and self-assessment by students without the requirement for further intervention by teachers (Zainuddin *et al.*, 2020; Hamilton *et al.*, 2021; Zalat, Hamed and Bolbol, 2021; Kung *et al.*, 2023). The re-use of examinations or other tests in this way also allows cost-effective re-use of the resources expended in their creation. SCTs may be especially cost effective in this way, because there are no 'right' or 'wrong' answers to the multiple-choice formatted questions, and individuals can retake the test and share their answers with others, without compromising the validity of the test in the same way that a standard multiple-choice test might be compromised.

9.5.3 The Use of Script Concordance Tests for Testing and Certification

Script Concordance Tests (SCTs) were originally devised as a way of testing and certifying the level of expertise of Medical Practitioners learning Medical Clinical Reasoning, and for testing and certifying that their level of expertise was adequate to practice in specialist areas of medicine, and they have been developed and used for certifying the competence of medical practitioners on a national level in the past(Aubart *et al.*, 2021; Kün-Darbois *et al.*, 2022). Therefore, it is probable that SCTs could similarly be used for testing and certifying the competence and expertise for those intending to provide professional services including investigation and remedial advice on Building Pathology in the UK and abroad. It is also probable that SCTs could usefully be used in testing and certification of expertise in other areas of the building professions as described at 9.5.6 below.

9.5.4 The Use of Script Concordance Tests for Further Research

As discussed at 9.3 and 9.4 above, preliminary analysis of the results of the Script Concordance Tests (SCTs) undertaken as part of this research project showed that the results of these tests might form the basis of further research into the teaching, learning and application of Building Pathology. Such research could then be used to inform the cost-effective application of interventions in current best practice in teaching and learning of this subject in the UK and abroad. Further research based on SCTs might also be used to help provide quantitative and qualitative information on the importance of professional or practical experience, previous academic experience, and previous teaching and learning interventions in the selection and teaching or learning of students and practitioners in the subject of Building Pathology.

9.5.5 The potential use of AI in production and application of Script Concordance Tests

In Medical Clinical Reasoning the traditional development of Script Concordance Tests (SCTs) involves expert input to create scripts and evaluate responses, AI is reported to be playing an increasing role in generating and assessing SCTs. This can include Automated language Translation, Natural language Processing (NLP), Data Analysis and Script Generation, Adaptive Testing, Automated Scoring, Personalised Feedback, and AI generated continuous evolution and improvement (Aubart *et al.*, 2021; Kung *et al.*, 2023; Hudon *et al.*, 2024; Kıyak and Emekli, 2024). It therefore appears highly likely that further developments in the use of AI for this purpose in Medical Clinical Reasoning will allow similar advances in the use of AI in the development and use of SCTs in the learning and testing of the metacognitive processes needed for Building Pathology.

9.5.6 Design and development of Script Concordance Tests for other non-medical subjects

While Script Concordance Tests (SCTs) were initially developed for assessing clinical reasoning and decision-making skills in medical education, their principles can be adapted for use in various non-medical fields. However, it should be noted that although SCTs have been developed and used in many medical professional and specialist medical related subjects; no reports or references to published literature on the use of SCTS outside of the teaching and testing of medical Clinical Reasoning have been found with online literature searches using Google and Google Schola. It might therefore be reasonably claimed that the use of SCTs for Building Pathology as part of the research project described above is the first reported use of Script Concordance Tests outside of the teaching and testing of medical Clinical Reasoning.

9.6 Summary

Analysis of the data gathered in the Script Concordance Tests (SCTs) developed as part of this research project has shown that it is possible and potentially very useful to adapt a methodology developed as part of best practice in medical Clinical Reasoning for use in Building Pathology. This supports the hypothesis that Building Pathology and medical Clinical Reasoning can be considered as similar or even the same subject, and indicates that the further development and analysis of SCTs could be useful for the teaching, learning, testing and further development of the subject of Building Pathology. This also indicates that other areas of research and development in the teaching, learning and application of medical Clinical Reasoning are likely to be useful in the further development of Building Pathology.

CHAPTER 10: CONCLUSIONS AND PROPOSALS FOR THE FURTHER DEVELOPMENT AND EVOLUTION OF THE SUBJECT OF BUILDING PATHOLOGY

10.1 Introduction

It has been demonstrated in the literature research and analysis described in Chapter 2 and Chapter 3 that buildings and building pathologies can be considered as complex systems evolving over time in the same way that the living organisms and cultures that build and occupy them evolve over time, and that Building Pathology can therefore reasonably be considered as a parallel or sister subject to Medical Pathology. It has further been demonstrated in the research described in Chapter 5 and Chapter 6 that current best practice in the application and learning of Medical Clinical Reasoning and Building Pathology appear to have many similarities because of this close relationship. This allowed the proposal of metacognitive processes for diagnosis and remediation for application in the exemplar subset of 'damp problems' in Building Pathology described in Chapter 7. The development and testing of a Script Concordance Test for the learning and application of these metacognitive processes based on current best practice in Medical Clinical Reasoning, described in Chapter 8 and Chapter 9 then demonstrated the potential utility of exploiting this relationship for the testing and learning of diagnosis in Building Pathology This Pragmatic and Mixed Method research therefore allowed the development and testing of the research Hypothesis, achieved the research Aim, and allowed a number of conclusions to be drawn as described below.

10.2 Summary of the Research Objectives

The overall aim of this research project was to develop and test the Hypothesis that Building Pathology could be usefully considered to be a parallel or sister subject to Medical Pathology; allowing the understanding, teaching, learning, application, and further development of the subject based on recent advances in the sister subject of Medical Pathology. Alternatively, the research question was posed as; ‘can the subject of Building Pathology be understood as a parallel subject to Medical Pathology; so as to allow the adaption of recent advances in the continuous learning of Medical Clinical Reasoning, to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology. The Objectives for this research project were therefore as described below:

Objective 1: To demonstrate that the parallels between the subject of Building Pathology and Medical Pathology are not just analogous, but can be understood as the result of the co-evolution of Humans and the built environment

Objective 1 was achieved by reference to the extensive literature on the parallel subjects of Animal Architecture, Vernacular architecture and Evolutionary Theory as described in Chapter 2 and summarised at 2.5 above As discussed at 10.3 below, this might reasonably be considered to be a significant contribution to knowledge; as it has not been formally asserted in previously published research or literature that the parallels between the subject of Building Pathology and Medical Pathology are not just analogous, but can be understood as the result of the co-evolution of Humans and the built environment.

Objective 2: To review the development of the subject of Building Pathology in the UK and compare this with the development of medical Clinical Reasoning

Objective 2 was achieved by extensive literature research as described in Chapter 3 and summarised at 3.5 above This showed clear parallels between the problems inherent in the investigation and understanding of the processes leading to pathologies in buildings and in the living organisms that build or inhabit them. In particular there are clear parallels in the requirements for ‘Diagnosis’, ‘Prognosis’, and ‘treatment’. It is therefore probable that procedures and methods developed and evolved in medical Pathology may be useful in understanding and developing methods for the diagnosis of building pathologies making these parallel or sister subjects.

Objective 3: To critically evaluate procedures and methods for the application and continuous learning of Holistic Building Pathology based on recent developments in medical Clinical Reasoning

Objective 3 was achieved by literature research and review of the metacognitive approach of the researcher and others to the investigation, diagnosis, prognosis, and remediation of building pathologies, as described in Chapter 5 and summarised at 5.5 above. This may be further developed by reference to the extensive research and literature on the teaching, continuous learning and application of the subject of Clinical Reasoning in Medicine. In particular it is clear that the use of Case Studies, History Taking, Reflective Learning, and Near Pear Mentoring are generally important for the student and practitioner developing the metacognitive skills required for Diagnosis in both the Medical Professions and in the parallel subject of Building Pathology.

Objective 4: To determine current best practices for the learning and teaching of Building Pathology in the UK

Objective 4 was achieved by interview and Thematic Analysis as described in Chapter 6 and summarised at 6.4 above. This confirmed that current best practice in the preparation and delivery of teaching and learning in Building Pathology modules in the UK has evolved similar methodologies to those found to be useful in the teaching and learning of Clinical Reasoning in the medical professions. However, the introduction to, and the learning of the metacognitive processes involved in diagnosis, prognosis, and remediation, did not generally appear to be specifically recognised or taught. In particular, although the probabilistic nature of investigations and resulting information, and the probabilistic nature of diagnosis and prognosis was recognised on prompting; this did not appear to be specifically taught. Similarly, the importance of ‘case histories and the general significance of time and the evolution of building structures and Building Pathologies; even in new buildings or buildings under construction, did not appear to be generally taught.

Objective 5: To develop tools to facilitate the learning of Schema for application to 'damp problems' as an exemplar subset of problems in Building Pathology

Objective 5 was achieved by showing in Chapter 7 that it is possible to combine current best practice in the practical application of medical Clinical Reasoning and in practical Building Pathology, to develop metacognitive tools and schema for application to the diagnosis and remediation of 'damp problems' as an exemplar subset of problems in Building Pathology. This might reasonably be expected, given the background research and findings described in the previous Chapters of this Thesis. Similarly, it can reasonably be expected that this and other recent developments from the continuous learning and application in the subject of medical Clinical Reasoning could be used to help in the learning and application of the metacognitive process required for Building Pathology.

Objective 6: To develop and test Script Concordance Tests on schema for application to 'damp problems' as an example of the potential utility of adapting recent advances in the continuous learning of Medical Clinical Reasoning to facilitate the learning and testing of the metacognitive processes needed for the continuous learning and application of holistic Building Pathology.

Objective 6 was achieved as it was proved to be possible to design, develop and apply an effective Script Concordance Test to Students, and Experts in Building Pathology; using scenarios and questions covering the exemplar subset of damp problems in buildings, as described in Chapter 8 and summarised at 8.4. This might reasonably be considered as a useful teaching and learning tool for Building Pathology. However, this also demonstrates that it is possible to develop useful teaching and learning interventions for the subject of Building Pathology by reference to research and current good practice in the parallel subject of medical Clinical Reasoning. This may be considered as a new and original contribution to knowledge as discussed at 10.3 below, as no recorded use of Script Concordance Tests outside the teaching and learning of medical related subjects have been found during this research.

Objective 7: To analyse data from Script Concordance Tests to answer the research question, and to allow the further development of web-based tools and Schema for the continuous learning and development of Building Pathology

Objective 7 was achieved by analysis of the data gathered in the Script Concordance Tests (SCTs) developed as part of this research project as described in Chapter 9 and summarised at 9.6 above. This showed that it is possible to adapt a methodology developed as part of best practice in medical Clinical Reasoning for use in Building Pathology. This supports the hypothesis that Building Pathology and medical Clinical Reasoning can be considered as parallel or sister subjects. This indicates that the further development and analysis of SCTs could be useful for the teaching, learning, testing and further development of the subject of Building Pathology. This also indicates that other areas of research and development in the teaching, learning and application of Medical Clinical Reasoning are likely to be useful in the further development of Building Pathology.

The research activities described above were undertaken in parallel rather than as a sequential program. This allowed the aims and objectives to be refined throughout the research project and for the objectives described above to be achieved, with key findings and new original contributions to knowledge as described below.

10.3 Key Findings

10.3.1 The Evolution of Buildings and Building Pathology

In the research described at Chapter 2 the evolution of construction technology and defects in buildings was investigated by review of available published literature. This clearly demonstrated the evolution of non-human and human built structures over time. This also showed that building pathologies were part of, and affected by, these evolutionary processes over time. This was a key finding on which it is concluded that the development of the subject of Building Pathology has been based, and from which the subsequent parts of this research project were developed as described below. In particular, the conclusion that buildings and building pathologies can be considered as complex systems evolving over time is key to the holistic application of Building Pathology as a practical subject, and to its further research and development.

10.3.2 Constraints on the development of Building Pathology as a practical and academic subject

The research described at Chapter 3 showed that a key constraint on the development of the practical and academic development of the subject to Building Pathology in the UK is likely to have been a failure to fully understand the principles on which it is founded, as described at 10.3.1 above. In particular, very little or no published literature was found on the foundations of the subject of Building Pathology or on its development, and the failure to recognise its nature as a complex system evolving over time. This has prevented the subject being able to benefit from its relationship to the parallel 'sister subject' of Medical Pathology, as described at 10.3.3 below.

10.3.3 The parallels between Building Pathology and Medical Clinical Reasoning

The literature research and action research described at Chapter 3 demonstrated that the subject to Building Pathology and medical Clinical Reasoning could be reasonably considered as parallel 'sister subjects' and might even reasonably considered as the same subject. Although similarities had been noted by previous authors, this parallel was not found to have been previously formally asserted and is therefore a key finding of this research project. This key finding allows the recent developments in Medical Pathology and Medical Clinical Reasoning to be used to allow the further development of the subject of Building Pathology, both in its application, continuous learning, and research.

10.3.4 Characterisation of a system of procedures and methods for the application and continuous learning of Holistic Building Pathology

Based on the key findings described above, a further key finding of this research project described at Chapter 5 has been the characterisation of a system of procedures and methods for the application of continuous learning for holistic Building Pathology based on recent developments in Medical Clinical Reasoning.

10.3.5 Assessment of current best practice for the teaching and learning of Building Pathology in the UK

The assessment of current best practice for the teaching and learning of Building Pathology in the UK gave academic grounding to the Action-based research resulting in the opinions of the educators responsible for delivering Building Pathology modules in the UK. In particular, a key finding was the importance of Practice Based Learning with practical case studies or virtual schema, followed by reflective learning and report writing, supported by Near Peer Mentoring as key parts of current best practice. These were similar to the findings of the extensive research undertaken into the teaching and learning of the parallel or sister subject of Medical Clinical Reasoning, further confirming the close relationship between these subjects previously described above.

10.3.6 Development of metacognitive tools and schema for application to 'damp problems' was an exemplar subset of problems in Building Pathology

The review of current best practice in the teaching and learning of Building Pathology and the extensive literature for the teaching and learning of the subject medical Clinical Reasoning combined with the Action-based research described at Chapter 7, allowed a system of schema for the diagnosis of 'damp problems' in buildings to be devised and formulated. Although previous authors have proposed checklists and schema for this purposed in the past, these have not taken account of developments in current best practice in Diagnosis in the medical professions, in particular, they have not taken into account the importance of understanding building pathologies as evolving complex systems over time, and the importance of the History of the apparent problems, which are included universally in protocols for Medical Diagnosis and in the system proposed as part of this research project.

10.3.7 The development and application of Script Concordance Tests to students, and experts in Building Pathology

A key finding of this research project has been a demonstration of the practicality and potential utility of the use of Script Concordance Tests for testing and developing diagnostic skills in the practical application of Building Pathology. This is also a key finding as it further demonstrates the similarity between the metacognitive processes needed for effective diagnosis in Building Pathology to those used in the parallel or sister subject of medical Clinical Reasoning. This is also a key finding as it is the first example of the use of Script Concordance Tests as a methodology for assessing teaching and learning outside of the medical professions.

10.4 Practical and Academic Implications

Given the proposition that building pathologies and the subject of Building Pathology is an emergent phenomenon of the continuously evolving complex systems of buildings and the built environment, as previously discussed in Chapter 2 and Chapter 3 above; it is apparent that they will continue to develop and evolve. This will occur irrespective of what conscious, or unconscious measures are taken by building occupants, regulators, building professionals, academics, or even those with a special interest in the subject of Building Pathology.

Given the findings of this research project and given a desire to improve the efficiency of these processes to the benefit of all involved; there appear to be a number of areas in which actions may be taken in order to promote the cost-effective development and application of the subject. These generally involve the transfer of information to those who have building pathology related problems requiring timely and cost-effective resolution, those wishing to learn the subject for application as part of their professional life, those involved in continuing professional development (CPD), those involved in research and academic study, and those involved in the production and enforcement of regulations and standards.

The clear association between building pathologies, and to failures to adequately identify and manage risks in complex building structures and environments, have been made absolutely clear by high profile catastrophic failings such as the Grenfell Tower fire. It is therefore proposed that the parallel evolution and application of the subjects of 'Building Pathology', and that of the Health and Safety of those building or occupying these structures, should be considered.

However, a significant constraint on the development of Building Pathology as a subject in the ways described above, appears to be the lack of a clear recognition of the basis of the subject and the lack of a recognised system of procedures and methods; to allow the teaching, application, and further development of the subject. The research findings could therefore facilitate the development of the subject as discussed below.

10.4.1 The Economic Imperative

It appears to be the general view of those involved in the development and application of the subject since its inception, that there has been a failure of clients, funders and their professional advisers to appreciate the importance of the timely, appropriate, and cost-effective application of the subject students(Cassar *et al.*, 2018). This may have been due to a lack of understanding of the subject or pressure from other vested interests as described at Chapter 3; except in some specialist areas of building such as Building Conservation and Building Forensics. This is thought to be due to a lack of an appropriate legal or regulatory imperative to adequately control building defects in buildings and the built environment.

However, as described at Chapter 3, an opportunity may be arising to change this situation in the UK and elsewhere in recent years based on high profile instance such as the Grenfell Tower fire (Mitchener, 2018; McKenna *et al.*, 2019; Dimka, 2023); but also, as a result of an increased requirements by clients and funders to control their financial and other risks. The latter appears to be a particularly good opportunity for the subject of Building Pathology to be applied; as this is fundamentally about the identification of 'risk', the identification of the 'ownership of risks', and the identification of cost-effective ways of 'managing risks. This has become imperative in the UK with the recent passing and application of the Building Safety Act 2022 and Building Regulations 2023 (Frame, 2022; Government, 2023). The probabilistic nature of the 'diagnostic' and 'prognostic' approach to the subject should be particularly useful to funders, because it parallels the established Decision-theory based business models that are generally applied (Ustinovichius, 2004; Kamari, 2023).

The procedures of Building Pathology as discussed at Chapter 5 can be especially useful in this context, where information has a 'cost' and 'value'. For example, as described at Chapter 5 a simple risk assessment based on prior knowledge or 'prejudice' can be made; and the probabilities further refined as necessary, based on the expenditure of time and resources on further tests and investigations; as necessary to allow the 'cost-effective' management of the risks identified. In these circumstances, it may be decided to accept the risk, and to put funding aside for repair or replacement if required; or remediation or replacement may be 'value engineered' to meet the client and end user requirements.

In this way, cost-effective solutions can be evolved in all situations, from leaky gutters in a slum dwelling, to nationwide housing projects consuming a significant portion of the gross national product. In order for this process to develop it is proposed that 'Building Pathology' risk assessments and risk management should become inherent in all building projects; in the same way that 'Health and Safety' Risk assessments and Risk management has developed in recent years.

The application of this process of Building Pathology 'Risk assessment' should be undertaken by a 'Competent Person', as defined in the Building Safety Act (Frame, 2022), and should reasonably be applied to all building projects, ranging from the simple 'tick box' mental process for an owner or occupier undertaking a DIY project; through an individual builder or building professional undertaking a brief formal assessment based on limited specialist training and understanding; through to specialist building professionals undertaking the task and carrying the 'professional indemnity' for other building professionals and clients; through to specialist organisations and institutes providing a service to governments and multinational organisations, based on specialist experts and research. Such a system could become effectively self-funding, given the readily demonstrable efficiencies generated by the process, not least the improvement in risk management for insurers and funders.

10.4.2 Professional and Academic Institutes or Societies

It is apparent that the subject of Building Pathology has developed since inception due to the work of many academics around the world, and that this has been effectively supported and encouraged by organisations such as the CIB Working Group 86; and by the international academic conferences often promoted by the specialist peer-reviewed journals, and others, as described at Chapter 3. However, there has not been a similar development of national or international professional bodies promoting the development and understanding of the subject of Building Pathology, and it appears that the academic work undertaken has failed to generate a wider understanding of the subject amongst other academics or building professionals. This may be a general problem where specialist interest groups increasingly communicate only with others of like mind.

In considering how the application of Building Pathology might be developed; again, the parallel evolution of medical Pathology and Building Pathology may usefully be considered ,as described at Chapter 3. In the field of medical Pathology, institutes or societies have been established in most developed societies around the World, for example, the Royal College of Pathologists in the UK. These take on the role of promoting and controlling education and standards and promoting research; as well as providing qualifications and recognition for practitioners and academics involved in the subject, both nationally and internationally. There appears to be a clear need for such an organisation or for such organisations; to promote the development of the subject of Building Pathology discussed above.

10.4.3 Education and Training

Although education and training are provided in some academic institutions and organisations throughout the world under the heading of Building Pathology; this generally revolves around the specialist interest of individual practitioners or academics, as described at Chapter 6. Similarly, although a number of textbooks have been published over the years, these do not provide the basis of a 'core subject', including accepted standard methods and procedures that can be applied and developed to meet particular professional or academic requirements. In particular, it appears that the 'holistic' basis of the subject of Building Pathology is generally not well understood by those delivering or receiving such training in most institutions.

In these circumstances, it is proposed that an introduction to the subject of Building Pathology should be introduced to all professional and academic courses covering building and the built environment, so that at least a basic understanding the subject can be grasped; in much the same way that principals of health and safety or first aid are included in many aspects of education and training. It is proposed that this should include an introduction to 'building anatomy', 'building physiology' and 'building evolution'; followed by an introduction to the subjects of' diagnosis' and 'prognoses'. The latter should include an introduction to an appropriate understanding of the psychology of probabilistic nature of risk assessment and decision making. This basic introduction to the subject could then be developed further to suit more specialist professional training or academic needs, at pre and post graduate levels; as currently occurs with Historic Building Conservation, as described at Chapter 6 and at Appendix F.

As with the related subjects in medicine, an essential part of any education or training after a basic introduction, would need to be the introduction of appropriate practical experience of 'diagnosis' and 'prognosis', as described at Chapter 6 and at Appendix F. As previously noted, this appears to require a minimum of at least 750 hours of practical experience supported by an appropriate qualified and experienced 'mentor'. Training in Building Pathology has been fortuitously provided to some individuals in the past in this way; due to their working with a more senior and expert colleague. This is similar to the specialist craft and professional training of the past; but does not generally allow for the rapid spread of understanding of a subject, or for its development. This may be due to practical constraints, and to perceived constraints of academic or professional confidentiality. In these circumstances, a more formally recognised and accepted 'mentoring' process is required, in which the benefits to the individuals and organisations involved are clearly defined. This is generally an important role of the specialist institutions or societies discussed at 10.4.2 above.

