Graduate Program in Historic Preservation
Stuart Weitzman School of Design, University of Pennsylvania

HSPV 5510 ***Building Pathology***
Michael C. Henry, PE, AIA **Adjunct Professor of Architecture**

Course Syllabus

Class Meetings
Fridays, 1:45 PM to 4:45 PM (Eastern Daylight Time/Eastern Standard Time)

Teaching and Learning Platforms
Canvas will be used to access course materials, lecture slides, readings, quizzes, and tests.
Class will meet in-person in MH-B7, dependent on weather and/or Covid-19 risk factors.
Zoom will be used for live on-line class meetings when in-person classes are not possible/advisable.
Zoom will be used for meetings with individuals and teams.

Communications
Each student is expected to meet with me at least twice during the semester, in addition to reviews of work product.
Office hours: By appointment, *via Zoom*, Wednesdays, 8:30 AM to 11:00 AM (EDT/EST)
E-mail: henrmic@design.upenn.edu
Include "HSPV 551" in the subject heading of your email to me.
Please add mhenry@watsonhenry.com to your "Safe Senders" list.

Teaching Assistant: Cameron Moon
Please contact Cameron regarding scheduling meetings with me, course materials in Canvas or if you wish for me to review/repeat/explain course content in class.

Teaching and Learning
Class meeting time will be structured to maximize active learning and interaction among participants. As a consequence, class discussion of lecture content and engagement in exercises is expected. This requires thorough preparation before class, including review of the readings and lecture slides.

Class meetings will not be recorded unless a student cannot attend due to exceptional circumstances, such as an acute health issue.

The final assignment consists of a professional consultation which will be submitted incrementally over the semester, so that feedback can be provided in time for more research and refinement of the final work product by the student teams.

Feedback on the effectiveness of the methods used in this course will be welcome, so that we can make mutually agreeable adjustments and introduce improvements as the course proceeds through the semester. Your candid feedback on course content, readings, class exercises and teaching methods are encouraged so that the course may be continuously developed and improved. Course feedback may be delivered directly, or through the Teaching Assistant. Real time feedback, rather than feedback at the end of the course, is preferred.

Course Description
Buildings, their sites , systems and supporting infrastructure embody substantial investments in capital, labor, and energy. Historic buildings embody the added value of their architectural, cultural, or social significance.

The post-construction performance and function of buildings inevitably decline due to various pathologies. These pathologies are enabled by factors present in the environment, by use and occupancy of the building and by time. Eventually, the aggregate effect of these pathologies necessitates appropriate interventions to slow the loss of, or reinstate, utility and functional performance of the building. Appropriate interventions address the causal factors of the pathologies, slowing damage and inappropriate or symptomatic interventions exacerbate pathologies, increasing damage.

Building Pathology is the study of the deterioration processes that can ultimately determine a building's survival or loss. The course presents building pathologies as dynamic systems with causal factors such as energy and moisture acting over time, thus informing prevention as well as remediation. The course prepares the historic preservation professional to analyze existing conditions and identify the causal mechanisms and enabling factors of deterioration and loss. The course prepares the architect to identify potential building longevity problems during design of new buildings.

Building Pathology will:
- Consider the problem inherent to the longevity and sustainability of any building – deterioration, loss of utility, and loss of functional performance – all as a *function of time*.
- Review the investment of capital, labor and energy embodied in new and existing buildings and the added value of buildings considered to be historically significant.
- Emphasize a *systemic approach* to understanding building deterioration, considering the building, its physical, economic and climatic contexts, its occupancy and use, and the implications of changes in these with time.
- Review the properties of building materials, their comparative values as performance assets and as potential vulnerabilities to deteriorative mechanisms.
- Review the mechanisms and causal factors of building deterioration - mechanical, hygrothermal, biological and electrochemical - as dynamic systems.
- Identify the factors necessary for the deterioration mechanisms to occur and the contextual sources for these factors.
- Study examples of how these mechanisms occur singly or synergistically in a building's structure, enclosure, or systems.
- Consider the implications of preventive conservation, sustainability, and adaptability for building survival.
- Consider how to set objectives for remedy, mitigation and prevention of deteriorative mechanisms once the causal mechanisms are known and how to Identify and evaluate intervention strategies for achieving the objectives.
- Consider the implications of designing and implementing the intervention strategies.

