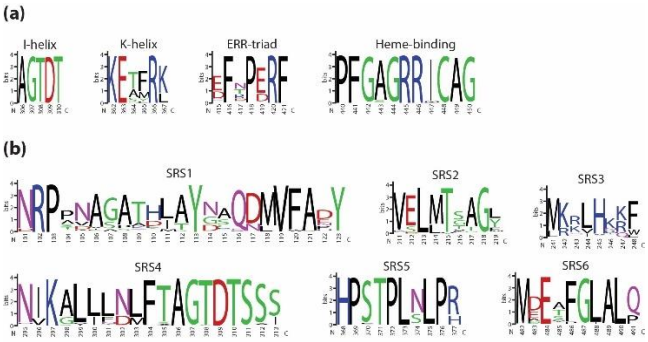
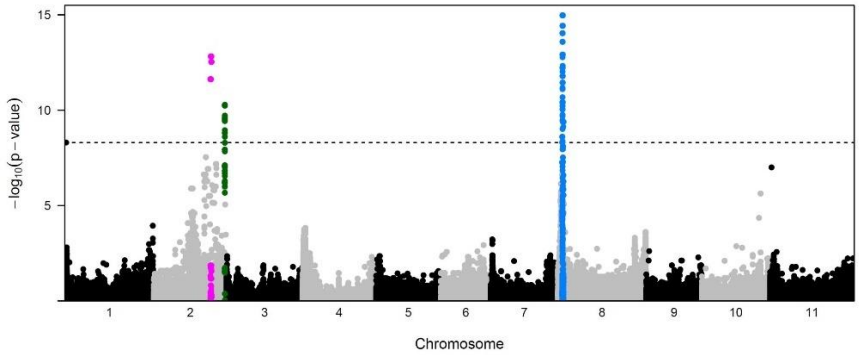
North Dakota State University

Genomics, Phenomics, and Bioinformatics Interdisciplinary Program

Graduate Student Handbook





This handbook was drafted to provide students in the program information regarding the policies and procedures followed by students and faculty in the program. Every effort was made to ensure its accuracy. Policies and procedures are subject to change. Drone photo: Creative Commons License; Credit: https://www.maxpixel.net/photo-5331566; February 14, 2022.

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VISION OF THE NDSU GENOMICS, PHENOMICS, AND BIOINFORMATICS INTERDISCIPLINARY PROGRAM

Genomics has radically altered problem solving in the biological, medical and agricultural sciences. Rather than studying a particular problem, one gene, one protein or one phenotype at a time, genomics takes a systems-wide approach in which many factors, genes, proteins, etc. are simultaneously studied. However, projects of this scale create unique problems because, rather than analyzing a few to several dozen data points, scientists are now confronted with a wealth of data that is quite daunting. To properly understand the results, insights are necessary from many fields including DNA sequencing, molecular biology, physiology, gene expression, structural biology, high-throughput phenotyping, big data, bioinformatics, computation, and statistics. The vision of the NDSU Genomics, Phenomics, and Bioinformatics interdisciplinary program is to provide a customized educational framework that enables students to use a broad array of knowledge and apply it to large data sets to address complex biological problems.

PROGRAM DEGREES

The program offers three degrees. Those degrees are:

Master's Degree, Plan A. This degree program requires a minimum of 16 didactic credits, a minimum of six research credits, a thesis accepted by the Graduate School, completion of other program course requirements (see below), and 30 credits overall.

Master's Degree, Plan C. This degree program requires a minimum of 16 didactic credits, an in-depth paper of a specific topic relevant to Genomics, Phenomics, or Bioinformatics, completion of other program course requirements (see below), and 30 credits overall.

Doctoral Degree. This degree program requires a minimum of 27 didactic credits (of which 15 must be at the 700 or 800 course level), a dissertation accepted by the Graduate School, completion of other program course requirements (see below), and 90 credits overall.

PROGRAM OPTIONS

The program has three study options. Those options are:

Functional Genomics. This option trains the student in how to use nucleic acid sequence data to discover factors associated with the expression of a particular trait of interest.

Phenomics. This option trains the student in how to use sensing technologies to collect high-throughput data sets that can be coupled with genomic and other omics data to uncover factors that control a particular trait of interest.

Bioinformatics. This option trains the student in how to apply computation tools and analyze large data sets to describe potential causative factors associated with a particular trait of interest.

ADMISSION TO THE PROGRAM

The Genomics, Phenomics, and Bioinformatics program accepts application throughout the year. Most students apply for fall semester admission, while other students look to begin in the spring or summer semester. Because of this policy, the program does not have set acceptance dates.

Genomics, phenomics, and bioinformatics each have different educational background needs for a student to be successful in a graduate program. Therefore, each program has different course backgrounds for admission into the program.

	Option		
Entrance Requirements	**Functional Genomics**	**Bioinformatics**	**Phenomics**
B. S. Degree	X	X	X
GPA (for MS or PhD)	3.0	3.0	3.0
Courses/Experience			
Introductory Biology	X	X	X
Genetics	X		
Physiology	X		
Biochemistry	X		
Upper division statistics	X	X	X
Calculus or Matrix Algebra		X	X
Programming Language Experience		X	X

FINANCIAL SUPPORT, TUTION WAIVER, STUDENT FEES, AND STUDENT CONTRACTS

All students in the program (except for rare exceptions) will be supported by a Research Assistantship. The funds for the assistantship will be provided by the student's major advisor. The amount of the assistantship will be determined by the major advisor. Your tuition will be waived while you are receiving an assistantship salary. You will still need to pay the NDSU student fees from your own funds. All students who receive an assistantship must sign a contract with the provider of your salary. The contract will typically state that you need to provide 20 hours per week to support the project from which your assistantship salary is provided. It is important to note that it is rare that you will be able to complete a degree by only provided 20 hours per week to a research endeavor. Therefore, it will be necessary to provide additional hours, beyond those 20 research hours for which you are receiving a salary, to complete your degree. The NDSU "Graduate Assistant Policy" can be found at the following WWW site: https://bulletin.ndsu.edu/graduate/graduate-school-policies/graduate-assistantship-policy/.

