**Population biology of infectious diseases of global health concern**
**Global Health Sciences BIOS27816**
**Paris, France**

**Course Instructor:**
Cara Brook, PhD (cbrook@uchicago.edu)

**Course Teaching Assistant:**
Gwen Kettenburg (gkettenburg@uchicago.edu)

**Course Location:**
U. Chicago Paris Center, Paris, France
January 8 – January 25, 2024
9:30am – 11:45am Monday-Thursday, with 2x full day Friday field trips

**Office Hours:** Gwen Kettenburg will be available for office hours following the end of class (12-1pm). These office hours will be held either in the library or in an open office space at the UChicago Center in Paris—we will announce the exact location the first week of class after discussing with the program administration. Dr. Brook is also available for office hours by appointment throughout the duration of the course; meetings with Dr. Brook can be arranged in person or via email.

**Overview & Format:**
This course is designed for students interested in pursuing careers in public health, global health, infectious disease modeling, or related disciplines. The aim of the course is to introduce students to the population biology of infectious diseases, in particular the use of dynamical transmission models in understanding and controlling diseases of global health concern. This is complementary to a classic epidemiological and biostatistical approach to infectious disease intervention.

The course will take place during the Winter Quarter Study Abroad track at the University of Chicago Paris Center, which has a focus on the Global Health Sciences. Class attendance (100%) is mandatory. Class will meet in the morning, Monday-Thursday, and two mandatory, full day field trips will be held on Friday, January 12 and Friday, January 19. During the January 12 field trip, we will travel to the Amsterdam Institute for Global Health and Development in Amsterdam, the Netherlands (aighd.org), and also visit the Museum Vrolik (museumvrolik.nl/en/), dedicated to depictions of the human body. During the January 19 field trip, we will visit the laboratory of Dr. Sylvain Hugel, who co-directs the Edible Insect Farming Working group (ipsio.org/superfood) at the Université de Strasbourg. This organization specializes in the farming of edible insects for human nutrition in the low income setting of Madagascar. This visit will be combined with a visit to the 'In the Days of AIDS' exhibit at the Museum of Modern and Contemporary Art in Strasbourg.

Outside of field trips, class time will be split between lecture format (with interspersed discussion topics related to the readings) and activities/tutorials, often involving programming modules in R. Prior to each class period, students will submit a "reading digest" (template provided) related to the reading material assigned for that day's session. In addition, students will be expected to submit small periodic assignments throughout the 3-week course period that build up to the final assignment. The final assignment will require that students select a disease of interest (preferably one of importance to global health) and write a term paper providing some background on the disease and the history of modeling approaches used to understand and control that disease. Students will also be required to pose a question related to that disease that can be addressed with a dynamical model, build the model in the programming language R, and include a figure or two in their paper that demonstrates the results of these efforts. All students will give a final presentation to share about their disease and corresponding modeling results on the last day of class.

**Course Eligibility:**
To be eligible, students should have previously completed the following courses or the equivalent Advanced Placement material prior to Winter 2024:

BIOS 20153: Fundamentals in Ecology and Evolution
BIOS 20151 or BIOS 20152: Introduction to Quantitative Modeling in Biology
MATH 13100-13200: Elementary Functions and Calculus I-II

Prior experience programming in R (or any other language) will be helpful but is not required.
Enrollment without the listed prerequisites is permitted with prior consent of the instructor.

**Late Policy:** Late work will not be accepted, unless under extreme circumstances (e.g. serious illness, injury, family trauma). If these circumstances apply, please notify Dr. Brook immediately to establish a make-up plan. Otherwise, late assignments will be given a score of 0.

**AI Policy:** Artificial Intelligence (AI) tools (e.g. ChatGPT) are not permitted for use in any capacity related to the preparation of any written assignments for this course (e.g. Reading Digests or the final paper). Any student caught using these tools in this context will receive a score of 0 on the corresponding assignment, and all previously-submitted written work will undergo re-evaluation under scrutiny for evidence of AI support. AI tools are permitted to aid in debugging R code related to the construction of the final mathematical model for the course. However, these tools are by no means essential to successful completion of this final assignment.

**Grading Breakdown:**
Homework (Reading Digests): 25%
Homework (Preparation Activities for Final Project): 15%
In-Class Participation (Including Field Trips): 20%
Final Presentation: 10%
Final Model + Paper: 30%

**Course Texts:** There is no single text for this course. All readings (mostly scientific articles but also a few book chapters) will be posted as pdfs to Canvas.