For 2023, HSPV 551 *Building Pathology* will include elements from HSPV 552 *Building Diagnostics and Monitoring*, which addresses diagnosis and monitoring of building pathologies.

Building Pathology will be taught by:
- Preparatory readings;
- Lectures;
- Class exercises and discussions;
- Test of knowledge; and,
- Final Assignment.

Learning Objectives

Upon successful completion of the course, you should be able to:

- Think of buildings systemically in spatial and temporal dimensions.
- Understand the problem of achieving and maintaining adequate utility and functional performance in buildings.
- Recognize building materials for their vulnerabilities to deterioration and for their performance assets and durability.
- Know the primary mechanisms/processes of deterioration in buildings, the causative factors that are necessary and sufficient for these mechanisms to occur, and the potential for synergistic interaction between different mechanisms.
- Understand building deterioration as a dynamic system, rather than symptomatic results.
- Think critically and broadly about factors that differentiate between building survival and loss.
- Express building pathology issues in quantitative and qualitative terms, using professional terminology.
- Research technical information on building and building materials in professional journals.
- Apply diagnostic thinking to correctly identify the causal factors of building deterioration.
- Define the objectives and evaluate potential intervention strategies to mitigate, remedy or prevent deterioration.
- Prepare professional-quality reports that demonstrate application of the above to case studies of actual buildings.

Learning - Your Responsibilities as a Student

- **Attendance**

You are expected to attend all classes. Attendance will be taken. Notify me by email before class if you will not be able to attend a class meeting.

- **Live and On-line Class Meetings**

You should treat on-line class meetings as if you are in a live classroom or a live business meeting with other professionals. Eliminate distractions to you and your fellow students. Turn off your phones, email and texting apps/programs during class. Do not consume your lunch/dinner during class.

- **Reflections on the Previous Class**

Prior to the second class meeting, and before each subsequent class meeting, you must post your reflections on content from the previous meeting in the discussion section of Canvas.

- **Class Exercises**

Class exercises are an important part of the student-centered learning process and will apply information or methods addressed by the readings and lectures. Class exercises require reasoning, analysis, basic mathematical calculations and sketching. Some exercises will be done individually; other exercises will be collaborative.

You must have knowledge and comprehension of the assigned reading materials and will need a simple calculator, graph paper and writing instruments to complete the class exercises.

- **Test of Knowledge**

The test of knowledge demonstrates that you have command of essential course content. The test of knowledge requires your comprehension and retention of information contained in the readings and lectures. The test will be "closed-book." You will need graph paper and writing instruments to complete the test.

- **Final Assignment Deadline**

The deadline for the final assignment is firm and there will be ample time for you to plan and execute the assignment. One letter graded will be deducted for late submission of the assignment.

- **Academic Integrity**

Honesty is fundamental to your future practice as a professional and academic honesty is fundamental to our community at the University of Pennsylvania. Honesty includes attributing and citing the sources used in your assignments.

The UPenn Code of Academic Integrity can be found at https://catalog.upenn.edu/pennbook/code-of-academic-integrity/ *A confirmed violation of that Code in this course will result in failure for the course.*

Metrics for Student Performance

Letter grades and their numerical equivalents will be based awarded upon successful completion of the course. The final grade will be based on the following allocation:

- Preparation for and participation in class 30 %
- Test 30 %
- Assignment 40 %
- Total (maximum) 100 %

The calculated grade will be adjusted to reflect unexcused absences and late assignments.

Participation in class will be based on your individual:

- Preparation, including demonstration of retention and comprehension of the readings;
- Exercises - participation and outcomes;
- Engagement in discussions;
- Reflections on class content in Canvas.

The *Test of Knowledge* will be scored based on based on points and letter grades will be assigned based on distribution of the numeric scores of the class.

The Assignment will be graded on:

- Focused, substantive and concise content, founded on clear and logical analysis, substantiated by facts, research beyond the course materials and citations, including professional citations from outside the course readings;
- Clear and logical narrative exposition of the information, substantially free of grammatical, punctuation and spelling errors;
- Graphical presentation of key concepts illustrating the important or complex points of the narrative;
- Conformance with format requirements.