YOUR ADVISOR

The role of your advisor is to provide guidance so that you can succeed in the graduate program. Experience shows that each advisor has a unique perspective on how they should help you succeed. You need to communicate with your advisor regarding what they believe your role is in succeeding and

what they believe their role is in helping you completing your degree. For example, some advisors will expect you to be proactive in all areas of your program, whereas other advisors will guide you through each step of the program. Most advisors fall somewhere in between these two extremes. You need to develop a professional relationship based on open communication to ensure you understand each of your roles in your graduate program.

PLAN OF STUDY

The student and their advisor will work together to develop a program of study. The Plan of Study must comply with the Genomics, Phenomics and Bioinformatics program requirements. (See Program Requirements section for details.) The plan for the Thesis Option (Plan A) will include both classroom courses and thesis credits. (For the Master's Comprehensive (Plan C) Option, this will just include classroom courses.) The plan should include courses that support the student's learning of general knowledge of Genomics, Phenomics or Bioinformatics focus area, and in addition, it should provide intellectual support for the student's thesis. ***The Plan of Study must be completed by the end of the student's second semester in the program.*** The Plan of Study Form can be downloaded from the following URL:

https://www.ndsu.edu/gradschool/current_students/forms/#c225106

It is recommended that Plan of Study be reviewed by the Program Director for compliance with the program requirements before it is circulated to committee members.

At times it may be necessary to change the Plan of Study. This should be done in consultation with the student's major advisor. The form to make the change is also available from the above URL.

GRADUATE COMMITTEE MEMBERS

Each student will be supported by a graduate committee that will provide advice on course and research direction. ***The student, in consultation with their advisor must develop a Graduate Committee by the end of the second semester in the program.*** The requirements for Master's and Ph.D. degrees follow.

Master's (Plan A or C) Students: The Graduate Committee must include a minimum of three members. The committee must include the student's advisor. The second member must be a full or affiliate member of the NDSU graduate faculty. The third member must be from outside the home department of the student's advisor.

Doctoral Students: The Graduate Committee must include a minimum of four members. The committee must include the student's advisor. The second member must be a full or affiliate member of the NDSU graduate faculty. The third member must be from outside the home department of the student's advisor. The fourth member will be the Graduate School Representative (GSR). The GSR will be appointed by the Graduate School. (See the NDSU Graduate School Graduate Student Handbook, page 10, for the GSR requirements.) Quoting the NDSU Graduate School Graduate Student Handbook, "The role of the GSR is to ensure policies are followed, expectations for the student's performance are reasonable and interactions with the supervisory committee are conducted in a professional manner."

Additional Committee Members: Other committee members may be added to provide additional expertise with regards to the student's research. These additional members must be a full or affiliate member of the NDSU graduate faculty.

YOUR RESEARCH PROPOSAL MEETING

Early in your graduate program, you should engage in conversations with your major advisor regarding the research that will be the major topic for your thesis. Often, your major advisor will have received funding from a granting funding agency, and your research will be based on some aspect of the funded proposal. Alternatively, your major advisor may be working on an exploratory research topic. It is possible this might also be a research topic for your thesis. Once you settle on the topic, you should develop a general outline of the research activities that will be necessary to complete the research.

Within the first two semester of your graduate program, you should schedule a meeting with your graduate committee to present your thesis proposal. There is not a fixed agenda for this meeting. In general, you should present a MS Powerpoint presentation that provides a general introduction to the topic, the research materials you will use in your research, how those materials will be treated, what data you will collect, what statistical analyses you will perform, and how the results of those analyses will be used to draw conclusions regarding your research. Your committee will then provide comments regarding your proposal. You and your major advisor should consider those comments and adjust the research plan if you believe the comments are helpful.

Remember, your committee are experts that are willing to help you in whatever manner. You should personally engage with them when you believe their advice will be helpful. If you would like to again engage the committee as a whole, you can call subsequent meetings while you are completing your research.

DOCTORAL COMPREHENSIVE/PRELIMINARY EXAMINATIONS

This Ph.D. comprehensive/preliminary exam consists of a **written** and an **oral** portion. The **written exam** emphasizes the application of knowledge presented in the core and elective courses. Questions will be requested from members of the Genomics, Phenomics, and Bioinformatics graduate programs and the students Graduate Committee members. The committee and the program director will select questions for the exam.

The **written exam** will span two days with a maximum of eight hours on each day. On each day, the student will be given six questions. The student must answer four of the six questions on each. Each answer will be graded by two individuals on a 0-100 scale, and the two scores averaged. To pass the written portion of the qualifying exam, the student must score 70% or greater on six of the eight questions. If the student does not pass this written portion of the qualifying exam, they will be offered a second opportunity. If the student does not pass the second opportunity, the student will be dismissed from the program.

Once the student successfully completes the written exam, they must schedule the **oral exam**. The student must submit the "Notification of Scheduled Exam" form to the Graduate School two weeks prior to the exam (https://www.ndsu.edu/gradschool/current_students/forms#c225106). The oral exam will

be administered by the student's graduate committee and will focus on higher-order concepts that integrate content in the core courses and topics more specific to the thesis research of the student.

If more than one committee members votes failure, the student will be offered a second chance to pass the oral exam. This exam cannot proceed until one month past the first exam. If the student's again receives more than one negative vote, the student can request support of their graduate committee and the Genomics, Phenomics, and Bioinformatics program director, and approval of the Graduate Dean for a third attempt. If the student does not pass the third opportunity, the student will be dismissed from the program.

Upon successful completion of the oral exam, the student will be accepted as a NDSU Doctoral candidate.

This is the link to the "Report of Preliminary Examination"

https://www.ndsu.edu/gradschool/current_students/forms#c225106

The form must be submitted to the Graduate School within 14 days of any exam.

YOUR THESIS (M.S.) OR DISSERTATION (Ph.D.)

As a rule, you and your major advisor will jointly decide the format of your thesis or dissertation. Here is the link to North Dakota State University Graduate School Format Guidelines for Papers, Theses, and Dissertations:
https://www.ndsu.edu/fileadmin/gradschool.ndsu.edu/Disquisitions/Format_Guidelines.pdf.