10.4.4 Information Technology and Transfer

There has been an increasing interest and reliance on information technology for provision of education and training in Medical Pathology over the years, especially with the use of 'checklists' and 'decision-trees'. In recent years it appears that the majority of 'pre-clinical' education training is delivered using information technology rather than physical lectures and textbooks. Indeed, currently most of this education training appears to be effectively delivered 'online'. Information technology and 'virtual reality' packages have also been developed to improve the delivery of clinical training in order to replace or at least supplement, the practical experience that is generally required. However, this appears to have had more limited success, as discussed at Chapter 3 and Chapter 5.

Similarly, in Building Pathology checklists and decision trees have been proposed; a number of studies have been undertaken, and systems developed to try and use information technology to help in the education and training of building professionals. Again, this appears to have had only limited success in replacing mentored, practical experience in developing the thought processes and experience required to undertake efficient 'type 1 and type 2 thinking', for both diagnosis and prognosis of building pathologies, as discussed at Chapter 3 and Chapter 6. However, there can be little doubt that increasing reliance will be placed on information delivered on-line, and increasingly on virtual reality packages supported by AI, to deliver education and training for all subjects.

Obviously, in a rapidly developing and evolving subject, there is a requirement for continuous transfer of information and training; both for academics and those involved in its professional practical application. This is especially important in subjects such as Medical Pathology and Building Pathology; where not only is the understanding of the subject rapidly evolving and changing with time, but there is also a fundamental requirement for practitioners to continually update and recalibrate their own 'prior probability' assessments or 'prejudices', as part of the diagnostic process. For those involved in academic study and research; the continuous updating of information is generally provided by constant review of the published literature, such as that provided in specialist peer reviewed journals; and by regular networking locally, virtually using information technology, and by occasional attendance at international meetings and conferences. These processes could be promoted for Building Pathology, given the financial imperative and support described above.

However, there is a particular need to promote the individual development of specialist professional practitioners, and more generally in professions purporting to provide Building Pathology as a service. This requires an individual commitment to continually reassessing prior-probabilities and prejudices; to allow the evolution of cost effective 'risk assessment' and investigative techniques. In other areas of similar activity such as, Medicine and Aviation; this process is promoted by a regular 'no-blame' review of failures or near failures, in a formerly or informally controlled and mentored environment, as discussed at Chapter 5.

This may be an integral part of continued qualification or membership of a controlling organisation, as part of obligatory CPD. For Building Pathology such a system might be delivered as part of CPD for the specialist within the professions involved; requiring the review of a set number of cases at set intervals, under the supervision and mentoring of a senior colleague, with the results recorded and audited as necessary. As in other related fields of human activity, the results of such a process could also form a useful source of information allowing further evolution, promotion and development of the subject.

10.5 Originality and Contribution to Knowledge

Building Pathology is a new scientific approach for risk identification and risk management in the construction, maintenance, and renovation of buildings, that does not appear to have been effectively theorised and systemised; generally limiting the understanding of the theory and the application of its methods and procedures to specialist practitioners. It is therefore hoped that the most significant 'new, original contribution to knowledge' arising from this work will be as follow:

1. The demonstration that buildings and building pathology can reasonable and usefully be considered as complex systems evolving over time. Although this has been understood by some practitioners in the past, this has not been formally asserted in the literature or been generally taught to students.

2. The demonstration that Building Pathology and Medical Pathology are not just analogous but can usefully be considered to be similar and parallel subjects. This has not been formal asserted in the literature in the past, and will allow researchers and practitioners in the subject of Building Pathology to reference and benefit from the extensive research and literature for the subject of Medical Pathology.

3. The demonstration that recent advances in the teaching and continuous learning in the subject of Medical Clinical Reasoning can facilitate the continuous learning and application of the subject of Building Pathology; especially the metacognitive process of diagnosis. This has not been formal asserted in the literature in the past, and will allow researchers and educators in the subject of Building Pathology to reference and benefit from the extensive research and literature for the teaching and continuous learning in the subject of Medical Clinical Reasoning.

4. Empirical grounding to support developments in current and future methods for the teaching and learning of Building Pathology for students in the UK. There is only limited research and literature on best practice for the teaching and learning of Building Pathology. The information and recommendations from this research could

therefore be of significant help to those providing teaching and learning for the subject of Building Pathology in the UK.

5. The proposal and demonstration of a practical methodology and protocol for the holistic investigation, diagnosis, and remediation of damp problems as a subset of problems in Building Pathology, and for general application to problems in Building Pathology. This is useful for the teaching and continuous learning of the practical application of holistic Building Pathology. This is there for commercially valuable, and is essential for effective Risk-identification and Risk- management of risks form building pathologies; especially with provisions of CDM2015 and the recent Building Safety Act 2022and Building Regulations 2023 in the UK.

6. The demonstration that Script Concordance Tests developed for testing medical Clinical Reasoning can be developed and applied to give an objective quantitative measure of the ability of students to investigate, diagnosis and remediate problems in Building Pathology. This demonstrates their potential as a tool for further research tool, as well for testing, learning and certification for Building Pathologists, and in other non-medical professions.

These original and new contributions to knowledge from this research could therefor enable Educators, Architects, Engineers, Surveyors, and other building professionals to understand, teach, continuously learn, and apply optimised methods and procedures of Holistic Building Pathology more effectively.

10.6 Limitations

10.6.1 Background research

The research project described in this Thesis has been undertaken part time over a period of over 8 years, and arguably over a working life; with all the limitations that this implies with time and continuity of research. There was also surprisingly little published work found on the bases or understanding of the subject Building Pathology; despite extensive online search and the review of over 800 publications. This was a limitation on the research described at Chapter 2 and Chapter 3 and was also what made this part of the research project necessary.

10.6.2 Interviews

The limitations on the research by interview described at Chapter 3 and Chapter 6 were what appear to be generic limitations in identifying suitable and willing subjects, and then arranging time for the interviews with very busy Professionals and Academics. It is recognised by the researcher that the analysis of the data gathered from interviews and questionnaires is likely to have been affected by the prior expectations inherent from over 35 years of practical experience as a Building Pathologist and from the results of the extensive literature review undertaken in the earlier parts of this research project. This is likely to have affected and guided the questions used during the interviews, and guided subsequent conversations and eventual Thematic Analysis (TA). It is also recognised that the data collected by interview represents the reported objectives and opinions of the interviewees, not objective facts.

10.6.3 Script Concordance Tests

Limitations on the research into the drafting of Script Concordance Tests (SCTs) in Medical Clinical Reasoning included difficulty in recruiting experts in Building Pathology for this research project. This appeared to be due to a lack of time or willingness to undertake the test by those with sufficient experience and expertise to act as experts, and as a result many of the Academics and Practitioners approached could not be persuaded to spend the time to complete the test. It was also possible that many of the practitioners and academics approached were concerned that the results of the test might be used to assess and comment on their expertise, despite written and verbal assertions to the contrary.

The recruitment of subjects or Students for preliminary or Beta testing of the Script Concordance Tests (SCTs) discussed above was a significant limitation on this part of the research project. However, the statistical basis of SCTs dose allow for the statistically valid comparison of individual test subjects or Students with the panel of Experts, and this part of the research was undertaken on that basis. The constraints on the recruitment of subjects or students for the research project included the effects and aftermath of the Covid-19 epidemic on student teaching and academia generally, and included the constraints on student time and motivation particularly on BSc surveying courses, that was reported during the research described at Chapter 6 above.

It was found to be difficult to recruit Experts or Student subjects for the Script Concordance Tests (SCTs) in this research project as described in 9.2 above. However, this is likely to have been due to other problems than acceptance of the testing format. Unfortunately, it was not possible to record how many prospective subjects to the online tests on the JSCA platform did not decide to take or complete the test after accessing these online, and it appeared possible that prospective subjects may have completed or partially completed a test without effectively 'saving' their tests because there was no automatic save function on the web-based platform used for the research. As a result, the limited sample size available was not large enough to allow further useful statistical analysis during this research project. However, this again demonstrated the efficacy of the SCTs in testing the concordance of the results from Experts and Student subjects, despite relatively small sample sizes. This further showed that this methodology developed for Medical Clinical Reasoning can be effectively developed for use in the teaching and learning of Building Pathology.

10.7 Further research

10.7.1 Script Concordance Tests

As discussed at 9.3 and 9.4 above, preliminary analysis of the results of the Script Concordance Tests (SCTs) undertaken as part of this research project showed that the results of these tests might form the basis of further research into the teaching, learning and application of Building Pathology. Such research could then be used to inform the cost-effective application of interventions in current best practice in teaching and learning of this subject in the UK and abroad. Further research based on SCTs might also be used to help provide quantitative and qualitative information on the importance of professional or practical experience, previous academic experience, and previous teaching and learning interventions in the selection and teaching or learning of students and practitioners in the subject of Building Pathology.

However, it should be noted that although SCTs have been developed and used in many medical professional and specialist medical related subjects; no reports or references to published literature on the use of SCTS outside of the teaching and testing of medical Clinical Reasoning have been found with online literature searches using Google and Google Schola. It is therefore probable that there are opportunities for research into the use of Script Concordance Tests in other non-medical subjects and professions.

10.7.2 Knowledge transfer from medical Clinical Reasoning

The demonstration the Medical Pathology and Clinical Reasoning can be considered as parallel and 'sister subjects' indicates that other areas of research and development in the teaching, learning and application of medical Clinical Reasoning are likely to be useful in the further development of Building Pathology. There therefor appear to be many areas for research into the potential for knowledge transfer from the extensive research done in the medical sciences and into Diagnosis in particular. The resulting recognition of the relationship between Building Pathology and human health and wellbeing should also facilitate cooperation between the subjects and facilitate joint research in this area.

10.7.3 AI and Building Pathology

It appears highly likely that further developments in the use of AI in Medical Clinical Reasoning will allow similar advances in the use of AI; in particular in the development and use of Script Concordance Tests in the learning and testing of the metacognitive processes needed for Building Pathology. It should be noted that no reports or references to published literature on the use of AI in Building Pathology have been found with online literature searches using Google and Google Schola, and the researcher has found no evidence of its practical application during their professional practice. However, AI is starting to be used for assisting in the production of Survey reports, and AI packages to assist in drafting reports utilising existing templates. This could expedite the learning of Building Pathology investigation and reporting protocols by new members of staff and help increase the productivity of experienced staff by reduce the time taken in the editing and production of reports. AI systems could also help in teaching and learning of the metacognitive processes required for Building Pathology and other areas of Surveying or other professions. These opportunities are likely to be areas for extensive research.

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APPENDIX A: NOTES FROM INTERVIEWS WITH BUILDING PATHOLOGISTS

Introduction

Thirty eminent academics and building professionals who have been active in developing the subject of Building pathology since the beginning of the 1990s were contacted by email, with a request for an interview as part of the research project 'Establishing a Theory and Methods for Holistic Building Pathology'; in order to discus and record their views on how the subject has developed, how it is understood, and how it may develop in the future . Of those contacted 16no. agreed to be interviewed by the author. These interviewees were asked 'What is Building Pathology?', 'How has Building Pathology developed?', 'How well is Building Pathology understood and applied?', and 'How can the understanding and application of Building Pathology be improved?'. The results of these interviews were recorded and summarised by the author in the written notes below.

1. Meeting with Expert 1 at 19:00 – 20:00 hrs on 31 January 2018

What is Building Pathology?

Building Pathology is the holistic investigation of failures in the inter-relationship with building structures and materials with their environments and the living organisms within them, so as to allow cost-effective diagnosis, prognosis, remediation and risk management as defined in the conferences in 1989-1992.

How has Building Pathology developed?

Although the technology used in the investigation of building failures has developed since 1989 the subject of Building Pathology, or its application, does not appear to have developed since that time. This is despite the structure and materials used in buildings having changed over the intervening years. There has been some development in the understanding of Building Pathology within the specialist remedial industry with regard to timber decay and damp related problems; for example, in the attitude to 'chemical remedial timber treatment'. This has been reflected in some change in attitude and improved understanding on behalf of other building professionals with regard to these subjects.

How well is Building Pathology understood and applied?

Generally, the subject of Building Pathology is not well understood or applied; this is despite an increasing number of building defects investigation practitioners describing themselves as 'Building Pathologists'. Generally, 'Building Pathology' as currently understood and applied is just another name for building defects surveying, with very few practitioners being able to take an holistic view. In this there appears to have been no real change in the understanding or application of the subject since 1989.

How can the understanding and application of Building Pathology be improved?

Improvement in the understanding and application of Building Pathology will only occur with practical training and experience. This will require a more general recognition of the role and requirement for Building Pathologists on building projects. This would then enable and motivate practitioners or potential practitioners to develop the site experience to develop the necessary skills ('chicken and egg', role of IRTS, RICS and similar organisations).

2. Meeting with Expert 2 at 13:00 – 14:00 hrs on 22 January 2018

What is Building Pathology?

Building Pathology is the holistic study of failures in buildings and the built-in environment as defined in the conferences in 1989-1992.

How has Building Pathology developed?

Building Pathology appears to have developed since 1989 as a subset of Systems Theory. However, although System Engineering has developed and been usefully applied; especially outside the building industry, System Design has not been developed or applied by architects or others in the building industry. Although there are a number of practitioners, academics and academic departments in the UK and abroad who study Building Pathology, it is not generally well taught; and no course in 'Building Pathology' is taught at UCL to architects or others.

How well is Building Pathology understood and applied?

Building Pathology is not generally well understood or applied, especially by architects and other building professionals. Certainly, Building Pathology is not understood or applied by policy makers, managers or planners in the UK. This has been tragically demonstrated by the recent fire at Grenfell Tower. Generally, policy makers and senior managers have failed to take a holistic approach to the development and application of Building Regulations, or the management of building failures.

How can the understanding and application of Building Pathology be improved?

Developments in Systems Science in other areas should be investigated and applied to the teaching and application of Building Pathology; in particular, in the areas of AI and medical diagnostics. Information and training on Building Pathology should be more effectively delivered; in particular, to those involved with architecture, design and project management. Consideration could be given to observing, analysing and comparing the diagnostic approach of a sample of medical professionals and a sample of building professionals to a Building Pathology problem.

3. Tele-meeting with Expert 3 on 17 May 2018

What is Building Pathology?

Building Pathology is the investigation and understanding of everything about a building including its interactions with its environment and use. In particular, finding the 'true course' of a problem and 'finding a solution' to that problem. Building Pathology includes understanding and taking account of 'change in use' and 'change in climate'.

How has Building Pathology developed?

Building Pathology was practiced in the 1980s but it was not named or understood as 'Building Pathology'. The term and description 'Building Pathology' first appeared in the late 1980s/1990s, and Professor Edwards first became aware of the subject with his work on Cardiff Castle and on and developed the subject and Building Pathology has developed as a holistic subject since that time. Unfortunately, the holistic understanding and application of the subject does not appear to have developed significantly as there are 'too many vested interests' in the status quo in the UK, which have been accepted by the RICS. This has limited the general understanding and application of the subject of Building Pathology despite it being a 'core subject' required in training by the RICS for many years.

How well is Building Pathology understood and applied?

While there is some detailed specialist understanding of elements of Building Pathology particularly in the areas of 'Energy Efficiency', 'air quality', 'solid wall insulation' and 'thermography'; not enough people take an 'holistic' approach. There is even a lack of 'holistic' understanding and a lack of appreciation of existing buildings in the UK, and even fundamental subjects like moisture movement in buildings is still not generally understood. There is therefore detailed understanding of aspects of Building Pathology in small groups for example at the BRE. However, there is no general understanding or application of the 'basics' of the subject. This is despite specialist professionals and academics delivering many short courses on 'moisture movement' and other subjects.

How can the understanding and application of Building Pathology be improved?

More training in 'traditional building' and Building Pathology is required in undergraduate courses. However, 'Mandatory requirements' for the application of Building Pathology is required to rectify the deficiencies described above in the UK. In the UK the lack of action by the RICS to promote the application of Building Pathology since the 1990s is a problem, especially with regard to damp and decay. It is probable that lobbying and vested interest from the PCA and similar trade organisations remains a problem in this context. There is a general problem of 'supply and demand' and 'commercial interest' and this may be a 'difficult nut to crack'. However, the CIOB might usefully develop a certification scheme; and after the disaster at Grenville Towers and the 'independent reports' may help.

4. Tele-meeting with Expert 4 at 10:00 – 11.30 hrs on 13 March 2018

What is Building Pathology?

Building Pathology was well defined by Prof James Douglas who compared the process of analysing the 'manifestation', diagnosis, therapy and prognosis of building defects with that used in the medical professions. This allowed a holistic approach to building investigations.

How has Building Pathology developed?

The theory and practical application of Building Pathology has not changed since the sad death of Prof Douglas; although the CIB established a working group and had held conference on the subject, and journals including 'Building Pathology' in the title are now available. 'Building Pathology' in the United States was generally perceived as a subset of 'Building Conservation'; while 'Building Pathology' in the UK and in Europe generally appears to be about the identification of 'building defects'. Some attempts had been made or are being made to develop the subject to help in the identification and management of pre- and post-construction defects.

How well is Building Pathology understood and applied?

Building Pathology as a subject or as a 'tool' for the investigation and management of building defects is not generally well understood or applied. In particular, there is a general failure to understand or allow for the time component in building failures; except in historic building conservation. New techniques for building investigation are constantly being developed. However, these often develop large data sets which are not readily managed or analysed, and the 'flow' of information from building investigations is generally poorly understood or managed. Currently no training in Building Pathology is offered at Herriot Watt and no building undergraduate surveying courses are currently offered. Building Pathology was only generally introduced at Herriot Watt and elsewhere to those studying for MScs in Building Conservation and related subjects.

How can the understanding and operation of Building Pathology be improved?

It is necessary to give academics and building professionals a 'mind map' to allow them to appreciate the significance and use of investigative techniques and the data that can be derived from building investigations. The increasing understanding of the psychology of this process as discussed in books such as 'Blink' by Malcom Gladwell; and reference to the developments in the teaching and application of investigation, diagnosis, therapy and treatment in the medical professions should help in this. Current work on 'machine learning' and engineered algorithms for acquiring and managing data may also help in this process; in the same way that simple machine learning and algorithms are being increasingly applied by the medical professions. However, practical experience and practical guidance in gaining and interpreting practical experience will be an essential part of helping building professionals or academics develop effective 'mind maps'. For the building professions the problem is likely to be 'customer focussed'; in that customers will also have to be educated into appreciating the financial and risk management benefits of the application of 'Building Pathology'.

5. Tele-meeting with Expert 5 at 11:00 – 12.30 hrs on 2 May 2018

What is Building Pathology?

Building Pathology is the understanding of the factors that can influence the durability of a building and its components, their inter-relationship; and how they might affect a property, its occupation, its ownership, both now and in the foreseeable future. This requires an holistic approach to the inspection and advice from the current and probable future consequence brought about by the state of the property. A building is or can be affected by the construction and materials used in its construction, materials added in changes – and the changes themselves, the ground upon which it sits, the external/internal climate (wind, rain, humidity, ice and the temperature of their components), as well as aspects of neighbouring intervention – such as disease and pestilence, and interaction of all or any of these influences. The use of the building, the performance of the occupants and the expectations, reasonable or otherwise, form the property matrix. Building Pathology is a holistic approach to studying and understanding buildings, and usually will have the outcome of reporting and advising upon, or determining the outcome in particular for building defects (or limitations), and upon the associated remedial action.

How has Building Pathology developed?

The practical application of Building Pathology became apparent during work in an architect's office and later in undertaking work for estate agents in the 1980s. However, the term 'Building Pathology' achieved formal acceptance by the RICS during discussions with European organisations in 1990 while getting recognition for the profession of 'Building Surveyor'. 'Building Pathology' had recognition at that time particularly in France as the investigation of building defects, while the profession of 'Building Surveyor' was not generally recognised outside of the UK at that time. The subject of 'Building Pathology' was then incorporated by the RICS as a core discipline, and the CIB started a working group. However, despite international conferences and text books defining the subject; the necessity of key players to focus on professional and commercial interests limited the further development and acceptance of the subject. This resulted in little development of the subject since 2000. Big clients, such as government agencies and insurance companies initially 'bought in' to the concept, and insurance companies and solicitors appreciated the value of expert witnesses who understood the subject. However, this largely resulted in the development of 'Building Forensics' which may best be understood as a subset of 'Building Pathology'. Despite this the general understanding and application of Building Pathology has not developed since 1990 to 2000; largely due to problems with effective teaching of the subject in the UK, and the fact that the majority of business for general surveyors is led by the requirements of estate agents. As a result, commercial pressures on general surveyors and the RICS has not encouraged the development of 'Building Pathology' as a commercial service to clients, there has therefore not been a commercial incentive for students to study the subject of 'Building Pathology', or for academic institutions to deliver effective teaching of the subject.

How well is Building Pathology understood and applied?

Although the value of 'Building Forensics' may be well understood and applied in the UK and abroad, 'Building Pathology' appears to generally thought of as a subset of building conservation in the UK and Europe; and particularly North America. Building Pathology is therefore not generally well understood and applied by building surveyors, architects or engineers in the UK. This appears to be because the RICS in particular is dominated by the requirements of business generated by estate agents; and there is little or no understanding of the cost-effective application of Building Pathology by the client base in the UK.

How can the understanding and application of Building Pathology be improved?

Effective teaching of the subject of Building Pathology is required in the UK, both to students and as part of CPD to building professionals. This will require effective teaching using 'visual systems' and 'case studies'. However, for effective teaching to occur, the requirements for the building professionals in the UK will require more formal definition; and it is probable that system of specialisation and qualification will have to be devised and recognised. For this to occur in the UK the commercial dominance of the RICS by the requirements of 'estate agents' will have to be addressed. The publication of articles in relevant journals, the holding of conferences, and the setting up of specialist interest groups within or alongside existing professional institutions should be; both nationally and internationally.

6. Meeting with Expert 6 at 17:00 – 18:00 hrs on 21 March 2018

What is Building Pathology?

