158H. Honors Organismal Biology Laboratory
Fall. 2(1-3) Interdepartmental with Lyman Briggs School. Administered by Lyman Briggs School. Not open to students with credit in BS 110 or LBS 144. C: LBS 148H concurrently.
Basic procedures used by organismal biologists, including experimental design and statistical methods. Development and implementation of research projects to test hypotheses in genetics, ecology, and evolution.

159H. Honors Cell and Molecular Biology Laboratory
Spring. 2(1-3) Interdepartmental with Lyman Briggs School. Administered by Lyman Briggs School. Not open to students with credit in BS 111L or LBS 145. C: LBS 149H concurrently.
Basic techniques of cellular and molecular biology including experimental design and hypothesis formulation. Student-initiated projects to test hypothesis-driven projects in biochemistry, molecular biology or genetics.

BIOMEDICAL ENGINEERING BME

Department of Materials Science and Mechanics
College of Engineering

424. Biomaterials and Biocompatibility
Spring of even years. 3(3-0) Interdepartmental with Materials Science and Mechanics. P: (PSL 250 and MSM 250)
Materials science of human implants. Design requirements imposed by the body's milieu and the need to protect the body.

441. Tissue Mechanics
Spring of odd years. 3(3-0) Interdepartmental with Materials Science and Mechanics. P: (MSM 211)
Application of solid mechanics to understanding mechanical responses of biological tissues. Microstructure and biological function for soft and hard connective tissues and muscle.

445. Biomechanical Design
Spring. 3(3-0) Interdepartmental with Materials Science and Mechanics. R: Open only to juniors or seniors in the College of Engineering.
Biomechanical product design with application to people or animals. Synthesis, prototyping, and analysis of designs. Project management. Market research.
SA: BME 491A

491. Special Topics (MTC)
Fall, Spring. 3 to 12 credits. A student may earn a maximum of 12 credits in all enrollments for this course.
Special topics in biomedical engineering or bioengineering such as biochemical design, occupational biomechanics, biological surface science, or low temperature biotechnology.

BIOSYSTEMS ENGINEERING BE

Department of Agricultural Engineering
College of Agriculture and Natural Resources
College of Engineering

180. Current Issues in Biosystems
Fall, Spring. 2(2-0) P: MTH 110 or MTH 116. R: Open only to freshmen or sophomores.
The relationship of biosystems engineering to current problems in food production and processing. Environment, natural resources, harvesting, handling, safety, and water quality.

230. Principles of Biosystems Engineering
Fall. 3(3-0) P: MTH 132. R: Open only to sophomores or juniors in College of Agriculture and Natural Resources, College of Engineering, or College of Natural Science.
Concepts of biosystems. Hard and soft systems. Conceptual and computer modeling of components of biosystems.

232. Food Production and Processing Systems
Fall. 1(0-2) R: Open only to students in College of Agriculture and Natural Resources or College of Engineering.
Crop and animal production systems. Food processing systems. Field trips required.

329. Fundamentals of Food Engineering
Spring. 3(3-0) Interdepartmental with Food Science. P: FSC 211, MTH 124, PHY 231. R: Not open to freshmen or sophomores.
Unit operations in food industry: fluid mechanics, heat transfer, rate processes, refrigeration, freezing, and dehydration. Thermal process calculations.
SA: FE 329

336. Machinery Systems for Food Production
Fall. 3(3-0) P: MTH 235.
Processes performed by agricultural production machines. Power systems, tillage mechanics, traction, metering, distribution, conveying, fluidization, mixing, separation, and atomization. Machinery management.
SA: AE 336

337. Machinery Systems for Food Processing
Spring. 3(3-0) P: MTH 235.
Principles of design, operation, and performance of equipment for processing raw materials into finished or intermediate products.
SA: AE 338, FE 338

350. Heat Transfer in Biosystems
Spring. 2(2-0) P: MTH 235; CSE 101 or CSE 131. Not open to students with credit in CHE 311 or ME 410.
Steady state and transient heat conduction. Radiation and convection heat transfer. Heat exchangers. Application problems in biosystems engineering.