In general, the thesis or dissertation should consist of the following sections:

- Overall Abstract
- Acknowledgements
- Table of Contents
- List of Tables
- List of Figures
- Literature Review
- Materials and Methods
- Results
- Discussion
- References

You and your major advisor should decide if you want separate chapters for different aspects of your research, or if you would like a single integrated presentation of all of your research. If you choose separate chapters, these have the potential of developing into individual manuscripts. Because of this view, separate chapters seem to be the preferred approach today. If you choose individual chapters, each chapter should include a chapter-specific Abstract and shorter versions of the Literature Review (called the Introduction), Materials and Methods, Results, Discussion, and References relevant to the research that is being featured in that chapter.

The following are general suggestions to help you draft your thesis in a timely manner.

- Write the majority of your Literature Review in the first year of your program
- Draft your Materials and Methods as you are performing your research
- Develop your Figures and Tables once results are complete and you and your major advisor determine they are accurate

You and your major advisor should also discuss when you should submit different sections of the thesis for review. It is best to have your advisor review sections as each section is complete. The larger the document your present to your major advisor, the longer it will take to receive the edits.

You will defend your thesis or dissertation during final examination. During the exam, take careful notes regarding the suggestions of your committee members. One the examination is complete, you will need to make your final revisions to you thesis. Once you and your major advisor are satisfied with the final version, you must submit it to the Graduate School for final review.

FINAL EXAMINATION: M.S. AND Ph.D. THESIS OPTIONS

The student must submit the "Notification of Scheduled Exam" form two weeks prior to the M.S. or Ph.D. final examination. The form can be found at the following link:

https://www.ndsu.edu/gradschool/current_students/forms#c225106

Plan A M.S. and Ph.D. students. The final exam will consist of a public seminar followed immediately by an oral exam. The student's advisor should work with the student to find a location for the public seminar. The seminar typically is 30-40 minutes in length followed by questions from the audience who are not members of the graduate committee. Once the seminar is complete, the student and the graduate committee will convene privately for the final oral examination. The primary focus of the oral exam will be the student's research. The final thesis document, that summarizes in detail the student's research, must be delivered to the graduate committee one week prior to the exam. Other topics related to the thesis can also be a discussion topic during the defense.

The final exam cannot be completed in the same semester as the Doctoral Comprehensive/Preliminary Examination.

Plan C M. S. Students. Plan C M.S. students pursuing the Comprehensive Study Option will be required to complete an in-depth paper of a specific topic relevant to Genomics, Phenomics, or Bioinformatics. The paper will be reviewed by the student's graduate committee and will form the basis of the student's oral exam.

NDSU STUDENT CODE OF CONDUCT

The NDSU academic community is operated on the basis of honesty, integrity, and fair play. NDSU Policy 335: Code of Academic Responsibility and Conduct applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context. Students found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Student academic misconduct records are maintained by the Office of Registration and Records. Informational resources about academic honesty for students and instructional staff members can be found at www.ndsu.edu/academichonesty.

STUDENTS WITH SPECIAL NEEDS

Any students with disabilities or other special needs, who need special accommodations in this course are invited to share these concerns or requests with the instructor as soon as possible. The instructor may ask for verification and that, plus other assistance, can be requested from Disability Services in the Lower Level of the NDSU Library (231-8463). http://www.ndsu.edu/disabilityservices/.

INTELLECTUAL PROPERTY POLICY

As a graduate student in the Genomics and Bioinformatics program, you will be performing research. In some cases, your research may generate products that have a financial value to you, your research advisor, and NDSU. The ownership of this intellectual and management of this intellectual property is governed by NDSU policy 190. This policy outlines general principle, provides definitions related the intellectual property, describes general patent policy, discusses the patent review procedures, and provides guidance relative to software and course related materials. This policy applies to all faculty, staff, and students. The following link leads you to the policy:

https://www.ndsu.edu/fileadmin/policy/190.pdf

The policy is intermittently updated, so the student should review it on an annual basis.

WHO TO CONTACT

If you have policy and procedures question, please contact the Genomics, Phenomics, and Bioinformatics program director. The current director and contact information follows:

Dr. Phil McClean
E-mail: phillip.mcclean@ndsu.edu (preferred)
Phone: 701-231-8443

M.S. AND Ph.D REQUIRED CORE COURSES

		OPTION					
	Credits	**M.S Functional**	**Ph.D. Functional**	**M.S. Bioinformatics**	**Ph.D. Bioinformatics**	**M.S. Phenomics**	**Ph.D. Phenomics**
PLSC 611. Genomics. 3 Credits. An integrated presentation of genome organization, genome sequencing and characterization, comparative genomics, transcriptomics, proteomics, and metabolomics. F {Also offered for undergraduate credit - see PLSC 411.}.	3	X	X	X	X		
CSCI, MATH, STAT 732. Introduction To Bioinformatics. 3 Credits. An introduction to the principles of bioinformatics including information relating to the determination of DNA sequencing. Prereq: **STAT 661**. Cross-listed with **MATH 732** and **STAT 732**.	3	X	X	X	X		
PLSC 721. Genomics Techniques. 2 Credits. Principles, techniques, and applications of the large-scale analysis of DNA organization and sequence, RNA expression, protein sequence, and structure. **OR** **BIOC 674. Methods of Recombinant DNA Technology. 3 Credits.** Principles and techniques of recombinant DNA construction, gene cloning, and analysis of gene structure. 1 lecture, 2 three-hour laboratories. Recommended co-req: BIOC 702. {Also offered for undergraduate credit - see BIOC 474.}.	2 or 3	X	X				
CSCI 859. Computational Methods in Bioinformatics. 3 Credits. An introduction to computer science and operations research methods and algorithms that are used for analysis and solution of optimization and other models in bioinformatics.	3			X	X		
CSCI 679. Introduction to Data Mining. 3 Credits. Introduction to data mining includes basic data mining techniques, querying, spreadsheet data mining, data warehouses, evaluation techniques, knowledge discovery in databases, examples and a survey of advanced techniques. Prereq: Basic database course (e.g. CSCI 668 or CSCI 765). {Also offered for undergraduate credit - see CSCI 479.}	3					X	X
ABEN 747. Numerical Modeling of Environmental and Biological Systems. 3 Credits. Numerical methods of systems analysis will be taught through real-world case studies. Topics covered include simplification and mathematical description of real systems; the finite-difference methods for solving differential equations; and parameter estimation sensitivity analysis, and uncertainty analysis methods. S (even years).	**3**					X	X
Physiology Course (Select from Physiology Elective list)	**3**					X	X
Current Topics in Genomics, Phenomics, and Bioinformatics	1	1x2	1x3	1x2	1x3	1x2	1x3
Seminar	1	1	1x2	1	1x2	1	1x2

