This is the Aerospace Engineering and Mechanics to Comparative Literature program and course sections of the 1996-1999 University of Minnesota Graduate School Catalog
For an explanation of the numbering system, punctuation, department prefixes, and symbols used throughout the course descriptions in this section, see the last page of this bulletin.

**Aerospace Engineering and Mechanics (AEM)**

*Regents’ Professor:* Daniel D. Joseph; James B. Serrin (*emeritus; mechanics)*

*Professor:* William L. Garrard, head; Theodore A. Wilson, associate head; Roger E. A. Arndt (aerospace engineering); Gordon S. Beavers; Roger L. Fosdick; Chih-Chun Hsiao (*emeritus*); Richard D. James; Thomas S. Lundgren; Mitchell B. Luskin (mechanics); Tayfun E. Tezduyar; Andrew Vano; William H. Warner (*emeritus*)

*Associate Professor:* Ellen K. Longmire, director of graduate studies; Amy E. Alving; Gary J. Balas; Graham V. Candler; Perry H. Leo; Thomas W. Shield; Lev Truskovsky; Yiyuan Zhao

*Adjunct Associate Professor:* Dale F. Enns

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

**Degrees Offered**—Aerospace Engineering: M.S.Aero.E. (Plan A and Plan B), M.Aero.E. (Coursework Only and Design Project), and Ph.D.; Mechanics: M.S. (Plan A and Plan B) and Ph.D.

**Curriculum**—The department offers graduate study in two major fields, mechanics and aerospace engineering. The graduate programs emphasize engineering sciences that are basic to these fields: fluid mechanics, dynamical systems and controls, and continuum and solid mechanics. Theoretical, analytical, experimental, and computational aspects of these fields are covered by the courses and research opportunities offered by the department.

**Prerequisites for Admission**—A four-year B.S. degree in an engineering, basic science, or mathematics program is required. Admission depends primarily on the applicant’s undergraduate record and letters of recommendation.

**Special Application Requirements**—Graduate Record Examination scores are not required but are strongly recommended for students applying for graduate fellowships. In all cases, these test scores are taken into account if they are provided.

Students are admitted fall quarter only. Only under unusual circumstances are students allowed to begin their studies at another time during the academic year.

**Master of Science Degree Requirements**—For the M.S. degrees, see the General Information section of this bulletin. At least one sequence of 8xxx courses is required.

**Master of Aerospace Engineering Degree Requirements**—See Professional Master’s Degree in Engineering in the General Information section of this bulletin.

**Doctoral Degree Requirements**—The Ph.D. program in the two major fields, mechanics and aerospace engineering, requires about two years of coursework, but the heart of the Ph.D. program is the thesis research. A Ph.D. program must contain a minimum of 64 credits of approved courses and six quarters of colloquium attendance. The first year of the Ph.D. program is similar to the master’s program and most Ph.D. students receive the master’s degree. By the end of the first year, the student has chosen an adviser. The second year is devoted to more advanced courses and beginning research. Subsequent years include some coursework with increased focus on research. The time required to complete a research project varies, but most students finish the Ph.D. about four years after their bachelor’s degree.

**Language Requirements**—None, for either major. Some doctoral candidates, however, may find that reading proficiency in one or more languages is essential.

**For Further Information and Applications**—Contact the Chair, Graduate Admissions Committee, Department of Aerospace Engineering and Mechanics, University of Minnesota, 107 Akerman Hall, 110 Union Street S.E., Minneapolis, MN 55455 (612/625-8000; fax 612/626-1558; e-mail dept@aem.umn.edu; http://www.aem.umn.edu).

*Note*—The courses listed below are appropriate for majors in both aerospace engineering and mechanics.
AEM 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

AEM 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

AEM 8888. Thesis Credits: Doctoral. (36 cr required)

AEM 5200. Kinematics and Dynamics of Fluid Flow. (4 cr; prereq IT or grad student, 3036, Math 3331 or Math 3252) Longmire
Stress and strain rate descriptions, fluid statics, use of differential and finite control volume analysis with continuity, momentum, energy equations, Bernoulli and Euler equations, introduction to Navier-Stokes equations, vorticity, potential flow.

AEM 5202. Viscous Flow. (4 cr; prereq 5200, IT or grad student) Aiving, Beavers, Wilson
Incompressible viscous flow using Navier-Stokes equations. Dimensional analysis; one-dimensional exact solutions; pipe flow; laminar and turbulent boundary layers, wakes, and jets; momentum integral; pressure gradients and separation; introduction to turbulence; Reynolds stresses.

AEM 5204. Shock Waves and Compressible Fluid Flow. (4 cr; prereq 5200, IT or grad student) Beavers

AEM 5205. Aerospace Propulsion. (4 cr; prereq 5204, ME 3301, upper div IT student) Beavers
Fundamentals; performance parameters; thermodynamic cycles; performance analysis of flight propulsion systems: turbojets, turbofans, ramjets, rockets, propellers.

AEM 5206. Aerodynamics of Lifting Surfaces. (4 cr; prereq 5200, CSci 3101 or CSci 3104) Candler
Pressure distributions, forces, and moments on airfoils and wings of finite span. Analysis of potential flow by thin airfoil theory, lifting line theory, and panel methods. Viscous effects and their relation to design variables.

AEM 5240. Rarefied Gas Dynamics. (4 cr; prereq IT or grad student, 5204 or A) Longmire
Relationship between continuum and molecular models for gas flow. Free molecule flows. Lift, drag, and energy transfer in free molecule flows. Slip flow and temperature jump.

AEM 5243. Advanced Aerodynamics. (4 cr; prereq IT or grad student, 5206)
Interaction between pressure distribution and boundary-layer growth on airfoils of arbitrary shape. Inviscid flow past non-planar wings of specified planform.

AEM 5244. Hypersonic Aerodynamics. (4 cr; prereq IT or grad student, 5204) Candler

AEM 5250. Computational Fluid Mechanics. (4 cr; prereq IT or grad student, FORTRAN, 5200 or A) Tezduyar
Finite element method; fundamentals of spatial discretization and numerical time-integration. Introduction to engineering and scientific computing environment and large-scale computing.

AEM 5300. Flight Mechanics. (4 cr; prereq 3005 or 5206, IT or grad student) Enns, Garrard
Standard atmosphere, analysis of power required, the classical performance data, maximum and minimum speed, maximum rate of climb, angle of climb and glide, absolute ceiling, service ceiling of propeller and jet-propelled aircraft. Static longitudinal stability, wing contribution, tail contribution, fuselage contribution and the neutral point. Power effect and longitudinal control. Formal aerospace vehicle design and wind tunnel projects.

AEM 5319. Dynamics and Control of Aerospace Vehicles. (4 cr; prereq 3401, 5300 or #, IT or grad student) Enns, Garrard
Reference frames, kinematics, and equations of motion. Forces and moments, trim, linearization, and dynamic response characteristics for aircraft and spacecraft. Handling qualities. Aircraft stability derivatives, phugoid, short period, spiral, roll subsidence, dutch roll modes, approximations, and transfer functions.

AEM 5321. Automatic Control. (4 cr; prereq 3401 or equiv) Balas, Garrard
Basic theory of linear, single-input, single-output feedback control systems. Analysis and design using root locus, Nyquist Bode techniques. Introduction to state-space formulation. Applications to automatic flight control and mechanical systems.

AEM 5329. Fundamentals of Aerospace Vehicle Design. (4 cr; prereq 5300 or #, AEM sr) Vano
Design process and requirements, mission analysis, tradeoffs, vehicle component sizing, weight estimates, performance, propulsion systems, weight and balance, stability and control, cost, ground and flight testing, compliance and certification. Students prepare conceptual design of aerospace vehicle and written and oral reports.

AEM 5330, 5331. Design of Aerospace Elements and Systems. (4 cr per qtr; prereq sr aerospace major or A) Vano
Group and individual design projects.

AEM 5359. Deceleration of Aerospace Craft. (4 cr; prereq 3036, 5200, IT student) Garrard
Parachutes and other aerodynamic decelerators. Types, characteristics and applications, drag coefficients and steady descent, stability, deployment and opening forces, apparent mass effects, trajectory analysis, stress analysis, engineering properties of textile materials. Individual design projects.

AEM 5370. Aerodynamics of V/STOL Flight. (4 cr; prereq 5206) Zhao
Aerodynamic characteristics of the classical rotor. Combinations of rotor-wing and direct thrust-wing configurations are analyzed for high speed V/STOL aircraft. Jet flap, boundary layer control, and ground effect machines.
AEM 5410. Introduction to Astrodynamics. (4 cr; prereq 3036)

AEM 5438. Intermediate Dynamics. (4 cr; prereq 3036) Enns, Garrard
Three-dimensional Newtonian mechanics, kinematics of rigid bodies, dynamics of rigid bodies, analytical mechanics, generalized coordinates, holonomic constraints, Lagrange equations and applications, multidegree-of-freedom dynamical systems.

AEM 5440. Dynamics of Systems and Structures. (4 cr; prereq 5438, IT or grad student) Balas
Application of Lagrangian methods to multidegree-of-freedom systems; vibrations of strings, rods, shafts, and beams; frequency and time domain analysis of multidegree-of-freedom mechanical systems; finite elements in structural dynamics.

AEM 5515. Aerospace Structures I. (4 cr; prereq 3016, IT student) Leo, Shield

AEM 5516. Aerospace Structures II. (4 cr; prereq IT student, 5515 or Δ) Shield
Use of prepared computer programs for microcomputers and mainframe computers to solve moderately sized problems of analysis and design of trusses, plane frames, torsion, plane stress, and combination structures; elastic and inelastic analysis; use of symmetry and superposition to extend power of prepared programs; basis of finite element methods used.

AEM 5518. Mechanics of Composite Materials. (4 cr; prereq 3016) Leo
Analysis, design, and applications of laminated and chopped fiber-reinforced composites. Micro- and macro-mechanical analysis of elastic constants, failure and environmental degradation.

AEM 5580. Mechanics of Solids. (4 cr; prereq Math 3251, IT or grad student) Fosdick, James, Truskinovsky
Nonlinear continuum mechanics and thermodynamics in one dimension. Kinematics; mass, momentum, energy, and entropy; balance equations and jump conditions. Linear and nonlinear elastic constitutive equations. Applications drawn from wave propagation, stability, fracture mechanics, plasticity and viscoelasticity.

AEM 5581. Thermodynamics of Solids. (4 cr; prereq Math 3251, IT or grad student) Truskinovsky
Energy, power, heating, entropy, and stability; their use in formulating nonlinear constitutive equations and designing experiments. Analysis of shear-induced phase transitions and other instabilities. Topics may include shock waves, solid state engines, and other devices.

AEM 5630. Aeromechanics Laboratory I: Fluid Mechanics. (4 cr; prereq 3016, 3036, 5200, upper div IT student) Alving, Longmire
Experimental methods and design in fluid mechanics. Wind tunnel and water channel experiments involving flow visualization, pressure, velocity, and force measurement techniques. Computerized data acquisition dimensional analysis, error analysis, and data reduction methods. Oral and written reports.

AEM 5631. Aeromechanics Laboratory II: Solids and Structures. (4 cr; prereq 3018, 3036, 5200, upper div IT student) James, Leo, Shield
Experimental determination of stresses, strains, and displacements that occur in solids and structures. Error analysis, computerized data acquisition and analysis, strain gauges, photo-elasticity, material behavior, stress concentrations, and composite materials. Written reports.

AEM 5632. Aeromechanics Laboratory III: Dynamics and Control. (4 cr; prereq 3016, 3036, 5200, upper div IT student) Balas, Garrard
Experimental determination of dynamic response of systems and design and implementation of feedback controllers. Actuators and sensors for dynamic systems, digital signal processing, fast Fourier transforms. Written and oral reports.

AEM 5650. Aeroelasticity I. (4 cr; prereq 5206)
Static aeroelastic phenomena, torsional divergence of a lifting surface, control surfaces reversal and elastic efficiency. Effects of elastic deformations on stability, aeroelastic twisting of propeller blades and rotary wings, theory of lifting surface flutter, problems of gust response and buffeting, scaling of aeroelastic force models.

AEM 5687. Introduction to Acoustics and Environmental Noise. (4 cr; prereq Math 3261, Phys 1253, IT or grad student) Wilson
Derivation of the wave equation, plane wave solution, transmission and reflection at boundaries, resonators and mufflers, three-dimensional wave propagation, properties of environmental noise sources, hearing and perception of sound, acoustical properties of rooms, lab experience in sound and noise measurements, noise control techniques.

AEM 5800, 5801, 5802. Problems in Mechanics and Materials. (1-4 cr per qtr; prereq Δ)
Topics of current interest. Individual projects.

AEM 5810, 5811, 5812. Problems in Fluid Mechanics. (1-4 cr per qtr; prereq Δ)
Topics of current interest. Individual projects.

AEM 8001, 8002, 8003. Seminar: Aerospace Engineering and Mechanics. (1 cr per qtr; prereq consent of director of graduate studies; S-N only)
Short project based on colloquium series required for credit.
AEM 8201-8202-8203. Fluid Mechanics I-III.
(4 cr per qtr; prereq undergrad fluid mechanics and vector analysis; 8203 offered alt yrs) Alving, Lundgren

AEM 8209. Rotating Fluids. (3 cr; prereq background in fluid mechanics especially boundary layer theory; offered when feasible) Lundgren

AEM 8216-8217. Theory of Turbulence I-II.
(3 cr per qtr; prereq 8202; offered alt yrs) Lundgren
8216: Analysis of turbulent flows. Reynolds equations, mixing length theory, classical boundary layer, pipe and wake flows, more general models. 8217: Theories of homogeneous turbulence.

AEM 8219. Computers in the Laboratory. (4 cr; offered alt yrs) Longmire
Overview of computer organization, including external communications and A/D, D/A conversion. Measurement techniques, such as pressure measurements, hot-wire and laser Doppler anemometry. Signal processing and uncertainty, computer control of experiments.

AEM 8220. Rheological Fluid Mechanics I.
(3 cr; prereq 8201 or 8510 or #; offered alt yrs) Joseph
Methods of solution for flows of simple fluids with general constitutive equations. Topics from viscometric flow, extensional flow, perturbations of the rest state with steady and unsteady flow, secondary flow.

AEM 8221. Rheological Fluid Mechanics II.
(3 cr; prereq 8220 or #; offered alt yrs) Joseph
Structure theories of constitutive relations. Suspension rheology. Anisotropic fluids.

AEM 8232. Physical Gas Dynamics.
(3 cr; prereq undergrad fluid mechanics, compressible flow, thermodynamics) Longmire

(3 cr; prereq 8202 or #; offered alt yrs) Joseph, Lundgren
Method of matched asymptotic expansions presented through simple examples and applied to viscous flows at high and low Reynolds numbers, lifting wings, hypersonic flow, acoustics, and other problems in fluid mechanics.

AEM 8250. Computational Aerodynamics.
(4 cr; prereq FORTRAN)
Navier-Stokes equations and different levels of approximations. Finite difference approximations; accuracy, consistency, conservation form, and stability. Solution of Burger’s equation; project: shock generation. Solution of Euler’s equations; project: flow inside shock tube. Subsonic potential flow and transonic flow around airfoil. Multigrid techniques and grid generation.

(4 cr; prereq grad-level numerical analysis course or #)

(3 cr; prereq 8201 or 8510 or #; offered alt yrs) Lundgren
Theory of kinematic, hyperbolic, and dispersive waves, with application to traffic flow, gas dynamics, elastodynamics, and water waves.

AEM 8410. Advanced Dynamics.
(4 cr; prereq 5438 or #)
Lagrange’s equations; ignorable coordinates and momentum integrals; Routh’s procedure; impulse motion; constraints and Lagrange multipliers; calculus of variations and Hamilton’s principle of stationary action; linearization; classical vibration theory; gyroscopic, circulatory, and non-stationary linear systems.

AEM 8411. Linear Systems.
(4 cr; prereq 5438, # or 8410)
Linearization of equations of motion; Jordan form; singular value decomposition; numerical methods; solution procedures; matrix methods; qualitative properties; stability; observability and controllability; frequency domain methods.

AEM 8412. Nonlinear Systems.
(4 cr; prereq 8411 or #)

(3 cr; prereq 8411, 8412 or #)
Dynamical systems with emphasis on higher dimensional (more than three) systems and global and chaotic phenomena. Bifurcation analysis with codimension greater than one, Melnikov method, and Silnikov phenomena. Concepts of symmetry. Application to problems modeled by partial differential equations.

AEM 8420. Trajectory Optimization Techniques.
(4 cr; prereq 5321 or #) Zhao
AEM 8421. Modern Control Theory for Aerospace Systems. (4 cr; prereq 5321, 8410 or #) Balas, Zhao
State space theory for multiple-input-multiple-output (MIMO) aerospace systems. Singular value decomposition (SVD) technique and its applications to performance and robustness. Linear quadratic gaussian (LQG) and eigenstructure assignment design methodologies. Topics in $H_\infty$. Examples of aerospace systems and synthesis.

AEM 8422. Robust Multivariable Control Design. (3 cr; prereq 8410, 8421 or similar courses in mech eng or elec eng) Balas
Emphasizes application to aerospace systems. Role of model uncertainty/modeling errors in design process. Control analysis and synthesis, including $H_\infty$ optimal control design and structural singular value ($\sigma$).

AEM 8425. Advanced Topics in Aerospace Guidance and Control. (3 cr [may be repeated for cr]; prereq 8410, 8421 or #; offered when feasible)

AEM 8501, 8502, 8503. Research Seminar in the Mechanics of Materials. (2-4 cr) Fosdick, James, Leo
Truskinovsky
Developing research programs from the macroscopic point of view. Topics drawn from current research and student interests.

AEM 8510. Continuum Mechanics I. (4 cr; prereq $\Delta$) Fosdick

AEM 8511, 8512. Continuum Mechanics II, III. (4 cr per qtr; prereq 8510 or #; 8512 offered alt yrs) Fosdick, James

AEM 8522. Theory of Plasticity. (4 cr; prereq 5580 or 8510 or #; offered alt yrs) Shield

AEM 8540. Theory of Viscoelasticity. (4 cr; prereq 5580 or 8510 or #; offered alt yrs) Fosdick, James

AEM 8570. Fracture Mechanics. (4 cr; prereq $\Delta$; offered alt yrs) Truskinovsky
Theories of mechanical breakdown. Kinetic rate theories and instability considerations. Formation of equilbrium cracks and circular crack propagation under pulses. Statistical aspects of strength and fracture of micromolecular systems. Time and temperature dependency in fracture problems and instability of compressed material systems.

AEM 8585. Advanced Topics in Continuum Mechanics. (3 cr; prereq 8510, 8511, 8512 or #) Fosdick, James
Finite elasticity theory; theoretical study of exact solutions and experimental significance of selected problems, inequalities and work theorems, plane problems, iterative solutions and second-order effects, small deformations superposed on large, and relationship to stability. Singular surfaces and waves. Viscometric flows of non-Newtonian fluids; viscometric functions. Solution of special problems that illustrate the normal stress effect. Selected experimental results. Possible additional topics: Cosserat materials, multipolar continuum mechanics, modern theories of plasticity, mixtures, hypoelasticity, elastic dielectric and electrified materials.

AEM 8589. Mechanics of Crystalline Solids. (4 cr; prereq 8510 or #) James
Molecular theory of crystals and origins of stress in crystals. Relation between atomic and macroscopic motion and constitutive equations for crystals; phase transformations and analysis of microstructure; effects of shear stress, pressure, temperature, electromagnetic fields, and composition on transformation temperatures and microstructure; surface energy in solids.

AEM 8594. Elastostatics I. (4 cr; prereq 5580 or 8510 or #, 8511 recommended; offered alt yrs) Fosdick, James, Leo
Principles and field equations of elasticity. Fundamental boundary value problems. Topics selected from energy theorems, St. Venant beam theory, plane problems, three-dimensional stress function methods, fundamental solutions.

AEM 8595. Elastostatics II. (3 cr; prereq 8594; offered alt yrs) Fosdick, James, Leo
(Continuation of 8594) Contact stress; finite deformations; other special topics.

AEM 8596. Elastodynamics. (4 cr; prereq 5580 or 8510 or #; offered alt yrs) Fosdick, James
AEM 8601. Finite Element Methods in Computational Mechanics. (4 cr; prereq IT grad student or ∆) Tezduyar
Fundamental concepts and techniques of finite element analysis. Variational equations and Galerkin’s method; weak formulations for problems with nonsymmetric differential operators; Petrov-Galerkin methods; examples from solid and fluid mechanics; properties of standard finite element families, implementation.

AEM 8602. Finite Element Methods in Computational Fluid Dynamics. (4 cr; prereq 8601) Tezduyar

AEM 8800, 8801, 8802. Selected Topics in Mechanics and Materials. (1-4 cr per qtr; prereq ∆) Fosdick, James, Leo, Shield, Truskinovsky
Topics of current interest. Individual student projects completed under guidance of faculty sponsor.

AEM 8810, 8811, 8812. Selected Topics in Fluid Mechanics. (1-4 cr per qtr; prereq ∆) Alving, Beavers, Candler, Joseph, Longmire, Lundgren, Tezduyar, Wilson
Topics of current interest. Individual student projects completed under guidance of faculty sponsor.

AEM 8820, 8821, 8822. Selected Topics in Dynamical Systems and Controls. (1-4 cr per qtr; prereq ∆) Balas, Enns, Garrard, Zhao
Topics of current interest. Individual student projects completed under guidance of faculty sponsor.

AEM 8880. Plan B Project. (1-4 cr [max 4 cr]; prereq grad major in aerospace engineering or mechanics, ∆)
Satisfies project requirement for Plan B master’s degree. May appear on M.S. program but does not count toward 20-credit minimum in the major field. Topic arranged by student and adviser; written report required.

Agricultural and Applied Economics (ApEc)

Professor: James P. Houck, head; Robert P. King, director of graduate studies; Jeffrey D. Apland; Dale C. Dahl; Reynold P. Dahl (emeritus); K. William Easter; Vernon R. Eidman; Earl I. Fuller (emeritus); William C. Gartner; Hans M. Gregersen; Jerome W. Hammond; Beth W. Honadle; Jean D. Kinsey; Richard A. Levins; Wilbur R. Maki (emeritus); Michael V. Martin; George W. Morse; Claudia A. Parliament; Glenn D. Pederson; Willis L. Peterson; Philip M. Raup (emeritus); Terry L. Roe; C. Ford Runge; G. E. Schuh; Benjamin H. Senauer; Wesley B. Sundquist (emeritus); Delane E. Welsch

Associate Professor: Sandra O. Archibald; Buddy G. Crewdson; Jeremiah E. Fruin; William F. Lazarus; Kent D. Olson; Philip G. Pardey; Stanley C. Stevens; Steven J. Taff; Yacov Tsur
Assistant Professor: Brian L. Buhr; Jay S. Coggins; Frances R. Homans; Donald J. Liu; Rodney B. Smith; Thomas Stinson

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B) and Ph.D.

Curriculum—Graduate study requires an operational knowledge of economic theory and modern methods of quantitative analysis as well as practical application in specialized fields of inquiry, including agricultural policy, consumption economics, development economics and trade, natural resource and environmental economics, prices and marketing, production economics, and regional economics and public services.

Prerequisites for Admission—A grade point average of 3.00 for the undergraduate program and for graduate-level work is the minimum standard for admission. Applicants with at most a bachelor’s degree are, except in a few special cases, considered only for admission to the M.S. program. The following coursework is considered the minimum preparation for admission to the M.S. program: intermediate-level micro and macroeconomic theory, elementary statistics, calculus, and linear algebra. Applicants to the Ph.D. program should also have completed courses in micro and macroeconomic theory at the master’s level. Students lacking background in economics or quantitative methods may be required to complete deficiencies before being accepted into the program.

Special Application Requirements—Graduate Record Examination scores are required for all students. A minimum TOEFL score of 550 is required for applicants whose native language is not English, including those with other academic study in the United States. Applicants should provide evidence of superior scholarship, professional experience, and general aptitude for graduate study. Students are admitted any quarter but should keep in mind that most assistantships are allocated by the end of February for the following fall quarter.
Applicants seeking fellowships should submit all application materials by December 15.

**Master’s Degree Requirements**—All M.S. students are required to complete graduate-level courses in micro- and macro-economic theory and statistics, or to have completed equivalent courses. Under Plan A, the thesis counts for 16 of 44 credits. Under Plan B, the project counts for 6 to 9 of 44 credits.

A minimum GPA of 3.00 in the graduate program is required for graduation. A final oral examination is required.

**Doctoral Degree Requirements**—Students follow a study program in the major that includes micro and macroeconomic theory, quantitative techniques, and three fields of specialization selected from those listed under Curriculum above. One of these fields can be replaced by a minor in another graduate program, such as economics, public health, or statistics, or sustainable agriculture systems (a free-standing graduate minor).

Preliminary written examinations cover economic theory and fields in agricultural and applied economics. Oral examinations are required for approval of the dissertation proposal and for its defense.

**Language Requirement**—None.

**Minor Requirements for Students Majoring in Other Fields**—Master’s students must take Econ 5151 and Econ 5152 (or approved substitute), plus three applied economics courses at the 5xxx or 8xxx level, for a total of 15 credits. Students must also take two graduate-level quantitative courses. Specific courses are approved by the director of graduate studies in the Department of Applied Economics. All courses must be taken for a letter grade (A-F) and completed with a GPA of 3.00 or better.

Doctoral students must complete 20 credits of coursework in economics or applied economics at the 5xxx or 8xxx level with a minimum of 12 credits in applied economics. Courses for the minor are approved by the director of graduate studies in the Department of Applied Economics. All courses must be taken for a letter grade (A-F) and completed with a GPA of 3.00 or better.

**For Further Information and Applications**—Contact the Department of Applied Economics, University of Minnesota, 231 Classroom Office Building, 1994 Buford Avenue, St. Paul, MN 55108 (612/625-2758; e-mail dgs@dept.agecon.umn.edu).

**ApEc 8666. Doctoral Pre-Thesis Credits**. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

**ApEc 8777. Thesis Credits: Master’s**. (16 cr required; Plan A only)

**ApEc 8888. Thesis Credits: Doctoral**. (36 cr required)

**ApEc 5020. Applied Linear Programming**. (4 cr; prereq 3002 or Econ 3101 or #) Apland Application of linear programming to economic problems of the firm. Resource allocation, product mix, investment and distribution decisions in context of cost minimization and profit maximization.

**ApEc 5030. Methods of Economic Data Analysis**. (4 cr; prereq Stat 5021 or equiv; familiarity with matrix algebra recommended) Emphasizes practical aspects. Econometric methods and models commonly used in applied economics; economic and statistical theory underlying these methods. Primarily for M.S. students.

**ApEc 5400. Intermediate Market and Price Analysis**. (4 cr; prereq 3003 or Econ 3101 or #) Hammond Development of analytical models and their application in various market situations. Unique market institutions developed in response to marketing problems and policies.

**ApEc 5440. Cooperatives and Agribusiness Organization**. (4 cr; prereq 3002 or Econ 3101 or #) Parliament Economic problems and issues facing agricultural cooperatives, including changing market organization, financing, taxation, antitrust regulations, and others.

**ApEc 5480. Futures Markets and Prices**. (4 cr; prereq 3002 or Econ 3101 or #) Liu Economics of futures trading; basis and theoretical price relationships in storable and nonstorable commodities; hedging and commercial use of futures markets, with illustrations; arbitrage; options on agricultural futures; financial futures; speculation; futures market performances and regulation.

**ApEc 5500. Financial Markets and Agricultural Credit Institutions**. (4 cr; prereq 3500 or BFin 3000 or grad student or #) Pederson Analysis of financial institutions and financial markets. Managerial policy issues confronting managers of financial intermediaries with particular reference to those operating in an agricultural setting. Current problems confronting financial intermediaries.

**ApEc 5550. Food Marketing Economics**. (4 cr; prereq 3001 or Econ 3101 or #) Senauer Economics of food marketing in the United States. Food consumption trends; consumer food behavior; food expenditure and consumption data; consumer survey methodology; food distribution and retailing system; food policy issues related to food marketing. Individual and group projects required.
ApEc 5580. Household Economics: Time, Labor, and Human Capital Around the Globe. (3 cr; prereq 3002 or Econ 3101 or #) Kinsey
Investment in household formation, children, education, health, labor force participation, and non-market work analyzed in context of household economics and national productivity. Effects of economic variables on investment decisions and returns.

ApEc 5600. Land and Water Economics. (3 cr; prereq 3002 or Econ 3101 or #) Taff
Land and water as public resources and as factors of production; economic analysis of policies that influence asset use; sale and rental markets; valuation of rights to land and water; taxation and regulation as instruments for influencing private management decisions; comparative land and water legal and market settings.

ApEc 5620. Regional Economic Analysis. (3 cr; prereq 3006 or Econ 3102 or #) Morse
Analysis of regional economies; alternative theories of firm location (neo-classical, profit cycle, competitive advantage, cumulative causation); labor markets and migration; alternative development approaches and public incentives; emphasis on medium-sized metro areas, rural areas, and value-added industries.

ApEc 5630. Regional Development Systems. (3 cr; prereq 3006 or Econ 3102 or #) Morse
Regional systems analysis (economic base, input-output, and computable general equilibrium); application of impact models to development problems; theoretical foundations of models; basic skills in developing and interpreting regional input-output analyses with real-world data and problems.

ApEc 5637. Law and Agricultural Policy. (3 cr; prereq ApEc grad student) Chen
Economic regulation of agriculture. Industrial organization and market structure in agribusiness, public lands and water law, agricultural cooperatives, farm labor, farm finance, crop insurance and disaster assistance, agricultural biotechnology, food and drug law, price and income regulation, and international agricultural markets.

ApEc 5640. Financing State and Local Governments. (4 cr; prereq 3002 or Econ 3101 or #) Honadle
Problems and issues in financing state and local public services in the United States, state and local revenue systems, debt and expenditures. Intergovernmental fiscal relations. Budget analysis.

ApEc 5650. Economics of Natural Resource and Environmental Policy. (4 cr; prereq 3002 or 3610 or Econ 3101 or #) Easter
Application of economic analysis, including project evaluation, to current natural resource and environmental issues. Emphasis on conservation and resource scarcity, environmental quality, and resource use issues and their implications for public policy.

ApEc 5660. Economics of Public Services. (3 cr; prereq 3002 or Econ 3101 or #) Honadle
Issues of finance and supply and demand for public services; pricing, producing, and financing public goods; bureaucratic decision making; implementing policies.

ApEc 5710. U.S. Agriculture: Farm, Food, and Environmental Policy. (3 cr; prereq ApEc 3002 or Econ 3101, ApEc 3006 or Econ 3102, ApEc 3007 or Econ 3102 or #) Runge
Development of U.S. agriculture and U.S. agricultural and trade policy; agricultural input and commodity markets; design and economic effects of U.S. agricultural policy; determinants of U.S. agricultural and trade policies.

ApEc 5720. Economics of World Agriculture. (3 cr; prereq ApEc 3002 or Econ 3101, ApEc 3006 or Econ 3102 or #) Ruttan
Theories of agricultural development, comparative agricultural organization and structure, technical and institutional change in agricultural development, national development policies, bilateral and multilateral assistance, international policy conflicts.

ApEc 5750. Agricultural Trade and Commercial Policies. (3 cr; prereq 3002 or Econ 3101 or #) Houck
Trade policies and practices of export and import nations; commodity agreements; agricultural trade policies of common market areas; negotiations and potential trade developments.

ApEc 5770. World Food Problems. (3 cr, §Agro 5200, §CAPS 5280, §FScN 5643; prereq sr or grad student) Peterson
A multidisciplinary examination of social, economic, and technical problems of feeding the world’s growing population. Principles sought from economic, plant, animal, and food sciences for their application to food problems.

ApEc 5860. Economics of Agricultural Production. (3 cr; prereq 3002 or Econ 3101 or #) Coggins
Production economics applied to agriculture, profitable combination of production factors; comparative advantage and location of production.

ApEc 5890. Independent Study: Advanced Topics in Farm Management. (1-6 cr; prereq #) Eidman, Olson
Special topics or individual work arranged on subjects suited to needs of particular groups of students.

ApEc 5990. Special Topics and Independent Study in Applied Economics. (Cr ar; prereq #)
Special classes, independent study; and supervised reading and research on subjects and problems not covered in regularly offered courses.

ApEc 8100. Graduate Seminar. (2 cr; prereq 2 qtrs regis in agric and applied econ MS prog, exam committee selected, #) Levins
Writing, critiquing, and oral presentation skills for master’s students. Oral presentation of research proposal for thesis or Plan B paper critiqued by peers and committee members.
ApEc 8110. Master's Paper: Plan B Project. (1-9 cr per qtr [max 9 cr]; prereq #; S-N only)

ApEc 8200. Advanced Topics in Agricultural and Applied Economics. (1-9 cr [may be repeated for cr]; may be used to develop PhD thesis proposal on S-N only) Special seminars or individual work on subject suited to needs of students.

ApEc 8210. Applied Econometrics. (3 cr; prereq Econ 8201 or Econ 5261, Econ 8202 or Econ 5262) Tsur
Basic skills for using econometrics in actual practice. Choosing functional forms and selecting variables; collinearity and outliers; limited dependent variable models in a single- and simultaneous-equation context. Emphasis on application to real-world data.

ApEc 8220. Applied Mathematical Programming. (3 cr; prereq Econ 5151 or MS-level operations research or #) Apland
Applications of mathematical programming to economic problems of the firm, sector, and economy. Classes of optimization problems include linear and nonlinear programming, integer, multiple objective, and stochastic programming. Use of economic concepts to build and interpret models.

ApEc 8231. Agricultural Prices. (3 cr; prereq Econ 5151, Econ 5152 or equiv) Smith
Nature of demand for farm products; supply considerations; price formation and markets; price variation and instability; dynamic analysis; methodological considerations.

ApEc 8245. Agricultural Marketing Economics. (3 cr; prereq Econ 5151, Econ 5152 or #) Liu
Time, space, and form dimensions of markets studied for cases of static and stochastic environments. Emphasis on use of current conceptual constructs. Implications of markets for contingent claims, incomplete information, and rent seeking on welfare.

ApEc 8264. Resource Economics. (3 cr; prereq Econ 5151, Econ 5152 or #) Homans
Economic analysis of resource use and management. Capital theory and dynamic resource allocation; applications to renewable and nonrenewable resources; empirical studies and policy issues.

Basic concepts underlying measurement of welfare change, problems of market failure and externalities, social welfare functions, and distribution within and across generations. Application of concepts, based on case studies of the environment, returns to research, technical change, and agricultural policy.

ApEc 8278. Agricultural and Economic Development. (3 cr; prereq Econ 8101 or #) Roe
Theories of socioeconomic growth; models of economic growth; consumption, production, and supply relations in agricultural development; agricultural development policy.

ApEc 8287. Production and Supply. (3 cr; prereq 5860 or equiv, Stat 5302 or equiv) Peterson
Functional forms and specification of production functions; measurement problems; specification bias; dummy variables; evaluating marginal products and returns to scale; supply estimation; distributed lags; demand for factors of production; project evaluation; technical change; returns to research; human capital.

ApEc 8288. Dynamic Production Economics. (3 cr; prereq Econ 5151, Econ 5152 or #) King
Analysis of firm-level production economics problems in dynamic setting. Alternative theories of the firm and techniques of analysis evaluated.

ApEc 8345. Seminar: Agricultural Marketing. (3 cr; offered when demand warrants) Hammond, Roe


ApEc 8366. Seminar: Applied Regional Economics. (3 cr; offered when demand warrants) Morse

ApEc 8370. Seminar: Agricultural and Trade Policy in Developed Countries. (3 cr; prereq 8270 or #) Runge
Agriculture in developed countries and the world economy: goals, principles, instruments of agricultural and trade policy intervention; implementation and problems of agricultural and trade policies in developed countries; political economy of agricultural policy decision making.

ApEc 8378. Seminar: Agricultural Development. (1 or 3 cr; offered when demand warrants) Roe, Ruttan

ApEc 8382. Seminar: Production Economics. (3 cr; offered when demand warrants) Petmill, Kinsey

ApEc 8590. Economics of Food and Consumer Policy. (3 cr; prereq 8270 or equiv, Econ 5113 or Econ 5151 or equiv) Kinsey
Economic analysis of issues and impact of public policies relating to food pricing and distribution, product quality and information, food safety and liability; international comparisons of food and agricultural policy and its impact on consumers’ welfare.

ApEc 8591. Consumption Economics. (3 cr; prereq microeconomic theory at the 5xxx level at least, basic regression analysis) Senauer
Analytical and empirical treatment of consumer behavior. Modern adaptations of theory to explain household economics, Lancaster models, consumer demand, and expenditure models and estimations.

Agricultural Engineering

See Biosystems and Agricultural Engineering.
Agronomy (Agro)

**Regents’ Professor:** Ronald L. Phillips  
**Professor:** R. Kent Crookston, *head*; Steve R. Simmons, *director of graduate studies*; Orvin C. Burnside; Robert H. Busch; Vernon B. Cardwell; Burle G. Gengenbach; Leland L. Hardman; Dale R. Hicks; Robert J. Jones; Hans-Joachim G. Jung; William E. Lueschen; Neal P. Martin; Ervin A. Oelke; James H. Orf; Donald L. Wyse  
**Adjunct Professor:** Howard W. Rines  
**Associate Professor:** Roger L. Becker; Beverly R. Durgan; Nancy J. Ehlke; Jeffrey L. Gunsolus; John V. Wiersma  
**Adjunct Associate Professor:** John W. Gronwald  
**Assistant Professor:** Gregg A. Johnson; Nicholas R. Jordan; Paul M. Porter  
**Adjunct Assistant Professor:** Frank Forcella; Mark E. Westgate  
**Other:** Helene Murray

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

**Degrees Offered**—M.S. (Plan A and Plan B) and Ph.D.

**Curriculum**—Training is provided in basic and applied aspects of management, physiology, production, and weed control of field crops, with emphasis on sustaining the environment and profitable practices. The program is closely aligned with the interdepartmental programs of plant breeding and plant biological sciences. Prospective students should consult other sections of this bulletin which describe these programs. The Department of Agronomy and Plant Genetics can supply information about all three programs on request.

**Prerequisites for Admission**—Applicants should have university-level training in agronomy, biology, chemistry, and mathematics. Applicants must have a background in biochemistry and biometrics, or must acquire this background as part of the degree program.

**Special Application Requirements**—Three letters of recommendation, a statement by the applicant outlining career objectives and experience, and Graduate Record Examination scores are required. Students may enter the program at any time, but most assistantships begin in the summer or fall, and applications are usually acted on by mid-February.

Master’s Degree Requirements—Most programs are Plan A. Students plan their course program and thesis research in consultation with their adviser and a department advisory committee. A final oral examination which includes a department seminar covering the thesis research or Plan B project is required.

Doctoral Degree Requirements—Course programs normally range from 60 to 75 quarter credits, depending on previous preparation. Students plan their course program and thesis research in consultation with their adviser and a department advisory committee. The final oral examination includes a department seminar covering the thesis research.

Minor Requirements for Students Majoring in Other Fields—Ph.D. minors must complete a minimum of 20 credits in agronomy including 8020.

Language Requirements—None.

For Further Information and Applications—Contact the Department of Agronomy and Plant Genetics, University of Minnesota, 411 Borlaug Hall, 1991 Buford Circle, St. Paul, MN 55108 (612/625-7773).

Agro 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

Agro 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

Agro 8888. Thesis Credits: Doctoral. (36 cr required)

Agro 5001f,w,s,su. Problems in Agronomy for Advanced Students. (1-5 cr; prereq GCB 3022 or Hort 3003 or equiv) Orf Applying genetic principles to improve crop plants. Includes self-pollinated, cross-pollinated, and asexually propagated crops. Lecture.

### GRADUATE PROGRAMS

**Agro 5050f. Management Technologies for Crop Production in Minnesota.** (4 cr; prereq agro course) Hardman, Sheaffer

**Agro 5070. Agroecology.** (3 cr; prereq 3010, 3 cr agronomic sciences or #) Jordan
Design, management, and evaluation of and structure-function relationships in agricultural ecosystems. Examines proposition that many current problems of agriculture can effectively be addressed by ecological analysis of agricultural systems. Case studies, discussion, experiential learning, field trips.

**Agro 5095. History of U.S. Agriculture.** (3 cr; prereq 2 courses in physical and biol sci, 2 courses in history and soc sci or #) Tjossem
Social, scientific, and political development of U.S. agriculture, focusing on issues of food supply and consumption and interaction with nature/soil, water, “pests,” and fellow humans (cooperation, competition, surpluses, subsidies, etc.); basis for contemporary sustainable agriculture.

**Agro 5120s. Growth and Development of Field Crops.** (4 cr; prereq 1007 or Biol 1009, Chem 1002, Chem 1051 or equiv) Cardwell
Principles and mechanisms that affect crop productivity. Physiological and morphological basis of growth and development; effects of physical and biological environmental factors. Lecture and lab.

**Agro 5130f. Harvest, Storage, and Utilization of Field Crops.** (4 cr; prereq 1007 or Biol 1009, Chem 1002, Chem 1051 or equiv) Cardwell
Crop quality traits associated with utilization: their influence on harvesting, processing, and storage. Principles and technology used in crop storage to minimize damage from fungi and insects and maximize crop quality. Lecture, lab, and discussion.

**Agro 5200f. World Food Problems.** (3 cr, §AgEc 5790, §CAPS 5280, §FScN 5643; prereq sr or grad student) Hardman
Multidisciplinary examination of social, economic, and technical problems of feeding the world’s growing population. Principles sought from social, economic, plant, animal, and food sciences for their application to food problems.

**Agro 5310su,f. Orientation to Field Crop Breeding.** (1 cr; prereq 5020 or #) Suthman
Field study of plant breeding programs and techniques.

**Agro 5320. Orientation to Agronomy and Soils Field Research.** (1 cr; S-N only) Cardwell
Field survey and discussion of research techniques in crop physiology, crop and soil management, and weed science programs.

**Agro 5330w. Plant Biotechniques.** (2 cr; prereq 3xx genetics and biochem courses)
Molecular and traditional biotechniques discussed by postdoctoral research associates to give broader understanding of molecular and quantitative techniques in agricultural research.

**Agro 5999. Special Workshop in Agronomy.** (1-4 cr; prereq #)
Offered off campus. Consult the Class Schedule or department for current topics.

**Agro 8000f. Supervised Teaching Experience.** (2 cr, §Hort 8000, §Soil 8000; prereq #) Simmons
Classroom or extension teaching experience in one of the following departments: Agronomy and Plant Genetics, Horticultural Science, or Soil, Water, and Climate. Participation in teaching topic discussions to strengthen skills and develop personal teaching philosophy.

**Agro 8010f,w,s, su. Research in Agronomy.** (Cr ar; prereq #)
Problems in physiology and production of crop plants.

**Agro 8020f,w. Seminar: Agronomy.** (1 cr)
Reviews and discussions of important agronomic literature.

**Agro 8050f. Physiology of Field Crops.** (3 cr; prereq 5120, PIPh 5131 or #; offered alt yrs) Jones
Physiology of crop productivity with emphasis on improving yield or quality. Assimilation and partitioning of nitrogen and carbon, transpiration, water stress, temperature stress, and vernalization.

**Agro 8080f. Current Topics in Agronomy.** (2 cr; prereq 5040, 8050, #; offered alt yrs)
Current developments in agronomy and crop physiology.

**Agro 8200f. Plant Breeding Principles and Methods I.** (3 cr; prereq 5020, Stat 5301 or equiv) Rasmusson
Principles and current methods involved in breeding, emphasizing self-pollinated crops. Parent selection, modifications of traditional breeding procedures, priority setting and allocation of resources, breeding for special traits.

**Agro 8210s. Plant Breeding Principles and Methods II.** (3 cr; prereq 8200, Stat 5301, GCB 5042)
Principles and methods of breeding, emphasizing cross-pollinated crops. Population concepts, constructing source populations, recurrent selection techniques, varietal development, and new approaches.

**Agro 8220f. Application of Quantitative Genetics to Plant Breeding.** (3 cr; prereq 8210, 8260, GCB 5042 or #) Elhike

**Agro 8230f. Cytogenetics.** (4 cr; prereq GCB 5034 or #; 3 lect and 2 lab hrs per wk) Phillips
Genetic principles in relation to the eukaryotic chromosome. Molecular cytogenetics of chromosome structure, replication, pairing, and crossing over. Behavior of deficiencies, duplications, inversions, interchanges. Aneuploidy, autopolyploidy, allopolyploidy, and uses of cytogenetic stocks in molecular and classical genetics and plant breeding.
American Studies (AmSt)

FACULTY

Professor: David Roediger, chair; Roland A. Delattre; Elaine T. May; David W. Noble; Gayle Graham Yates

Associate Professor: Riv-Ellen Prell, director of graduate studies; Lary L. May; Carol A. Miller

Assistant Professor: Leola A. Johnson

AFFILIATED FACULTY

Professor: Ronald R. Aminzade (sociology); Ayers L. Bagley (educational policy and administration); Kent R. Bales (English); Terence W. Ball (political science); Hyman Berman (history); David O. Born (health ecology); Kinley J. Brauer (history); Roger D. Clemence (architecture); Hazel Dicken-Garcia (journalism); Mary G. Dietz (political science); Sara M. Evans (history); James Farr (political science); Philip G. Furia (English); Philip J. Gersmehl (geography); Edward M. Griffin (English); John R. Howe, Jr. (history); Karen N. Hoyle (Children’s Literature Research Collections); Sally G. Kohlistedt (history of science and technology); Barbara Laslett (sociology); Richard D. Leppard (cultural studies and comparative literature); Alex J. Lubet (music); Marion Lundy-Dobbert (educational policy and administration); Karal Ann Marling (art history); Ronald C. McCurdy (music); Toni A. H. McNaron (English); Russell R. Menard (history); Paul L. Murphy (history); Paula Rabinowitz (English); Martin Roth (English); Harvey B. Sarles (cultural studies and comparative literature); Ellen J. Stekert (English); Roger H. Stuewer (physics; history of science and technology); Rudolph J. Vecoli (history); Jean W. Ward (journalism); Jack D. Zipes (German)

Associate Professor: W. John Archer (cultural studies and comparative literature); Rose M. Brewer (Afro-American and African studies); Maria Damon (English); John M. Dolan (philosophy); Arthur I. Geffen (English); George D. Green (history); Mary Jo Kane (kinetics and leisure studies); March L. Krotee (kinetics and leisure studies); Judith A. Martin (geography); Roger P. Miller (geography); Gail K. Noble (General College); Joanna O’Connell (Spanish and Portuguese); Nancy L. Roberts (journalism); Guillermo Rojas (Chicano studies); Steven Ruggles (history); Thomas M. Scanlan (rhetoric); Robert B. Silberman (art history); Allan H. Spear (history); Dennis N. Valdes (Chicano studies); John S. Wright (English; Afro-American and African studies); Jacquelyn N. Zita (women’s studies)

Assistant Professor: Angela D. Dillard (history); Josephine D. Lee (English); Lisa A. Norling (history); Jean O’Brien-Kehoe (history); Jennifer L. Pierce (sociology)

Other: William C. Beyer (coordinator, College of Liberal Arts Student Academic Support Services); Harry C. Boyte (senior fellow, Humphrey Institute of Public Affairs); Colleen J. Sheehy (program director, Frederick R. Weisman Art Museum)

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.A. (Plan A and Plan B) under special circumstances as part of the Ph.D. program, and Ph.D.

Curriculum—American Studies is an interdisciplinary, interdepartmental degree program. The graduate faculty of the program consists of core faculty members and graduate faculty members from participating departments.

Prerequisites for Admission—An undergraduate major in a field related to American Studies or other preparation acceptable to the Admissions Committee for American Studies is required.

Special Application Requirements—The following should be sent to the program office: a special application form available through the program office, a personal statement, three letters of recommendation, a writing sample,
scores from the General (Aptitude) Test of the Graduate Record Examination, and transcripts of all college work. Applications must be submitted by December 15. Entry is only in fall quarter.

**Master’s Degree Requirements**—The master’s degree is offered under Plan A and Plan B. A minimum of 13 courses is required, distributed as follows: introductory seminars 8201, 8202, and 8203; 1 two-quarter sequence from the American Studies specialty seminars or approved from another department; 2 comparative culture courses covering international or non-U.S. subjects; 2 courses in cultural pluralism within the American experience; and 4 other adviser-approved courses. A final oral examination is required for both plans.

**Doctoral Degree Requirements**—A minimum of 20 courses is required, distributed between the major field of American Studies and one or more fields of concentration that demonstrate programmatic coherence. Courses are distributed as follows: introductory seminars 8201, 8202, and 8203; dissertation seminars 8801, 8802; practicum in American Studies 8401; 2 two-quarter series from the American Studies specialty seminars or other approved two-quarter graduate seminars; 2 comparative culture courses covering international or non-U.S. subjects; 2 courses in cultural pluralism within the American experience; and 6 adviser-approved courses. Preliminary written and oral examinations covering coursework, and a dissertation and final oral defense of it, are required.

**Language Requirements**—For both the M.A. and the Ph.D. degrees, reading knowledge of one foreign language is required.

**Minor Requirements for Students Majoring in Other Fields**—Students are expected to choose courses consistent with or complementary to their major. Students should complete six courses in American Studies, one of which must be 8201, 8202, or 8203.

**For Further Information and Applications**—Contact the Program in American Studies, University of Minnesota, 104 Scott Hall, 72 Pleasant Street S.E., Minneapolis, MN 55455 (612/624-4190).

**AmSt 8666. Doctoral Pre-Thesis Credits.** (max 18 cr per qtr; doctoral student who has not passed oral prelims)

**AmSt 8777. Thesis Credits: Master’s.** (16 cr required; Plan A only)

**AmSt 8888. Thesis Credits: Doctoral.** (36 cr required)

**AmSt 5101. Religion in American Culture.** (4 cr, RelS 5101) Delattre
Not a survey, but a representative profile of religion in American, past and present, organized each quarter around a theme or problem.

**AmSt 5920. Topics in American Studies.** (1-4 cr per qtr [max 12 cr]) Topics specified in Class Schedule.

**AmSt 8201. Historical and Theoretical Foundations of American Studies.** (4 cr; prereq admission to AmSt grad program)
Exposition of American studies as a field of inquiry, including its history, major theoretical frameworks, and interdisciplinary methodologies.