351. Environmental Thermodynamics
Spring. 3(3-0) P: MTH 235. Not open to students with credit in CHE 321 or ME 201.
First and Second Laws of Thermodynamics with applications in food, biosystems, and environmental engineering. Refrigeration cycles. Entropy. Thermodynamic aspects of fluid flow. Psychrometrics.

402. Agricultural Climatology
Fall of even years. 3(3-0) Interdepartmental with Geography. Administered by Geography. P: MTH 116. R: Not open to freshmen and sophomores.
Relationships between climate and agriculture in resource assessment, water budget analysis, meteorological hazards, pests, crop-yield modeling, and impacts of global climate change.
SA: AE 402

403. Microclimate and Its Measurement
Fall of odd years. 4(3-3) Interdepartmental with Geography. P: MTH 116 R: Not open to freshmen or sophomores.
The climate near the Earth's surface. Energy balance, thermal radiation exchange, heat fluxes, temperature sensors, wind speed and direction, humidity and evapotranspiration and their measurement.

419. Applications of Geographic Information Systems to Natural Resources Management
Spring. 4(2-4) Interdepartmental with Fisheries and Wildlife; Forestry; Geography; Park, Recreation and Tourism Resources; and Resource Development. Administered by Fisheries and Wildlife. P: (GEO 221)
The application of geographic information systems, remote sensing, and global positioning systems to integrated planning and management for fish, wildlife, and related resources.

430. Power and Control Hydraulics
Spring. 3(2-2) P: CE 321 or CHE 311 or ME 332. R: Open only to majors in College of Engineering.
Hydraulic fluid properties. Pump and motor performance parameters. Control valves and hydraulic circuitry components. Analysis and design of hydraulic systems.
SA: AE 430

431. Resource Optimization
Spring. 3(2-2) P: BE 230, MTH 235 Not open to students with credit in BE 831.
Optimal solutions to problems with multiple and conflicting objectives and constraints. Applications to natural and manufactured biological systems.

438. Design of Machinery Structures
Fall. 3(3-0) P: MSM 211. R: Open only to majors in College of Engineering. Not open to students with credit in ME 471.
Design of structural components and systems in machines. Tension, compression, torsion, bending and combined loadings. Joint connections.
SA: AE 438

443. Restoration Ecology
Spring. 3(2-2) Interdepartmental with Fisheries and Wildlife; Zoology. Administered by Fisheries and Wildlife. P: (CSS 210 or BE 230) and (FOR 404 or FW 364 or ZOL 355)
Principles of ecological restoration of disturbed or damaged ecosystems. Design, implementation, and presentation of restoration plans. Field trips required.

453. Engineering Principles of the Plant Environment
Fall. 3(3-0) P: BOT 105 or BS 110 or BS 111; CEM 141, BE 350, BE 351. R: Open only to majors in College of Engineering.
Analysis of the soil-plant-atmosphere continuum. Thermodynamics effects on plant environment: water, soil heat flow, radiation, and soil water movement.
SA: AE 353

456. Electric Power and Control
Spring. 3(2-2) P: ECE 200 or ECE 345. R: Open only to majors in College of Engineering.
Alternating current circuits, power distribution, electrical machines, protection, and programmable motor controllers. Design project related to food and agricultural industries.
SA: AE 356

457. Postharvest Engineering
Fall. 3(3-0) P: BE 350 or CHE 311 or ME 410. R: Open only to majors in College of Agriculture and Natural Resources or College of Engineering.
Engineering principles involved with the storage and handling of grains and horticultural crops between harvest and processing.
SA: FE 460

460. Resource and Environmental Economics
Spring. 3(3-0) Interdepartmental with Resource Development; Public Resource Management; and Park, Recreation and Tourism Resources. Administered by Resource Development. P: RD 200; EC 201 or EC 202 or PRM 201 or RD 302.
Economics of land and related environmental resources. Production and consumption processes. Resource allocations and scarcity. Market failure and externalities. Market and institutional remedial approaches.