ADDITIONAL Ph.D REQUIRED CORE COURSES

		Option					
	Credits	**M.S Functional**	**Ph.D. Functional**	**M.S. Bioinformatics**	**Ph.D. Bioinformatics**	**M.S. Phenomics**	**Ph.D. Phenomics**
PLSC 631. Intermediate Genetics. 3 Credits. Expansion of classical and molecular concepts of genetics; basic concepts of Mendelian, quantitative, population, molecular, and evolutionary genetics. 2 lectures. F {Also offered for undergraduate credit - see PLSC 431.}.	3		X				
STAT 726. Applied Regression and Analysis of Variance. 3 Credits. Simple and multiple regression, ANOVA tables, correlation, regression diagnostics, selection procedures, analysis of covariance, one-way ANOVA, two-way ANOVA. Prereq: STAT 725.	3		X				X
Graduate Evolution Class	3		X				
CSCI 765. Introduction To Database Systems. 3 Credits. Basic database concepts, models, management facilities, data structures, storage structures, data definition languages, data manipulation languages, normalization, operator implementation algorithms, transactions, correctness, reliability, distribution, performance analysis.	3				X		
CSCI 679. Introduction to Data Mining. 3 Credits. Introduction to data mining includes basic data mining techniques, querying, spreadsheet data mining, data warehouses, evaluation techniques, knowledge discovery in databases, examples and a survey of advanced techniques. Prereq: Basic database course (e.g. CSCI 668 or CSCI 765). {Also offered for undergraduate credit - see CSCI 479.}.					X		
STAT 661. Applied Regression Models. 3 Credits. Simple linear regression, matrix approach to multiple regression, and introduction to various tests and confidence intervals. Includes discussion of multicollinearity and transformations. Knowledge of matrix algebra and knowledge of differential calculus is expected. {Also offered for undergraduate credit - see STAT 461.}.	3				X		
CSCI 765. Introduction To Database Systems. 3 Credits. Basic database concepts, models, management facilities, data structures, storage structures, data definition languages, data manipulation languages, normalization, operator implementation algorithms, transactions, correctness, reliability, distribution, performance analysis.	3						X
M.S. ELECTIVE COURSES (AT LEAST ONE COURSE FROM TWO ELECTIVE AREAS)		**MINIMUM 9 CREDITS**		**MINIMUM 9 CREDITS**		**MINIMUM 9 CREDITS**	
Ph.D. ELECTIVE COURSES (AT LEAST ONE COURSE FROM THREE ELECTIVE AREAS)			**MINIMUM 15 CREDITS**		**MINIMUM 15 CREDITS**		**MINIMUM 15 CREDITS**
RESEARCH		**to 30 CREDITS (Minimum 6 credits)**	**to 90 CREDITS**	**to 30 CREDITS (Minimum 6 credits)**	**to 90 CREDITS**	**to 30 CREDITS (Minimum 6 credits)**	**to 90 CREDITS**
PROGRAM TOTAL		**Minimum 30 CREDITS**	**Minimum 90 CREDITS**	**Minimum 30 CREDITS**	**Minimum 90 CREDITS**	**Minimum 30 CREDITS**	**Minimum 90 CREDITS**

PHYSIOLOGY ELECTIVES

	Credits
ANSC 663. Physiology of Reproduction. 3 Credits. Comparative anatomy, physiology, and endocrinology of reproduction in mammals. {Also offered for undergraduate credit - see ANSC 463.}.	3
BIOL 662. Physiological Ecology. 3 Credits. Study of the physiological mechanisms underlying life-history trade-offs and constraints in an ecological and evolutionary context. S {Also offered for undergraduate credit - see BIOL 462.}.	3
BIOL 664. Endocrinology. 3 Credits. Physiology and anatomy of endocrine glands; chemistry and interrelations of their secretions. {Also offered for undergraduate credit - see BIOL 464.}.	3
BIOL 660. Animal Physiology. 3 Credits. Study of the physical and chemical principles that govern cell, tissue, organ, organ system, and organismal function. {Also offered for undergraduate credit - see BIOL 460.}.	3
BIOL 683. Cellular Mechanisms of Disease. 3 Credits. This course will be focused on the cellular and molecular bases of selected diseases and some non-human animal diseases. Key cellular pathways/processes and molecular mechanisms that, when altered/disrupted, result in pathological changes/conditions will be discussed from scientific (e.g., functions, regulation and structures of cells, proteins and organs) and medical (e.g., clinical presentation, diagnostic and treatment) perspectives. {Also offered for undergraduate credit. See BIOL 483.}.	3
BIOL 825. Biology of Aging. 3 Credits. This course will take an integrative approach to understanding the biology of aging. We will examine both the evolutionary causes and underlying mechanisms of aging in diverse organisms including humans.	3
BIOL 861. Advanced Physiology.	3
MICR 650. Infectious Disease Pathogenesis. 3 Credits. Students will study mechanisms of bacterial, viral, fungal, and parasitic pathogenesis and the immune response to pathogens. Prereq: **MICR 660** or **MICR 670**. {Also offered for undergraduate credit - see **MICR 450**.}.	3
MICR 680. Microbial Physiology. 3 Credits. This class will explore the composition and function of eubacterial and archaeobacterial cell structure. Further functional exploration will go into nutrient transport in bacteria, principles of energy-yielding carbohydrate metabolism, bacterial fermentation, respiration, and gene regulations of metabolic pathways. Topics such as biofilms, quorum sensing, and the microbiome will be used to apply physiological concepts. {Also offered for undergraduate credit - see MICR 480.}.	3
MICR 781. Advanced Bacterial Physiology. 3 Credits. In-depth consideration of various topics in bacterial physiology such as autotrophy, bacterial growth and growth yields, energy-yielding metabolism, and regulation of catabolic pathways. Prereq: MICR 680.	3
MICR 785. Pathobiology. 3 Credits. A comprehensive understanding of the molecular mechanisms that underlie disease pathogenesis and lesion development. Investigation and presentation on mechanisms underlying a specific disease entity of either human or animal origin. Prereq: MICR 660.	3
PPTH 751. Physiology Of Plant Disease. 3 Credits. Infection, penetration, recognition, nutrient transfer, toxins, photosynthesis, and physiological materials. Use of tools, equipment, and supplies used in the industry and application of basic design styles, holiday designs, and displays. 1 lecture, 1 two-hour laboratory. S (odd years).	3
PLSC 686. Applied Crop Physiology. 3 Credits. Application of physiological principles on plant growth and development and crop production. 3 lectures. S {Also offered for undergraduate credit - see PLSC 486.}.	3
PLSC 750. Crop Stress Physiology. 3 Credits. Application of physiological principles to enhancement of stress tolerance in crops. S (odd years) Prereq: PLSC 686.	3
PSCI 747. Cardiovascular Pharmacology. 3 Credits. Study of action mechanisms of drugs affecting the circulatory systems, including their pathology.	3
PSCI 762. Advanced Biopharmaceutics. 2 Credits. Stability and kinetic factors involved in absorption, distribution, metabolism, and excretion of drug products.	2
PSCI 765. Cancer Cell Biology. 2 Credits. This course covers the principles of modern cancer cell biology, including topics on oncogenes, tumor suppressor genes, growth factors, signal transduction, cell cycle, apoptosis, angiogenesis, and mechanism of tumor metastasis.	2