**Objectives:**
By the end of the course, students will be able to:

- Explain the differences and similarities between classical epidemiological and population biological approaches to infectious disease control
- Understand and explain the simple SIR model, as well as its extensions to diseases with more complex transmission dynamics
- Build an SIR-like model in R and use it to interrogate a dynamical research question about a disease of interest
- Discuss important diseases of global health concern, and evaluate the effectiveness of population biological approaches to their control
- Understand and apply phylodynamic approaches to disease control.

**Schedule:**

- *A typical class will open with a lecture from 9:30-10:30am, followed by a 15 minute break, then close with 1-2 activities and/or computer tutorials from 10:45-11:45am.*
- *Some lectures may be longer or shorter, and the activity/tutorial time will be expanded or contracted accordingly to make up the difference.*
- *Some lectures will be split up into two segments, with tutorials/activities interspersed between the two segments.*
- *Lectures will be interactive, and students will be called upon or asked to participate throughout.*
- *If we run out of time during class while working on the computer tutorials, you will be expected to finish these tutorials on your own time, before the next class period.*
- *Readings should be done prior to the date on which they are listed.*
- *Homework will be assigned on the date on which it is listed and due the next class period unless otherwise indicated.*

**Preparation:**

If possible, please download and install the following on your personal computer prior to the start of the first lecture. If you are unable to do so, there will be class time available for you to do this the first day:

- Excel, or a compatible opensource spreadsheet software such as Google Spreadsheets
  - www.docs.google.com/spreadsheets/
- R – a statistical programming language
  - Windows: https://cran.r-project.org/bin/windows/base/
  - Linux: https://cran.r-project.org/bin/linux/
  - MacOS: https://cran.r-project.org/bin/macosx/
- R Studio – a user interface for R that will be needed for computer exercises
  - https://www.rstudio.com/products/rstudio/download/
- MEGA: Molecular Evolutionary Genetics Analysis - a tool for aligning sequences and building phylogenies.
  - https://www.megasoftware.net/

| Date | Lecture | Activities/Tutorials | Readings and Homework |
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| ***Week One: Transmission dynamics and interventions in infectious diseases*** | | | |
| **Monday, January 8** | *Introduction to population biology of infectious diseases*<br>• course overview<br>• emphasis on diseases of importance in global health<br>• overview of causative agents in infectious disease<br>• what is a model?<br>• contrast population biology of disease w/classic epidemiology<br>• refresher on ordinary differential equations (ODEs) and applications to population modeling<br>• introduction to the programming language R | *Activity:* Introduction to compartmental thinking<br>• define “states” vs. “processes” in an example disease system<br>• drawing box models of infectious diseases<br><br>*Computer Tutorial:* Introduction to programming in R | *Readings:*<br>No ‘reading digest’ due on day one. Get a head start on the readings for tomorrow.<br><br>*Homework:*<br>Complete ‘Intro to R’ tutorials and make sure you are comfortable using the software.<br><br>Start to brainstorm what disease you might like to study for your final project *(No formal assignment is due tomorrow for your final project preparation)* |
| **Tuesday, January 9** | *Understanding compartmental models of infectious diseases*<br>• introduction to the compartmental SIR model of infectious disease transmission<br>• assumptions and heterogeneities in the simple SIR model<br>• discrete vs. continuous time<br>• deterministic vs. stochastic models | *Epidemic Cards:*<br>Card game modeling of an epidemic curve<br><br>*Computer Tutorial:*<br>Exploring and visualizing infectious disease data using R | *Readings:*<br>Kilpatrick and Altizer 2010.<br>Bellan et al. 2012.<br><br>***Homework Jan-11:***<br>Choose a disease of interest, and formulate a research question about it that can be addressed with a dynamical (compartmental) model.<br><br>List the ‘states’ and ‘processes’ associated |