The subject to Building Pathology was first encountered when working as a conservation architect in the UK. However, the concepts of an holistic approach to buildings evolving over time was inherent in architectural education in Pakistan, where the tradition of 'Classical Architectural Training' was followed in conjunction with a more practically based course, that included an appreciation of an historic building heritage. This contrasts with the professional education of architects in the UK where no special provision appears to be currently made for the technical aspects of building, refurbishment or conservation in academic courses; and reliance is placed on largely unstructured learning in practice.

How has Building Pathology developed?

In the UK Building Pathology is recognised as a subject by conservation architects, particularly by Roger Myers RIBA who has acted as a mentor. Conservation architects therefore learn some aspects of Building Pathology from experience when in practice, or on post graduate conservation courses. However, there is no development of the concepts, procedures or methods. The RIBA has a 'Conservation Register' and 'Conservation Advisory Group', and more recently Building Pathology was taught as part of the AA Building Conservation Conference. Despite the above, no academic or practical architectural training in the UK includes Building Pathology as a core or specialist subject.

How well is Building Pathology understood and applied?

Building Pathology is generally not well understood or applied in the UK. Even conservation architects who may develop some of the necessary skills as they become more experienced in practice do not have a 'framework' in which to develop or apply the subject to design, refurbishment or conservation. Individual conservation architects and conservation practices may develop a high level or expertise; but this is not generally transferable, except by practical experience.

How can the understanding and operation of Building Pathology be improved?

Ideally, Building Pathology and a more practical and holistic approach to design would be taught as part of architectural professional training. However, the RIBA would currently find it difficult to encourage this via the ARB criteria; as there is currently an over-emphasis on the art aspect of architecture in undergraduate courses, and little or no technical training. The inclusion of Building Pathology as part of post graduate courses would therefore be easier. Ideally this would be in conjunction with appropriate accreditation. It would be necessary for the architectural schools to talk to professional practitioners in order to develop a more practically based training.

7. Tele-meeting with Expert 7 at 16:00 – 18:00 hrs on 3 May 2018

What is Building Pathology?

Building Pathology is the study of defects in both new and old buildings. The term was probably of French origin but was used to describe investigation of defects in buildings rather than in its more holistic sense. More holistic aspects of the subject may have developed in conjunction with pre- and post-occupancy assessment, and the evolution of building quality assessment. The subject of Building Pathology may have existed from 1985 onwards but the more holistic study of the subject including the evolution of recent buildings and the investigation and understanding of building conservation and rehabilitation was understood by 1996.

How has Building Pathology developed?

Building Pathology has been taught and studied since the 1990s and has become a core subject in Portugal for Civil Engineers and Architects for whom it is a mandatory subject. Many papers and technical journals have been written on the subject of Building Pathology and both national and international conferences have been held. This has generally involved studies associated with the conservation maintenance of buildings or the more holistic understanding of Building Physics which is essential for proper understanding of Building Pathology has been less well developed. Unfortunately, the commercial understanding and application of Building Pathology has not developed in a way that would encourage the development and application of the subject, as might have been hoped. There has been a continuing development of the technology for building investigation, and a rapid increase in the availability of information; especially associated with the development of the online information sources. However, there has not necessarily been a parallel development in the ability of building professionals or researchers to handle the resulting data in order to allow the study and application of Building Pathology

How well is Building Pathology understood and applied?

Building Pathology is a mandatory subject in the training of both Civil Engineers and Architects in Portugal who are often trained together. However, it is difficult to assess how well the subject is understood generally. It is probable that it is less well understood by

Architects and is generally not well applied in the design process. This may be due to a lack of commercial incentive for the application of Building Pathology in Europe and elsewhere.

How can the understanding and application of Building Pathology be improved?

For the understanding and application of Building Pathology to be improved it is necessary to teach building professionals and academics ‘how to think’, and how to source and handle the information that is increasingly available. In this context the understanding and teaching of processes of ‘inspection’, ‘diagnoses’, and the ‘prioritisation’ of defects is important.

8. Tele-meeting with Expert 8 at 12:00 – 13:30 hrs on 12 April 2018

What is Building Pathology?

The concept of 'Building Pathology' was first encountered when the idea of 'building diagnostics' was introduced as part of the architectural? course in 1983/84; although Building Pathology was not encountered as a subject until introduced by Bickerdike Allen during workshops presented at ABK Architects. In practical terms the subject to Building Pathology was only understood by practical experience supported by 'mentors' in the subject. In practice, this requires a 'team environment'.

How has Building Pathology developed?

There have been significant improvements in the 'availability of technical data' over the years, and many technical developments, investigations and tests. However, there has been no progress in the training of building professions or in the integration of the subject into the 'design process'. Generally, the design process does not teach people to think about how materials 'fit' and no formal process of studying the defects that may occur. Experienced designers understand the importance of managing risk, especially in the context of 'design and build'. However, generally the more brutal process of 'evolutionary feedback' and building forensics have been applied. This has not resulted in a development of cost-effective risk management systems in the design process, or the development of the subject of Building Pathology.

How well is Building Pathology understood and applied?

Building Pathology is very little understood or applied by architects or design teams generally, especially in the UK.

How can the understanding and application of Building Pathology be improved?

For the understanding and application of Building Pathology to be improved in the area of architecture and design; it would be necessary for both the professional bodies and clients to recognise the importance of the subject, and to recognise those with specialist knowledge in its application. In the USA, architectural specialities are recognised 'niche' roles such as 'technical design', however, this is not currently the situation in the UK.

Although, the role of 'conservation architects' or those specialising in facades are being increasingly recognised. There may be a problem in the term Building Pathology in that it has a negative context. It may therefore be necessary to use terms such as 'building longevity' or 'risk management' in its application; especially in a client facing environment. Generally, Scandinavian architects appear to have a better technical training and therefore have a better grasp of the avoidance and management of defects. Further understanding of how the subject has developed and is currently applied elsewhere in Europe is also necessary. Generally, it will be necessary to integrate Building Pathology into CPD, preferably in conjunction with a system of 'mentoring' and review of practice. This could be marketed to clients as part of 'QA' on projects as well as becoming a requirement of professional bodies. Such as process would be amenable to online teaching systems. Generally, there is a problem with academic training in identifying core subjects and core capabilities. It is therefore necessary to teach what specialist knowledge may be required and where this may be obtained, rather than teaching the knowledge itself. This may be provided as part of a continuing programme of 'mentoring', analysis and feedback before and after qualification.

9. Tele-meeting with Expert 9 at 12:00 – 12:20 hrs and 13:00 – 14:00 hrs on 2 March 2018

What is Building Pathology?

Building Pathology as a concept arose as a result of taking an 'Holistic' approach to building surveying. This was a reaction against the narrow minded, sub-contractor, and product-led solutions being offered by general practice surveyors; especially working for local authority clients where a longer-term view of the management of the buildings provided an incentive for longer term and 'Holistic' approach to identification of problems and cost-effective resolution offered significant savings. It became clear that the application of an 'Holistic' and wholly independent approach to identification of problems in buildings and their resolutions offered the opportunity for improved occupant satisfaction as well as savings in time and money. The terms 'Pathology' and 'Building Pathology' were used by a number of practitioners in conversations and conferences, both in the UK and the US, when trying to describe this more 'Holistic' approach to the subject of building defect surveying and resolution.

How has Building Pathology developed?

Building surveyors and other building professionals have continued to avoid taking responsibility for identifying building problems or their cost-effective resolution; and the RICS and other professional bodies have not embraced the subject in a way that would allow it to progress. Despite the efforts of a number of eminent practitioners, RICS, RIBA and other professional bodies have remained stubborn in this. This may be due to a reluctance to take on responsibility in a 'professional' manner but may also be due to the financial influence of specialist contractors and their trade organisations. As a result, the term 'Building Pathology' has been largely used by practitioners and academics to show that 'they are different' from others. This failure by the professions to embrace and develop the subject has meant that academics have not effectively taught or developed the subject.

How well is Building Pathology understood and applied?

Building Pathology is not generally well understood or applied, especially by surveyors and other building professionals. In particular, Building Pathology is not understood or applied by building professional bodies in the UK or abroad.

How can the understanding and application of Building Pathology be improved?

The younger generations of building professionals are used to being taught using electronic audio-visual and IT media, and a number of innovative projects are in hand to provide cost effective teaching aids to allow them to 'read buildings' and follow the 'Holistic' processes required for the effective application of Building Pathology. However, practical experience of applying the procedures and methods of Building Pathology is essential in developing the 'detective mind' required for the application of Building Pathology. Generally, for a minimum period of 1-2 years in order for them to be effective. However, 'interactive learning programmes' developed with industry and university support should be a significant help in doing this. It will be necessary to get professional bodies to recognise the subject to Building Pathology as a recognised speciality. Many of the building professionals and academics involved in the 'birth' of Building Pathology as a subject are now eminent and senior within their organisations. The time may therefore be right for them to form an 'institute of Building Pathology' and to press for the more formal recognition and teaching of the subject, for example, by recognising a 'diploma in Building Pathology'.

10. Tele-meeting with Expert 10 at 08:30 – 09:30 hrs on 9 April 2018

What is Building Pathology?

Building Pathology is the holistic investigation of failures in buildings recognising the way the components, occupants and environments affected the building, and the way these characteristics worked together. Building Pathology was first encountered as a subject approximately 20 years ago at the University of Wolverhampton; with regard to valuations and in programming the final year training modules for students, studying to get RICS 'professional competency' in this subject. However, the 'holistic' aspect of the subject is its defining feature compared to other aspects of building surveying.

How has Building Pathology developed?

Importantly, Building Pathology has become a core aspect of building surveying training in the UK. However, although there have been technical advances in investigation of building failures, there appears to have been no real advance in the way the subject is understood or taught. The journal 'Structural Survey' recently changed its name to include 'Building Pathology', in order to try and encourage the development of the subject. However, this has so far only been a partial success, and there has been some resistance to this change. This may be due to a poor understanding of the subject and its general applicability.

How well is Building Pathology understood and applied?

Although Building Pathology is generally introduced as part of training of building surveyors in the UK, the subject may not be generally well understood or taught in an academic environment. Generally, practical experience has been essential in developing the 'holistic' understanding of building failures. However, although practical modules are often included, and are often taught by experienced practitioners; this is generally not in a formal or structured way. Teaching of Building Pathology is also generally subsumed into other modules in the final years of training, and is not taught as a subject in its own right. Building Pathology is therefore often thought to be synonymous with the investigation of building failures; rather than being understood in a more holistic way.

How can the understanding and application of Building Pathology be improved?

Recent advances in building metrics may assist in the understanding and application of Building Pathology. However, there is a real challenge in teaching the breadth of the role of a Building Surveyor. Generally, the profession of 'Building Surveyor' is not well understood outside the UK, and the RICS currently appears to be focused on international 'outreach' and 'branding', rather than developing the application of core disciplines. Practical experience on site would be key in developing the mental processes required for the application of Building Pathology. However, health and safety issues often preclude this in undergraduate and post-graduate training. Generally, Building Pathology should be taught as an essential part of teaching building information and modelling, building defects, building maintenance and adaption of buildings; especially to meet environmental change. Consideration should be given to the early production of a paper in an appropriate peer reviewed journal covering the issues above; so as to highlight the issues described above, and so as to encourage interested parties to work together to develop the subject.

11. Tele-meeting with Expert 11 at 17:00 – 18:00 hrs on 20 March 2018

What is Building Pathology?

Building Pathology as the holistic investigation of failures in buildings was first encountered approximately 20 years ago in the UK, with references made to the subject in the 1980s and 1990s. Building Pathology was encountered initially in practice when trying to understand and 'design out defects', but no background information was not generally available.

How has Building Pathology developed?

Building Pathology has not been part of architectural teaching in the last 20 years. Indeed, very little if any teaching in the UK covers structures, and much is 'art orientated'. Some universities such as Nottingham Trent University and Cardiff University cover structures more effectively; but Oxford Brooks University tends to be art orientated.

How well is Building Pathology understood and applied?

For the reasons described above, Building Pathology is not generally understood or applied by architects. Architects generally have little understanding of building failures, structures, environments or weathering (except as an aesthetic rather than functional phenomena). In Germany, architecture training was more practically based and may thus have been more amenable to the procedures of Building Pathology. In the UK Building Pathology only appears to have been studied by those involved in building conservation, and generally at a post graduate level. This has not allowed the general understanding or application of the subject.

How can the understanding and operation of Building Pathology be improved?

In order for Building Pathology to be more generally understood and applied by those in the architectural profession; it will be necessary first for architects to be given a better understanding of structures and environments. This will require a more formalised approach to gaining practical experience as part of the educational process. For architects in the UK currently this aspect is generally covered 'in practice' and the wrong lessons and 'coping mechanisms' may therefore be learnt

12. Tele-meeting with Expert 12 at 09:00 – 09.40 hrs on 20 April 2018

What is Building Pathology?

Building Pathology was effectively defined in the Building Pathology conferences of 1989-92 and in many subsequent research papers. The key aspects of the subjects are the understanding of the interaction between building materials, building environments, and building occupants; and the study of building failures with a 'whole building approach'.

How has Building Pathology developed?

Building Pathology as a subject appears to have 'moved backwards' in the UK since its conception in the 1990s. This has been because of a failure of clients and their project managers to 'buy in'. With no commercial drive and no client requirements, the application of the subject has not developed; and as a result, development of education, training and research has not occurred. In Germany a more practical approach and better technical training of building professionals has resulted in the development of the subject but not necessarily under the heading of Building Pathology. Similarly, architects and other building professionals in Norway and Denmark appear to have a better understanding of the subject. However, Building Pathology in Europe tends to refer to 'building diagnostics'; rather than the more 'holistic' application of the subject to remediation, risk management and research.

How well is Building Pathology understood and applied?

Building Pathology is not understood or applied in the UK. The subject and its professional application are effectively 'killed' by client requirement for 'guarantees' for products or services. These 'guarantees' are heavily marketed to clients, as they imply that 'risks are managed'; even though this is not the case in the real world.

How can the understanding and application of Building Pathology be improved?

For the understanding and operation of Building Pathology to be improved in the UK, it will be necessary for its application to be formally required by being embodied in some form of 'legislation'. Training and education will be important but this must be 'market driven'. Professional bodies such as the RICS, RIBA, CIOB and CIB should have a role in this; and the publication of guidance notes such as those produced by BRE in the past, and the publication of British Standards or European Standards, would be helpful in specification. However, without a ‘legal obligation’ to apply Building Pathology the subject will not develop.

13. Tele-meeting with Expert 13 at 12.00 – 12.45 hrs on 15 June 2018

What is Building Pathology?

Building Pathology can be defined as 'providing a systemic scientific approach to discovering what has gone wrong in a failed building'. Though in this way broadly perceived, Building Pathology in practice appears to be mainly limited to technical/physical aspects and approaches. But unlike human beings, buildings are manmade artefacts subordinate to their owner's behaviour and decisions, and pathological approaches should thus also incorporate the behavioural side.

How has Building Pathology developed?

The approaches to building pathologies inherent in the subject were apparent in the 1970s in dealing with problems in housing estates in Holland. However, the subject Building Pathology was first encountered in the early 1990s. Since then there have been many publications and meetings on the subject of Building Pathology. However, 90 per cent of these publications cover technical or physical aspects of the subject rather than the philosophy of the subject or its methods and procedures. In practice the subject has developed into the sub-subject of Building Forensics in resolving legal issues and there has been no real developments in handling or understanding of 'information'. The CIBW089 Building Pathology Commission has become largely moribund in recent years; probably due to overcommitment of the leading academic and professional proponents of Building Pathology. Recently there has been an increased interest in the maintenance and 'lifecycle' of buildings, especially in domestic occupancy. This is because housing stocks in many parts of the world built since the middle of the 20^{th}C are now ageing and funding may not be available for total replacement. There is also more political interest in the probable effects of climate change and perceived requirements for energy efficiency. This has stimulated the development of 'Housing Pathology' as a discipline within Building Pathology and a new 'branch of the tree'.

How well is Building Pathology understood and applied?

Representatives from different countries prepared papers on the understanding and application of Building Pathology for presentation at a meeting of the CIBW086 Building Pathology Commission at the ISBP 2015 Conference. However, this does not give a picture of a subject well understood or applied. It was estimated that 60-70 per cent of domestic property was built within the last 35 years, and this of often of relatively poor quality. Although an increase in quality occurred with the recession in 2008 in Holland, there has been a subsequent fall-off in quality. This has been due to a fall-off in the level of skills in the work force, and lack of financing from banks. The mind-set is generally that of 'Developers' rather than taking a holistic view. In Holland this is particularly problematic due to the scarcity of suitable building land where it is estimated that 92 per cent of possible sites are already developed

How can the understanding and application of Building Pathology be improved?

For Building Pathology to be better understood and applied, Building Pathology is not taught as a subject in Holland either on its own or to building professionals and although there is an understanding and a commercial need for Building Forensics. A ?? mental need is for stakeholders to recognise the importance of the subject. In the long-term increasingly scarce finance and resources will make the application of Building Pathology essential in whatever form it is recognised and applied. However, for example only 50 per cent of office space is currently occupied there is still pressure to build more offices in Holland due to a mind-set unchanged since the 1960s.

Who could usefully be contacted to discuss the above?

International members of CIBWO86 Building Pathology Commission would be a good start.

14. Meeting with Expert 14 at 10:00 – 11:00hrs on 26 January 2018

What is Building Pathology?

Building Pathology is the holistic study of failures in buildings and the built environment as defined in the conferences of 1989 – 1992. However, there is a lack of a 'shared understanding' of the definition of the subject.

How has Building Pathology developed?

There has been a failure to develop a 'shared understanding' that works for all, is useful, and that people 'buy into'. Although a corpus of literature has developed, this has mostly emanated from outside the UK, and although there may have been some 'modules' purporting to cover 'Building Pathology'; there are no regular serious academic courses. This has prevented the subject gaining wide recognition within or outside academia as has occurred for example with 'Forensic Science'.

How well is Building Pathology understood and applied?

As discussed above; Building Pathology is not generally well understood or applied in academic as well as professional circles.

How can the understanding and application of Building Pathology be improved?

In order for the understanding and application of Building Pathology to be improved a common framework will have to be agreed. Although Building Pathology is a holistic subject and is therefore by definition multi-disciplinary; it will be necessary for people to develop a common training or experience so that it will become clearer who is 'in the tent' and who is 'out of the tent'. It will then be possible to further develop the corpus of literature, and to deliver courses and qualifications to confirm Building Pathology as an academic and practically useful subject. Further reference should be made to the 'History Science', 'Philosophy Science' and to the development of parallel subjects such as 'Forensic Science'. Reference should also be made to BIM, and the current work on the development and analysis of large data sets. Papers on the 'philosophy' and 'science' of Building Pathology should be published in appropriate peer-reviewed journals.

15. Tele-meeting with Expert 15 at 12:00 – 13:00 hrs on 5 March 2018

What is Building Pathology?

Building Pathology is the holistic study of failures in buildings and the built environment as defined in the conferences in 1989-1992, and in books with that title since that time. An official RICS definition does not appear to have been agreed.

How has Building Pathology developed?

Building Pathology has developed in the surveying and conservation of buildings and has been recognised as a subject by the RICS. However, it has not developed since the 1990s due to a lack of RICS 'buy-in'. This is largely related to failure of recognition of the subject by clients and in briefs from clients. Building Pathology in the UK has therefore become synonymous with 'defect surveying' for general surveyors.

How well is Building Pathology understood and applied?

Building Pathology as a subject is not generally well understood or applied in the UK, except by specialist 'Building Pathologists', and some of those involved with conservation science such as Toby Curtis who will produce 'building performance reports'. Generally, there has been a failure to 'value' the application of Building Pathology and to 'invest' in the development and application of the subject.

How can the understanding and operation of Building Pathology be improved?

It is very difficult to 'package a mindset'. However, whatever can be used to focus research and professional practice should be welcomed. However, this must take into account of existing organisations such as the Association of European Experts in Building Construction (AEEBC) and in particular, the International Council for Research and Innovation in Building 'Building Pathology Commission' (CIBW086). The RICS does not currently have a Building Pathology committee but does have committees concerned with maintenance, conservation and other related subjects. Obviously, it would be useful if the RICS could be motivated to form such a committee. The CIOB is becoming interested in conservation (largely through the work of John Edwards and Rory Cullen). It will be necessary to include the other main building professions such as the RIBA and the Institute of Structural Engineers; possibly via the IHBC who have some degree of technical interest. The original Building Pathology conferences are still talked about, and a conference even if a ‘one off event’ could draw focus on Building Pathology as a subject; especially if shared with an academic institution.

16. Tele-meeting with Expert 16 at 09:30 – 10:30 hrs on 27 February 2018

What is Building Pathology?

Building pathology is a subject started approximately 20-30 years ago with the use of terms from human pathology and medicine to try and described some of the decay processes in buildings. In particular, trials were made of some of the diagnostic procedures from the NHS to develop procedures for formal assessment of the condition of historic stone buildings. This implied a connectivity in the systems involved which may not have existed; while the procedures used in medical diagnosis having been developed over at least 50-70 years, and had been based on extensive research, as well as fundamental science. The attempts to apply these procedures may have been encouraged by the apparent need to take a more holistic approach to building and material failures and may have indeed encouraged this holistic approach. However, the undefined use of 'medical terminology' may have resulted in confusion.

How has Building Pathology developed?

A number of experienced and senior academics have encouraged the use of the term 'Building Pathology' in the past. This may be due to their holistic 'view' of the subject based on extensive experience and the interest in 'complex systems approximately 20 years ago. The term 'Building Pathology' has also been used in many papers. However, because of an apparent lack of clarity in the definition of the term and the associated medical related terminology, the subject has not developed in any coherent way.

How well is Building Pathology understood and applied?

Building Pathology as a subject is not well understood or applied, and although a few modules on Building Pathology have been taught in the past; these did not appear to have been well taught by those who have a clear understanding of the subject. As a result, students do not appear to have been given a clear understanding of the subject or how it could be applied to allow a holistic approach to building related problems. In particular, there is a general failure to effectively train students of architecture or other building professionals in 'holistic' decision making.