GENE EXPRESSION ELECTIVES

	Credits
BIOC 660. Foundations of Biochemistry and Molecular Biology I. **3 Credits.** Rigorous treatment of biomolecules, generation and use of metabolic energy, biosynthesis, metabolic regulation; storage, transmission, and expression of genetic information. 3 lectures. {Also offered for undergraduate credit - see BIOC 460.}.	3
BIOC 683. Cellular Signal Transduction Processes and Metabolic Regulation. 3 Credits. Advanced topics in regulation of metabolic processes including signal transduction, reversible and irreversible covalent modification, hormonal effects, protein turnover, and related phenomena. 2 lectures. Prereq: **BIOC 702**. F (alernate years) {Also offered for undergraduate credit - see **BIOC 483**.}.	3
BIOC 719. Molecular Biology of Gene Expression and Regulation. 3 Credits. Advanced topics in molecular biology and regulation in prokaryotes, eukaryotes, and archaea; early events in developmental gene expression. 3 lectures. Prereq: BIOC 702. F (alternate years).	3
BIOC 723. Structural Basis of Membrane Transport and Signaling. 3 Credits. Advanced topics discussing how three-dimensional structures of membrane proteins dictate their function in coordinating the extracellular environment with intracellular processes. Prereq: **BIOC 660** or **BIOC 701**.	3
BIOL 682. Developmental Biology. 3 Credits. Analysis of the processes of development, with an emphasis on animal development. Topics range from classical embryology to the cellular and molecular basis of development. {Also offered for undergraduate credit - see BIOL 482.}.	3
BIOL 820. Advanced Cell Biology. 3 Credits. In-depth survey of cell biology, including studies of membranes, secretion cytoskeleton, cellular movement organelles, and gene regulation.	3
MICR 775. Molecular Virology. 3 Credits. An in-depth study of current areas of research on human and animal viruses. The replication, pathogenesis, diagnosis, prevention, and control of viruses using contemporary molecular and cellular biology approaches will be examined.	3
PLSC 731. Plant Molecular Genetics. 3 Credits. Molecular aspects of plant genome organization and expression; basic and applied usages of molecular markers and gene transfer techniques. 3 lectures. Prereq: PLSC 631. S (even years).	3

GENETICS AND GENOMICS ELECTIVES

	Credits
ANSC 657. Genetic Improvement of Livestock. 3 Credits. Principles and applications of technologies for the genetic improvement of livestock including both quantitative and molecular techniques. {Also offered for undergraduate credit - see ANSC 457.}.	3
ANSC 751. A Primer to Quantitative Genetics. **1 Credit.** Language and foundational principles of quantitative genetics. Material includes basic model for quantitative genetics (additive and non-additive genetic effects, including Mendelian sampling, and environmental effects), sources of variation, heritability, family resemblance and repeatability, selection response, and family selection. Define expected values and concepts in applied statistics. Prereq: ANSC 750.	1
ANSC 752. Selection Index Theory and Application. 1 Credit. Theory and application of selection indices. Material includes design of animal breeding programs, estimating selection response, constructing economic selection indices, and developing multiple-stage selection strategies. Introduces approaches for deriving economic weights, and predicting economic response to selection. Prereq or Co-req: ANSC 751	1
ANSC 750. Quantitative Genetics Applications of Matrix Algebra. 1 Credit. Principles in matrix algebra to describe and solve problems in the agricultural and life sciences, and particularly quantitative genetics. Material includes vocabulary, concepts, and, to a lesser extent, theory of matrix algebra, with application to ecological systems, genotypic transition matrices, selection indices, and the numerator relationship matrix. With matrix algebra, use least squares procedures and canonical transformation to solve problems in biological sciences.	1
ANSC 751. A Primer to Quantitative Genetics. 1 Credit. Language and foundational principles of quantitative genetics. Material includes basic model for quantitative genetics (additive and non-additive genetic effects, including Mendelian sampling, and environmental effects), sources of variation, heritability, family resemblance and repeatability, selection response, and family selection. Define expected values and concepts in applied statistics. Prereq: ANSC 750.	1
ANSC 752. Selection Index Theory and Application. 1 Credit. Theory and application of selection indices. Material includes design of animal breeding programs, estimating selection response, constructing economic selection indices, and developing multiple-stage selection strategies. Introduces approaches for deriving economic weights, and predicting economic response to selection. Prereq or Co-req: ANSC 751	1
BIOL 679. Biomedical Genetics and Genomics. 3 Credits. This course will cover the diagnoses, clinical presentations, prevention and treatments of hereditary diseases (Mendelian and complex); the ever-increasing roles that genetics and genomics have in advancing medicine (including personalized medicine). {Also available for undergraduate credit - see BIOL 479.}.	3
BIOL 859. Evolution. 3 Credits. Evolution is the process by which species change over time through descent with modification. This course will focus on understanding the different applications of evolutionary theory to current issues in the biological sciences.	3
BIOL 860. Evolutionary Ecology. 3 Credits. Lecture-discussion course on recent developments in evolutionary theory and their implications in the study of animal adaptation, ecology, and behavior.	3
BIOL 862. Environment and Adaptation. 3 Credits. Environmental factors and responses evidenced with life-history patterns, genetic variation, population dynamics, species-interactions, and physiological processes.	3
MICR 681. Microbial Genomics with Computational Laboratory. 3 Credits. Microbial genome science with additional emphasis on microbial evolution and environmental science. Topics include: i) genomic diversity, ii) the consequences of horizontal gene transfer, iii) single cell and population genomics, and iv) environmental metagenomics. {Also offered for undergraduate credit - see MICR 481.}.	3
MICR 682. Microbial Genetics. 3 Credits. Microbial genetics will explore gene identification, mutation, DNA repair, gene transfer, recombination, bacteriophage genetics, and gene regulation. Topics such as bacterial antibiotic resistance, genetic testing and manipulation for biotechnological applications will be used to apply genetic concepts. {Also offered for undergraduate credit - see MICR 482.}.	3
PPTH 755. Population Biology of Plant Pathogens. 3 Credits. Discussion of the biological processes that affect plant pathogens populations and communities in natural and agricultural settings and how these processes affect disease development and their control.	3
PPTH 757. Advanced Techniques in Plant Pathology. A review of traditional and latest tools and techniques available to conduct research in plant pathology. Topics covered include pathogen detection, quantification of pathogen/disease, microscopy, pathogen and host genomics, phenomics, molecular host-microbe interactions, molecular disease control, and grant proposal development. This course involves classroom teaching including critical discussion of relevant literature on the application of techniques, methodology, data collection, and analysis.	3