**AmSt 8202. Theory, Current Research, and Practice in American Studies.** (4 cr; prereq admission to AmSt grad program)
Review of contemporary interdisciplinary scholarship in the field.

**AmSt 8203. American Studies Methodology.** (4 cr; prereq admission to AmSt grad program)
Application of American Studies methods to various types of cultural materials.

**AmSt 8219, 8220. American Cultural Regions.** (4 cr per qtr [max 12 for 8220]; prereq # or ∆ for 8219; 8219 or # or ∆ for 8220)
Regional, ethno-cultural investigation of United States, including national and regional cultures. Interdisciplinary use of historical, geographic, literary, and artistic approaches to describe and analyze regional character and to define and defend regional boundaries. 8219: Research strategies. 8220: Topical development.

**AmSt 8229, 8230. The United States in International Perspective.** (4 cr per qtr [max 12 for 8230]; #Hist 8229-8230; prereq # or ∆ for 8229, 8229 or # or ∆ for 8230)
Relationship between American culture and role of United States in world; how United States has been imagined, defined, responded to by other cultures; historical, cultural, economic, political factors. 8229: Research strategies. 8230: Topical development.

**AmSt 8239, 8240. Gender, Race, Class, Ethnicity, and Sexuality in America.** (4 cr per qtr [max 12 cr for 8240], #Hist 8239-8240; prereq # or ∆ for 8239, 8239 or # or ∆ for 8240)
Social, psychological, historical, and artistic modes of self-expression and intellectual analysis of people in the United States identified as female and male or as members of racial, ethnic, or national-origin groups. 8239: Research strategies. 8240: Topical development.

**AmSt 8249, 8250. Material Culture and/or Popular Culture.** (4 cr per qtr [max 12 cr for 8250], #Hist 8249-8250; prereq # or ∆ for 8249, 8249 or # or ∆ for 8250)
Patterns of American building, artifacts, customs; human-made plans and procedures for use of space and conduct of daily life in physical and social environments. 8249: Research strategies. 8250: Topical development.
AmSt 8259, 8260. Literature, History, and Culture. (4 cr per qtr [max 12 cr for 8260]; prereq # or Δ for 8259, 8269 or # or Δ for 8260) Interdisciplinary study of connections between literary expression and history, particularly as they articulate themes in American culture. 8259: Research strategies. 8260: Topical development.

AmSt 8269, 8270. Politics, Economics, and/or the Law. (4 cr per qtr [max 12 cr for 8270]; prereq # or Δ for 8269, 8269 or # or Δ for 8270) Interdisciplinary investigation of underlying ideas of politics, economics, and the law in American culture. Draws upon research by historians, literary critics, political scientists, economists, and sociologists. 8269: Research strategies. 8270: Topical development.

AmSt 8289, 8290. Religion, Ethics, and Public Life in America. (4 cr per qtr [max 12 cr for 8290]; prereq # or Δ for 8289, 8289 or # or Δ for 8290) Forms, practices, and history of religious life and institutions in the United States. 8289: Research strategies. 8290: Topical development.

AmSt 8401. Practicum in American Studies. (4 cr; prereq #) Application of American studies expertise, either inside or outside the classroom.

AmSt 8801-8802. Dissertation Seminar. (4 cr per qtr; prereq # or Δ) Intended for doctoral students beginning work on dissertations in American studies.

AmSt 8970. Readings in American Civilization. (Cr ar) Independent study of interdisciplinary aspects of American civilization under guidance of members of various departments.

Anatomy (CBN)

Professor: David W. Hamilton, head, director of graduate studies; G. Eric Bauer; Robert P. Elde; Stanley L. Erlandsen; Glenn J. Giesler; Ryoko Kuriyama; Paul C. Letourneau; Richard W. Linck; Steven C. McLoon; Jonathan A. Parsons; Arlen R. Severson; Virginia S. Seybold; Robert L. Sorenson

Associate Professor: Stephen W. Downing; Lillian A. Repesh; Donald W. Robertson

Course of Study—Minor in anatomy, applicable to M.S programs only.

Curriculum—Major research interests in the department focus on the cell biology of reproduction, development, transplantation, and endocrinology in mammals, as well as on the neurobiology of peptidergic pathways and the basic mechanisms of pain, cancer, and diabetes. Students thus have a broad range of opportunities for research at the cellular level using biochemical, electron microscopical, and cell physiological techniques.

Prerequisites for Admission—Nine credits of general biology, and at least one course each in chemistry and physics are required. Advanced mathematics (calculus) is recommended.

Special Application Requirements—Individuals interested in the M.S. program should consult the director of graduate studies before applying. Graduate Record Examination scores (General Test and Subject Test in biology) are required.

Language Requirements—None.

Minor Requirements for Students Majoring in Other Fields—Required coursework for the minor in anatomy includes two of the four introductory courses in anatomy (5100-5101, 5103, 5104, and 5111) and at least 6 credits of advanced courses.

For Further Information and Applications—Contact the Department of Cell Biology and Neuroanatomy, University of Minnesota, 4-135 Jackson Hall, 321 Church Street S.E., Minneapolis, MN 55455 (612/624-1123).

CBN 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

CBN 5058. Anatomy of the Extremities. (6 cr; prereq 1004, registration in occupational therapy or physical therapy) Lecture and lab dissection of bones, muscles, joints, nerves, vessels, connective tissue, and selected internal organs. Histology, embryology, and surface anatomy. Correlation to clinical conditions.

CBN 5100-5101. Human Gross Anatomy A-B. (8 cr for 5100, 4 cr for 5101, 55107 and 55108 for 5100, 55109 for 5101; prereq regis med fr or grad student with #) Parsons, staff

Lectures and dissections of the human body.

CBN 5103. Human Histology. (3-8 cr [7 cr for med/dent fr]; prereq regis med/dent fr, Anat grad student or grad student with #) Letourneau, staff

Microscopic structure, cytochemical and functional aspects of cells, tissues, and organs.

CBN 5104. Biochemistry, Molecular and Cellular Biology. (1 cr; prereq regis med fr, MdBC 5100) Integrated introduction to biochemistry, molecular biology, genetics, cell biology, and developmental biology.

CBN 5110. Neuroscience for Dental Students. (1.5 cr; Pshl 5100; prereq regis dentistry fr, #) Elde, staff

Introduction to structure and function of central nervous system. Correlation between morphology and physiology emphasized.

1 University of Minnesota, Duluth
CBN 5111. Human Neuroscience A. (3-4 cr; 3 cr for med students; prereq regis med fr or grad student or #; 5111-Phsl 5112) Ebner, staff
Structure and function of the nervous system including the organs of special sense.

CBN 5190. Advanced Anatomy. (1-10 cr; prereq regis med, #)
Teaching methods, supervision of student’s original research or combination of both.

CBN 5304. Head and Neck Anatomy for Medical/Dental Residents. (5 cr; prereq participation in a residency program in the medical or dental schools) Robertson, staff
Detailed consideration of head and neck anatomy from the gross morphological, functional, developmental, and radiographic aspects, with emphasis on areas of interest by specialty. Lab participation required.

CBN 8135. Biological Electron Microscopy: Techniques. (1-5 cr; prereq #; offered alt yrs) Erlandsen
Introduction to principles and techniques of electron microscopy. Lab emphasis on acquisition of skills in tissue preparation, photography, use of electron microscope and ancillary equipment.

CBN 8136. Biological Electron Microscopy: Techniques. (1-5 cr; prereq #; offered alt yrs) Erlandsen
Specialized ultrastructural techniques and their application to biologic problems. Lab emphasis on high resolution microscopy and use of scanning electron microscope.

CBN 8137. Biological Electron Microscopy: Interpretation. (1-5 cr; prereq 5103, 8135-8136, #; hrs ar; offered alt yrs) Erlandsen
Structure and function of cell organelles. Individual projects using advanced techniques for both transmission and scanning electron microscopy.

CBN 8148. Advanced Cell Biology I. (4 cr, §GCB 8148; prereq Biol 5004 or #)
Eucaryotic systems with emphasis on structure, function, and chemistry of cell organelles; specialized cells. Membranes and secretion, including membrane methodologies, structure, function, synthesis, and turnover; cell surfaces, protein synthesis, glycosylation, membrane fusion, lysosomes, endocytosis, role of peroxisomes, and detoxification by endoplasmic reticulum.

CBN 8149. Advanced Cell Biology II. (4 cr, §GCB 5049, §GCB 8149; prereq Biol 5003, Biol 5004) Yost
Eucaryotic systems with emphasis on structure, function, and chemistry of cell organelles; specialized cells. Motility and cell nucleus, including roles of microtubules and microfilaments in cell locomotion, shape changes, cytokinesis, ciliary beating, and organelle redistribution; cell cycle, chromosomal structure, replication, mitosis; compartmentalization and autonomy of mitochondria and chloroplasts.

CBN 8153, 8154, 8155, 8156. Advanced Anatomy. (1-6 cr per qtr; prereq #)
Cytochemistry, embryology, gross anatomy, hematology, histology, neurology, or experimental morphology.

CBN 8166. Seminar: Pancreatic Islet Biology. (3 cr; prereq #; offered alt yrs) Bauer, staff
Structure, development, physiology, and cell biology of pancreatic islets of Langerhans. Primary sources: original publications supplemented by recent reviews.

CBN 8200. Research. (1-10 cr [max 20 cr]; prereq #)
Faculty-directed research in cell and developmental biology and neuroscience.

CBN 8205, 8206, 8207. Seminar: Cell Biology and Neuroanatomy. (1 cr per qtr; prereq #)
Hamilton
Reviews of current literature and discussion of research work being carried on in the department.

CBN 8210. Developmental Neurobiology. (3 cr; prereq 5111, Phsl 5112 or #; offered alt yrs) McLoon
Nervous system development. General mechanisms and experimental approaches.

CBN 8215. Molecular and Cellular Basis of Development. (3 cr; prereq Biol 5003, Biol 5004) Yost
Molecular and cellular mechanisms of animal development; lectures, readings, and discussions of primary research literature; focus on historical concepts and principles of developmental biology and modern experimental analysis of these principles.

CBN 8221. Neurobiology of Pain and Analgesia. (3 cr; prereq #; offered in alt sequence with 8222 and 8223) Giesler, Seybold
Neural systems underlying pain perception, production of analgesia. Series of weekly lectures coordinated with student presentations on relevant topics.

CBN 8222. Central Regulation of Autonomic Function. (3 cr; prereq #; offered in alt sequence with 8221 and 8223) Elde, Seybold
Morphology and physiology of autonomic ganglia and enteric nervous system, discussions of neuronal circuitry underlying central regulation of the adrenal medulla, cardiovascular system, respiratory system, and pelvic viscera. Weekly lectures and presentations of student papers.

CBN 8223. Neurobiology of Endocrine Regulation. (3 cr; prereq #; offered in alt sequence with 8221 and 8222) Elde, Seybold
Neural systems involved in regulating endocrine function. Lectures and student-led discussions on the hypothalamic-pituitary-target organ axes.

CBN 8301s. Molecular Biology of the Cytoskeleton. (2 cr; prereq #; S-N only) Linck
Seminar with lecture and discussion and visiting speakers.

Ancient and Medieval Art and Archaeology
See Classical and Near Eastern Studies.
Animal Sciences (AnSc)

Professor: Donald E. Ottery, head; Bernard J. Conlin; Craig N. Coon; Bo G. Crabo; Brian A. Crooker; William R. Dayton; Gary E. Duke; Mohamed E. El-Halawani; Richard J. Épley; Douglas N. Foster; Esther M. Gallant; Leslie B. Hansen; Alan G. Hunter; Dennis G. Johnson; Shirley D. Johnston; Benjamin S. Leung; James G. Linn; George D. Marx; Sally L. Noll; Scott M. O’Grady; James E. Pettigrew; Jeffrey K. Reneau; William D. Schmid; Lawrence B. Schook; Anthony J. Seykora; Marshall D. Stern; Paul E. Waibel; Jonathan E. Wheaton

Adjunct Professor: Hans-Joachim G. Jung

Associate Professor: Marcia R. Hathaway, director of graduate studies; Hugh Chester-Jones; Lee J. Johnston; Mathur S. Kannan; William G. Olson; John W. Osborn; Gerald C. Shurson; Michael E. White

Assistant Professor: Mitchell S. Abrahamsen; Alfredo DiCostanzo; John B. Hall; William A. Head, Jr.; Hugh C. Hensleigh; Vijay M. Kumar; Brent W. Woodward

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B) and Ph.D.

Curriculum—Students emphasize one of the animal sciences subdisciplines such as genetics, growth biology, nutrition, physiology, or production systems. They have the option of taking a management component in conjunction with the subdisciplines. Technical training involves both animal and laboratory experience.

Prerequisites for Admission—A bachelor’s degree in agriculture or a biological field with training in chemistry, physics, and mathematics is required.

Special Application Requirements—A complete set of transcripts in addition to that required by the Graduate School, three letters of recommendation evaluating the applicant’s potential, and a statement of career goals are required. The minimum GPA generally required for admission is 3.00 for the M.S. and 3.20 for the Ph.D. Graduate Record Examination scores are required. Applicants are admitted every quarter.

Master’s Degree Requirements—For Plan A, the minimum number of course credits required (excluding thesis credits) is 20 credits in the major and 8 credits in one or more related fields outside the major. For Plan B, the minimum is 20 credits in the major and 8 credits in one or more related fields, with the adviser and the student choosing the balance of credits for meeting the 44-credit minimum for the degree. Students must complete basic courses in the chosen subdiscipline. The final examination for the M.S. degree is oral.

Doctoral Degree Requirements—Students must complete basic courses in the chosen subdiscipline. No minimum number of credits for the major is specified.

Language Requirements—None.

Minor Requirements for Students Majoring in Other Fields—Requirements are designed to fit the student’s needs. Doctoral students must complete a minimum of 18 credits in areas not closely related to the major; no more than 3 of these credits may be in research or special problems.

For Further Information and Applications—Contact the Department of Animal Science, University of Minnesota, 122 Peters Hall, 1404 Gortner Avenue, St. Paul, MN 55108 (612/624-3491; fax 612/625-5789; e-mail smith072@tc.umn.edu; http://www.animal.agri.umn.edu).

AnSc 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

AnSc 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

AnSc 8888. Thesis Credits: Doctoral. (36 cr required)

AnSc 5231s. Dairy Cattle Breeding. (4 cr; prereq 3220 or #) Hansen Application of quantitative genetic principles to the breeding of dairy cattle. Emphasis on evaluation of males, females, and systems of breeding. Rates of genetic improvement with and without artificial insemination.

AnSc 5322f. Physiology of Reproduction. (5 cr; prereq 6 cr systemic physiology or #) Crabo Principles of reproductive physiology with emphasis on endocrinological aspects.

AnSc 5327w. General Endocrine Physiology. (3 cr; prereq 3301 or #) Wheaton Biological effects, biochemistry, methods of assay, and regulatory aspects of hormones.

AnSc 5328s. General Endocrine Physiology Laboratory. (2 cr; prereq 5327 or #) Wheaton Demonstration of concepts in endocrinology using basic experimental approaches.
AnSc 5330s. Current Topics in Endocrinology. (1 cr; prereq 3301, Biol 5001) Wheaton
Discussion of current developments in endocrinology, including introductory and review material, methodology, applicability of results to basic and applied research, and impact on existing endocrine principles.

AnSc 5401f. Swine Nutrition and Feeding. (4 cr; prereq 3401) Shurson
Nutrient requirements of swine, nutrition interrelationships, nutritive value of feed ingredients, formulation of diets for optimum biological performance, nutritional management of all phases of pork production, quality control of on-farm feed manufacturing and feeding systems.

AnSc 5403w. Ruminant Nutrition. (4 cr; prereq 1401 or 3401) Crooker, Otterby, Stern
Nutrient requirements of ruminants (beef and dairy cattle, sheep); nutrient content of feedstuffs, primarily forages; protein and nonprotein nitrogen use; energy use; nutritional disorders, formulation of adequate rations.

AnSc 5405w. Poultry Nutrition. (3 cr; prereq 3401) Waibel
Nutrition and feeding of chickens and turkeys emphasizing nutrition concepts and feeding programs using least cost methods.

AnSc 5601s. Swine Production. (4 cr; prereq 3401; 3220 recommended) Shurson
Integration of economics, environment and facilities, nutrition, health, reproduction, genetics, management, and current industry issues in a systems approach to understanding pork production and solving pork production management problems.

AnSc 5602w. Sheep Production. (3 cr; prereq 3401 or #; 3220, 5403 recommended) Christians, Head, Wolfe
Status and characteristics of the sheep industry; application of principles of animal breeding, nutrition, physiology, and economics to sheep flock management. Sheep production systems, including breeding programs, selection of breeds and breeding animals, feeding, health programs, dairy sheep, marketing, and budgets.

AnSc 5603s. Beef Cattle Production. (4 cr; prereq 1401 or 3401; 3220, 5403 recommended) DiCostanzo, Woodward
Status and characteristics of the beef cattle industry; application of principles of animal breeding, nutrition, physiology, and economics to management of beef cattle breeding herds. Ration formulation, management, and marketing of feedlot cattle.

AnSc 5604s. Dairy Farm Management. (4 cr, §5614; prereq 5403 or #; 3220 recommended) Reneau
Application of the principles of animal breeding, nutrition, physiology, and economics to the planning and management of the dairy farm; genetic influences, housing requirements, health programs for large herds, feed budgets, and record analysis.

AnSc 5605f. Poultry Production. (4 cr; prereq 1401 or 3401; 5405 recommended) Coon, El-Halawani, Noll, Waibel
Physiology, genetics, diseases, and nutrition of poultry examined in relation to current management practices for production of eggs, broilers, and turkeys. Technical and practical phases of production and marketing and their underlying principles. Visits to commercial production units.

AnSc 5609w. Principles of Farm Animal Environment. (4 cr; prereq jr, 3301 or #) El-Halawani
Processes involved in the adjustment of animals to ambient environments, with applications to farm animal management.

AnSc 5710f,w,s,su. Special Problems. (Cr ar; open to students who have completed pertinent prereqs; prereq #)
Research in an area of animal science under supervision of a staff member. Written report of research is required.

AnSc 5715f,w,s,su. Tutorial. (Cr ar; prereq #)
Informally structured course to encourage study in depth of a specific discipline in animal science. Pertinent readings, centered around fundamental propositions; preparation of written essays of high quality. Available in cryobiology, cytogenetics, genetics, nutrition, and physiology.

AnSc 5999. Special Workshop in Animal Science. (1-4 cr; prereq #)
Offered off campus. Consult the Class Schedule or department for current topics.

AnSc 8210w. Genetic Improvement of Animals. (4 cr; prereq #) Seykora
Application of population genetics to livestock breeding; selection index theory and practice; basis of relationship and covariances among relatives; selection based on multiple sources of information.

AnSc 8230s. Linear Model Methods. (2-4 cr; prereq Stat 5021; GCB 5033, Math 3142 recommended) Hansen
Techniques and statistical tools for analysis of data. Matrix manipulations, least-squares procedures, correction for environmental factors, estimation of components of variance, and standard errors of estimates.

AnSc 8325w. Physiology of Fertilization and Gestation. (4 cr; prereq 5322 or #; offered alt yrs) Hunter
Physiological events occurring during gametogenesis; capacitation and fertilization; the period of the embryo; the period of the fetus; and parturition.

AnSc 8326s. Immunoreproduction. (4 cr; prereq 5322 or #; offered alt yrs) Hunter
Blood groups and polymorphic proteins affecting reproduction; immunoglobulin formation; antigens of semen, ova and genital secretions; immunopathology; maternal-fetal incompatibility, and antibodies to hormones.

AnSc 8332s. Preservation of Spermatozoa and Embryo. (5 cr; prereq 5322, 3 cr upper div biochemistry, #) Crabo
Chemical, physical, and physicochemical properties of gametes, reproductive secretions. Preservation of gametes using cryogenic techniques.
AnSc 8335. Molecular Biology Techniques in Animal Science. (4 cr; prereq Biol 5001, Biol 5003 or equiv or #) Foster
Basic theory and current methodologies of molecular biology and recombinant DNA technology. Lab work includes DNA and RNA hybridization, gene transfer, and polymerase chain reaction techniques. Primarily for students with limited exposure to molecular biology.

AnSc 8420f. Animal Bioenergetics and Nutritional Physiology. (3 cr; prereq #; BioC 5002 recommended; offered alt yrs) Crooker
Integrated systems approach to nutritional physiology and energy metabolism of animals. Application of classical techniques of calorimetry and comparative slaughter, development of systems for expressing energy content of feeds, and techniques for measuring whole body and organ metabolism of specific nutrients in vivo.

AnSc 8421s.* Protein and Amino Acid Nutrition. (3 cr; prereq BioC 5002 or equiv or #, BioC 5743 recommended; offered alt yrs) Coon
Role; sources, how determined; measurements of protein quality; fat and use of ingested protein and amino acids and interrelationships with other nutrients.

AnSc 8440w.* Ruminant Nutrition. (4 cr; prereq BioC 5002 or #; MicB 5321 recommended; offered alt yrs) Stern, staff
Development, physiology, and function of the rumen; role of rumen microflora in digestion and synthesis and factors influencing these phenomena.

AnSc 8441w. Research Techniques in Ruminant Nutrition. (4 cr; prereq BioC 5002 or #; MicB 5321 recommended; offered alt yrs) Stern
Techniques for measuring rumen fermentation and digestion in the gastrointestinal tract, including batch culture fermentation, in situ digestion, continuous culture fermentation, ruminal and intestinal cannulation, and blood sampling techniques.

AnSc 8740w. Concepts and Developments in Ruminant Nutrition. (2 cr; prereq #) Stern
Review and critical evaluation of recent research reports of relevance to ruminant nutrition.

AnSc 8742s. Concepts and Developments in Swine Nutrition. (2 cr; prereq #; offered alt yrs) Pettigrew
Review and evaluation of scientific literature pertinent to swine nutrition.

AnSc 8743. Concepts and Developments in Nutritional Physiology. (2 cr; prereq #) Crooker
Review and critical evaluation of scientific literature.

AnSc 8810.* Research in Animal Science. (Cr ar; prereq #)
Research including experimental studies in disciplines associated with animal production and research, with emphasis on interdisciplinary studies embracing environmental and managerial considerations.

AnSc 8820.* Research in Animal Genetics. (Cr ar; prereq #)
Research in quantitative genetics, cytagenetics, molecular genetics, and other areas related to animal breeding.

AnSc 8830.* Research in Animal Physiology. (Cr ar; prereq #)
Individual research under faculty direction. Topic to be determined by consultation—may be a specialized aspect of a thesis problem or an independent problem of mutual interest to graduate student and adviser.

AnSc 8840.* Research in Animal Nutrition. (Cr ar; prereq #)
Research in selected areas of animal nutrition. Research topics and animal species determined by consultation.

Anthropology (Anth)
Professor: Luther P. Gerlach; Guy E. Gibbon; Stephen F. Gudeman; Glenn L. Hendricks; John M. Ingham; Marion L. Lundy-Dobbert; Frank C. Miller; Eugene Ogan (emeritus); William L. Rowe (emeritus); Peter S. Wells
Associate Professor: Gloria Goodwin Raheja, chair; David M. Lipset, director of graduate studies; Timothy Dunnigan; Mischa Penn; Riv-Ellen Prell; Janet D. Spector
Assistant Professor: Kathleen Barlow; Lisette E. Josephides; Joy McCorriston
Other: John M. Weeks

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.A. (Plan A and Plan B) and Ph.D. Admission to the Ph.D. is conditional pending the results of a qualifying examination at the end of the first year of study.

Curriculum—The department offers M.A. and Ph.D. degrees in the subfields of sociocultural anthropology and archaeology. Strong supporting programs in related fields are available. A special M.A. track in public archaeology is offered.

Prerequisites for Admission—None. Any necessary background work may be completed after admission.

Special Application Requirements—Three letters of recommendation on a form furnished by the department and scores from the General (Aptitude) Test of the Graduate Record Examination should be sent to the director of graduate studies. Admission is usually in fall quarter; the deadline for all materials is January 15.
Master’s Degree Requirements—For the M.A. degree, 8001, 8002, 8003 or 8004, a course in the method of one subfield, and a graduate-level statistics course are required. The rest of each student’s program is individually designed with the provision that one-half of degree courses must be at the 8xxx level. A final oral examination is required of all students.

The Plan A master’s degree requires a minimum of 20 course credits in anthropology, a minimum of 9 credits for a designated minor (certified on transcript) or a minimum of 8 credits in one or more related fields (not certified on transcript), and 16 thesis credits, for a minimum total of 44 credits.

The Plan B master’s requires a minimum of 20 course credits in anthropology, a minimum of 8 credits in one or more related fields, and one to three Plan B projects (number is determined in consultation with student’s advisory committee), for a minimum total of 44 credits.

Doctoral Degree Requirements—Course requirements are the same as for the master’s degree, with additional courses and seminars selected in consultation with the student’s advisory committee. No minimum credit requirement for the major has been established. Minor or supporting fields should comprise 18-24 credits. In practice, the normative minimum total is 60 credits.

Language Requirements—For the M.A. degree, none. For the Ph.D. degree, students must demonstrate a basic reading knowledge of one language other than English for which there is an anthropological literature or a long-standing literate tradition (e.g., Chinese, Hindi).

Minor Requirements for Students Majoring in Other Fields—The minor program is individually designed by each student.

For Further Information and Applications—Contact the Department of Anthropology, University of Minnesota, 215 Ford Hall, 224 Church Street S.E., Minneapolis, MN 55455 (612/625-3400; fax 612/625-3095).

Anth 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

Anth 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

Anth 8888. Thesis Credits: Doctoral. (36 cr required)


Anth 5104. History of Anthropology. (4 cr; prereq 1102, 15 cr in 3xxx- and 5xxx Anth courses) Penn Principal themes in 19th- and 20th-century anthropological thought: diffusionism, autonomy of culture, evolutionism, and emerging methodological viewpoints such as functionalism, structuralism, cultural materialism, and interpretivism. Whether or not anthropological theory has a logic.

Anth 5112. Gender and Kinship. (4 cr; prereq 1102 or 5102, 3201 or #) Gudeman, Raheja Gender, sexuality, marriage, and kinship in cross-cultural perspective; role of kinship studies in anthropological theory, including contemporary feminist critiques.

Anth 5114. Structural Anthropology. (4 cr; prereq 1102 or 5102, 3201 or #) Gudeman, Penn Assumptions, methods, and problems of structural and semiotic anthropology; theory and analysis of kinship, myth, and social organization.

Anth 5115. Economic Anthropology. (4 cr; prereq 1102 or 5102, 3201 or #) Gudeman Systems of production and distribution, especially in nonindustrial societies; history, comparison, and critique of major theories in the field; development of anthropological approach to facts and processes of economy in the United States and other societies.

Anth 5116. Ecological Anthropology. (4 cr, §3116; prereq 1102) How humans interact with biophysical environment through nature. Cross-cultural comparative study of ways of making a living, e.g., foraging, herding, farming, industry; correlates environment with technology, economy, social and political organization, religion. Resource controversies and global environmental change.

Anth 5118. Political Anthropology. (4 cr; prereq 1102 or 5102 or #) Lipset Anthropological approaches to politics: the structural-functionalists, Manchester School, and others. Key political concepts: authority, legitimacy, power, ideology, order and conflict. Focus on how symbols and rituals shape political process. Symbolic dimensions of ethnic and class consciousness.

Anth 5121. Anthropology of Law. (4 cr; prereq 1102 or 5102—waived for majors in political science and law) Lipset Theory and method of various legal systems. Cultural background of law and relation of law to society. Functions and evolution of law in cultures ranging from small-scale to complex.

Anth 5131. Anthropology of Religion. (4 cr; prereq 1102 or 5102 or #) Lipset, Penn, Prell Comparative study of beliefs, myths, and rituals in folk and indigenous religions. Analysis of how religion and social relations are integrated.
Anth 5132. Symbolic Anthropology. (4 cr; prereq 1102 or 5102 or #) Ingham, Lipset
Introduction to semiotic or symbolic interpretation of cultures in anthropology. General problems in theory and method, structure and motivation of cultural symbolism in particular societies.

Anth 5141. Psychological Anthropology. (4 cr; prereq 1102 or 5102 or #—waived for majors in public health, nursing, psychology, sociology, and social work) Ingham
Self, emotion, cognitive processes, and child development in cross-cultural perspectives.

Anth 5145. Anthropology and Education. (4 cr; prereq 1102 or 5102 or #) Barlow, Lundy-Dobbert
Cross-cultural perspectives in examining educational patterns, implicit and explicit cultural assumptions underlying them. Methods and approaches to cross-cultural studies in education.

Anth 5151. Cultural Change and Development. (4 cr; prereq 1102 or 5102 or #) Miller
Processes of cultural change: invention, innovation, diffusion, and acculturation. Theories of modernization, dependency, and world systems. Roles of anthropologists in development programs.

Anth 5152. Anthropology of Social Movements. (4 cr) Gerlach
Cross-cultural study of nature, process, and function of social, political, and religious movements of change. Examination of theories and case studies including Christianity, Islam, Asia, Africa, the United States.

Anth 5153. Urban Anthropology. (4 cr; prereq 1102 or 5102 or #)
Structure and process in non-Western urban centers; role of rural migrants, relationship of urbanism to political and economic development, role of voluntary associations, adjustment of kinship groups to urban life.

Anth 5154. Anthropology of Colonialism. (4 cr; prereq 1102 or 5102 or #) Raheja
Social, structural, symbolic, and psychological aspects of the societies of colonizers and colonized; emphasis on South Asia, Oceania, and Puerto Rico.

Anth 5157. The Political Discourse of Social Change. (4 cr) Josephides
Tension between tradition and innovation of ideas, techniques, and material development in contexts of rapid social change, especially when local cultures come into contact with outside, politically more forceful ones. Tradition as an already politicized discourse.

Anth 5161. Cultural Semantics. (4 cr; prereq #)
Dunnigan
Language-based approaches to study of cultures.

Anth 5176. Environmental Archaeology. (4 cr; prereq 1101, 3111 or #) Spector
Archaeological and natural scientific approaches to studying past human society: human impact on and use of environment, reconstructing past environmental conditions. Field and lab techniques in association with archaeological research problems.

Anth 5191. Folklore, Power, and Cultural Description. (4 cr; prereq 1102 or 5102 or #) Raheja
Song, oral poetry, story, and other performed speech genres as sites of cultural contestation, in arenas of gender, class, and colonial relations. Politics of expressive forms in contemporary and colonial societies; implications for practice of ethnography.

Anth 5201. Contemporary Perspectives in Anthropology. (4 cr; prereq 1102; required for sr cultural anth majors)
Contemporary theoretical perspectives in anthropological and their historical background. Modernism, reconceptualization resulting from postmodern and feminist critiques of fieldwork and ethnographic writing, and application of these to contemporary American cultural diversity.

Anth 5258. Anthropological Analysis of American Culture. (4 cr; prereq 1102 or 5102 or #) Ingham
Anthropological perspectives on contemporary American culture and society with emphasis on values, family organization, socialization and kinship, education, community integration.

Anth 5301. Advanced Method and Theory in Archaeology. (4 cr; prereq 3111 or #; recommended for anth majors specializing in archaeology) McCorriston
Contemporary theoretical and methodological issues and approaches in archaeology. Projects incorporating theories and methods, including simple computer analysis.

Anth 5305. Studies in Ethnographic Classics. (4 cr) Penn
Intensive studies of notable theoretical and ethnographic works in the past and recent history of anthropology. Topics and works selected yearly.

Anth 5325. Gender and Power in South Asia. (4 cr; prereq 1102, 3261 or 5102 or #) Raheja
Multiple perspectives on gender, power, kinship, and sexuality in South Asian society; theoretical issues this multiplicity poses for ethnographic writing. Textual traditions, folklore, ritual and exchange, politics of everyday life, colonialism, and post-colonialism.

Anth 5331. Culture Theory: An Introduction. (4 cr; prereq jr or sr or grad student or #) Penn
Selected issues in the development of culture theory, e.g., do cultural phenomena have an independent reality, or are they a derived aspect of social systems?

Anth 5392. Philosophical Anthropology. (4 cr; prereq 1102 or 5102) Penn
Survey of traditional problems associated with certain major and broad ranging views on human nature and culture. Variations on these views; specific arguments of relativists, phenomenologists, behaviorists, and others. Recent ethnographic theory.

Anth 5461. North American Indian Architecture. (4 cr, §Arch 5461)
Historic and contemporary principles and theories. Culture, technology, environment, art, and craft of North American Indians in their architecture and settlements.
Anth 5520. Current Issues in Archaeology. (4 cr; prereq 3111 or #)
Discussion/review/analysis of specific theoretical and/or methodological issues in archaeology.

Anth 5524. Archaeological Research Design. (4 cr; prereq #)
Recommended for undergraduate anthropology majors specializing in archaeology who select senior project option.

Anth 5592. History of Archaeology. (4 cr; prereq 12 cr in 3xxx- or 5xxx Anth courses) Gibbon, McCorriston
Survey course emphasizing development of major concepts and research goals.

Anth 5910, 5920. Topics in Anthropology. (Cr ar)
Special courses in all branches of anthropology. Topic, prerequisites, and instructor specified in the Class Schedule.

Anth 5960. Senior Seminar. (4 cr; prereq sr major)
Research seminar. Topics vary according to staff and student interests.

Anth 5970. Directed Readings. (2-4 cr; prereq #, ∆, CLA approval)
Qualified students may register for work on tutorial basis.

Anth 8001, 8002. Foundations of Social and Cultural Anthropology I, II. (3 cr per qtr; prereq anth grad student or #)
Classical and contemporary foundations.

Anth 8003. Foundations of Social and Cultural Anthropology III. (3 cr; prereq anth grad student or #)
Theoretical foundations in contemporary perspective.

Anth 8004. Foundations of Anthropological Archaeology. (3 cr; prereq anth grad student or #)
Theoretical foundations in contemporary perspective.

Anth 8111. Pedagogy. (3 cr; prereq anth grad student) Barlow
Ways of teaching anthropology to undergraduates.
Understanding learning goals and processes; developing discipline-specific skills, teaching materials, a syllabus, written assignments, discussion groups, tests, and a grading system.

Anth 8124. Problems in Archaeology. (3 cr) Gibbon, McCorriston,

Anth 8125. Problems in Linguistic Anthropology. (3 cr) Dunnigan

Anth 8201. Method and Theory in Archaeology. (3 cr) Gibbon, McCorriston, Spector

Anth 8202. Research Methods in Social and Cultural Anthropology. (3 cr; prereq grad major in anth or #)

Anth 8211. Advanced Field Techniques in Archaeology. (3 cr) Gibbon, McCorriston

Anth 8320. Seminar: Social Anthropology. (3 cr)

Anth 8330. Seminar: Economic Anthropology. (3 cr) Gudeman

Anth 8340. Seminar: Political Anthropology. (3 cr) Lipset

Anth 8350. Seminar: Culture and Personality. (3 cr) Ingham

Anth 8370. Seminar: Symbolism. (3 cr) Ingham

Anth 8390. Seminar: Philosophical Anthropology. (3 cr) Penn

Anth 8420. Seminar: Cultural Change. (3 cr) Gerlach, Miller, Dunnigan

Anth 8460. Seminar: Anthropology of Gender. (3 cr) Barlow, Lipset, Raheja

Anth 8510. Seminar: Archaeology. (3 cr) Gibbon, McCorriston

Anth 8810. Seminar: Special Topics. (Cr ar)

Anth 8950. Directed Studies. (Cr ar; prereq #)

Arabic (Arab)1

Professor: Caesar E. Farah

Assistant Professor: Teirab AshShareef, director of graduate studies; Charles Ben Pike

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degree Offered—M.A. (Plan B only).

Curriculum—The program focuses on the Arabic language and the literature and culture of the Arab world.

Prerequisites for Admission—Two years of Arabic (Arab 3103 or equivalent) is required, and a minimum of 16 credits in Arabic literature or culture, 12 credits of which must be at the upper division level.

Special Application Requirements—A short statement of purpose (in Arabic) and three letters of recommendation are required. Students are admitted fall, winter, and spring quarters.

Master’s Degree Requirements—The minimum requirement is 44 credits in addition to one Plan B research paper (nine courses plus 8 credits for the research paper). The coursework must include 28 credits (seven courses) in Arabic literature or culture, including Arab 5001 (4 credits), and two 8xxx seminars (8 credits). The coursework must also include 8 credits

1 No new students will be accepted for the Arabic major during 1996-99.
(2 courses) in related fields outside Arabic depending on the student’s academic goals and subject to the approval of the director of graduate studies. The final examination is an oral defense of the research paper.

Language Requirements—Three years of Arabic (Arab 5103 or equivalent) is required. A reading knowledge of one classical or one modern language appropriate to the student’s academic goals and approved by the director of graduate studies is also required.

For Further Information and Applications—Contact the Arabic Program, Department of Afro-American and African Studies, University of Minnesota, 808 Social Sciences Building, 267 19th Avenue South, Minneapolis, MN 55455 (612/624-9847).

Arab 5001. Introduction to Research in Arabic Studies. (4 cr) AshShareef, Farah, Youssif Survey of most important research bibliographies in Arabic and Islamic studies. Bibliographic references in English and possibly in Arabic if sufficient interest.

Arab 5036. The Religion of Islam. (4 cr, §3036, §MELC 3036, §RelS 3036, §RelS 5036) Farah Evolution of Islam in historical context. Institutions that made for diversity and continuity: traditions, law, and observances of the faith; sectarian movements; philosophical and theological trends; modern developments (reformist, revolutionary, and militant).

Arab 5101, 5102, 5103. Advanced Arabic. (5 cr per qtr; prereq 3101 or # for 5101, 3102 or # for 5102, 3103 or # for 5103) AshShareef Reading, writing, listening, and speaking. Journals, compositions, and two oral presentations.


Arab 5505. Survey: The Middle East. (4 cr, §3505, §Hist 3505, §MELC 3505) Farah Cultures, religions, and scholarly achievements from pre-Islamic times to present.

Arab 5523. The Middle East in World Affairs: The 19th Century. (4 cr, §MELC 5523) Farah Structure of society; cultural and political impact of the West; revivalist and nationalist trends; reformist and separatist movements.

Arab 5545. Islamic Mysticism. (4 cr, §3545, §Hum 3545, §Hum 5545) AshShareef, Farah Rise of Sufism, from asceticism to theosophical mysticism; leading historical personalities, their beliefs and teachings; relationship to Orthodox Islam and non-Muslim mystical movements; concepts and organizations; place of Sufism in modern religious trends.

Arab 5546. Theological and Mystical Doctrines of Islam. (4 cr, §MELC 5546, §RelS 5546) AshShareef, Farah Classical works of scholastics, mystics, jurists, and philosophers; their writings on principal Islamic religious beliefs and institutions. Content analysis, beginning with Qur’an and traditions.

Arab 5730. Proseminar in Middle East History: 16th to 19th Century. (4 cr, §Hist 5730) Farah Topics, which vary quarterly, on Mamluk, Safavid-Qajar, and Ottoman era concerning relations with each other and outside world, including political, diplomatic, and ideological orientations and conflicts; cultural and social trends; commerce; transformations due to Western impact, to secularization, and to modernization and colonial encroachments that shaped new ideological trends and gave rise to nationalisms and Islamic activism.

Arab 5900. Topics: Readings in Arabic Texts. (4 cr per qtr [max 12 cr]; prereq 5103 or #) AshShareef, Farah, Youssif Reading and discussion of selected classical works in Arabic.

Arab 5910. Topics in Arabic Studies. (4 cr) Topics specified in Class Schedule.

Arab 5970. Directed Readings. (Cr ar; prereq #, Δ, CLA approval) AshShareef, Farah, Youssif Special problems for advanced students. Reading and periodic consultations.

Arab 5990. Honors Course: Research. (Cr ar; prereq 5970 or #) AshShareef, Farah, Youssif Individual studies for honors work at advanced level.
Arab 8801. Seminar: Modern Arabic Literature. (4 cr; prereq 5103 or #) AshShareef
In-depth study of single author (e.g., Mahfouz, Adunis, al-Hakim) or single theme (e.g., modern Arabic critical theory, Arabic modernism, free verse movement). Topic specified in Class Schedule. Readings in Arabic and English.

Arab 8802. Seminar: Orientalism. (4 cr) AshShareef

See South Asian and Middle Eastern Studies and Studies in Africa and the African Diaspora (in the Graduate Programs section) and Jewish Studies (in the Related Courses section).

Architecture (Arch)

Professor: Garth C. Rockcastle, head; Julia W. Robinson, director of graduate studies; Roger D. Clemence; Dennis Grebner; Lance LaVine; Roger B. Martin; William R. Morrish; Leon Satkowski; James E. Stageberg

Adjunct Professor: Dale Mulfinger; John G. Rauma; Milo H. Thompson; Duane E. Thorbeck

Associate Professor: Lee B. Anderson; Gunter Dittmar; Robert D. Sykes; J. Stephen Weeks

Adjunct Associate Professor: Bruno M. Franck; Thomas A. Meyer; Lee Tollefson

Assistant Professor: Mary M. Guzowski; Cynthia Jara; Andrzej Piotrowski; Katherine M. Solomonson

Adjunct Assistant Professor: Ralph K. Nelson; Bruce A. Parker; Lars H. Peterssen; Timothy G. Quigley; Todd J. Rhoades; Jeff Scherer; Julie V. Snow

Lecturer: William A. Blanski; Timothy J. Fuller; Vincent James; Gary L. Johnson; Janis LaDouceur; Robert C. Mack; Mark Searls; Mark S. Wentzell

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degree Offered—M.Arch.

Curriculum—The three-year professional curriculum accredited by the National Architectural Accreditation Board (NAAB) consists of a minimum of 131 graduate credits, including the thesis. Because the admitted student will already have a broad educational background and will have completed fundamental courses, the program focus is on professional and disciplinary coursework, including required and elective lecture, seminar, and design studio courses. For most students, the first-year integrated curriculum is followed by two years of less-structured coursework that culminates in a thesis.

Prerequisites for Admission—Applicants to the M.Arch. program must hold a baccalaureate degree and must have completed the equivalent of at least a year of preparatory work, including coursework in calculus, physics, architectural history, drawing, and architectural design.

Students are expected to have basic computer skills before beginning the M.Arch. program, including familiarity with either Macintosh or Windows operating systems, word processing, basic drawing or painting programs, and use of e-mail. Intermediate classes in computer methods in architecture (Arch 5371, 5372, 5373) are part of degree requirements during the first year; advanced classes (Arch 5374, 5375) are required during the second year.

In exceptional circumstances, students who have a nonprofessional baccalaureate degree in architecture and have completed the equivalent of the first year of the M.Arch. program requirements may qualify for advanced placement in the program. Depending on their academic record, their previous coursework, and their portfolio review, these students could complete the M.Arch. degree in a minimum of two years.

A small number of students who hold a Bachelor of Architecture professional degree (B.Arch.) are admitted each year to pursue a second professional degree. Admission is based on the quality of the previous academic work and the quality of the portfolio. Depending on their background, these students could complete the M.Arch. degree in a minimum of four quarters.

For more complete information, please see the College of Architecture and Landscape Architecture Bulletin and contact the Department of Architecture.

Special Application Requirements—Admission to the M.Arch. program is highly competitive. In addition to meeting Graduate School application requirements, students applying to the program must demonstrate design talent in a portfolio and must submit all of the following: a one-page statement of interest, transcripts of all coursework, three faculty recommendations, a recent paper written in English, and Graduate Record Examination scores. The portfolio should be a notebook no larger than 10" x 12" (other portfolio formats will be rejected). International students must submit scores from the Test of
English as a Foreign Language (TOEFL) or the Michigan English Language Assessment Battery (MELAB). Priority for admission and financial aid is given to students who apply by January 10.

Degree Requirements—The three-year, 131-credit M.Arch. program is a Plan A program consisting of required and elective courses distributed as follows: 8 each in design studio and technology; 2 each in history, theory, and professional practice; 5 one-credit courses in computer-aided design; and 1 each in urban design and visual communication; and 16 thesis credits.

Students who hold a B.Arch. degree (i.e., those who seek a post-professional degree) must take a minimum of 44 graduate credits in an individually developed program of study. Students may choose either Plan A or Plan B: the 44 credits include 16 thesis credits for Plan A and two or three major papers for Plan B.

Language Requirements—None.

Minor Requirements for Students Majoring in Other Fields—Students who want to minor in architecture should contact the director of graduate studies.

For Further Information and Applications—Contact the Department of Architecture, University of Minnesota, 110 Architecture Building, 89 Church Street S.E., Minneapolis, MN 55455 (612/624-7866; fax 612/624-5743; e-mail drasi001@tc.umn.edu).

**Note**—See also the program in Landscape Architecture.

**Arch 8777. Thesis Credits: Master's.** (16 cr required; Plan A only)

**Design**

**Arch 5241. Principles of Design Programming.** (4 cr, §5292, §5391; prereq 5111 or 8253, Arch or grad Arch major; A-F only)

Concepts and techniques of architectural programming, including space and activity analysis, site selection, precedent study, code review, appropriate technology identification, hypothesis formulation and evaluation. Emphasizes conceptual development, research, and analytic drawing.

**Arch 5250. Topics in Architecture Design.** (1-6 cr; prereq 5283 or grad Arch major)

**Arch 8250. Topics in Design.** (2-4 cr; prereq 1st-yr design or 8101 or #; A-F only)

**Arch 8251, 8252, 8253.* Graduate Architectural Design I.** (6 cr per qtr; prereq Arch grad student; A-F only)

Problems involving design as a creative inquiry; individual and collaborative effort.

**Arch 8254, 8255, 8256.* Graduate Architectural Design II.** (6 cr per qtr; prereq Arch grad student; A-F only)

Comprehensive architectural problems; in-depth exploration of fundamental architectural issues; individual and collaborative effort.

**Arch 8257, 8258. Graduate Architectural Design III.** (6 cr per qtr; prereq Arch grad student)

Case studies in architecture exploring societal issues in architecture and/or urban design; project resolution emphasized; individual and collaborative effort.

**Representation and Communication**

**Arch 5309. Representation in Architecture.** (4 cr, §LA 5309; prereq 3311 or LA 3311, Arch or Land Arch professional candidate) Piotrowski

Historical and theoretical study of representation and its depiction in architecture and landscape architecture. Media, conventions, and techniques used to visualize or reproduce architecture and how they affect production of ideas.

**Arch 5313. Visual Communication Techniques in Architecture.** (4 cr, §3033; prereq 3311 or #) Grebner

Professional delineation, exploration and use of variety of presentation and study techniques, methods/media investigation, modern techniques. Intended primarily for more advanced students in architectural design.

**Arch 5321. Architecture in Watercolor.** (4 cr, §3110; prereq Arch/BED major, 3311 or #)

Watercolor as representation and communication in design process. Foundation principles, techniques, medium, tools, and materials. Color relationships, mixing, composition, and applications to design.

**Arch 5350. Topics in Architectural Representation.** (Cr ar; prereq Arch or grad Arch major or #; A-F only)

Theory and practice of visual representation.

**Arch 5371, 5372, 5373. Intermediate Computer Methods in Architecture.** (1 cr per qtr; prereq grad Arch major, ¶8251 or ¶8252 or ¶8253, basic computer graphics course)

Drawing and painting, 3-D modeling, image and video editing, desktop publishing.

**Arch 5374, 5375. Advanced Computer Methods in Architecture.** (1 cr; prereq grad Arch major, 5371, 5372, 5373, ¶8254 or ¶8255)

CAD, 3-D modeling, and rendering.

**Arch 5381. Introduction to Computer Aids for Architectural Design.** (4 cr; prereq Arch/BED or Land Arch major) Anderson, staff

Document design, 2-D drawing, 3-D modeling, animation, printing, and plotting. Electronic networking and communication.
Arch 5382. Computer Aids for Architectural Design. (4 cr; prereq Arch/BED or Land Arch major) Anderson, staff
Database management, spreadsheet analysis, land-use analysis, 2-D/3-D CAD, image manipulation, project management.

Arch 5383. Advanced CAD Visualization for Architecture. (4 cr; prereq Arch/BED or Land Arch major) Anderson, staff
Solid modeling, photo-realistic imaging, animation, video editing and recording.

Arch 8350. Advanced Topics in Representation. (2-4 cr; prereq 1st-yr design or 8101 or #)
Theory and practice of visual representation in architecture.

History
Arch 5410. Topics in Architectural History. (Cr ar; prereq #)
Advanced study. Readings, research, seminar reports.

Arch 5417. Asian Architecture. (4 cr, §5057; prereq Arch major or #: A-F only)
Topics from history of architecture and urban design in West, South, and East Asia.

Arch 5422. Early Medieval Architecture. (4 cr, §5052; prereq 3411 or Arch major or #: 3 lect, 1 seminar hrs per wk; A-F only)
History of the development of architecture and urban design during early Christian, Byzantine, Islamic, Carolingian, and Romanesque periods in the Near East and Western Europe until 1150 A.D.

Arch 5423. Gothic Architecture. (4 cr, §5053; prereq 3411 or Arch major or #: 3 lect, 1 seminar hrs per wk; A-F only)
History of development of architecture and urban design in Western Europe from 1150 until 1400 A.D.

Arch 5424. Renaissance Architecture in Italy. (4 cr, §5054; prereq 3411, Arch major or #: 3 lect, 1 seminar hrs per wk; A-F only) Satkowski
History of architecture and urban design in Italy, 1400-1600 A.D. Emphasis on major figures (Brunelleschi, Alberti, Bramante, Palladio) and evolution of major cities (Rome, Florence, Venice).

Arch 5425. Baroque Architecture in Italy. (4 cr, §5064; prereq Arch major or #: 3 lect, 1 seminar hrs per wk) Satkowski
Architecture and urban design in Italy, 1600-1750 A.D. Emphasis on major figures (Bernini, Borromini, Cortona, Guarini) and evolution of major cities (Rome, Turin).

Arch 5426. Architecture and Nature, 1500-1750. (4 cr; prereq 3411, 3412 or #:) Satkowski
History of interaction between architecture and nature in Italy, England, and France in 16th and 17th centuries. Major monuments and their relationship to theories of architecture and gardening; urban and rural life.