How can the understanding and application of Building Pathology be improved?

It will be necessary to introduce effective modules in Building Pathology to existing engineering and architectural courses. However, there will be a problem in convincing students and institutions of the need for this; and it will be necessary to provide appropriate academic certification. Simply delivering 'modules' to students does not seem to change the way they 'think about buildings' or allow them to 'read buildings' in an effective way. Practical experience appears to be necessary to allow effective 'holistic' approaches to diagnosis and decision making to become embedded in the way students think.

APPENDIX B: PRELIMINARY ANALYSIS OF PUBLICATIONS IN THE INTERNATIONAL JOURNAL OF BUILDING PATHOLOGY AND ADAPTION

Analysis Table of Reading Instances by Country of Origin of Published Papers for 2016, 2017, and to the end of April 2018

IJBPA:	Country Usage		
Country	2016	2017	2018 (to end of April)
United Kingdom	19,981	21,293	9,437
Malaysia	12,979	15,047	3,999
Australia	6,041	5,386	1,901
USA	5,475	3,256	966
China	5,406	5,114	1,760
Canada	1,828	1,151	521
Ireland	1,683	1,320	396
Thailand	1,643	738	248
Hong Kong	1,469	1,688	472
Sri Lanka	1,333	1,136	191
South Africa	1,239	1,250	438
Egypt	1,081	1,334	592
Switzerland	872	299	161
Netherlands	701	658	346
New Zealand	681	889	283
India	678	726	397
Indonesia	640	1,144	334
Sweden	585	702	320
Germany	578	722	244
Brazil	528	681	246
Ghana	522	584	165
Turkey	433	928	466
Italy	394	577	138
Pakistan	384	447	174
Singapore	379	421	69
Mexico	350	300	82

IJBPA:	Country Usage		
Country	2016	2017	2018 (to end of April)
United Arab Emirates	342	298	99
Portugal	302	273	79
Kenya	284	191	69
Saudi Arabia	268	229	135
Republic Of Korea	252	297	90
Finland	251	306	97
Zimbabwe	227	199	110
Norway	218	179	85
Spain	208	230	108
Lithuania	191	264	77
Taiwan	181	201	43
Philippines	180	256	75
Belgium	180	181	51
Denmark	174	206	131
France	137	202	97
Mauritius	125	53	24
Greece	119	163	58
Tanzania	112	101	28
Botswana	111	119	59
Japan	109	74	23
Colombia	100	81	49
Poland	97	65	48
Austria	95	230	146
Iran	72	118	47
Jordan	65	62	23
Bangladesh	64	146	57
Uganda	61	103	30
Lebanon	60	69	46

Source: Data held by Emerald Group Publishing on the peer reviewed papers published in the International Journal of Building Pathology and Adaption in the period January 2016 to April 2017 was analysed by the publishers, on behalf of the author; in order to determine who is reading the contributions.

Analysis Table of Reading Instances by Country of Origin of Published Papers for 2016, 2017, and to the end of April 2018 (Continued)

IJBPA:	Country Usage		
Country	2016	2017	2018 (to end of April)
Peru	56	111	36
Serbia	55	28	3
Trinidad &Tobago	53	39	36
Malawi	52	1	1
Croatia	50	26	8
Oman	46	16	19
Slovenia	43	32	40
Malta	41	92	34
Jamaica	40	51	7
Estonia	38	35	46
Israel	35	29	1
Uzbekistan	30	26	21
Costa Rica	30	13	0
Kuwait	29	17	3
Cyprus	26	36	9
Zambia	23	13	7
Ethiopia	22	88	49
Qatar	21	15	12
Latvia	20	33	7
Palestine	19	29	33
Romania	19	57	14
Namibia	17	55	15
Puerto Rico	17	5	9
Russian Federation	17	22	6
Slovakia	16	2	2
Brunei Darussalam	16	42	1
Chile	14	12	9
Macao	14	14	7

IJBPA:	Country Usage		
Country	2016	2017	2018 (to end of April)
Vietnam	13	6	9
Czech Republic	13	15	5
Fiji	12	28	5
Barbados	11	12	0
Seychelles	11	7	0
Hungary	7	17	9
Luxembourg	7	6	0
Bahrain	6	8	5
Rwanda	6	3	4
Iceland	5	4	3
Nepal	5	0	0
Nigeria	4	18	4
Curacao	3	0	0
Kazakhstan	2	6	2
Ecuador	2	16	0
Bulgaria	1	6	1
Argentina	1	5	0
Aruba	1	1	0
Swaziland	1	0	0
Ukraine	0	0	4
Belarus	0	2	1
Mozambique	0	7	0
Uruguay	0	3	0
Venezuela	0	3	0
Algeria	0	1	0
Honduras	0	1	0
Jersey	0	1	0
Tunisia	0	1	0

Analysis Table of Papers Published by Author's Country of Origin

Countries	Number of Authors	Percentage of Total Authors
Australia	55	7.3%
Bangladesh	1	0.1%
Belgium	1	0.1%
Brazil	6	0.8%
Cambodia	1	0.1%
Canada	1	0.1%
China	13	1.7%
Denmark	1	0.1%
Finland	1	0.1%
France	9	1.2%
Germany	8	1.1%
Ghana	17	2.2%
Greece	2	0.3%
Hong Kong	37	4.9%
Iceland	1	0.1%
India	2	0.3%
Indonesia	4	0.5%
Iran	1	0.1%
Ireland	9	1.2%
Italy	16	2.1%
Japan	5	0.7%
Jordan	3	0.4%
Malaysia	49	6.5%

Countries	Number of Authors	Percentage of Total Authors
Mauritius	2	0.3%
Mexico	6	0.8%
Netherlands	21	2.8%
New Zealand	9	1.2%
Nigeria	6	0.8%
Norway	4	0.5%
Palestine	1	0.1%
Peoples Republic of China	1	0.1%
Portugal	34	4.5%
Saudi Arabia	10	1.3%
Singapore	14	1.8%
South Africa	1	0.1%
Spain	5	0.7%
Sri Lanka	4	0.5%
Sweden	8	1.1%
Turkey	8	1.1%
United Kingdom	247	32.6%
USA	17	2.2%
Zimbabwe	1	0.1%
No Country Identified	115	15.2%
Total:	**757**	**100%**

Description: The results of this analysis in the table, appear to show Australia, Malaysia and Portugal as disproportionately active presumably due to local academic and professional conditions. The results also appear to show the USA as relatively inactive, presumably due to the general use of the related term 'Building Forensics' to cover activity in this field.

Source: Data held by Emerald Group Publishing on the peer reviewed papers published in the International Journal of Building Pathology and Adaption in the period January 2016 to April 2017 was analysed by the publishers, on behalf of the author; in order to determine who is contributing to this journal.

Analysis Table of Downloads of Papers Published in the Period January 2016 to April 2017

Article Citation	Downloads (total to date at end of April 2018)
Anthony Mills (2001), "A systematic approach to risk management for construction", Structural Survey, Vol. 19, No. 5, pp 245-252	17,437
M.R. Abdul Kadir, W.P. Lee, M.S. Jaafar, S.M. Sapuan, A.A.A. Ali (2005), "Factors affecting construction labour productivity for Malaysian residential projects", Structural Survey, Vol. 23, No. 1, pp 42-54	11,414
Ahmed Hassanien (2006), "Exploring hotel renovation in large hotels: a multiple case study", Structural Survey, Vol. 24, No. 1, pp 41-64	9,826
G.C.J. Lynch (1994), "Bricks: Properties and Classifications", Structural Survey, Vol. 12, No. 4, pp 15-20	8,656
Peter A. Bullen, Peter E.D. Love (2011), "Adaptive reuse of heritage buildings", Structural Survey, Vol. 29, No. 5, pp 411-421	8,234
Y. Arayici, P. Coates, L. Koskela, M. Kagioglou, C. Usher, K. O'Reilly (2011), "BIM adoption and implementation for architectural practices", Structural Survey, Vol. 29, No. 1, pp 7-25	8,052
James Sommerville, Nigel Craig, Julie Hendry (2010), "The role of the project manager: all things to all people?", Structural Survey, Vol. 28, No. 2, pp 132-141	7,095
M.R. Abdul Kadir, W.P. Lee, M.S. Jaafar, S.M. Sapuan, A.A.A. Ali (2006), "Construction performance comparison between conventional and industrialised building systems in Malaysia", Structural Survey, Vol. 24, No. 5, pp 412-424	6,946
Andrew R.J. Dainty, Richard J. Brooke (2004), "Towards improved construction waste minimisation: a need for improved supply chain integration?", Structural Survey, Vol. 22, No. 1, pp 20-29	6,323
Charles O. Egbu, Subashini Hari, Suresh H. Renukappa (2005), "Knowledge management for sustainable competitiveness in small and medium surveying practices", Structural Survey, Vol. 23, No. 1, pp 7-21	6,062

Article Citation	Downloads (total to date at end of April 2018)
Stephen Todd (1995), "Part L and energy rating applied to UK housing", Structural Survey, Vol. 13, No. 2, pp 26-32	5,351
Y.T. Lo, W.M. Leung, H.Z. Cui (2005), "Roof construction defects of medium-rise buildings in sub-tropical climates", Structural Survey, Vol. 23, No. 3, pp 203-209	4,538
Dr Michelle C. Brennan, Dr Alison Cotgrave (2014), "Sustainable development: a qualitative inquiry into the current state of the UK construction industry", Structural Survey, Vol. 32, No. 4	4,014
Alan M. Forster, Brit Kayan (2009), "Maintenance for historic buildings: a current perspective", Structural Survey, Vol. 27, No. 3, pp 210-229	3,910
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APPENDIX C: EXAMPLE OF PATIENT REPORT FORM (PRF) USED IN MEDICAL DIAGNOSIS

0471924

Complete boxes in black ink & BLOCK CAPITALS.
Do not strike through blank sections.

South East Coast Ambulance Service NHS Foundation Trust

Incident Date / / | Incident Number
Call Sign Letter | Call Sign Number | Base OU Talk Group
ID Personnel Number | Grade | Call Time
1 2 3 4 5 6
At Scene | At Patient | Left Scene | Time at Hospital
Location of Incident
As Patient Address
Patient Unwilling / Unable to Provide Details
DNACPR/ RESPECT
First Name
Surname
D.o.B | Age | D/W/M/Y
Gender M/F/U/O | Ethnic Code | NHS Number
Patient Address
Tel: | Postcode
GP Name & Address
Next of Kin (Name, Relationship & Tel.)
Mental Capacity Concern Y N | Communication Difficulties
Safeguarding Concern Y N | Learning Disability | Physical Disability
Presenting Complaint | Onset of Symptoms | Symptom Onset Over 24hr

Primary Survey

Consent Y N | Catastrophic Haemorrhage Y N
Airway Clear | Obstruction
Breathing Present | Ineffective | Absent
Circulation Peripheral | Central Only | Absent
Alertness A C V P U

Airway Management

Effective | No. Attempts | ID
Manual | Size
OPA | NPA | SGA | ETT | Cric | Needle Decomp

Obs.

Time | Resps | SPO_2 (%) | On Air | On O_2 | Peak Flow | $EtCO_2$ | Heart Rate | Systolic BP | Diastolic BP | Temp | Blood Glucose | Pupil Size (mm) | Pupil Reaction
S=Slow N=Normal F=Fixed U=Unable to Assess
GCS E V M
Pain Score | NEWS2/ PEWS | Capillary Refill (Sec)
Rockwood Frailty Score
Major Trauma Step
ECG Interpretation | Time | 3-Lead | 12-Lead
Pre-Alert Yes No
Spinal Immobilisation Yes | Not Req | Refused
Cardiac Arrest DOA | Resuscitation
Burns % | Superficial | Partial | Full
Cooled for 20 min Y N
Clinical Impression
Condition Code 1 | Condition Code 2

Patient Assessment: HPC, PMH, SHx, Meds, Allergies, OA, OE, Tx, Plan, Any other useful information

Cannulation/Access

IV | Size | Time of Access | ID
IO
Suspected Stroke | L | R
Face Y N UTA
Arm Y N UTA
Speech Y N UTA

Drugs (including Gases)

Drug/Gas Name | Code | ID
Time | Dose / % | Unit | Route
Batch | Expiry

Cardiac Arrest/ROLE
Initial presenting rhythm
VF/VT | PEA | Asystole | Other
Bystander | EMS | Other | None
Witnessed By | CPR Started By | Shock Given By | ROSC Achieved By
Time of Arrest | Time CPR Started
Time 1st Shock | Time ROSC
Time CPR Ceased | Time ROLE Applied
Total No. of Shocks Given | Public Defib Applied
Pregnant/6wk Post Birth | ROSC at Any Time | ROSC at Handover
Unexpected Death | ROLE Form Completed | Cardiac Arrest Downloaded
Clinical Lead Name/Signature ID
Controlled Drugs Witness Name/Signature ID
Staff Receiving Patient Name/Signature | Handover Time

Outcome

Hosp Code | Ward/Dept | No. of Continuation Sheet(s) | Non Con Completed | Outcome Code | Form Completed By ID

NHS CONFIDENTIAL

RIC/20190703/PCRV4.2

APPENDIX D: TEACHER QUESTIONNAIRE

Interview Script and Questionnaire for Assessment of Current Best Practice for the Teaching and Learning of Building Pathology

Introduction

It is necessary to give academically valid empirical 'grounding' to proposals to introduce and test learning interventions, in order to facilitate the continuous learning and application of methods and procedures for Building Pathology. This is because it is expected that current best practice in teaching surveyors in the UK includes elements intended to allow the learning of the methods and procedures needed to Diagnose problems in buildings and the built environment; but it is not clear how they are currently prioritised and presented in courses, or how their learning by students is currently assessed. It is therefore intended to gather empirically valid data to answer the research question **"What are the perceived objectives and current best practice in the delivery of teaching and learning in 'Building Pathology modules' and Building Pathology courses in the UK".** As part of the Surveying courses at your institution the subject of Building Pathology is included as a core skill, so that students can learn to identify and diagnose defects in buildings, and give remedial recommendations. It is therefore hoped to interview you online or by telephone, in order to help answer the research question based on the questions bellow. It is intended to record your answers verbatim and electronically for your confirmation and future review, and to provide you with the results of this research in due course.

Question 1:
Profession: *(tick boxes, multiple choices allowed)*

- Architect:
- Archaeologist:
- Building pathologist:
- Conservator:
- Engineer:
- Historian:
- Material Scientist:
- Project Manager:
- Other: [ ]

Professional Affiliations: *(tick boxes, multiple choices allowed)*

- RICS:
- CIOB:
- RIBA:
- CIBSE:
- RISE:
- Other: [ ]

Nationality: *(tick boxes, multiple choices allowed)*

- UK:
- EU:
- F:
- D:
- PO:
- P:
- ES:
- NL:
- B:
- US:
- AU:
- NZ:
- SA:
- IR:
- I:
- CAN:
- Other: [ ]

Academic Qualifications: *(tick boxes, multiple choices allowed)*

NVQ:

Dip:

BA/BSc:

MA/MSc/MPhil

PhD:

Other: [ ]

Number of Years of Experience in Building Industry, Building Related Research and Building Related Education: [ ]

Do you have any special training, practical experience or expertise in Building Pathology?

Question 2: Please could you list what you believe to be the 5no. most important and useful teaching and learning activities in the order that they are prioritised in your current course.

Further clarification questions on interview:

"How would you like to change the prioritisation of learning activities?"

"To what extent is the prioritisation controlled by third party requirements, time, and resources?"

"Are the activities below used on your course?"

A: Introduction for Students to building defects and their causes.

B: Introduction for Students to common building defects and the usual remedial measures.

C: Enabling or encouraging the Students to talk through cases with more experienced senior colleagues (On course or on placement).

D: Enabling or encouraging Students to talk with colleagues of similar or slightly more experience on course or on placement (Near-pier Mentoring).

E: Providing Students with experience of investigating defects on site.

F: Encouraging Students to think through site investigations they have been involved with (Reflective Learning).

G: Providing references to articles or books on Building Pathology.

H: Providing or referring students to on line and/ or DVD based learning packages.

I Talking through case studies with Students on PowerPoint or other audio-visual media

J: Providing lectures from staff at university or college.

K: Providing lectures from specialist guest speakers on line, or at university or college

L: Introduction for Students to the importance of investigating the history of a defect and of previous remedial interventions.

M: Introduction for Students to diagnostic tests for defects and their limitations.

N: Introduction for Students to the probabilistic nature of investigations, and the concepts of prior probability or expectations refined by further tests to give probabilistic diagnosis and risk-management.

O: Introduction for Students to Building Pathology as a process in the evolution of buildings as complex systems.

P: Introduction for Students to Building Pathology as a Holistic subject where defects do not occur in isolation.

Question 3: Please could you also give each activity a score from 1 to 5 where 5 is very useful and 1 is of least use. Please score as 0 if not used as part of the course at your institution.

Further clarification questions on interview:

"Why is activity # not used?"

"Why do you score activity # as 5?"

Question 4: How would you like to change the time and resources for these learning activities?

Further clarification questions on interview:

"To what extent is this activity controlled by third party requirements?"

"To what extent do you rely on this activity being undertaken on placement?"

"To what extent do you rely on the individual Student to undertake this activity"

Question 5: How useful is the information available from the RICS or other Professional bodies in preparing your course material?

Further clarification questions on interview:

"Do you get useful feedback from the RICS or other Professional and Examining bodies on your course?"

Question 6: What other sources and standards do you use in preparing your course material?

Further clarification questions on interview:

"Do you rely on standard text books and which one(s) in preparing and delivering your course?"

Question 7: How do you assess the efficacy of the teaching and learning packages currently provided by the Building Pathology module in your course?

Further clarification questions on interview:

"Do you rely on examination, Student feedback, or feedback from other sources?"

APPENDIX E: DRAFT SYNOPSIS OF BUILDING PATHOLOGY COURSE COMPETENCIES AND TAUGHT MODULES

The following is a list of subjects that a qualified professional Building Pathologist should have understood and be able to demonstrate competency in. These could therefor form the modules of a Building Pathology course with academic credits leading to Certificate, Diploma, and MSc qualifications.

Each of the competencies and modules listed below could be taught by a face to face or online seminar supported with a reading list and, technical literature and bullet points. This could be followed by further directed study of say, 5 to 15 hours including further reading, Reflective learning, Near-Pier mentoring, and a relevant Case Study with a written report (for say, 60 credits).

Successful completion of the above could allow qualification at Certificate level. It could also allow qualification at Diploma level after completion of at least, say. 750 hours of supervised and logged practical experience working as a Building Pathologist, including, say, 20 no. case studies demonstrating specific competencies (for say, and additional 60 credits), and could form the basis of an MSc course with additional training in research and a research project (for say, an additional 60 Credits).

Principles of Building Pathology (Say, 14 Credits)

1. **Introduction to Principles of Building pathology:**

   Understand the background of Building Pathology and how and when it can be usefully applied for the diagnosis, remediation and risk-management of failure in buildings and the built environment. Understand how to learn to apply the subject of Building Pathology, and who and what resources can help with its application and learning

2. **Health and Safety of Structures, Contents, and Occupants:**

   Understand the potential effects of building failures on the health of structure, contents and occupants of buildings and the built environment.

3. **Principles and Practices of Diagnosis:**

Understand the principles and practice of the metacognitive processes for investigation, diagnosis, remediation and prognosis of building failures. Understand how to apply and continuously learn metacognitive processes and protocols for the investigation, diagnosis, remediation and prognosis of building failures. Understand how Building Pathology can be used for risk-identification, risk management, and allocation of 'risk-ownership' for building failures.

4. **The Evolution of Buildings and Building Pathologies Over Time:**

Understand the evolution of buildings and the built environment and occupancy as complex systems or 'superorganisms' evolving over time and understand building pathologies as emergent phenomena in these processes.

5. **History Taking:**

Understand the importance of the history of the building and of building failures in the understanding of Building Pathology. Understand the importance history taking in the diagnosis of building failure, and protocols for effective history taking.

6. **Best practice for Investigation and Testing:**

Understand the general limitations and probabilistic nature of investigations and testing. Understand the basis of Basian inference in diagnostic reasoning in Building pathology. Understand the use and limitations of the investigative techniques and tests commonly used in the investigation of building failures.

7. **Best practice for Ethical and Professional Recording and Report Writing:**

Understand the background and importance of Ethical and Professional recording and report writing. Understand the protocols and procedures for current best practice in recording and report writing for Building pathology. Understand the potential uses and abuses of AI in recording and Professional report writing.

Mechanisms of Building Failure and Remediation (Say, 40 Credits)

8. The Effects of Water and Moisture Movement:

Understand the causes and effects of water penetration and moisture movement in buildings and the built environment. Understand the uses and limitations of methodologies and tests used for investigation of water penetration, moisture movement and 'damp-problems' in buildings. Understand the role of the management of water penetration and moisture movement in the causation and remediation of building failures and associated building pathologies.

9. Timber Decay:

Understand the causation of timber decay in buildings and the built environment. Understand the biology and lifecycles of common timber decay organisms as it effects decay in buildings. Understand the uses and limitations of methodologies and tests used for investigation of timber decay in Building Pathology. Understand the methodologies and techniques commonly used for the control or prevention of timber decay in buildings and associated building pathologies.

10. Mould Growth:

Understand the causations of mould growth in buildings and the built environment. Understand the potential hazards and effects from moulds on the health and safety of building occupants, contents and materials. Understand the use and limitations of tests used for investigating mould in buildings and the built environment. Understand procedures and methodologies for mitigating and preventing the hazards from mould in buildings. Understand the implications of Legislation and Case law relevant to mould in buildings and the built environment.

11. Hygroscopic Salts:

Understand the causation and effects of apparent accumulation of hygroscopic salts in building materials. Understand the limitations of commonly used methodologies and techniques of controlling the accumulation of hygroscopic salts. Understand the methodologies and test that can be used for investigating and diagnosing hygroscopic salt problems and associate failures. Understand procedures and methodologies for the prevention, management and remediation of hygroscopic salt problems and associated building pathologies.