The grading rubric for the Assignment will be:

- A Exceptional work, equivalent to professional quality, thorough grasp and synthesis of all course content.
  Thorough preparation for class, demonstrated by engagement and participation.
  Writing: Logically organized, clear and concise with correct use of technical terminology.
  Research: citations from professional journals and publications other than class readings.
  Graphics: multi-variant, demonstrating causality & connections, clear and compelling.
- B Very good work, near-professional quality, thorough grasp and synthesis of nearly all course content.
  Rare lapses in preparation for class, occasional lack of engagement and participation in class.
  Writing: rare lapses in clarity or application of technical terminology.
  Research: citations from class texts and readings.
  Graphics: dual variant, showing causality or correlation, clear and convincing.
- C Average work, sub-professional quality, understanding of basic information.
  Marginal class preparation, moderately engaged, occasional participation.
  Writing: Weak organization or structure, poor application of technical terminology.
  Research: citations on technical matters from popular web sources, such as Wikipedia.
  Graphics: single variant, clear.
- F Unacceptable work.

The Assignment - *Building Pathology Consultation*: Overview, Format Submission & Disposition
In partial fulfillment of the course, you will work in teams of two, and each team will submit a *Building Pathology Consultation*. The consultation consists of a professional-level letter addressing a specific building pathology problem. The letter (up to 10 pages of text) will be supplemented by appendices and graphics.

The requirements for the consultation will be provided to you will submit a draft consultation as indicated in the *Course, Reading and Submission Schedule.*

In preparing the *Building Pathology Consultation*, you will apply and extend critical concepts, fundamental principles, methods and information from the lectures and readings, supplemented by your own research in professional and technical publications. This effort will provide active, student-centered learning in the context of authentic, real-world building problems.

The narrative must be clear and logical exposition of the facts,[1] substantially free of grammatical and spelling errors. Graphics should illustrate the important or complex points of the narrative.[2] Conclusions and recommendations must be substantiated by facts and reflect a rational thought process.

The required format for the *Building Pathology Consultation* is:
- 8.5 by 11.0-inch paper, portrait orientation, single-sided printing for text and small graphics;
- 11.0 by 17.0-inch paper, landscape orientation, single-sided printing, z-folded for large graphics;
- Calibri font, 10-point, black print, single spaced lines;
- Margins set at 1.25 inches (binding edge), 1.00 inches (other edges);
- Single-line footer with Project Name (left) and page number (right);
- Pages numbered sequentially:
  1, 2, …for report body; A1, A2, … for appendix A, similar for B, et cetera;
- Endnotes;
- Photographs, images and charts/graphics:
  Landscape format (top edge to rings) or portrait format.
  Black and white or color, laser/bubble jet printed from digital images or scans.
  4 inches in the least dimension.
  Captioned with self-evident descriptive text, source name and date;
- Cover (Title) page with:
  Course number, title and program and date of report
  Each student's printed name and signature with statement "I have contributed equally with my team partner(s) in this assignment"

Submission of Final Assignment:
- **Self-Evaluation:** Each team member must complete a self-evaluation of the final assignment using the grading rubric and submit the self-evaluation as an attachment to the assignment.
- Prepare a **digital copy** of the entire assignment as a single .pdf file and title the file: "2023 HSPV5510 Final Assignment xxxxx and xxxxx" where xxxxx are the names of the student team members. Upload the digital copy of the *Building Pathology Consultation* to the address provided to you of the *Building Pathology Consultations* **before the time and date** specified in the *Course, Reading and Submission Schedule*.
- Upload the digital copy of the *Building Pathology Consultation* and the self-evaluations **before the time and date** specified in the *Course, Reading and Submission Schedule*.

[1] *Elements of Style Illustrated* by William Strunk, Jr. and E. B. White is a classic guide to writing. The current edition is delightfully illustrated by Maira Kalman.

[2] *The Visual Display of Quantitative Information, Second Edition* by Edward R. Tufte provides an excellent review of graphical presentation of information.

Information Sources for the Course

- **Texts**

The following texts for the basis for the course and will be on reserve at the Fisher Fine Arts Library:

Blockley, David. *Structural Engineering – A Very Short Introduction.* Oxford: Oxford University Press, 2014.

Brand, Stewart. *How Buildings Learn – What Happens after They're Built*. New York, NY: Viking, Penguin Books, USA, 1994.

