

## PHC 7858: Causal Artificial Intelligence for Health Research

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**Department of Health Outcomes and Biomedical Informatics and  
Department of Epidemiology  
College of Medicine and College of Public Health and Health Professionals  
University of Florida**

**CREDIT HOURS: 3**

**SEMESTER:** Fall 2022 [classes: Aug 24 – Dec 7, 2022; exams: Dec 10-16, 2022]

**DELIVERY FORMAT:** On-Campus

**TIME:** Mondays 9-11 am and Wednesdays 9-10 am

**LOCATION:** COMM (HSC) CG-041

**INSTRUCTORS**

**Instructor Name:** Jie Xu, PhD

**Room Number:** 2004 Mowry Road, Room 3226

**Phone Number:** 435-238-0199

**Email Address:** xujie@ufl.edu

**Office Hours:** Tue 9am-5pm (appointment is needed)

**Instructor Name:** Takis Benos, PhD

**Room Number:** 2004 Mowry Rd, Room 4210

**Phone Number:** 352-273-5048

**Email Address:** pbenos@ufl.edu

**Office Hours:** Tue 9am-5pm (appointment is needed)

**Teaching Assistant(s):** TBD

**Course listserv:** [tbd@lists.ufl.edu](mailto:tbd@lists.ufl.edu)

You will be added to the listserv automatically through ONE.UF.

**Preferred Course Communications:** Students may email the instructor with questions but are encouraged to consider whether their questions are of general interest to the entire class. Dedicated class time will be devoted to discussing and answering general questions about either course content or course mechanics that are relevant to all students.

**Prerequisites:**

Instructor approval.

**PURPOSE AND OUTCOME**

**Course Overview**

This course will cover foundational issues in “causal AI” embedding machine learning with causal inference methods on real-world data, and methodologies for automated causal learning. Health research approaches such as target trials, and transportability will be discussed. Artificial Intelligence fairness tackling health disparities and inequity will be explored.

### Relation to Program Outcomes

- Apply epidemiological methods to address critical and/or emerging public health and clinical research issues through the use of: (i) Appropriate epidemiological research designs; (ii) Advanced statistical analysis methods for health studies; (iii) Data structures and measurement methods for health research;
- Apply ethical thinking to a questionable ethics case from the current news

### Course Objectives and/or Goals

Upon completion of this course, students will have:

- Basic understanding how causal inference methods can be tailored to AI for biomedical and health research
- Deeper understanding of data quality, data bias, and bias structures in real-world, data-intensive clinical biomedical research
- Ability to use available causal AI data analysis techniques and tools apt for large collections of observational data (e.g., electronic health records)
- Exposure to cutting edge causal AI methods from the most recent literature

Note: This course focuses on the new development in causal AI and the increasingly large collections of observational data but does not give a full biostatistical perspective of causal inference for which we recommend PHC 6937 – Causal Inference (3 credits).

### Bloom's Taxonomy

- *Remembering*: be able to define causal effects using potential outcomes, become familiar with formal definitions and concepts of AI and causal inference;
- *Understanding*: describe the difference between association and causation, categorize and compare AI/causal methodologies and their applications in the bio-health domains;
- *Applying*: apply suitable methods for a given study design and dataset, express assumptions with causal graphs, implement several types of causal inference methods (e.g., matching, instrumental variables, inverse probability of treatment weighting);
- *Analyzing*: be able to explain results upon research questions, identify which causal assumptions are necessary for each type of statistical method;
- *Evaluating*: develop critical thinking and make judgement about the results;
- *Creating*: leverage the acquired expertise to formulate new research hypotheses and study plans, explore newer methods at the intersection of causal inference and machine learning.

**Instructional Methods:** Teaching methods include lecture, discussion, and hands-on data analysis exercises.

### DESCRIPTION OF COURSE CONTENT

**Overview:** Big data, high-performance computing, and artificial intelligence (AI)/(deep) machine learning are increasingly becoming key to precision health—both precision medicine (i.e., "the right treatments at the right time, every time to the right person") and precision public health (i.e., "the right intervention at the right time, every time to the right population")—from identifying disease risks and taking preventive measures, to making diagnoses and personalizing treatment for individuals and populations. Precision health, however, is not only about predicting risks and outcomes, but also about weighing interventions. Interventional clinical predictive models require the correct specification of cause and effect, and the calculation of so-called counterfactuals. In biomedical research, observational studies are commonly affected by confounding and selection bias. Data-driven prediction models are often mistakenly used to draw causal effects, but neither their parameters nor their predictions necessarily have a causal interpretation. When pursuing intervention modelling, the bio-health informatics community needs to employ causal approaches and learn causal structures.

