BIOSTATISTICS (PHD)

Doctor of Philosophy in Biostatistics
Unit: School of Public Health and Information Sciences (https://louisville.edu/sphis/) (GH)
Department: Bioinformatics and Biostatistics (http://louisville.edu/sphis/departments/bioinformatics-biostatistics/)
Program Webpage (http://louisville.edu/sphis/departments/bioinformatics-biostatistics/academics/phd/)
Academic Plan Code(s): BDSCPHD, BDSCPHDBAC

Program Information
Introduction

Biostatistics involves the development and application of statistical techniques to scientific research in health-related fields, including medicine, epidemiology, and public health. Students in the PhD program receive state-of-the-art training in the latest statistical methodology in order to tackle the challenges associated with the study design and data analysis of modern research conducted in the health sciences. The PhD program provides advanced training in biostatistical theory and methods, with the goal of enabling the student to carry out original research. In addition, students may elect to train with an emphasis in bioinformatics.

Bioinformatics requires the development and application of statistical methods for many of the areas covered by the field, including genomics, proteomics, statistical genetics, and metabolomics. Current biomedical research technologies generate high volumes of data that require extension of existing statistical methodologies and development of new methodologies in order to extract important information regarding biological processes. The emphasis on bioinformatics is designed to fulfill the expanding need for biostatisticians with advanced training in this area. Students in the bioinformatics emphasis gain a basic understanding of molecular and cellular biology, genetics, and bioinformatics and an in-depth knowledge of statistical theory and methods. Graduates are able to carry out original statistical research in genomics, proteomics, metabolomics, and evolving areas of systems biology.

Students who complete the MS program in biostatistics with the Department of Bioinformatics and Biostatistics or who already possess the equivalent of an MS in statistics, biostatistics, or a related discipline may apply for admission to the PhD program.

Competencies

To graduate, a student must demonstrate mastery of the following core competencies*:

Competency	CE	SCP	Dsrt	CW
Thoroughly understand the broad discipline of biostatistics, including its theoretical underpinnings, its history of development, current applications, and areas of active inquiry	X		X	X
Thoroughly review and critique statistical methods literature.			X	
Conduct statistical analyses and data management using standard statistical software such as SAS, R, and SPSS.	X	X	X	X
Analyze research data using linear models and other appropriate statistical methods	X	X		X
Read, interpret, and review biomedical literature where biostatistical techniques are used.			X	
Advance the field of biostatistics through original and independent research			X	

Students are also expected to develop the following additional emphasis-specific proficiencies. These proficiencies may vary dependent upon a student's individualized course of study:

Biostatistics Emphasis:

Competency	CE	SCP	Dsrt	CW
Analyze dichotomous, count, and time-to-event data using appropriate statistical methods, including logistic regression, log-linear models, Kaplan-Meier curves, and Cox proportional hazards models				X
Assist researchers in planning research studies, proposing and evaluating statistical methods and computing power analyses		X		X

Bioinformatics Emphasis:

Competency	CE	SCP	Dsrt	CW
Analyze high-throughput, biological data, such as those obtained from microarrays and next generation sequencing technologies, with statistical models specifically geared to the data issues associated with these platforms.			X	X
Retrieve and leverage various types of biological information from online repositories			X	X
Apply models that use the knowledge and basic principles of molecular biology, especially the structure and functions of DNA, RNA, proteins and their inter-relationships to address important biological questions based on genomic and proteomic data				X

*Key for demonstration (method):
    CE = Comprehensive examinations
    SCP = Statistical consulting practicum
    Dsrt = Dissertation
    CW = Coursework

Curriculum

The curriculum consists of a minimum of 56 (34 if Master's Track) credit hours of coursework, a comprehensive examination, and a doctoral dissertation. The student is eligible to sit for comprehensive examinations upon completion of required coursework. Upon passing the comprehensive examination and completing required and elective coursework, the student enters candidacy to work on the dissertation. After the dissertation is submitted and approved, including an oral defense, the student is eligible to receive the PhD degree in Biostatistics.

Award of degree from an accredited school of public health requires successful completion of the equivalent of three (3) credit hours of instruction that provides students a broad introduction to public health.