12. Failures to Roofs and Roof-drainage:

Understand the causation and effects of apparent failures of roofs and roof drainage. Understand the methodologies and test that can be used for investigating and diagnosing failures of roofs and roof drainage systems and associate building pathologies. Understand procedures and methodologies for the prevention, management and remediation of roof and roof drainage problems and associated building pathologies.

13. Damp and Damp-proofing:

Understand the causation of apparent 'damp-problems' in buildings. Understand the limitations of commonly used methodologies and techniques of 'damp-proofing'. Understand the methodologies and test that can be used for investigating and diagnosing damp problems and failures in damp-proofing. Understand procedures and methodologies for the prevention, management and remediation of damp problems and associated building pathologies.

14. Failures of Ground and Surface Drainage:

Understand the causation and effects of apparent failures of ground and surface drainage. Understand the methodologies and test that can be used for investigating and diagnosing failures of ground and surface drainage systems and building pathologies. Understand procedures and methodologies for the prevention, management and remediation of roof and roof drainage problems and associated building pathologies.

15. Ventilation and Condensation:

Understand the causes and effects of general, superficial and interstitial condensation in buildings and building structures. Understand the role of ventilation of occupied areas and building voids in managing the causes and effects of condensation in buildings and in providing an environment suitable for occupancy. Understand the use and limitations of the methodologies and tests used for investigating ventilation and condensation. Understand methodologies and procedures for managing and preventing condensation and associated building pathologies in buildings.

16. Effects of Fire and Flood:

Understand the causes and effects of fire and flood and the effects of fire and food prevention measures to buildings and the built environment. Understand the uses and limitations of methodologies and tests used for investigation after fire and flooding. Understand the role of the management of water penetration and moisture movement in the causation and remediation of building failures and associated building pathologies. Understand the methodologies and procedures that can be used to prevent, mitigate and remediate the building pathologies that result from fire and flooding, and from fire and flood prevention measures.

17. Bird, Rodent and Insect Infestations:

Understand the causation and effects of infestations by birds, rodents, insects and other animals in buildings and the built environment. Understand the biology and lifecycles of birds, rodents, insects and other animals commonly found infesting buildings. Understand the methodologies and tests used for investigation of birds, rodents, insects and other animals commonly found infesting buildings. Understand the methodologies and techniques commonly used for the control or birds, rodents, insects and other animals commonly found infesting buildings and the associated building pathologies.

18. Failure of External Cladding:

Understand the causation and effects of apparent failures to external cladding systems. Understand the methodologies and test that can be used for investigating and diagnosing failures of external cladding systems and associate building pathologies. Understand procedures and methodologies for the prevention, management and remediation of external cladding problems and associated building pathologies.

19. Failures of Concrete and Reinforcement:

Understand the causation of failures to concreate and reinforcement in buildings and the built environment. Understand the physics and chemistry of failures in concrete and reinforcements in buildings. Understand the methodologies and tests used for investigation of concretes and reinforcements in buildings. Understand procedures and methodologies for the prevention, management and remediation concrete and reinforcement problems.

20. Failures of masonry:

Understand the causation of failures to masonry in buildings and the built environment. Understand the physics, chemistry, and biology of failures to masonry in buildings. Understand the methodologies and tests used for investigation of masonry in buildings. Understand procedures and methodologies for the prevention, management and remediation of masonry problems and associated building pathologies.

21. Failures of Brickwork and Mortar:

Understand the causation of failures to brickwork and mortar in buildings and the built environment. Understand the physics, chemistry, and biology of failures to brickwork and mortar in buildings. Understand the methodologies and tests used for investigation of brickwork and mortar in buildings. Understand procedures and methodologies for the prevention, management and remediation of brickwork and mortar problems and associated building pathologies.

22. Failures of External Renders:

Understand the causation of failures to external renders. Understand the physics, chemistry, and biology of failures to external renders. Understand the methodologies and tests used for investigation to external renders. Understand procedures and methodologies for the prevention, management and remediation of to external renders problems and associated building pathologies.

23. Failures of internal renders and Plaster:

Understand the causation of failures to internal renders and plaster. Understand the physics, chemistry, and biology of failures to internal renders and plaster. Understand the methodologies and tests used for investigation to internal renders and plaster. Understand procedures and methodologies for the prevention, management and remediation of to internal render and plaster problems and associated building pathologies.

24. Failures of Insulation

Understand the causation of failures to insulation. Understand the physics, chemistry, and biology of failures to insulation, especially the effects on superficial and interstitial condensation, and Energy efficiency on occupancy. Understand the methodologies and tests used for investigation of problems with insulation and associated building pathologies. Understand procedures and methodologies for the prevention, management and remediation of problems with insulation and associated building pathologies. Be familiar with regulations and standards affecting insulation in existing and new buildings.

25. Failures of M&E, Heating and Ventilation

Understand the causation of failures of M&E, Heating and Ventilation. Understand the physics, chemistry, and biology of failures to M&E, Heating and Ventilation, especially the effects on superficial and interstitial condensation, and Energy efficiency on occupancy. Understand the methodologies and tests used for investigation of problems with M&E, Heating and Ventilation and associated building pathologies. Understand procedures and methodologies for the prevention, management and remediation of problems with M&E, Heating and Ventilation and associated building pathologies. Be familiar with regulations and standards affecting M&E, Heating and Ventilation in existing and new buildings.

26. Failure of windows and Doors

Understand the causation of failures to windows and doors. Understand the physics, chemistry, and biology of failures to windows and doors, especially the effects ventilation and Energy efficiency on occupancy. Understand the methodologies and tests used for investigation of problems with windows and doors and associated building pathologies. Understand procedures and methodologies for the prevention, management and remediation of problems with windows and doors and associated building pathologies. Be familiar with regulations and standards affecting windows and doors in existing and new buildings.

27. Fire and Sound barriers and their Effects

Understand the causation of failures to Fire and Sound barriers and their effects. Understand the physics, chemistry, and biology of Fire and Sound barriers, especially their effects on superficial and interstitial condensation, ventilation and drying. Understand the methodologies and tests used for investigation of problems with Fire and Sound barriers and their effects. Understand procedures and methodologies for the prevention, management and remediation of problems with Fire and Sound barriers and associated building pathologies. Be familiar with regulations and standards affecting Fire and Sound barriers in existing and new buildings.

Legal and Regulatory Environment (Say, 6 Credits)

28. BSA 2022, CDM Regulations, and Building regulations:

Understand the background and importance of The Building Safety Act (2022), the Construction (Design and Management) Regulations 2015 and The Building Regulations (2023). Understand the effect of these and other regulations on the evolution of building failures and on their remediation. Understand the responsibilities imposed on building owners and occupiers, on Building Pathologist and on other building professionals by these regulations.

29. Planning and Historic Building Regulations:

Understand the background and importance of the law on planning and historic building conservation in the UK and abroad. Understand the effect of these and other regulations on the evolution of building failures and on their remediation. Understand the responsibilities imposed on building owners and occupiers, on Building Pathologist and on other building professionals by these regulations.

30. Expert Witness:

Understand the role and responsibilities of an Expert Witness. Understand the methodologies and protocols required for investigation, recording and report production when a Building Pathologist acts as an Expert Witness

APPENDIX F: SCRIPT CONCORDANCE TESTS FOR DIAGNOSIS AND MANAGEMENT OF DAMP PROBLEMS IN BUILDINGS

DRAFT1.2 TEST OF DIAGNOSTIC REASONING FOR BUILDING PATHOLOGY

ADAPTING AND TESTING RECENT ADVANCES IN LEARNING IN MEDICAL CLINICAL REASONING TO FACILITATE THE CONTINUOUS LEARNING AND APLICATION OF METHODS AND PROCEDURES FOR HOLISTIC BUILDING PATHOLOGY

Introduction

Buildings and the built environment are essential for the survival of individuals and cultures. The effective and efficient investigation and remediation of failures in buildings and the built environment is therefore also essential. This is an increasing problem in a rapidly changing and increasingly complex world; especially under accelerated changes in the societies that occupy them, and under the stress of Climate Change. Building Pathology is based on the techniques of medical pathology, and is conceived by the candidate as an holistic subject for the investigation, diagnosis, prognosis and remediation of failures in buildings and the built environment; based on the understanding of buildings as complex systems evolving over time.
In order to facilitate the above, the MPhil part of this research project at Oxford Brooks University aimed to establish a theory, methods and procedures for holistic Building Pathology; to allow the understanding, application and further development of the subject. This started with a literature review on the origins and evolution of buildings so as to demonstrate that buildings can be considered as evolving over time, and as a part of the more general evolution of biological and ecological systems. This introduced the evolution of biologically generated structures and the evolution of human built structures. The concept of building pathologies in structures built by non-human organisms and by human activity was then introduced. The parallels between the evolution and recent developments in medical and building pathology were then introduced in order to show how the former may be used to inform the latter.

The research methods used consisted of a critical meta-review of literature and research. These included the results of numerous interviews with eminent academics and practitioners active in the field. This section included a critical meta-review of the current understanding of the constraints on the understanding of subject of Building Pathology, and was then used to make proposals for the further development and evolution of the subject. This concluded that many of the proposals for the further development and evolution of the subject of Building Pathology discussed were beyond the scope of this research project; but that the adaption and testing of recent advances in learning in medical Clinical Reasoning to facilitate the continuous learning and application of methods and procedures for holistic Building Pathology could make a significant contribution to the subject.

Hypothesis to be tested

Given that Building Pathology can be understood as a parallel subject to Medical Pathology; can recent advances in continuous learning of medical Clinical Reasoning facilitate the learning of the metacognitive process needed for the continuous learning and application of holistic Building Pathology.

PARTICIPATION INFORMATION SHEET FOR ADAPTING AND TESTING RECENT ADVANCES IN LEARNING IN MEDICAL CLINICAL REASONING TO FACILITATE THE CONTINUOUS LEARNING AND APPLICATION OF METHODS AND PROCEDURES FOR HOLISTIC BUILDING PATHOLOGY

Invitation and Purpose We are inviting you to take part in a research study exploring the learning of the metacognitive process used in learning the application of Building Pathology. The study is being conducted by Dr Tim Hutton in partnership with the School of Architecture Design and the Built Environment at Nottingham Trent University. The project is self-funded. Please read the following information carefully before you decide whether or not to take part.

1. **Legal Basis for Research Studies** The University undertakes research as part of its function for the community under its legal status. Data protection allows us to use personal data for research with appropriate safeguards in place under the legal basis of public tasks that are in the public interest.

All University research is reviewed to ensure that participants are treated appropriately and their rights respected. This study has been approved by Professor Michael White the Chair of the AADH REC at Nottingham Trent University. Further information can be found at: https://www.ntu.ac.uk/research/research-environment-and-governance/governance-and- integrity

2. **Why have I been asked to participate?** You have been approached about this study because you are an Expert or Student in the subject of Building Pathology

3. **Do I have to take part?** Taking part in this research is voluntary. If you would prefer not to take part, you do not have to give any reason. If you change your mind you should contact up to 30 days after the date of the on-line test, interview or survey. If you withdraw after this point your anonymised data may be retained as part of the study.

4. **What will taking part involve?** You may be asked to complete an on-line multiple-choice paper taking about an hour to complete. You may also be offered the opportunity to view an online remote learning package, you may also be invited to complete questionaries to elicit your comments on the on-line test and learning offering; or on your opinions on the teaching and learning of Building pathology.

5. **What are the possible disadvantages and risks of taking part?** It is not anticipated that there are any risks in taking part. You will not be under any pressure to answer questions or talk about topics that you prefer not to discuss and you can choose to halt or withdraw from the interview or online correspondence at any point.

6. What are the possible benefits of taking part? It is anticipated that those taking part will be able to improve and develop their understanding of the learning and application of Building Pathology, both academically and professionally. If you make significant contributions to the study, you will be accredited in any publications, fully in accordance with academic good practice.

7. How will my confidentiality be protected?

Data will be stored on secure servers and only members of the research team will have access to recordings, transcripts and observation notes during the project using their NTU login details.

Your name, contact details or any other personal information provided will be kept confidential, and protected fully in accordance with the GDPR. Your name will not be used or given to others for any purpose without your formal specific written consent. Any answers to test questions or quotes that we use will be anonymised or pseudorandomised, which means that they cannot be linked to you, in publications, thesis or reports. Confidentiality will only be broken in circumstances where the researcher is concerned that there is a risk of harm to you or someone else. In this instance, the researcher must report this information to the relevant agency that can provide assistance.

8. What will happen to my data during the study and once the study is over? NTU will be responsible for all of the data during the study. Once the study is over, personal information about you such as your name, contact details and any pseudonym or key will be destroyed. We will only keep the research data that would allow others to check and verify our findings. These will be deposited in the NTU Data Archive, which is an archive of research data and will preserve data for at least ten years. Any anonymous data, which could not lead to the identification of either you or your organisation, [including analysed data and interview transcripts], will be publicly available. This will allow anyone else (including researchers, businesses, governments, charities, and the general public) to use the anonymised data for any purpose that they wish, providing they credit the University and research team as the original creators. However, if you could potentially be identified through any information in the data provided in your responses or other publicly available information; only approved researchers will have access to this data for the purposes of ethically approved research, and

they will be required, ethically and legally, to work to protect your identity.

9. How will the data be used? We will use data from your test and survey response to inform our final reports, thesis, journal articles and presentations –

which will be publicly available. If you are interested, copies of any resulting publications will be available on request.

10. Who can I contact if I have any questions or concerns about the study?

You should contact the Data Protection Officer if:

- you have a query about how your data is used by the University
- you would like to report a data security breach (e.g., if you think your personal data has been lost or disclosed inappropriately)
- you would like to complain about how the University has used your personal data

Email: DPO@ntu.ac.uk

You should contact the Chair of the REC Professor Michael White If you have concerns with how the research was undertaken or how you were treated

Email: michael.white@ntu.ac.uk

Telephone: 0115 848 2069

TEST OF DIAGNOSTIC REASONING FOR BUILDING PATHOLOGY

Name: ? *Required*

____

I consent to my responses to this questionnaire and test to be used for the research described in the introduction to this document: ? *Required*

Please select exactly 1 answer(s).

Yes, No

I consent to further contact by the researchers for tests or questionnaires:

Please select exactly 1 answer(s).

Yes, No

Please anonymise my responses to this questionnaire and test:

Please select exactly 1 answer(s).

Yes, No

Signature: ? *Required*

____

Date: ? *Required*

Dates need to be in the format 'DD/MM/YYYY', for example 27/03/1980.

Profession: ? *Required*

Please select exactly 1 answer(s).

Architect, Archaeologist Building Pathologist, Conservator, Engineer, Historian, Material Scientist, Project Manager, Other (please specify)

If you selected Other, please specify:

____

Professional Affiliations: ? *Required*

Please select exactly 1 answer(s).

RICS, CIOB, RIBA, CIBSE,RISE, Other (please specify)

If you selected Other, please specify:

____

Primary country you work in: ? *Required*

Please select exactly 1 answer(s).

UK, EU, F, D, PO, P, ES, NL, B, US, AU, NZ, SA, IR, I, CAN, Other (please specify)

If you selected Other, please specify:

____

Academic Qualifications ? *Required*

Please specify:

____

Number of years of experience in building industry, building related research and building related education: ? *Required*

Please specify:

____

INTRODUCTION TO SCRIPT CONCORDANCE TEST

The following test is formatted as a Script Concordance Test. This format has been developed for testing higher-order diagnostic reasoning and data interpretation skills. These are especially important in the practical application of Building Pathology and other professions where decisions have to be made on health and safety, risk management, probable causation, and on cost-effective investigation and remediation; often based on incomplete and probabilistic information. In these real-life situations, it should be noted that there is often no 'right' or 'wrong' answer to any question; only answers that are more or less likely to be correct interpretations of the information available, which information will also be more or less likely to be reliable.

The test is presented as a series of brief 'scenarios' with presenting complaints and histories derived from real cases. Questions are then posed based on the information in these scenarios, and on further information provided. Answers are then invited in a format similar to 'multiple-choice' tests. However, these answers are not 'wright' or 'wrong', but should be chosen based on their perceived probability, or on the chainage in the perceived probability of the suggested answers. For example; a question on diagnosis might offer the options of finding the proposed diagnosis of a building problem '**very unlikely**', '**unlikely**', '**neither likely nor unlikely**', '**more likely**' and **'very likely**'; a question on further investigation might offer the options of '**useless**', '**less useful'**, '**neither more nor less useful'**, '**useful**', and '**very useful**'.; a remediation question might offer the options of '**not useful**', '**less useful**', '**neither more or less useful**', **useful'**, and '**very useful**'; and a risk management question might offer the options of '**strongly not recommended**', '**not recommended**', **neither more or less recommended**', '**recommended**', and '**strongly recommended**'. Remember there is no 'wright or 'wrong' answer; but an invitation to give a probabilistic assessment, based on information and expertise.

QUESTION 1

PRESENTING COMPLAINT

A newly purchased 19c. row house in London has ‘damp problems’ affecting the base of the walls in the front room at ground floor level, despite evidence of a ‘guarantee' for a remedial damp-proof course being provided on purchase.

HISTORY OF PRESENTING COMPLAINT

The survey prior to purchase found high electronic moisture meter readings at the bases of the walls of the front room, but no visible evidence of damp, decay or mould growth was noted.
However, there was visible evidence of repeated remedial damp proofing works on previous occupancies.

Failure of the damp-proof course is suspected. You find this: *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

HEALTH & SAFETY

Central heating pipes and electrical systems were reported to have been replaced on previous occupancies.

You consider the risk to occupants and to survey to be: *Required*

Please select exactly 1 answer(s).
Very low, Low, Neither more nor less, High, Very high

ON INVESTIGATION

On investigation high readings were found to the base of the walls towards the front of the front room with a surface capacitance moisture meter, but the skirting boards were found to be ‘dry’ when tested with a resistance-based moisture meter.

As failure of the damp-proof course is suspected. You now consider this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to inspecting the sub-floor void in the front room by opening hatches and/or videoscope. You consider this to be: ? *Required*

Please select exactly 1 answer(s)
Useless Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ? Required

Please select exactly 1 answer(s)
Useless Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to taking samples and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: ? *Required*

Please select exactly 1 answer(s)
Useless Less useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Samples taken superficially and deep from representative masonry at the base of the walls towards the front of the front room, and analysed in the laboratory in accordance with the recommendations in BRE Guidance Note 245; had gravimetric and hygroscopic moisture contents around 5% w/w.

You now consider that failure of the damp-proof course is: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The injection of a new remedial chemical damp-proof course is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s)

Useless Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the plaster at the base of the walls at the front of the front room with a dry lining system is proposed. You consider this: ? *Required*

Please select exactly 1 answer(s)

Useless Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

An investigation of the decay state and structural adequacy of the floor timbers to the front room is proposed.

A damp proofing system with an insurance backed guarantee is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s)

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

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QUESTION 2

PRESENTING COMPLAINT

A 19c. row house in London used for tenanted occupancy by a Housing Association has 'damp problems' affecting the base of the walls in the background floor room despite previous remedial damp proofing works.

HISTORY OF PRESENTING COMPLAINT

The house has been occupied by an extended family since redecoration about two years ago, and the rear ground floor room has been used as a bedroom in recent months.

Failure of the damp-proof course is suspected. You find this: ? *Required*

Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

HEALTH & SAFETY

Mould growth is visible on the back external wall, and the room has a 'musty' smell.

You consider the risk to occupants and to survey to be: ? *Required*

Please select exactly 1 answer(s).
Very low, Low, Neither more nor less, High, Very high

ON INVESTIGATION

On investigation high readings were found to the base of the walls towards the back of the back room with a surface capacitance moisture meter, and the skirting boards were found to be 'damp' when tested with a resistance-based moisture meter.

As failure of the damp-proof course is suspected. You now consider this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to inspecting the ground levels and drainage to the exterior. You consider this to be: ? *Required*

Please select exactly 1 answer(s)
Useless Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to taking samples and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

The external ground levels are at or close to internal floor levels.

The room above is used as a laundry and kitchen with intermittent air extraction of up to 15 litres per second. The air in the room at the time of survey has a relative

humidity of 70% RH with a dew point of 17.3 td and the base of the wall has a surface temperature of 16.5 C

As failure of the damp-proof course is suspected. You now consider this:

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The injection of a new remedial chemical damp-proof course is proposed.

You consider this to be:: ? *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the plaster at the base of the wall with a dry lining system is proposed. You consider this: ? *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the provision for ventilation is proposed. You consider this to be:
? *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, V ery useful

RISK MANAGEMENT

The re-housing of the occupants is proposed. You consider this to be: ? Required

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

A damp proofing system with an insurance backed guarantee is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s)

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

QUESTION 3

PRESENTING COMPLAINT

Localised 'damp' problems have appeared affecting the base of the walls on the top floor of a recently constructed and occupied block of flats in central London.

HISTORY OF PRESENTING COMPLAINT

Localised damp problems have developed above the skirting boards on internal walls since occupancy, and mould growth has been discovered behind the skirting boards and within the cavity wall in an area exposed by the occupants.

HEALTH & SAFETY

No mould growth is visible on internal surfaces, and the flat does not have a 'musty' smell.

You consider the risk to occupants and to survey to be: *Required*

Please select exactly 1 answer(s).

Very low, Low, Neither more nor less, High, Very high

ON INVESTIGATION

On investigation high readings were found to the base of the walls with a surface capacitance moisture meter towards the south-west corner of the flat, but the skirting boards are found to be 'dry' when tested with a resistance-based moisture meter. No evidence of condensation is found on preliminary testing using a thermohydrometer and infrared thermal camera. However, the walls are found to have been built up off the surface of the structural concrete slab, with the plasterboard cladding and insulation extending beneath the subsequently installed floor insulation, underfloor heating, and floor screed.

Water penetration during construction is suspected. You find this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

Water penetration from a leak to the underfloor heating is suspected. You find this: ? *Required.*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

Water penetration from a service riser to the south-west is suspected. You find this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

HEALTH & SAFETY

Mould growth is visible on the back of skirtings and within the wall structure locally, and electrical systems run within the walls.

You consider the risk to occupants and to survey to be: ? *Required*

Please select exactly 1 answer(s).
Very low, Low, Neither more nor less, High, Very high

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to testing water and drainage pipes for leaks.