## Topical Outline/Course Schedule

The course schedule is subject to change according to students' background and interests based on the survey conducted at the beginning of the class.

| Week | Date(s)       | Topic  | Readings         |       |
|------|---------------|--|------------------|-------|
| 1    | Aug 29        | Introductions, course mechanics/overview, and formal definitions for AI and causality/inference methods          | Ref. 3 (ch. 1-3) | TB&JX |
| 2    | Aug 31, Sep 7 | Randomized experiments vs. observational studies, intervention vs. conditional probabilities                     | Ref. 3 (ch. 1-3) | TB    |
| 3    | Sep 12, 14    | Graphical representation of causal structures and pathways: Bayesian networks and directed acyclic graphs (DAGs) | Ref. 3 (ch.1-3)  | TB    |
| 4    | Sep 19, 21    | Types of bias: confounding, collider bias, M-bias  | Ref. 3 (ch.1-3)  | TB    |
| 5    | Sep 26, 28    | Total vs. direct causal effects, effect modification (mediators and moderators), interactions                    | Ref. 3 (ch.1-3)  | TB    |
| 6    | Oct 3, 5      | Introduction to d-calculus and adjustment criteria   | Ref. 3 (ch.6)    | TB    |
| 7    | Oct 10, 12    | Counterfactual prediction: individual treatment effects (ITE) vs. average treatment effects (ATE)                | Ref. 7           | JX    |
| 8    | Oct 17        | Introduction to DAG structure learning, e.g. PC algorithm  | Ref. 3 (ch.4, 7) | TB    |
| 9    | Oct 19        | Midterm presentation   | NA               | TB&JX |
| 10   | Oct 24, 26    | Propensity scores and inverse probability weighting  | Ref. 8           | JX    |
| 11   | Oct 31, Nov 2 | Trial emulation with real-world data   | Ref. 9           | JX    |
| 12   | Nov 7, 9      | Counterfactuals prediction with machine learning, e.g. deep counterfactual networks, virtual twin forests        | Ref. 3 (ch.5, 8) | JX    |
| 13   | Nov 14, 16    | Transportability/prediction invariance   | Ref. 6           | JX    |
| 14   | Nov 21, 28    | Algorithmic fairness, health disparities, and inequity   | Ref. 5           | JX    |
| 15   | Nov 30        | Computer walk in session and office hours for final project  | NA               | TB&JX |
| 16   | Dec 5, 7      | Course project final presentations   | NA               | TB&JX |

## Course Materials and Technology

1. (Optional) Pearl J. Causality: Models, Reasoning and Inference. 2nd ed. Cambridge. ISBN 978-0521895606.
2. (Optional) Pearl J, Glymour M, Jewell N. Causal Inference in Statistics - A Primer. 1st ed. Wiley. ISBN 978-1119186847.
3. (Free) Peters J, Janzing D, Scholkopf B. Elements of Causal Inference, Foundations and Learning Algorithms. Available at <https://library.oapen.org/bitstream/handle/20.500.12657/26040/11283.pdf>
4. (Free) Hardt M, Recht B. PATTERNS, PREDICTIONS, AND ACTIONS A story about machine learning. Available at <https://mlstory.org/>.
5. (Free) Barocas S, Hardt M, Narayanan A. Fairness and machine learning Limitations and Opportunities. Available at <https://fairmlbook.org/>.
6. Transportability: <https://www.pnas.org/content/113/27/7345>
7. Tutorial on treatment effect estimation: <https://www.vanderschaar-lab.com/individualized-treatment-effect-inference/>
8. Review paper: <https://ascpt.onlinelibrary.wiley.com/doi/full/10.1002/cpt.1907>
9. Target trial: <https://academic.oup.com/aje/article/183/8/758/1739860>
10. Other articles relevant to the course will be made available.

Students should have access to computing equipment for running code scripts, but are not necessarily required to bring laptops in class.

During the course, R and Python (both free software) code scripts will be used as examples, and all scripts will be made available for replication after class.

For technical support for this class, please contact the UF Help Desk at:

- [helpdesk@ufl.edu](mailto:helpdesk@ufl.edu)
- (352) 392-HELP - select option 2
- <https://helpdesk.ufl.edu/>

### **Additional Academic Resources**

- [Career Connections Center](#): Reitz Union Suite 1300, 352-392-1601. Career assistance and counseling services.
- [Library Support](#): Various ways to receive assistance with respect to using the libraries or finding resources.
- [Teaching Center](#): Broward Hall, 352-392-2010 or to make an appointment 352- 392-6420. General study skills and tutoring.
- [Writing Studio](#): 2215 Turlington Hall, 352-846-1138. Help brainstorming, formatting, and writing papers.
- Student Complaints On-Campus: [Visit the Student Honor Code and Student Conduct Code webpage for more information](#).
- On-Line Students Complaints: [View the Distance Learning Student Complaint Process](#).