477. Food Engineering
Fall. 3(2-2) Interdepartmental with Food Science. P: (BE 350 and CE 321)
Unit operations, process engineering, equipment, and industrial practices of the food industry. Emphasis on manufactured dairy products: thermal processing, pipeline design, heat exchange, evaporation, dehydration, aseptic processing, membrane separation, cleaning, and sanitation.
SA: FE 465

481. Agricultural and Small Watershed Hydrology
Spring. 3(2-2) P: CSE 101 or CSE 131; CE 321 or CHE 311 or BE 350; BE 453 or CE 312. R: Open only to seniors in College of Engineering or graduate students.
Runoff, infiltration, surface and subsurface drainage and soil erosion.
SA: AE 481

486. Biosystems Design Fundamentals
Fall. 3(3-0) P: BE 350 or BE 336 or BE 453. R: Open only to seniors in College of Engineering or graduate students.
Concepts, methods, and procedures of the total design process from problem identification to final specifications.
SA: AE 486

487. Biosystems Design Project (W)
Spring. 3(0-6) P: BE 486. R: Open only to seniors in College of Engineering. Completion of Tier I writing requirement.
Individual or team design project selected in BE 486. Information expansion, development of alternatives, and evaluation, selection, and completion of a design project.
SA: AE 488

490. Independent Study
Fall, Spring, Summer. 1 to 5 credits. A student may earn a maximum of 5 credits in all enrollments for this course. P: BE 230 or BE 336 or BE 350 or BE 453. R: Open only to majors in College of Engineering. Approval of department; application required.
Supervised individual student research and study in biosystems engineering.
SA: AE 490

491. Special Topics in Biosystems Engineering
Fall, Spring, Summer. 1 to 4 credits. A student may earn a maximum of 12 credits in all enrollments for this course. P: BE 230, BE 336 or BE 350 or BE 453. R: Open only to majors in College of Engineering. Approval of department.
Special topics in biosystems engineering.
SA: AE 491

802. Computational Methods in Biosystems Engineering
Summer of odd years. 3(3-0) R: Open only to graduate students in the College of Agriculture and Natural Resources or College of Engineering.
Formulation and solution of mathematical equations in biosystems engineering. Constitutive equations. Linear and nonlinear problems. Steady state and transient problems. Computer solutions.
SA: AE 802

809. Finite Element Method
Fall, Spring. 3(3-0) Interdepartmental with Materials Science and Mechanics; and Civil Engineering; Mechanical Engineering. Administered by Materials Science and Mechanics.
Theory and application of the finite element method to the solution of continuum type problems in heat transfer, fluid mechanics, and stress analysis.

812. Bio-Process Engineering
Spring of odd years. 3(3-0) R: Open only to graduate students in the College of Engineering.
Thermodynamics, heat and mass transfer, fluid flow, dehydration. Handling and storage of biological products.
SA: AE 812

815. Instrumentation for Biosystems Engineering
Fall. 3(3-0) R: Open only to graduate students in the College of Engineering.
Theory and techniques of measuring temperature, pressure, flow, humidity, and moisture in biological materials.
SA: AE 815

820. Research Methods in Biosystems Engineering
Fall. 1(1-0) R: Open only to graduate students in the College of Agriculture and Natural Resources or College of Engineering.
Procedures and methods for designing and executing research projects.
SA: AE 820

831. Biosystems Analysis
Fall. 3(2-2) P: MTH 132. Not open to students with credit in BE 431.
Systems concepts. Properties of biological systems. Effect of environmental, technological, and economic factors on biological systems.

832. Network Design and Optimization of Biological Systems
Spring. 3(2-2) P: BE 431 or BE 831
Techniques of process network theory and multicriteria optimization for designing environmentally sound and economically beneficial biosystems.

833. Artificial Neural Network Applications in Biological Systems
Fall. 3(2-2) P: BE 431 or BE 831
Neural network algorithms and their application to biological systems.