Ching, Francis D. K. *Building Construction Illustrated*, 5th Edition or later. New York, NY: Wiley, 2014 or later.

Harris, Samuel Y. *Building Pathology – Deterioration, Diagnostics and Intervention*. New York, NY: John Wiley & Sons, Inc, USA, 2001.

Meadows, Donella H. *Thinking in Systems, a primer.* White River Junction, VT: Chelsea Green Publishing, 2008.

Watt, David S. *Building Pathology – Principles and Practice.* London: Wiley-Blackwell, 2008.

- **Print and other media**

The Course, Reading and Submission Schedule lists other materials required for class preparation.

- **Resources**

The following professional references will be useful in the course and in the final assignment:

American Concrete Institute. Home page. https://www.concrete.org/

American Society of Civil Engineers.
ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings. New York, NY, USA: ASCE, 1999. https://ascelibrary.org/doi/book/10.1061/9780784404324
ASCE 30-14 Guideline for Condition Assessment of the Building Envelope. New York, NY, USA: ASCE, 2014. https://ascelibrary.org/doi/book/10.1061/9780784413258#

American Society for Testing and Materials. Home page. https://www.astm.org/

Architectural Engineering and Design Management. This publication analyses and discusses the integration of the main stages within the process of design and construction and multidisciplinary collaborative working between the different professionals involved. Taylor & Francis. http://www.tandfonline.com/action/journalInformation?journalCode=taem20#.Vpv4JfkrIfI

Architectural Science Review. This publication presents papers on environmental issues, covering topics such as thermal comfort, lighting, and sustainable architecture. Taylor & Francis. http://www.tandfonline.com/action/journalInformation?journalCode=tasr20

Association for Preservation Technology. Home page. http://www.apti.org/

Brick Industry Association. *Technical Notes*. http://www.gobrick.com/TechnicalNotes/tabid/7658/Default.aspx

Building and Environment. The International Journal of Building Science and its Applications. Elsevier. http://www.journals.elsevier.com/building-and-environment/

Building Research and Information. This publication focuses on buildings, building stocks and their supporting systems, reflecting the complexity and linkages between culture, environment, economy, society, organizations, quality of life, health, well-being, design and engineering of the built environment. Taylor & Francis. http://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=rbri20#.Vpv5xPkrIfI

Building Science Corporation. *Building Science Digests* and *Building Science Insights* series. http://www.buildingscience.com/index_html

Canadian Architect. Architectural Science Forum series. Ted Kesik. https://www.canadianarchitect.com/?s=Architectural+Science+Forum

Construction and Building Materials: An international journal dedicated to the investigation and innovative use of materials in construction and repair. Elsevier. http://www.journals.elsevier.com/construction-and-building-materials/

Energy and Buildings. An international journal devoted to investigations of energy use and efficiency in buildings. Elsevier. *http://www.journals.elsevier.com/energy-and-buildings*

Engineering Weather Data: a compilation of National Climate Data Center Charts and Tables for worldwide locations as used in the course. Can be accessed for free at University of Indiana University, Bloomington website. https://webapp1.dlib.indiana.edu/virtual_disk_library/index.cgi/4910250/FID2605/engwx/EngineeringWeather.html at bottom of page select either "Download" for the entire file or "Browse" then open "EngineeringWeather.html" to find a location.

Forest Products Laboratory. Home page. http://www.fpl.fs.fed.us/

International Journal of Architectural Heritage. This publication provides a multidisciplinary scientific overview of existing resources and modern technologies useful for the study and repair of historical buildings and other structures, including information on history, methodology, materials, survey, inspection, non-destructive testing, analysis, diagnosis, remedial measures, and strengthening techniques. Taylor & Francis. http://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=uarc20#.Vpv61PkrIfI

Journal of Building Engineering. An interdisciplinary journal that covers all aspects of science and technology concerned with the whole life cycle of the built environment, from the design phase through to construction, operation, performance, maintenance and its deterioration. Elsevier. http://www.journals.elsevier.com/journal-of-building-engineering

Journal of Building Physics. Covers on-structural performance of a building and particularly in heat, air, moisture transfer and includes: insulation and building envelope materials and systems including polymeric, mineral, cellulose-based, and composites, building interactions with the environment, occupants, and allied building materials, components, and sub-systems, green roofing, double skinned envelopes and interaction of building enclosure with mechanical systems. Sage. http://intl-jen.sagepub.com/