Consideration is given to taking samples from walls and floors, and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to inspecting cavities at the base of the walls and beneath the floor screed for moisture and raised relative humidity and interstitial mould growth. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less, useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

On further investigation a history of leaks and repairs to drainage pipes in a riser to the south- west is revealed. Raised moisture contents and interstitial mould growth is found within the base of the walls and beneath the floor screeds to the south-west.

Water penetration during construction is suspected. You now consider this: ? *Required.*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The stripping and replacement of all internal walls and floors is proposed. You consider this to be: ? *Required.*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The decontamination of all surfaces and voids is proposed. You consider this: ? *Required.*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the provision for ventilation is proposed. You consider this to be: ? *Required.*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

The re-housing of the occupants is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

QUESTION 4

PRESENTING COMPLAINT

Localised 'damp' problems have appeared affecting structures around window openings on the north side of original top floor of a building undergoing refurbishment as offices in central London, including the construction of a new mansard roof structure

HISTORY OF PRESENTING COMPLAINT

Localised damp problems have developed around recently installed windows in the later stages of fit-out. Extensive mould growth had been discovered behind the dot-and-dab dry lining to the external wall, which had been stripped. High readings had been found on testing external walls with electronic moisture meters in recent months. Problems with intermittent water penetration from defective provision for roof drainage is also reported.

It is suspected that the problems are due to water penetration through window openings. You consider this: ⍰ *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

HEALTH & SAFETY

Extensive mould growth is visible on internal surfaces of the original external walls

You consider the risk to occupants and to survey to be: ⍰ *Required*

Please select exactly 1 answer(s).

Very low, Low, Neither more nor less, High, Very high

ON INVESTIGATION

On investigation high readings were found to the exposed north walls with a surface capacitance moisture meter, but no visible evidence of current or recent water penetration around window openings is found. No evidence of condensation is found on preliminary testing using a thermohydrometer and infrared thermal camera, and internal relative humidities are below 70%. However, mould growth is visible extending behind the dry linings on the un- exposed external walls to the south

Water penetration during construction is suspected. You find this: ▯ *Required.*

Please select exactly 1 answer(s).

Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

Water penetration from leaks to roof drainage is suspected. You find this: ▯ *Required.*

Please select exactly 1 answer(s).

Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to testing water and drainage pipes for leaks. You consider this to be: ▯ *Required.*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to investigating ventilation systems. You consider this to be: ▯ *Required.*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to taking samples from walls and floors, and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: ▯ *Required.*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to inspecting cavities at the base of all external walls and beneath the raised floor for raised relative humidity and interstitial mould growth. You consider this to be: *Required*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

On further investigation, samples from the masonry of the accessible external walls are found to have gravimetric and hygroscopic moisture contents around 5% when tested in accordance with the methodology described in BRE Guidance Note 245, and interstitial mould growth is found behind the drylining on all external walls

It is suspected that the problems are due to water penetration through window openings. You now consider this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

Water penetration during construction is suspected. You now consider this: ?
Required

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The stripping and replacement of all external walls is proposed. You consider this to be:
? *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The decontamination of all surfaces and voids is proposed. You consider this: ?
Required

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the provision for ventilation is proposed. You consider this to be: ?
Required

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

Aerospora sampling and certification of decontamination prior to occupancy is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

It is proposed to test the windows in accordance with the recommendations in BS EN 14351. You consider this to be: ? *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

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QUESTION 5

PRESENTING COMPLAINT

A newly refurbished 19c. row house on the south coast has 'damp problems' affecting the west party wall, and the north-west corner of the basement.

HISTORY OF PRESENTING COMPLAINT

Intermittent liquid water penetration has occurred down the west wall from second to ground floor level causing damage to finishes, despite remedial roofing works.

HEALTH & SAFETY

Central heating pipes and electrical systems were reported to have been replaced on previous refurbishments.

You consider the risk to occupants and to survey to be: ⍰ *Required*

Please select exactly 1 answer(s).

Very low, Low, Neither more nor less useful, High, Very high

ON INVESTIGATION

On investigation there is evidence of liquid water penetration down the west party wall from roof to basement level and evidence of previous remedial works on current and previous occupancy. These include dry lining, repairs to pitched roof surfaces, and coping to the gable end. It is reported that water penetration appears to be associated with heavy rainfall. It is also reported that the adjoining property to the west is tenanted, and has been subject to recent roof and flashing repairs.

As failure of the roof is suspected. You now consider this: *Required*

Please select exactly 1 answer(s).

Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to inspecting the roof from the roof void beneath. You consider this to be: *Required*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: *Required*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to taking samples from representative masonry masses and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: *Required*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Samples taken superficially and deep from representative masonry of the party wall to the west, and analysed in the laboratory in accordance with the recommendations in BRE Guidance Note 245; had gravimetric moisture contents over 10% in some areas and hygroscopic moisture contents over 5% w/w in some areas. Sampling also revealed cavities in the brickwork of the party wall, including redundant flues.

You now consider that the failure of the roof surface cause is: *Required*

Please select exactly 1 answer(s).

Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The replacement of roof surfaces, flashings and soakers is proposed. You consider this to be:⍰ *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The clearing, ventilation, repair and repointing to the redundant chimneys is proposed.

The replacement of the plaster and cladding on the affected walls with a drylining system is proposed. You consider this: ⍰ *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

An investigation of the decay state and structural adequacy of the structural roof and floor timbers is proposed.

A damp proofing system with an insurance backed guarantee is proposed. You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

The appointment of a Party-wall Surveyor is proposed. You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

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QUESTION 6

PRESENTING COMPLAINT

A recently refurbished apartment on the upper floors of a 19c. row of shops in a south-west market town has developed damp and decay problems despite extensive remedial works and treatments on the recent refurbishment.

HISTORY OF PRESENTING COMPLAINT

The upper floors were converted to an apartment for domestic occupancy two years ago, but had been unoccupied since that time. Some problems of intermittent localised water penetration had occurred into adjoining structures in commercial occupancy, but no decay had been noted. The property was held on a long lease.

HEALTH & SAFETY

Central heating pipes and electrical systems were reported to have been replaced on previous refurbishments. However, there was evidence of mould growth and occupancy by feral pigeons.

You consider the risk to occupants and to survey to be: ? *Required*

Please select exactly 1 answer(s).
Very low, Low, Neither more nor less useful, High, Very high

ON INVESTIGATION

On investigation there is evidence of water penetration resulting in damage to finishes down the external wall at the back of the building, and evidence of condensation and mould growth, especially to the external wall of the staircase. Access for inspection to the back of the building is poor, but scaffolded access has been provided at the time of survey. There is evidence of decay to roof timber, floor timbers, window timbers and lintels down the back of the building on all levels. But no decay is found at the front of the building; where timbers have been re-supported isolated from the masonry, and external walls have been dry-lined

As failure of previous remedial treatments is suspected. You now consider this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to taking samples from representative masonry masses and analysing following the methodology described ion BRE Guidance Note 245.

Consideration is given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ? *Required*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Samples taken superficially and deep from representative masonry of the walls, and analysed in the laboratory in accordance with the recommendations in BRE Guidance Note 245; had gravimetric moisture contents locally over 10% in some areas of the back external wall and hygroscopic moisture contents over 5% w/w in some areas.

You now consider that failure of the previous remedial treatments is: ? *Required*

Please select exactly 1 answer(s).

Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The replacement of roof surfaces, flashings and soakers is proposed. You consider this to be:? *Required*

Please select exactly 1 answer(s).

Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the plaster and cladding on the affected walls with a drylining system is proposed. You consider this: ? *Required*

Please select exactly 1 answer(s).

Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The clearing ventilation and repair to the chimneys is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).

Not useful, Less useful, Neither more nor less useful, Useful, Very useful

Chemical remedial timber treatment and wall irrigations are proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).

Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement and re-detailing of provision for roof drainage, and access to roof drainage is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).

Not useful, Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

The culling of feral pigeons occupying the building is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

Chemical remedial treatments with insurance backed guarantee are proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

The appointment of a Party-wall Surveyor is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly recommended

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QUESTION 7

PRESENTING COMPLAINT

A domestic house extensively re-modelled about twenty years ago is suffering problems of localised intermittent water penetration, and from localised infestation by death-watch beetle; despite repeated remedial measures.

HISTORY OF PRESENTING COMPLAINT

The building was an extensively remodelled and converted inn generally dating from the 19c. and 20c, but including some residual 15c. timber frame elements. Intermittent liquid water penetration had occurred at the south-west corner of the master bedroom. It is reported that adult death-watch beetles are found at the south-east and south-west corners of the master bedroom in the spring and early summer months in recent years.

HEALTH & SAFETY

Central heating pipes and electrical systems were reported to have been replaced on previous refurbishments.

You consider the risk to occupants and to survey to be: ⍰ *Required*

Please select exactly 1 answer(s).
Very low, Low, Neither more nor less useful, High, Very high

ON INVESTIGATION

On investigation there is evidence of recent liquid water penetration to the south-west corner of the master bedroom, and in the first-floor room beneath. There is evidence of old wet rot decay and death watch beetle infestation to original residual oak timber frame elements. The pitched roofs appeared to have been replaced throughout about twenty years ago, and have been more recently patch repaired at the west side of the south gable. The timber framed wall to the south-west appears to have bowed since original construction and the last major refurbishment, and sole plates appear to be below existing ground levels as failure of the roof and structurally significant decay is suspected

As failure of the roof is suspected. You now consider this: ⍰ *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to taking samples from representative masonry masses and analysing following the methodology described ion BRE Guidance Note 245. Consideration is given to testing vulnerable structural timbers by deep drilling and moisture probing to determine their decay state and deep moisture content.

Consideration is given to inspecting the roof from the roof void beneath. You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Samples taken superficially and deep from representative masonry of the party wall to the west, and analysed in the laboratory in accordance with the recommendations in

BRE Guidance Note 245; had gravimetric moisture contents over 10% in some areas and hygroscopic moisture contents over 5% w/w in some areas. Sampling also revealed cavities in the brickwork of the gable end wall, including redundant flues, and gaps around steel lintels installed on the last major refurbishment. Extractor fans in bathrooms, showers and utility rooms are found to extract air at up to 15 litres per second with no overrun; and there is evidence of cold-bridging at the south-east and south-west corners of the master bedroom.

Deep moisture content of timbers in these areas is around 16% w/w. The polythene sarking felt beneath the south-west pitch is dressed about half way across the gable end.

As failure of the roof is suspected. You now consider this: *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The replacement of roof surfaces, flashings and soakers is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the plaster and cladding on the affected walls with a drylining system is proposed. You consider this: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The clearing, ventilation, repair and repointing to the redundant chimneys is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The chemical remedial timber and insecticidal treatment of the residual oak timber is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The provision of background ventilation and new provision for extraction of moisture laden air at point of source is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

An investigation of the decay state and structural adequacy of the structural roof, wall and floor timbers is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly

Remedial treatments with an insurance backed guarantee is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly

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QUESTION 8

PRESENTING COMPLAINT

'Damp problems' have appeared in all parts of a newly constructed 'marketing suite' during construction, making it unfit for purpose. Mould growth has appeared in many areas, and failure of the as-built provision for damp-proofing is suspected.

HISTORY OF PRESENTING COMPLAINT

The building is a single-story, flat roofed steel framed structure, with insulated cavity walls built off a structural concrete slab, and with floor screeds laid on top of insulation and electrical underfloor heating. 'Damp problems' have appeared during the fitout to the interiors, preventing occupancy. Liquid water has been found beneath floor surfaces where lifted in the plant room.

As failure of the as built provision for damp-proofing is suspected. You consider this:

Required

Please select exactly 1 answer(s).

Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

HEALTH & SAFETY

Extensive superficial mould growth is visible in many areas. Electrical systems are live.

You consider the risk to occupants and to survey to be: *Required*

Please select exactly 1 answer(s).

Very low, low, neither more nor less, high, very high

ON INVESTIGATION

On investigation there is evidence of extensive superficial and interstitial mould growth to the base of internal and external walls; especially in areas of restricted ventilation. Internal floor levels are generally over 400mm above external ground levels and the structural slab includes a concrete 'bund' around its perimeter. Although drainage in the adjoining site is poor, 'perched water levels' are over 1000mm below internal floor levels at the time of survey

As failure of the existing provision for damp proofing is suspected. You now consider this: *Required*

Please select exactly 1 answer(s).

Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to inspecting the roof and roof drainage systems. You consider this to be: *Required*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: *Required*

Please select exactly 1 answer(s).

Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to taking samples from representative masonry masses and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: *Required*

Please select exactly 1 answer(s).

Useless, less useful, neither more nor less useful, useful, very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Samples taken from the structural slab and 'bunds' and analysed in the laboratory in accordance with the recommendations in BRE Guidance Note 245; had gravimetric moisture contents around 4% w/w. Internal relative humidity's are between about 70% and 80%, and the insulation at the base of external walls inside the polyethene vapour check is saturated.
However, no liquid water is found beneath the floors at the time of survey.

As failure of the existing provision for damp-proofing is suspected. You now consider this: *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The replacement of roof surfaces and roof drainage is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The stripping and replacement of all external walls is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

The decontamination of all surfaces and voids is proposed. You consider this: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the provision for ventilation is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The replacement of the existing provision for damp-proofing is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

Aerospora sampling and certification of decontamination prior to occupancy is proposed. You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly

Remedial damp-proofing with insurance backed guarantees is proposed., You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

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QUESTION 9

PRESENTING COMPLAINT

Several newly constructed blocks of flats suffer from extensive problems of structural decay to composite timber suspended ground floors

HISTORY OF PRESENTING COMPLAINT

Localised structural decay to composite timber suspended ground floors of all the recently constructed timber framed seven story buildings has occurred soon after occupancy. Further investigation has revealed extensive and generalised problems of active fungal decay to composite floor timbers at ground floor level to all the buildings.

HEALTH & SAFETY

Sub-floor voids are between about 350mm and 3000mm deep, and the buildings remain occupied.. You consider there to be no special risk to occupants or to survey.

ON INVESTIGATION

On investigation there is evidence of problems with ground and surface drainage during and after construction, and damp-proof courses are locally bridged. Floors consist of layers of sealed cell insulation and OSB, and composite timber joists and wall plates, supported on blockwork dwarf walls and concrete foundations to the timber framed structures. These have been decayed or partially decayed by wet rot fungi in many areas, and are being actively decayed in areas of apparent water leaks beneath shower pods. There are a number of vents through the external brickwork into the base of the cavity wall structures

It is suspected that the decay is due to failure of the shower pods. You consider this: *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to investigating the decay state and deep moisture content of all timber elements by deep drilling and probing. You consider this to be: *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to investigating ventilation and condensation to the sub-floor voids using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to taking samples from representative masonry masses and sub-floor fill, and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Vents to the base of the external walls do not vent the sub-floor voids. Many areas of sleeper wall plate at the base of external walls are found to be decayed or partly decayed, and to have deep moisture contents over 20% w/w.

It is suspected that the decay is due to failure of the shower pods. You now consider this: *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The replacement of all remaining floor timbers is proposed. You consider this to be:
Required

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The laying of polythene damp-proof oversite membranes under all floors is proposed. You consider this: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The re-laying of ground and surface drainage around the buildings is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The installation of through and cross ventilation to all sub-floor voids is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

Chemical fungicidal treatment to all ground floor timbers is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

An investigation of the decay state and structural adequacy of all structural timbers is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

A damp proofing system with an insurance backed guarantee is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

Chemical remedial treatments with insurance backed guarantees is proposed is proposed. You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

The replacement of all shower pods is proposed. You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

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QUESTION 10

PRESENTING COMPLAINT

Several newly constructed specialist design-and-build cross laminated timber framed, flat roofed school buildings have suffered localised problems with water penetration since construction despite repeated tests and repairs to single ply membrane roof surfaces.

HISTORY OF PRESENTING COMPLAINT

Problems with water penetration to parapet coping details had been noted during construction, and coping to parapet walls had been re-built. Localised leaks had occurred to top floor class rooms after heavy rain since occupancy, and had become more noticeable with time.

HEALTH & SAFETY

No visible mould growth has been seen, and the buildings remain occupied.

You consider the risk to occupants and to survey to be: ? *Required*

Please select exactly 1 answer(s).
Very low, low, neither more nor less, high, very high

ON INVESTIGATION

On investigation it is found that the 150mm thick cross laminated roof deck is overlaid with a vapour check membrane, sealed cell insulation, a second membrane, 20mm ply, and a single ply roof membrane. This is poorly levelled and allowing ponding on the roof surfaces, and no provision had been made for ventilation of the roof deck, or at the parapets or the parapet coping. The cross laminated timber had been superficially decayed by wet rot to about 20% of its area, and structurally decayed locally; especially at parapet up-stands that the decay is due to failure of the single ply membrane.

It is suspected that the decay is due to failure of the single ply membrane. You consider this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to investigating the decay state and deep moisture content of all timber elements by deep drilling and probing. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to investigating ventilation and condensation to the roof and parapet structures using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

Consideration is given to computer modelling the hydrothermal performance of the as-built roof structure. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Less useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

No structural decay is found to cross laminated timber except as previously found to the roof. Although the deep moisture content of decayed timbers is locally over 20% w/w., the majority of the decayed timber is at below 20% w/w. No net annual accumulation of moisture is found on computer modelling except to the as built parapet details. It is reported that the roofs had been covered with snow during construction.

It is suspected that the decay is due to failure of the single ply membrane. You now consider this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The repair or replacement of all roof timbers is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

The re-detailing of ventilation to parapets and roofs is proposed. You consider this: ? *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

Chemical fungicidal treatment to all roof timbers is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Not useful, Less useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

An investigation of the decay state and structural adequacy of the all structural timbers is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

Chemical remedial treatments with insurance backed guarantees is proposed is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

A claim against the contractor is proposed: You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

A claim against the guarantee covering materials and workmanship for the roof membrane is proposed: You consider this to be: ⍰ *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

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QUESTION 11

PRESENTING COMPLAINT

A recently constructed 'oak frame barn structure' hospitality and entertainment facility in the countryside of the West Midlands, the property of a high net worth individual, with bedrooms and accommodation at first floor level, swimming pools, jacuzzies and dining facilities at ground floor level, and a cinema and combined gymnasium and bar facility at basement level, has suffered recurrent damp problems affecting basement structures during the defect period after construction; resulting in disputes between the owner, contactor and project management team.

HISTORY OF PRESENTING COMPLAINT

High value bespoke fitted carpets in the basements and high value finishes including 'art deco' oak skirting has suffered repeated moisture damage since completion, despite remedial measures during the defect period. This damage has become more pronounced, despite previous remedial measures including investigation and repair to the pools, jacuzzies and associated plant at ground and basement level

Continuing leaks from the swimming pools and jacuzzies are suspected. You find this: ? *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

HEALTH & SAFETY

Electrical systems in the building remain 'live'. Swimming pool treatment chemicals including ozone and soluble bromides are in use

You consider the risk to occupancy and to survey to be: ? *Required*

Please select exactly 1 answer(s).
Very low, low, neither more nor less, high, very high

ON INVESTIGATION

On investigation no special provision for drained cavities or other damp-proofing measures are found between the swimming pool plant areas or the external basement areas, and the highly finished occupied interiors. The decorative oak skirting boards are warped and water stained, and high readings are found in many areas to the skirtings and at the base of the walls, when tested with electronic resistance and capacitance-based moisture meters.

As failure of the swimming pool and jacuzzi linings is suspected. You now consider this: ?*Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely,
Very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to taking samples of damp affected floor screeds and blockwork, and testing for residual moisture and for residues of pool treatment chemicals. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Very useful, Neither more nor less useful, Useful, Very useful

Consideration is given to detailed inspection and testing of ground and surface drainage in external basement areas, and to inspecting 'water bars' around external door openings to the basement. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Very useful, Neither more nor less useful, Useful, Very useful

Consideration is given to detailed inspection and testing of ground and surface drainage in external basement areas, and to inspecting 'water bars' around external door openings to the basement. You consider this to be: ? *Required*

Please select exactly 1 answer(s).
Useless, Very useful, Neither more nor less useful, Useful, Very useful

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

1. Chemical analysis

The samples taken from damp affected areas were found to contain bromide salts.

You now consider leaks from the swimming pool, jacuzzi and associated plant to be:
Required

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

2. CCTV investigation of provision for drainage

Investigations to existing provision for drainage to basement areas finds blockage to drainage galleys, and evidence of liquid water overflowing water bars around door openings.

You now consider failure of the swimming pool, jacuzzi and associated plant is: *Required*

Please select exactly 1 answer(s).
Very unlikely, Unlikely, Neither likely or unlikely, More likely, Very likely

REMEDIAL RECOMMENDATIONS

The replacement of the existing swimming pool, jacuzzi and plant is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Useless, Very useful, Neither more nor less useful, Useful, Very useful

The re-detailing of thresholds to external basement door openings and regular cleaning of drainage galleys is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Useless, Very useful, Neither more nor less useful, Useful, Very useful

Re-detailing of provision for 'damp-proofing' around swimming pool plant at basement level using vented and drained cavity systems in accordance with the recommendations in BS 8102:2009 is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).
Useless, Very useful, Neither more nor less useful, Useful, Very useful

RISK MANAGEMENT

A claim against the specialist sub-contractor installing the pool, jacuzzi and associated plants is proposed. You consider this to be: *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

A claim against the design team is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

A claim against the building insurers is proposed. You consider this to be: ? *Required*

Please select exactly 1 answer(s).

Strongly not recommended, Not recommended, Neither more or less recommended, Recommended, Strongly Recommended

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QUESTION 12

PRESENTING COMPLAINT

A new reinforced concrete subterranean structure has been excavated beneath a 19th century house belonging to a high net worth individual in the west of London, including an underground swimming pool, car parking, cinema and art gallery facilities. However, localised damp problems have appeared during construction, including damage to finishes and localised mould growth.

HISTORY OF PRESENTING COMPLAINT

The recently constructed reinforced concrete subterranean structure was built with 'waterproof concrete' and areas extending beneath exterior paving and garden areas had been coated with a 'torch-on' bituminous damp-proofing. The structure has been subject to water penetration and recurrent damp problems during construction, despite 'remedial damp- proofing' on behalf of the specialist 'waterproof concrete' suppliers, including the injection of specialist damp-proofing materials at suspected cracks and construction joints in the 'waterproof concrete box'.

