**PHP 2530: Bayesian Inference**
Spring Semester 2021

*Instructor:* Joseph Hogan, Professor of Biostatistics
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*Hours:* TBD
*Zoom:* https://brown.zoom.us/my/jwhogan

*Teaching Assistant:* TBD

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**Course overview.** This course provides a graduate-level introduction to Bayesian statistical inference. The Bayesian approach differs from the *frequentist* approach to inference, which is often taught in introductory statistics courses. As recently as 25 years ago, Bayesian methods were seen as impractical for solving 'real' problems because of limitations in computing. More recently, advances in computing, combined with theoretical developments in the field, have unlocked the potential of Bayesian methods for addressing highly complex applied problems.

An important feature of the Bayesian paradigm is that it is based on a probability model for both data and the parameters underlying the distribution of data. This means Bayesian models assign a probability distribution to both, with inferences being based on the probability distribution of parameters conditional on data. In particular, parameters are treated as random variables. In the frequentist approach, parameters are viewed as fixed quantities about which the data can provide information in terms of estimates and uncertainty about those estimates.

The field of Bayesian inference is vast, and it's impossible to provide a deep treatment in a single semester. This course will have five units.

1. Prior, likelihood, posterior
2. Model formulation and prediction
3. Posterior computation
4. Regression modeling (including multilevel models)
5. Advanced topics (missing data, nonparametric models)

**Pre-requisites.** Students should have completed a one-year biostatistics sequence at the level of PHP 2510-2511, at minimum, and ideally a course in either probability theory or mathematical statistics. The course material will make regular use of basic ideas from calculus (including multivariable calculus) and linear algebra.

Students taking this course *must* be comfortable with some advanced-level programming in a language like R or Matlab. The course will rely primarily on R and on the Stan computing package. Please be sure the latest versions of both of these are installed.

**Course text and other readings.** We will rely primarily on the book by Gelman et al (2014, 3rd edition). The book has a website with a substantial amount of supplementary materials (and includes a link to the pdf of the book): `http://www.stat.columbia.edu/~gelman/book/`

I will draw material from two other books on some occasions. One is a somewhat unorthodox but insightful text on Bayesian inference (McElreath, 2020) and the other is a book on Bayesian approaches to incomplete data (Daniels and Hogan, 2008; available online through Brown library). Papers and other readings will be assigned periodically.


Gelman A, Carlin JB, Stern HS, Dunson DB, Vehtari A, Rubin DB (2014). Bayesian Data Analysis, 3rd Edition. CRC Press.

McElreath R (2020). Statistical Rethinking, 2nd Edition. CRC Press.

Daniels MJ, Hogan JW (2008). Missing Data in Longitudinal Studies: Strategies for Bayesian Modeling and Sensitivity Analysis. CRC Press.


**Schedule of topics**

| Dates | Content |
|---|---|
| Jan 21 | Probability and inference<br>BDA3 Chapter 1 |
| Jan 26-28 | Single parameter models<br>BDA Chapter 2 |
| Feb 2-4 | Multi parameter models<br>BDA Chapter 3 |
| Feb 9-11 | Hierarchical models<br>BDA Chapter 5 |
| Feb 18, 23-25 | Model checking, evaluation, comparison<br>BDA Chapters 6, 7 |
| Mar 2-4 | Intro to Bayesian computation<br>BDA3 Chapter 10 |
| Mar 9-11 | Basics of Markov chain simulation<br>BDA3 Chapter 11 |
| Mar 16-25 | Regression models<br>BDA3 Chapters 14, 15, 16 (selected sections) |
| Mar 30 - Apr 1 | Missing data and imputation<br>DH selected reading |
| Apr 6-8 | Finite mixture models<br>BDA Chapter 22 |

**Method of evaluation**

*Homework assignments (70%).* Students will be asked to complete assignments about every other week. Each assignment will combine written answer and data analysis exercises. Students can discuss the homework but must prepare their own solutions.

*Final exam – take home (30%).* Students will be required to work alone on the exam.

**General expectations.**

*Please complete the reading in advance of the lecture.* The lecture will generally cover main ideas for the topic being discussed, and illustrate with examples. However the lecture notes are emphatically not a substitute for engaging the reading.

*You will not understand the readings on a first pass. Read with a pencil and paper at your side.* The readings will be somewhat technical and require some dedicated time for full understanding. You may have to read some things twice. Have patience, and take notes as you go. Consider printing copies of the paper to avoid too much screen time. Just keep in mind that to maximize your understanding of the material, you will have to invest time outside of the classroom.

*Late or missed assignments.* Assignments must be turned in online at or before the posted due date. The lowest homework grade will be dropped. This provides some flexibility if you need to miss an assignment or anticipate having trouble completing it by the due date.

*Learning during a pandemic.* We continue to travel in uncharted territory. I appreciate that everything is more difficult during a pandemic. This is the second course I have taught online and I am committed to make the experience a positive one. Please feel free to reach out and let me know if you are having difficulty with the format, or if there is anything I can do to help make the experience a good one. Also – and this is important – if anything comes up that will affect your participation or performance in the class, please get in touch as soon as possible so we can discuss.

**Credit hours and time expectations** . Over 13 weeks, students are expected to spend 3 hours per week in class, 6 hours on assigned reading, and 4 hours on data-analytic homework (156 hours total). The final exam is expected to take up to 24 hours, including research, data analysis, and writeup, for an overall total of 180 hours.

**Books, Supplies, and Materials.** If your Brown undergraduate financial aid package includes the Book/Course Material Support Pilot Program (BCMS), concerns or questions about the cost of books and course materials for this or any other Brown course (including RISD courses via cross-registration) can be addressed to bcms@brown.edu. For all other concerns related to non-tuition course-related expenses, whether or not your Brown undergraduate financial aid package includes BCMS, please visit the Academic Emergency Fund in E-GAP (within the umbrella of "E-Gap Funds" in UFunds) to determine options for financing these costs, while ensuring your privacy.

**Accessibility and Accommodations.** Brown University is committed to full inclusion of all students. Please inform me early in the term if you may require accommodations or modification of any of course procedures. You may speak with me after class, during office hours, or by appointment. If you need accommodations around online learning or in classroom accommodations, please be sure to reach out to Student Accessibility Services (SAS) for their assistance (seas@brown.edu, 401-863-9588). Students in need of short-term academic advice or support can contact one of the academic deans in the College.

**Class Recording and Distribution of Materials.** Lectures will be delivered on Zoom and will be recorded and posted on Canvas. The Canvas site can only be accessed by the TA and by students enrolled in the class. I'm doing this because some students may be in different time zones, have poor internet connections, or have health issues. This means that we will record all classes to make them available to all students that are enrolled but cannot be present. If you have questions or concerns about this protocol, please contact me so that we can talk through those to also ensure your full participation in this course. Lectures and other course materials are copyrighted. Students are prohibited from reproducing, making copies, publicly displaying, selling, or otherwise distributing the recordings or transcripts of the materials. The only exception is that students with disabilities may have the right to record for their private use if that method is determined to be a reasonable accommodation by Student Accessibility Services. Disregard of the University's copyright policy and federal copyright law is a Student Code of Conduct violation.

**Use of Technology to Support Student Learning in Your Course.** This course will use Canvas, Zoom and possibly Google Drive. I am committed to ensuring access to online course resources by students. If you have any concerns or questions about access or the privacy of any of these platforms, please reach out to me. The IT Service Center (https://it.brown.edu/get-help) provides many IT Services including remote assistance, phones, tickets, and chat. Please also see the Online and Hybrid Learning Student Guide.