The course PHPH 523 Public Health in the United States fulfills this requirement. The three (3) credit hours for PHPH 523 do not accrue toward the 34 credit hours required for PhD degree completion. Students with a prior degree from a CEPH accredited school or program of public health may be relieved of this requirement, per approval of the Associate Dean for Academic Affairs.

Faculty Advisor

Upon admission to the PhD program, each student is assigned to the graduate coordinator of the PhD program for course advising. The graduate coordinator assumes the role of faculty advisor until the student chooses a dissertation advisor at which point this responsibility shifts to the dissertation advisor. If it becomes clear that a PhD student will be working with a given faculty member prior to forming a dissertation

committee, the student may request a change in course advisor by completing the form *Request to Change Academic Advisor*.

Program of Study

Upon admission to the PhD program, a program of study is developed for each student by the faculty advisor and approved by the program director and department chair. Students who did not complete the MS program in Biostatistics with the Department of Bioinformatics and Biostatistics may be required to complete additional coursework normally offered in the MS program. Decisions regarding additional coursework are made by the student's assigned faculty advisor and such courses become part of the program of study. This approach gives maximum flexibility for addressing differing student qualifications and interests.

Application Requirements

The PhD program is available to students entering with either a bachelor's degree (referred to as the Bachelor's Entry Track) or a master's degree (referred to as the Master's Entry Track) in mathematics, biostatistics, statistics, engineering, computer science, or a related discipline.

Applicants with only a bachelor's degree must have completed the following coursework:

1. Calculus I-III or equivalent
2. Linear Algebra
3. Statistics/biostatistics course at least at a sophomore level.
4. Two additional mathematics/statistics courses at least at junior level.
5. A computing course at least at a sophomore level

The following are additionally required for admission:

- Graduate application (https://graduate.louisville.edu/admission/apply/)
- Non-refundable application fee
- All postsecondary transcripts, including those from any institution attended. Transcripts from institutions outside of the U.S.A. require a foreign credential evaluation. The minimum grade point average that will be considered for acceptance is 3.25 on a 4.0 scale.
- At least two letters of recommendation written within past twelve months.
- GRE Scores are required and are considered in the context of other required components of the application. Students who have been successful in our programs in the past typically have a median [Q1, Q3] GRE Quantitative score at the 87th percentile.
  - GRE requirement may be waived for any applicant whose mathematical background is deemed to be sufficient for doctoral study in Biostatistics.
- Statement of goals, including the desired emphasis, if any.
- International students for whom English is not their primary language must show English language proficiency by one of the following:
  - TOEFL examination score at or above 550 (paper based test and a 5.0 on the TWE test), 213 (computer based test), 79 (internet based test)
  - IELTS test score of 6.5 or higher
  - Duolingo (English) test score of 105 or higher
  - Demonstration of a degree awarded from an institution with instruction primarily in English, as formally documented by an appropriate institutional official

Application Deadline

Fall semester – Applications are accepted on a rolling basis.

> Domestic student are encouraged to apply no later than 30 days prior to the start of the fall semester.

> International students are encouraged to apply no later than 90 days prior to the start of the fall semester.

Spring semester – Applications are not accepted.

Summer semester – Applications are not accepted.

Program Requirements

Completion of the required coursework is the prelude to sitting for the comprehensive examination. Successful completion of the comprehensive examination allows the student to enter doctoral candidacy. A doctoral candidate must then develop and successfully defend a dissertation proposal that describes an original and independent research project. Upon successful defense of the proposal, a student may then proceed to continue dissertation research. Upon successful completion of the research, defense of the dissertation, and demonstration of the required competencies, a student is awarded the PhD degree.

Academic Standing

To maintain good academic standing in the PhD in Biostatistics program, students must maintain a cumulative GPA of 3.0 or higher for all coursework in the program. A student must be in good academic standing in order to receive the degree.

Any PhD in Biostatistics student with a program cumulative GPA below 3.0 will be placed in probationary status. Any student who remains in probationary status for two consecutive terms may be considered for dismissal from the program.