Failure of the damp-proofing to the as built structure is suspected. You find this: ? *Required*

Please select exactly 1 answer(s).

Very unlikely, unlikely, neither likely or unlikely, more likely, very likely

HEALTH & SAFETY

You consider the risk to occupants and to survey to be: ? *Required*
Very low, low, neither more or less, very high

ON INVESTIGATION

Localised moisture and salt damage, and some localised mould growth is found on visual inspection, and some localised relative 'cold-bridging' is found on infra-red thermography. A drained cavity system formed of studded plastic damp-proof membrane is found lining the waterproof concrete block structure. This contains some liquid water but also contains accumulations of cementitious fines. Evidence of water staining and calcium salts is found where services penetrate through the concrete structure.

As failure of the external damp-proofing and 'waterproof concrete' is suspected. You now consider this: ? *Required - very unlikely, unlikely neither likely or unlikely, more likely very likely*

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to determining the ground water level. You consider this to be: ?
Required. Useless, less useful, neither more nor less useful, useful, very useful

Consideration is given to taking moisture and salt profiles through wall and floor structures and inspecting with high-powered borescope. You consider this to be: ? *Required. Useless, less useful, neither more nor less useful, useful, very useful*

You consider monitoring relative humidity temperature and dew point of internal air. You consider this to be: ? *Required. Useless, less useful, neither more nor less useful, useful and very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Relative humidity, temperature and dew point within the basement areas are similar to those elsewhere in the building due to an air conditioning system which is generally set at 50 per cent RH at 20°C. You now consider that inadequate provision for ventilation with occupancy is a significant contributory factor to the damp problems is: ? *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

The samples taken from representative floor screeds are found to have gravimetric moisture contents over 5 per cent W/W and evidence of liquid water was found entrapped in the insulation above the studded damp-proof membrane of the cavity drainage system. You now consider that water penetration into the structure during construction is a significant cause of damp problems is: ? *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

REMEDIAL RECOMMENDATIONS

The stripping back and exposure of the concrete box structure in all areas of visible damp problems to allow inspection, drying and further injection of damp-proofing materials is proposed. You consider this to be: ? *Required. Note useful, less useful, neither more nor less useful, useful, very useful*

The further inspection, 'flushing out' and repair or replacement of the existing cavity drainage system is proposed. You consider this: ? *Required. Note useful, less useful, neither more nor less useful, useful, very useful*

The repair or replacement of existing provision for ventilation to the basement is proposed. You consider this to be: ☐ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

RISK MANAGEMENT

Regular inspection and maintenance to cavity drainage system is proposed. You consider this to be: ☐ Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended

The regular management and maintenance of the ventilation and air conditioning system is proposed. You consider this to be: ☐ *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the manufacturers and suppliers of the 'waterproof concrete' is proposed. You consider this to be: ☐ *Required*

QUESTION 13

PRESENTING COMPLAINT

A 16th century brick and oak frame building with a history of use as a farmhouse and public house is in single domestic occupancy, is suffering from problems with moisture and salt damage to finishes in the area around a massive brick chimneystack; both in a first floor bedroom, and around the 'inglenook' type fireplaces in the kitchen and dining room beneath.

HISTORY OF PRESENTING COMPLAINT

No 'damp problems' were reported on survey prior to purchase approximately 10 years previously. However, increasing problems of damage to finishes have become apparent since redecoration and refurbishment works approximately three years ago. These had included the installation of wood burning stoves to the ground floor rooms, and the redecoration of the walls around the fireplace at ground floor level including the 'injection of chemical damp-proof course materials', and use of moisture resistant additives to the sand and cement render.

Failure of the damp-proof course is suspected. You find this: ? Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely

HEALTH & SAFETY

Corrosion has been noted affecting electrical sockets in the structures at ground floor level, and some localised superficial mould growth has been noted.

You consider the risk to occupants and to survey to be: ? Required. Very low, low, neither more nor less, high, very high

ON INVESTIGATION

On investigation, the building is found to be very exposed from wind driven rain to the south- west, and ground and surface drainage is found to drain water into the base of the walls and foundations with the slope of the land. There is also evidence of recent replacement to roof drainage systems and the gullies at the base of rainwater downpipes at the re-entrant corner adjacent to the damp affected area. Damage to internal finishes is typical of that to be expected with salt efflorescence and is especially evident at ground floor level, adjacent to areas subject to recent remedial works. There is clear evidence of past problems of damage and repair to the brickwork around the inglenook fireplaces at ground floor level. Timber elements at ground floor level were found to have been partially decayed by wet rot in the past and to be locally damp enough for further decay to occur at the time of survey. There is some evidence of water staining to the interiors of the inglenook fireplaces where boarding has been used to block the original flue on installation of the wood burning stoves

As failure of the damp-proof course is suspected. You now consider this: ? Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to taking samples from representative blockwork and screeds for analysis to determine their gravimetric and hygroscopic moisture content, following the methodology described in BRE Digest 245. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to investigating ventilation and condensation to the interiors, using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to high-powered fibre optic borescope inspection of building voids and cavities in affected areas. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Moisture and salt profiles taken in accordance with the methodology described in BRE Digest 245, show that the affected structures at ground floor level are damp and locally saturated, with very high hygroscopic salt content, and with the structures above approximately 500mm from floor levels relatively dry but with high hygroscopic salt content. A sample taken from the area of damaged finishes at first floor level is also found to be damp with high hygroscopic moisture content. You now consider the failure of the damp-proof course is: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Dew point of internal air is significantly raised compared to external dew point, and the extractor fans serving the kitchen, utility room and bathroom are found to be capable of extracting air at significantly less than 15 litres per second. You now consider that failure of the damp-proof course as the most significant cause of damage

to finishes is: ▯ Required. Very unlikely, unlikely, neither likely or unlikely more likely, very likely

RISK MANAGEMENT

A claim against the guarantee provided by the remedial company undertaking previous damp- proofing works is proposed. You consider this to be: ▯ *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

Regular inspection and clearing of ground and surface drainage systems is proposed. You consider this to be: ▯ Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended

QUESTION 14

PRESENTING COMPLAINT

The ground floor flat in a recently constructed brickwork and block work building intended to be highly energy efficient are suffering from recurrent problems of localised mould growth soon after occupancy, especially at the base of external walls and at window reveals.

HISTORY OF PRESENTING COMPLAINT

The building had been constructed on a reinforced concrete cavity floor structure, cast on proprietary polystyrene shuttering; with an outer leaf of brickwork, with an inner leaf of blockwork with the cavity filled with polystyrene in polyethene bags, clad with insulated dry linings on dot-and-dab fixings to the blockwork. The building was built on clay with the ground sloping towards the foundations, resulting in water ponding on the foundations during construction.

Failure of provision for ground and surface drainage and moisture entrapped in the structure from construction is suspected. You find this: *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

HEALTH & SAFETY

The flat is occupied.
You consider the risk to occupants and to survey to be: ⍰ Required. Very low, low, neither more nor less, high, very high

ON INVESTIGATION

On investigation, there is evidence of localised recurrent mould growth, despite cleaning, affecting the base of the walls and window reveals. Some attempts had been made to reduce ground levels and provide effective ground and surface drainage and there is no visible evidence of current or recent water penetration to the base of the walls. The problems are reported to have been apparent soon after completion and to have continued for over 2 years, despite remedial interventions to ground and surface drainage, ground levels and ventilation to sub-floor voids.

As water penetration from defective ground and surface drainage during and after construction is suspected. You now consider this: ⍰ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to taking samples from representative blockwork and screeds for analysis to determine their gravimetric and hygroscopic moisture content, following the methodology described in BRE Digest 245. You consider this to be: ⍰ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to investigating ventilation and condensation to the interiors, using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ⍰ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to high-powered fibre optic borescope inspection of building voids and cavities in affected areas. You consider this to be: ⍰ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Samples taken superficially and deep from representative structures at the base of the walls find relatively high available moisture content to plasterboard and locally raised gravimetric moisture content in some locations to dabs and blockwork behind. Floor screeds are relatively dry with elevated hygroscopic moisture content. You now consider that water penetration from defective drainage during and after construction is: ⍰ *Required. Very unlikely, unlikely, neither likely nor unlikely, more likely, very likely*

The extractor fans are found to be capable of extracting air at significantly less than 15 litres per second and many have been turned off by occupants. 'Trickle vents' to windows are found to be closed. You now consider that water penetration from defective drainage during and after construction is: ⍰ *Required. Very unlikely, unlikely, neither likely nor unlikely, more likely, very likely*

High-powered fibre optic borescope inspection of structures at the floor/wall junction reveal plasterboard supported on dot and dabs on blockwork with accumulations of debris at the base of the wall cavity between the inner and outer leaf, and poorly levelled irregular membranes acting as a cavity tray or damp-proof course. This has been locally bridged by landscaping.
You now consider that failure of the damp-proof course is.: ⍰ Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely

REMEDIAL RECOMMENDATIONS

Replacement and re-detailing of plasterboard at the base of external walls is proposed. You consider this to be: ⍰ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

Relaying of existing landscaping, and ground and surface drainage is proposed. You consider this to be: ⍰ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

The installation of new extractor fans and ducts, and the re-detailing of windows, so as to provide for 'background ventilation' is proposed. You consider this: ⍰ *Required Not useful, less useful, neither more nor less useful, useful, very useful*

QUESTION 15

PRESENTING COMPLAINT

A number of blocks of flats constructed in the 1960's in west London are suffering from chronic problems of recurrent 'damp' affecting the reveals and soffits of window openings.

HISTORY OF PRESENTING COMPLAINT

There have been chronic problems with water penetration, damage to finishes and mould growth around window openings in the past. This has continued despite recent remedial works, including the fitting of specially made metal frame double glazed units and recladding of reveals and soffits. In some flats, liquid water is reported to have penetrated through ceilings and soffits.

Failure of the new windows is suspected as is moisture generated by occupants. You consider this to be: ⍰ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

HEALTH & SAFETY

Flats are occupied.
You consider the risk to occupants and to survey to be: ? Required. Very low, low, neither more nor less, high, very high

ON INVESTIGATION

On investigation, it is found that affected structures are generally on the exposed west elevations or south-west corners of the building, and on the upper floors; and affect those with both original and new windows. However, there is evidence of recent liquid water penetration around new window openings. The building is found to be of reinforced concrete clad with tiles. The building has flat roofs with parapet walls, subject to water ponding and problems with intermittent blockage to roof drainage systems.

As failure of new windows is suspected. You now consider this: ? Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to taking samples from representative structures and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: ? *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration should be given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ? *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to disassembling representative recently constructed windows to confirm the 'as-built' structure. You consider this to be: ? *Required. Useless, less useful, neither more nor less useful, useful, very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Samples taken from representative structures, following the methodology described in BRE Guidance 245 show relatively high moisture contents in relatively soft concrete behind the joints between external tile cladding, and damp and locally saturated concrete and plaster behind recently installed dry linings to the reveals and soffits to window openings. You now consider that failure of the recently installed windows is: ? *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Investigation of existing provision for extraction of moisture laden air and background ventilation indicate that these are inadequate to prevent the build-up of moisture laden air; especially with moist wet occupancy. You now consider that failure of the windows is: ? *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Investigation of the 'as-built' new window installations reveal the new frames to have been installed supported on the original tile cladding to the reveals and soffits, in front of the original steel frames, with new plasterboard cladding overlaying the residual original steel frame elements. You now consider that failure of the new windows is: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

REMEDIAL RECOMMENDATIONS

The recladding of the exposed elevations on the buildings is proposed. You consider this to be: ▯ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

The replacement of existing provision for ventilation to the flats is proposed. You consider this to be: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

The replacement of all existing windows is proposed. You consider this to be: *Not useful, less useful, neither more nor less useful, useful, very useful*
The re-detailing of window reveals, soffits and cills, including the creation of a drainage channel around and beneath window frames is proposed. You consider this to be: ▯ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

RISK MANAGEMENT

A claim against the manufacturers and suppliers of the new windows is proposed. You consider this to be: ▯ *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the contractor installing the windows is proposed. You consider this to be: ▯

Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended

A claim against the project managers is proposed. You consider this to be ▯ *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

QUESTION 16

PRESENTING COMPLAINT

A very large stately home dating from the 17th to early 20th century, previously occupied as a school and recently refurbished as a gated community for multiple domestic occupancy, has multiple outbreaks of dry rot (*Serpula lacrymans*) infection and decay affecting the recently re- modelled and refurbished apartments, preventing sale.

HISTORY OF PRESENTING COMPLAINT

The building was found to have multiple areas of dry rot (*Serpula lacrymans*) infection and decay prior to refurbishment, when extensive remedial treatments and repairs were undertaken, over a period of five years since survey. However, localised areas of damp and dry rot infection and decay have been discovered prior to occupancy.

Spread of dry rot infection from previous out breaks is suspected due to inadequate remedial treatment. You find this: *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

HEALTH & SAFETY

You consider the risk to occupancy and to survey to be: *Required. Very low, low, neither more nor less, high, very high*

ON INVESTIGATION

On investigation, there is evidence of chronic problems with overcharging and leaks from hoppers and rainwater downpipes serving roof drainage systems and some localised evidence of water staining to new finishes installed on refurbishment. Generally, accessible materials are effectively dry with moisture contents below 15 per cent w/w. However, a search of the building with a search dog, trained to detect dry rot (*Serpula lacrymans*) in buildings produces multiple indications of localised dry rot infection in the area of defective rainwater goods.

Spread of dry rot infection from previous out breaks is suspected due to inadequate remedial treatment. You now consider this: *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to undertaking a high-powered fibre optic borescope inspection on localised exposure in areas of dry rot infection. You consider this to be: *Required. Useless, less useful, neither more or less useful, useful, very useful*

Consideration is given to taking samples from masonry in affected areas, to determine their deep moisture content, following the methodology described in BRE Digest Guidance note
245. You consider this to be: Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely

Consideration is given to investigating ventilation and condensation to interiors and building voids using thermo hygrometers, anemometers, and infrared thermal cameras. You consider this to be: *Required. Useless, less useful, neither more or less useful, useful, very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

High-powered fibre optic borescope inspection and localised exposure in areas of dry rot infection reveal dry rot mycelia and strands and decayed and partially decayed timbers with deep moisture contents varying between 10 and 33 per cent w/w. Some timbers were found to be over 50 per cent decayed. However, many were found to have been repaired or partnered on previous refurbishments. Accumulations of building debris are found in building voids. You now consider that failure of remedial treatments is: ? *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

The masonry at or close to ground level is found to have available deep moisture contents over 3 per cent. The deep moisture content of masonry samples at first floor level is found to be less than 2 per cent. You now consider that failure of remedial treatments is: ? *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

REMEDIAL RECOMMENDATIONS

The cutting back of decayed timbers to 1m beyond the last sign of timber decay, the fungicidal treatment of timbers and the injection of fungicides into the masonry masses in all areas of known decay is proposed. You consider this to be: ? *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

The repair of decayed or partially decayed timbers as necessary and the re-support of all timber elements isolated from damp or potentially damp masonry with a damp-proof material or through ventilated air gap is proposed. You consider this to be: ? *Required. Useless, less useful, neither more or less useful, useful, very useful*

The clearing of dust and debris from building voids, and the provision of through and cross ventilation to roof and sub-floor voids in accordance with requirements of current Building Regulations is proposed. You consider this to be: ? *Required. Useless, less useful, neither more or less useful, useful, very useful*

The re-detailing and regular inspection and repair of roof drainage systems is proposed. You consider this to be: ? *Required. Useless, less useful, neither more or less useful, useful, very useful*

RISK MANAGEMENT

A claim against the specialist timber treatment companies undertaking the remedial works on recent refurbishment is proposed. You consider this to be: ? *Required. Strongly not recommended, note recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the insurance company providing building guarantees is proposed. You consider this to be: ? *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the project managers and refurbishment contractors is proposed. You consider this to be: ? *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

QUESTION 17

PRESENTING COMPLAINT

A recently refurbished block of flats included a 'podium deck' with pavements, planters and areas of lawn with a multistorey car park beneath. The underground car park has been subject to chronic problems of water penetration since construction, resulting in complaints of damage to high value vehicles and to high value items in storage areas.

HISTORY OF PRESENTING COMPLAINT

The underground car park and storage areas have been subject to chronic problems of water penetration since construction, despite repeated attempts at remedial works by the builders, developers and property owners. This had included localised attempts at patch repair to the membrane beneath the podium paving, and the installation of gutters and drainage trays beneath some of the areas of water penetration through the ceilings and soffits of the underground car park.

Failure of the membrane over the podium is suspected. You find this: ☐ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

HEALTH & SAFETY

You consider the risk to occupants and to survey to be: ☐ *Required. Very low, low, neither more nor less, high, very high*

ON INVESTIGATION

On investigation, evidence of chronic problems of water penetration is found through cracks and construction joints in the reinforced concrete slab forming the ceilings underlying the podium deck. This had resulted in accumulation of calcium salts in the location of the leaks and on surfaces beneath; especially where steel drainage pipes pass through the structure from above. Liquid water is found dripping through affected areas. This is reported to be more marked after periods of heavy rain.

As failure of the damp-proof membrane is suspected. You now consider this: ☐ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to localised exposure of the membrane by lifting paving and localised lifting of planters and planting and associated structures above. You consider this to be: ☐ *Required. Useless, less useful, neither more or less useful, useful, very useful*

Consideration is given to taking samples of damp affected structures and analysing following the methodology described in BRE Digest Guidance Note 245. You consider this to be: ☐ *Required. Useless, less useful, neither more or less useful, useful, very useful*

Consideration is given to undertaking 'flood tests' with coloured dyes. You consider this to be:

☐ *Required. Useless, less useful, neither more or less useful, useful, very useful*

Consideration is given to CCTV investigation of drainage gullies and drainage pipes serving the podium above the underground car park. You consider this to be: ☐ *Required. Useless, less useful, neither more or less useful, useful, very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Liquid water is found ponding beneath the paving of the podium deck on exposure, but no visible defects are found to the membrane in areas accessible for inspection. You now consider the failure of the damp-proof membrane is: ☐ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

CCTV inspection of gullies and drainage pipes revealed that these to be generally blocked or partially blocked with cementitious materials. You now consider that failure of the damp-proof membrane is: ☐ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

REMEDIAL RECOMMENDATIONS

Lifting of the podium deck and relaying of the membrane throughout is proposed. You consider this to be: ☐ *Required. Note useful, less useful, neither more nor less useful, useful, very useful*

The clearing and/or replacement as necessary of the gullies and drainage pipes passing through the podium deck is proposed. You consider this: ☐ *Required. Note useful, less useful, neither more nor less useful, useful, very useful*

The provision of damp-proofing to the underground car park in accordance with the recommendations of BS8102:2009 is proposed; in particular the general installation of drained cavity systems. You consider this: ☐ *Required. Note useful, less useful, neither more nor less useful, useful, very useful*

RISK MANAGEMENT

A claim against the manufacturers and suppliers of the damp-proof membrane used on construction of the podium deck is proposed. You consider this to be: ☐ *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the contractors responsible for the construction of the podium deck is proposed. You consider this to be: ☐ *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the designers of the podium deck and underground car park is proposed. You consider this to be: ? *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

You consider the risk to occupants and to survey to be: ? *Required. Very low, low, neither more nor less, high, very high*

QUESTION 18

PRESENTING COMPLAINT

A recently constructed row of houses on the south coast of England are suffering from chronic problems of intermittent water penetration and 'staining' to the self-coloured render cladding on the south elevation of the properties.

HISTORY OF PRESENTING COMPLAINT

A recently constructed row of houses on the south coast of England are suffering from chronic problems of intermittent water penetration and 'staining' to the self-coloured render cladding on the south elevation of the properties. Liquid water is reported to be dripping through ceilings and soffits on the south sides of the buildings during stormy weather. This is becoming more marked with time and occupancy, despite remedial works by the contractors.

Failure of the external render is suspected. You find this ? *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

HEALTH & SAFETY

You consider the risk to occupants and to survey to be: ? *Required. Very low, low, neither more nor less, high, very high*

ON INVESTIGATION

The outlines of the blockwork beneath the 'self-colour render coat' is visible in some areas on the south elevation, but this is less marked on other elevations. There is visible water staining at the thresholds to door openings, to the internal sills of windows, and to soffits and reveals down the south elevations.

Failure of the external render is suspected. You now consider this: ? *Required, very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to taking samples through the external render and blockwork and determining its moisture content following the methodology described in BRE Guidance Note 245. You consider this to be: ☐ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to high-powered fibre optic borescope inspection of building voids behind ceilings, soffits and reveals in areas of water staining. You consider this to be: ☐ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to investigating ventilation and condensation to the interiors using thermos-hygrometers, anemometers and infrared thermal cameras. You consider this to be: ☐ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to reviewing the as-built detailing and specification of the building. You consider this to be: ☐ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

The gravimetric moisture content of samples taken through the external render and blockwork vary between 2 and 7 per cent w/w. However, the render coat is found to have been of variable thickness between 9 and 20mm. You now consider that failure of the render coat is:☐ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Evidence of water penetration through construction joints around window and door openings is found on high-powered fibre optic borescope inspection on the south elevation but not in other areas. You now consider that failure of the external render is: ☐ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

No evidence of condensation is found at the time of survey. However, only limited provision appears to have been made for 'background ventilation' or 'trickle ventilation'. You now consider that failure of the external render is: ☐*Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

REMEDIAL RECOMMENDATIONS

The re-rendering of the affected facades is proposed. You consider this to be: ☐ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

Replacement of all windows and door openings on the south elevation is proposed. You consider this: ☐ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

The re-detailing of provision for 'background ventilation', 'make up air' and 'trickle ventilation', so as to allow equalisation of internal and external air pressure is proposed. You consider this to be: ☐ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

RISK MANAGEMENT

A claim against the manufacturers and suppliers of the self-colour render coat is proposed. You consider this to be: *Required. Strongly recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the contractors and sub-contractors is proposed. You consider this to be: *Required. Strongly recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the design team is proposed. You consider this: *Required. Strongly recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

QUESTION 19

PRESENTING COMPLAINT

A mid-19th century row house in West London had been extensively remodelled for commercial occupancy in the past and is being further extensively remodelled and refurbished for commercial occupancy; including the remodelling of the existing basements, plant rooms and lift shafts. The basement structure has been subject to flooding from a burst water main in the adjoining street, allowing water penetration through the tanked retaining wall, which had been subsequently repaired and dried. However, the basement has suffered from continuing 'damp problems' including extensive mould growth affecting refurbished render and plasterboard to walls, ceilings and soffits.