Arch 5431. Eighteenth-Century Architecture and the Enlightenment. (4 cr, §5055; prereq 3412 or Arch major or #: 2 lect hrs per wk; A-F only) Solomonson
Architecture, urban planning, and garden design in Europe, 1700-1850.

Arch 5432. Modern Architecture. (4 cr, §5056; prereq 3412 or Arch major or #: 3 lect, 1 seminar hrs per wk; A-F only) Solomonson
Architecture and urban design from early 19th-century sources in Europe and America to World War II.

Arch 5433. American Architecture and Urbanism to 1870. (4 cr; prereq 3412 or #) Solomonson
American vernacular landscape and architect-designed structures and spaces, from colonization through Civil War. Topics range from colonial architecture in Southwest and New England to development of an expression of national identity, from Southern plantations and Midwestern farms to architecture of industrial city.

Arch 5434. Contemporary Architecture. (4 cr, §5061; prereq Arch major or #: 3 lect, 1 seminar hrs per wk) Solomonson
Developments, theories, movements, and trends in architecture and urban design from World War II to the present.

Arch 5439. History in Architectural Theory. (4 cr, §5067; prereq 3412 or #:) Satkowski, Solomonson
From antiquity to 20th century.

Arch 8410. Topics in History. (2-4 cr; prereq 1st-yr design or 8101 or #: A-F only)

Theory and Criticism
Arch 5401. Principles of Design Theory. (4 cr; prereq grad Arch or #: A-F only) Jara
Principles of design and their instrumentation. How and why architecture theory is generated. Types and significance of formal analysis. Theoretical positions and modes of criticism.

Arch 5450. Topics in Architectural Theory. (Cr ar; prereq Arch or grad Arch major or #: A-F only)
Topics in theory and criticism.

Arch 5451. Architecture: Theory and Philosophy. (4 cr; prereq BArch major or MArch major or #: A-F only) Dittmar
Architecture as a discipline: its nature, role, purpose, and meaning within a general philosophical and theoretical framework. Paradigms through which architecture defines itself and derives its mode of operation.

Arch 5452. Architecture: Thought and Design Process. (4 cr; prereq BArch major or MArch major or #: offered when feasible; A-F only) Dittmar
Fundamental, constituent elements of architectural form and order; inherent tectonic, phenomenal, experiential, and symbolic characteristics of these elements and their potential and implications for creation and structure of meaningful, human place(s).
Arch 5454. Semiotics and Deconstruction in Architecture. (4 cr; prereq 5401, grad Arch major or #; A-F only) Rockcastle
Expressive and cultural dimensions of architecture, especially as they relate to linguistic analogies, knowledge production, and contemporary philosophy, including broad critical perspective of architectural discussion and argumentation which addresses current aspects of the debates.

Arch 5455. Typology and Architecture: Theories of Analysis and Synthesis. (4 cr; prereq 5401, grad Arch major or #; A-F only) Rockcastle
Theoretical traditions and development of the use of typology in architecture. Historical works of Laugier, Quatremerd de Quincy, Viollet-Le-duc, Ledoux, Durand, Camillo Sitte, and Le Corbusier. Recent developments and theoretical positions of the “neorationalist” and “contextualist” arguments for contemporary applications of idea of type.

Arch 5458. Architecture and Culture. (4 cr; prereq 3412, Arch major or #) Robinson
Architecture as a cultural medium; relation between architecture, people, and culture; physiological and symbolic messages; relation between research findings and design and between vernacular and high-style architecture; reception theory in architecture; cultural critique and cultural change; implications for architectural practice.

Arch 5461. North American Indian Architecture. (4 cr, §Anth 5461)
Historic and contemporary principles and theories. Culture, technology, environment, art, and craft of North American Indians in their architecture and settlements.

Arch 8450. Topics in Theory. (2-4 cr; prereq 8101 or 8401 or #; A-F only)

Technology
Arch 5511. Construction Materials in Architecture. (4 cr, §3061; prereq grad Arch major or #; A-F only)
Study and analysis of building materials, assemblies, and operations affecting construction of building designs. Considerations of materials performance, durability, workmanship, and compatibility in detailing of masonry, wood, and metal framing design. Examination of building partner relationships and their implications for materials, elements, components, and assembly selections.

Arch 5512. Historic Building Conservation. (4 cr, §5142; prereq Arch major or #; 2 lect, 2 lab hrs per wk) Mack
Historic building systems and materials and methods for their conservation; introduction to use of contemporary systems in historic buildings.

Arch 5521. Building Methods in Architecture. (4 cr, §3062; prereq BArch or BED or MArch student or #; A-F only) Weeks
Analysis of architectural materials, building products, and construction operations related to structural and enclosure systems in design and detailing of noncombustible and fire-resistant constructions. Emphasizes concrete systems and structural steel frames and composite structures. Application of legal constraints and regulations, cost controls, and life safety factors in preparation of construction documents, specifications, and drawings.

Arch 5522. Techniques and Form. (4 cr per qtr, §5116; prereq 5511, 5571, grad Arch major or #; A-F only) Rauma
Form as interface between programmatic requirements for environmental change and physical means available to the architect: social and cultural paradigms and physical environment; search for organizational principles of architectural form; geometrical order, properties of materials, distribution of forces, construction techniques, accommodation of building infrastructure.

Arch 5523. Light Frame Buildings: Design for Energy Efficiency, Health, and Durability. (4 cr; prereq 5521, 5541, grad Arch major or #) Weeks
Design principles and construction methods for resolution of problems of comfort, energy efficiency, and durability. Problems integrating building systems and envelope assemblies with design solutions for moisture, infiltration, indoor air quality, and material degradations.

Arch 5525. Design in Masonry. (4 cr; prereq grad Arch major, 5521, 8253 or #)
Design principles, construction methods, and document production for masonry structures.

Arch 5531. Lighting and Acoustic Design. (4 cr, §3065; prereq BArch or BED or MArch student or #)
Principles of daylighting, electric lighting, and acoustic design in architecture. Relation between luminous and acoustic environments, human comfort, and architectural experience. Analytic methods, design process, and modeling of daylighting.

Arch 5539. Daylighting and Architectural Design. (4 cr, §3066, §5959; prereq 5551, grad Arch major or #; A-F only) Guzowski
Principles, strategies, energy and environmental issues, psychology of light and color, and integration of electric lighting. Design projects investigate qualitative and quantitative issues through drawing, physical models, and photometric analyses.

Arch 5541. Thermal Design in Architecture. (4 cr, §3064; prereq BArch or BED or MArch student or #)
Thermal and climatic issues in design of small and midsize buildings. Built and mechanical means to modify climate. Evaluation of design techniques in terms of potential impacts on energy use, environment, and architectural meaning.

Arch 5542. Building Energy Systems. (4 cr, §5966; prereq 5541, grad Arch major or #; A-F only)
Through case studies, conceptual understanding of functions of building mechanical systems and their integration with other building components. Residential and commercial HVAC systems, alternative energy sources, energy efficiency, and structural implications of mechanical systems, indoor air quality, and environmental control strategies.

Arch 5543. Climate and Architecture. (4 cr, §5957; prereq 5541, grad Arch major or #; A-F only)
Role of climate in architectural design and theory. Environmental and energy implications at site, building, and component scales. Design projects explore graphic analysis, physical modeling, and quantitative assessment.
Arch 5550. **Topics in Architecture Technology**. (Cr ar; prereq Arch or grad Arch major or #) Construction, environmental management, energy performance, lighting, or materials.

Arch 8550. **Topics in Technology**. (2-4 cr; prereq 5535, 5541, 5551 or 8101 or #)

**Structures**

Arch 5572. **Theory and Design of Architectural Structures: Space, Span, Order**. (4 cr; prereq 5511, 5521, BArch major or MArch major or #) Principles and concepts of historic and modern architectural structures; interrelated nature of design and structure. Structural elements, systems, materials, and technical principles. Lectures, construction exercises, graphical analyses, and lab modeling.

Arch 5573. **Architectural Structures I: Wood and Steel Construction**. (4 cr; prereq BArch major or MArch major or #) Principles of structural behavior, analysis, and design in wood and steel materials and systems. Emphasizes whole building design and individual structural elements. Conceptual design strategies: example studies; estimating loads; wall, beam, and column design; connection design; performance problems. Case studies, exercises, design problems, physical models, computer and quantitative analysis.

Arch 5574. **Architectural Structures II: Concrete and Masonry Construction**. (4 cr; prereq BArch major or MArch major or #) Principles of structural behavior, analysis, and design in reinforced concrete framing systems and structural masonry constructions. Emphasizes whole building design and individual structural elements. Conceptual design strategies: properties of materials; estimating loads; footing, wall, beam, slab, and column design; connection design; performance problems. Case studies, exercises, design problems, physical models, computer and quantitative analysis.

Arch 5541. **Historic Preservation Process**. (4 cr, §5141; prereq Arch major or #; 4 lect hrs per wk) Mack Philosophy and theory of historic preservation, historic origins, descriptive analysis of buildings, building documentation, technology of building conservation, historical archaeology, economic considerations, preservation law, guidelines for preservation, neighborhood conservation, international preservation, and case studies of representative preservation projects.

Arch 5513. **Historic Building Research and Documentation**. (4 cr, §5143; prereq Arch major or #; 2 lect, 2 lab hrs per wk) Mack Philosophy, theory, and methods of historic building research, descriptive analysis of buildings, building documentation, historical archaeology, and architectural taxonomy.

Arch 5621. **Professional Practice in Architecture**. (4 cr, §5126; prereq Arch or grad Arch major or #; Scherer) Legal, ethical, business, and practical requirements to practice architecture. Contemporary and historical models of contract formation, business principles, accounting, project management, and design services marketing.

Arch 5631. **Legal Contracts in Architecture I**. (4 cr, §5127; prereq 3093 or #; A-F only) Legal subject matter relevant to work of architects and design professionals.

Arch 5650. **Topics in Architectural Practice**. (Cr ar; prereq Arch major, 5621 or #) Topics in architectural practices, methods of design production, marketing, operation, and relationships between clients, architects, and society.

Arch 8650. **Topics in Architectural Practice**. (2-4 cr; prereq 1st-yr design or 8101 or #; A-F only)

**Urban Design**

Arch 5711. **Design Principles of the Urban Landscape**. (4 cr, §5137; prereq Arch/BED major or #; Morrish, staff) Art and design of making city, neighborhood, and development plans. Public policies, planning tools and process, and physical models for design professionals and private and civic institutions to shape physical environment.

Arch 5724. **The Meanings of Place**. (4 cr; prereq #; A-F only) Clemence Analyzing meanings and messages of surroundings. What present-day environments reveal about the past; links between sense of place and feelings of well-being. Twin Cities central districts and selected neighborhoods and other settings within and outside Minnesota.

Arch 5750. **Topics in Urban Design**. (Cr ar; prereq 5711, grad Arch major for #; A-F only) Theory and practice of urban design.

Arch 8750. **Topics in Urban Design**. (2-4 cr; prereq 1st-yr design or 8101 or #)

**General**

Arch 8101. **Seminar: Subjects and Methods in Architecture**. (2 cr)

**Art (ArtS)**

**Professor:** Wayne E. Potratz (sculpture), chair; Curtis C. Hoard (ceramics), director of graduate studies; Karl Bethke (printmaking); Diane Katsiaficas (drawing and painting); Clarence E. Morgan (drawing and painting); Mark Pharis (ceramics); Thomas A. Rose (sculpture)

**Associate Professor:** Guy A. Baldwin (sculpture); Thomas R. Cowette (drawing and painting); David L. Feinberg (drawing and painting); Lynn A. Gray (drawing and painting); Gary L. Hallman (photography); James V. Henkel (photography); Jerald Krepps (printmaking and papermaking); Thomas J. Lane
Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degree Offered—M.F.A. (Plan B).

Curriculum—The master of fine arts program places major emphasis on studio work of high quality. The program normally takes three years to complete. Most students concentrate in one area of study, but may take courses in studio areas outside the major concentration. The following areas of concentration are available: ceramics; drawing and painting; photography; printmaking; and sculpture.

Prerequisites for Admission—A bachelor of fine arts or its equivalent, or an undergraduate major in studio arts, is required.

Special Application Requirements—All applications for the M.F.A. are reviewed once a year for fall quarter entry. Applicants must submit from 10 to 20 color slides of work completed in their chosen medium to the director of graduate studies in art. Printmaking applicants must submit a minimum of 4 original prints in addition to slides. Photography applicants may submit a minimum of 10 finished prints. Three letters of recommendation are required from all applicants.

Completed Graduate School applications (including official transcripts) must reach the Graduate School by January 5. Slides, letters of recommendation, the statement of purpose, along with a second set of transcripts and other supporting materials, must reach the director of graduate studies in the Department of Art also by January 5.

Degree Requirements—Students must complete a minimum of 75 graduate credits, at least 45 of which must be earned at the University of Minnesota. Additional credits may be required by the graduate faculty. Upon completing the required credits, students must present an acceptable thesis exhibition accompanied by a supporting paper. The related fields requirement may be satisfied by completing either (a) 15 credits in art history or (b) 8 credits in art history plus 8 credits in another field outside of studio arts. The individual program, although designed by the student, must be approved by the adviser and director of graduate studies. Final oral examinations are taken after the thesis exhibition and the supporting paper are completed.

Language Requirements—None.

Minor Requirements for Students Majoring in Other Fields—A minor in art consists of a minimum of 16 credits for the M.A. degree, chosen in consultation with the director of graduate studies, and a minimum of 18 credits for the Ph.D. degree, as approved by the director of graduate studies. The minor must include ArtS 8400.

For Further Information and Applications—Contact the Department of Art, University of Minnesota, 208 Art Building, 216 21st Avenue South, Minneapolis, MN 55455 (612/625-8096 or 612/625-1848; fax 625-7881; http://artdept.umn.edu).

Drawing and Painting

ArtS 5110. Drawing. (4 cr per qtr [max 16 cr]; prereq 12 cr of 3110 or #) Cowette, Feinberg, Gray, Katsiaficas, Lyon, Morgan, Roode
Drawing in all mediums from life.

ArtS 5120. Painting. (4 cr per qtr [max 16 cr]; prereq 12 cr of 3120 or #) Cowette, Feinberg, Katsiaficas, Lyon, Morgan, Roode
Various media. Individual problems.

ArtS 5123. Dimensional Painting. (4 cr; prereq 3123 or #) Feinberg
Two-dimensional concepts combined with three-dimensional form.

ArtS 5141. Interpreting the Present. (4 cr; prereq 3141 or #; offered alt yrs) Feinberg
Advanced drawing focuses on search for personal visual form and content as inspired by specific sites. Field visits to area locations to stimulate development of new marks and symbols to interpret responses into visual language of drawing.

ArtS 5160. Drawing and Electronic Media. (4 cr per qtr [max 16 cr]; prereq 12 cr of 3160) Katsiaficas
Expands traditional drawing methods and materials with use of electronic technology. Access to computers, scanner, and color copier to aid in image making.

ArtS 8110. Drawing. (4 cr per qtr [max 12 cr]) Cowette, Feinberg, Gray, Katsiaficas, Lyon, Morgan, Roode

ArtS 8120. Painting. (4 cr per qtr [max 24 cr])
Cowette, Feinberg, Katsiaficas, Lyon, Morgan, Roode
**Sculpture**

**ArtS 5310. Sculpture: Direct Metal.** (4 cr per qtr [max 16 cr]; prereq 3301) Baldwin
Advanced work in welding and brazing; metal construction.

**ArtS 5320. Sculpture: Spatial Projects and Problems.** (4 cr per qtr [max 16 cr]; prereq 3302) Rose
Physical relationships between objects, elements, and materials and how these can be manipulated to affect space.

**ArtS 5330. Sculpture: Cast Metal.** (4 cr per qtr [max 16 cr]; prereq 3303) Potratz
Lost-wax and sand casting in bronze, aluminum, iron.

**ArtS 5331. Primitive and Low-Tech Approaches to Metal Casting.** (4 cr; prereq 3331 or #) Potratz
Metal casting of sculpture using techniques and materials derived from Meso-American, African, Indian, Chinese, and Japanese sources. Design and construction of primitive molds, tools, and furnaces.

**ArtS 5340. Sculpture: Wood and Stone.** (4 cr per qtr [max 16 cr]; prereq 3304) Lucey
Examination of possibilities of wood and stone with emphasis on construction, assemblage, and arrangement.

**ArtS 5350. Sculpture: Kinetics.** (4 cr per qtr [max 16 cr]; prereq 3305) Baldwin
Constructions, kinetics, electronics.

**ArtS 5370. Sculpture: Modeling and Casting.** (4 cr [max 16 cr]; prereq 3307) Baldwin, Potratz
Modeling with clay and other materials from human figure and other subjects; moldmaking with plaster and rubber; casting in plaster and other materials.

**ArtS 8310. Sculpture: Direct Metal.** (4 cr per qtr [max 12 cr]) Baldwin

**ArtS 8320. Sculpture: Spatial Projects and Problems.** (4 cr per qtr [max 12 cr]) Rose

**ArtS 8340. Sculpture: Wood and Stone.** (4 cr per qtr [max 12 cr]) Lucey

**ArtS 8350. Sculpture: Kinetics.** (4 cr per qtr [max 12 cr]) Baldwin

**ArtS 8370. Sculpture: Modeling and Casting.** (4 cr [max 12 cr]; prereq #) Potratz

**Printmaking**

**ArtS 5510. Printmaking: Intaglio.** (4 cr per qtr [max 16 cr]; prereq 12 cr of 3510 or #) Bethke, Krepps
Color processes, intaglio, and combined techniques.

**ArtS 5520. Printmaking: Lithography.** (4 cr per qtr [max 16 cr]; prereq 12 cr of 3520 or #) Krepps
Specialized work in color printing and planographic techniques.

**ArtS 5530. Printmaking: Relief.** (4 cr per qtr [max 16 cr]; prereq 12 cr of 3530 or #) Bethke
Relief processes. Letter press and combined techniques.

**ArtS 5540. Printmaking: Screen.** (4 cr per qtr [max 16 cr]; prereq 12 cr of 3540 or #) Bethke
Screen processes and combined techniques.

**ArtS 5550. Printmaking: Expanded Approaches/Monoprints.** (4 cr per qtr [max 16 cr]; prereq 12 cr of 3550 or #) Krepps
Advanced, contemporary approach to printmaking that investigates variations of, departures from, and alternatives to traditional print processes and results. Focuses on immediacy and flexibility of monoprint in conjunction with handmade paper and other print processes.

**ArtS 8510. Printmaking.** (4 cr per qtr [max 36 cr]) Bethke, Krepps

**Photography**

**ArtS 5710. Photography.** (4 cr per qtr [max 16 cr]; prereq 12 cr of 3710 or #) Hallman, Henkel
Continued individual work in photographic controls, processes; related photosensitive media.

**ArtS 8710. Photography.** (4 cr per qtr [max 24 cr]) Hallman, Henkel

**Ceramics**

**ArtS 5810. Ceramics.** (4 cr per qtr [max 16 cr]; prereq 12 cr of 3810 or #) Hoard, Lane, Pharis
Aesthetic awareness and development; techniques and materials.

**ArtS 5811. Mold-Made Ceramics.** (4 cr; prereq 3811 or #) Lane
Advanced mold-forming ceramics. Plaster mold-making techniques. Conceptual and aesthetic issues applied to making of ceramic objects.

**ArtS 5821. Ceramic Materials Analysis.** (4 cr; prereq 1811, 1812, 8 cr of 3810) Pharis
Glaze analysis and calculation; glaze types, formulation, materials. Procedures for investigation of unidentified ceramic materials.

**ArtS 8810. Ceramics.** (4 cr per qtr [max 24 cr]) Hoard, Lane, Pharis

**Advanced Entrance Courses**

The following are courses in which students from one area of concentration bring skills and insights into another area for application to new materials, processes, and approaches.

**All courses:** (4 cr per qtr [max 16 cr per area]; prereq #, ∆)

**ArtS 5190. Drawing and Painting**

**ArtS 5390. Sculpture**

**ArtS 5590. Printmaking**

**ArtS 5790. Photography**

**ArtS 5890. Ceramics and Glass**
General Courses

ArtS 5360. Performance Art. (4 cr per qtr [max 16 cr]; prereq 3306) Lucey
Development of individual performance artworks and research on pioneers of this art form.

ArtS 5430. Paper: Pulp to Plastic Expression. (4 cr per qtr [max 16 cr]; prereq 12 cr of 3430 or #) Krepps
Creative and traditional approaches to papermaking.

ArtS 5830. Glass: Neon. (4 cr per qtr [max 16 cr]; prereq 12 cr of 3830) Lane
Advanced conceptual and aesthetic applications of neon tube manipulation; applications to other media.

ArtS 5970. Directed Studies. (1-5 cr [max 12 cr]; prereq 24 cr studio arts, #, ∆, CLA approval)

ArtS 8410. Post Studio. (4 cr; prereq ArtS grad student, 16 8xxx cr or #)
Conceptual concern and aesthetic awareness across media boundaries. Critical and theoretical inquiry into individual graduate projects from diverse media areas. Readings, projects, and topics depend on instructor and student interests.

Seminars

ArtS 5401. Art from the Source. (4 cr; prereq 8 cr ArtS; offered alt yrs) Feinberg
Field trips to current area exhibitions and artists’ studios as basis for discussion and hands-on visual projects. Exposure to diversity of artistic interpretations; investigation of origins of differences in perception.

ArtS 8100. Twentieth-Century Art Theories in Painting. (2 cr; required of painting majors)

ArtS 8300. Twentieth-Century Art Theories in Sculpture. (2 cr per qtr [6 cr required]; MFA candidate in studio arts or #)

ArtS 8400. Concepts in Contemporary Art. (required) (4 cr; prereq ArtS grad student or #)

ArtS 8402. Presentation and Instruction. (4 cr; prereq MFA candidate or #)
Workshop on presenting workshops, lectures, instructional activities, and professional discourse.

Art Education

See Curriculum and Instruction.

Art History (ArtH)

Professor: Frederick M. Asher, chair; Frederick A. Cooper; Karal Ann Marling; Sheila J. McNally; Robert J. Poor; Leon G. Satkowski (architecture); Gabriel P. Weisberg

Associate Professor: Catherine E. B. Asher, director of graduate studies; W. John Archer (humanities); Timothy T. Blade (design, housing, and apparel); Robert B. Silberman; John W. Steyaert; Michael W. Stoughton

Assistant Professor: Katherine M. Solomonson (architecture)

Other: Lyndel I. King (director, Weisman Art Museum); Patricia McDonnell (associate curator, Weisman Art Museum)

Adjunct Faculty: Robert D. Jacobsen (Minneapolis Institute of Arts); Bruce L. Jenkins (Walker Art Center); Evan M. Maurer (Minneapolis Institute of Arts)

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.A. (Plan B only) and Ph.D.

Curriculum—Areas of specialization (all of the following pertain to the M.A.; those with an asterisk also pertain to the Ph.D.): *American art, architecture, and popular culture; Baroque art; *East Asian art and Bronze Age archaeology; *film and photography studies; Greek and Roman art and archaeology; *Islamic art and architecture; Italian Renaissance and mannerist art; Late Gothic and northern Renaissance art; *nineteenth- and twentieth-century art; *South Asian art and architecture.

Prerequisites for Admission—For the M.A. program, a bachelor’s degree is required, preferably in art history or a closely related field. Ability and scholarly promise must be demonstrated by a past record of academic excellence. For the Ph.D. program, an M.A. degree in art history or in a field closely related to the chosen area of specialization is required, as well as coursework or other experience indicating substantial background in art historical methods and knowledge.

Special Application Requirements—For the M.A. program: results from the Graduate Record Examination (GRE) General Test, at least one substantial research paper in art history, and three letters of recommendation from persons well acquainted with the applicant’s research and writing skills. In addition, M.A. applicants must provide a detailed statement describing previous experience and academic training as related to the projected course of study and academic goals. For the Ph.D. program: results from the GRE General Test, an M.A. thesis or a minimum of two substantial M.A. papers in art history, and three letters of recommendation from persons well acquainted with the applicant’s research and writing skills. In addition, Ph.D. applicants must provide a statement describing previous experience and academic training as related to the projected course of study and academic goals. Ph.D. candidates are urged to contact the director of graduate studies before application.
Applications for the Ph.D. program (if not previously enrolled in the department) and M.A. program are reviewed in January for admission in the fall quarter only. For both of these, the application form, statement of purpose, official transcripts, and official GRE scores must reach the Graduate School by early in January (contact the Department of Art History for the precise date); duplicates of these materials, as well as the three letters of recommendation and research paper(s), must reach the department by the same deadline. Internal Ph.D. applicants should contact the department for details and deadlines. All applications for financial aid (M.A. and Ph.D.) are due on the same date in early January as the applications for admission.

Master’s Degree Requirements—A minimum of 44 course credits (about eleven courses) is required, including at least four 8xxx seminars in art history. A minimum of 28 course credits must be art historical in content and drawn from courses in at least three of the following areas: ancient, medieval, renaissance/baroque, modern, East Asian, South Asian, and Islamic. Of these, three courses must be in an area of primary concentration, two courses in an area of secondary concentration, and one course in a third area. Students focusing on western art must take at least one course in Asian/Islamic art, while students focusing on Asian/Islamic art must take at least one course in western art. In addition, students must take 8 credits in courses not art historical in content. Two Plan B papers are required, the first of which should be completed by the end of the first year of full-time study. The final M.A. examination is written during the sixth quarter of full-time work.

Doctoral Degree Requirements—The Ph.D. program is designed by the student in consultation with the faculty adviser and other faculty members in or outside the department in related areas of interest. Coursework, including credits accepted from the M.A. degree, should total no fewer than 70 credits. Of these, at least 24 credits must be in an area of primary concentration and 12 credits in an area of secondary concentration; a minimum of 18 credits must be in courses not art historical in content. In addition, 36 doctoral thesis credits are required.

Language Requirements—For the M.A. degree, students must attain reading proficiency in a second language directly related to their course of study by no later than the third quarter of residence. For the Ph.D., reading proficiency of two second languages directly related to their course of study is required. Students should contact the director of graduate studies for details.

Minor Requirements for Students Majoring in Other Fields—For an M.A. degree, a minimum of 16 graduate credits in art history is required for a designated minor. For a Ph.D. degree, the Graduate School requirement of a minimum of 18 graduate credits in art history is necessary for a designated minor.

For Further Information and Applications—Contact the Department of Art History, University of Minnesota, 107 Jones Hall, 27 Pleasant Street S.E., Minneapolis, MN 55455 (612/624-0847 or 612/624-4500; fax 612/626-8679; e-mail arthist@tc.umn.edu; http://www.umn.edu/arthist).

ArtH 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)
ArtH 8888. Thesis Credits: Doctoral. (36 cr required)
ArtH 5055. Eighteenth-Century Architecture and the Enlightenment. (4 cr, §Arch 5055; prereq Arch 1021 or #) Satkowski, Solomonson
Architecture, urban planning, and garden design in Europe, 1770-1850.
ArtH 5102. Classical Greek Art. (5 cr, §Clas 5102) McNally
Architecture, sculpture, and painting in Greece from Persian Wars to conquests of Alexander.
ArtH 5104. Roman Architecture. (5 cr, §Clas 5104; prereq jr or sr or #) Cooper, McNally
Buildings in Rome and the empire from the 5th century B.C. to the 4th century A.D. Major archaeological sites.
ArtH 5105. Roman Painting and Mosaics. (5 cr, §Clas 5105; prereq jr or sr or #) McNally
Roman painting and mosaics, specific problems; sites such as Pompeii and Antioch.
ArtH 5106. Greek Painting. (5 cr, §Clas 5106; prereq jr or sr or #; offered every 3rd yr) McNally
Research and analysis in classical art as applied to study of vases; original objects and sources.
ArtH 5107. Roman Sculpture. (4 cr, §Clas 5107; prereq jr or sr or #) Cooper, McNally
Sculpture from Rome and its provinces from the 1st century B.C. to the 4th century A.D.; the role of sculpture in Roman politics and religion.
ArtH 5108. Greek Architecture. (4 cr, §Clas 5108; prereq jr or sr or #) Cooper, McNally
Archaic and classical examples of religious and secular architecture; their setting in major archaeological sites.
**Arth 5111. Bronze Age Art and Architecture in Greece: Ca. 3000-1100 B.C.** (4 cr; §Class 5111; prereq one ancient art or archaeology course) Cooper

Artistic and architectural forms in the Neolithic period in the Aegean area and the Cycladic, Minoan, and Mycenaean cultures.

**Arth 5113. Archaic and Classical Greek Art and Archaeology.** (4 cr, §Class 5113; prereq jr or sr or #) McNally

Greek architecture, sculpture, and painting from 9th through 5th centuries B.C. Material remains of Greek culture; archaeological problems such as identifying and dating buildings; analysis of methods and techniques.

**Arth 5120. Field Research in Archaeology.** (3-6 cr, §Class 5120; prereq #) Cooper

Field excavation, survey, and research in archaeological sites in Mediterranean area. Techniques of excavation and exploration; interpretation of archaeological materials.

**Arth 5234. Gothic Sculpture of the Cathedral Age.** (5 cr; prereq 3009 or grad student or #) Steyaert

Sculpture in France and Germany from 1150 to 1350. Emphasis on stylistic evolution.

**Arth 5324. Fifteenth-Century Painting in Northern Europe.** (5 cr; prereq 3009 or 3011 or grad student or #) Steyaert

Painting in the Netherlands, France, and Germany during the late Gothic period and its influences.

**Arth 5346. Baroque Art in Italy and Spain.** (5 cr; prereq 3011 or grad student or #; offered alt yrs) Stoughton

Italian sculpture, painting, and architecture and Spanish painting of the 17th century.

**Arth 5347. Baroque Art in France and the Lowlands.** (5 cr; prereq 3011 or grad student or #; offered alt yrs) Stoughton

French architecture, painting, and sculpture; Flemish and Dutch painting of the 17th century. Major artists: Rembrandt, Rubens, Poussin.

**Arth 5356. Eighteenth-Century Art in France.** (4 cr, §3303; prereq 3011 or grad student or #; offered alt yrs) Stoughton

Rococo and neoclassical painting, sculpture, and architecture in France.

**Arth 5358. Eighteenth-Century Art in Italy, Germany, Austria.** (4 cr; prereq 3011 or grad student or #) Stoughton

Italian painting, sculpture, and architecture; German and Austrian architecture.

**Arth 5422. History of 19th-Century Graphic Arts.** (5 cr, §3422; prereq one 3xxx art history course or grad student or #; offered alt yrs) Weisberg

History and theory of creation and evolution of lithography, social caricature (e.g., Daumier, Gavarni), revival of etching at mid-century, and emergence of color lithography at turn of century (e.g., Toulouse-Lautrec, Vuillard, Bonnard). Major artistic figures and revolutionary nature of new media. Local print collections used.

**Arth 5423. Gothic Architecture.** (4 cr, §5053, §Arch 5053, §Arch 5423; prereq Arch major or Arch 3411 or #) Steyaert

History of development of architecture and urban design in Western Europe from 1150 to 1400 A.D.

**Arth 5425. Baroque Architecture in Italy.** (4 cr, §5064, §Arch 5064, §Arch 5425; prereq Arch major or Arch 3411 or #) Stoughton

Architecture and urban design in Italy from 1600 to 1750 A.D. Emphasis on major figures (Bernini, Borromini, Cortona, Guarini) and evolution of major cities (Rome, Turin).

**Arth 5431. Age of Revolution: French Painting From 1789 to 1848.** (5 cr; prereq one 3xxx art history course or grad student or #) Weisberg

Major styles and movements in France and their leading exponents: neoclassicism—David; romanticism—Corot and Delacroix; early landscape painting—the Barbizon group.

**Arth 5432. Realism to Impressionism: French Painting From 1848 to 1886.** (5 cr; prereq one 3xxx art history course or grad student or #) Weisberg

Major movement of French painting from realism of Courbet through end of impressionism. Roots of popular imagery, critical study of realism, and radical innovations of impressionism.

**Arth 5433. The Advent of Modernism: Later 19th-Century French Painting From 1886 to 1905.** (5 cr; prereq one 3xxx art history course or grad student or #) Weisberg, staff

Major styles and movements: post-impressionism, symbolism, fin de siècle, jugendstil.

**Arth 5434. Contemporary Architecture.** (4 cr) Solomonson

Developments, theories, movements, and trends in architecture and urban design from World War II to present.

**Arth 5435 (formerly 5056). Modern Architecture.** (4 cr; §Arch 5432; prereq Arch 1021 or 3411 or #) Solomonson

Architecture and urban design from early 19th-century sources in Europe and America to World War II.

**Arth 5454. Art Nouveau.** (5 cr; prereq one 3xxx art history course or grad student or #) Weisberg

History and evolution of art nouveau movement in France, England, Belgium, Germany, Austria, Scotland, and the United States. Innovations in architecture, graphics, and decorative arts; continental variants of style (e.g., Liberty Style). Major promoters (e.g., S. Bing) and pioneers of modern design (e.g., William Morris).

**Arth 5463. Early 20th-Century Painting.** (5 cr; prereq one modern art course or #) Weisberg, staff

Fauvism, cubism, surrealism, dadaism, and early abstraction.

**Arth 5535. Art in the United States.** (5 cr; prereq 4 cr art history or #; offered alt yrs) Marling

Painting and sculpture in the United States. Selected key works and artists from early settlement to the early 20th century.
ArtH 5546. American Architecture From 1860 to 1914. (5 cr; prereq sr or grad student or #; offered alt yrs) Archer, Marling
American developments and European influences from Civil War to about 1914. New materials and structural methods. Emphasis on Hunt, Richardson, McKim, Mead and White, Sullivan, early Wright, others.

ArtH 5725. Ceramics of East Asia. (5 cr; offered alt yrs) Poor
Ceramic art in East Asia: China, Korea, and Japan, from Neolithic times to the present.

ArtH 5765. Early Chinese Art. (5 cr; offered alt yrs) Poor
Development of ancient ceramics and ritual bronzes, early Buddhist sculpture, and early Chinese painting.

ArtH 5766. Chinese Painting. (5 cr; offered alt yrs) Poor
Survey of major works from the 4th to the 17th centuries. Development of the landscape tradition and the literary genre of later Chinese painting.

ArtH 5767. Japanese Painting. (4 cr; offered alt yrs) Poor
Japanese pictorial arts from earliest to modern times; works that best exemplify development of indigenous traditions.

ArtH 5769. Connoisseurship in Oriental Art. (5 cr; prereq jr or sr or #; offered alt yrs) Poor
Examination of Oriental art objects in local collections.

ArtH 5775. Early Indian Art. (5 cr; prereq 4 cr art history or #; offered alt yrs) F Asher
Sculpture and architecture of India from the Indus Valley civilization through the Kushana period.

ArtH 5776. Art of India: 300 to 1200. (5 cr; prereq 4 cr art history or #; offered alt yrs) F Asher
Sculpture, architecture, and painting. Focus on Buddhist and Hindu monuments throughout South Asian subcontinent; earliest Islamic monuments of India.

ArtH 5777. Painting of India. (5 cr; prereq 4 cr art history or #; offered alt yrs) C Asher
Entire history of Indian painting beginning with the early tradition of mural painting but concentrating primarily on miniature painting from the 12th century onward.

ArtH 5781. Age of Empire: The Mughals, Ottomans, Safavids. (4 cr; offered alt yrs) C Asher
Development of art and architecture in three contemporary Islamic empires: the Mughals of India, Safavids of Iran, and Ottomans of Turkey.

ArtH 5783. Art of Islamic India. (4 cr; offered alt yrs) C Asher
Development of art and architecture in Indian subcontinent during period of Islamic domination into colonial period.

ArtH 5785. Art of Islamic Iran. (4 cr; offered alt yrs) C Asher
Development of art and architecture in Iranian-dominated eastern Islamic realm (Iran, the former southern Soviet Union, and Afghanistan) from inception of Islam to present.

ArtH 5787. Art of the Western Islamic World. (4 cr; offered alt yrs) C Asher
Development of art and architecture in western Islamic world from inception of Islam to present.

ArtH 5895. Methods of Research in Art History. (4 cr, §8801; prereq sr art history major, #; offered alt yrs)
For highly qualified undergraduate majors intending to pursue professional training and for incoming master’s majors.

ArtH 5925. History of Photography as Art. (4 cr; prereq 3012 or #; offered alt yrs) Silberman
Origins and development of photography with attention to both technology and cultural impact. Investigation of major aesthetic achievements in photography from beginnings to present.

ArtH 5940. Topics: Art of the Film. (4 cr; prereq 3921-3922 or #; offered alt yrs) Silberman
Film and society. Topics include sex and violence in the cinema, race and ethnicity in the cinema; films of the 30s, 50s, or 60s.

ArtH 5950, 5960. Topics in Art History. (2-5 cr per qtr; prereq jr or sr or #)
Topics specified in the Class Schedule.

ArtH 5970. Directed Readings. (1-5 cr; prereq sr, #, Δ, CLA approval)

ArtH 5990. Directed Research. (1-5 cr; prereq sr, #, Δ, CLA approval)

ArtH 8190. Seminar: Problems in Ancient Art. (4 cr; prereq #) Cooper, McNally
Selected topics in ancient art.

ArtH 8200. Seminar: Problems in Medieval Sculpture. (4 cr; prereq #) Steyaert

ArtH 8230. Seminar: Problems in Medieval Art. (4 cr; prereq 9 cr art history or #) Steyaert

ArtH 8340. Seminar: Baroque Art. (4 cr; prereq #) Stoughton

ArtH 8400. Seminar: 19th-Century Art. (4 cr; prereq #) Weisberg

ArtH 8440. Seminar: 20th-Century Art. (4 cr; prereq #)

ArtH 8520. Seminar: American Art. (4 cr; prereq #) Marling

ArtH 8720. Seminar: Asian Art. (4 cr; prereq #) Poor

ArtH 8770. Seminar: Art of India. (4 cr; prereq #) C Asher, F Asher

ArtH 8910. Seminar: Problems in Classical Archaeology. (4 cr [may be repeated for cr]; §Clas 8910; prereq #) Cooper, McNally
ArH 8940. Seminar: Film History and Theory. (4 cr per qtr [max 8 cr]; prereq #) Silberman
Selected problems, including study of specific periods, genres, and directors. Topics such as concept of national cinema, nature of film spectatorship, representation of women in film, and changing role of film after development of television. Topic varies quarterly.

ArH 8950. Seminar: Issues in the History of Art. (4 cr; prereq #)
Theoretical or topical issues; topic varies.

ArH 8970. Directed Studies. (1-5 cr; prereq #)

ArH 8975. Directed Museum Studies. (1-3 cr; prereq #)
Projects in museum studies based on the literature, practice, or internship.

Astrophysics (Ast)
Professor: Thomas W. Jones, chair; Kris D. Davidson; John M. Dickey; Robert D. Gehrz; Roberta M. Humphreys; Terry J. Jones; Paul J. Kellogg; Leonard V. Kuhi; Robert L. Lysak; Keith A. Olive; Robert O. Pepin; Lawrence Rudnick; C. J. Waddington; Paul R. Woodward
Associate Professor: Evan D. Skillman, director of graduate studies

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B) and Ph.D.

Curriculum—The program offers emphases in observational, theoretical, and computational astronomy and astrophysics and in instrument development. Current research emphasizes the properties and dynamics of normal and active galaxies, quasars, stellar evolution, interaction of stars with their environments, the interstellar medium, astrophysical magnetohydrodynamics, and galactic and cosmological structure. Observational research includes ultraviolet, optical, infrared, and radio astronomy. Extensive research programs in space physics and the elementary particle-cosmology interface are also carried out in the School of Physics and Astronomy.

Facilities—The University operates a 60-inch telescope on Mt. Lemmon, near Tucson, Arizona, which is well equipped for both optical and infrared observations. A 30-inch telescope with a CCD camera and infrared instruments is maintained at the O’Brien Observatory about 40 miles from the Twin Cities campus. Both telescopes are fully computer controlled and can be operated remotely. Plans are under development for a major (3.5 meter) observatory. Excellent shop facilities support our instrument development for the telescopes at O’Brien and Mt. Lemmon, for the University of Wyoming’s infrared telescope, and for major national observatories such as the NASA Infrared Telescope Facility (IRTF) in Hawaii.

The Automated Plate Scanner (APS) is a high-speed, high-precision measuring engine. It is unique in its ability to scan two photographic plates simultaneously. The APS is currently used to digitize the famous Palomar Sky Survey to produce a massive database of stars and galaxies. The associated computer reduction system can analyze 100,000 images per hour.

Another image-processing system is coupled to the departmental SUN and SGI network for the reduction and analysis of optical, infrared, single-dish radio, and Very Large Array (VLA) radio interferometry data. The department is connected through an ethernet backbone to clusters of supercomputers and super-workstations at the University’s Supercomputer Institute and the Laboratory for Computational Science and Engineering. These facilities are available to faculty and students for their research.

In addition, members of the department regularly use such national facilities as the Kitt Peak National Observatory; Cerro Tololo Inter-American Observatory in Chile; National Radio Astronomy Observatory’s single-dish facilities in Green Bank and Kitt Peak and its VLA; Arecibo Radio Observatory; the International Ultraviolet Explorer satellite; the Hubble Space Telescope; and the IRTF in Hawaii.

Prerequisites for Admission—For major work, an undergraduate degree in astronomy or physics or the equivalent. Contact the director of graduate studies for exceptions.

Special Application Requirements—A statement of career goals, scores from the Graduate Record Examination General (Aptitude) Test and Subject (Advanced) Test in physics, and three letters of recommendation are required. Applications for financial aid are due January 15. Applications are accepted for entry in fall quarter only.

Master’s Degree Requirements—Two quarters of the classical physics sequence Phys 5051-5052-5053 and three 5xxx astronomy courses are
required. Additional requirements depend on whether the student chooses the thesis (Plan A) or non-thesis (Plan B) option. Completion of the degree normally takes two years. An oral examination is required.

**Doctoral Degree Requirements**—Five 5xxx astronomy courses are required along with Phys 5051-5052-5053. Competence in quantum physics at the level of Phys 5101-5102 is expected. A comprehensive written examination in astrophysics is taken during spring of the second year. A research project that must be completed before fall quarter of the third year serves as a focus for the preliminary oral examination.

**Language Requirement**—None.

**Minor Requirements for Students Majoring in Other Fields**—Ast 3051 or the equivalent, differential and integral calculus, and one year of college physics are prerequisites for admission to the minor.

For Further Information and Applications—Contact the Department of Astronomy, University of Minnesota, 356 Tate Lab of Physics, 116 Church Street S.E., Minneapolis, MN 55455 (612/624-0211; fax 612/626-2029; e-mail grad-req@astro.spa.umn.edu; http://ast1.spa.umn.edu).

Ast 8666. **Doctoral Pre-Thesis Credits.** (max 18 cr per qtr; doctoral student who has not passed oral prelims)

Ast 8777. **Thesis Credits: Master’s.** (16 cr required; Plan A only)

Ast 8888. **Thesis Credits: Doctoral.** (36 cr required)

Ast 5061. **Computational Methods in the Physical Sciences I.** (4 cr; Phys 5061; prereq CLA jr or sr or IT upper div student or grad student or #; 2 lect, 6 lab hrs per wk)
Introduction to solution of problems in physical sciences with computer programs. Selected numerical methods and general spirit of mapping problems onto computational algorithms. Arranged lab at scientific computer workstation.

Ast 5062. **Computational Methods in the Physical Sciences II.** (4 cr; Phys 5062; prereq CLA jr or sr or IT upper div student or grad student, Phys/Ast 5061 or #; 2 lect, 6 lab hrs per wk)
Introduction to advanced techniques in computer simulation through examples from classical statistical mechanics, classical electrodynamics, and fluid dynamics. Computer experiments using SUN systems and their graphics capabilities.

**Ast 5161.** **Astrophysics of Diffuse Matter.** (4 cr; prereq 3051, Phys 5024 or #; offered alt yrs)

Ast 5162. **Stars and Stellar Evolution.** (4 cr; prereq 3051, Phys 3513 or 3501 or #)

Ast 5163. **Galactic Astronomy and the Interstellar Medium.** (4 cr; prereq 3051 or #; offered alt yrs)
Structure, kinematics, and evolution of Milky Way galaxy and its constituents, stars, star clusters, and interstellar medium. Observed properties of the galaxy.

Ast 5164. **Extragalactic Astronomy.** (4 cr; prereq 5163 or #; offered alt yrs)
Structure and evolution of external galaxies. Classification, stellar and gaseous contents, kinematics and dynamics, extragalactic distance scale, clusters, galactic nuclei and associated activity.

Ast 5165. **Cosmology.** (4 cr; prereq Phys 3513 or #; offered alt yrs)
Large-scale structure and history of universe. Newtonian and relativistic world models, Big Bang model, microwave background, physics of early universe; cosmological tests, measurement of Hubble constant and deceleration parameter, galaxy formation.

Ast 5201. **Methods of Experimental Astrophysics.** (4 cr; prereq 3051, Phys 3513; offered alt yrs)
Introduction to contemporary techniques and instrumentation in astronomy. Astronomical observations including data acquisition and instrument control at O’Brien Observatory and data reduction and image processing using department computing facilities.

Ast 5321. **Radiation Processes in Astrophysics.** (4 cr; prereq Phys 5024, 5102 or #; offered alt yrs)

Ast 5362. **Stellar Astrophysics.** (4 cr; prereq 5321 or #; offered alt yrs)

Ast 5421. **High Energy Astrophysics.** (4 cr; prereq 3051, Phys 5024, 5101 or #; offered alt yrs)
Ast 5990. Directed Research. (3 cr minimum; prereq #, △)
Independent research in observational and/or theoretical astrophysics under the direction of a faculty member. Intended for senior astrophysics majors.

Ast 8200.* Seminar. (1-3 cr)

Ast 8481,8482,8483.* Topics in Astrophysics. (3 cr per qtr; prereq #)
Advanced discussions of important topics of current research interest. Recent topics include stellar spectroscopy, astrophysical fluid dynamics, signal processing, galactic dynamics, and modern instrumentation.

Ast 8990.* Research in Astronomy and Astrophysics. (Cr ar; prereq #)

Other Courses of Interest

Phys 5051-5052-5053.* Classical Physics
Phys 5151-5152-5153.* Quantum Mechanics
Phys 5162.* Introduction to Plasma Physics
Phys 5301.* Introduction to Nuclear Physics
Phys 5371.* Introduction to Elementary Particle Physics
Phys 5401.* Introduction to Contemporary Problems in Cosmic Ray and Space Physics
Phys 8081-8082.* General Relativity
Phys 8161.* Atomic and Molecular Structure
Phys 8163-8164.* Plasma Physics
Phys 8400.* Seminar: Space Physics
Phys 8411.* Cosmic Ray and Space Physics
Phys 8421. Solar and Magnetospheric Physics

Biochemistry, Molecular Biology and Biophysics

Professor: David A. Bernlohr, interim head, Department of Biochemistry; John D. Lipscomb, interim head, Department of Biochemistry; Lester R. Drewes, head, Department of Biochemistry and Molecular Biology; and associate director of graduate studies; John S. Anderson, co-director of graduate studies (biochemistry); Brian G. Van Ness, co-director of graduate studies (biochemistry); Norma M. Allweil (biochemistry); Paul M. Anderson (biochemistry); Ian M. Armitage (biochemistry); Leonard J. Banaszak (biochemistry); Victor A. Bloomfield (biochemistry); James W. Bodley (biochemistry); Bianca M. Conti-Fine (biochemistry); Anath Das (biochemistry); James E. Dempsey (biochemistry); Joseph DiSalvo (medicine); Edward H. Egelman (cell biology and neuroanatomy); Michael C. Flickinger (biochemistry); James A. Fuchs (biochemistry); Nelson D. Goldberg (biochemistry); Gary R. Gray (chemistry); Harry P.C. Hogenkamp (biochemistry); Alan B. Hooper (genetics and cell biology); James B. Howard (biochemistry); James F. Koerner (biochemistry); David C. LaPorte (biochemistry); Dennis M. Livingston (biochemistry); Charles F. Louis (vet pathobiology); Rex E. Lovrien (biochemistry); Matthew F. Mescher (laboratory medicine and pathology); Gary L. Nelsestuen (biochemistry); Theodore R. Oegema (orthopaedic surgery); Douglas H. Ohlendorf (biochemistry); Harry T. Orr (laboratory medicine and pathology); Joseph R. Prohaska (biochemistry); Michael A. Raftery (biochemistry); Palmer Rogers (microbiology); Janet L. Schottel (biochemistry); David D. Thomas (biochemistry); Howard C. Towle (biochemistry); Kamil Ugurbil (radiology); Lawrence P. Wackett (biochemistry); Clare K. Woodward (biochemistry)

Associate Professor: Kenneth W. Adolph (biochemistry); Bridgette A. Barry (biochemistry); Robert J. Brooker (genetics and cell biology); David J. Eide (biochemistry); Thomas E. Huntley (biochemistry); Kevin H. Mayo (biochemistry); Robert J. Roon (biochemistry); Wilmar L. Salo (biochemistry); Michel M. Sanders (biochemistry)

Assistant Professor: Vivian J. Bardwell (biochemistry); Benjamin L. Clarke (biochemistry); Stephen C. Ekker (biochemistry); Gregg B. Fields (laboratory medicine and pathology); Alex J. Lange (biochemistry); Kathryn E. McLane (chemistry); Karin Musier-Forsyth (chemistry); Ann E. Rougvie (genetics and cell biology); Paul G. Siliciano (biochemistry); Jeffrey A. Simon (biochemistry); David A. Zarkower (biochemistry)

Other Courses of Interest

Astrophysics.
Ast 8990.* Research in Astronomy and Astrophysics. (Cr ar; prereq #)

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Ast 8990.* Research in Astronomy and Astrophysics. (Cr ar; prereq #)

Other Courses of Interest

Astrophysics.
Ast 8990.* Research in Astronomy and Astrophysics. (Cr ar; prereq #)

Other Courses of Interest

Astrophysics.
Ast 8990.* Research in Astronomy and Astrophysics. (Cr ar; prereq #)
**Prerequisites for Admission**—The graduate program in biochemistry, molecular biology and biophysics is flexible enough to accommodate students with a wide variety of educational backgrounds. The program encourages application from students with undergraduate or master’s degrees in the biological, chemical, or physical sciences. Recommended academic preparation includes one year each of calculus, organic chemistry, and physics and a background in basic biology, including biochemistry and genetics. Coursework in physical chemistry is recommended for graduate-level biochemistry courses. For students of demonstrated ability, background deficiencies can be made up during the first year of graduate study.