Coursework

Bachelors Entry Track
56 total credit hours
   34 credit hours of required core coursework
   22 credit hours of elective courses (vary based on area of emphasis)

Code	Title	Hours
Required Coursework (34 credit hours)		
PHST 620	Introduction to Statistical Computing	3
PHST 624	Clinical Trials I: Planning and Design	2
PHST 625	Clinical Trials II	2
PHST 661	Probability	3
PHST 662	Mathematical Statistics	3
PHST 680	Biostatistical Methods I	3
PHST 681	Biostatistical Methods II	3
PHST 684	Categorical Data Analysis	3
PHST 691	Bayesian Inference and Decision	3
PHST 710	Advanced Statistical Computing I	3
PHST 762	Advanced Statistical Inference	3
PHST 781	Advanced Linear Models	3

Subtotal		34

Recommended Elective Coursework (22 credit hours)

No Emphasis

PHST 703	Biostatistical Consulting Practicum	1
PHST 724	Advanced Clinical Trials	3
PHST 782	Generalized Linear Models	3
PHST 783	Advanced Survival Analysis	3
Additional Electives (see list below)		12
Subtotal		22

Bioinformatics Emphasis

PHST 703	Biostatistical Consulting Practicum	1
PHST 750	Statistics for Bioinformatics	3
PHST 751	High-throughout Data Analysis	3
CSE 632	Data Mining	3
Biochemistry Elective		3
Additional Electives (see list below)		9
Subtotal		22

Bachelors Track students may apply Year 1 coursework towards completion of the MS in Biostatistics should they choose to apply to that program.

Masters Entry Track
34 total credit hours
    12 credit hours of required core coursework
    22 credit hours of elective courses (vary based on area of emphasis)

Code	Title	Hours
Required Coursework (12 credit hours)		
PHST 691	Bayesian Inference and Decision	3
PHST 710	Advanced Statistical Computing I	3
PHST 762	Advanced Statistical Inference	3
PHST 781	Advanced Linear Models	3
Subtotal		12
Recommended Elective Coursework (22 credit hours)		
No Emphasis		
PHST 703	Biostatistical Consulting Practicum	1
PHST 724	Advanced Clinical Trials	3
PHST 782	Generalized Linear Models	3
PHST 783	Advanced Survival Analysis	3
Additional Electives (see list below)		12
Subtotal		22
Bioinformatics specialization		
PHST 703	Biostatistical Consulting Practicum	1
PHST 750	Statistics for Bioinformatics	3
PHST 751	High-throughout Data Analysis	3
CSE 632	Data Mining	3
Biochemistry Elective		3
Additional Electives (see list below)		9
Subtotal		22

The student may be required to take one or more prerequisite courses for a required course if the student does not meet the prerequisites. These prerequisite courses become part of the program of study but are in addition to the number of coursework credit hours presented above.

Electives

The six to nine (6-9) credit hours of Additional Electives listed in the table on the previous page must be taken from the following lists. The student's program of study specifies the particular courses permitted to be taken.

No Emphasis

Code	Title	Hours
PHST 675	Independent Study in Biostatistics	1-3
PHST 682	Multivariate Statistical Analysis	3
PHST 704	Mixed Effect Models and Longitudinal Data Analysis	3
PHST 711	Advanced Statistical Computing II	3
PHST 750	Statistics for Bioinformatics	3
PHST 751	High-throughout Data Analysis	3
PHST 752	Statistical Genetics	3
PHST 780	Advanced Nonparametrics	3
PHST 785	Nonlinear Regression	3
CSE 632	Data Mining	3

Bioinformatics Emphasis

Code	Title	Hours
PHST 675	Independent Study in Biostatistics	1-3
PHST 682	Multivariate Statistical Analysis	3
PHST 704	Mixed Effect Models and Longitudinal Data Analysis	3
PHST 711	Advanced Statistical Computing II	3
PHST 752	Statistical Genetics	3
PHST 780	Advanced Nonparametrics	3
PHST 782	Generalized Linear Models	3
PHST 785	Nonlinear Regression	3

The student may be required to take one or more prerequisite courses for an elective course if the student does not meet the prerequisites. These prerequisite courses become part of the program of study but are in addition to the number of coursework credit hours presented above. Enrollment in other courses such as GS 699 Interdisciplinary Research (if a student has remaining coursework to complete) or GS 799 Doctoral Exam Prep (if a student has no remaining coursework to complete)may be required to maintain academic status for funding purposes.