PPTH 759. Host-Parasite Genetics. 3 Credits. Host-parasite genetics including genetics of plant and pathogens and gene-for-gene relationships. 3 lectures. S (even years).	3
PLSC 631. Intermediate Genetics. 3 Credits. Expansion of classical and molecular concepts of genetics; basic concepts of Mendelian, quantitative, population, molecular, and evolutionary genetics. 2 lectures. F {Also offered for undergraduate credit - see PLSC 431.}.	3
PLSC 741. Cytogenetics. 3 Credits. This course covers the fundamentals of cytogenetics with an emphasis on molecular aspects of chromosome biology including chromosome structure, organization, behavior/transmission, variation, mapping, engineering, and their relationships with gene expression/regulation, inheritance, and breeding. The genetic network and subcellular processes of cell divisions (mitosis and meiosis) are also covered. In addition, both conventional and modern chromosome technologies and their applications in genome studies will be discussed in this course. 3 lectures. F (even years).	3
PLSC 751. Advanced Plant Genetics. 3 Credits. Advanced topics in plant genetics regarding the study of genetic linkage, marker-assisted selection, statistical analysis and interpretation of genetic data, and the study of the inheritance in autotetraploid species. 3 lectures. Prereq: PLSC 631. S (odd years).	3
PLSC 782. Population and Quantitative Genetics. 4 Credits. Population and quantitative genetics theories and application to applied plant breeding. Prereq: **PLSC 718** and **PLSC 724**.	4
PSCI 617. Pharmacogenomics. 2 Credits. This course provides students with a broad perspective on the emergence of pharmacogenomics as a new field and the potential role of pharmacogenomics in future clinical therapeutics and drug design. Prereq: Admission to PharmD/graduate PSCI program. {Also offered for undergraduate credit - see PSCI 417.}.	2

COMPUTER SCIENCE, STATISTICS, AND COMPUTATION BIOLOGY ELECTIVES

	Credits
ANSC 850. Linear Models in Animal Breeding. 1 Credit. Principles of linear models used in animal breeding. Models discussed in the context of the random variable that is to be predicted. Material includes animal models, sire/maternal grandsire models, and sire models, models with a single and repeated records, and models with both direct and maternal effects. Prereq: **ANSC 751**, **ANSC 752**.	1
ANSC 851. Genetic Prediction. 1 Credit. Principles for using best linear unbiased prediction (BLUP) in genetic prediction. Material includes data integrity diagnosis, contemporary grouping strategies, adjusting for known non-genetic effects, the AWK Programming Language, UNIX/Linux scripting, and use of modern computational tools to perform genetic evaluations. Emphasis on real-world datasets designed to develop applied analytical skills in animal breeding. Prereq: **ANSC 752**, **ANSC 850**.	1
ANSC 852. Applied Variance Component Estimation. 1 Credit. Principles in the estimation of (co)variance components and genetic parameters required to solve mixed models typical in livestock genetics. Focus on applied knowledge of approaches used to estimate the G and R sub-matrices of the mixed model equations. Demonstrate models commonly used in parameter estimation. Introduce scientific literature concerning implementation, and attributes of the solutions, of variance component estimation strategies. Prereq; **ANSC 850**, **ANSC 851**.	1
ANSC 856. Prediction and Control of Inbreeding in Breeding Programs. 1 Credit. Principles in the prediction and control of inbreeding in livestock breeding program. Material includes definition of inbreeding and identity by descent, impacts of inbreeding on genotype frequencies, trait means and variances, random drift, computation of inbreeding coefficients in pedigreed populations, prediction of rates of inbreeding in closed populations, and control and management of inbreeding in breeding populations. Prereq: ANSC 751.	1
BIOL 842. Quantitative Biology. 3 Credits. Philosophy and techniques for collecting, handling, and interpreting research data in the biological sciences. S.	3
BIOL 877. Analysis of Population and Demographic Data. 3 Credits. Contemporary maximum likelihood approaches to estimating abundance, survival, reproduction, and dispersal in free-living populations. Goodness-of-fit and information theory applied to population model selection. Examples from a variety of real populations. Prereq: **BIOL 876**, **STAT 660** or **STAT 661**, ENT 842.	3
CSCI 679. Introduction to Data Mining. 3 Credits. Introduction to data mining includes basic data mining techniques, querying, spreadsheet data mining, data warehouses, evaluation techniques, knowledge discovery in databases, examples and a survey of advanced techniques. Prereq: Basic database course (e.g. CSCI 668 or CSCI 765). {Also offered for undergraduate credit - see CSCI 479.}	3
CSCI 724. Survey of Artificial Intelligence. 3 Credits. Survey of major areas of AI including theorem proving, heuristic search, problem solving, computer analysis of scenes, robotics, natural language understanding, and knowledge-based systems.	3
CSCI 736. Advanced Intelligent Systems. 3 Credits. This course acquaints students with intelligent systems to provide them with working knowledge for building these systems. The course describes expert systems, fuzzy logic, neural networks, evolutionary computation, swarm intelligence, and multi-agent systems.	3
CSCI 765. Introduction To Database Systems. 3 Credits. Basic database concepts, models, management facilities, data structures, storage structures, data definition languages, data manipulation languages, normalization, operator implementation algorithms, transactions, correctness, reliability, distribution, performance analysis.	3
CSCI 879. Advanced Data Mining. 3 Credits. Advanced data mining includes in-depth coverage of Association Rule Mining (ARM), Classification and Clustering. The course is designed for those interested in doing research in data mining. Prereq: CSCI 679.	3
MATH 630. Graph Theory. 3 Credits. Graphs and directed graphs, graph models, subgraphs, isomorphisms, paths, connectivity, trees, networks, cycles, circuits, planarity, Euler's formula, matchings, bipartite graphs, colorings, and selected advanced topics. {Also offered for undergraduate credit - see MATH 430.}.	3
MATH 636. Combinatorics. 3 Credits. Recurrence relations, formal power series, generating functions, exponential generating functions, enumeration, binomial coefficients and identities, hypergeometric functions, Ramsey theory, Sterling and Eulerian numbers. {Also offered for undergraduate credit - see MATH 436.}.	3
MATH 684. Mathematical Methods of Biological Processes. 3 Credits. This course provides an introduction to mathematical methods in biology. {Also offered for undergraduate credit - see MATH 484.}.	3
MATH 830. Graph Theory. 3 Credits. Graduate-level survey of graph theory: paths, connectivity, trees, cycles, planarity, genus, Eulerian graphs, Hamiltonian graphs, factorizations, tournaments, embedding, isomorphism, subgraphs, colorings, Ramsey theory, girth. Prereq: MATH 630.	3