**Special Application Requirements**—Applicants must submit three letters of recommendation from persons familiar with their academic and research capabilities. A statement of interests and goals, a complete set of transcripts, and official scores from the General Test of the Graduate Record Examination (GRE) are required. The GRE Subject Test in biochemistry, cell and molecular biology, biology, or chemistry is strongly recommended, but not required. The recommended date for receipt of completed applications is January 15. Completed files are reviewed between January and March. Graduate studies typically begin fall term. Information about an early start program involving participation in laboratory research beginning on August 1 may be obtained from the director of graduate studies.

**Master’s Degree Requirements**—Students must satisfactorily complete one year of graduate biochemistry (8001-8002-8003), one laboratory rotation, and two special topics biochemistry courses and must participate in seminars, for a minimum total of 25 credits. A thesis based on original laboratory research and an oral examination also are required.

**Doctoral Degree Requirements**—Students must satisfactorily complete one year of graduate biochemistry (8001-8002-8003), two laboratory rotations, and two advanced topics courses in their area of concentration and must participate in seminars. One written and two oral examinations are required. A thesis based on extensive original laboratory research is the primary requirement. For more information, contact the director of graduate studies.

**Language Requirements**—None.

**Minor Requirements for StudentsMajoring in Other Fields**—For the M.S. degree, a minimum total of 10 credits of graduate-level courses in biochemistry, with at least 5 of these credits in 8xxx courses, is required. For the Ph.D. degree, a minimum total of 18 credits of graduate-level courses in biochemistry, with at least 10 of these credits in 8xxx courses, is required. Students planning a minor program should consult with the director of graduate studies in biochemistry.

**For Further Information and Applications**—Contact the Department of Biochemistry (Medical School), University of Minnesota, 4-225 Millard Hall, 435 Delaware Street S.E., Minneapolis, MN 55455 (612/625-6100; fax 612/625-2163), or Department of Biochemistry (Biological Sciences), 140 Gortner Lab, University of Minnesota, 1479 Gortner Avenue, St. Paul, MN 55108 (612/624-7755; fax 612/625-5780). Information may also be requested through e-mail (bmbbgp@brain.biochem.umn.edu).

**BioC 8666. Doctoral Pre-Thesis Credits.** (max 18 cr per qtr; doctoral student who has not passed oral prelims)

**BioC 8777. Thesis Credits: Master’s.** (16 cr required; Plan A only)

**BioC 8888. Thesis Credits: Doctoral.** (36 cr required)

The courses directly below have both biochemistry designators, BioC and MdBc. Courses with only the BioC or MdBc designator follow this listing.

**Biochemistry (BioC and MdBc)**

(College of Biological Sciences and Medical School)

**BioC and MdBc 5525s. Physical Biochemistry: Solution Structure and Interactions of Biological Macromolecules.** (4 cr, §Chem 5525; prereq BioC 5331 or equiv, 2 qtrs physical chemistry) Allewell, Bloomfield Physical chemistry of equilibrium, transport and scattering phenomena in solution, with application to proteins and nucleic acids. Intermolecular forces, macromolecular dynamics, conformational transitions, binding thermodynamics, and methods for determining biopolymer size and shape, including sedimentation, diffusion, viscosity, electrophoresis, and scattering.

BioC and MdBc 5527f. Physical Biochemistry: Spectroscopic Methods II. (4 cr, §Chem 5527; prereq 2 qtrs physical chem, BioC/MdBc 5526) Barry, Thomas
Applications of optical and magnetic resonance techniques to study of structure and dynamics in proteins, lipids, nucleic acids, and synthetic analogs.

BioC and MdBc 5528w. Physical Biochemistry: Enzyme Kinetics. (4 cr, §Chem 5528; prereq 2 qtrs physical chem, BioC 5331 or BioC/MdBc 8001 or equiv) Lipscomb
Theory and application of steady-state and transient kinetics for study of enzymes, enzyme systems, and cellular regulation.

BioC and MdBc 5529s. Protein Structure and Folding. (4 cr, §Chem 5529; prereq BioC 5331 or equiv, 1 qtr physical chem or #) Banaszak, Woodward
Advanced course on protein structure, stability, folding, and molecular modeling. Results from X-ray crystallography, solution thermodynamics, NMR, computer graphics, and protein engineering.

BioC and MdBc 8001f. Advanced Biochemistry I: Protein Structure and Function. (4-5 cr, §BioC/MdBc 5751; prereq # or 3 qtrs organic chem, 2 qtrs physical chem, 1 qtr biochem) Ohlendorf, Wackett
Primary, secondary, tertiary, and quaternary structure of proteins. Methods to determine structure. Protein folding, forces stabilizing macromolecular structure; examples related to protein engineering and design. Interaction of proteins with ligands: structural change and reaction energetics. Dynamic properties of proteins and enzymes; enzyme substrate complexes and mechanism of enzyme catalysis.

BioC and MdBc 8002w. Advanced Biochemistry II: Molecular Biology. (4-5 cr, §BioC/MdBc 5753; prereq BioC/MdBc 8001 or #) Das, Siliciano
Structure and stability of nucleic acids; organization of prokaryotic and eukaryotic genomes. Chromosome mechanics, including DNA replication, recombination, and transposable elements. Mechanism and regulation of gene expression, including transcription, processing, and translation in both prokaryotic and eukaryotic organisms.

BioC and MdBc 8003s. Advanced Biochemistry III: Regulation of Metabolism and Biological Processes. (4-5 cr, §BioC/MdBc 5752; prereq BioC/MdBc 8002 or #) Bernlohr, LaPorte
Membrane structure and function; strategies for metabolic control. Important control points in key metabolic pathways. Transmembrane signaling and second messengers; their role in regulation. Coordination of genetic and enzymatic controls. Regulation of cell division, regulation of development, and integration of regulatory systems such as nerve transmission, muscle contraction, and vision.

BioC and MdBc 8094. Research and Literature Reports. (1 cr)
Current developments in biochemistry.

BioC and MdBc 8206f. Cell Signaling and Metabolic Regulation. (3 cr, §MdBc 8206; prereq BioC/MdBc 8001-8002 or GCB 8132 or equiv) Raftery, staff
Mechanisms of regulation of signal receptors and second messengers, including cyclic nucleotides, calcium, and phosphoinositol derivatives; polypeptide and catecholamine hormone-mediated processes; molecular basis of neurotransmitter signaling and ion-channels.

BioC and MdBc 8213f. Advanced Molecular Biology I. (4 cr, §GCB 8213; prereq BioC/MdBc 8002 or GCB 8132 or #) Bodley, Ekker, LaPorte, Siliciano, Towle, Zarkower
Lectures, readings, and discussions. Topics include DNA replication, recombination and gene conversion, regulation of gene expression in procaryotes, regulation of gene expression in eucaryotes, chromatin structure and transcription, organellar gene expression.

BioC and MdBc 8214w. Advanced Molecular Biology II. (4 cr, §GCB 8214; prereq BioC/MdBc 8002 or GCB 8132 or #) Bardwell, Das, Mauro
Lectures, readings, and discussions. Topics include RNA splicing, RNA stability, initiation and control of translation, animal viruses, gene families, transposable elements, somatic recombination, yeast molecular biology, oncogenes.

BioC and MdBc 8230w. Membrane Biochemistry. (3 cr; prereq BioC/MdBc 8001 or #) Thomas, staff
Lectures and readings on molecular structure, dynamics, and function of cell membranes. Fundamental principles and current research topics, with emphasis on systems and methods under investigation at University of Minnesota.

BioC and MdBc 8290f,w,s,su. Current Research Techniques. (1-3 cr; prereq grad major in biochemistry) Research projects in biochemistry, each to be carried out in the research laboratory of an individual staff member. Satisfies all or part of the laboratory requirements for the Ph.D. degree.

Biochemistry (BioC)
(College of Biological Sciences)

BioC 5025f,w,s. Laboratory in Biochemistry. (2 cr; prereq 3021 or ¶3021 or 5331 or ¶5331 or Biol 5001 or ¶Biol 5001) Barry, Conti-Fine, Fuchs, Lovrien
Discussions of techniques and problem-solving approaches illustrated with laboratory experiments and demonstrations.

BioC 5301w. Ecological Biochemistry. (3 cr; prereq 3021 or 5331 or #) Wackett

BioC 5331f. Structure, Catalysis, and Metabolism in Biological Systems. (4 cr, ¶3021, ¶Biol 5001; prereq 2 qtrs organic chem, Biol 1009 or Biol 1202 or #) Allewell, Flickinger, Nieslischew
Structure and function of biological molecules. Protein structure, catalysis, and intermediary metabolism. Enzyme kinetics, thermodynamics, and role of cofactors in catalysis.
BioC 5332w. Energy and Signal Transduction in Biological Systems. (4 cr; prereq 5331 or #)
Barry, Bernlohr
Biological membrane structure and membrane-associated proteins. Transport, oxidation/reduction, photosynthesis, electron transfer mechanisms, membrane receptors, signal transduction, and specific regulatory systems.

BioC 5333s. Molecular Mechanism of Gene Action. (4 cr; prereq 5332 or #) Das, Fuchs, Schottel, Simon
Structure and function of nucleic acids and regulatory process involved in gene expression from biochemical point of view.

BioC 5352w. Applied Microbial Biochemistry. (4 cr, §MicB 5352; prereq 3021 or 5331 or MicB 5321, intro microbiology course or #) Flickinger
Biochemistry of microorganisms and enzymes of industrial interest. Heterologous peptide overproduction by microorganisms and yeasts; polymer, antibiotic, organic acid, and amino acid production; genetics of industrially useful microorganisms; biological systems useful for biotransformation and environmental remediation; introduction to fermentation technology.

BioC 5401f. Metabolism and Its Regulation. (3 cr; prereq 3021 or 5331) Nelsestuen
Underlying principles determining metabolism of common and unusual compounds in plants, animals, and microorganisms. Regulation of carbon and energy flow in whole organisms.

BioC 5418s. Topics in Molecular Immunology. (4 cr; prereq MicB 5218) Conti-Fine
Molecular interactions occurring among proteins and peptides involved in immune recognition.

BioC 5950. Special Topics. (1-5 cr; prereq #, ∆)
BioC 5970. Directed Studies. (Cr ar; prereq #, ∆)
Individual study of selected topics; selected readings and use of scientific literature.

BioC 5990. Directed Research. (Cr ar; prereq #, ∆)
Laboratory or field investigation of selected areas of research.

Biochemistry (MdBc)
(Med School)
MdBc 5033f,w,s,su. Problems in Biochemistry. (Cr and hrs ar [may be repeated 1 or more qtrs for cr]; prereq ∆, grad majors must regis S-N)
MdBc 5100f.1 Biochemistry, Molecular and Cellular Biology. (9 cr; prereq regis med fr, ¶CBN 5104) Livingston, staff
Integrated introduction to biochemistry, molecular biology, genetics, cell biology, and developmental biology.
MdBc 5101w. Human Nutrition. (1 cr; prereq 5100, regis med fr or grad student) Towle
Principles of nutrition as foundation for understanding clinical nutrition.

1 Offered on the Medical School calendar, which is different from the regular University calendar. Fall classes may start as much as one month ahead of other courses.

MdBc 5201f. Biochemistry for Dental Students. (4 cr; prereq regis dental fr or grad student) Lange, Roon
Chemical properties, biosynthesis, catabolism, structure, and function of biomolecules. Fundamentals of molecular biology and metabolic regulation.

MdBc 5202w. Biochemistry for Dental Students. (3 cr; prereq regis dental fr or grad student) Adolph, Oegema, Roon
Introduction to physiological chemistry emphasizing biological processes that occur in human tissues and fluid compartments.

MdBc 5300f. Biochemistry. (4 cr; prereq organic chem or #; recommended for med tech majors)
Bardwell, Roon
Survey of chemical properties, biosynthesis, catabolism, and structural interaction of biomolecules. Metabolic regulation and molecular biology.

MdBc 5301w. Biochemistry. (3 cr; prereq 5300 or #; recommended for med tech majors) Adolph, Oegema, Roon
Survey of physiological biochemistry emphasizing human processes.

MdBc 5444s. Muscle Contraction. (3 cr; prereq undergrad courses in biochemistry or physiology or #)
Thomas, staff
Introduction to physiology, biochemical regulation, and physical chemistry of muscle contraction.

MdBc 5460-5461. Cellular and Molecular Neuroscience. (3 cr per qtr; for 5460: §GCB 5460, §NSc 5460, §Phcl 5460, §Phsl 5460, §VB 5460; for 5461: §GCB 5461, §NSc 5461, §Phcl 5461, §Phsl 5461, §VB 5461; prereq biochem)
Gene structure and regulation, cloning and molecular strategies for studying gene function, ion channels and membrane excitability, synaptic transmission, receptor structure and function, signal transduction.

MdBc 5531f. Macromolecular Crystallography: Fundamentals. (1 cr; prereq 1 qtr organic chem, biochem or ¶biochem, 2 qtrs calculus, college physics) Ohlendorf
Basics of macromolecular crystallography as required for protein structure determination and engineering. Properties of X-rays, crystal growth and handling, space groups and symmetry, data collection and reduction, structure factors.

MdBc 5532w. Macromolecular Crystallography: Techniques. (1 cr; prereq 5531) Ohlendorf
Techniques for determining structure of macromolecule from its diffraction. Properties of Patterson function, heavy atoms techniques, molecular replacement, phase determination, generation and interpretation of electron density maps and refinement.

MdBc 5533s. Macromolecular Crystallography: Applications. (1 cr; prereq 5532) Ohlendorf
Practical use of current software in macromolecular crystallography. Density modification, molecular dynamics refinement, computer graphics, modeling, computational aspects.
Bioethics

Professor: Muriel J. Bebeau (preventive sciences—dentistry); Norman O. Dahl (philosophy); Jasper S. Hopkins (philosophy); Rosalie A. Kane (public health); H. E. Mason (philosophy); David J. Mayo (philosophy); H. E. Mason (philosophy); David J. Mayo (philosophy); Muriel B. Ryden (nursing); Naomi B. Scheman (philosophy)

Associate Professor: Mila A. Aroskar (health management and policy), director of graduate studies; Ronald E. Cranford (neurology); Patricia Crisham (nursing); John M. Dolan (philosophy); John M. Eyler (history of medicine); Steven H. Miles (medicine); Michael D. Root (philosophy); Susan M. Wolf (law)

Assistant Professor: Kathy Faber-Langendoen (medicine)

Course of Study—Minor in bioethics, applicable to master’s (M.A. and M.S.) and doctoral programs.

Curriculum—A structured graduate minor in bioethics is offered in conjunction with the Center for Biomedical Ethics in cooperation with the Department of Philosophy. While recognizing that philosophy is the focal discipline for the field of bioethics, the program offers varied opportunities for multidisciplinary study, including coursework in history and philosophy of medicine, health law and public policy, healthcare economics, professional ethics, medical humanities, and moral development. In addition to a sequence of required courses in ethical theory and bioethics, the program consists of approximately 50 additional courses offered by a wide variety of departments within the University from which students make a selection in consultation with the director of graduate studies for bioethics.

Prerequisites for Admission—Admission to the bioethics graduate minor is contingent upon prior admission to a master’s or doctoral degree-granting program within the Graduate School. Students are encouraged to have some previous exposure to philosophy or biomedicine or both. Graduate students in philosophy are expected to have successfully completed at least one graduate course in ethical theory.

Special Application Requirements—Contact the director of graduate studies in bioethics for an “Intent to Enroll” form, which students are encouraged to submit by the end of winter quarter the year before initiating coursework in the minor. Later submissions are considered as space permits. Fifteen students can be accepted per year. Although some priority is given to doctoral students, students familiar with philosophy, biomedicine, or both are admitted to the minor program on a first-come, first-served basis. Enrollment is contingent upon approval by the director of graduate studies for bioethics.

Minor Requirements—Students are encouraged to attend monthly seminars sponsored by the Center for Biomedical Ethics, preferably during the year the student is completing coursework for the minor.

Master’s students are required at a minimum to complete 10 graduate-level quarter credits in ethical theory and bioethics.

Doctoral students are required at a minimum to complete 18 graduate-level quarter credits in ethical theory and bioethics.

If mastery of the field of bioethics is desired, the student should consider coursework in addition to the minimum requirements for the minor program. Students also have the option of the related field(s) at the master’s level or the supporting program at the doctoral level in the programs described further in this bulletin.

Language Requirement—None specific to the minor program.

For Further Information and Applications—Contact the Graduate Minor in Bioethics, Center for Biomedical Ethics, University of Minnesota, University Office Plaza, 2221 University Avenue S.E., Suite 110, Minneapolis, MN 55455 (612/626-9756; fax 612/626-9786).

Biological Sciences

The biological sciences at the University of Minnesota offer both traditional and custom-designed interdisciplinary graduate programs that allow students to obtain the combination of advisers and courses needed to support their research and career interests. A high degree of interdisciplinary cooperation allows graduate students access to state-of-the-art equipment, facilities, and the expertise of more than 1,000 members of the graduate faculties in biological sciences across the Twin Cities and Duluth campuses.

Graduate programs in the biological sciences are found in many colleges and departments. Most programs offer master’s degrees under Plan A (involving a thesis) and Plan B (coursework only), and doctoral degrees, although some programs do not accept master’s students (see

1 University of Minnesota, Duluth
listing of majors and degrees in the General Information section). All graduate programs follow general Graduate School requirements, but many programs have additional requirements unique to their own program. Brief information about each program’s curriculum, prerequisites for admission, special application requirements, degree requirements for the master’s and doctoral degrees, and language requirements is listed under the appropriate graduate program heading.

Detailed and up-to-date information about a particular program can be obtained by writing to or calling the director of graduate studies of that program. Students who are undecided about a graduate field of study, or have general questions about the biological sciences, may contact the Coordinator for Life Sciences, College of Biological Sciences, University of Minnesota, 124 Snyder Hall, 1475 Gortner Avenue, St. Paul, MN 55108 (612/624-4240), or the Graduate School, Biological Sciences Graduate Programs, University of Minnesota, 306 Johnston Hall, 101 Pleasant Street S.E., Minneapolis, MN 55455 (612/625-9364).

The table on the following page illustrates the inter-relatedness of major fields of study in the biological sciences at the University of Minnesota. The table shows that training and research opportunities in any particular discipline of the biological sciences are available to graduate students in a number of different programs. Undecided students, or students contemplating entering graduate school in a specific biological discipline, may find more than one program that offers graduate training and research in their chosen field of study. The table is divided into three parts: Basic Biological Sciences, Agricultural Sciences, and Natural Resource Sciences. Use the following codes to identify the graduate programs offering training in each discipline:

**Graduate Programs and Codes:**

- Agro ......... Agronomy
- AnSc ........ Animal Sciences
- BMBB ....... Biochemistry, Molecular Biology and Biophysics
- BMSc ....... Biomedical Science
- CBio ....... Conservation Biology
- DU .......... Duluth Campus: Biology
- EEB ......... Ecology
- Ent ........... Entomology
- FW .......... Fisheries
- FScN ........ Food Science
- Fors ......... Forestry
- Hort ........ Horticulture
- LA ........... Landscape Architecture
- MCDBG .. Molecular, Cellular, Developmental Biology and Genetics
- MedC ...... Medicinal Chemistry
- MicE ...... Microbial Engineering
- MIMP ...... Microbiology, Immunology, and Molecular Pathobiology
- NSc ........ Neuroscience
- Nutr ........ Nutrition
- PBio ........ Plant Biological Sciences
- Phcl ........ Pharmacology
- Phm ........ Pharmaceutics
- Phsl ........ Cellular and Integrative Physiology
- PiBr ........ Plant Breeding
- PiPa ........ Plant Pathology
- Soil ........ Soil Science
- ‘Txcl ‘ .... Toxicology
- VB ........ Veterinary Biology
- VP ........ Veterinary Pathobiology
- WC ........ Wildlife Conservation
- Zool ........ Zoology

**Free-Standing Minors:**

- MiEc .......... Microbial Ecology—applicable to master’s (M.S. only) and doctoral programs.
- PNI .......... Psychoneuroimmunology—applicable to doctoral programs only.
- QP .......... Quaternary Paleoecology—applicable to master’s (M.A. and M.S.) and doctoral programs.
- SAgr .......... Sustainable Agriculture Systems—applicable to master’s (M.A. and M.S.) and doctoral programs.

1 A nondepartmental, interdisciplinary program.
2 The graduate program in biochemistry, molecular biology and biophysics is jointly administered through the Department of Biochemistry in the College of Biological Sciences (BioC) and the Medical School (MdBc).
3 Refer to Graduate Offerings, Duluth Campus, at the end of this bulletin for more specific information about the opportunities for research and training on that campus.
4 The graduate programs in fisheries and in wildlife conservation are administered in the Department of Fisheries and Wildlife.
5 The graduate program in food science is administered in the Department of Food Science and Nutrition. The graduate program in nutrition is an intercollegiate program, administered in the Department of Food Science and Nutrition.
6 The graduate program in forestry is administered in the Department of Forest Products and the Department of Forest Resources.
7 The master of landscape architecture (M.L.A.) is offered by this program.
8 An interdisciplinary program with most coursework offered through the Department of Genetics and Cell Biology.
9 The graduate program in microbiology, immunology, and molecular pathobiology is administered through the Department of Microbiology.
10 The graduate program in plant breeding is administered in the Department of Agronomy and Plant Genetics and the Department of Horticultural Science.
11 The graduate program in plant pathology also offers the Ph.D. degree with a concentration in mycology.
12 The graduate programs in veterinary biology and veterinary pathobiology are administered in the Department of Veterinary Pathobiology.
Fields of Study

Basic Biological Sciences
- Animal and Human Anatomy: DU, MCDBG, NSc, Phsl, VB, Zool
- Biochemistry/Chemistry: AnSc, BMBB, BMSc, Ent, Fors, FScN, FW, Hort, MCDBG, MedC, MIMP, MicE, NSc, Nutr, PBio, Phcl, Phm, Phsl, PiBr, PiPa, PNI, Soil, Txcl, VB, VP, Zool

Biomedical Sciences
- BMSc (as part of the M.D./Ph.D. program in the Medical School)

Biototechnology
- AnSc, BMBB, Ent, FScN, Hort, MedC, MIMP, MicE, NSc, Nutr, PBio, Phm, Phsl, PiBr, PiPa, SAg, Soil, Txcl, VB, VP, Zool

Cell/Developmental Biology
- AnSc, BMBB, BMSc, DU, Ent, Fors, Hort, MCDBG, MIMP, NSc, PBio, Phsl, PiPa, VP, VC, Zool

Ecology/Environmental Biology
- CBio, DU, EEB, Ent, Fors, FW, Hort, LA, MiEc, NSc, PBio, QP, Soil, SAg, WC, Zool

Entomology
- CBio, DU, EEB, Ent, NSc, PlPa, Zool

Evolutionary/Systematic Biology
- CBio, EEB, Ent, Fors, FW, Hort, MCDBG, MIMP, PBio, PiPa, QP, SAg, Zool

Genetics
- AnSc, BioC, BMSc, CBio, EEB, Ent, Fors, Hort, MCDBG, MIMP, MicE, NSc, PBio, Phsl, PiBr, PiPa, VP, WC, Zool

Immunology
- AnSc, BMBB, BMSc, MIMP, PNI, VP

Microbiology
- BMSc, FScN, MIMP, MicE, MiEc, PiPa, Soil, VP

Molecular Biology
- The techniques of molecular biology are used in nearly all fields, but are important components of biological research in the following programs: AnSc, BMBB, BMSc, DU, Ent, Fors, Hort, MCDBG, MedC, MIMP, MicE, MiEc, NSc, Nutr, PBio, Phsl, Phsl, PiBr, PiPa, PNI, VP, VB, Zool

Neurobiology
- AnSc, BMSc, DU, Ent, FW, MCDBG, NSc, Phcl, Phsl, PNI, VB

Nutrition
- AnSc, FScN, Nutr

Parasitology
- Ent, VP

Pharmacokinetics/Drug Delivery
- Phcl, Phm, Txcl, VB

Physiology, Animal and Plant
- Agro, AnSc, BMSc, DU, Ent, Fors, Hort, MCDBG, MIMP, NSc, Nutr, PBio, Phcl, Phsl, PiBr, PiPa, Txcl, VB, VP, WC, Zool

Plant Biology
- Agro, BioC, CBio, DU, EEJB, EEB, Fors, Hort, PBio, PiBr, PiPa, QP, Soil, WC

Plant Pathology
- PiPa, SAg

Toxicology
- BMSc, CBio, FW, MedC, Phcl, Phm, SAg, TXcl, VB

Virology
- BMSc, Hort, MIMP, PiPa

Zoology
- CBio, DU, EEB, Zool

Agricultural Sciences
- Agronomy and Plant Breeding: Agro, Hort, PiBr, SAg, Soil
- Animal Sciences: AnSc, VB, VP, WC, Zool
- Food Sciences/Nutrition: AnSc, FScN, MIMP, Nutr
- Horticulture: Hort, LA, PBio, PiBr

Natural Resource Sciences
- Conservation: CBio, DU, EEB, Fors, FW, LA, SAg, Soil, WC
- Environmental Sciences: See Ecology/Environmental Biology above
- Fish/Wildlife: AnSc, CBio, DU, EEB, FW, WC
- Forestry: CBio, EEB, Soil

Biomedical Engineering (BMEf)

Professor: Matthew V. Tirrell (chemical engineering and materials science), director of graduate studies; Robert J. Bache (medicine); David G. Benditt (medicine); Jerry L. Blackshear, Jr. (emeritus: mechanical engineering); William R. Brody (radiology); Henry Buchwald (surgery); Dennis D. Caywood (small animal clinical sciences); Frank B. Cerra (surgery); Jay N. Cohn (medicine); Max Donath (mechanical engineering); Arthur G. Erdman (mechanical engineering); Stanley M. Finkelstein (laboratory medicine and pathology); John E. Foker (surgery); Leo T. Furcht (laboratory medicine and pathology); James R. Gage (orthopaedic surgery); Robert P. Hebbel (medicine); Russell K. Hobbie (physics); Mostafa Kaveh (electrical engineering); Tarauld O. Kvalseth (mechanical engineering); David G. Levitt (physiology); Jack L. Lewis (orthopaedic surgery); Rex E. Lovrien (biochemistry); James B. McCarthy (laboratory medicine and pathology); Wilmer G. Miller (chemistry); David A. Nelson (otolaryngology); Sudha V. Patankar (mechanical engineering); Dennis L. Polla (electrical engineering); Richard E. Poppele (physiology); Gundu H. R. Rao (laboratory medicine and pathology); Donald R. Riley (mechanical engineering); John F. Soechting
(physiology); Ephraim M. Sparrow (mechanical engineering); Ahmed H. Tewfik (electrical engineering); Neal F. Viemeister (psychology)

Associate Professor: Jerome H. Abrams (surgery); Michael G. Garwood (radiology); James E. Holte (electrical engineering); Wei-Shou Hu (chemical engineering and materials science); Robert P. Patterson (physical medicine and rehabilitation); Clark M. Smith II (pediatrics)

Assistant Professor: Joan E. Bechtold (orthopaedic surgery); John C. Bischof (mechanical engineering); Gregg B. Fields (laboratory medicine and pathology); Bruce E. Hammer (radiology); Linda K. Hansen (laboratory medicine and pathology); William B. Gleason (laboratory medicine and pathology); Robert T. Tranquillo (chemical engineering and materials science); Paul A. Iaizzo (anesthesiology); Daniel L. Mooradian (laboratory medicine and pathology); Lisa M. Schutte (orthopaedic surgery); Xiaoping Hu (radiology); Allison Hubel (laboratory medicine and pathology); Wei-Shou Hu (chemical engineering and materials science); Jay Zhang (medicine)

Clinical Instructor: Carl S. Smith (surgery)

Other: Arthur J. Coury (vice president in biomaterials and pharmaceutical research, Focal Interventional Therapeutics); Prakash Keshaviah (corporate research fellow, Baxter Clinical Laboratories)

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B) and Ph.D.

Curriculum—Biomedical engineering is an interdisciplinary program designed to provide familiarity with the interactions among the engineering, biological, and medical sciences. Thesis research topics might include the following areas of biomedical engineering research: blood fluid mechanics; hemodynamics of cardiovascular function, structure, and instrumentation; design of artificial internal organs; biomaterials and biointerfaceal science; tissue engineering; biomedical imaging; organ preservation; chemotaxis; modeling of lung dynamics and study of pathological pulmonary conditions; bone and joint mechanics and design of bone and joint prostheses; microbial population dynamics; membranes and mass transfer; development of instrumentation and control devices to correct neurological defects; human factors engineering; health effects of design of tools and workplace; application of computer science to a wide variety of problems in physiological simulation, diagnosis, and medical data recording. Further information on current research areas is available from the director of graduate studies.

Prerequisites for Admission—A baccalaureate degree in engineering or in a physical or biological science is required. Successful applicants without an engineering degree are required to complete appropriate coursework to provide preparation for graduate-level engineering courses before being admitted as a candidate for the degree. In most cases, this coursework is not considered part of the degree program.

Special Application Requirements—Three letters of recommendation are required. In evaluating applications, consideration is given to whether or not an appropriate focus exists within the program to match the candidate’s interests. The Graduate Record Examination is required of all students. For international students requiring the Test of English as a Foreign Language (TOEFL), the minimum score is 575.

Master’s Degree Requirements—For the M.S. degree, students are required to complete 53 credits, including 3 credits of graduate seminars and a 12-credit minor program in a traditional engineering field (approved by that department). Plan B students are required to complete an internship and Plan B paper. Plan A students are required to complete a research thesis. A final oral examination is required for the M.S. degree.

Doctoral Degree Requirements—Ph.D. programs are planned with the aid of an adviser and a committee selected jointly by the candidate and the director of graduate studies from the above list of department faculty and approved by the Biomedical Engineering Graduate Program Review Committee. The committee decides on the suitability of the program and thesis topic and is responsible for the appointment of examination committees, subject to Graduate School approval.

The major program provides students with comprehensive training in both the engineering and life sciences aspects of at least one area of biomedical engineering. Students normally complete a broad but cohesive program consisting of coursework from a variety of departments. Students are required to take six credits of graduate seminar. In addition, students are required to complete a minor program in a traditional engineering field. That engineering department must approve the minor program.

Language Requirements—None.
Minor Requirements for Students Majoring in Other Fields—For the M.S. degree, students are required to complete 12 credits in two departments other than that of their major. For the Ph.D. degree, 18 credits outside the major are required. For both degrees, courses are approved by the director of graduate studies based on consultation with the student. Students must also register for three quarters of an approved biomedical engineering seminar series.  

For Further Information and Applications—Contact the Biomedical Engineering Program, University of Minnesota, Box 107 Mayo, 420 Delaware Street S.E., Minneapolis, MN 55455 (mailing address) (612/626-3446; e-mail bmengp@tc.umn.edu). Program office is located at 2-639 Malcolm Moos Tower, 515 Delaware Street S.E., Minneapolis campus.  

**BMEn 8666. Doctoral Pre-Thesis Credits.** (max 18 cr per qtr; doctoral student who has not passed oral prelims)  

**BMEn 8777. Thesis Credits: Master’s.** (16 cr required; Plan A only)  

**BMEn 8888. Thesis Credits: Doctoral.** (36 cr required)  

**BMEn 5001. Biomaterials I.** (3-4 cr, §MatS 5481, §MatS 5482; prereq IT upper div or grad student or med student or #)  

Physical and chemical aspects of biomaterials.  

**BMEn 5002. Biomaterials II.** (3 cr, §MatS 5483; prereq IT upper div or grad student or med student or #)  

Biological aspects of biomaterials.  

**BMEn 5003. Tissue Engineering.** (4 cr, §ChEn 5757; prereq IT upper div or grad student or med student or #)  

Hansen, Hubel  

Engineering of matrix from synthetic and natural polymers; cell matrix interactions; case studies of engineered tissues, e.g., skin, vessel, cartilage; regulatory and manufacturing issues associated with development of engineered tissues.  

**BMEn 5701. Biomedical Applications of Heat Transfer in Humans.** (4-5 cr; prereq Phsl 3053, Phsl 3056, Phsl 5441) laizzo, Sparrow  

Overview of physiology underlying thermoregulation in humans, clinical applications of heat transfer in humans, and framework for a design project.  

**BMEn 5950. Bioelectric Measurements.** (3 cr; prereq Phsl 5441, calculus, college physics)  

Electrodes, instrumentation, and processing requirements for endogenously generated electric potentials and electrical impedance of tissue. Electrode characteristics, signal processing, and interpretation of physiological events by ECG, EEG, EMG, and EOG. Measurement of respiration, blood flow and volume, and other physiological events by electrical impedance.  

**BMEn 5951. Bioelectric Stimulation.** (3 cr; prereq Phsl 5441, engineering-level calculus and physics)  

Theory and application of electrical stimulation in areas of therapeutic and functional neuromuscular stimulation and pain control, cardiac pacing, and defibrillation, tissue healing, and electrotherapy. Efficiency, safety, and environmental electrical fields.  

**BMEn 8002. Internship in Biomedical Engineering.** (3 cr; prereq BMEn grad major or Δ)  

Supervised lab experience unrelated to student’s normal employment. Report required.  

**BMEn 8100-8200-8300. Biomedical Engineering Seminar.** (1 cr per qtr)  

Lectures, demonstrations, and individual research that introduces graduate students and faculty to techniques and goals of biomedical engineering and surgery.  

**BMEn 8400. Biomedical Engineering Graduate Student Seminar.** (1 cr per qtr [max 3 cr]; prereq BMEn grad major or #)  

Mooradian  

Student presentations of current thesis research or other areas of biomedical engineering.  

**BMEn 8702. Advanced Topics in Biomaterials.** (2 cr; prereq 5001, 5002, 5003 or #)  

Surgical implantation of materials, hybrid artificial organs, inflammation and infection caused by implants; collagen and biopolymers; biocompatibility; blood-surface interactions; biodegradation; mineralization; antimicrobial treatments; drug delivery; wound healing; Society of Biomaterials conference report.  

**BMEn 8770. Plan B Project.** (4 cr, no cr toward PhD; prereq #)  

May be taken to satisfy Plan B master’s project requirement. May appear on master’s program, but does not count toward 20-credit minimum in major. Project topic arranged between student and instructor. Written report required.  

**BMEn 8970. Independent Study.** (1-4 cr; prereq #)  

Topic determined by interests of student in consultation with instructor; requires approval by consenting faculty member and director of graduate studies.  

**BMEn 8990. Directed Research.** (1-4 cr; prereq #)  

Content determined by interests of student in consultation with instructor.  

**Biomedical Science (BMSc)**  

*Regents’ Professor: Alfred Michael (pediatrics); James G. White (laboratory medicine and pathology)*  

*Professor: Theodore R. Oegema (orthopaedic surgery; biochemistry), director of graduate studies; Norma M. Allewell (biochemistry); Dwight L. Anderson (microbiology); Robert J. Bache (medicine); Leonard J. Banaszak (biochemistry); James W. Bodley (biochemistry); Frank B. Cerra (surgery); P. Patrick Cleary (microbiology); Bianca M. Conti-Fine (biochemistry); David L. Dunn (surgery); Martin Dworkin (microbiology); Timothy J. Ebner*
(neurosurgery); Edward H. Egelman (cell biology and neuroanatomy); Robert P. Elde (cell biology and neuroanatomy); Esam E. El-Fakahany (psychiatry); Stanley L. Erlandsen (cell biology and neuroanatomy); David P. Fan (genetics and cell biology); Anthony J. Faras (microbiology); Stanley M. Finkelstein (laboratory medicine and pathology); Leo T. Furcht (laboratory medicine and pathology); Apostolos P. Georgopoulos (physiology); Glenn J. Giesler (cell biology and neuroanatomy); Gordon D. Ginder (medicine); Gary R. Gray (chemistry); Ashley T. Haase (microbiology); Perry B. Hackett (genetics and cell biology); David W. Hamilton (cell biology and neuroanatomy); Janet W. Heasman (cell biology and neuroanatomy); Robert K. Herman (genetics and cell biology); Jordan L. Holtzman (medicine); Margaret K. Hostetter (pediatrics); Thomas H. Hostetter (medicine); James B. Howard (biochemistry); Harry S. Jacob (medicine); Ronald R. W. Jemmerson (microbiology); Marc K. Jenkins (microbiology); Ross G. Johnson (genetics and cell biology); Russell C. Johnson (microbiology); M. Colin Jordan (medicine); James F. Koerner (biochemistry); Ryoko Kuriyama (cell biology and neuroanatomy); David C. LaPorte (biochemistry); Alice A. Larson (veterinary pathobiology); Tucker W. LeBien (laboratory medicine and pathology); Hon Cheung Lee (physiology); Paul C. Letourneau (cell biology and neuroanatomy); Jack L. Lewis (orthopaedic surgery); Richard W. Linck (cell biology and neuroanatomy); John D. Lipscomb (biochemistry); Horace H. Loh (pharmacology); Charles F. Louis (veterinary pathobiology); Walter C. Low (neurosurgery); James B. McCarthy (laboratory medicine and pathology); Steven C. McLoon (cell biology and neuroanatomy); Matthew F. Mescher (laboratory medicine and pathology); Eric A. Newman (physiology); Jack H. Oppenheimer (medicine); Harry T. Orr (laboratory medicine and pathology); Peter G. W. Plagemann (microbiology); Richard E. Popplee (physiology); R. Paul Robertson (medicine); Irwin Rubenstein (genetics and cell biology); Michel M. Sanders (biochemistry); Patrick Schlievert (microbiology); Virginia S. Seybold (cell biology and neuroanatomy); Norman E. Sladek (pharmacology); John F. Soeckting (physiology); Chang W. Song (therapeutic radiology); Robert L. Sorenson (cell biology and neuroanatomy); Sheldon B. Sparer (pharmacology); David D. Thomas (biochemistry); Matthew V. Terrell (chemical engineering and materials science); Howard C. Towle (biochemistry); Daniel Vallera (laboratory medicine and pathology); Brian G. Van Ness (biochemistry); Ben G. Zimmerman (pharmacology); Stanley M. Finkelstein (laboratory medicine and pathology); Robert E. Foker (surgery); Russell K. Hobbie (orthopaedic surgery); Richard W. Linck (cell biology and pathology); Leon L. MacCrimmon (pediatrics); William H. Douglas (operative dentistry); Stanley M. Finkelstein (laboratory medicine and pathology); Paul G. Siliciano (biochemistry); Stanley A. Thayer (pharmacology); H. Joseph Yost (cell biology and neuroanatomy)

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degree Offered—Ph.D.

Curriculum—In consultation with their faculty advisers and the Committee on Graduate Studies, students custom-design interdisciplinary programs at the interfaces of biology, medicine, engineering, and physical sciences.

Prerequisites for Admission—Admission is limited to students who have been accepted by the Medical School’s M.D./Ph.D. program.

Language Requirements—None.

For Further Information and Applications—Contact the director of the M.D./Ph.D. Program, Medical School, University of Minnesota, Box 293 Mayo, 420 Delaware Street S.E., Minneapolis, MN 55455 (mailing address) (612/626-3680; fax 612/626-6800; e-mail mdphd@lenti.med.umn.edu).

BMSc 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

BMSc 8888. Thesis Credits: Doctoral. (36 cr required)

BMSc 8990. Research: Biomedical Science. (Cr ar; req prereq enrollment in MD/PhD program)

Biophysical Sciences and Medical Physics (BPhy)

Professor: Dean E. Abrahamson (public affairs); Eugene Ackerman (emeritus: laboratory medicine and pathology); Dwight L. Anderson (oral sciences); Victor A. Bloomfield (biochemistry/biological sciences); Bianca M. Conti-Fine (biochemistry/biological sciences); William H. Douglas (operative dentistry); Stanley M. Finkelstein (laboratory medicine and pathology); John E. Foker (surgery); Russell K. Hobbie (orthopaedic surgery); Richard W. Linck (cell biology and pathology); Leon L. MacCrimmon (pediatrics); William H. Douglas (operative dentistry); Stanley M. Finkelstein (laboratory medicine and pathology); Paul G. Siliciano (biochemistry); Stanley A. Thayer (pharmacology); H. Joseph Yost (cell biology and neuroanatomy)
BIOPHYSICAL SCIENCES AND MEDICAL PHYSICS

M. Uckun (therapeutic radiology); Kamil Ugurbil (radiology); Warren J. Warwick (pediatrics); Clare K. Woodward (biochemistry/biological sciences)

Associate Professor: E. Russell Ritenour (radiology), director of graduate studies; Michael G. Garwood (radiology); Bruce J. Gerbi (therapeutic radiology); Xiaoping Hu (radiology); Stephen C. Strother (radiology)

Assistant Professor: Vincent A. Barnett (physiology); F. Christopher Deibel, Jr. (therapeutic radiology); Ralph DeLong (operative dentistry); Richard A. Geise (radiology); Bruce E. Hammer (radiology); Bruce E. Hasselquist (radiology); Patrick Higgins (therapeutic radiology); Kelly Rehm (radiology); Beth A. Schueler (radiology); Arthur E. Stillman (radiology)

Research Associate: Jeih-San Liow (radiology)

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B) and Ph.D.

Curriculum—Degree programs include concentration in one or more of the four areas: experimental biophysics, applied biophysics, theoretical biophysics, and medical biophysics. A list of more than 50 courses offered by a variety of departments and accepted for credit in the biophysical sciences major is available on request from the director of graduate studies. Other pertinent courses may also be used as part of the program.

Prerequisites for Admission—All students should have some familiarity with physical chemistry, intermediate physics, intermediate mathematics, biostatistics, computer programming, biology, physiology, and biochemistry. This may be demonstrated by coursework completed at the undergraduate level or as part of the graduate program; by reading or practical experience; or by informal competency examinations.

Special Application Requirements—Three letters of recommendation and scores from the General Test of the Graduate Record Examination are required. Applicants are considered for admission in all quarters.

Master’s Degree Requirements—Three core courses—Phys 5551, 5552, and 5553—are normally required. A special three-person committee, chaired by the adviser, is responsible for assuring that the student’s program includes broad training in the biophysical sciences. This committee is usually recommended to the Graduate School to administer the oral examination. A final oral examination is required.

Doctoral Degree Requirements—The core curriculum consists of Phys 5551, 5552, and 5553. A significant portion of the coursework should be relevant to the area of thesis research. Programs should also include an area of specialization outside the thesis area. Students are required to take a written preliminary examination at the end of one year of postbaccalaureate study, or as soon as possible after completing Phys 5551, 5552, and 5553. This examination is prepared by a committee and is given at the start of the fall quarter. A special committee is recommended to the Graduate School to administer the Ph.D. oral preliminary examination, which should be taken by October of the third year of full-time registration or its equivalent. The oral examining committee is also expected to review the student’s course program.

Language Requirements—For the M.S. degree, none. For the Ph.D. degree, candidates must demonstrate competence in reading scientific literature in at least one foreign language. International students may submit evidence of competence in their native language if significant, relevant publications exist in that language. All other students must meet Graduate School requirements for the language selected.

Minor Requirements for Students Majoring in Other Fields—Programs are arranged on an individual basis and must consist of courses that represent broad coverage of the biophysical sciences. Eight-credit minors are not acceptable.

For Further Information and Applications—Contact the Biophysical Sciences and Medical Physics Program, Department of Radiology, University of Minnesota, Box 292 Mayo, 420 Delaware Street S.E., Minneapolis, MN 55455 (mailing address) (612/626-6638).

Note—The following courses are offered in biophysical sciences. Those numbered 5170 through 5174 are taught concurrently with courses in radiology and/or in therapeutic radiology that bear the same course numbers.
BPhy 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

BPhy 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

BPhy 8888. Thesis Credits: Doctoral. (36 cr required)

BPhy 5138. Seminar: Biophysical Sciences. (Cr ar)

BPhy 5155, 5156, 5157. Biophysics. (3 cr per qtr; prereq basic preparation in biological sciences, physical sciences, mathematics, #) Schmitt

Selected topics in theoretical, experimental, and technical areas of biophysical science where quantitative methods of the physical sciences are especially applicable. 5155: Basic principles of biophysical analysis and experimentation.

Biostatistics; structure of biological systems, especially as revealed by electronic, optical, and ionizing radiation imaging techniques; hypermicroscopy, birefringence, colloidal and micellar systems. 5156: Biophysical function; dynamics of biophysical systems, excitatory state in nerve and muscle, contractility, secretion, synthesis, sensory and motor transducers. 5157: Organization of biological systems for communication and control; stability of feedback and feed-ahead systems; biocommunication theory, computer aspects of living systems, biomimetics.

BPhy 5170. Basic Radiological Physics. (3 cr, §Rad 5170, §TRad 5170; prereq #) Khan

Theoretical and experimental aspects of radiological physics. Physical properties of various ionizing radiations; interactions of ionizing radiations with matter; methods of radiation dose measurement.

BPhy 5171. Physics of Nuclear Medicine. (3 cr, §Rad 5171, §TRad 5171; prereq 5170, #) Geise, Hasselquist, Ritenour

Theoretical and experimental applications of radionuclides in medicine and biology. Imaging devices and techniques; dynamic tracer analysis; internal emitter dosimetry. Radioimmunoassay and statistics of counting.

BPhy 5172. Radiation Biology. (3 cr, §Rad 5172, §TRad 5172; prereq 5170, #) Song

Effects of ionizing radiation on cells, tissues, and organisms; biochemical and physiological bases of radiation effects; biological rationale for radiation therapy practices.

BPhy 5173. Physics of Radiation Therapy. (3 cr, §Rad 5173, §TRad 5173; prereq 5170 or #) Khan


BPhy 5174. Physics of Diagnostic Radiology. (3 cr, §Rad 5174, §TRad 5174; prereq 5170 or #) Ritenour

Physics of diagnostic imaging; includes CAT scanning and ultrasound. X-ray production, image receptors, radiation exposure and protection. Special imaging modes including computerized tomographic scanning and electron radiography.

BPhy 5181. Physics of Nuclear Medicine Laboratory. (1 cr; prereq 5171 or #) Hasselquist

Supplements 5171. Basic counting devices, gamma counters, gamma cameras, quality control techniques, hot lab techniques, and radiation safety.

BPhy 5184. Diagnostic Radiological Physics Laboratory. (2 cr; prereq 5174 or #) Geise

Introduction to techniques of performance testing and calibration of radiological imaging equipment and related radiation safety survey methods.

BPhy 8147. Physics of Magnetic Resonance Imaging. (3 cr; prereq 5174 or #) Hammer, Hu

NMR physics, spatial selection and encoding, imaging hardware and system engineering. Imaging sequences and associated contrast. Advanced topics, including more recent development in MRI.

BPhy 8204. Research in Biophysics and Radiation Biology. (Cr ar)

BPhy 8221, 8222, 8223. Research in Biophysics. (Cr ar)

See also Phys 5551, 5552, 5553.

Biophysics

See Biochemistry, Molecular Biology and Biophysics.

Biostatistics (PubH)¹

Professor: Thomas A. Louis, head; Anne I. Goldman, director of graduate studies; James R. Boen; Kathryn M. Chaloner; John E. Connett; David R. Jacobs; Marcus O. Kjelsberg; Chap T. Le; James D. Neaton; Vernon E. Weckwerth

Associate Professor: Bradley P. Carlin; Patricia M. Grambsch; Kathleen M. Keenan; J. William Thomas

Assistant Professor: Aparna B. Anderson; Lance A. Waller

Senior Research Associate: Dorothee P. Aeppli; James S. Hodges; John P. Matts

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B) and Ph.D.

Curriculum—The field of biostatistics combines statistics, computing, and biomedical science to further research in human health. Biostatisticians design, direct, and analyze clinical trials; plan and carry out health surveys; develop new statistical

¹ A master of public health degree (M.P.H.) with an emphasis in biostatistics is offered by the School of Public Health. Consult the School of Public Health Bulletin for more information.
methods; and analyze data from observational studies, laboratory experiments, follow-up studies, and surveys. The program is designed to develop methodologically sound and applications-oriented biostatisticians. The research program couples collaboration on projects in human health with development of biostatistical methods to meet the challenges of these applications.

**Prerequisites for Admission**—For the M.S., program-specific admission requirements are as follows: mathematics through multivariable calculus (four quarters or three semesters) and linear algebra (one quarter or semester); at least one (quarter or semester) course in applied statistics; and at least one (quarter or semester) course in computer programming using a standard procedural language, such as FORTRAN or C. For the Ph.D., direct admission of non-University of Minnesota applicants is rare but possible with the following requirements: fulfillment of all M.S. admission prerequisites, an M.S. in statistics or biostatistics from a strong program, real analysis, mathematical statistics, and inference equivalent to the first-year biostatistics M.S. sequence.

Admission preference is given to those with a demonstrated background and interest in health sciences and public health. Applicants should have an overall grade point average of 3.10 or above on a 4.00 point scale with a 3.40 or above in quantitative courses for the M.S., and an average of 3.70 or above in mathematics/statistics courses for the Ph.D. The Graduate Record Examination (GRE) is required, with expected scores in the verbal area of at least 450 for the M.S. and 550 for the Ph.D., and in the quantitative and analytical areas of 550 in each for the M.S. and 650 in each for the Ph.D. If the applicant’s native language is not English, the Test of English as a Foreign Language (TOEFL) is required. A score of 600 or better on the TOEFL may replace the minimum verbal GRE requirement. Three letters of recommendation are also required from all applicants.

**Special Application Requirements**—Fall quarter entry is recommended.

**Master’s Degree Requirements**—Biostatistical inference, theory of statistics, clinical trials, statistical computing, analysis of categorical data, survival analysis, statistics, biostatistics, and health sciences electives. The master’s degree usually requires two years of full-time study.

**Doctoral Degree Requirements**—The doctoral program is open to students who have completed the requirements for the M.S., have shown proficiency in statistics and computing, and have adequate background in mathematics and health sciences. The Ph.D. degree usually requires one or two years of coursework beyond the M.S., plus the dissertation. Additional course topics for the Ph.D. include general linear models, analysis of longitudinal data, sequential analysis, advanced survival analysis, bio assay and screening, Bayes and empirical Bayes methods, spatial biostatistics, and modern nonparametric methods. Consult the director of graduate studies for more details.

