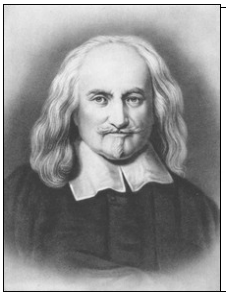

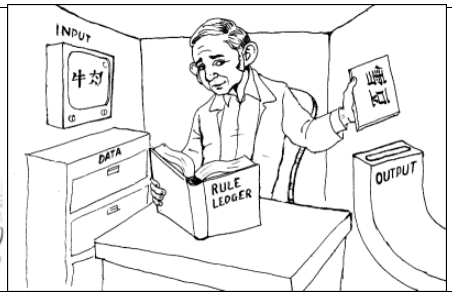

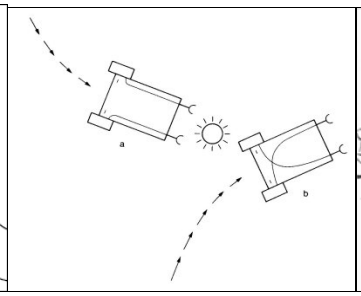
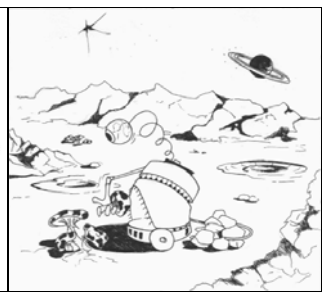

Animats, Minds, and Mobots (FYS 438)

Exploring Cognitive Science with Lego Robots

MW 2:40-4:00, Pettengill 127 & The Imaging Center (*the computer classroom*)

Professor William Seeley, 315 Hedge Hall
Office Hours, Fall 2016: MW 4:00-5:00 pm, F 2:00pm-4:00pm (Skype) & by appointment
wseeley@bates.edu

Course Description:
Philosophers have traditionally treated minds and bodies as somehow distinct, with the mind serving as the executive center, directing action by directing the activity of an otherwise passive body. *Embodied Cognition* is an alternative view within the field of cognitive science. The central claim of embodied cognition is that our bodies and minds have co-evolved as partners in cognition and behavior, and that the nature of intelligence and the structure of our minds are determined by the shapes of our bodies, by the ways different organisms have evolved to perceive and meaningfully engage with their environment. Minds and bodies are not distinct on this account, but rather our minds extend into our bodies. In this First Year Seminar we will use a series of autonomous robotics exercises developed for the Lego Mindstorms platform to explore this debate. The first half of the course covers conceptual issues. The second half of the course explores these conceptual issues through a series of robotics exercises. Along the way we will also introduce students to the role robotics research has played in the development of artificial intelligence and cognitive science.

Course Goals:
a) to introduce students to some of the central philosophical problems within cognitive science.
b) to introduce students to some fundamental design principles for autonomous robots that challenge standard philosophical solutions to these problems.
c) to develop foundational research and writing skills necessary to engage with a liberal arts curriculum.
d) TO PLAY WITH LEGOS!

Texts:
- *Vehicles: Experiments in Synthetic Psychology*, Valentino Braitenberg (Cambridge, MA: MIT Press, 1986). ***(V)***
- ebooks in the Ladd Library holding. ***(ebook)***
- online resources. ***(Onl)***
- electronic journal articles on Lyceum. **(*L)***

Requirements:
- ***Class participation***…class attendance, participation in discussion, & effort (10%).
- A **2 page free writing assignment** discussing the nature of intelligence (700-900 words) (10%)
- A **2 page d*escriptive writing assignment*** & ***rewrite*** (700-900 words) (10%).
- A **4 *page analysis paper*** & ***rewrite*** due early in the semester (20%).
- A ***6 page compare/contrast/synthesize paper*** due just before Thanksgiving (20%).
- A rewrite of your ***6 page compare/contrast/synthesize paper*** due the final day of classes (10%).
- A ***Robot Exercise Journal***: hands-on experience with autonomous agents (20%).
- A ***Robot Rodeo*** where we will celebrate the semester and you with present your group's successful robots.
- There is ***no final exam*** in this class.

