Philosophy 435/635: Direction of Time, Fall 2010
M 1:30-3:20, CT Hall 104
Professor J. North (jill.north@yale.edu)

We will focus on the following problem: How can we explain the temporal asymmetries we experience in everyday life—that coffee cools and ice melts, not the reverse; we have memories of the past and not the future; we can causally affect the future but not the past—when the underlying physical laws are symmetric in time? Is there a unified explanation for the different asymmetries we experience? If so, does this suggest that time itself has a direction? We will also examine the probabilities that appear in the resulting explanations: how should we understand these probabilities metaphysically, and what does this tell us about the status of statistical mechanics as a scientific theory?

Readings

David Albert, *Time and Chance*, available at Labyrinth
All other readings are available on the classes server or online at an address given below. Note: readings listed as "optional" really are that; they contain additional background or material for further thought, including paper topics.

Prerequisites

At least a strong high school physics class. Exposure to basic concepts of calculus is helpful, but not required. If you are unsure whether your background is sufficient, please discuss with me.

Requirements and grading

Attendance and participation; weekly reading. Attendance and participation will count for 10% of your final grade. Participation in class discussion can only help your grade; low participation will not hurt it. Poor attendance may lower your grade.
Written work. Three options for a take-home midterm and/or final assignment:

1. Take-home midterm and final exams. Each exam will comprise around 5 questions with two-page answers each; the exams count equally toward your final grade. The midterm will be handed out in class on October 11 and is due in class on October 25. The final will be handed out in class on November 29 and is due by email by 5pm on December 13.

2. Take-home midterm as above and final paper of 8-10 pages, on a topic of your choice, due by email by 5pm on December 13. Each assignment counts equally toward your final grade.

3. Final paper, about 20 pages, on a topic of your choice, due by email by 5pm on December 13.

Options 1 and 2 are open to all students in the class. My permission is required for option 3. Paper topics must be discussed with me in advance.

Problem sets. There will be a few problem sets throughout the semester for practice with the physics. The problem sets will be graded on a credit/no credit basis. They won't factor into your final grade, but you must do them in order to get credit for the class.

Office hours: Monday 12:30-1:30pm, 405a CT Hall

Schedule

This is a tentative schedule. Details are subject to change during the semester. Readings are listed next to the date on which they will be discussed. If you miss a class, it is *your responsibility* to get notes and announcements from a classmate.

Class 1, September 6: Introduction

Explanation of the problem. Symmetry of fundamental laws, asymmetry of macroscopic phenomena. Asymmetries in phenomena vs. asymmetry of time.

B. Greene, "Chance and the Arrow," through p. 5 of the pdf
H. Price, "The View from Nowhen"

Optional:

C. Callender, "Thermodynamic Asymmetry in Time" (contains an overview of many topics we'll be discussing throughout the class), available at http://plato.stanford.edu/entries/time-thermo/
J. North, "Time in Thermodynamics," through section 2

Class 2, September 13: Time reversal invariance and the existence of instantaneous velocities

What is it for a physical theory to be symmetric in time? Is classical mechanics time reversal invariant? Is classical electromagnetism? What does the time reversal (a)symmetry of a theory tell us about the structure of time itself? If a theory is not symmetric under time reversal, does this indicate that time has an "arrow," an objective distinction between past and future underlying our subjective experience of a distinction between the two? More generally, what are the fundamental quantities according to a given physical theory, and what do these tell us about the symmetries of the theory and the world it describes?

Problem set 1 handed out; due in class September 20.

D. Albert, ch. 1: Time-Reversal Invariance

F. Arntzenius, "Are There Really Instantaneous Velocities?", especially sections 1-4 (we likely won't have time to discuss the rest)

Optional:

S. Smith, "Are Instantaneous Velocities Real and Really Instantaneous?: An Argument for the Affirmative"

F. Arntzenius, "An Arbitrarily Short Reply to Sheldon Smith on Instantaneous Velocities"

K. Hutchison, "Is Classical Mechanics Really Time-Reversible and Deterministic?"

C. Callender, "The Metaphysics of Time Reversal: Hutchison on Classical Mechanics"

J. Carroll, "Instantaneous Motion"

Class 3, September 20: Time reversal and indeterministic theories

The standard account of time reversal must be modified for indeterministic theories. What it is for an indeterministic theory to be symmetric under time reversal, and what does this tell us about the structure of time itself? Is there an important difference here from the deterministic case? Do chances themselves develop asymmetrically in time? (More on this last question November 15.)

