ARCH 6210 Architectonics
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T/R 3:00 p.m. – 4:30 p.m.
COA 260
School of Architecture
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ARCHITECTONICS

The subject of architectural design and mathematics is one of the most pervading and perplexing topics in architecture discourse. This series of lectures looks at various ways mathematics has been used historically to describe, interpret and evaluate spatial composition and design. The mathematical discourse is drawn from Euclidean geometry, Pythagorean arithmetic, and selected topics in discrete mathematics including group theory, the Polya enumeration theorem, and production systems, in particular, shape grammars.

The class is divided in three parts: The first part lays the foundations for the course with the reworking of the earliest account of design and mathematics in architectural discourse in Vitruvius' De Architectura. The three well-known, and still useful, prerequisites of architectural form, firmness, commodity and delight, are juxtaposed with the six principles of architectural design to provide a theoretical framework for the inquiry of formal (spatial and mathematical) composition. The second part focuses on symmetry and proportion, the most important elements of Vitruvius' theory of design, and traces their intellectual trajectories within the body of architecture discourse starting from Greek architecture to Alberti and to contemporary designs. The third part expands upon the relation of new mathematics to contemporary discourse and especially recursive formalisms for generative design.

This series of lectures take their name Architectonics to relate both to contemporary architectural discourse on the mathematical study of design pursued by the Cambridge school from the 60's onwards (see for example, March, 1974, 1998) and further back to Architectonicks, a term introduced in the seventeenth century by the Cambridge Platonist, Henry More, as a category distinct from Letters and Musick with the sense of the science of architecture.

Prerequisites
There are no prerequisites. Although the course presents a formal and systematic exposition of mathematical principles related to proportion, symmetry and order in architectural design, no mathematical background is assumed on the part of the students.

Pedagogical objectives
Apart from the substantive content, the sequence of lectures serves to introduce the student to scholarly habits of mind and a sense of ongoing research in the field.

Instructional methodology
The class will meet once per week. The theoretical concepts covered in each lecture will be fully covered by visual, and, whenever possible, musical material. The visual material will be based in examples drawn from architecture, painting, and sculpture, as well as in examples from biology, chemistry, physics or other related fields. All musical material presented, including fugues, canons or other compositional techniques found in works of predominately modern twentieth century composers, will be accompanied by scores or other graphical representations.

The course includes ten brief weekly assignments and one final project. The assignments will be presented weekly and they will reflect on the work presented. The final project will be an extension of one of the ideas initially worked in one of the assignments and it will given in the form of a paper.

Completion requirements
Students are expected to attend the lectures, participate in the discussions, read the weekly readings and do two projects. The grade for this course is divided in the following sections: attendance / participation: 20%; two projects: 40% each.

Required readings

Alberti L B, 1988, On the Art of Building in Ten Books, Trs. Rykwert, Leach, Tavernor, MIT Press, Cambridge

Corbusier L, 1954, Le Modulor, Faber and Faber, London

Jones, Marc Wilson, 2009. Principles of Roman Architecture, Yale University Press

March L, Steadman P, 1974, *The Geometry of Environment: An Introduction to Spatial Organization in Design*, M.I.T, Cambridge, MA

Vitruvius, Vitruvius. 1960. The Ten Books on Architecture: Translated by Morris Hicky Morgan, Dover

Wittkower R, 1998 *Architectural Principles in the Age of Humanism*, Academy Editions, London

The bibliography on the architecture of form is vast. Here a very small catalogue stressing the mathematical background is given. Selective readings from architecture theory, music theory and aesthetics relevant to the concepts and ideas of symmetry as discussed in the class will be given during the sequence of the course.

Baglivo J A, Graver J E, 1983, *Incidence and Symmetry in Design and Architecture*, Cambridge University Press, Cambridge

Budden F J, 1972, *The Fascination of Groups*, Cambridge University Press, London

Economou A, 2001, "$C_2C_2C_2$: A Pythagorean structure in design" Proceedings of the 3rd Conference on Design and Mathematics 2001, Deaking University, Australia

Economou A N, 1998b, "The Symmetry of the equal temperament scale" in *Mathematics and Design 98, Proceedings of the Second International Conference*, University of the Basque Country, 557-566

Economou A N, 1999a, "The Symmetry Lessons from Froebel's Building Gifts": *Environment & Planning B, Planning and Design*

Economou A, 1999b, " Counting, Coloring, computing: Lessons from the kindergarten", *ISAMA Proceedings of the International Conference on Architecture, Design and Mathematics,* , University of the Basque Country,