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| | | | with your research question.<br><br>(*due on Thurs, Jan 11*). |
| **Wednesday, January 10** | *Thresholds to persistence in infectious diseases*<br>• $R_0$, $R_E$, force of infection ($\lambda$)<br>• critical community size and pathogen persistence<br>• herd immunity<br>• critical vaccination threshold | *Activity*:<br>Dynamical Fever (group exercise and discussion) | *Readings:*<br>Bartlett 1957.<br>Swinton et al. 1998.<br><br>*Homework Jan-11 (continued from Tuesday):*<br>Choose a disease of interest, and formulate a research question about it that can be addressed with a dynamical model.<br><br>List the 'states' and 'processes' associated with your research question.<br><br>(*due on Thurs, Jan 11*). |
| **Thursday, January 11** | *Challenges to interventions in infectious disease control*<br>• imperfect vaccines<br>• public health policy and access<br>• complex transmission dynamics (animal reservoirs, environmental transmission, metapopulation dynamics, sexually transmitted diseases) | *Computer Tutorial:*<br>(SIR) modeling of infectious diseases using R | *Readings:*<br>Klepac et al. 2013.<br>Cobey 2000.<br><br>***Homework Jan-15:***<br>Build a model diagram for your disease of interest and define its states and processes.<br><br>(*due on Mon, Jan 15*) |
| **Friday, January 12** | Course field trip to Amsterdam Institute for Global Health and Development. Paired with visit to Museum Vrolik. | | Atwell et al. 2918<br>GlobalTBReport2023 |
| ***<u>Week Two: Applications of transmission modeling to diseases of global health concern</u>*** | | | |
| **Monday, January 15** | *Transmission dynamics and interventions for HIV and TB*<br>• history of HIV, with emphasis on past and present dynamics in LMICs, particularly Sub-Saharan Africa<br>• application of transmission models to understanding and intervening in HIV spread<br>• coupled dynamics of HIV and TB in LMICs | *Activity:*<br>Model Telephone<br><br>*Computer Tutorial:*<br>Compartmental modeling of HIV in Harare via ShinyApp | *Readings:*<br>Hargrove et al. 2011.<br>Corbett et al. 2004.<br><br>***Homework Jan-16:***<br>Refine your model diagram after today's 'Model Telephone' activity.<br><br>(*updated Model Diagram due on Tues, Jan 16*) |
| **Tuesday, January 16** | *Transmission dynamics and interventions for vector-borne diseases*<br>• biology of malaria and impact on human evolution | *Activity:*<br>Writing equations for a model world<br><br>*Computer tutorial:* | *Readings:*<br>Mordecai et al. 2012.<br>Katzelnick et al. 2017.<br><br>***Homework Jan-17:*** |

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| | • models of malaria and challenges to control<br>• biology of dengue and challenges to control<br>• brief overview of other VBDs<br>• impacts of climate change on VBD transmission | Live coding – constructing an infectious disease transmission model | Write out the equations for your model.<br><br>(*due on Wed, Jan 17*) |
| **Wednesday, January 17** | *Transmission dynamics and interventions to control zoonotic diseases (case study: rabies)*<br>• key terms in understanding zoonotic diseases: reservoir vs. spillover hosts, maintenance vs. target populations<br>• reservoir culling and vaccination<br>• population biology of rabies persistence and elimination | *Computer tutorial:*<br>Fitting models to data – follow up from Epidemic Cards<br><br>*Activity:*<br>Refining your model equations in partner pairs | *Readings:*<br>Lembo et al. 2008.<br>Hampson et al. 2009.<br><br>***Homework Jan-19:***<br>Build your transmission model in R.<br><br>(*draft R script due on Friday, Jan 19*) |
| **Thursday, January 18** | *Transmission dynamics and interventions for diseases of the poor (case studies: helminths, poverty traps*<br>• transmission and control of schistosomiasis<br>• hygiene hypotheses<br>• poverty traps and social-ecological systems | *Computer tutorial:*<br>Coupled SIR models in social-ecological systems<br><br>*Mentored work time on your own projects.* | *Readings:*<br>Bonds et al. 2012<br>Sokolow et al. 2015.<br><br>*Homework Jan-19:*<br>Build your transmission model in R.<br><br>(*draft R script due on Friday, Jan 19*) |
| **Friday, January 19** | Course field trip to laboratory of Dr. Sylvain Hugel at the Université de Strasbourg. Dr. Hugel is co-director of the Edible Insect Farming Working Group within the Insects and People of the Southern Indian Ocean consortium (ipsio,org/superfood).<br><br>Paired with visit to the 'In the Days of AIDS' exhibit at the Museum of Contemporary and Modern Art in Strasbourg. | | *Readings: TBA*<br><br>*Homework:*<br>Work on your **Final Presentation** and **Final Model + Paper**.<br><br>(*final R script + paper + presentation due on Thurs, Jan 25*) |
| ***Week Three: Molecular epidemiology as a tool for global public health*** | | | |
| **Monday, January 22** | *Introduction to phyolgenetics*<br>history of phylodynamics as a field<br>• introduction to DNA, alignments, and phylogenies | *Activity:*<br>Building and interpreting simple maximum likelihood phylogenies using MEGA | *Readings:*<br>Grenfell et al. 2004.<br>Pybus & Rambaut 2009.<br><br>*Homework:*<br>Work on your **Final Presentation** and **Final Model + Paper**.<br><br>(*final R script + paper + presentation due on Thurs, Jan 25*) |