**Language Requirements**—None.

**For Further Information and Applications**—Contact the Student Services Center, School of Public Health, University of Minnesota, Box 819 Mayo, 420 Delaware Street S.E., Minneapolis, MN 55455 (612/626-3500 or 1/800/774-8636; fax 612/626-6931; e-mail sph-uofm@greg2.sph.umn.edu; http://www.sph.umn.edu).

**Note**—Biostatistics courses are listed and described in the Public Health section of this bulletin. See PubH 5404 to 5470 and 8420 to 8450.

**PubH 8666. Doctoral Pre-Thesis Credits.** (max 18 cr per qtr; doctoral student who has not passed oral prelims)

**PubH 8777. Thesis Credits: Master’s.** (16 cr required; Plan A only)

**PubH 8888. Thesis Credits: Doctoral.** (36 cr required)

**Biosystems and Agricultural Engineering**

**Professor:** R. Vance Morey, head; Kevin A. Janni, director of graduate studies; Frederick G. Bergsrud; Theodore P. Labuza; John L. Nieber

**Associate Professor:** Mrinal Bhattacharya; James J. Boedicker; Jonathan Chaplin; Charles J. Clanton; Philip R. Goodrich; Larry D. Jacobson; John M. Shutiske; William F. Wilcke; Bruce N. Wilson

**Assistant Professor:** Rongsheng R. Ruan; Anu Subramanian

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

**Degrees Offered**—M.S.B.A.E. (Plan A and Plan B); M.B.A.E.; and Ph.D.
Curriculum—Areas of emphasis include bioprocessing; food engineering; livestock environment; water quality, surface and subsurface flow, contaminant transport; waste management and resource utilization; terramechanics; safety; and grain quality. With approval from the department faculty, supporting courses in other fields of engineering and the physical, biological, or agricultural sciences may be included in the major.

Prerequisites for Admission—A B.S. degree in biological, agricultural, or related field of engineering, or equivalent coursework in mathematics, physics, engineering science, and engineering design, is required. A strong academic record is also required.

Special Application Requirements—Graduate Record Examination scores, while not required, are encouraged. Students are admitted each quarter.

Master’s Degree Requirements—The M.S.B.A.E. degree is normally taken under Plan A, but may be completed under Plan B with approval from the department faculty. The M.B.A.E. program is recommended for those desiring design-oriented study beyond the B.S. degree. See Professional Master’s Degree in Engineering in the General Information section of the bulletin for a program description. The final examination for both master’s degrees is oral.

Doctoral Degree Requirements—Coursework for the major should provide in-depth knowledge in a specific area. It may include closely related topics, and should provide adequate background for the thesis investigation. A minimum of 16 credits in mathematics, statistics, and numerical analysis, including two or more mathematics courses, is required. The student may use these credits as a supporting program or may choose a designated minor in a single, related field.

Enrichment Program—In lieu of a language requirement for the Ph.D., the department requires completion of an enrichment program, consisting of 2 or more credits of nontechnical courses in a single area. Possible areas include (a) communication, educational methods, (b) foreign language and culture, (c) sociology, psychology, humanities, or (d) some other field related to the candidate’s career objectives and approved by the department faculty.

Language Requirements—For the master’s degree, none. For the Ph.D. degree, see above under Enrichment Program.

For Further Information and Applications—Contact the Director of Graduate Studies, Department of Agricultural Engineering, University of Minnesota, 1390 Eckles Avenue, St. Paul, MN 55108 (612/625-7733; fax 612/624-3005).

BAE 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

BAE 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

BAE 8888. Thesis Credits: Doctoral. (36 cr required)

Biosystems and Agricultural Engineering (BAE)

Courses That Carry Graduate Credit for Majors or Minors

BAE 5070. Instrumentation and Control for Biological Systems. (4 cr; prereq EE 1400, EE 3009, ME 3900 or Stat 3091, forest products major or upper div IT or grad student; 3 lect, 2 lab hrs per wk) Chaplin
Measurement of motion, force, pressure, flow, temperature, size, shape, color, texture, rheology, moisture, water mobility, fat, and pH. Linking physical and biological control systems.

BAE 5072. Finite Element Method: Fundamentals and Applications. (4 cr; prereq Math 3261, upper div IT or grad IT major; 4 lect hrs per wk) Bhattacharya
Basic theory and principles of implementation of the finite element method for a number of fundamental engineering areas. Applications in heat transfer, fluid mechanics, solid mechanics, radial and axisymmetric field problems, and time-dependent field problems.

BAE 5074. Microcomputer Interfacing. (4 cr; prereq CSci 3101, CSci 3102 or CSci 3113, EE 1400, EE 3009, upper div IT or grad IT major; 2 lect, 4 lab hrs per wk) Goodrich
Introduction to digital components, integrated circuits, and microcomputers. Interfacing of microcomputers for data acquisition and control.

BAE 5140. Thermal Processes for Food. (4 cr; prereq ChEn 5103 or ME 5342, upper div IT or grad IT major; 3 lect, 3 lab hrs per wk) Bhattacharya
Engineering principles of thermal processing of food, pasteurization, microwave heating, heat exchange, evaporation, refrigeration, and freezing. Process design and evaluation.
BAE 5191-5192. Special Problems in Biosystems and Agricultural Engineering. (1-5 cr per qtr; prereq #) Individual study project in agricultural engineering at advanced level. Application of engineering principles to a specific problem.

BAE 5350. Agricultural Machinery and Terramechanics. (4 cr; prereq AEM 3018, AEM 3036, upper div IT or grad IT major; 3 lect, 3 lab hrs per wk) Chaplin Engineering principles governing performance of agricultural machinery. Soil-machine interaction (traction and tillage), off-road vehicle dynamics, operator-machine interaction, drive-line design, power unit selection, and duty cycle analysis.

BAE 5540. Watershed Engineering. (4 cr; prereq 3052 or §3052 or CE 3300, CE 3400, upper div IT or grad IT major; 3 lect, 3 lab hrs per wk) Wilson Applying engineering principles to management of surface runoff and soil water in agricultural, range, and urban lands. Designing facilities to control surface runoff to mitigate problems of flooding and degradation of surface water quality.

BAE 5550. Water Management Engineering. (4 cr; prereq 3052 or §3052 or CE 3300, CE 3400, upper div IT or grad IT major; 3 lect, 3 lab hrs per wk) Nieber Applying engineering principles to management of water for production and environmental protection in agricultural systems. Designing facilities to irrigate and drain croplands and enhance water quality.

BAE 5560. Mechanics of Flow in the Unsaturated Zone. (4 cr; prereq 5232, Math 3261 or #, upper div IT or grad IT or grad COAFES major; 3 lect hrs per wk) Nieber Fluid retention and transmission properties of unsaturated porous media. Equations of mass conservation and Darcy’s law for unsaturated porous media. Simultaneous flow of immiscible fluids. Analytical, finite difference and finite element solutions to governing equations.

BAE 5745. Ventilating Systems for Indoor Air Quality. (4 cr; prereq ME 3301, AEM 3200 or CE 3400, upper div IT or grad IT major; 4 lect hrs per wk) Janni Impact of indoor air quality on humans, animals, and plants. Contaminant sources. Ventilating processes, systems, control strategies, and equipment for indoor air quality control. Case studies from residential, commercial, and agricultural systems.

BAE 5751. Biochemical Engineering I. (3 cr, §ChEn 5751; prereq BAE major or chem eng major or grad or #; 3 lect hrs per wk) Srnecn Applications of material and energy balances and of concepts from thermodynamics, kinetics, and transport phenomena to cellular and enzyme systems.

BAE 5910. Agricultural Waste Management Engineering. (4 cr; prereq 3052, upper div IT or grad IT major; 3 lect, 3 lab hrs per wk) Clanton Sources and characteristics of agricultural wastes, including livestock, food processing, and domestic wastes. Physical, biological, chemical, rheological, and microbiological properties. Effects on environment. Collection, storage and treatment (aerobic and anaerobic), and use/disposal. Land application of livestock and food processing wastes, municipal effluents, and sludges. On-site sewage treatment.

BAE 8000. Supervised Teaching Experience. (2 cr, §Agro 8000, §Hort 8000, §Soil 8000; prereq #) Janni Classroom or extension teaching experience in one of the following departments: Biosystems and Agricultural Engineering, Agronomy and Plant Genetics, Horticultural Science, or Soil, Water, and Climate. Students strengthen skills and develop personal teaching philosophy.

BAE 8100. Seminar. (1 cr; prereq #, grad IT major) Janni Reports on current topics and department research.

BAE 8190, 8191. Advanced Problems and Research. (2-6 cr per qtr; prereq 5191, 5192, ∆) Research problems in agricultural engineering.

BAE 8500. Hydrologic Modeling—Small Watersheds. (4 cr; prereq CE 5405, grad IT major; 3 lect, 1 rec hrs per wk; offered alt yrs) Wilson Study and representation of hydrologic processes by mathematical models; infiltration, overland flow, return flow, evapotranspiration, channel flow, and storage. Time-flow relationships. Linear and nonlinear methods. Frequency relationships. Emphasis on parametric methods.

BAE 8700. Coupled Moisture, Heat, and Chemical Transfer in Porous Media. (4 cr; prereq knowledge of differential equations, numerical solutions methods, a computer programming language; offered alt yrs) Mathematical study of coupled transfer of moisture, heat, and chemical mass in porous media with emphasis on freezing processes. Numerical solution of governing equations with emphasis on applications.

Agricultural Engineering Technology (AgET)

Courses That Carry Graduate Credit for Nonengineering Students Only


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AgET 5091. Special Problems in Agricultural Engineering. (2-5 cr; prereq #) Individual study project in agricultural engineering at advanced level. Application of engineering principles to a specific problem.

AgET 5200. Health and Safety Issues in Agricultural Work Environments. (3 cr; 3 lect/ rec hrs per wk) Hazards and control strategies for at-risk populations working in agricultural production and processing.

AgET 5410. Hydrology and Water Quality. (5 cr; prereq Math 1111, Phys 1041, Chem 1052; 3 lect, 3 lab, 1 rec hrs per wk) Wilson Hydrologic cycle: precipitation, infiltration, evaporation, surface and subsurface run-off, ground water recharge. Flow in streams and in aquifers, flow measurement; soil erosion, sediment transport and deposition; chemical pollution of surface water and groundwater.

AgET 5999. Special Workshop in Biosystems and Agricultural Engineering. (1-4 cr; prereq #) Offered off campus. Consult Class Schedule or department for current topics.

Building Science (Bldg)

Professor: James L. Bowyer (forest products); Thomas H. Kuehn (mechanical engineering); Lance LaVine (architecture); James W. Ramsey (mechanical engineering)

Associate Professor: Kevin A. Janni (bioystems and agricultural engineering); Elmer L. Schmidt (forest products); Becky L. Yust (design, housing, and apparel)

Research Fellow: Mary Vogel (landscape architecture)

Other: David T. Grimsrud (program director, Minnesota Building Research Center), director of graduate studies

Course of Study—Minor in building science, applicable to master’s (M.A. and M.S.) and doctoral programs.

Curriculum—A graduate minor in building science is offered in conjunction with the Minnesota Building Research Center. The minor offers varied opportunities for multidisciplinary study, including relevant coursework in agricultural engineering, architecture, civil engineering, computer science, electrical engineering, forest products, housing, landscape architecture, mechanical engineering, public affairs, and public health.

In addition to a required seminar in building science, the program consists of courses offered by a wide variety of departments within the University from which students make a selection in consultation with the director of graduate studies in building science.

Prerequisites for Admission—Admission to the building science graduate minor is contingent upon prior admission to a master’s or doctoral degree-granting program within the Graduate School.

Special Application Requirements—Contact the director of graduate studies in building science for an Intent to Enroll form, which students are encouraged to submit by April 1 in the academic year before beginning coursework in the minor. Later submissions are considered as space permits. A maximum of 15 students are accepted each year. Enrollment is contingent upon approval by the director of graduate studies in building science.

Minor Requirements—The required seminar must be taken before the elective courses.

   Master’s students are required to complete at least 12 graduate credits outside their major, which include 3 credits for Seminar: Building Science and 9 credits for elective courses.

   Doctoral students are required to complete at least 21 graduate credits outside their major, which include 3 credits for Seminar: Building Science and 18 credits for elective courses from two departments.

Language Requirements—None specific to the minor program.

For Further Information and Applications—Contact the Graduate Minor in Building Science, Minnesota Building Research Center, University of Minnesota, 1425 University Avenue S.E., Room 220, Minneapolis, MN 55455 (612/626-7419).

Bldg 8000. Topics in Building Science. (3 cr; prereq admission to bldg sci minor or #) Major topics and research methods used in different disciplines to investigate research questions about buildings.

Arch 5381. Computer-Aided Architectural Design

Arch 5539. Daylighting and Architectural Design

CE 5301. Foundation Engineering

CE 8605. The Finite Element Method in Civil Engineering

CE 8606. Advanced Topics in Finite Element Analysis

CSci 5121. Algorithms and Data Structures II
BUSINESS ADMINISTRATION

CSci 5280. Computer-Aided Design I
CSci 5511. Artificial Intelligence I
EE 5255. Digital Control Systems
ForP 5303. Wood Deterioration
ForP 5355. Mechanics and Structural Design With Wood Products
LA 5228. Seminar: Topics in Campus Planning
ME 5342. Heat Transfer
ME 5603. Thermal Environmental Engineering
ME 5604. Heating and Cooling Loads in Buildings
ME 5605. Refrigeration and Air Conditioning Systems
ME 5712. Solar Energy Utilization
PA 5711. Energy Policy I
PA 5721. Environmental Policy I
PubH 5181. Air Pollution

Business Administration

Professor: Paul E. Johnson, director of graduate studies, Ph.D. program; Carl R. Adams; Gordon J. Alexander; Beth E. Allen; Amin H. Amershi; John C. Anderson; Richard D. Arvey; Rajiv D. Banker; Frederick J. Beier; Lawrence M. Benveniste; R. Glen Berryman (emeritus); Mario F. Bognanno; Norman E. Bowie; John H. Boyd; Philip Bromiley; Richard N. Cardozo; Balaji S. Chakravarthy; Norman L. Chervany; Terry L. Childers; Larry L. Cummings; Gordon B. Davis; John W. Dickhaut; Michael U. Dothan; W. Bruce Erickson; John A. Fossum; Joseph Galaskiewicz; Donald V. Harper; Arthur V. Hill; Thomas R. Hoffman; Michael J. Houston; Ravi K. Jagannathan; Deborah Roedder John; George John; James S. Jordan; Edward J. Joyce; Chandra S. Kanodia; John H. Kureken; Stefanie A. Lenway; Stephen F. LeRoy; Barbara J. Loken; Salvatore T. March; Alfred A. Marcus; Christopher J. Nachtsheim; Timothy J. Nutant; Mary Lippich Nichols; Kenneth J. Roering; Richard D. Arvey; Frederick R. Jacobs, director of graduate studies, business taxation; Paul G. Gutterman; Howard Strauss; Terry L. Tranter

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.B.T. (Plan B only) and Ph.D.

Master of Business Taxation (M.B.T.)

Curriculum—This degree program is designed to help students acquire a conceptual understanding of taxation and to develop technical competence in the practical application of the rules of taxation in business and personal decision making. The program is offered only in the evening through the Carlson School of Management and University College (formerly Continuing Education and Extension). It is designed to accommodate the nontraditional student who is employed during the day and enrolled in the program on a part-time basis during the evening. Students enrolled part-time can expect to complete the program in approximately two to three years. Students enrolled full-time can complete the program in a shorter period.

Special Application Requirements—Results of the Graduate Management Admissions Test (GMAT) or the Law School Admission Test (LSAT) are required. Applicants are considered for admission for fall, winter, spring, and first summer term.

Degree Requirements—Students are required to have gained, through coursework, a common body of knowledge in the various areas of business. When the appropriate coursework is lacking, students must make up the deficiencies. These courses may be taken after admission.

Students must complete 47 credits, including 16 credits in business, economics, and accounting; 15 credits in tax methods and periods, tax research, tax procedure, and

1 As of July 1, 1996, the M.B.A. program is offered through the Carlson School of Management (CSOM), rather than through the Graduate School. All queries regarding the M.B.A. should be directed to CSOM.
corporate tax; and 16 credits of elective tax courses. Students must maintain a 3.00 grade point average.

For Further Information and Applications—
Contact the Master of Business Taxation Degree Program, Department of Accounting, University of Minnesota, 645 Management & Economics, 271 19th Avenue South, Minneapolis, MN 55455 (612/624-7511; fax 612/626-7795; e-mail mcooper@csom.umn.edu; http://www.cee.umn.edu/mbt).

Doctor of Philosophy

Curriculum—The doctoral program in business administration offers advanced graduate education for students seeking academic positions at leading universities and research-oriented positions in business and government. The study program is designed for individuals who have the intellectual capacity for advanced study, enjoy independent research and analytical thinking, and wish to master a discipline within business administration and contribute to its future development. The following areas of specialization are offered: accounting, finance, information and decision sciences, marketing and logistics management, operations and management science, and strategic management and organization.

Special Application Requirements—Scores from the Graduate Management Admission Test (GMAT) taken within the last five years are required unless the applicant has already taken the Graduate Record Examination (GRE), in which case GRE scores may substitute for GMAT scores.

Degree Requirements—The program includes a field of specialization within the Carlson School of Management, research methodology, supporting fields of study, preliminary written and oral examinations, and a doctoral dissertation. If a student does not have a bachelor’s or master’s degree in business administration, certain basic courses may also be required. Three to four years of full-time study are usually required to complete the Ph.D.

Minor Requirements for Students Majoring in Other Fields—For a Ph.D. minor in business administration, students must complete a cohesive program of 24 credits of graduate work in the field, developed in consultation with an adviser who is a full member of the graduate faculty in business administration.

For Further Information and Applications—
Contact the Ph.D. program, Carlson School of Management, University of Minnesota, 295 Humphrey Center, 271 19th Avenue South, Minneapolis, MN 55455 (612/624-0875; fax 612/626-7785).

BA 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

BA 8888. Thesis Credits: Doctoral. (36 cr required)

Accounting (Acct)

Acct 5101. Corporate Financial Reporting. (4 cr; prereq 1050 or MBA 8030, MBA student or Sch Mgmt approval)
Preparation and interpretation of corporate financial reports. Income determinations, revenue recognition, income tax allocation, inventories, fixed assets, long-term debt, and leases.

Acct 5102. Advanced Financial Reporting I. (4 cr; prereq 3101 or 5101, mgmt or grad mgmt student or Sch Mgmt approval)
Relationship between complex events such as defined benefit pension plans, leases, and intercorporate investments and their reflection in financial statements. Introduction to business combinations and consolidated financial reporting.

Acct 5125. Auditing Principles and Procedures. (4 cr; prereq 3101 or 5101, accounting major or Sch Mgmt approval)
The auditor’s role and function. Includes audit standards, ethics, procedures, legal responsibilities.

Acct 5126. Internal Auditing. (4 cr; prereq 3201 or 5201, 5102, accounting major or Sch Mgmt approval)

Acct 5135. Income Tax Accounting. (4 cr; prereq 1025 or 1050, accounting major or Sch Mgmt approval)
Introduction to principles of federal income taxation of various taxing entities.

Acct 5160. Financial Statement Analysis. (4 cr; prereq 1050 or MBA 8030, accounting major or Sch Mgmt approval)
Interpretation and analysis of financial statements and schedules for investors and other users.

Acct 5180. Advanced Accounting II. (4 cr; prereq 5102, mgmt or MBA student or Sch Mgmt approval)
Consolidated financial reporting with focus on international business organizations. Introduction to reporting issues in governmental and not-for-profit entities.
Acct 5230. Corporate Taxation. (4 cr; prereq 5135 or equiv, MBT program approval) Jacobs
Tax consequences of formation, operation, and liquidation of a business corporation.

Acct 5236. Taxation II. (4 cr; prereq 5135, accounting major or Sch Mgmt approval)

Acct 5310. International Accounting. (4 cr; prereq 3001, Sch Mgmt approval)
Macroeconomic concepts of international economics; survey of accounting policies and approaches among nations.

Acct 5340. Partnership Taxation. (4 cr; prereq 5135 or equiv, MBT program approval)
Tax consequences of formation, operation, and dissolution of a partnership.

Acct 5390. Current Topics in Taxation. (Cr ar; prereq 5135 or equiv, MBT program approval)
Current tax legislation problems. Topics vary quarterly.

Acct 8100. Tax Accounting Methods and Periods. (4 cr; prereq 5135 or equiv, MBT program approval) Carter
Rules affecting timing of income and deductions for tax purposes. Cash and accrual accounting methods examined overall and with respect to individual items of income and deductions. Rules for changing accounting methods and accounting periods.

Acct 8150. Financial Accounting Issues. (4 cr; prereq 1050, 3001, MBT program approval) Tranter
Accounting principles and practices underlying preparation of financial statements and additional disclosures. Includes recent pronouncements on financial accounting.

Acct 8220. Tax Research and Communication. (3 cr; prereq 5135 or equiv, MBT program approval) Guttermann
In-depth treatment of tax research methodology including tax questions, locating potential authority, assessing potential authority, and communicating research results.

Acct 8225. Tax Procedure and Practice. (4 cr; prereq 5135 or equiv, MBT program approval) Guttermann
Procedure dealing with the IRS including sources of IRS policy; processing returns; auditing returns; rulings and determination letters; closing agreements; assessments and collections.

Acct 8230. Taxation of Corporations I. (4 cr; prereq 5135 or equiv, MBT program approval) Jacobs
Federal income taxation of corporations and shareholders. Organization of a corporation; establishment of its capital structure; determination of its tax liability; dividends and other nonliquidating distributions, stock redemptions, and liquidations.

Acct 8330. Taxation of Corporations II. (4 cr; prereq 8230 or equiv, MBT program approval)
Corporate readjustments related to multiple corporations and consolidated returns.

Acct 8340. Taxation of Partners and Partnerships. (4 cr; prereq 5135 or equiv, MBT program approval)
Reviews tax consequences associated with formation, operation, and dissolution of a partnership.

Acct 8350. Taxation of Estates, Gifts, and Trusts. (4 cr; 5135 or equiv, MBT program approval)
Taxation of transfers under federal estate and gift tax laws. Includes property owned by the decedent; retained life estates; transfers taking effect at death; revocable transfers; joint interest; powers of appointment; valuation problems; expenses, debts, and taxes; charitable requests; marital deduction; taxable inter vivos gifts, gift splitting and credits.

Acct 8356. Taxation of Deferred Compensation and Fringe Benefits. (4 cr; prereq 8230 or equiv, MBT program approval)
Federal income taxation of corporate deferred compensation and fringe benefits with emphasis on pension plans, profit sharing plans, stock options plans, individual retirement accounts, annuities and insurance, medical related compensation benefits, and reporting requirements.

Acct 8360. State and Local Taxation. (4 cr; prereq 5135 or equiv, MBT program approval)
Minnesota individual and corporate income, property, sales, and excise taxes. Tax problems of businesses with multistate operations.

Acct 8380. Tax Aspects of International Business. (4 cr; prereq 8230 or equiv, MBT program approval)
Multinational business operations and transactions involving foreign income. Tax consequences of transactions with foreign organizations and by related foreign companies.

Acct 8390. Current Topics in Taxation. (Cr ar; prereq 5135 or equiv, MBT program approval)
Current tax legislation and problems. Topics may vary quarterly.

Acct 8805. Seminar I. (4 cr; prereq PhD student or Grad Sch Mgmt approval)
Economics modeling applied to accounting issues.

Acct 8810. Seminar II. (4 cr; prereq PhD student or Grad Sch Mgmt approval)
Empirical financial accounting research.

Acct 8820. Seminar III. (4 cr; prereq PhD student or Grad Sch Mgmt approval)
Behavioral accounting research.

Acct 8990. Readings in Accounting. (Cr ar; prereq #, Grad Sch Mgmt approval)
Readings not available in regular courses.

Acct 8995. Research in Accounting. (Cr ar; prereq PhD student, Grad Sch Mgmt approval)
Business, Government, and Society (BGS)

BGS 8017. Organizational Politics and Management. (4 cr; prereq grad mgmt student or Grad Sch Mgmt approval)
Political aspects of managing a large corporation. Political considerations examined both in terms of the political process within an organization and in terms of the organization’s political relationships with other institutions.

BGS 8019. Topics in Business, Government, and Society. (4 cr; prereq grad mgmt student)
Selected topics and problems of current interest and of a varied nature considered in depth. Class discussion and course projects. Content varies quarterly depending on the instructor.

Business Law (BLaw)

BLaw 8158. Introduction to Law, the Law of Contracts and Sales Contracts. (4 cr, §3058; prereq Econ 1002, grad mgmt student or Grad Sch Mgmt approval)
Origin of law, its place in and effect upon society; history and development of law; system of courts, legal procedure. Extensive study of the law of contracts as the basic law affecting business transactions; law affecting sales of goods contracts.

BLaw 8278. Agency, Partnerships, Corporations, and Commercial Paper. (4 cr, §3078; prereq 8158, grad mgmt student or Grad Sch Mgmt approval; offered when feasible)

BLaw 8288. Law of Personal Property, Real Property, Wills and Estates. (4 cr, §3088; prereq 8158, grad mgmt student or Grad Sch Mgmt approval; offered when feasible)

Entrepreneurship (Entr)

Entr 8082. Entrepreneurship. (4 cr, §Mgmt 8082, §Mktg 8082; prereq MBA core courses) Cardozo Analysis of entrepreneurial activities, including identifying opportunities, creating value, developing business concept and plan, attracting resources, building an organization, handling risks, managing growth, coping with failure, restructuring and redirecting an organization. Role of entrepreneurship in organization, economy, society. Integrates concepts and materials from all business functions. Extensive use of case studies.

Finance (BFin)

BFin 8100. Cases in Financial Management. (4 cr; prereq MBA 8040 or #, grad mgmt student or Grad Sch Mgmt approval)
Introduction to corporate project analysis and financial planning and to corporate financial decision making. Cases used to illustrate what modern finance theory implies for evaluation of operating, e.g., marketing, production, strategic, and capital structure decisions. Intended primarily for students not specializing in finance.

BFin 8150. Theory of Finance. (4 cr; prereq MBA 8040 or #, grad mgmt/IR student or Grad Sch Mgmt approval)
Rigorous introduction to modern theory of finance. Discussion of, inter alia, capital budgeting, capital structure, dividend policy, asset pricing, application of option pricing to corporate finance, and efficiency of financial markets.

BFin 8200. Financial Markets and Interest Rates. (4 cr; prereq MBA 8040 or #, grad mgmt student or Grad Sch Mgmt approval)
Survey of financial markets of modern economies and introduction to theory of how interest rates in the various markets are related. Discussion of, inter alia, interest rate term structure, relationship between interest rate and exchange rate, inflation and interest rates, and use of financial futures.

BFin 8300. Investments and Portfolio Management. (4 cr; prereq 8150 or #, grad mgmt student or Grad Sch Mgmt approval)
Introduction to investment decision-making procedures and environment for individuals and institutions. Analytical methods for evaluating securities and how these methods relate to modern portfolio theory. Focus on common stocks.

BFin 8400. International Financial Management. (4 cr; prereq 8150 or #, grad mgmt student or Grad Sch Mgmt approval)
Implications of modern finance theory for multinational corporation. Discussion, for background, of alternative exchange rate regimes and risks each regime imposes on the multinational and how different international risks influence basic corporate financial decisions.

BFin 8601. Corporate Investment and Financial Strategy. (4 cr; prereq 8150 or #, grad mgmt student or Grad Sch Mgmt approval)
In-depth theoretical analysis of long-term financial decisions, using case studies. Discussion of, inter alia, Modigliani-Miller results for capital structure and dividend policy, and use of capital asset pricing models in capital budgeting.

BFin 8602. Financial Management of Financial Institutions. (4 cr; prereq 8150 or #, grad mgmt student or Grad Sch Mgmt approval; Econ 3101 or Econ 3105 recommended)
Introduction to decision making in commercial banks and other depository institutions, with emphasis on lending and funding decisions. Interest rate risk and, inter alia, influence of technological change on banking business.

BFin 8603. Futures Markets. (4 cr; prereq 8150 or #, grad mgmt student or Grad Sch Mgmt approval)
Markets and uses for financial futures and options on these futures. Rational pricing of these instruments and their application by financial and portfolio managers.

BFin 8604. Options Markets. (4 cr; prereq 8150 or #, grad mgmt student or Grad Sch Mgmt approval)
Basic features and uses of options. Stock, stock index, bond, currency, and futures options. Use of options in management of portfolio risk, interest rate risk, and foreign currency risk.
BFin 8606. Investment Banking. (4 cr, §8605; prereq 8150 or #, grad mgmt student or Grad Sch Mgmt approval)
How investment bankers serve corporate clients (and themselves), optimal contracts, pricing of new issues, mergers and acquisitions, and legal framework of investment banking.

BFin 8801. Introduction to Finance. (4 cr; prereq Math 1261 or equiv, Math 3251 or equiv or Math 3251, Math 3261 or equiv or Math 3261, Econ 8101 or Econ 8101 or #, PhD student)
Expected utility theory, measures of risk, portfolio choice, aggregation and separation, linear pricing models.

BFin 8810. Corporate Finance. (4 cr, §8821; prereq 8801, PhD student)
Separation and unanimity, investment strategies, valuation of corporate liabilities, financing strategies, dividend policy.

BFin 8811. Mathematical Methods in Finance. (4 cr, §8802; prereq 8801, Stat 5121 or equiv or #, PhD student)

BFin 8812. Econometric Methods in Finance. (4 cr, §8831; prereq 8801, Stat 5121-5122 or Stat 5131-5132 or #, PhD student)
Econometric tests of linear pricing models, tests of market efficiency, event studies.

BFin 8813. Theory of Financial Contracts. (4 cr; prereq 8801, PhD student)
Risk sharing contracts, incentive contracts, agency, signaling, self-selection, incentive compatibility, financial intermediation.

BFin 8814. Advanced Theory of Capital Markets. (4 cr, §8803; prereq 8801, 8811, Econ 8102 or equiv or #, PhD student)
Intertemporal portfolio choice, intertemporal general equilibrium models, options, futures, theory of the term structure, rational expectations.

BFin 8850. Independent Study in Finance. (Cr ar [may be repeated for cr]; prereq #, grad mgmt student, Grad Sch Mgmt approval)
Problems or developments of special interest in finance.

BFin 8900. Directed Research in Finance. (Cr ar [may be repeated for cr, max 24 cr]; prereq PhD finance student, completion of required coursework for PhD)
Individualized directed research. Project approved and advised by faculty member.

Information and Decision Sciences (IDSc)

IDSc 5410. Decision Support and Expert Systems. (4 cr; prereq 3030 or MBA 8025 or MBA 8225 or equiv or #)
Overview of technical and organizational aspects of decision support systems (DSS), including individual and group DSS, expert systems, and executive information systems. Management of DSS within end-use computing environments. Conceptual foundations of DSS, DSS software reviews, and case examples.

IDSc 5998. Special Research Topics. (4 cr; prereq Δ; offered when feasible)

IDSc 8110. Individual Productivity With Information Technology. (4 cr, §8103) Davis, Naumann
Analysis design, development, and use of information technology and systems in support of productivity by a knowledge worker or work group. Information resources for individual knowledge worker tasks and activities. Analyzing individual information requirements and defining an appropriate information technology infrastructure. Defining data needs plus access and retention of records, text, and multimedia data. Tailoring and extending capabilities and utility of common tools and software packages. Applying application development tools to specify, design, and implement individual information system applications. Defining work-group information access and connectivity needs. Differentiating role of knowledge worker in building and maintaining individual systems from role of IS specialist in departmental and corporate application development and maintenance.

IDSc 8120. Organizational Productivity With Information Technology. (4 cr, §8102)
Conceptual foundations and trends in hardware, software, databases, and telecommunications. Program architecture, information architectures, systems development, programming languages and tools, operations, re-engineering, data management, systems planning, IT industry, data security, disaster recovery, and legal issues in management of computing. Conceptual foundations, alternative corporate approaches, and case examples. Perspectives of information systems manager and user manager.

IDSc 8130. Information Systems Analysis, Design, and Development. (4 cr, §8103; prereq 8110 or #) March
Development of large-scale applications systems, including abstraction, design, and construction. Theoretical and methodological perspectives. Basic systems concepts; information requirements determination; data flow, data structure, behavior, and object-oriented modeling; relational database concepts. Use of CASE tools in storing and analyzing data flow diagrams.
IDSc 8140. Managing Information Services. (4 cr; 58101; prereq 8120, 8130 or #) Chervany, Wanninger
Issues, strategies, and tactics for managing delivery of information technology and related services to organizations. Major topics in the managing of information systems at corporate and business-unit level. Case examples, role-playing, and outside speakers. Alternative corporate approaches. Students prepare briefing reports on corporate MIS approaches.

IDSc 8430. Advanced Database Design and Administration. (4 cr; prereq grad mgmt student, 8130 or equiv or #) Everest
Perspective of data administrator serving users of information and DBMS. Role, organization, functions, and tools of data administration. Data planning and information architectures. Advanced logical database design. Advanced database manipulation with high-level and natural languages. Object-oriented DBMS and support for graphics and CAD/CAM applications. Data security, maintaining database integrity, and managing data in a shared, networking, or distributed environment. Strategies for using advanced DBMS tools in systems development and operations.

IDSc 8440. Advanced Information Systems Development. (4 cr; prereq 8130 or equiv or #) March
Emerging technologies affecting information systems development process and information systems. Computer-aided software engineering tools, distributed systems, and electronic data interchange. Field study of new technology or new technique required.

IDSc 8450. Telecommunications. (4 cr; prereq MBA 8225 or equiv or #) Naumann
Introduction to concepts and terminology of electronic communications. Data communications hardware, software, and facilities. Public and private, local and wide area networks. Communications industry, telecommunications regulations, standards, and standards development process. Data communications systems, including network planning, implementation and maintenance, systems development in telecommunications environment, and planning and management of telecommunications systems in organizations.

IDSc 8500. Conceptual and Research Introduction to Information and Decision Sciences. (4 cr; prereq PhD student or #) Davis, staff
Relationships to underlying disciplines. Major research streams. Seminal articles, survey literature, and major researchers. Framework for organizing knowledge about information and decision sciences.

IDSc 8502. Organization Theory and Research in the Information and Decision Sciences. (4 cr; prereq PhD student or #) Goodhue
Review of organization theory and research from economics, organization studies, and sociology relevant to study of information and decision sciences.

IDSc 8503. Cognitive Science Research and Theory in the Information and Decision Sciences. (4 cr; prereq PhD student or #) Johnson
Empirically based concepts of knowledge and reason. Mental representation and conceptual systems that guide problem solving and decision making. Computational metaphor of mind drawn from psychology, computer science, linguistics, anthropology, and philosophy. Implications for understanding of knowledge work.

IDSc 8599. Seminar in Information and Decision Sciences Topics. (4 cr; may be repeated for cr; prereq PhD student or #)
Topic selected from new areas of research, research methods, and significant issues.

IDSc 8601. System Development Seminar. (4 cr; prereq PhD student or #; offered alt yrs) March
Concepts and practice in information systems development; process and data analysis; development life cycle research issues; research methods, emphasizing modeling and simulation.

IDSc 8702. Behavioral Decision Theory. (4 cr; prereq PhD student or #, offered alt yrs) Curley

IDSc 8710. Heuristic Decision Making. (4 cr; prereq PhD student or #) Johnson
Cognitive basis for human decision making; theory and methodology for study of the knowledge individuals use to meet demands of tasks in work settings and everyday life.

IDSc 8990. Readings in Information and Decision Sciences. (Cr ar; prereq PhD student, #)

IDSc 8995. Graduate Research in Information and Decision Sciences. (Cr ar; prereq PhD student, #)

Insurance (Ins)

Ins 5100. Risk Management and Insurance. (4 cr; prereq grad mgmt student or Grad Sch Mgmt approval)
Recognizing and evaluating the property, liability, and personal risks facing businesses, nonprofit organizations, government units, individuals, or families. Tools of risk management—retention, loss control, and insurance—and conditions under which they should be used. Selecting and dealing with an insurer. Public policy issues—government regulation, social insurance, health insurance and pension legislation, and automobile insurance problems.
Ins 5230. Life Contingencies I. (4 cr, §Math 5057; prereq Math 1211, Math 1221, Math 1231 or Math 1131 or #) Calculation of net premiums, gross premiums, reserves, and nonforfeiture values for major life insurance contracts. Impact of assumed mortality, interest, and expense assumptions on these items.

Ins 5231. Life Contingencies II. (4 cr, §Math 5058; prereq 5230 or #) Advanced topics such as compound interest and annuities certain, the measurement of mortality, life insurance and annuity premiums and reserves. Multilife functions. Population problems and multiple-decrement theory.

Logistics Management (LM)

LM 5010. Topics in Logistics Management. (4 cr; prereq 3000 or 5030 or 5020, #, mgmt or grad mgmt student, Sch Mgmt approval) Beier, Harper Specialized topics in field of logistics; topics change quarterly.

LM 5020. Advanced Logistics Management. (4 cr; prereq 3000 or 5030 or equiv, mgmt or grad mgmt student, Sch Mgmt approval) Beier, Harper Management of flow of physical products (supply and distribution) of an organization. Transportation alternatives, customer service, inventory management, location decisions, warehousing, logistics information systems, international logistics, and logistics system design. Primarily case problems. Includes simulation exercise.

LM 5030. Principles of Transportation. (4 cr; prereq Econ 1101 or equiv, mgmt or grad mgmt student, Sch Mgmt approval) Beier, Harper Organizational, economic, and service aspects of U.S. transportation system, including rail, highway, water, pipeline, and air transportation. Decision making in transportation companies. Government promotional and regulatory policy.

LM 8030. Seminar in Logistics Management. (4 cr; prereq 3000 or 3010 or 5030; offered when feasible)

LM 8990. Readings in Logistics Management. (Cr ar; prereq consent of adviser, #, Grad Sch Mgmt approval)

LM 8995. Graduate Research in Logistics Management. (Cr ar; prereq Grad Sch Mgmt approval)

Management (Mgmt)

Mgmt 5101. Advanced Topics in Management. (Cr ar [may be repeated for cr]; prereq sr or grad student, #) Specialized topics; content varies quarterly.

Mgmt 5175. Strategic Forecasting for Managers. (4 cr; prereq 3001 or MBA student or #) Methods of economic, social, and technological forecasting and applications to problems of managerial decision making and planning.

Mgmt 8004. Advanced Topics in Management. (4 cr [may be repeated for cr]; prereq 3001 or 8001 or MBA 8010, grad mgmt student or Grad Sch Mgmt approval) Topics of special interest; content varies quarterly.

Mgmt 8006. Psychology in Management. (4 cr, §3002; prereq grad mgmt student or Grad Sch Mgmt approval) Development and application of behavioral principles, methods, and skills fundamental to managerial competence in preventing and solving problems within and between individuals and groups and that aid in effective use of human resources. Various lab procedures used to study these concepts, methods, and skills and furnish practice in applying them to management problems.

Mgmt 8012. Organizational Behavior and Management Analysis. (4 cr; prereq grad mgmt student or Grad Sch Mgmt approval) Concepts, theories, and empirical research relevant to diagnosis, prediction, and control of human behavior in complex organizations. Models and techniques for analyzing group processes, leadership styles, and organizational structure, change, and environment. Students prepare papers based on their own research or on secondary analysis of existing literature.

Mgmt 8021. Organization Design and Development. (4 cr; prereq grad mgmt student or Grad Sch Mgmt approval) Design and implementation of organizational change. An information processing point of view used to examine design of communication, decision making, and task systems. Theories and techniques of change at both the organization-wide and individual levels. Emphasis on developing skills for managing change and conflict.

Mgmt 8031. Industry and Competitive Analysis. (4 cr; prereq MBA 8060) Formulating competitive strategies at business unit level. Students acquire skills necessary to analyze an industry and competition within it.

Mgmt 8032. International and Cooperative Strategies. (4 cr; prereq MBA 8060) International corporate strategies and cooperative strategies between organizations, such as licensing, franchising, joint ventures, and other strategic alliances.

Mgmt 8033. Managing the Strategy Process. (4 cr; prereq MBA 8060) Process through which strategy is formed and implemented in large diversified organizations. Structuring the organization, strategic planning and control systems, incentives systems, strategic human resource management, and top management style.

Mgmt 8050. The Management of Innovation and Change. (4 cr, §5050; prereq grad mgmt student or Grad Sch Mgmt approval) Application of theories and research on development and implementation of new organizational programs, products, and technologies, and which paths lead to success, which to failure. Builds diagnostic skills and principles for managing organizational innovation and change.
Mgmt 8082. Entrepreneurship. (4 cr; §Entr 8082, §Mktg 8082; prereq MBA core courses) Cardozo Analysis of entrepreneurial activities, including identifying opportunities, creating value, developing business concept and plan, attracting resources, building an organization, handling risks, managing growth, coping with failure, restructuring and redirecting an organization. Role of entrepreneurship in organization, economy, society. Integrates concepts and materials from all business functions. Extensive use of case studies.

Mgmt 8101. Seminar in Strategic Management. (4 cr; prereq PhD student or Grad Sch Mgmt approval) Research and theory on strategic management, including policy formulation and implementation, long-range corporate planning, internal organizational design, administrative behavior, management of external environment, interactions between business, government, and society, and interorganizational relations.

Mgmt 8102. History of Management Thought. (4 cr; prereq PhD student or #, Grad Sch Mgmt approval) History and philosophy of management thought as it emerged from economics, sociology, psychology, industrial engineering, and management perspectives.

Mgmt 8201. Foundations of Business-Government-Society. (4 cr; prereq PhD student or #, Grad Sch Mgmt approval) Original works in political philosophy, legal philosophy, social theory, and economics. Understanding of history of thought in this area, critical awareness of competing contemporary approaches to public policy decisions.

Mgmt 8202. Seminar in International Management. (4 cr; prereq PhD student or Grad Sch Mgmt approval) Substantive strategic and organizational challenges posed to firms by global market integration; links to economics, political science, and macro- and micro-organization theory.

Mgmt 8203. Research Topics and Methods in Business-Government-Society. (4 cr [may be repeated for cr]; prereq PhD student or Grad Sch Mgmt approval) Helps students understand current research area, identify research topics, formulate researchable problems, and choose appropriate methods. Critique of methods used in outstanding current research required.

Mgmt 8301. Seminar in Organization Behavior. (4 cr; prereq PhD student or Grad Sch Mgmt approval; offered alt yrs) Major theories and current research on individual and group processes in organizations from a micro perspective.

Mgmt 8302. Seminar in Organization Theory. (4 cr; prereq PhD student or Grad Sch Mgmt approval; offered alt yrs) Major theories and current research on organizational and interorganizational topics from a macro perspective.

Mgmt 8303. Organizational Research Seminar. (4 cr; prereq PhD student, #) Advanced topics and research problems related to specific organizational issues. Development of focused research problems, theory building, hypotheses formulation, research design, and observation.

Mgmt 8401. Seminar in Strategy Formulation. (4 cr; prereq PhD student or Grad Sch Mgmt approval) Theories and current research on processes by which organizations develop goals, objectives, strategic policies, long-range plans, and programs. Theories and research across functions of marketing, finance, accounting, operations research, and other disciplines.

Mgmt 8402. Seminar in Strategy Implementation. (4 cr; prereq PhD student or #, Grad Sch Mgmt approval) Process through which strategy is formed/implemented in multibusiness firms. Introduces important theoretical and empirical literature on how senior managers can effectively establish premises that guide subordinate managers in making/implementing strategic decisions.

Mgmt 8403. Strategic Management Research Seminar. (4 cr [may be repeated for cr]; prereq PhD student or Grad Sch Mgmt approval) Special, advanced theories and research in strategic management. Helps students formulate strategic problems, create theories and hypotheses, design research, collect and analyze data, and critique current theories and methods used to examine strategic managerial problems.

Mgmt 8990. Readings in Management Theory and Administration. (Cr ar; prereq 2nd-yr grad student, requisite intro courses, adviser consent, #, Grad Sch Mgmt approval) Intensive research in a particular subject; preparation of a major term paper normally required.

Mgmt 8995. Graduate Research in Management Theory and Administration. (Cr ar; prereq 2nd-yr grad student, requisite intro courses, adviser consent, #, Grad Sch Mgmt approval) Special research projects on a specific problem completed in cooperation with a business firm.
Marketing (Mktg)

Mktg 8051. Marketing Research. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ. grad mgmt student or Grad Sch Mgmt approval) Childers, D John, Stone Methods for collecting and analyzing data to solve marketing problems. Survey research techniques. Research design, secondary and primary data collection, sample design, and data analysis. Application of these techniques to marketing problems.

Mktg 8053. Marketing Research: Advanced Topics and Fieldwork. (4 cr; prereq 8051, grad mgmt student or Grad Sch Mgmt approval) Childers Application of marketing research in a study with an actual client. Advanced topics such as single source data and computer-assisted interviewing. Advanced techniques for sampling and data analysis.

Mktg 8055. Consumer Behavior. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Loken, Rao Applications of behavioral sciences to understanding customer behavior in the marketplace. Perception, learning, persuasion, motivation, personality, decision-making strategies, and family, social, and cultural influences. Managerial implications and applications.

Mktg 8060. Distribution Systems. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Ritson, Walker Analysis of interrelationships between marketing institutions and their formation into channels of distribution. Interorganizational problems, including design and management of distribution channels.

Mktg 8072. International Marketing. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Beier, G John, Roering, Rueskt Analysis of the development of international marketing function. Identifying marketing-based international business opportunities; constructing and evaluating culturally adjusted marketing strategies.

Mktg 8074. Product Policy. (4 cr, §8084; prereq MBA 8045 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Rukert, Shocker New product development process. Modification of existing product lines and managing product portfolio.

Mktg 8075. Pricing Strategy. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad School Mgmt approval) Rukert Analysis of cost, customer, and competition issues in formulation of pricing strategy. Pricing new and existing products, product lines, and services through channels of distribution for industrial and consumer markets.

Mktg 8076. Sales Management. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Rao, Walker Management of personal selling function of promotional mix. Problems of performance evaluation, sales force selection, compensation, and territorial design.

Mktg 8078. Marketing Communications. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Ritson Managing communication aspect of marketing strategy. Advertising and sales promotion. Setting advertising objectives and budgets, media selection, creative strategy, and sales promotion techniques.

Mktg 8080. Business-to-Business Marketing. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) G John Marketing issues facing firms that buy/sell products and services to other firms. Combining tools and analytic techniques. Buying behavior of organizational clients, trade marketing programs, vertical integration, and alliances between firms.

Mktg 8082. Entrepreneurship. (4 cr, §Entr 8082, §Mgmt 8082; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad School Mgmt approval) Cardozo Analysis of entrepreneurial activities, including identifying opportunities, creating value, developing business concept and plan, attracting resources, building an organization, handling risks, managing growth, coping with failure, restructuring and redirecting an organization. Role of entrepreneurship in organization, economy, society.

Mktg 8088. Strategic Marketing. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) G John, Roering, Rueskt Determination of product-markets where organization should compete; sustainable competitive advantage to be developed. Matching marketing strategy with environment. Coordination between marketing and other business functions. Organization of marketing function and management of marketing process.

Mktg 8090. Marketing Topics. (4 cr [may be repeated for cr]; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Selected topics and problems of current interest and of a varied nature considered in depth. Class discussion and course projects. Content varies quarterly.

Mktg 8800. Seminar: Marketing Theory. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Rukert, Shocker Topics and Fieldwork.

Mktg 8810. Seminar: Consumer Behavior. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval) Loken Applications of behavioral sciences to understanding customer behavior in the marketplace. Perception, learning, persuasion, motivation, personality, decision-making strategies, and family, social, and cultural influences. Managerial implications and applications.

Mktg 8830. Seminar: Inter-Organizational Relations. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad School Mgmt approval) G John

Mktg 8840. Seminar: Theory and Methods of Measurement. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad School Mgmt approval) Childers
Mktg 8850. Seminar: Design and Implementation of Marketing Strategies. (4 cr; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad School Mgmt approval) Ruekert

Mktg 8890. Seminar: Marketing Topics. (4 cr [may be repeated for cr]; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad School Mgmt approval)

Mktg 8890. Readings in Marketing. (Cr ar [may be repeated for cr]; prereq MBA 8045 or MBA 8210 or equiv or Δ, grad mgmt student or Grad Sch Mgmt approval)

Mktg 8895. Graduate Research in Marketing. (Cr ar; prereq MBA 8045 or MBA 8210 or equiv or Δ, consent of adviser, #, grad mgmt student or Grad Sch Mgmt approval)

Master of Business Administration (MBA)

Graduate School students who wish to take MBA courses must contact CSOM.

MBA 5100. Management Topics. (Cr ar; prereq #)

MBA 8005. Computer Access and Programming for Business Analysis. (1 cr; prereq MBA student; evening program)

MBA 8010. Management and Organization Behavior. (4 cr; prereq MBA student; evening program)
The process of planning, organizing, directing, and controlling. Theories of organization performance, structure, and design. Interpersonal and leadership skills. Emphasis on applications of theory to business situations faced by the practicing manager and on development of interpersonal skills. Case studies and in-class simulations used.

MBA 8015. Human Resources Management. (4 cr; prereq MBA student; evening program)

MBA 8020. Business Statistics: Data Sources, Presentation, and Analysis. (4 cr; prereq MBA student; evening program)

MBA 8025. Decision Sciences and Information Systems. (4 cr; prereq MBA student; evening program)

MBA 8030. Financial Accounting. (4 cr; prereq MBA student; evening program)

MBA 8035. Managerial Accounting. (4 cr; prereq MBA student; evening program)

MBA 8040. Financial Management. (4 cr; prereq MBA student; evening program)

MBA 8050. Operations Management. (4 cr; prereq MBA student; evening program)

MBA 8055. Business, Government, and Macroeconomics. (4 cr; prereq MBA student; evening program)

MBA 8060. Strategy and Policy. (4 cr; prereq MBA student; evening program)

MBA 8070. Problem Formulation and Decision Making. (5 cr; prereq MBA student; evening program)

GRADUATE PROGRAMS
MBA 8110. Behavioral Science for Business. (4 cr; prereq MBA student) Basic knowledge from various disciplines about human, collective, and institutional behavior, and methods for learning this knowledge. Fundamental behavioral science theories and evidence; ability to diagnose situations and critique applications presented in subsequent courses.

