# Computational foundations of mind, evolution, and society*

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**Abstract**

This two-part course focuses on the key insight into the nature of mind and society — namely, that minds and their social dynamics are fundamentally computational processes and can only be ultimately understood as such. NOTE: each of the two parts will be graded separately, as explained below.

## 1 Part I: Computing the mind

The first, foundational part of the course states, motivates, and supports the idea that cognition (in all its aspects, including emotions, consciousness, etc.) reduces to computation [Edelman, 2008, 2012]. Students are introduced to a number of conceptual tools for thinking about natural behavior and the cognitive information processing that underlies it, including statistical learning from experience and the use of patterns distilled from past experience in guiding future actions. The application of these tools to the understanding of natural minds and to advancing the goals of artificial intelligence (AI) is illustrated on selected examples drawn from the domains of perception, memory, language, problem solving, decision making, reasoning, intelligence, and creativity. The material is conceptually advanced and moderately technical. It is based on readings drawn from a **textbook** that has been written by the instructor especially for his course at Cornell: *Computing the Mind: How the Mind Really Works* (Oxford University Press, 2008).

### 1.1 Key information

- The website for this part of the course is here: `http://kybele.psych.cornell.edu/~edelman/Computing-the-Mind`
- The **prerequisite** for this part of the course is prior exposure to basic science and to working with data (statistics). Reading comprehension and speaking fluency in English is an absolute requirement.
- The course will be taught over a period of 6 weeks, 5 days/week, in 1.5-hour units, for a total of 45 hours (see the list of units below).[1]

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[1] For reference purposes, a standard 14-week version of this course as it has been taught at Cornell University — Psych 3140/6140 Computational Psychology — can be found here.

- The required **readings** for each unit are drawn from the textbook (the list appears in the next section). To best prepare for this course, read it ahead of time, then reread each section before the corresponding material is discussed in class.
- **To get CREDIT, you must:**
  1. *Before each lecture*, read the assigned material, have a look at the slides, and write down a question or two.
  2. *During the lecture*, ask any questions that you may have.
  3. *At the end of each unit*, submit the **unit question** via email to the TA (with a copy to the instructor). These questions will be graded on a scale of 0 to 3 (0 = missing question; 3 = perfect question) and will count towards the final grade (see below).
  4. *At the end of the course*, write and submit via email to the TA (with a copy to the instructor) your **research paper** (between 1000 and 2000 words, in pdf) summarizing your lessons and thoughts about the material that has been covered in this part of the course.
- The final **grade** for this part of the course will be determined by the 20 unit questions (3% each, for a total of 60%) and the final paper (40%).

## 1.2 The units

The material is divided into 20 units. Following is the list of unit topics, along with the textbook sections that you must read for each unit:

1. The subject matter of psychology. The fundamentality of computation. [1.1–1.3]
2. The blind men and the elephant. [2.1–2.5]
3. The Marr-Poggio research program and methodology. [4.1-4.3]
4. Perception I: representation spaces. [5.1, 5.2]
5. Probability and the Bayes Theorem. [A.1]
6. Perception II: constancies, learning and generalization. [5.3, 5.4]
7. Perception III: perceptual truth. [5.5]
8. Managing action; motor control. [6.3, 8.4]
9. Action and reward; reinforcement learning. []
10. Language I. [7.1]
11. Language II. [7.2, 7.3]
12. Language III. [7.5]
13. Graphical models; reasoning. [8.3]
14. Induction, general intelligence, and IQ. [8.5]

15. Problem solving I. [8.2]

16. Problem solving II. Analogy, and creativity. [8.5]

17. Neural computation I: tuning. [3.1]

18. Neural computation II: assemblies and readout.

19. Neural computation II: learning, timing, dynamics. [3.3]

20. Brains vs. computers: a perspective on AI.

# 2 Part II: Computing societies

The second part of the course focuses on the role of computational simulation in two disciplines — evolutionary science and sociology — which are both uniquely important to the understanding of the world we live in, and at the same time uniquely difficult to study by the traditional scientific method, which tries to derive mathematical models from experimental data. In both these domains of study, scientists often resort to simulation, using an agent-based modeling (ABM) approach. In evolutionary ABM, simulated actors (agents) carrying various traits of interest share an environment in which they undertake actions and compete for resources. The agent's cumulative outcomes determine its fitness, which in turn affects its chances for reproduction. The effectiveness of traits can then be assessed by tracking their prevalence in the population over evolutionary time. Similarly, in computational social science, the ABM approach involves simulated agents with controlled cognitive abilities, "personalities," and interpersonal attitudes. The social dynamics that arises out of the agents' interactions is then analyzed and used to support theory development.