Sample Program of Study for a Bachelors Track Student

Year 1

Fall		Hours
PHST 620	Introduction to Statistical Computing	3
PHST 624	Clinical Trials I: Planning and Design	2
PHST 661	Probability	3
PHST 680	Biostatistical Methods I	3
	Hours	**11**

Spring		
PHST 625	Clinical Trials II	2
PHST 662	Mathematical Statistics	3

PHST 681	Biostatistical Methods II	3
PHST 684	Categorical Data Analysis	3
	Hours	**11**
Summer		
Optional [1]		
PHST 603	Biostatistics Public Health Practicum I	
GS 699	Interdisciplinary Research (Optional)	
	Hours	**0**
Year 2		
Fall		
PHST 710	Advanced Statistical Computing I	3
PHST 762	Advanced Statistical Inference	3
PHST 781	Advanced Linear Models	3
	Hours	**9**
Spring		
PHST 691	Bayesian Inference and Decision	3
Additional Elective		3
One of the following		3
PHST 724	Advanced Clinical Trials (No Emphasis)	
PHST 750	Statistics for Bioinformatics (Bioinformatics Emphasis)	
	Hours	**9**
Summer		
Variable [2]		
PHST 703	Biostatistical Consulting Practicum	1
GS 799	Doctoral Exam Prep [2]	
	Hours	**1**
Year 3		
Fall		
PHPH 523	Public Health in the United States	(3)
Additional Elective		3
One of the following:		3
Additional Elective (No Emphasis)		
CSE 632	Data Mining (Bioinformatics Emphasis)	
	Hours	**6**
Spring		
Additional Elective		3
Emphasis Coursework:		6
PHST 782	Generalized Linear Models (No Emphasis)	
PHST 783	Advanced Survival Analysis (No Emphasis)	
PHST 751	High-throughout Data Analysis (Bioinformatics Emphasis)	
Biochemistry Elective (Bioinformatics Emphasis)		
	Hours	**9**
	Minimum Total Hours	**56**

All pre-candidacy PhD students (from the second year for BT and from the first year for MT) on support of any kind (Fellowship, GRA, TA, Hourly) must be enrolled in the Department's seminar course (PHST 602) for one (1) credit hour during semesters they are supported.

Sample Program of Study for a Masters Track Student

Year 1		
Fall		**Hours**
PHST 710	Advanced Statistical Computing I	3
PHST 762	Advanced Statistical Inference	3
PHST 781	Advanced Linear Models	3
	Hours	**9**
Spring		
PHST 691	Bayesian Inference and Decision	3
Additional Elective		3
One of the following		3
PHST 724	Advanced Clinical Trials (No Emphasis)	

PHST 750	Statistics for Bioinformatics (Bioinformatics Emphasis)	
	Hours	**9**
Summer		
Variable [2]		
PHST 703	Biostatistical Consulting Practicum	1
GS 799	Doctoral Exam Prep [2]	
	Hours	**1**
Year 2		
Fall		
Additional Elective		3
PHPH 523	Public Health in the United States	(3)
One of the following		3
Additional Elective (No Emphasis)		
CSE 632	Data Mining (Bioinformatics Emphasis)	
	Hours	**6**
Spring		
Additional Elective		3
Two of the following:		6
PHST 782	Generalized Linear Models (No Emphasis)	
PHST 783	Advanced Survival Analysis (No Emphasis)	
PHST 751	High-throughout Data Analysis (Bioinformatics Emphasis)	
Biochemistry Elective (Bioinformatics Emphasis)		
	Hours	**9**
	Minimum Total Hours	**34**

[1] Students must be enrolled in six (6) credit hours if they are to receive summer funding. A Bachelors Track student may choose not to receive summer funding. Students that choose not receive summer funding do not need to enroll in the summer session.

[2] Required for all funded students. Optional for any non-funded students.

Comprehensive Examination

One students have passed PHST 691, PHST 710, PHST 762, and PHST 781 they must take a written comprehensive examination at the first available offering of the examination. The objective of this examination is for the student to demonstrate a comprehensive knowledge of statistical theory and methods as learned in the courses taken during the first few semesters in the program and for students to show their ability to apply this knowledge to solve new and/or complex problems. This examination is given over two consecutive days shortly before the start of the fall semester. Students will be notified of the dates and location at least one month in advance.