MBA 8120. Data Analysis and Statistics for Managers. (4 cr; prereq MBA student) Application of exploratory data analysis, basic inferential procedures, statistical process control, and regression analysis; methods selected for relevance to managerial decision making and problem solving. Improvement of “statistical thinking” abilities.

MBA 8130. Financial Accounting. (3 cr; prereq MBA student) Hughes, Rayburn Basic principles of financial accounting underlying construction, interpretation, and use of corporate financial reports.

MBA 8140. Managerial Economics. (4 cr; prereq MBA student) Leroy, McCabe How markets work, how positive economic rents (profits) are made, and how strategic behavior affects profits. Market micro-structure, industrial structure, uncertainty, and incentives and firm governance.

MBA 8210. Marketing Management. (4 cr; prereq MBA student) D John, Roering, Walker Managing the marketing function; understanding foundational marketing concepts, marketing strategy and planning. Diagnosis of marketing problems and opportunities at operational and strategic levels. Part of integrated functional core.


MBA 8225. Integrated Information Management. (2 cr; prereq MBA student) Chervany, Davis Managing information resources and providing support services for users. Information resources include internally and externally developed information and associated hardware and software technology, personnel and users, and operational and management systems. Part of integrated functional core.

MBA 8230. Financial Management. (4 cr; prereq MBA student) Gahlon, Nantell Tools and concepts of financial management and their use by financial and non-financial managers to measure creation of value within organizations. Valuation of businesses and business opportunities; identification of financial requirements and financing sources. Part of integrated functional core.

MBA 8235. Managerial Accounting. (3 cr; prereq MBA student) Joyce, Kanodia Cost systems as potential sources of sustainable competitive advantage. Designing cost systems to provide manager with accurate, relevant, and timely information. Part of integrated functional core.

MBA 8300. Strategic Management. (4 cr; prereq MBA student) Balakrishnan, Bromley Introduction to concepts and techniques of strategic analysis and management used to create and implement a coherent concept of overall corporate direction. Strategy formulation and implementation at business unit and corporate levels. Takes international orientation.

MBA 8305. The International Environment of Business. (2 cr; prereq MBA student) Jacques, Lenway Dynamics of international business environment (institutions, markets, and sociocultural systems) and its impact on competitiveness of firms. Roles of and relationships with governments and sociopolitical systems, trade theories and policies, international monetary and financial systems.

MBA 8315. The Ethical Environment of Business. (2 cr; prereq MBA student) Bowie, Maitland Relationship of ethical management and the law. Implications for corporate profitability. Managing to maximize profits of shareholders vs. managing to harmonize interests of various stakeholders. Workplace safety, product liability, the environment, regulation, and fiduciary obligations to shareholders.


MBA 8335. Managing for Quality and Continuous Improvement. (2 cr; prereq MBA student) Theory and practice of quality management and continuous improvement. Incorporation of issues of quality improvement in business strategy, customer requirements, organizational design, process and product design and control, and management of products and services in the field.

MBA 8500. Field Consulting Project. (6 cr; prereq MBA student; offered in day MBA program only) Interdisciplinary team approach to formulation and execution of a study of an actual business problem. Teams work on problems currently faced by business, nonprofit, and government organizations in the Twin Cities metropolitan area.
MBA 8600. Top Management Perspectives. (2 cr; prereq MBA student)
Brings students face-to-face with leading executives and entrepreneurs from throughout the nation. Values, attitudes, and skills for leadership. How personal characteristics and beliefs of leaders shape situations.

Operations and Management Science (OMS)

OMS 5155. Methods for Quality and Productivity Improvement. (4 cr, §DSci 5055; prereq 1020 or MBA 8020 or #, mgmt or grad mgmt student)
Statistical methods for on-line and off-line quality control. Quality management philosophy, Pareto analysis, control charts, experimental design, and sampling inspection. Applications to administrative, service, and production operations.

OMS 5170. Simulation Modeling. (4 cr; prereq MBA student, Grad Sch Mgmt approval)
Survey of probabilistic modeling, with emphasis on computer simulation of complex systems. Event-scheduling simulation models, process-interaction simulations using high-level simulation language, structural and quantitative simulation modeling, overview of simulation methodological issues, animation. Use of computers and various languages to carry out actual simulation studies. Business applications.

OMS 5180. Reliability Design and Analysis. (4 cr; prereq MBA student, Grad Sch Mgmt approval)
Fundamental aspects of reliability theory and practice. Designing reliability into products or systems via probabilistic modeling and analysis, and development of cost-efficient, life-testing procedures for analysis of lifetime data.

OMS 5850. Topics in Operations and Management Science. (4 cr; prereq 1020, 3000 or #, MBA student, Grad Sch Mgmt approval)
Topics may vary quarterly.

OMS 6051. Management of Service Operations. (4 cr; prereq 3000 or MBA 8050 or #, grad mgmt student or Grad Sch Mgmt approval)
Decision making for producing services and improving service firm productivity and quality. Service output measurement, defining customer contact, service classification, designing service delivery systems, capacity management in service firms, service automation, and service quality improvement. Lectures and case studies.

OMS 8056. Production and Inventory Management. (4 cr, §OM 8056; prereq 3000 or MBA 8050 or #, grad mgmt student or Grad Sch Mgmt approval)
Inventory planning, production planning, Materials Requirement Planning (MRP), Just-In-Time concepts, finite loading systems, distribution systems, forecasting, master scheduling, capacity management, production activity control, and purchasing. Taught from planning and control systems viewpoint with managerial orientation.

OMS 8057. Process, Technology, and Innovation in the Operations Function. (4 cr, §OM 8057; prereq 3000 or MBA 8050 or #, grad mgmt student or Grad Sch Mgmt approval)
Comparison of different operations process types; fundamental management problems in each type, including importance of process technology choice, innovation, and future technological advances. Case studies used in conjunction with lectures.

OMS 8058. Operations Strategy. (4 cr, §OM 8058; prereq 3000 or MBA 8050 or #, grad mgmt student or Grad Sch Mgmt approval)
Integrated view of operations function within an organization, with focus on decision making and policy from chief operations manager perspective. Structural and infrastructure decisions. Managing operations for competitive advantage. Cases and lectures.

OMS 8059. Quality Management. (4 cr, §OM 8059; prereq 3000 or MBA 8050 or #, grad mgmt student or Grad Sch Mgmt approval)
Managing quality improvement within service and manufacturing organizations, including establishing culture and strategy for quality, quality costs, process analysis, statistical process control, customer/supplier management, quality control, and organization for quality. Taught from managerial perspective. Lectures, demonstrations, and cases.

OMS 8650. Regression Analysis. (4 cr, §DSci 8650; prereq MBA 8020 or equiv or #)
Regression and correlation models, inferences in simple and multiple regression, multicollinearity, indicator variables, variable selection techniques, assumption violation treatment, applications to management problems, introduction to logistic regression and other advanced topics.

OMS 8651. Experimental Design. (4 cr, §DSci 8651; prereq 8650 or #)
Variance analysis for one-way, two-way, and multi-way data. Basic statistical design concepts and result analysis. Randomized block, latin square, cross-over, factorial designs, confounding; estimation and effect comparison; response surfaces; applications to management.

OMS 8660. Linear Programming. (4 cr; prereq 5160 or equiv or #)
Revised simplex, primal-dual, and large-scale methods, including decomposition and partitioning and methods for bounded variables.
OMS 8662. Combinatorial Optimization. (4 cr; prereq 8660 or #; offered alt yrs)
Solution techniques for class of optimization problems characterized by an optimal solution drawn from a finite or countably infinite set of feasible solutions. Such problems can be formulated in general as integer programs. Specialized solution techniques, such as for network flow, matching, and matroid problems, and more general solution techniques, such as cutting plane methods and enumeration methods (e.g., dynamic programming and branch-and-bound). Theory of NP-Completeness as classification scheme for computational complexity of such problems.

OMS 8670. Stochastic Modeling and Analysis. (4 cr, 5DSci 8670; prereq Stat 5122 or #; offered alt yrs)
Probabilistic modeling of dynamic process, including Markov chains; Poisson, renewal, and continuous-time Markov processes; queuing models. Statistical estimation of selected models; applications to managerial problems, such as brand shift, industrial migration, manufacturing, and computer/communications networks.

OMS 8671. Simulation Analysis. (4 cr, §DSci 8671; offered alt yrs)
Treatment of underlying probabilistic and statistical aspects of computer simulation. Random number generators, variate and process generation, statistical analysis of simulation output, ranking and selection of simulation models, and variance reduction techniques.

OMS 8680. Queueing Theory: A Computational Approach. (4 cr; prereq 8670; offered alt yrs)
Theory of Stochastic Service Systems (theory of queues) from an algorithmic point of view. Prepares students to model and analyze complex stochastic service systems via classical methods and algorithmic methods and approximations.

OMS 8710. Research in Operations Strategy. (4 cr; prereq PhD student or #; offered alt yrs)
Operations performance, competitive advantage, focused factory, product and process innovation, operations strategy implementation. Research results and methods.

OMS 8720. Management of Technological Operations. (4 cr; prereq PhD student or #; offered alt yrs)
Theories and models used to address problems of managing technological operations and operations in manufacturing and service firms. Technology strategy, economic/organizational perspectives on technology, productivity analysis, technology evaluation, project selection and evaluation, learning, etc.

OMS 8730. Research On Scheduling. (4 cr; prereq 5160, PhD student or #; offered alt yrs)
Literature and research methods in aggregate planning, scheduling, routing, sequencing, and dispatching in manufacturing and service industries. Advanced research papers and methods discussed.

OMS 8735. Operations Forecasting and Inventory Research. (4 cr; prereq PhD student or #; offered alt yrs)
Research on forecasting, inventory control, Materials Requirement Planning (MRP), Just-In-Time manufacturing, and related subjects. Research studies and methods discussed.

OMS 8745. Research On Quality Management. (4 cr; prereq PhD student or #; offered alt yrs)
Examination of research literature, methods, and results. Research on quality strategy, economics of quality, statistical process control, vendor management, statistical process control, off-line quality, and quality practice.

OMS 8799. Seminar: Operations and Management Science. (4 cr)
Examination of current literature and research methods. Topics vary according to faculty and student interest.

OMS 8850. Topics in Operations and Management Science. (4 cr, §OM 8850; prereq MBA 8050, MBA 8020 or #, grad mgmt student or Grad Sch Mgmt approval)
Seminar providing broad range of state-of-the-art topics.

OMS 8990. Readings in Operations and Management Science. (Cr ar, §OM 8990; prereq #, Grad Sch Mgmt approval)
OMS 8995. Graduate Research in Operations and Management Science. (Cr ar; prereq #, Grad Sch Mgmt approval)

Business Taxation
See Business Administration.

Cell and Developmental Biology
See Molecular, Cellular, Developmental Biology and Genetics.

Cellular and Integrative Physiology (Phsl)
Professor: Robert F. Miller, head; Peter B. Bitterman; Dwight A. Burkhardt; Frank B. Cerra; Joseph DiSalvo1; Timothy J. Ehner; John E. Foker; Esther M. Gallant; Robert P. Hebbel; Lois J. Heller1; Thomas H. Hostetter; Hon Cheung Lee; Arthur S. Leon; David G. Levitt; Walter C. Low; Eric A. Newman; Scott M. O’Grady; Richard E. Poppele; Richard L. Purple
Associate Professor: Stephen A. Katz, director of graduate studies; Edwin W. Haller1, associate director of graduate studies; W. Dale Brunton; Janet M. Dubinsky; William C. Engeland; Jurgen Fohlineister; Costantino Iadecola; Paul A. Iaizzo; David H. Ingbar; David Mohnman1; John W. Osborn; Winfried A. Raabe; Edward K. Stauffer1; O. Douglas Wangensteen; Lorentz E. Wittmers, Jr.1

1 University of Minnesota, Duluth
Assistant Professor: Vincent A. Barnett; Linda M. Boland; LaDora V. Thompson

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B) and Ph.D.

Curriculum—Physiology is the application of mathematics, physics, and chemistry to the study of structure and function in living systems. This interdisciplinary program emphasizes a quantitative approach to understanding normal and abnormal functions of cells, organs, and organ systems in humans and other animals. Twin Cities faculty members are from the Department of Physiology, other basic science departments in the Medical School and College of Veterinary Medicine, and clinical departments in the Medical School. Duluth faculty members are from the Department of Medical and Molecular Physiology of the Duluth School of Medicine. Research possibilities for students range from molecular to organ system studies, with opportunities for learning and applying modern techniques of organ, cell, and molecular physiology.

The Ph.D. program typically requires four to five years. In the first two years, students take core courses that provide a broad background in molecular, cell, and organ physiology. Supporting work may be from any of several disciplines, including but not limited to, biochemistry, cell and molecular biology, computer science, engineering, mathematics, and physics. Individualized programs are structured so each student can build a core of commonly required knowledge as well as strengths for particular areas of research. By the start of the second year, students must choose an adviser and begin laboratory work. A preliminary written examination is taken after the end of the first year. A preliminary oral thesis proposal is prepared after the second year when coursework has been completed and a plan for thesis research has been formulated. Specialty areas of this program include membrane and epithelial transport, ion channels, signal transduction, contractile processes, renal and cardiovascular integration, and neurophysiology, with emphasis on motor systems, vision, and computational neuroscience.

Prerequisites for Admission—For the major, an undergraduate degree with at least one year (three quarters or two semesters) of calculus, one year of physics, one year of biology, and two years of chemistry. For the minor, a background in mathematics, physics, chemistry, and biology acceptable to the graduate faculty.

Special Application Requirements—For the Ph.D., applicants must take either the General Test of the Graduate Record Examination or the Medical College Admission Test. For all applicants, three letters of recommendation must be submitted. Admission is generally in fall quarter.

Master’s Degree Requirements—A one-year core academic program is offered in cellular and human physiology. Programs are thereafter individualized to meet the needs of each student.

Doctoral Degree Requirements—The two-year core sequence consists of courses in cell and molecular biology, cell physiology, medical physiology, and medical neuroscience. Substitution or waiver of these requirements is possible upon petition to and concurrence by the graduate program executive committee. Supporting work is individualized to meet the needs of each student.

Language Requirements—None, although all students are expected to gain a solid background in the use of computers and in a computer language.

For Further Information and Applications—Contact the Department of Physiology, University of Minnesota, 6-255 Millard Hall, 435 Delaware Street S.E., Minneapolis, MN 55455 (612/625-5902). Additional information concerning the master’s program is available by contacting the Associate Director of Graduate Studies, Department of Medical and Molecular Physiology, School of Medicine, University of Minnesota, 10 University Drive, Duluth, MN 55812 (218/726-8551).

Phsl 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

Phsl 8888. Thesis Credits: Doctoral. (36 cr required)

Phsl 5100w. Systems Physiology. (5 cr; prereq biochem, human anatomy; primarily for dental, pharmacy, med tech, nurse anesthetist students; not recommended for students who have taken 3051 or 3052 or 3053 or 3055 or 3056 or 5440 or 5441) Katz, staff

Cell, general, endocrine, cardiovascular, respiratory, gastrointestinal, energy metabolism, and renal physiology.
Phsl 5101s. Neuroscience for Dental Students. (1.5 cr; prereq biochem and human anatomy courses; ¶CBN 5110 [1.5 cr] required; 3 lect and 3 lab hrs per wk)
Basic principles of nervous function examined through study of neuroanatomy and neurophysiology.

Phsl 5110-5111. Human Physiology. (3 cr for 5110, 4 cr for 5111; primarily for 1st-yr med students and grad students) Wangensteen, staff
Basic principles of nervous function examined through study of neuroanatomy and neurophysiology.

Phsl 5112. Human Neuroscience B. (3 cr; prereq 1st-yr med or grad student; Anat 5111-Phsl 5112†) Ebner, staff

Phsl 5130-5131†. Intermediate Systems Physiology. (4 cr for 5130, 5 cr for 5131; prereq phsl grad student or #, physics, calculus, cell biol) Wangensteen, staff
Survey of systems physiology. Lectures and labs same as Phsl 5110-5111. Weekly discussion sessions.

Phsl 5150. Introduction to Neuroscience. (3 cr, §Biol 5150, §NSc 5150; prereq 3055-3056 or Biol 3011 or equiv, BioC 3021 or equiv or #)
Survey from invertebrates to humans. Ion channels and membrane currents, neurotransmitters and signal transduction, neuroanatomy, sensory and motor systems, learning and memory, emotion, disease states, neural networks, and development.

Phsl 5201. Computational Neuroscience I: Membranes and Channels. (5 cr; prereq 5112 or equiv; 3 lect, 4 lab hrs per wk) Fohlmeister
Comprehensive examination of membrane and ion channels using UNIX work stations to simulate their properties. Includes Hodgkin-Huxley model, non-linear dynamic systems, voltage and ligand gated ion channels, and impulse propagation.

Phsl 5202. Computational Neuroscience II: Cells and Circuits. (5 cr; prereq understanding of UNIX, 5201 or equiv) Miller, staff
Comprehensive investigation of computational properties of single neurons and locally connected cell networks. Linear cable theory, compartmental modeling of single neuron properties, spatio-temporal interactions between synaptic inputs in neuronal dendritic trees, computational properties of passive and active dendritic spines and spine clusters, quantitative interpretation of whole-cell voltage-clamp data, and dynamics of locally connected cell networks.

Phsl 5203. Computational Neuroscience III: Neural Systems and Information Processing. (5 cr; prereq 5202) Soechting
Quantitative examination of information processing by networks of neurons based on experimental data and theoretical models. Neural codes, neural network models and information processing, neural control systems, and computational maps.

Phsl 5440f-5441w. Quantitative Physiology. (3 cr; prereq 1 yr each of college chem, physics, math through integral calculus) Levitt, staff
Diffusion, surface tension, and mechanics of respiration, circulation, digestion, and locomotion. Chemical aspects of blood, respiration, renal function, nutrition, and metabolism. Endocrine, sensory, neuromuscular, and central neural functioning.

Phsl 5444s. Muscle Contraction. (3 cr, §MdBc 5444; prereq undergrad biochem or physiology courses, #)
Introduction to physiology, biochemical regulation, and physical chemistry of muscle contraction.

Phsl 5460-5461. Cellular and Molecular Neuroscience. (3 cr per qtr; for 5460: §GCB 5460, §MdBc 5460, §NSc 5460, §Phcl 5460, §VPB 5460; for 5461: §GCB 5461, §MdBc 5461, §NSc 5461, §Phcl 5461, §VPB 5461; prereq biochem)
Gene structure and regulation, cloning and molecular strategies for studying gene function, ion channels and membrane excitability, synaptic transmission, receptor structure and function, and signal transduction.

Phsl 8113f,w,s,su. Problems in Physiology. (Cr and hrs ar; prereq #)
Topics assigned for readings or lab study; conferences.

Phsl 8202.* Readings in Physiology. (Cr and hrs ar)
Topics selected for each student; written reviews prepared and discussed.

Phsl 8203.* Research in Physiology. (Cr and hrs ar)

Phsl 8211.1 Selected Topics in Heart and Circulation. (2-4 cr; prereq 5130-5131 or equiv or #) Heller, Mohrman, staff
One or more seminars in advanced physiology of heart and circulation.

Phsl 8300. Cellular and Molecular Physiology. (4 cr; prereq GCB 5035, GCB 8148, GCB 8149 or equiv or #) Branton, Lee, Levitt, Miller, Newman, O’Grady
Contemporary concepts and developments in mechanisms of signal transduction, ion channel, and transport processes. Cellular and molecular approaches. Lectures, readings, and discussion.

Phsl 8316. Current Topics in Cellular and Molecular Physiology. (1 cr; prereq #)
Topics vary quarterly.

For additional graduate course listings, please consult the Duluth Bulletin.
Chemical Engineering and Materials Science and Engineering

CHEMICAL ENGINEERING

Regents’ Professor: Rutherford Aris; L. Edward Scriven
Professor: Matthew V. Tirrell, head; Lanny D. Schmidt, director of graduate studies; Frank S. Bates; Robert W. Carr, Jr.; Barry C. Carter; James R. Chelikowsky; Edward L. Cussler; John S. Dahler; H. Ted Davis; D. Fennell Evans; Michael C. Flickinger (biochemistry); Arnold G. Fredrickson; Christie J. Geankoplis; William W. Gerberich; Wayne L. Gladfelter (chemistry); Wei-Shou Hu; Timothy P. Lodge (chemistry); Christopher W. Macosko; Wilmer G. Miller (chemistry); David A. Shores; William H. Smyrl; Tayfun E. Tezduyar (aerospace engineering and mechanics); Michael D. Ward; John H. Weaver

Associate Professor: Jeffrey J. Derby; Lorraine F. Francis; Alon V. McCormick; Christopher J. Palmstrom; John M. Sivertsen; Friedrich Srienc; Robert T. Tranquillo

Assistant Professor: Prodromos Daoutidis; C. Daniel Frisbie; J. Ilja Siepmann (chemistry); Renata M. M. Wentzcovitch

MATERIALS SCIENCE AND ENGINEERING

Regents’ Professor: Rutherford Aris; L. Edward Scriven
Professor: William W. Gerberich, associate head; Michael D. Ward, director of graduate studies; Frank S. Bates; Robert W. Carr, Jr.; Barry C. Carter; James R. Chelikowsky; Philip I. Cohen (electrical engineering); Edward L. Cussler; E. Dan Dahlberg (physics); John S. Dahler; H. Ted Davis; D. Fennell Evans; Arnold G. Fredrickson; Wayne L. Gladfelter (chemistry); Allen M. Goldman (physics); J. Woods Halley (physics); Shun-ichiro Karato (geology and geophysics); David L. Kohlstedt (geology and geophysics); Timothy P. Lodge (chemistry); Christopher W. Macosko; Wilmer G. Miller (chemistry); Marshall I. Nathan (electrical engineering); Emil Pfender (mechanical engineering); Dennis L. Polla (electrical engineering); Hermann Schmalzried; Lanny D. Schmidt; David A. Shores; William H. Smyrl; James H. Stout (geology and geophysics); Tayfun E. Tezduyar (aerospace engineering and mechanics); Matthew V. Tirrell; John H. Weaver

Adjunct Professor: Daniel M. Kroll (medicinal chemistry)

Associate Professor: Jeffrey J. Derby; Alfonso Franciosi; Lorraine F. Francis; Alon V. McCormick; Christopher J. Palmstrom; John M. Sivertsen; Robert T. Tranquillo

Assistant Professor: Prodromos Daoutidis; C. Daniel Frisbie; J. Ilja Siepmann (chemistry); Renata M. M. Wentzcovitch

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—Chemical Engineering: M.Ch.E., M.S.Ch.E. (Plan A only), and Ph.D.; Materials Science and Engineering: M.Mat.S.E., M.S.Mat.S.E. (Plan A only), and Ph.D.

Curriculum—Emphases are available in colloids, interfaces, microelectronic materials, ceramics, polymers, molecular materials, nanostructures and nanocomposites, organic solid state chemistry, catalysis, surface chemistry and physics, chemical kinetics, molecular theory of rate processes, thermodynamics, chemical reactor analysis, control and optimization, fluid and interfacial mechanics, crystal growth, bioengineering, molecular interfaces, interface chemistry and physics, physical and chemical metallurgy, metal physics, electronic properties of materials, electronic structure theory, superconductivity, electrochemistry, corrosion, rheology, structure-property relationships, electron microscopy, scanning tunneling microscopy, and atomic force microscopy.

Prerequisites for Admission—A bachelor’s degree in chemical engineering, materials science, metallurgy, polymer engineering, chemistry, physics, or electrical engineering is required. Applicants may be accepted without this prerequisite, but may be required to complete additional preparatory studies prescribed by their adviser or the director of graduate studies after admission.

Special Application Requirements—Three letters of recommendation are required. Graduate Record Examination scores are required for students with degrees in other disciplines and are strongly recommended for all applicants. Deadline for application is February 1; late applications are considered if space is available.

Master’s Degree Requirements—For the M.S.Ch.E. and M.S.Mat.S.E. degrees, see the General Information section of this bulletin. For the M.Ch.E. and M.Mat.S.E. degrees, 28 credits, of which 20 must be in the major field, plus a work-related project, are required. A final oral examination is required for all master’s degrees.

Doctoral Degree Requirements—The Ph.D. program requires 45 credits in the major (including up to 9 seminar credits) and 21 to 23
credits in the minor or supporting program. If a minor is chosen instead of a supporting program, the field is generally mathematics, physics, chemistry, or electrical engineering.

Language Requirements—None.

For Further Information and Applications—Contact the Department of Chemical Engineering and Materials Science, University of Minnesota, 151 Amundson Hall, 421 Washington Avenue S.E., Minneapolis, MN 55455 (612/625-0382).

**Chemical Engineering (ChEn)**

ChEn 5001. Computational Methods in Chemical Engineering and Materials Science. (4 cr; §MatS 5001; prereq ChEn or MatS major; 3 lect, 1 computer lab hrs per wk)

Introduction to analysis of representative chemical engineering problems by computer and mathematical methods.

ChEn 5101. Principles of Chemical Engineering I. (4 cr; prereq 5001 or §5001, IT student; 3 lect, 2 rec hrs per wk)

Energy and material balances applied to chemical engineering systems.

ChEn 5102. Principles of Chemical Engineering II. (4 cr; prereq 5001, 5101; 3 lect, 2 rec hrs per wk)

Fluid dynamics and its application to chemical engineering unit operations.

ChEn 5103. Principles of Chemical Engineering III. (4 cr; prereq 5102, upper div ChEn or MatS major; 3 lect, 2 rec hrs per wk)

Heat and mass transfer and their application to chemical engineering unit operations.

ChEn 5104. Unit Operations and Separation Processes. (4 cr; prereq 5101, upper div ChEn or MatS major; 3 lect, 2 rec hrs per wk)

Absorption, extraction, distillation, stagewise and continuous separations.

ChEn 5201. Thermodynamics and Materials States. (4 cr; prereq 5001, 5101, Chem 5534, upper div ChEn or MatS major; 3 lect, 2 rec hrs per wk)

Principles of thermodynamics applied to closed and open systems and to equilibrium states of homogeneous and heterogeneous substances, gases, liquids, and solids.

ChEn 5202. Chemical Engineering Thermodynamics and Kinetics. (4 cr; prereq 5201, upper div ChEn or MatS major; 3 lect, 2 rec hrs per wk)

Chemical equilibrium and chemical kinetics applied to chemical engineering systems.

ChEn 5301. Chemical Reactor Analysis. (4 cr; prereq 5202, upper div ChEn or MatS major; 3 lect, 2 rec hrs per wk)

Principles of reactor design for homogeneous and heterogeneous reactions. Analysis of reactors from a kinetic and thermodynamic point of view.

ChEn 5302. Applied Reactor Analysis. (4 cr; prereq 5301 or equiv)

Treatment of practical chemical reaction systems and the reactors for them. Catalysis and its role in chemical industry. Analysis of functioning chemical reaction systems such as ammonia synthesis, polymerization reactors, combustion, sulfur dioxide removal systems.

ChEn 5401. Chemical Engineering Laboratory. (2 cr; prereq 5102, §5103, upper div ChEn or MatS major; 4 lab, 1 conf hrs per wk)

Applications of unit operations; principles of fluid flow, heat and mass transfer; experiments with reports.

ChEn 5402. Chemical Engineering Laboratory. (4 cr; prereq 5103, upper div ChEn or MatS major; 4 lab, 1 lect, 1 conf hrs per wk)

Continuation of 5401.

ChEn 5501. Process Evaluation and Design. (4 cr; prereq 4th yr or §, upper div ChEn or MatS major; 3 lect, 3 design lab hrs per wk)

Dynamics of chemical engineering industries, economics of process evaluation, bases for cost estimations. Plant designs prepared and compared with actual installation. Special applications of unit operations, reaction kinetics, and thermodynamics.

ChEn 5502. Process Evaluation and Design. (4 cr; prereq 5501 or §, upper div ChEn or MatS major; 3 lect, 2 lab hrs per wk)

Computer-aided design of unit operations, chemical reactors and integrated plants; operability characteristics of chemical processes; design for optimum operability (safety, reliability, control).

ChEn 5601. Process Control. (4 cr; prereq 4th yr or §, upper div ChEn or MatS major; 3 lect, 2 rec hrs per wk)

Elementary theory of control and its application to chemical processes. Synthesis of feedback control loops for linear systems.

ChEn 5603. Process Control. (3 cr; prereq 5601 or §; 3 lect hrs per wk)

Advanced topics in chemical process control; synthesis.
ChEn 5604. Process Control Laboratory. (2 cr; prereq 5601) Experiments that illustrate and apply control theory. Measurement techniques, calibration, tuning of controls, characterization of sensors and control circuits.

ChEn 5640. Polymerization Reactor Engineering. (4 cr available to grad for 3 cr; prereq chemical engineering reactor design course or #; 3 lect hrs, 1 lab hr ar per wk) Introduction to analysis and design of polymerization reactors. Topics include mathematical modeling techniques, chain-growth and step-growth polymerization, copolymerization, molecular weight distributions, composition and sequence distributions. Emphasis on application of results.

ChEn 5751. Chemical Engineering in Biotechnology and Environment. (3 cr; prereq ChEng sr or grad student or #; 3 lect hrs per wk) Chemical engineering principles applied to biological systems and to analysis and design of complex cellular and enzyme processes, such as production of proteins, synthesis of antibodies, and degradation of toxic compounds.

ChEn 5753. Biochemical Engineering III. (3 cr; prereq Biol 5001, ChEng sr or grad student or #; 3 lect hrs per wk) Description and analysis of methods for separation of biochemical products of cellular and enzyme activity; applications to process synthesis.

ChEn 5754. Food Processing Technology. (4 cr; prereq 5103 or #; 3 lect hrs per wk) Heat transfer in food processing; protein processing; financial evaluation of projects; case studies; discussions of marketing, government regulation, nutrition.

ChEn 5756. Biochemical Engineering Laboratory. (2 cr; prereq 5751 or 5752; 4 lab hrs per wk) Microbial growth, biochemical product formation, isolation, purification, and medium sterilization.

ChEn 5757. Principles of Artificial Internal Organ Design. (3 cr; prereq #; 3 lect hrs per wk) Survey of artificial internal organs important in the maintenance of homeostasis; emphasis on general principles and particular problems of design including blood compatibility, access, and alternative approaches to replacing natural organ function.

ChEn 5761. Science and Technology of Porous Media. (3 cr; 3 lect hrs per wk) Fundamentals of porous media structures and of flow, transport, and deformation in them. Relations of macroscopic properties and behavior to underlying microscopic structures and mechanisms. Examples from nature and technology, with reference to in situ processing and enhanced recovery.

ChEn 5771. Colloids and Dispersions. (3 cr; prereq physical chem; 3 lect hrs per wk) Preparation, stability, and coagulation kinetics of colloidal solutions. DLVO theory, electrophoretic phenomena, and properties of micelles and other microstructures.

ChEn 5774. Interfacial Phenomena of Liquids. (3 cr; prereq physical chem, 5012 or equiv) Surface tension, surface geometry and capillarity, thin-films and disjoining pressure, contact angle; capillarity-driven and surface tension gradient-driven flows; wetting, spreading, dewetting, retraction; surfactant effects; fluid displacement, detergency, flotation, dynamic wetting, entrainment, adhesion. Examples from science and technology.

ChEn 5780. Principles of Mass Transfer in Engineering and Biological Engineering. (3 cr; prereq upper div engineering or science student; 3 lect hrs per wk) Mass transfer in gases, liquids, biological and macromolecular solutions, gels, solids, membranes, capillaries, and porous solids. Interaction between mass transfer and chemical reaction. Applications in biological, environmental, mineral, chemical engineering systems.

ChEn 5810. Processing of Electronic Materials. (3 cr; prereq MatS 5011 or #; 3 lect hrs per wk) Materials science and chemical engineering aspects of processing of materials for microelectronic devices (e.g., semiconductor memories and microprocessors) and optical devices (e.g., semiconductor lasers and optical waveguides).

ChEn 5902, 5903, 5904, 5905. Special Problems. (Cr ar) Investigations in chemical engineering. Library or lab research.


ChEn 8101. Intermediate Fluid Mechanics. (3 cr; prereq 5103, #) Derivation of equations of change; analysis of statics, kinematics, and dynamics of viscous fluids; survey of rectilinear, boundary-layer, creeping, inviscid, irrotational, and other flow approximations; representative problems with emphasis on chemical engineering applications.

ChEn 8102. Problems in Fluid Mechanics. (3 cr; prereq 8101) Application of principles to prototypal cases of flow and transfer. Problem solving and critical analysis of literature of physicochemical fluid mechanics.

ChEn 8104. Interfaces and Interfacial Phenomena. (3 cr; prereq 8101; offered alt yrs) Theory of boundary conditions. Equilibrium and dynamics of fluid interfaces. Analysis of surface tension-driven motions and other interfacial phenomena.

ChEn 8105. Principles and Applications of Rheology. (3 cr; prereq 8101, 8103; offered alt yrs) Deformation and flow of non-Newtonian and viscoelastic fluids, plastic materials, and perfectly elastic solids. Phenomenological and molecular interpretation of rheology of elastomers, polymer melts and polymer solutions, application of rheology to polymer processing.

ChEn 8301-8302. Physical and Chemical Thermodynamics. (3 cr per qtr; prereq 5202 or #) Principles of thermodynamics and applications to phase equilibria and chemical equilibria, especially in flow systems, with examples drawn from applied chemistry, chemical engineering, and materials science.


ChEn 8402. Chemical Reaction Kinetics—Surface Chemistry. (3 cr; prereq #) Atomistics of adsorption and reaction on solid surfaces. Discussion of modern techniques for characterization of surfaces such as AES, LEED, UPS, XPS, SEM, and TEM. Principles of heterogeneous catalysis and survey of important existing and developing catalytic processes.

ChEn 8403. Chemical Reaction Kinetics—Advanced Topics. (3 cr; prereq #)


ChEn 8601-8602-8603. Molecular Theory of Equilibrium and Nonequilibrium Processes. (3 cr per qtr) Theory and interpretation in terms of molecular scale processes of (a) structure and thermodynamic properties of homogeneous and inhomogeneous systems at equilibrium (8601-8602) and (b) transport phenomena and theory of irreversible processes (8602-8603). Major emphasis on fluids.

ChEn 8701. Analysis of Chemical Engineering Problems. (3 cr; prereq 8203) Critical analysis of current chemical engineering literature.

ChEn 8702. Advanced Topics in Chemical Engineering. (1-3 cr per qtr)

ChEn 8703. Process Control. (3 cr; prereq 5601 or #; 3 lect hrs per wk) Advanced topics in chemical process control; synthesis of control structures; multivariable control schemes; optimal control and estimation; computer-aided real-time process control.

ChEn 8774. Interfacial Phenomena of Liquids. (3 cr; prereq physical chem, 8101 or equiv) Scriven Surface tension, surface geometry and capillarity, thin-films and disjoining pressure, contact angle; capillarity-driven and surface tension gradient-driven flows; wetting, spreading, dewetting, retraction; surfactant effects; fluid displacement, detergency, flotation, dynamic wetting, entrainment, and adhesion. Examples from science and technology.

ChEn 8801, 8802, 8803. Seminar. (1 cr per qtr) Presentation and discussion of papers concerning the newer developments in chemical engineering.

ChEn 8810. Processing of Electronic Materials. (3 cr; prereq MatS 5011 or #; 3 lect hrs per wk) Materials science and chemical engineering aspects of processing of materials for microelectronic devices (semiconductor memories, microprocessors) and optical devices (semiconductor lasers, optical wave guides).

ChEn 8850. General Survey of Chemical Engineering. (1 cr) Independent reading under staff guidance.

ChEn 8901, 8902, 8903. Research in Chemical Engineering. (Cr ar) Heat and mass transfer, fluid dynamics, chemical kinetics, chemical reactor theory, thermodynamics, process control, bioengineering, applied mathematics.

Materials Science and Engineering (MatS)

MatS 5011. Introduction to the Science of Materials. (4 cr; prereq upper div ChEn or MatS major; 3 lect and 2 rec hrs per wk) Introduction to materials. Metals, polymers, ceramics, glasses, composites, electronic and magnetic materials.

MatS 5012. Introduction to Dislocations and Physical Metallurgy. (4 cr; prereq upper div IT standing, 5011 or #; 3 lect, 1 rec hrs per wk) Basis of work hardening, solid solution strengthening, precipitation hardening and heat treatment of alloys.

MatS 5013. Introduction to Electrical and Magnetic Properties of Materials. (4 cr; prereq upper div IT standing, 5011 or #; 3 lect, 1 rec hrs per wk) Introduction to quantum mechanics and semi-quantitative theories of electrical and magnetic properties of solids.
**MatS 5101. Thermodynamics of Solids.** (4 cr; prereq Chem 5534 or #; 3 lect, 1 rec hrs per wk) Fundamental concepts, 1st and 2nd laws, free energy, equilibrium constant, fugacity and activity relationships, solution models, order-disorder.

**MatS 5102. Diffusion and Solid State Kinetics.** (4 cr; prereq 5101 or #, upper div IT standing; 3 lect, 1 rec hr per wk) Kinetics: quantitative relationship between rate of reaction and reactant concentration. Diffusion: interstitial and substitution diffusion, steady-state and transient systems.

**MatS 5112. Ceramics.** (4 cr; prereq 5102 or #; 3 lect, 1 rec hrs per wk) Introduction to ceramics, including glasses. Crystalline and non-crystalline structures; phase relations; ternary phase diagrams; mechanical, thermal, electrical, magnetic, and optical properties of ceramics.

**MatS 5200. Optical and Electron Microscopy of Solids.** (4 cr; prereq upper div IT standing, 3400 or #; 2 lect, 3 lab hrs per wk) Practical experience in materials and techniques of evaluation. Investigation of microstructure using optical metallography. Use of transmission electron microscopy, scanning electron microscope, and elemental microanalysis for metallurgical systems.

**MatS 5202. X-Ray Structural Analysis.** (4 cr; prereq upper div IT standing; 1 lect, 1 rec, 5 lab hrs per wk) Geometry of crystals; properties and diffraction of X-rays; single crystal Laue methods and powder techniques; crystal structure determination; structure of polycrystals; single crystal orientation; crystal texture; precision lattice parameter measurements; chemical analysis; stress measurements; radiography.

**MatS 5304. Failure Analysis.** (4 cr; prereq 3400, 5013, 5411 or #; 2 lect, 4 lab hrs per wk) Embrittlement, wear, corrosion, integrated circuit breakdown, vibration, and fatigue. Analysis of failure using metallographic, electron microscopy, and microanalytic techniques.

**MatS 5411. Materials Design.** (4 cr; prereq sr MatS major; 3 lect, 1 rec hrs per wk) Mechanical and thermal processing with applications to forging, extrusion, rolling; advanced topics on heat treatment of steel, titanium and aluminum alloys, and materials for microelectronic applications. Materials selection based on cost and design function.

**MatS 5450. Corrosion and Electrochemistry of Corrosion.** (4 cr; prereq IT upper div, 5101 or #; 3 lect, 2 lab hrs per wk) Electrochemical thermodynamics, Butler-Volmer equation, electrochemical kinetics, theory of corrosion, passivation, inhibition, forms of corrosion, environmental degradation of mechanical properties, cathodic and anodic protection.

**MatS 5455. Electrochemical Engineering.** (4 cr; prereq upper div IT, grad student or #; 4 lect hrs per wk) Fundamentals of electrochemical engineering. Topics include electrokinetics, thermodynamics of cells, batteries, fuel cells, electrolysivers, and modern sensors.

**MatS 5460. Oxidation of Metals.** (4 cr; prereq 5102, upper div IT standing; 3 lect, 1 rec hrs per wk) Theory of high temperature oxidation of metals and alloys; oxidation in complex environments; practical applications and design criteria.

**MatS 5470. Corrosion and Electrochemistry of Homogeneous and Heterogeneous Surfaces.** (4 cr; prereq 5450 or 5460 or #; 3 lect, 1 rec hrs per wk) Transport and kinetic phenomena in corrosion processes. Wagner-Traud coupling of oxidation and reduction reactions on homogeneous and heterogeneous surfaces. Principles of current, potential, and concentration distribution modeling in general and localized corrosion.

**MatS 5481-5482-5483. Special Problems in Physical Metallurgy and Materials Science.** (Cr and hrs ar; prereq #) Library or lab studies of scientific or engineering problems in physical metallurgy and materials science.

**MatS 5610. Polymer Chemistry I.** (4 cr; prereq upper div IT student, ChEn 3301 or ChEn 3331 or #; 3 lect, 3 lab hrs per wk) Polymer synthesis and physical chemistry: polymerization kinetics and reactors, molecular weight distribution, network formation, macromolecules in solution and their characterization, glassy and crystalline state, rubber elasticity, flow and viscoelasticity, environmental degradation.

**MatS 5613. Polymer Laboratory.** (2 cr; prereq 5610 or 5630 or 5630 or Chem 8611) Synthesis and characterization of molecular structure and properties of several polymers. Experiments include free radical copolymerization, copolymer ratio by IR, molecular size by SEC, crosslinking polymerization, solubility, swelling, crystallization kinetics, thermal transitions by DSC, viscoelasticity, rubber elasticity, tensile properties.

**MatS 5620. Processing of Polymers and Their Composites.** (4 cr [3 cr w/o lab by dept permission]; prereq heat transfer, fluid mechanics or #; 3 lect, 1 lab-rec hrs per wk) Polymer processing principles and applications: rheology of long chain molecules, flow in simple geometries, die design, mixing, thermal properties, heat transfer and phase change; thermoplastic operations—extrusion, forming, and molding; thermoset operations—fiber and particulate reinforced composite molding, pultrusion, and filament winding.

**MatS 5630. Polymer Physical Properties.** (4 cr; prereq 3400 or 5011, MatS/Chem 5610 or #; 3 lect, 1 open lab hrs per wk) Polymer structure-property relations: structure and morphology of the crystalline and amorphous state. Crystallization kinetics, vitrification and the glass transition, mechanical properties, failure, permeability, optical and electrical properties, polymer composites, effect of processing on properties.
MatS 5820. Thin Films and Interfaces of Microelectronic Materials. (3 cr; prereq 5013 or #; 3 lect hrs per wk)
Oxidation of Si; formation of interfaces, silicides, and multilayers; interface growth and morphology; thermodynamic and kinetic parameters of evolving interfaces; distribution of reaction products; fabrication of diffusion barriers; epitaxial overlayers; electrical and analytical techniques for characterization.

MatS 8110. Fundamentals of Materials Science. (3 cr)
Chemical bonding: perfect and imperfect crystals; defects; thermodynamics and kinetics; phase diagrams and phase transformation; diffusion; electronic structure of solids and electrical properties; semiconductor statistics.

MatS 8112. Solid State Reactions. (3 cr; prereq #)
The kinetics of phase transformations and processes such as oxidation and epitaxial layer formation are considered in the framework of modern concepts of nucleation and growth theory such as the theory of spinodal decomposition.

MatS 8114. Symmetry and Scattering in Soft Materials. (3 cr; 3 lect hrs per wk)

MatS 8210. Structure-Property Relationships: Mechanism and Microelectronic. (3 cr; prereq #)
Geometry and properties of metal crystals; electrical and thermal conductivity; Hall effect; optical properties; elastic and plastic behavior of metals; principles of microelectronic materials and devices.

MatS 8213, 8214. Electronic Properties of Materials. (3 cr per qtr; prereq #)
Basic physical theory of bonding in metals, alloys, and semiconductors. Crystal structures related to fundamental parameters. Band theory using free electron, tight binding, APW, KKR, pseudopotential, and other techniques. Experimental techniques for measuring electronic properties, including photoemission, Auger spectroscopy, and optical spectroscopy. Transport properties, microelectronic materials, metal-semiconductor interface phenomena, and other topics.

MatS 8311. Theories of Mechanical Behavior of Solids. (3 cr)
The theoretical analysis of the mechanical behavior of solids. Included are theories of work-hardening, recovery, creep, fatigue, and fracture. Fracture mechanics theories examined in lab exercises associated with compliance, strain-energy release rate, and J-integral techniques.

MatS 8401. Transformations in Alloys and Origins of Microstructure. (3 cr; prereq #)
Factors governing polycrystalline microstructures, including topology of two-dimensional and three-dimensional cellular arrays, nature of grain boundaries and interfaces, recovery, recrystallization and grain growth, allotropic transformation, eutectoid decomposition, martensitic transformations, precipitation reactions.

MatS 8460. Oxidation of Metals. (4 cr; prereq 5102 or #; 3 lect, 1 rec hrs per wk)
Theory of high temperature oxidation of metals and alloys; oxidation in complex environments; practical applications and design criteria.

MatS 8470-8471-8472. Seminar: Materials Science and Engineering. (Cr ar)

MatS 8480-8481-8482. Selected Topics in Materials Science and Engineering. (Cr ar)

MatS 8520. Electron Diffraction and Electron Microscopy. (3 cr)
Scattering of electrons by solids, mass thickness, and diffraction contrast. Kinematic theory of diffraction and image interpretation. Chemical and structural analysis by electron diffraction. X-ray energy microanalysis and secondary electron topography. Instruction in use of the TEM and SEM. Five lab exercises.

MatS 8521. Topics in Electron Microscopy. (3 cr)
(Continuation of 8520) Research projects using either scanning or transmission electron microscopy. Lectures on specimen preparation techniques, and special applications of the microscope.

MatS 8522. Advanced X-Ray Diffraction of Metals. (3 cr; prereq 5403 or #)
Reciprocal lattice, structure factor, Fourier analysis, diffuse and low angle scattering.

Chemical Physics (ChPh)

Professor: Norma M. Allewell (biochemistry); Paul F. Barbara (chemistry); Victor A. Bloomfield (biochemistry); Charles E. Campbell (physics and astronomy); James R. Chelikowsky (chemical engineering and materials science); John S. Dahler (chemistry); H. Ted Davis (chemical engineering and materials science); W. Ronald Gentry (chemistry); Clayton F. Giese (physics and astronomy); Allen M. Goldman (physics and astronomy); J. Woods Halley (physics and astronomy); Cheng-Cher Huang (physics and astronomy); Sanford Lipsky (chemistry); Wilmer G. Miller (chemistry); Albert J. Moscovitz (chemistry); Lanny D. Schmidt (chemical engineering and materials science); David D. Thomas (biochemistry); Donald G. Truhlar (chemistry); John H. Weaver (chemical engineering and materials science); Walter Weymann (physics and astronomy)

Associate Professor: Doreen G. Leopold (chemistry), director of graduate studies; Christopher J. Cramer (chemistry); Kenneth R. Leopold (chemistry); Jeffrey T. Roberts (chemistry)

Assistant Professor: David M. Ferguson (medicinal chemistry); Karin Musier-Forsyth (chemistry); J. Ilja Siepmann (chemistry)

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.
Degrees Offered—M.S. (Plan A) and Ph.D.

Curriculum—Focus is on areas where the techniques of chemistry and physics are brought together for the study of atoms and molecules, their interactions in gases, liquids, and solids, and the detailed structure and dynamics of material changes. Areas of research and specialization include spectroscopy, optical properties, laser applications, molecular collisions, chemical dynamics, quantum mechanics, statistical mechanics, thermodynamics, low-temperature behavior, polymers or macromolecules, surface science, biochemistry, computational chemistry, and biochemical and heterogeneous catalysis.

Prerequisites for Admission—Applicants should have adequate preparation in mathematics, physics, and chemistry. For financial support, applicants should apply either to the Department of Chemistry or the Department of Physics. Applicants not requiring financial support have their academic qualifications reviewed by the director of graduate studies in chemical physics.

Special Application Requirements—Three letters of recommendation are required.

Master’s Degree Requirements—At least 8 credits of coursework must be in chemistry and must include statistical or chemical thermodynamics or both; at least 8 credits must be in appropriate physics courses; and at least 8 credits must be in quantum mechanics, which may be taken in either the chemistry or physics department.

Doctoral Degree Requirements—A proficiency examination in physical chemistry is required. Programs ordinarily include at least 36 graduate credits, which include coursework in chemistry and/or physics with options for coursework in quantum mechanics, thermodynamics, statistical physics, and/or chemical dynamics. There is no minor or supporting field requirement. A graduate student handbook that provides complete requirements is available from the address below.

Language Requirement—None.

For Further Information and Applications—Contact the Chemical Physics Program, Department of Chemistry, University of Minnesota, 137 Smith Hall, 207 Pleasant Street S.E., Minneapolis, MN 55455 (612/626-7444; fax 612/626-7541; e-mail inquiry@chmsun.chem.umn.edu).

ChPh 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

ChPh 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

ChPh 8888. Thesis Credits: Doctoral. (36 cr required)

ChPh 8101. Chemical Physics Seminar. (1 cr; prereq ChPh grad student) Seminar by student on his or her research.

Chemistry (Chem)

Professor: W. Ronald Gentry, chair; Wilmer G. Miller, vice chair; John E. Ellis, director of graduate studies; Norma M. Allewell; George Barany; Paul F. Barbara; Victor A. Bloomfield; J. Doyle Britton; Peter W. Carr; John S. Dahler; H. Ted Davis; John F. Evans; Wayne L. Gladfelter; Gary R. Gray; Thomas R. Hoye; John D. Lipscomb; Sanford Lipsky; Hung-wen Liu; Timothy P. Lodge; Kent R. Mann; Larry L. Miller; Albert J. Moscowitz; Wayland E. Noland; Louis H. Pignolet; Lawrence Que; Michael A. Raftery; Marian Stankovich; Harold S. Swofford, Jr.; Donald G. Truhlar

Associate Professor: Frank S. Bates; Christopher J. Cramer; Steven R. Kass; Doreen G. Leopold; Kenneth R. Leopold; Jeffrey T. Roberts; William B. Tolman; Michael D. Ward

Assistant Professor: Mark D. Distefano; Craig J. Forsyth; Eric J. Munson; Karin Musier-Forsyth; George A. O’Doherty; J. Ilja Siepmann; Andreas Stein; Li Sun

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B) and Ph.D.¹

Curriculum—Graduate work in the Department of Chemistry is organized into six specialty areas: analytical chemistry, biological chemistry, inorganic chemistry, materials chemistry, organic chemistry, and physical chemistry. Interdisciplinary work is also an option.