Journal of Cultural Heritage. A multidisciplinary journal of science and technology for conservation and awareness; presents innovative methods concerning all aspects of science and technology of cultural heritage as well as interpretation and theoretical issues related to preservation. Elsevier. http://www.journals.elsevier.com/journal-of-cultural-heritage

Masonry Institute of America. Technical Publications. http://www.masonryinstitute.org/products.php?catID=5

National Geologic Map Database. https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

National Research Council of Canada:
Canadian Building Digests series https://researchguides.georgebrown.ca/CBD
Construction Innovations series http://www.nrc-cnrc.gc.ca/ci-ic/
Construction Technology Updates series http://www.nrc-cnrc.gc.ca/ctu-sc/

Torraca, Giorgio. *Lectures on Materials Science for Building Conservation*. Los Angeles, CA: The Getty Conservation Institute, 2009. http://www.getty.edu/conservation/publications/pdf_publications/

US Department of Agriculture, Natural Resources Conservation Service, *Web Soil Survey*. http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Date	Topics	Required readings before class	Other preparation before class
13 January Class 1 *Getting underway*	Introductions, course orientation, content Learning methodologies Student work product Performance evaluation Building pathology, survival & loss, Utility & use, Functional performance, Obsolescence & adaptability, Assets & liabilities, Value, Sustainability, Contexts	**Required Readings (* available in Canvas):** Henry. HSPV 551 Course Syllabus* Henry, *GCI Technical Note: Context and Use** Levin, *Preventive Conservation,* in *Conservation Perspectives* 7.1 Spring 1992* **Required Readings (From Texts)** Brand, *How Buildings Learn*, Chapters 1-4, Chapter 10, Appendix. **Optional Resources:** Ching, *Building Construction Illustrated*, 1.07-1.22: The Building Site	**Submit** Self-assessment Current resume **Prepare** • How does Brand's diagram of shearing layers of change inform understanding of buildings? • What are examples of new forces that are changing buildings today? • What does "preventive conservation" mean when applied to immoveable cultural heritage?
20 January Class 2 *Entropy: It's a law & inevitable*	Basic concepts in material longevity: 2nd Law of Thermodynamics Durability & service life Deterioration & loss of performance Damage & failure Intervention & prevention Sustaining building longevity through reinvestment Exercise: Building Reinvestment	**Required Readings (* available in Canvas):** For fun: http://www.youtube.com/watch?v=KTHiIwxcexI Watt, *Building Pathology*, Chapters 1-2* Lstiburek, BSD 144, *Increasing Durability of Building Construction** Henry, *Technical Note: Building Reinvestment Model** CSA S478-95 *Guideline on Durability in Buildings, Appendix D pp65-72** **Optional Resources:** Ching, *Building Construction Illustrated*, A.19-A.25: CSI Masterformat & ASTM Uniformat II	• What costs does the Heritage Building Reinvestment Model not include? • Why does the Reinvestment Model not include these costs? • What are the terms used to define durability in buildings?
27 January Class 3 *Materials:* *A brick is* *A brick is* *A brick…* *Or is it?*	Materials properties Quantitative & qualitative comparisons Archaic materials vs. modern materials Variability Properties of interest Design – Indicators of strengths Durability – Indicators of vulnerabilities Composite materials & assemblies Exercise: Identify materials by properties	**Required Readings (* available in Canvas):** Harris, *Material Profile Charts – Brick, Steel, Wood & Blank** Watt, *Building Pathology*, Chapter 3* Henry, *NCPTT Technical Note: Materials and Older Buildings** Porous Building Materials Handout* **Optional Resources:** Ching, *Building Construction Illustrated*, Chapter 12: Notes on Materials	• How do the units of measure inform our understanding of the property? • Do some material properties have more than one unit of measure? Why? • How do you define material compatibility if selecting a replacement material in historic fabric? • Complete the blank Materials Property Chart by entering the *units of measure* for each of the properties. For which properties were units of measurement difficult to find?