The examination will consist of four sections, each corresponding to one of the required courses (PHST 710, PHST 762, PHST 781, PHST 691) and each given individually. Each section is designed to test the student's competency in a core area of the discipline and to assess his/her ability to apply this knowledge to solve new and/or complex problems.

- The Statistical Inference (PHST 762) section will be a two-hour written examination given in the morning of the first day.
- The Computing section (PHST 710) will be a three-hour computing examination given in the afternoon of the first day.
- The Linear Models (PHST 781) section will be a two-hour written examination given in the morning of the second day.
- The Bayesian Inference section (PHST 691) will be a 90-minute written examination and a two-hour computing exam, both given in the afternoon of the second day.

Material from courses corresponding to each section of the comprehensive exam will help students prepare for those sections. However, questions from any sources may appear that cover the same topics as listed in the syllabi of PHST 691, PHST 710, PHST 762, and PHST 781. Further, problems on the Computing section of the exam may draw on topics covered in PHST 691, PHST 762, and PHST 781.

Each student receives a grade of either "pass" or "fail" for the entire comprehensive examination and each student must pass all four sections of the comprehensive examination to receive a "pass". Students that pass the exam will be eligible to enter doctoral candidacy upon completion of the remaining, second-year coursework. A failing grade indicates a deficiency in one or more areas, and a student with a grade of "fail" will have one opportunity to retake the full Comprehensive Examination (all four sections), typically in the following January. The results from a student's first attempt at the comprehensive exam will not be considered in the grading of the second attempt and will not factor into the determination of a pass or fail score for the second attempt at the exam. Students that fail to pass the examination on their second attempt will be dismissed from the program without any further consideration.

Neither scores nor graded copies of completed examinations will be shared with students. Students may review ungraded copies of their own completed comprehensive exams with the exam graders. The ungraded, completed copies will be held in the department office. Students will not be permitted to keep ungraded copies of the completed comprehensive exams.

Special Notes on the Comprehensive Exam

- For all the exams, the students will not have access to any course books, notes or any other materials (paper or electronic copies)
- Students will write programs and run code in the Bayesian and non-Bayesian computing examinations. These examinations will be given either in a computer lab in the SPHIS building or the students will be required to bring their own laptop to run the programs.
- The only materials which can be consulted for the computing portions of the examinations are R help menus locally available on the specific computer. Students will be asked ahead of time to upload all R packages needed to appear for the exam. Students will not be allowed to avail the internet by any means.
- Any suspected cheating on the Comprehensive Examination will be addressed according to university policies provided in Section 5 of Dean of Students document, Students Rights and Responsibilities (https://louisville.edu/dos/students/studentrightsandresponsibilities/). Additionally, students found guilty of academic dishonesty on the Comprehensive Examination will be expelled from the PhD program immediately.
- More than one faculty members will grade all the examinations.

Dissertation

In order to complete the degree, a candidate must submit and successfully defend a dissertation on a topic approved by his or her major professor and the dissertation committee. Dissertation work may be started following successful completion of doctoral comprehensive examinations.

Dissertation Committee

The dissertation committee is formed by the candidate's proposing a major professor (or principal advisor) and at least four other committee members. The major professor (or all of them when there are co-major professors) must be from the Department of Bioinformatics and Biostatistics. One member of the dissertation committee must be external to the Department of Bioinformatics and Biostatistics and the majority of the committee must be from the Department of Bioinformatics and Biostatistics. The committee is appointed by the dean of the school upon the recommendation of the program director and chair of the department.

Dissertation Proposal (Pre-Dissertation Essay)

A dissertation proposal or pre-dissertation essay must be submitted to the major professor and the dissertation committee within two semesters of the student entering candidacy. Students must make an oral presentation of the proposal to the dissertation committee, after which the members of the committee vote upon approval of the proposal. The proposal must be approved by a majority vote of the dissertation committee before the candidate undertakes further work on the dissertation. In rare situations adjustments to this schedule can be made with the approval of the dissertation committee and the department chair.