## 2.1 Key information

- The website for this part of the course is here:
  `http://kybele.psych.cornell.edu/~edelman/Computing-Societies`
- As with Part I, reading comprehension and speaking fluency in English is an absolute requirement.
- The course will be taught over a period of 6 weeks, 5 days/week, in 1.5-hour units, for a total of 45 hours (see separate detailed schedule).
- The required **readings** are academic papers, which are available in PDF format, as a zipped archive, here:
  `http://kybele.psych.cornell.edu/~edelman/Computing-Societies/readings.zip`. You should try to read each required paper *before* its assigned date, but please note that these papers will be thoroughly explained and discussed in class. [Optional papers are… optional; if you do read them, you will have a deeper and broader grasp of the material.]
- **To get CREDIT, you must:**
  1. *Before each lecture*, read the assigned material, have a look at the slides, and write down a question or two.
  2. *During the lecture*, ask any questions that you may have.

3. *At the end of each unit*, submit the **unit question** via email to the TA (with a copy to the instructor). These questions will be graded on a scale of 0 to 3 (0 = missing question; 3 = perfect question) and will count towards the final grade (see below).
4. *At the end of the course*, write and submit via email to the TA (with a copy to the instructor) your **research paper** (between 1000 and 2000 words, in pdf) summarizing your lessons and thoughts about the material that has been covered.[2] You will briefly present your paper to the class during the last meeting.

- The final **grade** for this part of the course will be determined by the 19 unit questions (3% each, for a total of 57%) and the final paper (43%).

### 2.2 The units

The material is divided into 19 units (plus one unit for paper presentations). Following is the list of the 19 unit topics, along with the paper(a) that you must read for each unit:

1. General introduction. Cognitive psychology, social psychology, and sociology. *Nothing in biology makes sense except in the light of evolution* [Dobzhansky, 1973]. The multilevel nature of explanation in "special" sciences:
   - *Cause and effect in biology* [Mayr, 1961].
   - *On aims and methods in ethology* [Tinbergen, 1963].
   - *From understanding computation to understanding neural circuitry* [Marr and Poggio, 1977].
2. In-depth discussion: *The extended evolutionary synthesis: its structure, assumptions and predictions* [Laland, Uller, Feldman, Sterelny, Müller, Moczek, Jablonka, and Odling-Smee, 2015]; *Tinbergen's four questions: an appreciation and an update* [Bateson and Laland, 2013].
3. A view from cognitive and social psychology: *Computational models of collective behavior* [Goldstone and Janssen, 2005].
4. A view from sociology: *From factors to actors: computational sociology and agent-based modeling* [Macy and Willer, 2002].
5. Intro to ABM:
   - *A guide for newcomers to agent-based modeling in the social sciences* [Axelrod and Tesfatsion, 2006].
6. ABMs and complexity:
   - *Complexity: the bigger picture* [Vicsek, 2002].
7. ABM methodology:

[2] If you can program in Python and are familiar with the Mesa environment (see https://mesa.readthedocs.io/en/master/), you can submit an agent-based modeling (ABM) project instead of the final paper. Under this option, group projects (2-3 students per group) will be acceptable. Please contact the instructor for details if you choose this option.

- *Pattern-oriented modeling of agent-based complex systems: lessons from ecology* [Grimm, Revilla, Berger, Jeltsch, Mooij, Railsback, Thulke, Weiner, Wiegand, and DeAngelis, 2005].

8. Case study: civil violence.
    - *Modeling civil violence: an agent-based computational approach*, [Epstein, 2002].
9. Case study: learning social norms.
    - *Learning to be thoughtless: social norms and individual competition*, [Epstein, 2001].
10. Case study: political institutions.
    - *Political institutions and sorting in a Tiebout model*, [Kollman, Miller, and Page, 1997].
11. Case study: inequality.
    - *Inequality in nature and society* [Scheffer, van Bavel, van de Leemput, and van Nes, 2017].
12. Inequality (cont.):
    - *The spread of inequality* [Rogers, Deshpande, and Feldman, 2011].
13. Inequality (cont.):
    - *Computational justice: simulating structural bias and interventions* [Momennejad, Sinclair, and Cikara, 2019].
14. Case study: happiness.
    - *Between pleasure and contentment: evolutionary dynamics of some possible parameters of happiness* [Gao and Edelman, 2016a].
    - [OPTIONAL] Background reading (book): *The happiness of pursuit* [Edelman, 2012].
15. Happiness (cont.):
    - *Happiness as an intrinsic motivator in reinforcement learning* [Gao and Edelman, 2016b].
16. Case study: morality.
    - *Testing the theory of morality-as-cooperation in 60 societies* [Curry, Mullins, and Whitehouse, 2019].
    - [OPTIONAL] *The evolution of political systems* [Gintis, van Schaik, and Boehm, 2015].
17. Morality (cont.):
    - *The evolution of altruistic punishment* [Boyd, Gintis, Bowles, and Richerson, 2003, Boyd, Gintis, and Bowles, 2010].
18. Morality (cont.):
    - *Altruistic punishment and other theories* [Smirnova, 2019].

19. Morality (cont.):

    - *How selfish genes beget selfless beings: the evolution of conscience* [Smirnova and Odouard, 2020].

20. Project presentations.

## References


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