MATH 839. Topics in Combinatorics and Discrete Mathematics. 3 Credits. Selected topics in combinatorics and discrete mathematics. Topics vary each time the course is offered and may include: symmetric functions, Coxeter theory, geometric combinatorics of polytopes, computational combinatorics, statistical mechanics and combinatorics, or dynamical algebraic combinatorics.	3
MATH 867. Topics in Applied Mathematics. 3 Credits. Topics will vary and may include: Optimal Control, Robust Control, Stability Analysis, Mathematics of Networks, Models in Biology, Levy Processes, Asymptotic Expansions. May be repeated for credit with change in subtopic. Prereq: **MATH 650** or **MATH 680**.	3
MICR 724. Applied Epidemiology and Biostatistics. 3 Credits. This course will enable the students to get an understanding of how to apply epidemiological tools in study designs data management and analysis. Students will create or use existing databases and learn data management and analysis using software such as EPIINFO.	3
PLSC 749. Applied Plant Molecular Breeding. 3 Credits. This course provides principles and applications of genomics-assisted plant breeding such as germplasm characterization, molecular marker and gene discovery, marker-assisted selection, and genomic selection. Recommend: **PLSC 611**. F (odd years). Prereq: **PLSC 718**.	3
PH 674. Epidemiology. 3 Credits. Study of the distribution and dynamics of disease in populations. {Also offered for undergraduate credit - see PH 474.}.	3
PH 706. Essentials of Epidemiology. 3 Credits. Emphasis on application of the principles of epidemiology as applied to the investigation and prevention of individual and population health problems.	3
PH 731. Biostatistics. 3 Credits. This core course introduces the selection, use and interpretation of basic statistical tests and concepts that may be used in addressing, analyzing and solving problems in public health, biomedical and health care research.	3
PH 750. Epidemiologic Methods I. 2 Credits. This course covers the development of an observational epidemiologic study and the use and interpretation of methods and techniques for analyzing observational epidemiologic data. Prereq: **PH 706**, **PH 731**.	2
PH 752. Epidemiologic Methods II. 2 Credits. Distribution and dynamics of disease in populations and methods for detecting and interpreting spatial patterns of disease.	2
PLSC 724. Field Design I. 3 Credits. Application of various field designs, factorial and split-plot arrangements, orthogonal and non-orthogonal comparisons, models, components of variance, correlation, and regression to biological problems. 3 lectures. Recommended Prereq: **STAT 725**.	3
STAT 650. Stochastic Processes. 3 Credits. Discrete time Markov chains, Poisson processes, continuous time Markov chains, birth and death processes, renewal processes, branching processes, queuing systems, and applications. {Also offered for undergraduate credit - see STAT 450.}.	3
STAT 661. Applied Regression Models. 3 Credits. Simple linear regression, matrix approach to multiple regression, and introduction to various tests and confidence intervals. Includes discussion of multicollinearity and transformations. Knowledge of matrix algebra and knowledge of differential calculus is expected. {Also offered for undergraduate credit - see STAT 461.}.	3
STAT 711. Basic Computational Statistics using R. 3 Credits. Basic Statistics, General R, Data Manipulation, Basic Statistical Programming Skills, Simple Linear Regression, Classical Testing, and Categorical Data Analysis. Restriction: This course is designed for the certificate degree in Big Data Applied Statistics Analysis and it may not be used toward any other statistics degree.	3
STAT 712. Applied Statistical Machine Learning. 3 Credits. This course provides several fundamental concepts and methods in statistical machine learning: linear method for regression, linear method for classification, KNN, regression tree, classification tree, bagging, random forest, boosting, support vector machine, neural networks, K-means clustering. Knowledge of basic inferential statistical methods is expected. Restriction: This course is one of the courses for the Certificate of Applied Big Data Analysis and it may not be used for the M.S. or Ph.D. in Statistics.	3
STAT 713. Introduction to Data Science. 3 Credits. Large Scale Data Manipulation, Data Management, Big Data Construction using Probabilistic and Machine Learning Data Linkage, Web Crawling, Parallel Statistical Computing, and Transferring Data Between Statistical Software. Restriction: Prereq: STAT 711. Restrictions: This course is designed for the certificate degree in Big Data Applied Statistics Analysis and it may not be used toward any other statistics degree.	3
STAT 714. Statistical Big Data Visualization. 3 Credits. Principles of Data Visualization: charts, tables, line, density curve, and effective presentations using R, SAS, Matlab, and Python. Graphical Methods and Interpretation for Specialized Data Types. Advanced Data Visualization R packages and Software, Dynamic and Interactive Plot, Network Visualization: Twitter API Visualization of Spatial Data: Google Map API. Prereq: STAT 711. Restrictions: This course is designed for the certificate degree in Big Data Applied Statistics Analysis and it may not be used toward any other statistics degree.	3
STAT 725. Applied Statistics. 3 Credits. Data description, probability, inference on means, proportions, difference of means and proportions, categorical data, regression, analysis of variance, and multiple comparisons. Prereq: Knowledge of algebra. This course is not intended for statistics or mathematics majors.	3