## **ACADEMIC REQUIREMENTS AND GRADING**

### **Assignments**

#### Homework Assignments:

Assignments are reading relevant papers (6) in the field and lead in-class discussions. Students will be asked to read articles in topics related to causal AI for health research and be prepared to lead the discussion in the next course.

#### Course Project:

The final product of the course is a technical report/term paper on topics relevant to the course, which consists of 65% of overall the grade. You can collaborate with other students as a team. However, each team can have up to two (2) members. Exception can only be made with written explanation and subject to the instructor's approval. And, please clearly delineate roles and responsibilities of each team member. Your final grade of the course project will be adjusted based on your contribution (e.g., merely presenting the project in the final presentation is NOT a contribution).

Students will be asked to conduct a case study using the methods and tools learned from this course (or a review of literature relevant to specific area of the course) and write a technical report (or a term paper). You are encouraged to come up novel ideas related to the course. You will conduct extensive background research (e.g., literature review), and you are expected to write a project proposal and give a presentation during the midterm. Please follow the requirements below for the project proposal and presentation.

#### Project Proposal Requirements:

- Cover Page: Include title and list of team members.
- Abstract: Up to 1 page. Explain the motivation for the work to be accomplished.
- Project description: Up to five (10) pages, and please include the following:
  - Specific Aims/Objectives
  - Background and Significance
  - Approach/Research Design (preliminary data and analysis if applicable)
  - Timeline
- Literature cited (no page limit); please follow the JAMIA style.

Proposals must use single column and double spacing; font size no smaller than 11 point; tables and figure labels can be in 10 point; minimum 0.5 inch margins.

Midterm (Proposal) Presentation:

- Up to fifteen (15) slides and no more than 20 minutes of presentation with 10 minutes Q&A.
- Please send the slides to the instructor at least three (3) days in advance.

Each project team is expected to turn in a final project report, associated code and datasets (or reference to used datasets), and a group presentation.

Project Report Requirements:

The project report can be up to ten (20) pages (excluding references), and please structure the report to include:

- Title (14 point typeface) and names of each team member
- Abstract: no more than 1 page summarizing the project.
- Introduction: background and objective(s) of the study.
- Methods: design, setting, and approaches.
- Results: key findings
- Discussion: key conclusions with direct reference to the implications of the methods and/or results.
- References: please follow the JAMIA style.

Final Project Presentation:

- Up to fifteen (25) slides and no more than 30 minutes of presentation with 10 minutes Q&A.
- Please send the slides to the instructor at least three (3) days in advance.

**Grading**

| Requirement   | Due Date    | % of Final Grade |
|---|-------------|------------------|
| Attendance  | Weekly      | 5%               |
| Homework assignments  | Fortnightly | 30%              |
| Midterm (proposal for the technical report/term paper and presentation) | Week 9      | 25%              |
| Final (technical report and presentation)                               | Week 16     | 40%              |

**Grading Scale**

| Percentage Earned | Letter Grade |
|-------------------|--------------|
| 95-100            | A            |
| 90-94             | A-           |
| 87-89             | B+           |
| 83-86             | B            |
| 80-82             | B-           |
| 77-79             | C+           |
| 73-76             | C            |
| 70-72             | C-           |
| 67-69             | D+           |
| 63-66             | D            |
| 60-62             | D-           |
| Below 60          | E            |

Please be aware that a C- is not an acceptable grade for graduate students. The GPA for graduate students must be 3.0 based on 5000 level courses and above to graduate. A grade of C counts toward a graduate degree only if based on credits in courses numbered 5000 or higher that have been earned with a B+ or higher.

| Letter Grade | Grade Points |
|--------------|--------------|
| A            | 4.0          |
| A-           | 3.67         |
| B+           | 3.33         |
| B            | 3.0          |
| B-           | 2.67         |
| C+           | 2.33         |
| C            | 2.0          |
| C-           | 1.67         |
| D+           | 1.33         |
| D            | 1.0          |
| D-           | 0.67         |
| E            | 0.0          |
| WF           | 0.0          |
| I            | 0.0          |
| NG           | 0.0          |
| S-U          | 0.0          |

More information on UF grading policy may be found at:

[UF Graduate Catalog](#)  
[Grades and Grading Policies](#)

#### **Policy Related to Make up Work**

Students are allowed to make up work only as the result of illness or other unanticipated circumstances. In the event of such emergency, documentation will be required in conformance with University policy. Work missed for any other reason will earn a grade of zero.