SCHEDULE OF READINGS:

Lecture 0. **CONCEPTUAL ISSUES (Pettigrew)**
This session introduces a) a definition of intelligence as a capacity for flexible and adaptive autonomous problem solving, b) representational theories of mind & the mind body problem, c) the role bodies might play in thinking and intelligence, and c) a methodological distinction between analytic and synthetic psychology.

watch: The Cognitive Science Song (https://www.youtube.com/watch?v=XH42KFvnXyI)
watch: Rolf Pfeifer: Embodied Cognition (https://www.youtube.com/watch?v=mhWwoaoxIyc)
watch: Michael Dawson: Legos & Synthetic Psychology (https://www.youtube.com/watch?v=h8t9HBK15cU)

watch: Scientific American Frontiers: Natural Born Robots (Season 10, Episode 2)
http://www.chedd-angier.com/frontiers/season10.html

watch: Scientific American Frontiers: Games Machines Play (Season 12, Episode 8)
http://www.chedd-angier.com/frontiers/season12.html

watch: Scientific American Frontiers: Life's Big Questions (Season 12, Episode 3, 28:49-40:00)
http://www.chedd-angier.com/frontiers/season11.html

Lecture 1. **INTELLIGENCE & INTELLIGENT BEHAVIOR I (Seminar Room)**
This session opens discussion about a) the relationship between intelligence and behavior and b) the role perspective, or frames of reference, plays in characterizing a behavior as intelligent. We will use Darwin's discussion of the behaviors of earthworms as a case study.

- Charles Darwin, *The Formation of Vegetable Mould Through the Actions of Worms, with Observations on Their Habits* (http://www.biodiversitylibrary.org/title/48549#page/71/mode/1up), New York: D. Appleton and Company, 1896, 55-89. ***(ebook, Ladd Library)***
- George Zappler, "Darwin's Worms" *Natural History*, www.naturalhistorymag.com ***(web resource)***
  http://www.naturalhistorymag.com/htmlsite/master.html?http://www.naturalhistorymag.com/htmlsite/editors_pick/1958_11_pick.html

  - Yerkes RM. 1912. The intelligence of earthworms. Journal of Animal Behavior 2:322–352.
  - Rosenkoetter JS, Boice R. 1975. Earthworm pheromones and T-maze performance. Journal of Comparative and Physiological Psychology 88:904–910.

Lecture 2. **INTELLIGENCE & INTELLIGENT BEHAVIOR II (Seminar Room)**
This session extends the discussion of intelligent behavior to several primate studies: Kholer's discussion of the problem solving behaviors of chimpanzees and more recent work on the reasoning capacities of capuchins and cotton-topped tamarins.

- Wolfgang Kholer, *The Mentality of Apes*, *2nd Edition*, New York: Harcourt, Brace, & Company, 1927, 7-9; 39-45; 135-139. ***(L)***
- Clive D. L. Wynn, *Do Animals Think? (*Princeton, N.J.: Princeton University Press, 2004), 60-64. ***(L)***
- Scientific America Frontiers: Chimp Minds (Sseason 15, Episode 4)
  http://www.chedd-angier.com/frontiers/season15.html

Lecture 3. **THE INTENTIONAL STANCE (Seminar Room)**
This session continues the discussion of the relationship between intelligence and intelligent behavior. The goal of the session is to explore what Dan Dennett calls *the intentional stance* and evaluate how it shapes our concept of intelligence.

- Daniel Dennett, "True Believers: The Intentional Strategy and Why It Works," in ed. John Haugeland *Mind Design II* (Cambridge, MA: MIT Press, 1997), 57-65. ***(L)***

Lecture 4. **THE COMPUTATIONAL THEORY OF MIND: THE SYMBOL SYSTEM APPROACH (Seminar Room)**
This session introduces *the computational theory of mind* that has dominated modern philosophical thinking about intelligence and the classical *symbol system model* that serves as the foundation for much recent research in artificial intelligence and cognitive science.