Date	Topics	Required readings before class	Other preparation before class
04 February Class 4 *Thinking in systems*	Thinking in Systems System structures Stacks, flows & dynamic equilibrium Feedback loops, types & effects System response Exercises & Problem Solving 1. Timelines 2. Systems diagrams	**Required Readings (* available in Canvas):** Henry, *Technical Note: Systems Thinking** Keene, S. A systems view of museums. In *Managing Conservation in Museums*. 2nd ed., 2002, pp. 79-96. Meadows, Donella H. *Thinking in Systems, a primer.* (pp. 1-72) **Required Readings On-Line** • Notre Dame Fire: https://www.nytimes.com/interactive/2019/07/16/world/europe/notre-dame.html?searchResultPosition=1 • Champlain Towers South Condominium collapse: https://www.nytimes.com/interactive/2021/09/01/us/miami-building-collapse.html https://www.wsj.com/articles/behind-the-florida-condo-collapse-rampant-corner-cutting-11629816205?page=1	• How does "systems thinking" apply to a diagnostic process for built cultural heritage? • List the subsystems that comprise the Notre Dame fire event. What is the starting point in time for the event? • List the subsystems that comprise the Champlain Towers South collapse event. What is the starting point in time for the event?
10 February Class 5 *Psychrometrics* *Air, moisture & earth: The stuff around the building*	Basics of psychrometrics Climate characterization Soils Composition Classification Behavior Groundwater	**Required Readings (* available on Canvas):** Soils & Water Handout* USGS, *Basic Groundwater Hydrology Water Supply Paper 2220** NCDC Climate Data Handbook* **Required Preparation On-Line:** Psychrometric Chart tutorial – in depth with quiz https://www.uwsp.edu/papersci/Pages/charttut/story_html5.html Download & review climate data for a city you have lived in: http://www1.ncdc.noaa.gov/pub/data/EngineeringWeatherData_CDROM/engwx/ Go to the Web Soil Survey & learn about soil at a site of interest: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm Watch: Water Movement in the Soil https://www.youtube.com/watch?v=ego2FkuQwxc Watch: Capillary rise in soil https://www.youtube.com/watch?v=5waNTa2b-yg	• Do you have a proficient understanding of psychrometrics? • Do you understand the relationship of the properties of moisture vapor? • Do you understand what the NCDC climate data presents? (Read the NCDC Handbook) • Compare climate data for a city you are familiar with to data from an unfamiliar city. • Do you know the properties & behaviors of the different soil types? • What is the fundamental difference between water moving in gravel pipe & water moving through clay?

Date	Topics	Required readings before class	Other preparation before class
17 February Class 6 *Building physics: "Follow the water"*	Building Physics Material structure Moisture & thermal energy transport in materials Thermal response Moisture transport & soluble salts Exercise: Africa House	**Required Readings (* available in Canvas):** Straube*, Moisture, Materials and Buildings** Straube, BSD 138, *Moisture & Materials** CBD 130, *Wetting and Drying of Porous Materials** Building Science Insight 011, "Capillary: Small Sacrifices"* Melloy, *Heat Transfer Handout** *Porous Building Materials Handout** Watt, Chap. 4, p. 114-119*	• Consider water & its molecular structure. How is this tendency manifested in the three regimes of moisture storage outlined by Straube? • Define hysteresis. What causes hysteresis in the movement of moisture in & out of a material? • What are the different transport mechanisms for thermal energy transport?
27 February Class 7 *Deterioration: understanding causality* *Goo & crud: How & why*	Overview of deterioration pathologies Necessary & sufficient factors Types of deterioration Combined or sequential mechanisms Synergies Biological Deterioration Microorganisms, vermin & critters Electrochemical Deterioration Corrosion Alkali deterioration of wood Ozone & ultraviolet light	**Required Readings (* available in Canvas):** Watt, *Building Pathology*, Chapter 4, p. 96-114* Watt, *Building Pathology*, Chapter 4, p. 120-125* Watt, *Building Pathology*, Chapter 4, p. 130-137* Harris, *Building Pathology*, Chapter 2, p. 15-28* Harris, *Building Pathology*, Chapter 3, p.95-130* Meloy, Technical Note: "Biological Mechanism of Deterioration"* Andrady, et. al., "Effects of Increased Solar Ultraviolet Radiation on Materials"* Davis, *Corrosion: Understanding the Basics*, Chapter 2*	• Can we represent a deterioration mechanism, or a necessary & sufficient factor for a deterioration mechanism, with a system diagram? • What are the necessary & sufficient factors for fungal growth to occur? • What are the several types of wood-attacking insects & how do they interact with wood differently? Consider characteristics such as the insect's diet, modes of transportation, etc. • How does the electromotive series influence how galvanic corrosion occurs? • How are ozone degradation & UV degradation related? In what ways are they different?
03 March Class 8 *Cracks & fractures How & why*	Mechanical deterioration Principal stresses Elastic versus plastic deformation Strain hardening, fatigue, creep & cracks Hygrothermal deterioration Linear & volumetric expansion/contraction Freeze-thaw Exercise: Estimating expansion & contraction	**Required Readings (* available in Canvas):** Harris, *Building Pathology*, Chapter 3, p. 58-95* CBD 047, *Extreme Temperatures at the Outer Surfaces of Buildings** CBD 056, *Thermal and Moisture Deformation in Building Materials** Stresses & Constraints Handout*	• Why is constraint/restraint an essential consideration in building assemblies? • What kinds of materials are anisotropic? How can anisotropy affect hygrothermal response? • Consider thermal, moisture, & stress gradients. Why are gradients important to understand & identify?
11 March	Spring Break NO CLASS		• Relax/Learn/Catch-up!