Prerequisites for Admission—Applicants must offer the substantial equivalent of the courses in analytical, inorganic, organic, and physical

¹ For information on the doctoral degree program offered in conjunction with the University of Minnesota, Duluth, please contact the director of graduate studies on the Twin Cities campus, or the program director or Graduate School office on the Duluth campus.
chemistry required of undergraduate majors in the Minnesota chemistry curriculum. They must also have at least one year of college physics plus college mathematics through calculus.

**Special Application Requirements**—Three letters of recommendation are required for all applications. Scores from General (Aptitude) and Subject (Advanced) Tests of the Graduate Record Examination (GRE) are required for fellowship consideration and are strongly recommended for all other applicants. International applicants are expected to provide scores of at least 580 on the Test of English as a Foreign Language (TOEFL), as well as GRE scores.

**Proficiency Examination**—Students working toward the M.S. or Ph.D. in chemistry are required to take a set of four proficiency examinations, one each in analytical, inorganic, organic, and physical chemistry. These examinations are taken on entrance; the results are used for guidance. Ph.D. students are expected to satisfy the proficiency requirements in all four fields during their first academic year in residence. M.S. students are expected to pass the proficiency examination in their specialty area during their first academic year in residence.

**General Degree Requirements**—A list of required and recommended courses, including courses from outside the field of chemistry, can be obtained from the director of graduate studies. Procedures are available for satisfying course requirements through special examination rather than course registration.

**Master’s Degree Requirements**—One to three 4-credit project papers are required for Plan B. A final oral examination is required for both Plan A and Plan B.

**Doctoral Degree Requirements**—Ph.D. candidates must complete 36 credits of work in approved graduate courses (30 credits for students in organic chemistry). Analytical, biological, inorganic, materials, and organic chemistry specialty areas require a written research dossier. For students specializing in physical chemistry, this examination consists of two papers. A student needs to pass the written preliminary examination in only one of the five specialty areas. When the written examination has been passed, the student may proceed to the preliminary oral examination.

**Language Requirements**—None.

**For Further Information and Applications**—Contact the Assistant to the Director of Graduate Studies, Department of Chemistry, University of Minnesota, 137 Smith Hall, 207 Pleasant Street S.E., Minneapolis, MN 55455 (612/626-7444 or 1-800-777-2431; fax 612/626-7541).

**Chem 8666. Doctoral Pre-Thesis Credits.** (max 18 cr per qtr; doctoral student who has not passed oral prelims)

**Chem 8777. Thesis Credits: Master’s.** (16 cr required; Plan A only)

**Chem 8888. Thesis Credits: Doctoral.** (36 cr required)

**Chem 5122. Advanced Analytical Chemistry.**
(4 cr; prereq 1 yr organic chem, thermodynamics course)
Equilibria in aqueous and nonequilibrium systems.

**Chem 5126. Modern Analytical Chemistry.**
(4 cr; prereq 3332 and 3335, IT chemical engineering major or Δ; 2 lect hrs, two 3-hr labs per wk)
Strategies and techniques for solving modern analytical problems. The use of modern instruments in analysis.

**Chem 5127. Analog Instrumentation.** (5 cr; prereq Phys 1253, Math 1262 or equiv or #, chem major or grad student)
Basic principles of electronic design and circuitry, servo systems, operational amplifiers, feedback control, oscillators, digital gates, converters for signal processing and control of measurement systems.

**Chem 5128. The Small Computer in the Chemical Laboratory.** (5 cr; prereq 5127 or #; 3 lect hrs, two 4-hr labs per wk)
Applications of the lab computer to control of chemical instrumentation and acquisition of data. Hardware (interfacing) and software (assembly language programming) aspects of automating the chemical experiment.

**Chem 5130. Analytical Chemistry.** (3 cr; prereq 1 yr organic chem with lab, CLA or IT chem major; 3 lect, 1 rec hrs per wk)
Methods and concepts of measurement by chemical and instrumental analysis, including titrimetry, quantitative spectrophotometric analysis, chromatographic separations, and equilibrium and rate methods of analysis emphasizing applications to organic and biochemical systems.

**Chem 5131. Analytical Chemistry Laboratory.**
(2 cr; prereq 5130 or §5130; two 4-hr labs per wk)
High-precision methods, acidimetry and complexometry, single- and multi-component analysis by spectrophotometry, analysis of mixtures by ion exchange and gas chromatography, enzymatic and rate methods of analysis.
Chem 5133. Chemical Instrumentation and Analysis Lecture. (3 cr; prereq 5130, 5131, 5534, 5535 or #)
Methodology and practices for solving analytical problems. Application of modern instrumental techniques to analysis.

Chem 5139. Chromatography and Separation Science. (4 cr; prereq 5133, 5140 or equiv or #, chem major or grad student)
Fundamental and practical aspects of gas liquid chromatography, modern liquid chromatography, electrophoresis, and other techniques used for analyses and separations.

Chem 5140. Chemical Instrumentation and Analysis Laboratory. (3 cr; prereq 5133, chem major)
Instrumental techniques including spectroscopic methods of analysis, electrochemical methods of analysis, and analyses based on separation. Emphasis on use of computers in data collection and reduction.

Chem 5301. Spectral Methods of Organic Qualitative Analysis. (4 cr, §8302; prereq 3303 or 3333 or equiv; 3 lect, 1 conf hrs per wk)
Practical application of nuclear magnetic resonance, mass, ultraviolet infrared spectral analysis to solution of organic problems.

Chem 5331, 5332. Advanced Organic Chemistry I, II. (4 cr per qtr, §8331, §8332; prereq 3303, #)
Depending on year and instructor, emphasizes heterocyclic chemistry, natural products chemistry, organic electrochemistry, synthetic applications of organometallic chemistry, solid-state chemistry, polymer chemistry and/or stereochemistry.

Chem 5344. Heterocyclic Compounds. (3 cr; prereq 3303 or 3333 or equiv; offered alt yrs)
Typical classes of heterocyclic compounds, their chemical and physical properties and uses, synthesis.

Chem 5520-5521. Elementary Physical Chemistry. (3 cr per qtr; prereq 1 yr college chem, Phys 1291 or §Phys 1291 or Phys 1106, Math 3211)
Brief general survey. 5520: Thermodynamics and applications to chemistry. 5521: Elementary statistical mechanics, kinetics, and structure.

Chem 5525. Physical Biochemistry: Solution Structure and Interactions of Biological Macromolecules. (4 cr, §BioC 5525, §MdBc 5525; prereq 2 qtrs physical chem, Biol 5001 or equiv)
Physical chemistry of equilibrium, transport, and scattering phenomena in solution, with application to proteins and nucleic acids. Intermolecular forces, macromolecules dynamics, conformational transitions, binding thermodynamics, methods for determining biopolymer size and shape, including sedimentation, diffusion, viscosity, electrophoresis, and scattering.

Lectures on fundamental spectroscopic principles with emphasis on development of magnetic resonance theory used in study of biological macromolecules.

Chem 5527. Physical Biochemistry: Spectroscopic Methods II. (4 cr, §BioC 5527, §MdBc 5527; prereq 2 qtrs physical chem, BioC/Chem/MdBc 5526 or #)
Application of optical and magnetic resonance techniques to study of structure and dynamics in proteins, lipids, nucleic acids, and synthetic analogs.

Chem 5528. Physical Biochemistry: Enzyme Kinetics. (4 cr, §BioC/MdBc 5528; prereq 2 qtrs physical chem, BioC/MdBc 5751; BioC 5002 or equiv recommended)
Theory and application of steady-state and transient kinetics to study of enzymes, enzyme systems, and cellular regulation.

Chem 5529. Protein Structure and Folding. (4 cr, §BioC/MdBc 5529; prereq Biol 5001 or equiv, 1 qtr physical chem or #)
Advanced course on protein structure, stability, folding, and molecular modeling. Results from X-ray crystallography, solution thermodynamics, NMR, computer graphics, and protein engineering.

Chem 5533. Quantum Chemistry. (4 cr; prereq 1 yr college chem, Phys 1291 or §Phys 1291 or 1106 with #, Math 3211)
Principles of quantum mechanics with applications to atomic and molecular structure and to spectroscopy.

Chem 5534. Chemical Thermodynamics. (4 cr; prereq IT upper div or CLA chem major or Δ, Phys 1291 or §Phys 1291 or 1106 with #, Math 3211)
Principles of thermodynamics with applications to chemical systems.

Chem 5535. Statistical Mechanics and Reaction Kinetics. (4 cr; prereq 5534)
(Continuation of 5534) Developing statistical thermodynamics and the kinetic theory of gases with applications to reaction rate theory. Phenomenological kinetics and experimental methods.

Chem 5536. Physical Chemistry Laboratory. (1 cr; prereq 5538 or §5535; not open to chem majors)
Experiments in thermodynamics and reaction kinetics.

Chem 5540. Physical Chemistry Laboratory. (3 cr; prereq chem major, 5533, 5535 or §5535; 1 lect, 8 lab hrs per wk)
Experiments illustrating principles and methods of thermodynamics, reaction kinetics, and quantum mechanics.
Chem 5610. Polymer Science. (4 cr; §MatS 5610; prereq physical chem or MatS 5011 or #; 3 lect hrs, one 3-hr lab per wk)
Polymer synthesis and physical chemistry: polymerization kinetics and reactors, molecular weight distribution, network formation, macromolecules in solution and their characterization, the glassy and crystalline state, rubber elasticity, flow and viscoelasticity, environmental degradation.

Chem 5732. Transition Metal Inorganic Chemistry. (3 cr; prereq 5533 or §5533 or 5534 or §5534, chem or chem eng major)
Transition metal compounds where 3d electrons are important. Organometallic, bioinorganic, and metal cluster chemistry.

Chem 5740. Inorganic Chemistry Laboratory. (3 cr; prereq chem major, 5731, 5732 or §5732; 1 lect, 8 lab hrs per wk)
Experiments in inorganic and organometallic chemistry illustrating synthetic and spectroscopic techniques.

Chem 5803. The Chemistry of Industry. (4 cr; prereq chem sr or grad student or #)
Basic industry and polymer chemistry, and technology on which industry is based. Relationship of basic properties to industrial utility. Emphasis on economics, social problems, and industrial environment.

Chem 5991, 5992, 5993. Selected Topics in Chemistry. (Cr ar; prereq sr, Δ)
Topics of current interest in chemistry. Consult department for details of offerings for any particular quarter.

Chem 8001. Applied Chemical Thermodynamics. (4 cr; prereqchem grad student or #; 3 lect hrs per wk)
Systems in gas and solution phase, inorganic, organic, and biochemical reactions. Chemically important consequences of first and second laws. Heat reaction, entropy of reaction, and heat capacity changes from chemical measurement. Fluid, solid state equilibria, electrochemical equilibria, and surface processes. Phenomenological interpretation of phase diagrams in solid state chemistry and polymer mixtures.

Chem 8002. Mechanisms of Chemical Reactions. (4 cr; prereq chem grad student or #; 3 lect hrs per wk)
Reaction mechanisms and methods of study. Mechanistic concepts in chemistry. Topics include gas phase reactions to mechanisms, “electron pushing” mechanisms in organic reactions, mechanism of enzymatic reactions. Kinetic schemes and other strategies to investigate mechanisms.

Chem 8003. Computational Chemistry. (4 cr; prereq chem grad student or #; 3 lect hrs per wk)

Chem 8104. Spectroscopic Methods of Analysis. (4 cr; prereq 5133 or equiv or #)
Systematic treatment of modern optical methods of analysis.

Chem 8133. Modern Electroanalytical Techniques, Principles, and Practices. (3 cr; prereq 5122)
Polarography, galvanostatic and potentiostatic methodology, coulometry, linear scan and cyclic voltammetry, pulse methods, and OTTLE applications.

Chem 8134. Bioanalytical Chemistry. (3 cr; prereq 5133 or equiv, BioC 5001 or equiv)
Theory and practical aspects of analytical methods used in determination and characterization of biologically important materials. Enzymatic and kinetic methods in study of amino acids, proteins, carbohydrates, lipids, and nucleic acids.

Chem 8135. Mass Spectrometry. (3 cr; prereq #)
Introduction to physical and chemical aspects of mass spectrometric analysis.

Chem 8136. Surface and Thin Film Analysis. (3 cr; prereq #)
Survey of modern ultrahigh vacuum techniques appropriate to analysis of surface and thin film structure.

Chem 8190. Seminar: Modern Problems in Chemical Instrumentation and Analysis. (1 cr [may be repeated for cr]; prereq chem grad student or #)

Chem 8191. Seminar Presentation: Modern Problems in Chemical Instrumentation and Analysis. (1 cr; prereq chem grad student, #)

Chem 8211. Introduction to Materials Chemistry. (3 cr; prereq 3301, 5501 or 5534 or #)
Gladfelter
Structure of and molecular routes to solids, including CVD and sol-gel processing; self-assembly of organic arrays and properties of organic crystals; basic properties of polymers, including important polymer synthetic methods.

Chem 8290. Seminar: Materials Chemistry. (1 cr; prereq chem grad student or #)

Chem 8291. Seminar Presentation: Materials Chemistry. (1 cr; prereq chem grad student, #)

Chem 8302. Interpretation of Organic Spectra. (4 cr; prereq 1 yr undergrad organic chem or #)
Practical application of nuclear magnetic resonance, mass, ultraviolet, and infrared spectral analyses to the solution of organic structural problems.

Chem 8311. Organic Synthesis I. (4 cr; prereq 3303 or equiv or #)
Core course; fundamental concepts, reactions, reagents, structural and stereochemical issues, and mechanistic skills necessary for understanding organic chemistry.

Chem 8312. Organic Synthesis II. (4 cr; prereq 8311 or #)
Topics such as complex carbon skeleton synthesis, asymmetric synthesis, and/or modern studies in organic chemistry.
(4 cr; prereq 8002 or #)  
Core course. Fundamental concepts, mechanistic tools, and methods for the understanding and critical analysis of detailed mechanistic studies in organic chemistry.

Chem 8322. Physical Organic Chemistry II.  
(4 cr; prereq 8321 or #)  
Topics such as reactive intermediates, gas-phase chemistry, photochemistry, and/or strained-ring chemistry.

(4 cr, §5331; prereq 3303 or #)  
Topics such as heterocyclic chemistry, natural products chemistry, organic electrochemistry, synthetic applications of organometallic chemistry, solid-state chemistry, polymer chemistry, and/or stereochemistry.

Chem 8332. Advanced Organic Chemistry II.  
(4 cr, §5332; prereq chem grad student, 3303 or #)  
Topics, which vary by instructor and year, include heterocyclic, natural products, solid-state, and polymer chemistry; organic electrochemistry; stereochemistry; and synthetic applications of organometallic chemistry.

(1 cr; prereq chem grad student or #)

(1 cr; prereq chem grad student, #)

Chem 8401. Bioorganic Chemistry I.  
(4 cr; prereq 3303 or equiv)  
Chemistry of amino acids, peptides, and proteins; peptide structure determination, synthesis, and reactivity; biological applications of synthetic peptides.

Chem 8402. Bioorganic Chemistry II.  
(4 cr; prereq 3303 or equiv)  
Chemistry of lipids and carbohydrates; structure, nomenclature, characterization by NMR spectroscopy, synthesis, and reactivity.

Chem 8403. Bioorganic Chemistry III.  
(4 cr; prereq 3303 or equiv)  
Chemistry of nucleic acids: structure and reactivity, interactions with small molecules and proteins, chemical oligonucleotide synthesis, ribozymes, overview of techniques used in nucleic acid research.

Chem 8404. Bioorganic Chemistry IV.  
(4 cr; prereq 3303 or equiv)  
Enzymecatalyzed reactions: group transfers, eliminations, isomerizations, rearrangements, oxidation-reduction reactions, chemical mechanisms in enzymatic systems.

Chem 8521. Methods of Theoretical Chemistry.  
(4 cr; prereq undergrad physical chem)  
Basic theoretical techniques of physical chemistry, application to selected chemical problems.

(4 cr per qtr; prereq 8521 or equiv)  
Wave mechanics, soluble problems, approximate methods, chemical applications, structure of molecules, group theory, elementary treatment of scattering, atomic and molecular spectroscopy.

Chem 8535. Molecular Quantum Mechanics.  
(4 cr; prereq 8531)  
Application of quantum mechanics to molecular problems including topics such as Born-Oppenheimer approximation, symmetry of electronic and vibrational wave functions, molecular orbital theory, and rotational and vibrational eigenstates and spectra.

Chem 8545. Reaction Dynamics.  
(4 cr; prereq undergrad physical chem)  
Reaction dynamics from microscopic viewpoint with an emphasis on modern experimental methods and interpretation of scattering data.

(4 cr; prereq undergrad physical chem)  
Principles of equilibrium statistical mechanics, ensemble theory, partition functions; application to simple systems such as ideal gases and crystals, and simple lattice statistics.

(4 cr; prereq 8547)  
More advanced topics in statistical mechanics, such as nonideal gases and solutions, distribution functions, and nonequilibrium statistical mechanics.

(1 cr; grad student or #)

(1 cr; prereq chem grad student, #)

(1 cr; prereq chem or chem phys grad student; S-N only)

(1 cr; prereq chem or chem phys grad student or #)

Chem 8611. Introduction to Polymer Properties.  
(3 cr, prereq 5534 or #)  
Molecular weight distribution, formation of network polymers, statistical thermodynamics of polymer solutions, polymers characterization by viscosity, light scattering, sedimentation methods, viscoelastic behavior of polymers.

Chem 8612. Advanced Topics in Polymer Science.  
(3 cr; prereq 8611 or #; offered alt yrs)  
For graduate students in chemistry, chemical engineering, and materials science, and others interested in modern statistical theories of equilibrium and nonequilibrium polymer systems.

Chem 8751. Physical Inorganic Chemistry I.  
(4 cr, §5751; prereq chem grad student or #)  
Physical methods and concepts applied to inorganic and organometallic systems, including NMR, IR, UV-VIS, ESR, Mossbauer and mass spectroscopy, magnetic measurements, X-ray crystallography.
Chem 8756. X-Ray Crystallography. (4 cr, $5756; prereq chem grad student or #) Determination of crystal structures by X-ray diffraction of single crystals. Data collection, structure solving and refining for inorganic and organic molecules of 100 or fewer atoms.

Chem 8761. Organometallic Chemistry. (4 cr, $5761; prereq chem grad student or #) Syntheses, reactions, structures, and other important properties of main group and transition metal organometallic compounds; treatment in terms of modern electronic and structural theory; emphasis on their use as stoichiometric and homogeneous catalytic reagents in organic and inorganic systems.

Chem 8762. Chemistry of the Elements. (4 cr, $5762; prereq chem grad student or #) Survey of synthesis, structure, physical properties, and chemical reactivity of the elements. Topics equally divided between transition and nontransition elements.

Chem 8765. Bioinorganic Chemistry. (4 cr, $5765; prereq chem grad student or #) Survey of role of metal ions in biology with emphasis on structure, function, and spectroscopy of metalloproteins and their synthetic analogs.

Chem 8766. Solid State Chemistry. (4 cr; prereq chem grad student or #) Synthetic methods, structures of crystalline solids, and bonding in solids. Solid state phase diagrams and kinetics of solid state reactions. Classes of solids include molecular, ionic, metallic, and semiconducting compounds.

Chem 8790. Seminar: Modern Problems in Inorganic Chemistry. (1 cr; prereq chem grad student or #)

Chem 8791. Seminar Presentation: Modern Problems in Inorganic Chemistry. (1 cr; prereq chem grad student, #)

Chem 8881, 8882, 8883. M.S. Plan B Project I, II, III. (4, 1-4, 1-4 cr; prereq grad major in chem or chem physics, #) Satisfies project requirement for Plan B master’s degree. May appear on M.S. degree program, but does not count toward 20-credit minimum in major field. Topic arranged by student and adviser; written report required. 8881 required; 8882 and 8883 optional.

Chem 8990. Research in Chemistry. (Cr ar; prereq chem grad student or #)

Chem 8991. Special Topics in Chemistry. (Cr ar; prereq #)

Chem 8992. Special Topics in Chemistry. (Cr ar; prereq #)

Chem 8993. Special Topics in Chemistry. (Cr ar; prereq #)

Chem 8994, 8995, 8996. Special Topics in Chemistry. (Cr ar; prereq #)

Chem 8997, 8998. Special Topics in Chemistry. (Cr ar; prereq chem grad student or #)

Child Psychology (CPsy)

Professor: Richard A. Weinberg, director; Charles A. Nelson, director of graduate studies; Geraldine K. Brookins; William R. Charlesworth (emeritus); W. Andrew Collins; Byron R. Egeland; Norman Garmezy (emeritus); Harold D. Grotevant; Megan R. Gunnar; Willard W. Hartup; Susan C. Hupp; Gloria R. Leon; Michael P. Maratos; Ann S. Masten; Shirley G. Moore (emeritus); Anne C. Petersen (on leave); Anne D. Pick; Herbert L. Pick, Jr.; L. Alan Sroufe; Mildred C. Templin (emeritus); James E. Turnure; Albert Yonas

Associate Professor: Patricia J. Bauer; Sandra L. Christenson; Scott R. McConnell; Charles N. Oberg; Maria D. Sera; Elsa G. Shapiro; Paulus W. van den Broek; Carolyn L. Williams

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—Ph.D. and M.A. (Plan A and Plan B). Students are admitted only for the Ph.D.; the M.A. is a necessary part of the Ph.D. program.

Curriculum—Emphases include developmental aspects of cognition, genetics-ethology, language, learning, cognitive neuroscience, perception, personality, social psychology, child clinical, and school psychology.

Prerequisites for Admission—At least 12 quarter credits in psychology and one course in statistics are required.

Special Application Requirements—New students are normally admitted in fall quarter. Application deadline is January 15 of the preceding year. A department application, a statement of goals and interests, three letters of recommendation, and scores from the General (Aptitude) Test of the Graduate Record Examination are also required. A résumé is also recommended.

Master’s Degree Requirements—Courses in history, current issues, and research methods of child psychology and in advanced statistics are required. Other courses, including those for a minor or supporting field, are selected in consultation with the adviser. The individual examining committee determines whether the final examination is written, oral, or both.

1 See the College of Education and Human Development Bulletin for information on the master of education (M.Ed.) program in early childhood education.
Doctoral Degree Requirements—Courses in history, current issues, and research methods in child psychology, statistical analysis, and research are required. Other courses are selected in consultation with the adviser. Completion of a supporting program, rather than a minor, is required. Non-coursework requirements include successful completion of a predoctoral research paper, a teaching apprenticeship, preliminary written and oral examinations, and a dissertation.

Language Requirement—None.

Minor Requirements for Student Majoring in Other Fields—For the doctoral degree, at least 12 of the minimum 18 credits must be at the 8xxx level.

For Further Information and Applications—Contact the Child Psychology Program, University of Minnesota, 156 Child Development Building, 51 East River Road, Minneapolis, MN 55455 (612/624-2576; fax 612/624-6373).

CPsy 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

CPsy 8777. Thesis Credits: Master's. (16 cr required; Plan A only)

CPsy 8888. Thesis Credits: Doctoral. (36 cr required)

CPsy 5302. Infancy. (4 cr; prereq 1301 or #) Nelson, Yonas
Perceptual, motor, emotional, social, and cognitive development during first two years of life; developing infant in its social and physical environment.

CPsy 5303. Adolescent Psychology. (4 cr, §3303; prereq 5 cr introductory psychology) Egeland, Masten
Physical, cognitive, and social development during adolescence.

Multidisciplinary introduction to aging and the aging process.

CPsy 5310. Topics in Child Psychology. (1-4 cr; prereq 1301)
Selected topics in general content area.
CPsy 5334. Children and Youth in Society. (4 cr; prereq 4 cr child psych) Child development principles relative to social policy decision making; application of theories and findings to such issues as media influences, mainstreaming, day care, child abuse, effects of peers.

CPsy 5336. Development and Interpersonal Relations. (4 cr, §5339; prereq 1301 or equiv, 3331 or 5331, 3306 or Psy 1005) Collins, Hartup Processes and functions of interactions with parents and peers; analysis of theory and research on developmental changes and influences.

CPsy 5341. Perceptual Development. (4 cr; prereq 1301 or #, 3308 or Psy 1005) H Pick, Yonas Perceptual learning and the development of sensory and perceptual processes.

CPsy 5343. Cognitive Development. (4 cr; prereq 3343, 3308 or Psy 1005) Bauer, A Pick, H Pick, Sera Cognitive processes; relevant theory, research literature, and methodology.

CPsy 5345. Language Development. (4 cr; prereq 1301 or #, 3308 or Psy 1005) Maratsos Structure and function of language; factors influencing development; methodological problems, language scales, theories.

CPsy 5353. Development During the School Years. (4 cr; prereq 4 cr psych) Principles of psychological development, emphasizing ages 5-18. Theory and research from developmental psychology relevant to individual growth and achievement; issues in applying developmental perspective to topics in child and adolescent development (e.g., fostering learning, risk for school failure, behavior and emotional problems, diversity).

CPsy 5970. Directed Study in Child Psychology. (Cr ar; prereq #) Independent reading.

CPsy 5990. Directed Research in Child Psychology. (Cr ar; prereq #) Individual empirical investigation.

CPsy 8301. Developmental Psychology: Biological Processes. (4 cr; prereq doctoral student or #) Nelson Biobehavioral development, including embryology and prenatal development; molecular/behavioral genetics and ethology; developmental neurobiology; physical growth/motor development; sensory development.

CPsy 8302. Developmental Psychology: Cognitive Processes. (4 cr; prereq doctoral student or #) Sera, Yonas Perceptual, cognitive, and language development. Conceptual framework for understanding research issues in these areas.

CPsy 8303. Developmental Psychology: Social and Emotional Processes. (4 cr; prereq doctoral student or #) Normative issues and individual differences in social development from infancy through adolescence, with special reference to developmental psychopathology. Life span considerations.

CPsy 8304. Research Methods in Child Psychology. (3 cr) A Pick Review of principal research methods and designs in child psychology, including issues of scientific integrity.

CPsy 8310. Seminar: History of Child Development. (1 cr) Hartup, Weinberg Problems and issues in professional child psychology for first-year graduate students.

CPsy 8320. Seminar: Current Issues in Teaching Developmental Psychology. (1 cr) Charlesworth, Collins Problems and issues in professional child psychology for advanced graduate students.

CPsy 8330. Directed Field Experiences. (1-6 cr; prereq #: S-N only) Intellectual and/or social development of children as individuals or members of groups; may include interactions with children in natural settings, or research on applied topics or with atypical populations.


CPsy 8970. Independent Study. (Cr ar) Independent reading.

CPsy 8980. Research Seminar. (1-3 cr; S-N only) Participation in organized research group in developmental psychology.

CPsy 8990. Research Problems. (Cr ar) Individual empirical investigation.

Chinese

See East Asian Languages, Literatures, and Linguistics.
Civil Engineering (CE)

Professor: Steven L. Crouch, head; Heinz G. Stefan, director of graduate studies; Roger E. A. Arndt; Patrick Brezonik; Andrew Drescher; Charles Fairhurst; Cesar Farel; Efi Foufoula-Georgiou; Theodore V. Galambos; John S. Gulliver; Malcolm T. Hepworth; Walter J. Maier; Panos G. Michalopoulos; John L. Nieber; Gary Parker; Kenneth J. Reid; Michael J. Semmens; Charles C. S. Song; Yorgos J. Stephanedes; Otto D. L. Strack

Adjunct Professor: Peter A. Cundall

Associate Professor: Randal J. Barnes; Gary A. Davis; Emmanuel M. Detournay; Daryl F. Dwyer; Catherine E. French; Gerald W. Johnson; Joseph F. Labuz; David E. Newcomb; Arturo E. Schultz; Karl A. Smith; Mark B. Snyder; Henryk K. Stolarski; Vaughan R. Voller

Assistant Professor: Jerome F. Hajjar; Carol Kittredge Shield

Adjunct Assistant Professor: Paul D. Capel

Research Associate: Eil Kwon; Victor Sapozhnikov

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.S. (Plan A and Plan B), M.C.E. (Coursework Only and Design Project), and Ph.D.

Curriculum—Please refer to the General Information section of this bulletin for information about Plans A and B of the master of science (M.S.) degree.

The professional master’s degree (M.C.E.) is intended for engineering graduates interested in design, planning, or operation rather than in research. It is offered under both the design project track and the coursework only track. The coursework only track requires 44 course credits, of which 12 should be from a set of core courses in one of the subdisciplines. All subdisciplines of civil engineering (e.g., environmental and water resources engineering, structures, transportation, geotechnical engineering) are available for the M.S. and M.C.E. programs.

Emphases in the Ph.D. program are structural design and analysis; construction materials engineering; water resources engineering (including fluid mechanics, hydrology, and water resources management); environmental engineering (including water and wastewater process engineering, environmental chemistry, and environmental microbiology); transportation engineering (including traffic and pavement engineering); and geotechnical engineering. Students are expected to concentrate the major part of their coursework and research in one of these areas.

Prerequisites for Admission—For the master’s and doctoral programs, the normal requirement for admission is an adequate academic record in a civil engineering undergraduate program accredited by the Accreditation Board for Engineering and Technology (ABET). Some areas of civil engineering are so broad that students with other undergraduate preparation may be considered for admission. For example, in environmental engineering, students with an undergraduate concentration in chemistry, chemical engineering, physics, or certain of the biological sciences may be admitted. In transportation, applicants with an undergraduate concentration in electrical engineering, computer science, mathematics, or physics may be admitted. Applicants who lack civil engineering training are often required to complete one or more appropriate courses from the undergraduate civil engineering program. Graduate degree credit is not awarded for such preparatory work. For the M.C.E. program, an ABET-accredited bachelor’s degree in engineering is required.

Special Application Requirements—

Applicants should submit to the director of graduate studies three letters of recommendation, either from professors qualified to estimate their class rank and evaluate their ability to complete a program of graduate study, or from engineering professionals who can assess their professional potential. These letters may also be used in applying for financial aid. Applicants for admission should also submit a résumé of their academic history and professional experience and a statement of purpose, including the proposed area of emphasis within civil engineering. Applicants for the M.S. or Ph.D. are required to submit results of the General Test of the Graduate Record Examination (GRE). International applicants are also required to submit a score of 550 or better on the TOEFL (Test of English as a Foreign Language). Students are admitted each quarter, but applicants are strongly encouraged to begin fall quarter and to submit their applications in December before the year their studies are expected to begin.
Professional Registration—Applicants who have as their goal a professional career as a civil, structural, or geological engineer need to obtain registration as a professional engineer. Admission to the registration examination is, in most states, restricted to graduates of an ABET-accredited curriculum for the bachelor’s degree in engineering. Students who lack this preparation should seriously consider obtaining the training before entering a graduate program. For a student with an undergraduate background in mathematics, for example, this can normally be accomplished in four or five quarters. Prospective students may receive counseling on the need for professional registration in light of their career objectives from the director of graduate studies.

Degree Requirements—For M.C.E. degree requirements, see Professional Master’s Degree in Engineering in the General Information section of this bulletin. All students should also consult the Department of Civil Engineering General Information Bulletin for Graduate Students for more information.

The final examination for the M.S. and M.C.E. degrees is oral.

For M.S. and Ph.D. requirements, see the General Information section of this bulletin. Certain graduate-level civil engineering courses are acceptable for graduate credit only as part of a minor or supporting program for students majoring in a field other than civil engineering. Consult the director of graduate studies for further information.

Language Requirements—None.

For Further Information and Applications—Contact the Department of Civil Engineering, University of Minnesota, 122 Civil Engineering Building, 500 Pillsbury Drive S.E., Minneapolis, MN 55455 (612/625-5522; fax 612/626-7750; e-mail cive@tc.umn.edu; http://www.cme.umn.edu).

CE 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

CE 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

CE 8888. Thesis Credits: Doctoral. (36 cr required)
CE 8097-8098-8099.* Civil Engineering Research. (1-5 cr per qtr; prereq #) Original work in concrete, structural steel, soils, hydraulics, hydrology, and municipal, environmental, or transportation problems. Investigations, reports, tests, designs.

CE 8970. Directed Research: Doctoral. (Cr ar; prereq PhD student, #)

Surveying and Land Use Planning

CE 5102. Site and Route Engineering. (4 cr; prereq 3100, IT or grad student) Site and route design fundamentals and problems based on spatial data obtained through photogrammetric mapping. Problems in geometric design; grades, horizontal and vertical curves; fitting of design to topography; earthwork, area and volumes; drainage. Construction control and layout.

Transportation

CE 5200. Geometric Design of Highways. (4 cr; prereq 3200 or #, IT student or grad) Forecast of traffic volume demand; impact of vehicle type on geometric design; vertical and horizontal alignment; intersection design; highway capacity.

CE 5201. Highway Traffic Characteristics and Operations. (4 cr; prereq 3200, IT or grad student) Davis Characteristics and measurements of volume, speed, density, and travel time; characteristics of vehicles and road users; parking characteristics and design of facilities; applications of signs, signals, and markings in traffic control.

CE 5210. Introduction to Transportation Systems Analysis. (4 cr; prereq #; offered alt yrs) Stephanedes Techniques of analysis and planning for transportation services; demand-supply interactions; evaluating transportation alternatives; travel demand forecasting; integrated modal systems; citizen participation in decision making; proposal writing.


CE 8201. Urban Traffic Operations. (4 cr; prereq #) Michalopoulos Capacity analysis techniques for urban streets, optimal traffic signal control, real time control, signal hardware and detectors, operational techniques for optimizing traffic flow, use of computer programs in traffic engineering practice, air and noise pollution, street and intersection design.

CE 8210. Modeling Consumer Choices in Transportation. (4 cr; prereq Stat 3091 or #; offered alt yrs) Davis Overview of existing models derived from theories of individual choice behavior; properties of statistical estimators, model specification, and sources of model error; applications in urban and rural transportation; transportation-energy interactions; transportation as related to social services, recreation, and other human activities.


CE 8214. Transportation Systems Dynamics and Control. (4 cr; prereq Math 3211 or #; offered alt yrs) Stephanedes Nonlinear differential equations describing demand, service, economics, and energy consumption of transportation systems. Optimal control policies to improve typical performance indices such as transit service frequency and energy consumption by all transportation modes. Second order linear approximation. Stability analysis and controllability. System synthesis and simulation.

CE 8215. Stochastic Models of Traffic Flow and Travel Demand. (4 cr; prereq 8200 or 8210 or #) Davis Random variables and estimation; time-series models, linear systems and Kalman filtering; discrete-time Markov processes and dynamic models of traveler choice; continuous-time Markov processes and traffic flow.

Water Resources Engineering and Fluid Mechanics

CE 5401. Water Resources Engineering. (4 cr; prereq 3400 or #, IT or grad student) Introduction to water resources engineering including flow in conduits, pumps, open channels, and culverts; introduction to flow measurements, hydraulic structures, and systems approach to water resources engineering.

CE 5402. Computational Hydraulics. (4 cr; prereq 5401, CSci 3101 or #, IT or grad student) Parker Computer applications and numerical methods in hydraulic engineering. Computational analysis of water surface profiles in open channel and river flow; bridge waterways; culverts, pipe system; flow in sewer systems; reservoir routing. Numerical interpolation and integration.

CE 5403. Hydraulic Structures. (4 cr; prereq 5401 or #, IT or grad student; offered alt yrs) Stefan Hydraulic design procedures for such structures as culverts, dams, spillways, outlet works; river control works; drop structures, water intakes, bridge crossings, pipeline crossings.
CE 5405. Hydrology and Hydrologic Design. (4 cr; prereq 5401 or #, IT or grad student) Foufoula-Georgiou
Hydrologic cycle, precipitation, evaporation, infiltration, runoff analysis, flood routing, statistical procedures in hydrology, urban hydrology, introduction to mathematical models of medium and large watersheds, application of hydrology to design of outlet works and flow control structures.

CE 5410. Open Channel Hydraulics. (4 cr; prereq 3400, 5401 or #, IT or grad student) Arndt, Song
Mechanics of flow in open channels including gradually varied, spatially varied, and rapidly varied flow; unsteady flow (waves and surges); and flow in alluvial channels.

CE 5425. Groundwater Mechanics. (4 cr; prereq 3400 or #, IT or grad student) Strack

CE 5426. Computer Modeling of Groundwater Flow. (4 cr; prereq IT or grad student, 5425 or #) Strack

CE 5435. Intermediate Fluid Mechanics With Applications. (4 cr; prereq 3400, IT or grad student) Parker
Basic laws and equations of mass, energy, and momentum transport in fluid flow; exact and approximate solutions; viscous flow; irrotational flow; similitude and inspectional analysis. Application to engineering problems.

CE 8401. Introduction to Environmental Boundary Layer Theory. (4 cr; prereq 5435 or #) Parker
Laminar and turbulent boundary layers and their interaction with potential flow. Application to engineering problems.

CE 8402. Introduction to the Theory and Measurement of Turbulent Flows. (4 cr; prereq 8401 or #) Farell
Free-turbulence shear flows, dimensional analysis; statistical description of turbulence; random data analysis, measurement in transient flows.

CE 8407. Stochastic Hydrology. (4 cr; prereq Stat 5021 or #) Foufoula-Georgiou
Analysis and synthesis of hydrologic series and systems; derived distributions; flood frequency analysis; hydrologic time series; correlation and spectral analysis; reservoir range analysis; linear analysis; linear estimation; geostatistics; sampling networks; and real-time hydrologic forecasting.

CE 8408. Special Topics in Hydrology. (4 cr; prereq 8407) Foufoula-Georgiou
Dynamical systems theory, systems approach in hydrology, state-space representation of hydrologic systems, optimal control and estimation. Kalman filtering; scaling processes in hydrology, multiresolution and space-scale analysis.

CE 8413.* Mechanics of Sediment Transport. (3 cr; prereq 5410 or #) Parker
Theories of sediment transport. Transport processes and types of movement. Interrelationship of sediment transport, channel geometry, and channel stability in alluvial streams. Applications to river regulation, artificial channels, local scour, deposition in reservoirs, beach processes, other areas.

CE 8415. Hydropower Development. (3 cr; prereq 5405) Arndt, Gulliver

CE 8418. Computational Hydrodynamics I. (4 cr; prereq 5401 or #) Song
Theory and applications of finite difference methods to solving unsteady one-dimensional flow problems.

CE 8419. Computational Hydrodynamics II. (4 cr; prereq 8418 or #) Song
Computer simulation of 1-, 2-, and 3-dimensional flows of incompressible and weakly compressible fluids with and without free-surface. Basic principles of governing equations, finite difference, and other numerical schemes, and their application to hydraulic and water resources engineering problems.

CE 8425. Advanced Groundwater Mechanics I. (4 cr; prereq 5425 or #) Strack

CE 8426. Advanced Groundwater Mechanics II. (4 cr; prereq 5425 or #) Strack

CE 8435. Special Topics in Hydrodynamic Theory. (3 cr; prereq #)
Linearized theory, wave motion, cavity and separated flow, and other topics to meet special requirements of students.
CE 8440. Flow Effects On Structures. (4 cr; prereq 5435 or #) Farell
Flow around bluff bodies. Hydroelastic (aerelastic) phenomena; vortex-induced vibrations, lock in, galloping, flutter. Vibrations induced by oscillating flows and turbulence. Analytical and experimental modeling. Wind loads on buildings, forces on hydraulic structures, and propulsion devices. Wave forces on submerged structures, piles, walls, floating bodies.

Environmental Engineering

CE 5500. Analysis and Design of Water Supply Systems. (4 cr; prereq 3400 or #, IT or grad student) Reid, Semmens
Planning and engineering design considerations in developing water supply systems for urban centers. Supply quality, storage, treatment, distribution, and cost analysis.

CE 5501. Analysis and Design of Wastewater Systems. (4 cr; prereq Chem 1005, 3400 or #, IT or grad student) Dwyer, Maier
Planning and engineering design considerations in developing wastewater disposal systems for urban centers. Volumes and quality of waste streams, treatment and ultimate disposal of domestic and industrial wastewaters, storm water run-off. Environmental effects, cost, and political aspects of ultimate disposal.

CE 5504. Mass Transport with Environmental Applications. (4 cr; prereq 3400, IT upper div or grad student) Gulliver
Reactor design for water and wastewater treatment and pollutant transport in the environment.

CE 5505. Water Quality Engineering. (4 cr; prereq 5506 or #) Brezonik
Chemical, physical, and biological properties of natural waters; water quality criteria, standards, and legislation; mathematical modeling to predict fate/effects of oxygen-demanding pollutants, nutrients, and refractory organic contaminants on receiving waters.

CE 5506. Environmental Water Chemistry. (4 cr; prereq Chem 1052 or #, IT or grad student) Brezonik, Capel
Composition of natural waters and wastewater; chemical processes affecting distribution of chemical species, including pollutants, in water; methods to evaluate fate of organic pollutants.

CE 5507. Environmental Engineering Laboratory. (4 cr; prereq 5506, 5500 or 5501 or #; 3 lect, 3 lab hrs per wk) Brezonik
Methods of sampling natural water and wastewater; techniques for the chemical, biological, and physical characterization of samples, including nutrients, indicator organisms, BOD, major and minor ions, natural synthetic organic matter.

CE 5510. Solid and Hazardous Waste Management. (4 cr) Hepworth
Analysis and design of engineered systems for collection, transportation, processing, and disposal of solid and hazardous waste materials. Waste characteristics affecting management options, discussion of relevant regulatory legislation.

CE 5512. Solid and Hazardous Waste Processing I. (4 cr; prereq 5510 or IT upper div or grad student or #; 4 lect hrs per wk) Hepworth
Application of physical and chemical principles to unit operations and processes for recovering and recycling solid wastes. Remediation and pollution prevention methodologies on solid and hazardous wastes from manufacturing industries, municipal waste treatment plants, electric power utilities, and the mining industry. Student presentations and reports.

CE 5513. Solid and Hazardous Waste Processing II. (4 cr; prereq 5512 or #; 4 lect hrs per wk) Hepworth
Continuation of CE 5512. Pyro-processing and high-temperature systems; thermal incineration principles; encapsulation of radioactive waste; developing technologies in high-temperature treatment of hazardous wastes.

CE 5515. Water and Wastewater Microbiology. (4 cr; prereq Chem 1052 or #, IT or grad student) Dwyer
Role of microbes in environmental degradation and pollution control. Organism growth and selection in wastewater treatment systems. Pathogens in water supplies and receiving waters. Microbial indicators of water quality.

CE 5540. Analysis of Groundwater-Soil Pollution Abatement Technology. (4 cr; prereq IT major or grad student, 5401, 5501 or #) Maier
Fate of chemicals in groundwater and soils analyzed and modeled. Combined effects of chemical-biological transformation, transport, dispersion, and accumulation. Models for studying in situ clean-up of groundwater and aquifers and for simulating time-dependent changes in pollutant concentration.

CE 5580. Introduction to Environmental Law for Engineers. (4 cr; understanding of pollution control technology recommended; 4 lect hrs per wk) Braaten
Environmental regulatory law relevant to civil and environmental engineering; specific provisions of federal statutory and regulatory laws such as NEPA, CWA, RCRA, CAA, and CERCLA.

CE 8500.* Physical and Chemical Processes for Water and Wastewater Treatment. (3 cr; prereq 5500, 5501 or #) Semmens
Theoretical principles underlying physical and chemical processes for water and wastewater treatment including sedimentation, flotation, adsorption, precipitation, and disinfection.

CE 8501.* Physical and Chemical Processes for Water and Wastewater Treatment—Part II. (3 cr; prereq 5500, 5501, 5506 or #) Semmens
Theoretical principles, design considerations, and performance of processes not covered in CE 8500. Coagulation flocculation, filtration, membrane processes, gas transfer, sludge dewatering, mixing, and other processes commonly used in water pollution control.
CE 8502.* Biological and Chemical Processes for Wastewater Treatment. (3 cr; prereq 5501 or #) Maier
Theoretical principles underlying chemical and biological wastewater treatment processes including aerobic and anaerobic biological processes for carbon and nitrogen removal, aeration, and chemical processes for phosphorus and nitrogen removal.

CE 8505.* Aquatic Chemistry for Environmental Engineers. (4 cr; prereq Chem 5506 or #) Brezonik
Application of principles of physical-chemistry to quantification of chemical processes in aquatic systems. Natural waters as equilibrium and dynamic systems. Ionic equilibria; protolysis, complexation, solubility, and redox equilibria. Precipitation and mineral dissolution kinetics. Aqueous metal species in electrolyte solutions.

CE 8507s. Environmental Processing of Organic Chemicals. (3 cr; prereq grad student, 5506 or #; offered alt yrs)

CE 8508. Groundwater Microbiology. (4 cr; prereq #) Dwyer
Subsurface microbial ecology; biogeochemical cycling; metabolic classification of subsurface bacteria; modeling bacterial transport; diagnosis of microbial induced fouling (MIF) events; bioremediation of contaminated aquifers; kinetic analyses of biodegradation for pollutants in subsurface samples.

CE 8509. Environmental Microbiology. (4 cr; prereq #) Dwyer
Molecular biology techniques used in environmental microbiology; measuring microbial biomass; analyzing microbial activities important for bioremediation; constructing and using genetically engineered microorganisms in environmental engineering.

CE 8540. Interfacial Mass Transfer With Environmental Applications. (4 cr; prereq 5504 or #) Gulliver
Interfacial mass transfer in turbulent flows. Applications to air-water transfer in rivers, lakes, and oceans; to sediment-water mass transfer; and to pollution abatement technology.

CE 8551. Seminar: Models of Aquatic Environments. (1-5 cr; prereq 8550) Stefan
Case studies of specific aquatic stream and lake systems.

Structural Engineering, Soil and Rock Mechanics, Construction Materials

CE 5300. Critical State Soil Mechanics. (4 cr; prereq 3300, IT upper div or grad student) Drescher

CE 5301. Foundation Engineering. (4 cr; prereq 3300, 3301, IT upper div or grad student)
Settlement analysis; retaining walls and earth pressure theories; stability of slopes; bearing capacity of shallow foundations; deep foundations.

CE 5302. Applied Rock Mechanics. (4 cr; §GeoE 5302; prereq 3300 or #, IT upper div or grad student) Detournay
Site investigation; rock mass classifications; in situ stress; behavior of intact rock; shear strength of joints; rock mass behavior; stereographic projections; kinematic analysis of rock slopes; foundations on rock.

CE 5304. Design of Highway and Airport Pavements. (4 cr; prereq 3300, 5603, IT or grad student) Newcomb, Snyder
Theories of pavement design, flexible and rigid; equivalent wheel loads. Strength tests and frost action. Design procedures for flexible and rigid pavements.

CE 5305. Design of Underground Excavations in Rock. (4 cr, §GeoE 5218; prereq IT or grad IT major, GeoE 5302 or #) Fairhurst
Stresses and deformations around underground excavations in rock; design of linings and support systems; excavation by boring, drilling, and blasting; tunneling under adverse conditions; materials handling and tunnel ventilation.

CE 5600. Linear Structural Systems. (4 cr; prereq AEM 1015, 3016, IT or grad student)
Analysis of determinate and indeterminate linear structural systems; analysis of trusses and frames by virtual work, moment distribution, energy methods, and slope-deflection equations. Influence lines. Approximate methods of analysis. Design considerations.

CE 5601. Matrix Analysis of Structures. (4 cr; prereq 5600, IT or grad student) Stolarski
Analysis of linear structural systems by matrix methods; stiffness and flexibility methods of analysis. Introduction to computerized structural analysis of trusses and frames.

CE 5602. Topics in Structural Mechanics. (4 cr; prereq 5600, AEM 3036, IT upper div or grad student) Shield
Introduction to theory of elasticity; theory of vibration for single-degree-of-freedom structures; energy methods of approximate structural analysis; torsion of beams; numerical calculation of buckling loads of bars and plates.
CE 5603. Introduction to Construction Materials. (4 cr; prereq IT upper div student, AEM 3016; 3 lab hrs per wk)
Basic concepts of behavior mechanisms of materials. Characteristics of materials such as concretes, metals, and woods.

CE 5610. Design of Metal Structures: Introduction. (4 cr; prereq 5600, 5603 or ¶5603, upper div IT or grad student)
Loads on civil structures, load factor and working stress philosophies of design. Design of tension, compression, and flexural members and their connections. Codes, properties of structural metals.

CE 5611. Design of Reinforced Concrete Structures. (4 cr; prereq 5600, 5603 or ¶5603, upper div IT or grad student)
Principles of strength and serviceability in reinforced concrete structural design. Strength analysis, design of beams, joists, one-way slabs for flexure and shear. Anchorage development, splicing of reinforcement. Stresses at service, deflections, cracking, long-term effects. Introduction to design of columns; continuity; simple footings.

CE 5612. Design of Metal Structures: Intermediate. (4 cr; prereq 5610, IT or grad student)
Galambos, Hajjar
Design of complete metal structures; plate girder bridges, industrial buildings, multistory structural frames.

CE 5613. Intermediate Reinforced Concrete Design. (4 cr; prereq 5611, IT or grad student)
French, Schultz

CE 5615. Prestressed Concrete. (4 cr; prereq 5611; 5613 recommended, IT or grad student; offered alt yrs) French, Schultz

CE 5617. Design of Masonry Structures. (4 cr; prereq 5600 or #, IT or grad student; offered alt yrs) Schultz
Masonry materials and their production; mortars and grouts; design of nonreinforced and reinforced masonry structural systems; walls; columns; lintels; arches. Codes and specification, testing and inspection.

CE 5701. Bituminous Materials I. (4 cr; prereq 5603, IT upper div or grad student; 3 lect, 3 lab hrs per wk) Newcomb
Physical and chemical properties and characteristics of bituminous binders and aggregates. Properties and design of bituminous mixtures and surface treatments.

CE 5702. Components, Properties, and Design of Portland Cement Concrete. (4 cr; prereq 5603, IT upper div or grad student; 3 lect, 3 lab hrs per wk) Snyder
Physical and chemical properties and characteristics of portland cement, aggregates, and admixtures. Properties and design of concrete mixtures.