Problem set 1 due in class.

F. Arntzenius, "Mirrors and the Direction of Time"

Optional:

F. Arntzenius, "Indeterminism and the Direction of Time"

Class 4, September 27: Time reversal transformations in general

What is the proper test for whether a physical theory is time reversal symmetric? Is the standard account correct, or is there a better time reversal transformation available? What considerations should guide us in making this decision? Does anything important hinge on the answer?

J. North, "Two Views on Time Reversal"

Optional:

D. Malament, "On the time reversal invariance of classical electromagnetic theory." (This paper is hard. Sections 1-2 are easiest, and contain a nice picture of Albert's view. I will explain the relevant parts in class.)

S. Leeds, "Malament on Time Reversal"

F. Arntzenius and H. Greaves, "Time Reversal in Classical Electromag-

netism"

Class 5, October 4: Thermodynamics and statistical mechanics

Overview of thermodynamics and statistical mechanics. The second law, entropy, Maxwell's demon, phase space, probability in statistical mechanics.

Problem set 2 handed out; due in class October 11.

D. Albert, ch. 2: Thermodynamics
D. Albert, ch. 3: Statistical Mechanics

Optional:

C. Callender, "Reducing Thermodynamics to Statistical Mechanics: The Case of Entropy"
B. Greene, "Chance and the Arrow," pp. 5-11
J. North, "Time in Thermodynamics," sections 3-4

Class 6, October 11: The past hypothesis

Can classical statistical mechanics account for the thermodynamic asymmetry? The reversibility objections; the past hypothesis and objections.

Problem set 2 due in class.

Midterm exam handed out; due in class October 25.

D. Albert, ch. 4: The Reversibility Objections and the Past Hypothesis
H. Price, "'More Apt to Be Lost than Got': The Lessons of the Second Law"

Optional:

R. Feynman, ch. 5 of *The Character of Physical Law*
B. Greene, "Chance and the Arrow," pp. 11-18
S. Goldstein, "Boltzmann's Approach to Statistical Mechanics"
J. North, "Time in Thermodynamics," section 5.1
C. Callender, "Measures, Explanation and the Past: Should 'Special' Initial Conditions Be Explained?"
C. Callender, "The Past Hypothesis Meets Gravity"
J. Earman, "'The Past Hypothesis': Not Even False"
D. Parker, "Thermodynamic Irreversibility: Does the Big Bang Explain What It Purports to Explain?"
H. Price, "Arrows and Errors in Contemporary Cosmology"
R. Wald, "The Arrow of Time and the Initial Conditions of the Universe"
D. Wallace, "Gravity, Entropy, and Cosmology: In Search of Clarity"

E. Winsberg, "Can Conditioning on the 'Past Hypothesis' Militate Against the Reversibility Objections?"

Class 7, October 18: Quantum mechanics and thermodynamics

Does quantum mechanics make a difference to the explanation of thermodynamics? Overview of quantum mechanics and Albert's argument that it does.

D. Albert, ch. 7: Quantum Mechanics

Optional:

J. North, "Time in Thermodynamics," section 5.2
C. Callender, "Is Time 'Handed' in a Quantum World?"
H. Price, "Boltzmann's Time Bomb"
J. North, "What is the Problem about the Time-Asymmetry of Thermodynamics?—A Reply to Price"

Class 8, October 25: The wave asymmetry

Waves diverge from their sources; we never see them converge on their sources. For example, if we drop a pebble in a pond, we will see waves ripple outwards to the edge of the pond *after* we drop the pebble, not before. How can we explain this asymmetry when the laws governing waves are symmetric in time? Is there a similar explanation to that of the other asymmetries we've seen?

Midterm exam due in class.