STAT 726. Applied Regression and Analysis of Variance. 3 Credits. Simple and multiple regression, ANOVA tables, correlation, regression diagnostics, selection procedures, analysis of covariance, one-way ANOVA, two-way ANOVA. Prereq: STAT 725.	3
STAT 764. Multivariate Methods. 3 Credits. Sample geometry; correlation; multiple, partial, canonical correlation test of hypothesis on means; multivariate analysis of variance; principal components; factor analysis; and discriminant analysis. Prereq: STAT 661.	3
STAT 840. Introduction to Statistical Design and Analysis of Gene Expression Experiments. 3 Credits. Introduction to microarray and next generation sequencing technologies; design of gene expression experiments; normalization methods; methods for identifying differentially expressed genes; multiple testing and false discovery rate; gene category analysis.Prereq: **STAT 661**, **STAT 662**. Prereq or Co-req: **STAT 671**.	3
STAT 851. Bayesian Statistical Inference. 3 Credits. Bayesian approach to statistics inference including model estimation and hypothesis test. The topic covers prior and posterior, Bayes estimate, credible interval, risk, Bayes factor, hypothesis testing, Bayesian hierarchical models, and Bayes computational methods. Prereq: STAT 768.	3
STAT 860. Statistical Machine Learning. 3 Credits. This course provides several fundamental concepts and methods in statistical machine learning: linear method for regression, linear method for classification, KNN, regression tree, classification tree, bagging, random forest, boosting, support vector machine, neural networks, K-means clustering. Prereq: **STAT 661**, **STAT 671** and **STAT 768**.	3

MODELING AND SENSING ELECTIVES

	Credits
ABEN 747. Numerical Modeling of Environmental and Biological Systems. 3 Credits. Numerical methods of systems analysis will be taught through real-world case studies. Topics covered include simplification and mathematical description of real systems; the finite-difference methods for solving differential equations; and parameter estimation sensitivity analysis, and uncertainty analysis methods. S (even years).	3
ABEN 758. Applied Computer Imaging and Sensing for Biosystems. 3 Credits. Sensors and non-destructive sensing principles (e.g., computer vision, spectroscopy, imaging, fiber optic sensing) for bioproduction and processing applications. Data/signal acquisition, signal conditioning/analysis techniques, signal interpretation, and pattern recognition using statistical, neural networks, and fuzzy logic techniques.	3
CE 725. Biomaterials-Materials in Biomedical Engineering. **3 Credits**. This course covers the fundamentals of synthesis, properties, and biocompatibility of metallic, ceramic, polymeric and composite materials that are designed for replacement of biological materials such as hard and soft tissues.	3
CSCI 628. Computational Techniques for Environmental Sustainability. 3 Credits. This course covers computational technology that is relevant for work in sustainability. Geo-spatial data management, statistical concepts for data mining, and computational modeling techniques, are discussed in the context of environmental sustainability.	3
GEOG 655. Introduction to Geographic Information Systems. 4 Credits. Application of the principles of geographic information systems and integrally related mapping to solve problems related to environment site characterizations, resource exploration, soil and groundwater contamination, geological and geotechnical investigations, waste management, construction, etc. Comprehensive lab assignments included to give students hands-on experience solving probems with current state-of-the-art software and hardware, digitizers, scanners, and GPS units.	4
GEOG 656. Advanced Geographic Information Systems. 3 Credits. Application and analysis of advanced techniques and principles of geographic information systems and remote sensing technologies to fully address spatial and time related problems related to urban site characterizations, hydrologic analyses, risk assessment, policy making, disaster response and strategies defense techniques. Comprehensive lab assignments included to give students hands-on experience solving problems with current state-of-the-art software and hardware, digitizers, scanners, and GPS units. Prereq: GEOG 655.	3
GEOG 665. Remote Sensing of the Environment. 3 Credits. This course will focus on developing practical skills for using various types of accessible remote sensing technologies as applied to environmental sciences. We will learn to work with aerial photographs, aerial lidar data, Terrestrial Laser Scanning (TLS), structure from motion (sfm), and Unmanned Aerial Vehicles (UAVs). We will explore the drawbacks and benefits of each technology and how it can be used to gather information and measure change in the environment. Cross-listed with GEOL. {Also offered for undergraduate credit	3
GEOG 670. Remote Sensing. **3 Credits**. Application of principles of Remote Sensing technology to integrate multiple interrelated data, to identify and/or accentuate spectral indices, magnetic force, electromagnetic energy and other remotely collected data to analyze temporal and spatial variation.	3
GEOG 680. Geographic Information Systems Pattern Analysis and Modeling. 3 Credits. Application of GIS for determination of: factors or variables that influence geospatial patterns, data limitations in spatial and temporal continuum scales, identification of data anomalies, optimal data prediction, and evaluation of prediction uncertainty. Prereq: GEOG 655.	3
PAG 654. Applications of Precision Agriculture. 3 Credits. The course is designed to introduce students to current technologies that are being used for crop production, and how to use the data collected by them to make more informed crop management decisions. The course is offered as two 50-minute lectures and one lab meeting per week. {Also offered for undergraduate credit	3