#### **Policy Related to Required Class Attendance**

Class attendance is mandatory. Excused absences follow the criteria of the UF Graduate Catalogue (e.g., illness, serious family emergency, military obligations, religious holidays), and should be communicated to the instructor prior to the missed class day when possible. UF rules require attendance during the first two course sessions. Missing more than three scheduled sessions will result in a failure. Regardless of attendance, students are responsible for all material presented in class and meeting the scheduled due dates for class assignments. Finally, students should read the assigned readings prior to the class meetings and be prepared to discuss the material for each session.

Excused absences must be consistent with university policies in the Graduate Catalog (<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#attendance>). Additional information can be found here: <https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>

### **STUDENT EXPECTATIONS, ROLES, AND OPPORTUNITIES FOR INPUT**

#### **Expectations Regarding Course Behavior**

We expect polite, inclusive and active participation to the classes respecting civil rules and UF academic regulations (see next sections).

Cell phones should be silenced during class, and their usage should be minimal unless related to class activity (e.g. typing notes).

Use of recording devices is not allowed unless pre-agreed with the instructor, the students, and vetted by the program director.

### **Communication Guidelines**

All members of the class are expected to follow rules of common courtesy in all email messages, threaded discussions, and chats. The first instance of clearly rude and/or inappropriate behavior will result in a warning. The second instance will result in a deduction of five percentage points from your overall grade. The third instance will result in a drop of a letter grade (A to B, A- to B-, and so on).

### **Students Requiring Accommodations**

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the [Disability Resource Center](#). It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

### **Course Evaluation**

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. [Click here for guidance on how to give feedback in a professional and respectful manner](#). Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via [ufl.bluera.com/ufl/](http://ufl.bluera.com/ufl/). [Summaries of course evaluation results are available to students here](#).

### **University Honesty Policy**

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." [The Honor Code](#) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

### **Software Use**

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

### **Student Privacy**

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see the [Notification to Students of FERPA Rights](#).

### **Policy Related to Guests Attending Class:**

Only registered students are permitted to attend class. However, we recognize that students who are caretakers may face occasional unexpected challenges creating attendance barriers. Therefore, by exception, a department chair or his or her designee (e.g., instructors) may grant a student permission to bring a guest(s) for a total of two class sessions per semester. This is two sessions total across all courses. No further extensions will be granted. Please note that guests are **not** permitted to attend either cadaver or wet labs. Students are responsible for course material regardless of attendance. For additional information, please review the Classroom Guests of Students policy in its entirety. Link to full policy:

<http://facstaff.php.ufl.edu/services/resourceguide/getstarted.htm>

### **Inclusive Learning Environment**

Public health and health professions are based on the belief in human dignity and on respect for the individual. As we share our personal beliefs inside or outside of the classroom, it is always with the understanding that we value

and respect diversity of background, experience, and opinion, where every individual feels valued. We believe in, and promote, openness and tolerance of differences in ethnicity and culture, and we respect differing personal, spiritual, religious and political values. We further believe that celebrating such diversity enriches the quality of the educational experiences we provide our students and enhances our own personal and professional relationships. We embrace The University of Florida's Non-Discrimination Policy, which reads, "The University shall actively promote equal opportunity policies and practices conforming to laws against discrimination. The University is committed to non-discrimination with respect to race, creed, color, religion, age, disability, sex, sexual orientation, gender identity and expression, marital status, national origin, political opinions or affiliations, genetic information and veteran status as protected under the Vietnam Era Veterans' Readjustment Assistance Act." If you have questions or concerns about your rights and responsibilities for inclusive learning environment, please see your instructor or refer to the Office of Multicultural & Diversity Affairs website:

[www.multicultural.ufl.edu](http://www.multicultural.ufl.edu)

### **Campus Resources:**

#### Health and Wellness

##### **U Matter, We Care:**

If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) or 352 392-1575 so that a team member can reach out to the student.

**Counseling and Wellness Center:** [counseling.ufl.edu/cwc](http://counseling.ufl.edu/cwc), and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

##### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or [police.ufl.edu](http://police.ufl.edu).

#### Academic Resources

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto:Learning-support@ufl.edu).

**Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling.

**Library Support**, Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.

**Writing Studio**, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers.

**[Student Complaints Campus](#)**

**[On-Line Students Complaints](#)**