HISTORY OF PRESENTING COMPLAINT

The flooding incident due to the burst water main occurred approximately 18 months ago and affected structures have been subject to previous remedial treatment, including patch repair to the tanking system and the use of refrigerant dehumidifiers. However, mould growth had become apparent in the late summer and autumn months and has rapidly extended across the majority of surfaces within the basements.

Continuing problems of water penetration from mains water leaks and failure of tanking is suspected. You find this: *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

HEALTH & SAFETY

You consider the risk to occupants and to survey to be: *Required. Very low, low, neither more nor less, high, very high*

ON INVESTIGATION

On investigation extensive superficial mould growth is visible throughout the basements; affecting both the retaining walls and party walls with adjoining structures. There is extensive interstitial mould growth behind plasterboard claddings, and superficially at the base of walls in some locations. Many of the walls had been clad with a proprietary insulating render coat, which has been overlayed with insulated plaster board secured with 'dot-and-dab' fixings.

There was evidence of recent 'patch repair' to cementitious 'Sika type' tanking in the area of the mains water leak. However, no 'guarantees' covering materials and workmanship could be provided. There was some visible evidence of further water penetration, resulting in water and salt staining. However, this is generally in the area of rainwater downpipes above.

Continuing problems of water penetration from mains water leaks and failure of tanking is suspected. You now consider this: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Consideration is given to taking samples of visible mould growth and mould aerospora samples to determine the distribution and hazard represented by the mould growth in basements and adjoining areas. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to taking samples of visible mould growth and mould aerospora samples to determine the distribution and hazard represented by the mould growth in basements and adjoining areas. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to taking samples from representative structures and determining their moisture content following the methodology described in BRE Guidance Note 245. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

Surface sampling and aerospora sampling shows extensive growth of *Aspergillus/Penicillium* species and *Stachybotrys chartarum*. Elevated aerospora counts are found in staircases, adjacent structures and the lift shaft extending from basement to roof level. Continuing problems of water penetration from mains water leaks and failure of tanking is suspected. You now consider this: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Investigation of internal environments and ventilation show inadequate or no provision for through and cross ventilation to the basement, providing conditions for intermittent condensation. Preliminary computer modelling indicates that the proprietary insulated render is likely to result in condensation. Continuing problems of water penetration from mains water leaks and failure of tanking is suspected. You now consider this: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Moisture and salt profiling of representative structures indicate high moisture and hygroscopic salt contents to the 'Sika type' render and underlying structures in many areas with some localised saturation at the junction between the patch repair and older tanking systems. You now consider that failure of the damp-proof course as the cause of extensive mould growth is:▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

REMEDIAL RECOMMENDATIONS

Replacement of the existing 'Sika type' render tanking system with new throughout so as to allow for the issuing of 'guarantees' covering materials and workmanship is proposed. You consider this to be: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Provision of through and cross ventilation with fresh external air to all parts of the basement during and after refurbishment is proposed. You consider this to be: ▯ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

The provision of supplementary damp-proofing using a drained cavity system in accordance with the recommendations in BS8102:2009 to the external walls is proposed. You consider this to be: ▯ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

Access controlled to those wearing respirator protection to FFP3, and urgent specialist decontamination of all mould affected structures of basement and adjacent areas is proposed. You consider this to be: ▯ *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

RISK MANAGEMENT

Insurance backed guarantees covering materials and workmanship for tanking systems are proposed. You consider this to be: ▯ *Required. Strongly recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the remedial sub-contractor undertaking the tanking is proposed. You consider this to be: ▯ *Required. Strongly recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

A claim against the design team is proposed. You consider this to be: ▯ *Required. Strongly recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

The independent testing of all areas of the basement and adjacent structures for residual mould spores and fragments at completion is proposed. You consider this to be: *Required. Strongly recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

QUESTION 20

PRESENTING COMPLAINT

Chronic problems of liquid water penetration and mould growth are occurring in the basement rooms of an apartment in a recently remodelled late 19^{th} and early 20^{th} century building in north-west London.

HISTORY OF PRESENTING COMPLAINT

Localised problems of ‘damp’ including moisture and salt damage to finishes, mould growth and intermittent liquid water penetration have occurred since occupancy of a recently constructed apartment in an extensively remodelled and refurbished late 19^{th} or early 20^{th} century building. Water penetration appears to be associated with periods of heavy rain and has continued to occur despite repeated remedial works to damp-proofing systems, and overlying ‘roof’ and surface drainage systems.

Failure of external roof drainage systems and flashings at ground level are suspected. You consider this to be: *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

HEALTH & SAFETY

The apartment is unoccupied due to concerns about exposure to mould growth. However, electrical systems remain live.

You consider the risk to occupants and to survey to be: *Required. Very low, low, neither more nor less useful, high, very high*

ON INVESTIGATION

On investigation the area of water penetration and ‘damp’ problems is found to be at the interface between new and original structures, where a reinforced concrete slab forms the roof over an underground car park adjoins the structure of the apartment. Affected parts of the apartment includes the basement bedroom and the structure of an external basement area opening into the basement via French windows. This includes recently constructed cavity walls and windows at basement, first and second floor level above, and a hopper and rainwater downpipe discharging onto the paving of a podium deck or patio overlying the underground car park and draining through gullies and rainwater downpipes, passing through the structures beneath. Electrical services and other electrical wiring and other services penetrate through the structure at this location. However, there is evidence of recent and repeated laying of new roof membranes including liquid and physical membranes, so as to form waterproof tanking and flashing details. These are reported to be covered by ‘guarantees’ covering materials and workmanship. There is also visible evidence of water penetration into the adjacent cavity wall structure around window sills and to the parapet wall.

A failure of the roof membranes is suspected. You now consider this: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

FURTHER INVESTIGATIONS OR TESTS

Consideration is given to high-powered fibre-optic borescope inspection of existing structures. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to investigating ventilation and condensation to the interiors using thermo hygrometers, anemometers and infrared thermal cameras. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

Consideration is given to taking samples from damp affected structures and analysing following the methodology described in BRE Guidance Note 245. You consider this to be: ▯ *Required. Useless, less useful, neither more nor less useful, useful, very useful*

RESULTS OF FURTHER INVESTIGATIONS OR TESTS

High-powered fibre optic borescope inspection of the damp affected structures reveal heavily corroded RSJs supporting the original structure above and the more recent reinforced concrete slabs, with evidence of liquid water draining through the construction joints between steel and concrete elements. A studded damp-proof membrane is found forming a drained cavity system to the external walls of the basement extending to approximately 1m above internal floor levels and extending beneath the basement floor. However, liquid water is found dripping onto the plasterboard soffits through construction joints round steels and around electrical wiring, passing through construction joints. There is also evidence of liquid water draining down through the cavity wall structures; especially around the ends of the external concrete sills beneath window openings, which have inadequate flashing and drip details, and cavity trays appear to be allowing water to drain through to structures beneath, rather than out through weep holes. The 'roof membrane' is found to be laid onto an insulation layer laid directly onto the reinforced concrete slab, overlaying the damp affected structure and the adjoining underground car park. Liquid water is visible beneath this insulation.

You now consider failure of the damp-proof membrane and flashings is: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

Investigation of internal environments reveals inadequate provision for extraction of moisture laden air with occupancy and inadequate provision for 'background ventilation'. Infrared thermal imaging reveals localised 'cold-bridging' in areas of chronic water penetration. You now consider that failure of the damp-proof membrane is: ▯ *Required. Very unlikely, unlikely, neither likely or unlikely, more likely, very likely*

REMEDIAL RECOMMENDATIONS

It is proposed to lift and re-lay the paving, membranes and insulation over the reinforced concrete slab over the affected structure and adjoining underground car park, so as to form a roof structure in accordance with the requirements of current Building Regulations. You consider this to be: ? *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

It is proposed to replace the existing roof membranes and flashings with a new product including guarantees covering materials and workmanship. You consider this to be: ? *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

It is proposed to re-detail and replace provision for cavity drainage over ceilings and soffits. You consider this to be: ? *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

It is proposed to re-detail and replace existing provision for electrical services and roof drainage systems, so as to avoid services penetrating through the external shell. You consider this to be: ? *Required. Not useful, less useful, neither more nor less useful, useful, very useful*

RISK MANAGEMENT

It is proposed to investigate the structural adequacy and corrosion state of existing structures and to provide additional support and corrosion protection as directed by a Structural Engineer. You consider this to be: ? *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

It is proposed to undertake mould decontamination to all interior surfaces, carpets, contents and air handling systems. You consider this to be: ? *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

It is proposed to make a claim against the manufacturers, suppliers and installers of the roof membrane system. You consider this to be: ? *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

It is proposed to make a claim against the contractors and developers undertaking the recent remodelling work. You consider this to be: ? *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

It is proposed to make a claim against the design team involved in the recent remodelling and refurbishment works. You consider this to be: ? *Required. Strongly not recommended, not recommended, neither more or less recommended, recommended, strongly recommended*

COMMENTS:

Thank you very much for participating in this research project and for spending time answering the questions in this test. Please could you record any observations or recommendations you would like to contribute below:

Key for selection options

1.a.vii - Academic Qualifications
NVQ
BA/BSc MA/MSc/MPhil PhD
Other

APPENDIX G: DATA FROM SCRIPT CONCORDANCE TESTS FOR DIAGNOSIS AND MANAGEMENT OF DAMP PROBLEMS IN BUILDINGS

Results Table for BPSCT1 – Scenarios 1 to 10

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
1	1	0.83	0.42
1	2	0.75	0.84
1	3	0.75	0.53
1	4	0.81	0.78
1	5	0.85	0.63
1	6	1.00	0.33
1	7	0.67	0.67
1	8	1.00	0.07
1	9	0.83	0.60
1	10	0.81	0.83
1	11	0.92	0.36
2	12	0.75	0.37
2	13	0.79	0.52
2	14	0.75	0.82
2	15	0.83	0.51
2	16	0.83	0.62
2	17	0.85	0.44
2	18	0.75	0.60
2	19	1.00	0.13
2	20	0.75	0.69
2	21	0.83	0.67
2	22	0.83	0.42
2	23	0.69	0.32
3	24	0.92	0.69
3	25	0.89	0.44
3	26	0.85	0.51
3	27	0.81	0.78
3	28	0.75	0.43
3	29	0.85	0.83
3	30	0.75	0.71
3	31	0.79	0.46
3	32	1.00	0.47
3	33	0.83	0.27
3	34	0.85	0.63
3	35	0.81	0.70
3	36	0.67	0.56

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
3	37	0.75	0.69
3	38	0.79	0.72
4	39	0.69	0.22
4	40	0.85	0.56
4	41	0.75	0.57
4	42	0.75	0.57
4	43	0.75	0.56
4	44	0.75	0.43
4	45	0.75	0.35
4	46	0.89	0.41
4	47	0.75	0.29
4	48	0.79	0.32
4	49	0.70	0.47
4	50	1.00	0.67
4	51	0.75	0.58
4	52	0.81	0.68
4	53	0.75	0.33
4	54	0.75	0.69
5	55	0.75	0.36
5	56	0.79	0.54
5	57	0.85	0.77
5	58	0.83	0.78
5	59	0.75	0.49
5	60	0.70	0.52
5	61	0.83	0.73
5	62	0.70	0.39
5	63	0.85	0.56
5	64	0.85	0.81
5	65	0.75	0.44
5	66	0.85	0.67
6	67	0.69	0.50
6	68	0.69	0.38
6	69	0.75	0.52
6	70	0.75	0.73
6	71	0.81	0.55
6	72	0.69	0.60
6	73	0.79	0.48
6	74	0.79	0.38
6	75	0.89	0.07
6	76	0.89	0.41
6	77	0.85	0.48
6	78	1.00	0.07

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
6	79	0.69	0.57
7	80	0.92	0.73
7	81	1.00	0.87
7	82	0.75	0.57
7	83	0.89	0.40
7	84	0.70	0.60
7	85	0.75	0.67
7	86	1.00	0.53
7	87	0.70	0.41
7	88	0.69	0.62
7	89	0.69	0.43
7	90	0.79	0.47
7	91	0.69	0.72
7	92	1.00	0.07
7	93	1.00	0.73
7	94	1.00	0.87
7	95	0.69	0.20
8	96	0.83	0.60
8	97	0.79	0.43
8	98	0.70	0.23
8	99	0.89	0.29
8	100	0.75	0.60
8	101	0.79	0.39
8	102	0.75	0.20
8	103	0.69	0.50
8	104	0.75	0.50
8	105	0.81	0.55
8	106	0.75	0.44
8	107	0.79	0.14
8	108	0.83	0.58
8	109	0.92	0.24
9	110	0.75	0.89
9	111	0.81	0.58
9	112	0.85	0.68
9	113	0.85	0.51
9	114	0.79	0.49
9	115	0.85	0.39
9	116	0.81	0.50
9	117	0.75	0.43
9	118	0.85	0.56
9	119	0.89	0.46
9	120	0.83	0.09

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
9	121	0.83	0.58
9	122	0.69	0.23
9	123	0.85	0.11
9	124	0.75	0.37
10	125	0.92	0.87
10	126	0.83	0.91
10	127	0.83	0.24
10	128	0.85	0.45
10	129	0.75	0.47
10	130	0.81	0.45
10	131	0.92	0.62
10	132	0.85	0.69
10	133	1.00	0.13
10	134	0.89	0.40
10	135	0.85	0.11
10	136	0.70	0.52
10	137	0.75	0.36

Results Table for BPSCT2 – Scenarios 11 to 20

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
11	1	0.75	0.54
11	2	0.75	0.50
11	3	0.79	0.50
11	4	1.00	0.89
11	4.1	0.85	0.87
11	5	1.00	0.89
11	6	1.00	0.50
11	7	0.75	0.42
11	8	0.83	0.65
11	9	0.85	0.89
11	10	0.75	0.61
11	11	0.89	0.49
11	12	0.75	0.51
11	13	0.75	0.83
12	14	0.75	0.61
12	15	0.69	0.81
12	16	0.81	0.78
12	17	0.89	0.47
12	18	0.81	0.71
12	19	0.69	0.57
12	20	0.85	0.76
12	21	0.75	0.74
12	22	0.81	0.81
12	23	0.81	0.54
12	24	0.85	0.66
12	25	0.75	0.51
12	26	0.81	0.61
13	27	0.69	0.14
13	28	0.75	0.78
13	29	0.75	0.39
13	30	0.81	0.72
13	31	0.69	0.57
13	32	0.75	0.64
13	33	0.67	0.67
13	34	0.75	0.64
13	35	0.75	0.70
13	36	0.85	0.68
13	37	0.83	0.93
14	38	0.75	0.76
14	39	0.79	0.29
14	40	0.85	0.58

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
14	41	0.79	0.40
14	42	0.89	0.36
14	43	0.83	0.89
14	44	0.85	0.41
14	45	0.89	0.63
14	46	0.89	0.68
14	47	0.79	0.47
14	48	0.85	0.70
15	49	1.00	0.94
15	50	0.79	0.37
15	51	0.69	0.47
15	52	0.92	0.74
15	53	0.81	0.65
15	54	0.69	0.39
15	55	0.75	0.69
15	56	0.75	0.70
15	57	0.83	0.70
15	58	0.69	0.72
15	59	0.81	0.85
15	60	0.79	0.22
15	61	0.75	0.64
15	62	0.75	0.24
15	63	0.69	0.54
15	64	0.75	0.63
16	65	0.67	0.80
16	66	0.75	0.53
16	67	0.83	0.74
16	68	0.75	0.46
16	69	0.75	0.43
16	70	0.75	0.50
16	71	0.75	0.65
16	72	0.81	0.67
16	73	0.69	0.26
16	74	0.85	0.62
16	75	0.85	0.64
16	76	0.79	0.58
16	77	0.83	0.87
16	78	0.67	0.70
16	79	0.75	0.69
16	80	0.75	0.77
17	81	0.75	0.28
17	82	0.69	0.54
17	83	0.81	0.56

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
17	84	0.83	0.89
17	85	0.70	0.64
17	86	0.81	0.89
17	87	0.69	0.65
17	88	0.83	0.74
17	89	1.00	1.00
17	90	0.89	0.67
17	91	0.69	0.60
17	92	0.83	0.89
17	93	0.89	0.37
17	94	0.88	0.92
18	95	1.00	0.44
18	96	0.81	0.81
18	97	0.70	0.64
18	98	0.83	0.76
18	99	0.75	0.83
18	100	0.85	0.54
18	101	0.75	0.70
18	102	0.83	0.44
18	103	0.75	0.70
18	104	0.75	0.57
18	105	0.75	0.64
18	106	0.75	0.64
18	107	0.75	0.64
18	108	0.69	0.65
18	109	0.75	0.50
18	110	0.79	0.67
18	111	0.67	0.67
19	112	0.81	0.82
19	113	0.69	0.63
19	114	0.92	0.89
19	115	0.67	0.89
19	116	0.81	0.79
19	117	0.83	0.83
19	118	0.81	0.60
19	119	0.75	0.56
19	120	0.92	0.94
19	121	0.75	0.68
19	122	0.81	0.92
19	123	0.75	0.48
19	124	0.81	0.86
19	125	0.75	0.81
19	126	0.83	0.70

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
19	127	0.79	0.48
20	128	0.81	0.83
20	129	0.81	0.94
20	130	0.75	0.53
20	131	0.69	0.74
20	132	1.00	0.94
20	133	0.81	0.72
20	134	1.00	0.83
20	135	0.81	0.65
20	136	0.81	0.54
20	137	0.85	0.82
20	138	0.83	0.74
20	139	0.75	0.71
20	140	1.00	1.00
20	141	0.85	0.88
20	142	0.83	0.81
20	143	0.75	0.58
20	144	0.81	0.76
20	145	0.75	0.78

Results Table for BPSCT3– Scenarios 1 to 20

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
1	1	0.80	0.52
1	2	0.80	0.56
1	3	0.84	0.44
1	4	0.80	0.44
1	5	0.67	0.47
2	6	0.77	0.33
2	7	0.92	0.82
2	8	0.80	0.71
2	9	0.82	0.53
2	10	0.86	0.16
2	11	0.68	0.42
3	12	0.78	0.72
3	13	0.78	0.63
3	14	0.82	0.63
3	15	0.82	0.83
3	16	0.82	0.63
3	17	0.70	0.71
3	18	0.71	0.73
4	19	0.70	0.58
4	20	0.74	0.38
4	21	0.71	0.42
4	22	0.84	0.83
4	23	0.78	0.77
4	24	0.70	0.58
4	25	0.77	0.35
4	26	0.80	0.67
4	27	0.78	0.46
5	28	0.84	0.44
5	29	0.83	0.65
5	30	0.82	0.62
5	31	0.78	0.57
6	32	0.84	0.16
6	33	0.82	0.35
7	34	0.82	0.68
7	35	0.78	0.18
7	36	0.74	0.63
7	37	0.92	0.39
7	38	0.70	0.44
8	39	0.70	0.81

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
8	40	0.92	0.76
8	41	0.67	0.47
8	42	0.74	0.61
8	43	0.74	0.75
8	44	0.80	0.54
8	45	0.70	0.77
8	46	0.77	0.52
8	47	0.92	0.83
8	48	0.82	0.72
8	49	0.82	0.78
9	50	0.78	0.83
9	51	0.71	0.35
9	52	0.67	0.80
9	53	0.71	0.37
9	54	0.78	0.30
9	55	0.75	0.46
9	56	0.82	0.33
9	57	0.80	0.71
10	58	0.84	0.42
10	59	0.80	0.60
10	60	0.68	0.51
10	61	0.71	0.24
10	62	0.74	0.46
10	63	0.71	0.77
11	64	0.84	0.77
11	65	0.80	0.65
11	66	0.68	0.42
11	67	0.92	0.85
11	68	0.78	0.60
11	69	0.78	0.60
12	70	0.80	0.38
12	71	0.80	0.73
12	72	0.92	0.83
12	73	0.92	0.63
13	74	0.71	0.38
13	75	0.94	0.78
13	76	0.71	0.57
14	77	0.78	0.77
14	78	0.84	0.85
14	79	0.84	0.52

Scenario Number	Question Number	Expert Mean Sub-Q Score	Student Mean Weighted Sub-Q Score
14	80	0.77	0.60
14	81	0.71	0.56
15	82	0.71	0.72
15	83	0.80	0.64
15	84	0.84	0.65
15	85	0.80	0.61
15	86	0.84	0.29
15	87	0.80	0.81
15	88	0.84	0.61
15	89	0.84	0.92
15	90	0.92	0.83
15	91	0.74	0.82
16	92	0.77	0.42
16	93	0.80	0.88
16	94	0.92	0.79
16	95	0.84	0.55
16	96	0.80	0.81
16	97	0.78	0.21
16	98	0.86	0.51
17	99	0.74	0.51
17	100	0.74	0.65
17	101	0.70	0.71
17	102	0.71	0.63
17	103	0.93	0.96
18	104	0.83	0.86
18	105	0.78	0.70
18	106	0.71	0.44
18	107	0.77	0.60
19	108	0.78	0.55
19	109	0.82	0.62
19	110	0.78	0.55
19	111	0.83	0.56
19	112	0.71	0.72
19	113	0.77	0.63
20	114	0.92	0.58
20	115	0.93	0.70
20	116	0.83	0.84

Results Table for BPSCT 1 to 3 – Expert and Student Mean Scores and Standard Deviations

	Experts			Students		
	Number	Mean score, %	Standard Deviation, %	Number	Mean score, %	Standard Deviation, %
BPSCT1	8	80.3%	4.1%	15	50.5%	11.1%
BPSCT2	8	79.8%	6.6%	18	66.0%	7.2%
BPSCT3	11	79.2%	4.0%	12	59.8%	10.2%