Date	Topics	Required readings before class	Other preparation before class
18 March Class 9 *Structures:* *Loads* *& bones*	Building Structures Strength & stiffness Forces & loads Soils & groundwater Foundations Types of structures Performance deterioration Failures	**Required Readings (* available in Canvas):** Blockley, *Structural Engineering: A Very Short Introduction* CBD 003, *Soil & Buildings** CBD 054, *Horizontal Deflections of Structural Members** CBD 148, *Foundation Movements** Expansive soils https://www.youtube.com/watch?v=SW-NoiM726U&t=23s **Optional Resources:** Ching, *Building Construction Illustrated*, 1.30-1.33; 2.08-3.26; 4.02-4.40; A.06-A.07 Active statics: http://ocw.mit.edu/ans7870/4/4.461/f04/module/Start.html	• What are the components of the three-phase system of soil? What are the important implications of this system with respect to building foundations? • Imagine you are in a historic wood-frame house. According to the L/360 rule for allowable deflection without cracking of finishes, how much is a 15-foot-long wood joist allowed to deflect? • Settlement typically occurs in two phases: immediate settlement & consolidation settlement. What are the differences? How do these two phases affect/cause differential settlement of a structure?
24 March Class 10 *Enclosure:* *external organs*	Building enclosure systems Static elements: roofs & walls Types of wall systems Operable elements Sash, shutters/shades & doors Energy efficiency improvements	**Required Readings (* available in Canvas):** Straube, BSD 018, *Building Enclosures** Straube, BSD 011, *Thermal Control in Buildings** Straube, BSD 030, *Rain Control Theory** Straube, BSD 013, *Rain Control in Buildings** Lstiburek, BSD 106, *Understanding Vapor Barriers** Lstiburek, BSI 117 *Rain Control in Buildings** Leslie, *Insulation with Vision** **Optional Resources:** Ching, *Building Construction Illustrated*, Chapters 5-7 Harris, *Building Pathology*, Chapters 3, 4, 5	• Review the vapor profiles for the several types of wall assemblies laid out in Lstiburek's article. What might complicate these assemblies, i.e. how is the cladding connected to the structure? • Comfort is an extremely important consideration in how buildings function. What are the features of traditional enclosures that can be used to improve comfort?