837. Food Rheology
Fall. 3(3-0) Interdepartmental with Food Science.
Definition, analysis, and measurement of rheological properties to describe the steady shear, dynamic, viscoelastic, extensional, and solid behavior of biological materials. Industrial applications of rheological methods with emphasis on fluid and semi-solid foods.

850. Dimensional Analysis and Theory of Models
Fall of odd years. 3(2-2) R: Open only to graduate students in the College of Agriculture and Natural Resources or College of Engineering.
Dimensional concepts, systems of measurements and transformation of units, and formation of dimensionless groups. Development of prediction equations, concepts of similarity, and scaling laws. Distortion.
SA: AE 850

852. Systems Modeling and Simulation
Fall of even years. 3(3-0) Interdepartmental with Fisheries and Wildlife; Forestry; and Resource Development. Administered by Fisheries and Wildlife. P: STT 422 or STT 442 or STT 464 or GEO 463.
General systems theory and concepts. Modeling and simulation methods. Applications of systems approach and techniques to natural resource management, and to ecological and agricultural research.

853. Applied Systems Modeling and Simulation for Natural Resource Management
Spring of odd years. 3(2-2) Interdepartmental with Fisheries and Wildlife; Forestry; Resource Development; and Zoology. Administered by Fisheries and Wildlife. P: FW 820 or BE 486 or ZOL 851 or approval of department. R: Open only to seniors and graduate students
Mathematical models for evaluating resource management strategies. Stochastic and deterministic simulation for optimization. System control structures. Team modelling approach.

882. Irrigation and Water Management Engineering
Spring of even years. 3(3-0) P: BE 481, CE 321.
Design and management of systems for supplemental irrigation. Water supply and transport. Economic and engineering optimization of irrigation design.
SA: AE 882

890. Special Problems
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Approval of department; application required.
Individual study in biosystems engineering.
SA: AE 890

891. Advanced Topics in Biosystems Engineering
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Open only to graduate students in the College of Engineering. Approval of department.
Biosystems engineering topics not covered in regular courses.
SA: AE 891

892. Biosystems Engineering Seminar
Spring. 1(1-0) R: Open only to graduate students in the College of Agriculture and Natural Resources or College of Engineering.
Current topics in biosystems engineering.
SA: AE 892

899. Master's Thesis Research
Fall, Spring, Summer. 1 to 10 credits. A student may earn a maximum of 99 credits in all enrollments for this course. R: Open only to master's students in the Biosystems Engineering major.
SA: AE 899

999. Doctoral Dissertation Research
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 99 credits in all enrollments for this course. R: Open only to doctoral students in the Biosystems Engineering major.
SA: AE 999

BOTANY AND PLANT PATHOLOGY BOT

Department of Botany and Plant Pathology
College of Agriculture and Natural Resources
College of Natural Science

105. Plant Biology
Fall, Spring. 3(3-0)
Plant structure, function, development, genetics, diversity and ecology.

106. Plant Biology Laboratory
Fall, Spring. 1(0-3) P: BOT 105 or concurrently.
Cell structure, anatomy, physiology, growth and development, and diversity of plants.

111L. Cell and Molecular Biology Laboratory
Fall, Spring, Summer. 2(1-3) Interdepartmental with Biological Science; Microbiology; and Zoology. Administered by Biological Science. P: BS 111 or concurrently
Principles and applications of common techniques used in cell and molecular biology.

202. The Plant Kingdom
Spring. 3(2-3) P: BS 110 or BOT 105 or LBS 144.
Morphology of the major plant groups with an emphasis on structure, reproduction and evolution. Field trips required.

205. Pests, Society and Environment
Fall, Spring. 3(3-0) Interdepartmental with Entomology. Administered by Entomology.
Nature of pests and their impact on society. Principles of integrated pest management in relation to environmental quality and sustainable development.

218. Plants of Michigan
Fall. 3(2-3) P: BS 110 or BOT 105 or LBS 144.
Plant taxa of Michigan and the Great Lakes region and the major habitats in which they occur. Principles and rationale of classification. Relationships between life histories, morphology and environment. Field trips required.