M. Frisch, "(Dis-)Solving the Puzzle of the Arrow of Radiation"
J. North, "Understanding the Time-Asymmetry of Radiation"

Optional:

M. Frisch, "A Tale of Two Arrows"
H. Price, "Recent Work on the Arrow of Radiation"

Class 9, November 1: The counterfactual asymmetry

If I were to do something different now, the future, but not the past, would be different. How can we explain the fact that the future counterfactually depends on the past, and not vice versa? Can we account for this asymmetry in a similar way to the explanations of other asymmetries? (We will continue discussing these questions in the following class. This class, we will focus on Lewis' account of the counterfactual asymmetry and Elga's objection to it stemming from statistical mechanics. Next time we will look in more detail at the positive account of the asymmetry stemming from the Past Hypothesis.)

Problem set 3 handed out; due in class November 8.

D. Lewis, "Counterfactual Dependence and Time's Arrow"
A. Elga, "Statistical Mechanics and the Asymmetry of Counterfactual Dependence"

Optional:

D. Lewis, "Counterfactual Dependence and Time's Arrow" postscripts
M. Frisch, "Counterfactuals and the Past Hypothesis"
D. Kutach, "The Entropy Theory of Counterfactuals"
B. Loewer, "Counterfactuals and the Second Law"

Class 10, November 8: The asymmetries of knowledge and intervention; the prospects for a universal statistical mechanics

How can we explain the fact that we have knowledge of the past and not the future, and that we can generally affect things in the future but not the past? How do these asymmetries relate to the asymmetry of counterfactuals? Can Albert's statistical mechanics explain all the macroscopic asymmetries we've considered so far? If so, then what is the status of this statistical mechanics as a scientific theory? Is it a special science, a fundamental theory, *the* fundamental scientific theory? Does the answer to this question depend on the metaphysics of the theory's probabilities?

Problem set 3 due in class.

D. Albert, ch. 6: The Asymmetries of Knowledge and Intervention
D. Albert, "Physics and Chance" (classes server)

Optional:

C. Callender, "What is 'The Problem of the Direction of Time'?"
C. Callender and J. Cohen, "Special Sciences, Conspiracy and the Better Best System Account of Lawhood"
M. Frisch, "Does a Low-Entropy Constraint Prevent Us from Influencing the Past?"
M. Frisch, "Causation, Counterfactuals, and Entropy"
A. Hájek, "Interpretations of Probability," available at http://plato.stanford.edu/entries/probability-interpret/
S. Leeds, "Foundations of Statistical Mechanics—Two Approaches"
B. Loewer, "Why There Is Anything Except Physics"
J. North, "Time in Thermodynamics," section 6
J. North, "An Empirical Approach to Symmetry and Probability"
J. Norton, "What Can We Learn about Physical Laws from the Fact that We Have Memories Only of the Past?"

Class 11, November 15: Time-asymmetric chances, deterministic chance, and the connection between chance and credence

Are there objective probabilities in the world? What is the relation between chance, or objective probability, and subjective probability, or credence (degree of belief)? Do chances develop asymmetrically in time, as Lewis' account suggests? If so, why do they? Can there be non-trivial chances in a deterministic world? How should we understand the relationship between chance and credence given Albert's theory of statistical mechanics?

D. Lewis, "A Subjectivist's Guide to Objective Chance", with postscripts

Optional:

L. Glynn, "Deterministic Chance"
J. Ismael, "Probability in Deterministic Physics"
B. Loewer, "Determinism and Chance"
T. Maudlin, "What Could Be Objective about Probabilities?"
C. Meacham, "Three Proposals Regarding a Theory of Chance"
C. Meacham, "Two Mistakes Regarding the Principal Principle"
J. Schaffer, "Deterministic Chance?"

Class 12, November 29: The passage of time

Does the flow or passage of time account for our experience of an asymmetry between the past and the future? Does time's passage presuppose an objective distinction between the two directions, an objective arrow of time?

B. Greene, "The Frozen River"
T. Maudlin, "On the Passing of Time"
Optional:
B. Skow, "What Makes Time Different from Space?"

Final paper or exam Due by 5pm on December 13. No extensions. The exam will be handed out in class on November 29. Final assignments must be emailed to me.

Note: I will not be on campus after December 2. If you wish to meet with me in person to discuss your final paper or exam, we must schedule a meeting for the last week of classes. After that, I will be available to discuss your final assignments by email or Skype.