Date	Topics	Required readings before class	Other preparation before class
31 March Class 11 *Systems: internal organs*	Building systems Comfort, climate & environmental Health & sanitation Fire detection & protection Information: security, data & communications	**Required Readings (* available in Canvas):** Harris, *Building Pathology*, Chapter 6, p. 618-635 NPS, *Preservation Brief 24: Heating, Cooling & Ventilation in Historic Buildings** Straube, BSI-022 *Perfect HVAC** Straube, BSD 109 *Pressure in Buildings** Padfield, *How Air Conditioning Works** **Optional Resources:** Ching, *Building Construction Illustrated*, Chapter 11	• The importance of ventilation is clear with respect to moisture transport in wall assemblies. What are the negatives of having good ventilation? • What features do all utility systems have? Consider how these features could fail & the consequences of these failures, • Human thermal comfort can be affected by both physiological & psychological factors. How must we address this as climate changes?
07 April Class 12 *Diagnostic Thinking*	Diagnostic biases & traps Critical thinking: *Evidence & information gathering, analysis & conclusions* Active listening Seeing is knowing: *How we see, what we don't see & why* Qualitative Assessment: *Describing what we see, sharing what we've seen, terminology & visual glossaries, the repeatability problem*	**Required Readings (* available in Canvas):** Croskerry, P. *The Cognitive Imperative: Thinking About How We Think.* Academic Emergency Medicine 2000/7:11/pp 1223-31 Croskerry, P. *The Theory and Practice of Clinical Decision-Making.* Canadian Journal of Anesthesiology 2005/52:6/pp R1-R8 Croskerry, P. *Context is everything or How could I have been that stupid?* Healthcare Quarterly 2009/v12 special/pp 171-7 Bondreau, Cassell, Fuks. *Preparing Medical Students to become Attentive Listeners.* Medical Teacher 31 (2009) Aper, et al. *The Dilemmas and Challenges that Medical Students Experience When Learning to Conduct Consultations.* Patient Education and Counseling 98 (2015) Ashley-Smith, J. 1999. Definitions of damage. In *Risk Assessment for Object Conservation*. 1st ed., 1999, pp 99-119. Castelhano, Mack, & Henderson. *Viewing task influences eye movement control during active scene perception.* Journal of Vision 2009 9(3):6, pp. 1-15. Williams & Castelhano. *The Changing Landscape – Influences on Eye Movement*. Vision 2019, 3, 33, pp 1-20.	• Are there parallels or similarities between active listening and careful observation? • What are examples of your own failure to see something in plain sight? • How will you apply what you have learned to observation of a building. • How can you make qualitative observations precise?

Date	Topics	Required readings before class	Other preparation before class
14 April Class 13 *Problem solving* *Visualizing Information*	Creative problem solving: *Open ended & closed ended problems, problem definition, creative problem solving* Aids to the diagnostic process: Visualizing information, making connections. Visualizing Information: *Tufte's principles, sketching,* *spatial & temporal coordinates,* *graphs & trendlines, tables and matrices*	**Required Readings (* available in Canvas):** *Thoughts on Problem Solving* http://www.engin.umich.edu/~problemsolving/index.htm (ignore examples that deal with chemical engineering) Creative Problem-Solving model http://members.optusnet.com.au/~charles57/Creative/Brain/cps.htm Tufte. *Visual and Statistical Thinking: Displays of Evidence for Making Decisions* Tufte. Excerpt from *The Visual Display of Quantitative Information* Tufte. *The Visual Display of Quantitative Information, Second Edition* Koch & Denike, *Essential, Illustrative, or . . . Just Propaganda? Rethinking John Snow's Broad Street Map.* Cartographica 45 (1) 19 31 2010	Henry. Lecture Slides Class 6 Question: 1. How do System 1 and System 2 thinking relate (or not relate) to Bloom's Taxonomy and CPS Model of divergent and convergent thinking phases? 1. What are Tufte's Principles? 2. How does visualization of information help in the diagnostic process?
21 April Class 14 Test Closing topics	**Test of Knowledge** Interventions Setting objectives Identifying evaluating & selecting preferred strategies Design for intervention & prevention Longevity & maintainability, reversibility Material & craft availability, costs Implementation Setting & achieving construction quality Follow-through, measuring efficacy	**Prepare for the Test** **Required Readings (* available in Canvas):** Harris, *Building Pathology*, Chapter 1, p. 36-56 Watt, *Building Pathology*, Chapter 5 Brand, *How Buildings Learn*, Chapter 8 & 11-12 NPS Preservation Brief 17: "Architectural Character—Identifying the Visual Aspects of Historic Buildings as an Aid to Preserving Their Character"	• How are the questions & tables that Watt presents helpful? How could they potentially be problematic given that each building is unique? • Harris' general categorization of intervention approaches is helpful; however, the interventions he discusses are really more like individual treatments. • How should character-defining features guide interventions?
29 April	**Upload digital copy of Final Assignment and Self-Evaluation before 12 Noon EDT. No Extensions**		
12 May	**Grades due**		