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| **Tuesday, January 23** | *Introduction to molecular epidemiology and phylodynamics*<br>• history of phylodynamics as a field<br>• zoonotic origins of SARS-CoV-2<br>• Nextstrain and GISAID<br>• global expansion of pathogen genomic sequencing in response to COVID-19 | *Activity:*<br>Building and interpreting TimeTrees using BEAST | *Readings:*<br>Pekar et al. 2022.<br>Tegally et al. 2022.<br><br>*Homework:*<br>Work on your **Final Presentation** and **Final Model + Paper**.<br><br>*(final R script + paper + presentation due on Thurs, Jan 25*) |
| **Wednesday, January 24** | *Next Generation Sequencing and Emerging Infectious Diseases*<br>• Sangar vs. Illumina vs. nanopore sequencing<br>• modern tools in pathogen surveillance<br>• Realtime outbreak response from NGS data | *Activity:*<br>Investigating novel viruses from Next Generation Sequencing data | *Readings:*<br>Gire et al. 2014.<br>Poon et al. 2016.<br><br>*Homework:*<br>Work on your **Final Presentation** and **Final Model + Paper**.<br><br>*(final R script + paper + presentation due on Thurs, Jan 25*) |
| **Thursday, January 25** | *Last day of class – hand in final code, final term papers, and give final presentations.* | | |

**Readings:**


Bartlett 1957. “Measles periodicity and community science.” *Journal of the Royal Statistical Society, Series A* 120 (1): 48-70.

Bellan, Steve E., et al. "How to make epidemiological training infectious." *PLoS Biology* 10.4 (2012): e1001295

Cobey, Sarah. "Modeling infectious disease dynamics." *Science* 368.6492 (2020): 713-714.

Corbett, Elizabeth L., et al. "Human immunodeficiency virus and the prevalence of undiagnosed tuberculosis in African gold miners." *American journal of respiratory and critical care medicine* 170.6 (2004): 673-679.

Gire, Stephen K., et al. "Genomic surveillance elucidates Ebola virus origin and transmission during the 2014 outbreak." *Science* 345.6202 (2014): 1369-1372.

Graham, Andrea L. "Ecological rules governing helminth–microparasite coinfection." *Proceedings of the National Academy of Sciences* 105.2 (2008): 566-570.

Grenfell, Bryan T., et al. "Unifying the epidemiological and evolutionary dynamics of pathogens." *science* 303.5656 (2004): 327-332

Hampson, Katie, et al. "Transmission dynamics and prospects for the elimination of canine rabies." *PLoS biology* 7.3 (2009): e1000053.

Hargrove, John W., et al. "Declining HIV prevalence and incidence in perinatal women in Harare, Zimbabwe." *Epidemics* 3.2 (2011): 88-94.

Katzelnick, Leah C., et al. "Antibody-dependent enhancement of severe dengue disease in humans." *Science* 358.6365 (2017): 929

Kilpatrick, A. M. and Altizer, S., Disease Ecology. *Nature Education Knowledge* 1 (11), 13 (2010).

Klepac, Petra, et al. "Towards the endgame and beyond: complexities and challenges for the elimination of infectious diseases." *Philosophical Transactions of the Royal Society B: Biological Sciences* 368.1623 (2013): 20120137.

Lembo, Tiziana, et al. "Exploring reservoir dynamics: a case study of rabies in the Serengeti ecosystem." *Journal of Applied Ecology* 45.4 (2008): 1246-1257.

Mordecai, Erin A., et al. "Optimal temperature for malaria transmission is dramatically lower than previously predicted." *Ecology letters* 16.1 (2013): 22-30.

Pekar, Jonathan E., et al. "The molecular epidemiology of multiple zoonotic origins of SARS-CoV-2." *Science* 377.6609 (2022): 960-966.

Poon, Art FY, et al. "Near real-time monitoring of HIV transmission hotspots from routine HIV genotyping: an implementation case study." *The lancet HIV* 3.5 (2016): e231-e238.

Pybus, Oliver G., and Andrew Rambaut. "Evolutionary analysis of the dynamics of viral infectious disease." *Nature Reviews Genetics* 10.8 (2009): 540-550.

Sokolow, Susanne H., et al. "Reduced transmission of human schistosomiasis after restoration of a native river prawn that preys on the snail intermediate host." *Proceedings of the National Academy of Sciences* 112.31 (2015): 9650-9655.

Swinton, et al. "Persistence thresholds for phocine distemper virus infection in harbour seal Phoca vitulina metapopulations." *Journal of Animal Ecology* 67.1 (1998): 54-68.

Tegally, Houriiyah et al. “The evolving SARS-CoV-2 epidemic in Africa: Insights from rapidly expanding genomic surveillance.” *Science* 378.6615 (2022): eabq5358.