The dissertation proposal document will include a general overview of the selected research project/projects, and discuss the relevant literature. It will also contain a detailed description of the project(s), describing both the research that the students have already accomplished and that which remains. In most cases, this will take the form of one or more chapters corresponding to preliminary or submitted academic manuscripts. There are no formal formatting requirements for the dissertation proposal, although students are encouraged to use the formatting specifications required of the dissertation.

Data Application

All dissertations must include analysis of at least one real data set. This may be in the context of demonstrating new statistical methodology in a real application. Students are expected to explore the relevant scientific literature to provide the appropriate context for the results of the data analysis.

Dissertation Preparation

The dissertation is to be prepared in format according to the guidelines established by the Graduate School (http://louisville.edu/graduate/current-students/thesis-dissertation-information/). It is the responsibility of each student to ensure that the readability and quality of writing in his/her thesis meets professional standards. Students are strongly encouraged to take advantage of the services offered by the University Writing Center (http://louisville.edu/writingcenter/) when writing their dissertation. The services offered by the Writing Center are free to the student.

Dissertation Approval

Final approval of the dissertation is voted upon by the dissertation committee after an oral defense of the dissertation by the student. Students submit their dissertations to members of their committee two or more weeks prior to the date of the oral defense. Approval of the dissertation is by a majority vote of the committee after the oral defense.

Students are required by the Graduate School to provide two weeks' notice when scheduling oral defenses (http://louisville.edu/graduate/current-students/thesis-dissertation-information/). This requirement

permits those wanting to attend the oral defense adequate time to make arrangements for attending. Students must follow the below procedure for scheduling oral defenses:

1. Identify a date and time for the oral defense in consultation with the dissertation advisor and members of the committee.
2. Request a room reservation for the oral defense through the Department's Administrative Assistant.
3. Notify the Department's Administrative Assistant of the date, time, and location of the oral defense as well as the title of the dissertation. The Department's Administrative Assistant will circulate an announcement of the defense as well as notify the SPHIS Office of Student Services of the defense, who in turn will notify the Graduate School.
4. Distribute technically and grammatically error-free copies of the dissertation to all committee members at least two weeks prior to the defense date.

There are no exceptions to these requirements and students will not be permitted by the Department to schedule defenses with less than 2 weeks' notice. Students are expected to be aware of university deadlines for dissertations (http://louisville.edu/graduate/current-students/thesis-dissertation-information/) and to ensure that the two weeks' notice requirement is fulfilled within these university deadlines. Students are strongly encouraged to allow for even greater than two weeks' notice to ensure that all deadlines and requirements are fulfilled.

Dissertation Submission

The following steps must be taken to submit the final copy of the dissertation electronically after oral defense and approval of the committee:

1. Final document must be converted to a PDF (following the guidelines as noted above) and sent to the Graduate School and the department's administrative assistant.
2. Submit as advised by the Graduate School through the ThinkIR repository. The directions on submission will be provided upon review of the dissertation by the Graduate School.
3. The signature page within the electronic version must have the names of your committee members typed under the signature line; the signatures cannot be scanned into the document.
4. Submit a signed signature page (digital/electronic signature page (http://louisville.edu/graduate/current-students/thesis-dissertation-information/ElectronicDissertationSignaturePage.pdf)or a hard copy on white paper, with original signatures) to the Graduate School.

An electronic copy of the dissertation must be provided to the Department's Administrative Assistant.

Applying for a Degree

Students are responsible for completing an "Application for Degree" form at the beginning of the semester in which they will defend their thesis or dissertation. Students may apply for their degree via ULink. The steps are as follows:

1. Log on to your ULink account.
2. Go to Student Services Page.
3. Scroll down and on the right of the screen you will find a column labeled "Registration".
4. Under Registration click on the Degree Application link.

5. Follow the Prompts to complete your application for degree. Once completed, you will receive an e-mail confirmation of submission in your University e-mail.

Future deadline dates can be found on the Graduate Academic calendar (http://louisville.edu/calendars/academic/undergrad-grad/).

For any questions or concerns students might have during the semester in which they plan to graduate, students' best resource is the Graduate School. The Department of Bioinformatics and Biostatistics faculty and staff are also here to advise and assist you with any questions you might have.