301. Introductory Plant Physiology
Fall, Spring. 3(2-3) P: CEM 141 or CEM 151; CEM 161; BOT 105 or BS 111 or LBS 145. R: Completion of Tier I writing requirement.
General principles of plant physiology relating plant structure to function. Cell physiology, water relations, effects of light and temperature, respiration, photosynthesis, mineral nutrition, and hormone action.

319. Introduction to Earth System Science
Fall. 3(3-0) Interdepartmental with Entomology; Geological Sciences; Zoology; and Sociology. Administered by Entomology. P: Completion of one course in biological or physical science.
Systems approach to Earth as an integration of geochemical, geophysical, biological and social components. Global dynamics at a variety of spatio-temporal scales. Sustainability of the Earth system.

335. Plants Through Time
Spring of odd years. 3(3-0) Interdepartmental with Geological Sciences. P: BS 110 or BOT 105 or GLG 201 or LBS 144. R: Juniors and above.
Evolutionary history of plants, the development of ecosystems, and the use of plant fossils in the reconstruction of ancient environments and climate.

336. Useful Plants
Fall of odd years. 3(3-0) P: CEM 142 or CEM 143 or CEM 152; BOT 105 or BS 110, BS 111 or LBS 144, LBS 145.
Ways in which plants are used for myriad purposes from food and construction materials to medicines and perfumes. The potential for expanding the uses of plants through biotechnology will be explored.

341. Fundamental Genetics
Fall, Spring, Summer. 4(4-0) Interdepartmental with Zoology. Administered by Zoology. P: (BS 111 or LBS 145 or LBS 149H)
Principles of heredity in animals, plants and microorganisms. Classical and molecular methods in the study of gene structure, transmission, expression and evolution.

355. Ecology
Fall, Summer. 3(3-0) Interdepartmental with Zoology. Administered by Zoology. P: (BS 110 or LBS 144 or LBS 148H)
Plant and animal ecology. Interrelationships of plants and animals with the environment. Principles of population, community, and ecosystem ecology. Application of ecological principles to global sustainability.
SA: ZOL 250

355L. Ecology Laboratory
Fall, Summer. 1(0-3) Interdepartmental with Zoology. Administered by Zoology. P: (ZOL 355 or concurrently or BOT 355 or concurrently) and Completion of Tier I writing requirement.
Population, community and ecosystem ecology utilizing plant and animal examples to demonstrate general field principles.

362. Management of Turfgrass Pests
Fall. 4(3-2) Interdepartmental with Crop and Soil Sciences; and Entomology. Administered by Crop and Soil Sciences. P: (CSS 232)
Chemical, biological, and cultural methods of managing weeds, diseases, and insect pests of turfgrass. Environmental considerations in pest management.

402. Biology of Fungi
Fall. 3(2-3) P: BS 110, BS 111 or BOT 105 or LBS 140 or MIC 302.
Major groups of fungi: characteristics, habitats and diversity. Significance of fungi in nature and their economic importance.

405. Introductory Plant Pathology
Spring. 4(2-4) P: BS 110, BS 111 or BOT 105 or LBS 140. R: Completion of Tier I writing requirement. Not open to students with credit in BOT 407.
Important plant diseases and the organisms that cause them. Principles of disease management including application of chemicals, plant breeding, biological control, and genetic engineering.

407. Diseases and Insects of Forest and Shade Trees
Spring. 4(3-3) Interdepartmental with Entomology. P: BOT 105 or BS 110 or LBS 144; BOT 218 or FOR 204 or HRT 211. R: Completion of Tier I writing requirement. Not open to students with credit in BOT 405.
Diseases, insects, and environmental problems affecting trees in forests, parks, suburbs, and nurseries. Methods of control.

412. Environmental Plant Physiology
Fall. 3(3-0) P: BOT 105 or BS 111 or LBS 145; CEM 141 or 152; CEM 161.
General concepts underlying interactions between plants and the environment. Light sensing and utilization. Energy budgets. Water uptake and utilization. Mineral nutrition.