CE 8302. Soil/Rock Plasticity and Limit Analysis. (4 cr, ¶GeoE 8302; prereq 3300; offered alt yrs) Drescher

CE 8320. Thermoporelasticity. (4 cr, ¶GeoE 8320; prereq AEM 5580 or #) Detournay

CE 8321. Mechanics of Granular Media. (4 cr; prereq 5301 or 5302 or #; offered alt yrs) Drescher
Advanced constitutive models for granular media; simple hardening and double hardening plastic models. Bifurcation analysis; localized and diffuse bifurcation. Experimental methods for validation of constitutive models.

CE 8322. Storage and Flow of Granular Materials. (4 cr; prereq 5301 or 5302 or #; offered alt yrs) Drescher
Plasticity of granular media; static and dynamic method of slices; storage and flow of granular materials in bins and hoppers; stress concentrations, rarefaction waves, arching, piping.

CE 8360. Engineering Model Fitting. (4 cr; prereq civil or geo or mineral engr grad student or #) Barnes
Parameter estimating and inverse modeling in civil, geological, and mineral engineering. Formulating engineering model fitting problems, comparing and selecting various fit criteria, selecting and implementing solution algorithms on computer, analyzing and interpreting results, and designing future measurement plans.

CE 8605. The Finite Element Method in Civil Engineering. (4 cr; prereq 5601 or #) Stolarski
CE 8606. Advanced Topics in Finite Element Analysis. (4 cr; prereq 8605 or #; offered alt yrs) Stolarski
Large strains and work conjugate stresses; equilibrium and principle of virtual work for nonlinear problems; nonlinear elasticity and plasticity; finite element discretization and discrete nonlinear equations; linearization and solution algorithms for nonlinear problems; structural stability.

CE 8608. Advanced Analysis and Design of Structures. (4 cr; prereq 5601, 5612 or equiv or #; offered alt yrs) Stolarski
Advanced theory and computational techniques for analyzing and designing complex structural systems. Using comprehensive geometric and material nonlinear analysis for designing steel and composite structures.

CE 8609. Principles of Structural Stability. (4 cr; prereq #; offered alt yrs) Galambos, Stolarski
Classification of discrete and continuous conservative and nonconservative systems; buckling analysis of structural members, frameworks, plates, etc., by classical and numerical methods.

CE 8610. Shell Structures. (4 cr; prereq #; offered alt yrs) Shield, Stolarski
Static analysis of thin elastic shells based on Love's postulates; membrane and bending resistance; approximate analytical solutions; higher order theories; design considerations.

CE 8611. Plate Structures. (4 cr; prereq #; offered alt yrs) Shield, Stolarski
Analysis and design of flat plate structures based on the small-deflection elastic Kirchoff-Love theory. Classical and numerical design methods. Skew and orthotropic plate structures. Large-deflection theory.

CE 8612. Plastic Design of Steel Structures. (4 cr; prereq 5610 or #; offered alt yrs) Galambos, Hajar
Plastic analysis and design of structures with applications to grillages, continuous beams, portal and gable frames, collapse mechanisms, minimum weight design, plastic deformations.

CE 8616. Nonlinear Structural Systems. (4 cr; prereq 5610 or #; offered alt yrs) Galambos, Shield
Modern analysis of structural members and systems taking into account geometrical and material sources of nonlinearity. Second-order analysis of simple structures. Inelastic buckling. Emphasis on design considerations.

CE 8618. Reliability in Structural Engineering. (4 cr; prereq 5612, 5613 or equiv) Galambos, Stolarski
Structural design standards and methods, uncertainties in structural design, basic probabilities concepts and statistical distributions, resistance and load statistics, first- and second-order reliability methods, systems reliability, development of probability-based design codes.

CE 8620. Structural Dynamics I. (4 cr; prereq AEM 3036 or #) French, Galambos, Hajjar, Shield, Stolarski
Response of lumped parameter systems to dynamic loading; formulation and solution of problems of one or more degrees of freedom for discrete systems, modal analysis, numerical integration, and transform techniques. Response of continuous systems.

CE 8621. Structural Dynamics II. (4 cr; prereq 8620 or #) French, Schultz
Introduction to earthquake engineering; response spectra; energy absorption capacity of structures; estimation of damping; aseismic design; seismic codes; soil-structure interaction. Wind effects on structures. Blast resistant design. Approximate design methods.

CE 8625. Behavior of Reinforced Concrete Structures. (4 cr; prereq 5611, 5613, 5615) French, Schultz
Advanced topics in behavior of reinforced concrete structures, relationship with element design. Code requirements, reasons behind theoretical and experimental studies for understanding structural behavior and applications to design.

CE 8626. Behavior of Reinforced Concrete Structures II. (4 cr; prereq 8625 or #) French, Schultz
Limit analysis and failure mechanisms for reinforced concrete structures; response and behavior under cyclic, blast, and impact loading; membrane effects; design code requirements.

CE 8697-8698-8699. Seminar: Structures. (1 cr per qtr)
Syllabus varies according to interests of instructor and student; in recent years the following topics have been offered: theory of elasticity, optimization and reliability, wave propagation, soil dynamics, structural lab, wind forces on structures, design in prestressed concrete, modern construction practices.

Classical and Near Eastern Studies

Regents' Professor: Rutherford Aris
Professor: Elizabeth S. Belfiore; Thomas S. Clayton; Frederick Cooper; Gerald M. Erickson (emeritus); Jackson Herschell; Thomas Kelly; Eva Keuls; Sheila McNally; Robert P. Sonkowsky; Theofanis Stavrou; Peter S. Wells

Adjunct Professor: William D. E. Coulson
Associate Professor: Nita Krevans, director of graduate studies; Oliver P. Nicholson; Jonathan S. Paradise; Sandra L. Peterson; Philip H. Selllew; George A. Sheets
Assistant Professor: André P. M. H. Lardinois

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.
Degrees Offered—Classics¹, Greek, Latin, and Ancient and Medieval Art and Archaeology: M.A. (Plan B and, in exceptional cases only, Plan A) and Ph.D.

Curriculum—In addition to Classical Greek and Latin literary studies, flexible degree programs under the Greek and Latin rubrics permit minors or supporting programs in other disciplinary areas such as archaeology, linguistics, modern Greek and Hellenic studies, Medieval and Renaissance Latin, myth and folklore, oral performance, philosophy, and religious studies. The art and archaeology degree includes a variety of programs ranging broadly over ancient and medieval periods, with flexible emphases on languages and textual studies. While full faculty participation from a wide variety of fields provides differing coursework, all students take a common core of courses to promote optimum collegiality and intellectual exchange. Related special facilities include Interdisciplinary Archaeological Studies, the Center for Medieval Studies, and the Center for Modern Greek Studies.

Prerequisites for Admission—Prerequisites for unqualified admission to majors in Classics, Greek, and Latin include sufficient knowledge to begin graduate reading courses in at least one of the two Classical languages and at least intermediate ability in the other. For a major in Ancient and Medieval Art and Archaeology, a background in archaeology, art history, and history sufficient for beginning graduate-level studies, and evidence of language acquisition ability, are required for unqualified admission. Ability, motivation, imagination, and creativity are important criteria. Some course prerequisites can be made up on provisional admission.

Applications from students with undergraduate majors in such fields as the following are welcomed: English, history, Greek and Latin, Near Eastern languages, philosophy, comparative literature, anthropology, theatre, religious studies, art history, political science, the modern languages, and linguistics.

Special Application Requirements—Applicants must send the following directly to the Department of Classical and Near Eastern Studies: results of the Graduate Record Examination; three letters of recommendation from persons well acquainted with their academic work and professional experience; and a two-page statement describing their previous experience and academic training as related to the intended course of study and professional goals. Students may be admitted in any academic term, but financial assistance is normally available only to applicants admitted in the fall quarter (deadline: January 15).

Master’s Degree Requirements—There are four degree programs:

M.A. in Greek: Advanced courses and seminars in Greek literature and supporting work in related fields such as Latin, Modern Greek, myth, Near Eastern language, and religion are required. The total minimum course credit requirement for Plan A is 57 credits (not including 16 thesis credits) and for Plan B is 63 credits.

M.A. in Latin: Advanced courses and seminars in Latin literature and supporting work in related fields such as Greek, English, and Medieval and Renaissance Latin are required. The total minimum course credit requirement for Plan A is 57 credits (not including 16 thesis credits) and for Plan B is 63 credits.

M.A. in Classics: This program requires nearly equal emphasis on courses and seminars in Greek and Latin, as well as in related fields. The total minimum course credit requirement for Plan A is 61 credits (not including 16 thesis credits) and for Plan B is 67 credits.

M.A. in Ancient and Medieval Art and Archaeology: This program includes not only core courses and seminars in the Department of Classical and Near Eastern Studies, but also work in related fields in the Department or other departments. It is offered in cooperation with the Department of Art History, Interdisciplinary Archaeological Studies, and the Center for Medieval Studies. The total minimum course credit requirement for Plan A is 49 credits (not including 16 thesis credits) and for Plan B is 55 credits.

The final examinations for all master’s degrees are both written and oral. Consult the department’s Graduate Student Handbook for details.

¹ For degree purposes, “Classics” indicates a program in which courses in Greek and Latin are combined to form a major. This use of the term should not be confused with the course designation “Classics (Clas),” which indicates courses that do not require knowledge of Greek or Latin.
Doctoral Degree Requirements—Although the M.A. degree is not a prerequisite for admission to the Ph.D. program, doctoral students must complete departmental M.A. course requirements or their equivalent and incorporate them into their Ph.D. programs. In the Classics, Greek, and Latin programs, additional work leads to specialized study and research in Greek and Latin literature, a special (elective) author or genre, and a special (elective) topic or subdiscipline. In the Ancient and Medieval Art and Archaeology program, the four foci are art and archaeology, an ancient textual component, a complementary area (e.g., ancient and medieval history, geology, anthropology), and a special (elective) topic. The Ph.D. program normally averages 90-100 credits.

Minor Requirements for Students Majoring in Other Fields—For master’s students, the minimum credit requirement is 13 credits for a minor in Greek, Latin, or Ancient and Medieval Art and Archaeology, and 17 credits for a minor in Classics. For doctoral students, the minimum credit requirement is 25-33 credits.

Modern Language Requirements—For the M.A. degree, reading knowledge of one modern foreign language appropriate to the student’s program is required (normally German or French). For the Ph.D. degree, reading knowledge of German and one other modern foreign language appropriate to the program (normally French) is required.

For Further Information and Applications—Contact the Department of Classical and Near Eastern Studies, University of Minnesota, 330 Folwell Hall, 9 Pleasant Street S.E., Minneapolis, MN 55455 (612/625-5353; fax 612/624-4894; e-mail cnes@tc.umn.edu).

Clas 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)
Clas 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)
Clas 8888. Thesis Credits: Doctoral. (36 cr required)
Grk 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)
Grk 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)
Grk 8888. Thesis Credits: Doctoral. (36 cr required)

Classical Languages, Literatures, and Cultures

Greek (Grk)
Grk 5012. Prose Composition. (4 cr; prereq 3106 or ∆)
Grk 5032. Textual Criticism. (4 cr)
Theory and practice. Basic tools for analyzing a textual apparatus with some independence; constructing a critical edition of Greek or Latin literary text.
Grk 5121. Biblical and Patristic Greek. (4 cr; prereq 3106 or 3120 or ∆ Sellew)
The Septuagint, Philo, Josephus, New Testament, Apostolic Fathers, and other patristic literature. Reading and discussion of selected texts in the major genres to the fifth century A.D.
Grk 5310, 5320, 5330, 5340, 5350, 5360, 5370, 5380, 5390. Greek Literature. (4 cr per qtr [max 12 cr in each course])
One or more appropriate authors studied in a given course. Authors vary from term to term and from year to year. 5310: oratory. 5320: tragedy. 5330: comedy. 5340: history. 5350: philosophy. 5360: religious texts. 5370: epic. 5380: lyric. 5390: romance.
Grk 5715. Introduction to Classical Philology. (4 cr, §Lat 5715) Sheets
Historical grammar of Greek and Latin from their Indo-European origin to Classical norms.
Grk 5716. History of Greek. (4 cr; prereq Grk/Lat 5715 or equiv, 2 yrs Greek) Sheets
Reading and analysis of documents illustrating the evolution of the Greek language from Mycenaean to modern times.
Grk 5718. Greek Dialects. (4 cr; prereq 3 yrs Greek or #) Sheets
Nature and extent of dialectal variation within ancient Greek through reading and analysis of inscriptions and earlier Greek literature.
Grk 5970. Directed Study. (1-5 cr; prereq #, ∆, CLA approval)
Grk 5980. Directed Teaching. (Cr ar; prereq #, ∆, CLA approval)
Grk 5990. Directed Research. (Cr ar; prereq #, ∆, CLA approval)
**Grk 8120. Greek Text Course.** (4 cr; prereq 3052 or Δ; restricted to students in depts other than Classical and Nr East Sts) Students attend 3xxx Greek courses if they meet the prerequisites for these courses. Supplementary work at the discretion of the instructor.

**Grk 8264. Survey of Greek Literature: Archaic.** (4 cr)

**Grk 8265. Survey of Greek Literature: Literature of the Fifth Century.** (4 cr)

**Grk 8266. Survey of Greek Literature: Literature of the Fourth and Third Centuries.** (4 cr)

**Grk 8510. Seminar: Philosophy.** (4 cr; offered when feasible) Hershbell

**Grk 8910. Seminar.** (4 cr) Seminars on various topics or authors, such as Greek lyric poetry, Greek tragedy, Greek rhetoric, Greek comedy, Homer, Pindar, and Euripides.

**Latin (Lat)**

**Lat 5012. Prose Composition.** (4 cr; prereq 3106 or Δ)

**Lat 5032. Textual Criticism.** (4 cr) Theory and practice. Basic tools for analyzing a textual apparatus with some independence; constructing a critical edition of Greek or Latin literary text.

**Lat 5310, 5320, 5330, 5340, 5350, 5360, 5370, 5380, 5390. Latin Literature.** (4 cr per qtr [max 12 cr in each course])

One or more appropriate authors studied in each course. Authors vary from term to term and from year to year. 5310: history. 5320: epistles and essays. 5330: oratory. 5340: epic and pastoral. 5350: lyric and elegiac poetry. 5360: drama. 5370: satire. 5380: law. 5390: religious texts.

**Lat 5410. Latin Literature of Late Antiquity.** (4 cr [max 12 cr)] Nicholson, Sonkowsky

Pagan and Christian Latin literature from 3rd to 8th centuries.

**Lat 5420. Medieval Latin.** (4 cr [max 12 cr]) Nicholson, Sonkowsky

Literature from 6th to 15th centuries. Authors and genres vary.

**Lat 5430 (formerly 5236). Renaissance Latin.** (4 cr [max 12 cr]) Nicholson, Sonkowsky

Literature after 14th century.

**Lat 5621. Latin Paleography.** (4 cr; prereq 3 cr 3xxx-5xxx Latin or #) Aris

Analysis of various hands used in manuscripts of Latin authors with attention to date and provenance; transmission of ancient Latin literature.

**Lat 5715. Introduction to Classical Philology.** (4 cr; §Grk 5715) Sheets

Historical grammar of Greek and Latin from their Indo-European origin to Classical norms.

**Lat 5717. History of Latin.** (4 cr; prereq Grk/Lat 5715 or equiv or #, 2 yrs Latin) Sheets

Reading and analysis of documents illustrating the evolution of the Latin language from its origins to late antiquity.

**Lat 5735. Italic Dialects.** (4 cr; prereq Grk/Lat 5715 or #; offered when feasible) Sheets

**Lat 5970. Directed Study.** (1-5 cr; prereq #, Δ, CLA approval)

**Lat 5980. Directed Instruction.** (Cr ar; prereq #, Δ, CLA approval)

**Lat 5990. Directed Research.** (Cr ar; prereq #, Δ, CLA approval)

**Lat 8120. Latin Text Course.** (4 cr; prereq 3052 or Δ; restricted to students in depts other than Classical and Nr East Sts)

Students attend 3xxx Latin courses if they meet the prerequisites for these courses. Supplementary work at the discretion of the instructor.

**Lat 8150. Medieval Latin Texts.** (4 cr; prereq #; offered when feasible) Nicholson, Sonkowsky

**Lat 8160. Renaissance Latin Texts.** (4 cr; prereq #; offered when feasible) Nicholson, Sonkowsky

**Lat 8264. Graduate Survey: Literature of the Republic.** (4 cr)

**Lat 8265. Graduate Survey: Literature of the Augustan Age.** (4 cr)

**Lat 8266. Graduate Survey: Literature of the Empire.** (4 cr)

**Lat 8267. Graduate Survey: Latin Literature of Late Antiquity.** (4 cr; prereq #)

Wide range of Latin authors of pagan and Christian prose and poetry, from revival of Latin literature under last pagan emperors to dawn of Middle Ages.

**Lat 8910. Seminar.** (4 cr)

Various topics or authors such as Roman drama, Cicero, Lucretius, odes and epodes of Horace, Ovid, and Juvenal.

**Classics (Clas)**

**Courses for Which Knowledge of Latin or Greek Is Not Required**

**Classical Humanities**

**Clas 5001. Greek, Roman Lyric Poetry in Translation.** (4 cr, §3001; prereq 2 courses in Engl lit beyond Engl 1002 or in foreign lit or Δ; offered when feasible)

**Clas 5007. The Pastoral Tradition.** (4 cr; prereq 2 lit courses or #) Krevans

Clas 5011su. The World of Greece. (4 cr, §3011) Survey of Greek civilization from Homer to Alexander. Way of life as seen in art, history, literature, and philosophy. Special attention to golden age in fifth century B.C. and to expansion of Greek presence under Alexander.

Clas 5012su. The World of Rome. (4 cr, §3012) Survey of Roman civilization from origins to Constantine. Way of life as seen in art, history, literature, and philosophy. Special attention to Etruscans and golden age under Augustus.

Clas 5013. Roman Law and Society. (4 cr) Sheets Roman law as a social institution: basic concepts of persons, property, obligations in historical and social perspective.

Clas 5071. Greek and Hellenistic Religions. (4 cr, §3071, §3071H, §RelA 3071, §RelA 3071H, §RelA 5071) Sellew Ancient Greek religion from Bronze Age to Hellenistic times. Sources include literature, art, and archaeology. Prehistoric religion; Homer and Olympian deities; music, dance, and procession as ritual performance; prayer and sacrifice; temple architecture and sanctuaries; oracles; beliefs about death and afterlife; mystery cults; philosophical religion; criticism of traditional myths; ruler cult; and Near Eastern salvation religions.

Clas 5072. The New Testament. (4 cr, §3072, §3072H, §RelA 3072, §RelA 5072, §RelS 3072, §RelS 5072) Sellew Early Jesus movement in its social and historical setting: origins in Judaism; traditions about Jesus; Paul, his controversies and interpreters; questions of authority, religious practice, and structure in early communities; apocryphal literature and emergence of a scriptural canon. Contemporary methods of New Testament study. Ancient sources studied as evidence for constructing critical history; appreciating their narrative structures and other literary techniques.


Clas 5080. New Testament Proseminar. (4 cr per qtr [max 12 cr]; prereq 3072 or 5072 or #) Sellew Selected topics in study of the New Testament and related ancient literatures. Topics announced in the Class Schedule.

Clas 5081. Classical Epic in Translation. (4 cr, §3081) Homer’s Iliad and Odyssey, Virgil’s Aeneid: cultural context of epic, the heroic character, epic formulas, and poetic techniques.

Clas 5082. Greek Tragedy in Translation. (4 cr, §3082) Origin of European drama as distinct literary form; characteristics of Greek tragedy; ancient theatres and theatrical conventions. Selected tragedies. Problems posed in relation to cultural patterns of the time.

Clas 5085. Greek Philosophy: The Pre-Socratics to Plato. (4 cr; prereq jr) Hershbell Fragments of the pre-Socratics and Sophists and selected dialogues of Plato.

Clas 5086. Topics in Greek Philosophy. (4 cr; prereq #) Selected topics in ancient Greek philosophy to be announced in the Class Schedule.

Clas 5145. Greek and Roman Mythology II. (4 cr, §3145; prereq 1042 or #) Methodologies for the interpretation of myth, such as those of Müller, Jung, and Levi-Strauss, examined on the basis of Classical mythology; successive reinterpretations and applications of selected myths in literature, art, music, and modern sociological disciplines. Independent reading and research assignments completed in consultation with instructor. Meets with 3145; students do additional work for graduate credit.

Clas 5794. Proseminar: Introduction to Classical and Near Eastern Studies. (1 cr; prereq grad major or #) Introduction to core research materials in classical studies and reference tools that give access to them. Organization of library collections and services.


Clas 5970. Directed Study. (1-5 cr; prereq #, ∆, CLA approval)

Clas 5980. Directed Instruction. (Cr ar; prereq #, ∆, CLA approval)

Spch 5611. Classical Rhetoric. (4 cr; prereq Spch 1101 or 1101H) Scott

Art and Archaeology

Clas 5089. Introduction to Biblical Archaeology. (4 cr, §RelS 5089; offered when feasible) Sellew

Clas 5102. Classical Greek Art. (5 cr, §ArtH 5102) McNally Architecture, sculpture, and painting in Greece from Persian Wars to conquests of Alexander.

Clas 5104. Roman Architecture. (5 cr, §ArtH 5104; prereq jr or #) Cooper, McNally Buildings in Rome and the empire from the 5th century B.C. to the 4th century A.D. Major archaeological sites.

Clas 5105. Roman Painting and Mosaics. (5 cr, §ArtH 5105; prereq jr or #) McNally Specific problems; sites such as Pompeii and Antioch.
**Class 5106. Greek Painting.** (5 cr, §ArtH 5106; prereq jr or #)
Research and analysis in Classical art as applied to the study of vases, original objects, and sources.

**Class 5107. Roman Sculpture.** (4 cr, §ArtH 5107; prereq jr or #) McNally
Sculpture of Rome and its provinces from the 1st century B.C. to the 4th century A.D.; role of sculpture in Roman politics and religion.

**Class 5108. Greek Architecture.** (4 cr, §ArtH 5108; prereq jr or #) McNally
Archaeic and Classical examples of religious and secular architecture, their setting in major archaeological sites.

**Class 5111. Bronze Age Art and Architecture in Greece, CA. 3000-1100 B.C.** (4 cr, §ArtH 5111; prereq one ancient art or archaeology course) Cooper
Artistic and architectural forms in the Neolithic period in the Aegean area and the Cycladic, Minoan, and Mycenaean cultures.

**Class 5113. Archaic Greek Art.** (4 cr, §ArtH 5113; prereq jr or #) McNally
Architecture, sculpture, and painting from 9th century B.C. through 480 B.C. Material remains of Greek culture; scholarly problems such as identifying and dating buildings; analysis of methods and techniques.

**Class 5120. Field Research in Archaeology.** (3-6 cr; prereq #; offered when feasible)

**Class 5122. Greek Art, Architecture, and Archaeology.** (4 cr, §3122) McNally
Survey of Greek art from earliest times to 31 B.C. Main trends and concepts in architecture, sculpture, and painting; the art in its social, literary, and historical context.

**Class 5340. Practicum in Archaeological Field Techniques.** (4 cr, §3340, §CICv 3340; prereq major in Grk or Lat or Clas or Hebr or ANE Studies or CICv or #, ancient art or archaeology course) Cooper
Introduction to methods of excavation on classical sites. Meets at selected Minnesota site for day-long sessions for half of quarter. Arranged according to procedures in field: handling instruments, setting up field notebooks, preparing trenches, excavating, and recording and analyzing strata and artifacts.

**Class 8114. Seminar: The Topography of Athens.** (4 cr, §ArtH 8114; prereq #)

**Class 8190. Seminar: Problems in Ancient Art.** (4 cr [may be repeated for cr], §ArtH 8190; prereq #)

**Class 8910. Seminar: Problems in Classical Archaeology.** (4 cr [may be repeated for cr], §ArtH 8910; prereq #)

**Modern Greek**

**Modern Greek (MdGk)**

**MdGk 5970. Directed Study.** (1-5 cr; prereq #, Cla approval)

**MdGk 5980. Directed Teaching.** (Cr ar; prereq #, Cla approval)

**MdGk 5990. Directed Research.** (Cr ar; prereq #, Cla approval)

**Near Eastern Studies**

**Akkadian (Akka)**

**Akka 5011-5013. Elementary Akkadian.** (4 cr per qtr; prereq advanced undergrad with permission or grad student; offered alt yrs)
Introduction to cuneiform script. Outline of Akkadian grammar, written drills, selected readings from historical annals, law collections, religion and epic literature.

**Ancient Near Eastern (ANE)**

**ANE 5501, 5502. Ancient Israel.** (4 cr per qtr, §3501, 3502; prereq grad student or #; knowledge of Hebrew not required)
History of Israel and development of its religion, from earliest times through intertestamental period. 5501: Formation of Hebrew people; patriarchal period; development of Israelite religious and legal institutions; conquest of Canaan; development of monarchy and United Kingdom. 5502: Divided kingdom; classical prophecy, destruction, exile, and restoration.

**ANE 5505. Ancient Israel: The Hellenistic Period.** (4 cr, §3505; prereq grad student or #; knowledge of Hebrew not required)
Period of Ezra and Nehemiah, Samaritans; apocalyptic and other eschatological types; Maccabean period; Sadducees, Pharisees, Zealots, Christians, Qumran, wisdom literature; Philo; Josephus; Jewish rights in Roman Empire. Emphasis on evaluation of sources for historical reliability.

**ANE 5711. Northwest Semitic Inscriptions.** (4 cr; prereq Hebr 3013 or #; offered when feasible)

**ANE 5970. Directed Studies.** (1-4 cr; prereq #)

**Aramaic (Arm)**

**Arm 5011, 5012, 5013. Aramaic.** (4 cr per qtr; for students preparing for biblical studies, ancient history majors, and students specializing in Semitic languages; recommended for students of Talmud; prereq 1 yr Hebrew or Arabic or #; offered alt yrs)
5011: Biblical Aramaic—fundamentals of grammar and fluency in reading of biblical and ancient Aramaic. 5012: Syriac—grammar, fluency of reading Syriac texts. 5013: Aramaic inscriptions—study of epigraphy, morphology, and syntax of old Aramaic inscriptions from the 9th to 5th centuries B.C.

**Coptic (Copt)**

**Copt 5011-5012. Elementary Coptic.** (4 cr per qtr; prereq some knowledge of another ancient language, preferably Greek) Sellew
5011: Introduction to Coptic grammar and vocabulary (Sahiic dialect). 5012: Further instruction in grammar, introduction to other dialects; first reading of texts.
Copt 5300. Readings in Coptic. (4 cr [may be repeated twice for cr]; prereq 5012 or equiv) Sellew. Advanced reading in variety of Coptic literature, such as Nag Hammadi treatises, Hermetic writings, and Egyptian monastic texts. Authors vary each year.

Hebrew (Hebr)

Hebr 5200. Problems in Biblical Studies. (4 cr per qtr; for majors and others adequately prepared to read the Bible in Hebrew; prereq 3202 or #; offered when feasible)

Hebr 5970. Directed Readings. (Cr ar; prereq 3013, #, ∆, CLA approval) Special problems for advanced students.

Sumerian (Sum)

Sum 5011-5012. Elementary Sumerian. (4 cr per qtr; prereq advanced undergrad with 2 yrs other foreign language or grad student; offered alt yrs) Introduction to Sumerian writing and grammar. Readings from classical Sumerian literary and historical texts.

Classical and Indo-Iranian Linguistics

Grk 5715, 5716, 5718; Lat 5715, 5717, 5733, 5735 (For course descriptions see Greek and Latin under Classical Languages, Literatures, and Cultures above.)

See South Asian and Middle Eastern Languages and Cultures for descriptions of the following courses:

SALC 5090. Instruction in South Asian Languages
Skt 5131-5132-5133. Beginning Sanskrit
Skt 5201-5202-5203. Intermediate Sanskrit

Representative courses of interest offered by Classical and Near Eastern Studies faculty through other departments: Hist 5061, 5062, 5063 (Ancient Greece); Hist 5276, 5756-5757 (Modern Greece); Phil 5005.

Classics

See Classical and Near Eastern Studies.

Clinical Laboratory Science (CLS)

Professor: Fred S. Apple; Ellis S. Benson (emeritus); Richard D. Brunning; Jaroslav Cervenka; Paul P. Cleary; Agustin P. Dalmasso; Gary M. Dunny; John H. Eckfeldt; J. Roger Edson; Stanley L. Erlandsen; Patricia Ferrieri; Alexandra H. Filipovich; Russell C. Johnson; Karen Karni; John H. Kersey; Tucker W. LeBien; J. Jeffrey McCullough; Harry T. Orr; Herbert F. Polesky; Andreas Rosenberg; Daniel A. Vallera; Carol L. Wells

Associate Professor: Helen M. Hallgren, director of graduate studies; Robert J. Boudreau; Ronald R. W. Jemmerson; Karen G. Lofsness; R. Scott McVor; Miriam Segall; Amy P. Skubitz; William R. Swaim; Michael Y. Tsai; Michael J. Wilson

Assistant Professor: Ronald C. McGlennen; Angela Mortari

Senior Research Associate: Robert D. Nelson

Research Associate: Connie J. Gebhart

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degree Offered—M.S. (Plan A only).

Curriculum—Graduate work in clinical laboratory science offers students with basic science or medical technology backgrounds the opportunity to gain competence in a specialized area of laboratory medicine. It provides training in the research, supervisory, and teaching aspects of the field. Students pursue investigative work in one of six specialty areas: chemistry, genetics, hematology, immunohematology, immunology, and microbiology.

Prerequisites for Admission—A bachelor’s degree in a basic science or in medical technology, including standard college courses in organic/inorganic chemistry, biochemistry, quantitative analysis, physics, and mathematics, is required. Previous laboratory experience is desirable.

Special Application Requirements—Applicants must forward to the Department of Laboratory Medicine and Pathology three letters of recommendation, an autobiographical outline that includes a statement of career goals, and scores from the General Test of the Graduate Record Examination. A minimum score of 550 on the Test of English as a Foreign Language (TOEFL) is required for applicants whose native language is not English. Students may be admitted any quarter.

Degree Requirements—Students are encouraged to file their program after completing 9 to 15 graduate credits. At least 25 credits are required in the specialty area; at least 9 credits are required in a single supporting program, or 8 credits in related fields outside the major. Students must pass a final oral examination for defense of the thesis.

Language Requirement—None.
CLS 5165. Advanced Clinical Immunohematology. (5 cr [may be repeated for cr], $MedT 5165; prereq #) Hallgren
Observation, study, and practice in special problems, advanced techniques, and methodology in clinical immunohematology.

CLS 5175. Advanced Clinical Chemistry. (5 cr [may be repeated for cr], $MedT 5175; prereq #) Tsai
Observation, study, and practice in special problems, advanced techniques, and methodology in clinical chemistry.

CLS 5196s. Computer Methodology in the Delivery of Healthcare I: Physiological Monitoring and Testing. (3 cr, $HInf 5433; prereq HInf 5432 or #) Finkelstein
Role of the computer in monitoring and testing patients; hardware and software requirements for processing clinically significant signals; comparison and evaluation of currently available systems.

CLS 5197f. Computer Methodology in the Delivery of Healthcare II: Introduction to Medical Decision-Making Techniques. (3 cr, $HInf 5434; prereq HInf 5432, PubH 5452 or #) Connelly
Introduction to biometrical concepts and techniques used to support the medical decision-making process, including test efficacy, decision analysis, Bayes theorem, and multivariate analysis. Current studies of the medical problem-solving process, and computer-based medical decision support systems.

CLS 5198w. Computer Methodology in the Delivery of Healthcare III: Operations Research and Control Systems for Hospitals. (3 cr, $HInf 5435; prereq HInf 5432 or #) Potthoff
Health information systems for inpatient, outpatient, and research use, including status of current systems, costs and benefits, and legal/ethical considerations. System 2000 and other database management systems for clinical research used for class problems.

CLS 5272f. Immunohematology I: Immunology and Hematology in Immunohematology. (3 cr) Polesky
Immunology and HLA; principles of inheritance and molecular genetics; review hematopoeisis; structure, function, and disorders of red and white blood cells and platelets.

CLS 5273w. Immunohematology II: Blood Group Systems. (3 cr) Polesky
Biochemistry, genetics, antigens, antibodies, serology, and clinical significance of blood group systems. Neutrophil and platelet antigens and antibodies. Parentage testing.

CLS 5274s. Immunohematology III: Transfusion Medicine. (3 cr) Polesky
Donor selection, collection, processing; apheresis; component preparation; indications for use of blood components; transfusion in selected clinical conditions; transplantation and transfusion; hemolytic disease of the newborn and Rh immune globulin; transfusion reactions; transfusion transmitted viruses.
COGNITIVE SCIENCE

CLS 5280f, 5281w, 5282s. Advanced Immunohematology Practicum I, II, III. (2 cr per qtr; prereq #) Component preparation; collection and processing blood from donors; testing for transfusion transmitted viruses; HLA methods; parentage testing; advanced serological techniques and problem solving. Educational methods; exposure to management in blood center and transfusion service.


CLS 5311. Clinical Chemistry I: Laboratory Applications. (2 cr, §MedT 5311; prereq Chem 3301, Chem 3302, Chem 3305, Chem 3306, MdBc 5300, MdBc 5301) Analyzing urine and body fluids using physical, chemical, and microscopic examination; developing lab skills in performing renal function tests (e.g., creatinine, urea) and using instrumentation (e.g., spectrophotometers).


CLS 5346f. Computer Applications in Healthcare. (4 cr, §Hinf 5430; prereq health professional or student in healthcare discipline) Finkelstein Current applications of computers and associated provider roles in healthcare areas in hospitals and communities.

CLS 5765f. Hematology. (4 cr; prereq #) Lofsness Blood and blood forming organs; blood and bone marrow from the standpoint of diagnosis and prognosis.

CLS 5768f,w,s,su. Advanced Hematology. (Cr ar; prereq #) Brunning Use of statistics, predictive value of tests, new concepts in methodology and automation, principles and advantages of kinetic and equilibrium assays.

CLS 8176. Advanced Topics in Clinical Chemistry. (3 cr; prereq #; offered when feasible) Tsai Use of statistics, predictive value of tests, new concepts in methodology and automation, principles and advantages of kinetic and equilibrium assays.

CLS 8236f,w,s,su. Research On Clinical Laboratory Problems. (1-10 cr)

CLS 8240. Educational Administration in Medical Technology. (3 cr; prereq #) Karni Responsibilities of administration to students, faculty, and educational community. Topics include curriculum planning, accreditation, staffing, student selection, finances. Sample administrative problems and decisions used as practice vehicles.

Cognitive Science (CgSc)

Professor: Paul W. Fox (psychology); Jeanette K. Gundel (linguistics); Keith Gunderson (philosophy); Paul Johnson (information and decision sciences); Michael B. Kac (linguistics); Daniel J. Kersten (psychology); Gordon E. Legge (psychology); Charles A. Nelson (child development); J. Bruce Overmier (psychology); Herbert L. Pick, Jr. (child development); C. Wade Savage (philosophy); Gerald M. Siegel (communication disorders); James R. Slagle (computer science); Joseph P. Stemberger (linguistics); Albert Yonash (child development)

Associate Professor: Charles R. Fletcher (psychology), director of graduate studies; Patricia J. Bauer (child development); Maria L. Gini (computer science); David S. Knopman (neurology); Mary Jo Nissen (psychology); Maria D. Sera (child development); Paulus W. van den Broek (educational psychology)

Course of Study—Minor in cognitive science, applicable to master’s (M.A. and M.S.) and doctoral programs.

Curriculum—Cognitive science is a field of inquiry at the interface of cognitive psychology, computer science, linguistics, neuroscience, and philosophy. Cognitive science is concerned with the acquisition, representation, and use of knowledge by humans and machines. The curriculum provides students with a broad foundation in psychological, philosophical, and computational approaches to the study of cognition.

Prerequisites for Admission—Admission to the cognitive science graduate minor is
contingent upon prior admission to a master’s or doctoral degree-granting program within the Graduate School. Admission to the minor program is limited and only by permission of the director of graduate studies in cognitive science. Applications for admission to the minor are due November 1; students are admitted effective winter quarter.

**Minor Requirements**—Students seeking to complete the cognitive science minor at either the M.A./M.S. or Ph.D. level are required to take those of the following core courses that are outside their major department: CgSci 8000, CSci 5511, and Psy 5015. In addition, CgSci 8001 (a three-quarter proseminar) is required for the Ph.D. minor. The minor program at the M.A./M.S. level requires a minimum of 12 graduate-level quarter credits; the minor at the Ph.D. level requires 21 credits. Additional credits beyond the required courses must be taken in courses selected from the list of elective courses. Credits from courses in the student’s major department, however, do not count toward the minor.

**Language Requirement**—None specific to the minor program.

**For Further Information and Applications**—Contact Professor Charles R. Fletcher, Center for Research in Learning, Perception, and Cognition, University of Minnesota, 205 Elliott Hall, 75 East River Road, Minneapolis, MN 55455 (612/625-6096 or 612/625-9092).

**Core Courses**

CgSc 8000. *Philosophy of Cognitive Science.* 
(4 cr; prereq #) Savage
Philosophical framework for analyzing cognitive sciences. Recent developments in metaphysics and epistemology. Nature of scientific theories, methodologies of cognitive sciences, relations among cognitive sciences, relation of cognitive science to epistemology and various philosophical problems.

CgSc 8001. *Proseminar in Cognitive Science.* 
(1 cr per qtr for 3 qtrs; prereq admission to cog sci grad minor) Fletcher
Survey of major topics in cognitive science, including theoretical assumptions, methods, and samples of current research.

CgSc 8360. *Seminar: Topics in Cognitive Science.* 
(1-4 cr; prereq admission to cog sci grad minor or #)
Lectures and in-depth discussion.

CSci 5511. *Artificial Intelligence I.* 
(4 cr; prereq 3322 or #; informal lab)

Psy 5015. *Cognitive Processes.* 
(4 cr; prereq 3011 or 3051 or 5014 except for honors sequence students and grads)

**Elective Courses—Cognition**

Anth 5114. *Structural Anthropology*

Anth 5132. *Symbolic Anthropology*

CPsy 5343. *Cognitive Development*

Psy 5014. *Psychology of Human Learning and Memory*

Psy 8970. *Seminar: Special Areas of Psychology and Related Sciences* 
(Some of these seminars are acceptable for the minor, including the Seminar in Computer Models of Cognitive Processes and the Seminar in Cognitive Neuropsychology. Students should consult with the director of graduate studies in cognitive science to determine whether a particular seminar is acceptable.)

**Elective Courses—Philosophy**

Phil 5615. *Minds, Bodies, and Machines*

Phil 8180. *Seminar: Philosophy of Language*

**Elective Courses—Perception**

CPsy 5341. *Perceptual Development*

Psy 5031. *Perception*

**Elective Courses—Language**

Anth 5161. *Cultural Semantics*

CPsy 5345. *Language Development*

Ling 5001. *Introduction to Linguistics*

Ling 8820. *Topics in Language and Cognition*

Psy 5054. *Psychology of Language*

Psy 8056. *Seminar: Psychology of Language*

**Elective Courses—Applications**

CSci 5512. *Artificial Intelligence II* 
(Some of these seminars are acceptable for the minor. Students should consult with the director of graduate studies in cognitive science to determine whether a particular seminar is acceptable.)

Psy 5051. *Psychology of Human-Machine Interaction*

Psy 8201. *Social Cognition*
Communication Disorders (CDis)

Professor: Charles E. Speaks, chair; Joe E. Reichle, director of graduate studies; Patricia A. Broen; Robert H. Brookshire; Julia M. Davis; Samuel K. Haroldson; Robert H. Margolis; Karlind T. Moller; David A. Nelson; Gerald M. Siegel; Clark D. Starr; Joseph P. Stemberger; Dianne J. Van Tasell

Associate Professor: Arlene E. Carney; Robert S. Schlauch; Jennifer A. Windsor

Adjunct Associate Professor: David A. Preves

Assistant Professor: Timothy N. Doyle; Nancy P. Solomon

Visiting Assistant Professor: Leslie E. Glaze

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

Degrees Offered—M.A. (Plan A and Plan B) and Ph.D.

Curriculum—Emphases in the master’s program are speech-language pathology and audiology. Emphases in the doctoral program are speech-language pathology, speech science, audiology, and hearing science.

Prerequisites for Admission—There are no specific academic prerequisites. Prospective students generally have completed an undergraduate degree or coursework in the field, but individuals from other academic areas are welcome. Students entering the M.A. program with minimal background in communication disorders should expect their program to extend beyond the usual two years.

Special Application Requirements—Three letters of recommendation evaluating the applicant’s scholarship (at least two from professorial-rank faculty), a complete set of transcripts (in addition to that required by the Graduate School), and Graduate Record Examination scores are required. Deadline for application to the master’s program is February 1; late applications are considered only if space is available. Master’s students ordinarily begin graduate study during fall or summer terms.

Master’s Degree Requirements—Students who complete the master’s degree with emphasis in speech-language pathology or audiology are eligible for clinical certification by the American Speech-Language-Hearing Association. A complete list of degree program requirements may be obtained from the director of graduate studies. An oral final examination is required for Plan A and Plan B students.

Doctoral Degree Requirements—Programs are designed by the student and the adviser to develop skills in research and scholarship. Required courses are EPsy 8260, 8261, and 8262.

Language Requirement—None.

For Further Information and Applications—Contact the Department of Communication Disorders, University of Minnesota, 115 Shevlin Hall, 164 Pillsbury Drive S.E., Minneapolis, MN 55455 (612/624-3322; fax 612/624-7586).

CDis 8666. Doctoral Pre-Thesis Credits. (max 18 cr per qtr; doctoral student who has not passed oral prelims)

CDis 8777. Thesis Credits: Master’s. (16 cr required; Plan A only)

CDis 8888. Thesis Credits: Doctoral. (36 cr required)

CDis 5101. Communication Problems of Children. (3 cr; prereq non-speech and hearing science major; offered alt yrs) S Doyle, staff

CDis 5102. Communication Problems Associated With Aging. (3 cr; prereq non-speech and hearing science major; offered alt yrs) Starr

CDis 5103. Communication Disorders and Cultural Diversity. (4 cr) Siegel

CDis 5301. Introduction to Acoustics. (5 cr) Speaks

Please contact the Department of Communication Disorders for further information.
CDis 5302. Anatomy and Physiology of the Speech and Hearing Mechanisms. (5 cr)
Solomon
Gross anatomy, physiology, and function of structures related to phonation, articulation, and audition.

CDis 5303. Phonetics Laboratory. (2 cr) Broen
Phonetic analysis of speech, the IPA classification system and articulatory correlates of English phonemes. Lab transcription of isolated sounds, words, and connected speech.

CDis 5304. Speech Science. (4 cr; prereq 5301, 5302, 5303 or #) Speaks
Acoustic characteristics of speech. Consideration of theories of speech production and speech perception, and critical review of classical and current research in production and perception. Introduction to techniques for analysis and synthesis of speech.

CDis 5305. Language Acquisition. (4 cr)
Windsor
Theory and experimental research dealing with language development.

CDis 5306. Hearing Science. (4 cr; prereq 5301, 5302 or #) Schlauch
Fundamental concepts in normal audition. Psychoacoustic methods; sensitivity and acuity; loudness, pitch, timbre, distortion, aural harmonics; masking, adaptation; the auditory reflex; binaural phenomena, localization.

CDis 5502. Stuttering. (4 cr) Haroldson
Description, nature, and treatment of stuttering in children and adults. Students are involved at various levels in therapeutic and research activities.

CDis 5504. Normal and Disordered Child Phonology. (4 cr; prereq 5302, 5303 or #) Broen
Theory and research relating to normal and disordered phonological development. Emphasis on assessment and treatment of phonological disorders.

CDis 5507. Cleft Palate, Oral-Facial Anomalies and Speech. (4 cr; prereq 5304, 5504 or #) Starr, Moller
Relationships between oral-facial structures and speech. Emphasis on speech problems associated with dental and palatal anomalies and on their clinical management. Observations of clinical activities.

CDis 5508. Voice Disorders. (4 cr; prereq 5304 or #) Starr, Haroldson
Physical and physiological bases of normal voice production reviewed. Voice disorders (pitch, loudness, quality); their symptomatology, etiology, and clinical management. Laryngectomy and other organic disorders emphasized.

CDis 5509. Motor Speech Disorders. (4 cr; prereq 5304 or #5304) Solomon

CDis 5606. Language Assessment, Intervention: Early Stages. (4 cr; prereq 5305 or #) Reichle
Analysis of communication disorders in preschool-age children. Emphasis on assessment and management of language disorders observed in children with developmental disabilities as well as intellectually normal children.

CDis 5607. Language Assessment, Intervention: Later Stages. (4 cr; prereq 5305 or #) Windsor

CDis 5608. Language Assessment, Intervention: Adults. (4 cr; prereq 5302 or #)
Brookshire
Analysis of language disorders in adolescent and adult populations. Emphasis on assessment and intervention strategies applicable to aphasia and other neurogenic disorders.

CDis 5611. Augmentative Systems of Communication. (4 cr) Reichle
Review of equipment and instructional procedures used to establish communication board and signing skills in severely handicapped populations.

CDis 5701. Hearing Loss and Audiometry. (5 cr; prereq 5301, 5302 or #) Carney, Schlauch
Basic orientation to audiology. Overview of hearing disorders: audiometric and medical correlates, medical and surgical management, effects on communication and psychosocial adjustment. Introduction to basic audiometry: pure-tone audiometry, speech audiometry, screening, acoustic immittance. Lab participation required.

CDis 5702. Advanced Audiometry. (5 cr; prereq 5701 or #) Schlauch
Advanced audiometric procedures, including speech discrimination testing, pediatric testing, detection and evaluation of pseudohypacusis. Behavioral diagnostic procedures for determining site of lesion, along with auditory pathologies that these procedures are designed to detect. Lab participation required.

CDis 5703. Communication Problems of the Hearing-Impaired. (5 cr; prereq 5701 or #) Carney
Effects of hearing loss on development of language, perception and production of speech, and psychosocial adjustment. Techniques for habilitation and rehabilitation of hearing-impaired children and adults, including use of amplification, speechreading, and auditory training. Basic instruction in finger spelling and elements of manual communication.

CDis 5705. Objective Measures of Auditory Function. (3 cr; prereq 5701 or #; offered alt yrs) Margolis
Advanced techniques for clinical physiological evaluation of the auditory system. Major emphasis on acoustic immittance and auditory evoked potentials, with some discussion of electroneystagmography, galvanic skin response, and electrocardiac response. Lab participation required.
**CDis 5706. Hearing Aids.** (4 cr; prereq 5701 or #) 
Van Tasell  
Electroacoustic characteristics of personal hearing aids and group amplification systems. Acoustical principles of earmold design and modification. Methods for selecting amplification for hearing-impaired children and adults.

**CDis 5707. Audiology in Educational Settings.** (3 cr; prereq 5703 or #; offered alt yrs) 
Carlstrom  

**CDis 5900. Topics in Communication Disorders.** (1-4 cr)

**CDis 5970. Directed Studies.** (Cr ar [may be repeated for cr]; prereq #)  
Directed readings and preparation of reports on selected topics.

**CDis 8305. Laboratory Instrumentation.** (2 or 4 cr; prereq 5301 or #) Schlauch, Speaks, Van Tasell  
Two-credit course includes basic theoretical and practical information; 4-credit course also includes application of basic principles to the calibration and evaluation of audiometric equipment. M.A. students in speech pathology must enroll for 2 credits; in audiology, for 4 credits. Doctoral students from any department may enroll for either 2 or 4 credits. Lab participation required.

**CDis 8502. Seminar: Stuttering.** (3 cr; prereq 5502 or #) Siegel  
Theoretical explanations of stuttering; research data and methodologies subserving the respective theories. Students independently design and, when feasible, execute research studies that derive from, and are consistent with, a particular theory of stuttering.

**CDis 8504. Seminar: Normal and Disordered Child Phonology.** (3 cr; prereq 5504 or #) Broen  
Advanced study and independent research.

**CDis 8507. Seminar: Cleft Palate.** (3 cr; prereq 5507 or #) Starr, Moller  
Research on communication problems of persons with cleft palates.

**CDis 8508. Seminar: Voice.** (3 cr; prereq 5508 or #) Starr  
Advanced study and independent research.

**CDis 8520, 8521. Clinical Education in Speech-Language Pathology.** (1-6 cr [may be repeated for cr]; prereq grad major in comm dis)

**CDis 8590. Seminar: Current Issues in Speech-Language Pathology.** (3 cr) Solomon, Sternberger, staff  
Significant problem areas in speech-language pathology; relation to other rehabilitation programs and personnel. Class projects involving in-depth exploration of a specific problem.

**CDis 8605, 8606, 8607. Seminar: Language Disorders.** (3 cr per qtr; prereq 5305 or #) Broen, Reichie, Siegel, Windsor  
Advanced study and independent research.

**CDis 8608. Seminar: Aphasia.** (3 cr; prereq 5608 or #) Brookshire  

**CDis 8715, 8716, 8717, 8718. Seminar: Hearing.** (3 cr per qtr) Carney, Schlauch, Van Tasell  
Major experimental research in psychophysiological and psychoacoustical nature of hearing. Critical analysis of theory, experimental method, and treatment of data.

**CDis 8720, 8721. Clinical Education in Audiology.** (1-6 cr [may be repeated for cr]; prereq grad major in comm dis)

**CDis 8990. Research.** (Cr ar [may be repeated for cr])  
Open to graduate students doing research.

**Comparative Literature (CLit)**

*Professor:* Tom C. Conley (French and Italian); Peter E. Firchow (English); Harvey B. Sarles (cultural studies and comparative literature); Jochen Schulte-Sasse (cultural studies and comparative literature; German); Nicholas Spadaccini (Spanish and Portuguese); Anthony N. Zahareas (Spanish and Portuguese); Jack D. Zipes (German)  

*Associate Professor:* Maria M. Brewer (French and Italian); John W. Mowitt (cultural studies and comparative literature)

*Assistant Professor:* Prabhakara Jha (cultural studies and comparative literature)

Please read the General Information section of this bulletin for Graduate School requirements that apply to all major fields.

**Degrees Offered**—M.A. (Plan B only) and Ph.D.