Euclid, 1956, The Elements Books I-XIII, Trs. T Heath, Dover, New York

Fowler D, 1987, The Mathematics of Platoo's Academy, Clarendon Press, Oxford
Gkyka M, 1956, Geomtrical Composition and Design, Alec Tiranti, London
Grónbaum B, Grónbaum Z, Shephard G C, 1986, "Symmetry in Moorish and Other Ornaments", in *Symmetry: Unifying Human Understanding*, ed. Hargittai I, Pergamon, New York, 641-53
Grónbaum B, Shephard G C, 1987, *Tilings and Patterns*, Freeman, San Francisco
Heath T, 1956, History of Greek Mathematics, Dover NY
Hersey G, 1976, Pythagorean Palaces: Magic and Architecture in the Italian Renaissance, Cornel University Press, Ithaca, NY
Huntley, H E, 1970, The Divine Proportion, Dover, New York
Jones O, 1856, 1982, *The Grammar of Ornament*, Van Nostrand Reinhold, New York
Knight T, 1995, "Constructive symmetry", *Environment and Planning B: 22*
Knight T, 1994, *Transformations in Design: A formal approach to stylistic change and innovation in the visual arts,* Cambridge University Press
Lockwood E H, Macmillan R H, 1978, *Geometric Symmetry*, Cambridge University Press
March L, 1998*, The Architectonics of Humanism: Essays on Number in Architecture*, Academy Editions, London
March L, Earl C F, 1979, "Configurational Studies: network Geometry - An Example", *Proceedings: International Conference on the Application of Computers in Architecture, Building Design and Urban Planning*, Berlin, 354-363
March L, Steadman P, 1979, "From Descriptive Geometry to Configurational Engineering*", Proceedings: International Conference On Descriptive Geometry, Vancouver*, B.C, 21-24
March L, Stiny G, 1985, "Spatial systems in architecture and design: some history and logic", *Environment and Planning B: Planning and Design* **12**, 31 - 53
Mitchell W J, 1990*, The Logic of Architecture: Design, Computation, and Cognition*, MIT Press, Cambridge, Massachusetts
Nichomachus, 1938, Introduction to Arithmetic, Transl. M L Ooge, Unoversity of Michigan Press, Ann Arbor
Park J H, 2000, *"Subsymmetry analysis of architectural designs: some examples*", Environment and Planning B: Planning and Design, volume 27, 121-136
Park J H, 1997, "Schindler, Symmetry and the Free Public Library", *ARQ*, Vol 2, 72-83
Palladio A, 1965, The Four Books of Architecture, Trs. I Ware, Dover, New York
Pearce P, 1978, *Structure in Nature is a Strategy for Design*, MIT Press, Cambridge, MA
Plato, 1983, Timeaus, Trs. D Lee, Penguin Books, London
Polya G, Tarzan R, Woods D, 1983, *Notes on Introductory Combinatorics*, Birkhεuser
Schattschneider D, 1990, *M.C Escher, Visions of Symmetry*, Freeman, NY
Schattschneider D, 1986, "In Black and White: How to Create Perfectly Colored Symmetric Patterns", in *Symmetry: Unifying Human Understanding*, ed. Hargittai I, Pergamon, New York, 673-95
Schattschneider D, 1978, "The Plane Symmetry Groups: Their recognition and their notation*", American Mathematical Monthly* **85** (6): 439-50
Schillinger J, 1976, *The Mathematical Basis of the Arts,* Da Capo Press, New York
Schofield P H, 1958, The Theory of Proportion in Architecture, Cambridge University Press
Senechal M, 1979, Color Groups, *Discrete Applied Mathematics*, **1**: 51-73
Senechal M, 1983, Coloring Symmetrical Objects Symmetrically, *Mathematics Magazine*, 56: 3-16
Senechal M, Fleck G, 1977, *Patterns of Symmetry*, Amherst, University of Massachusetts
Shubnikov A V, Belov N V, 1964, *Colored Symmetry*, Pergamon, New York

Shubnikov A V, Koptsik V A, 1974, *Symmetry in Science and Art*, Phenum, New York
Stevens P S, 1980, *Handbook of Regular Patterns: An Introduction to Symmetry in Two Dimensions*, MIT Press, Massachusetts
Stiny G, 1976, "Two exercises in formal composition", *Environment and Planning B 3 187 – 210*
Taylor T, 1991, *The Theoretical Arithmetic of the Pythagoreans*, Samuel Weiser: York Beach, Maine
Theon of Smyrna, 1979, *Mathematics Useful for Understanding Plato*, Trans. R and D Lawlor, San Diego, CA
Tyng A G, 1969, “Geometric Extension of Consciousness”, *Zodiac*, 19, 130-162
Thomson D W, 1917, 1992, *On Growth and Form*, Cambridge University Press
Vitruvius, 1960,*The Ten Books on Architecture*, Dover, New York
Washburn D, Crowe D, 1988, *Symmetries of Culture: Theory and Practice of Plane Pattern Analysis*, University of Washington Press, Seattle and London
Weyl H, 1952, *Symmetry*, Princeton University Press, Princeton
Wieting T W, 1982*, The Mathematical Theory of Chromatic Plane Ornaments*, Marcel Dekker, New York
Williams R, *1972, Natural Structure, Towards a Form - Language,* Dover
Yale P, 1968, *Geometry and Symmetry*, Dover, New York