- Thomas Hobbes, *The Metaphysical System of Hobbes in Twelve Chapters from Elements of Philosophy Concerning Body together with Briefer Extracts from Human Nature and Leviathan* (Chicago: Open Court, 1658/1913), chapter 1, 5-9. ***(ebook)***
  https://archive.org/stream/cu31924014604007#page/n35/mode/2up

- Thomas Hobbes, *Leviathan* (New York: Penguin, 1651/1968), chapter 5, 48-50. ***(ebook)***
  https://archive.org/stream/ost-history-leviathan/Leviathan#page/n45/mode/2up

- John Haugeland, "What Is Mind Design?" in ed. John Haugeland, *Mind Design II* (Cambridge, MA: MIT Press, 1997), 8-21. ***(L)***

Lecture 5. **THE COMPUTATIONAL THEORY OF MIND: THE SYMBOL SYSTEM APPROACH (Seminar Room)**
This session continues the discussion of *the computational theory of mind* that has dominated modern philosophical thinking about intelligence and the classical *symbol system model* that serves as the foundation for much recent research in artificial intelligence and cognitive science.

- Thomas Hobbes, *The Metaphysical System of Hobbes in Twelve Chapters from Elements of Philosophy Concerning Body together with Briefer Extracts from Human Nature and Leviathan* (Chicago: Open Court, 1658/1913), chapter 1, 5-9. ***(ebook)***
  https://archive.org/stream/cu31924014604007#page/n35/mode/2up

- Thomas Hobbes, *Leviathan* (New York: Penguin, 1651/1968), chapter 5, 48-50. ***(ebook)***
  https://archive.org/stream/ost-history-leviathan/Leviathan#page/n45/mode/2up

- John Haugeland, "What Is Mind Design?" in ed. John Haugeland, *Mind Design II* (Cambridge, MA: MIT Press, 1997), 8-21. ***(L)***

Lecture 6. **THE COMPUTATIONAL THEORY OF MIND: THE CHINESE ROOM PROBLEM (Seminar Room)**

This session introduces a standard objection to symbol system models in artificial intelligence. The argument suggests that the symbols and operations "in the head" of a symbol system are not meaningfully connected to the world they are taken to represent. If correct this would entail that the "thoughts" of these kinds of intelligent systems are not about the world they describe, and so can not constitute an understanding of either their world or their behaviors within it.

- John Searle, "Minds, Brains, & Programs," in ed. John Haugeland, *Mind Design II* (Cambridge, MA: MIT Press, 1997), 183-193 (exerpt). ***(L)***

- Rolf Pfeifer and Christian Scheir, "The Symbol Grounding Problem," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 69-71. ***(L)***

- Searle and the Chinese Room Argument, Parts 1 & 2, *The Mind Project: Consortium on Cognitive Science Instruction*. ***(Onl)***
  http://www.mind.ilstu.edu/curriculum/searle_chinese_room/searle_chinese_room.php

Lecture 7. **KNOWLEDGE REPRESENTATION, COMMON SENSE, AND THE FRAME PROBLEM (Seminar Room)**
This session introduces the frame problem as a second objection to symbol system models in artificial intelligence. The frame problem suggests that knowledge representation in symbol systems is too inflexible to model the smooth adaptability of everyday interactions with a dynamic environment. This has really been the sticking point for symbol system approaches and the point of departure for alternative approaches to artificial intelligence in autonomous robotics.

- Rolf Pfeifer and Christian Scheir, "The Frame Problem," *Understanding Intelligence* (Cambridge, MA: MIT Press, 1999), 63-69. ***(L)***

- Rolf Pfeifer and Christian Scheir, "The Problems of Embodiment and Situatedness," *Understanding Intelligence* (Cambridge, MA: MIT Press, 1999), 63-69. ***(L)***

- Jack Copeland, "Knowledge Representation" and "Micro-Worlds," *Artificial Intelligence: A Philosophical Introduction* (Malden, MA: Blackwell Publishers, 1993), 91-92. ***(L)***

  - *Optional:* Daniel C. Dennett, "Cognitive Wheels: The Frame Problem for AI," in Margaret C. Boden (ed.) *The Philosophy of Artificial Intelligence* (pp. 147-170). New York: Oxford University Press, 1990. ***(L)***

Lecture 8. **BEHAVIOR BASED ROBOTICS I (Seminar Room)**
The goal of this session is to introduce *Behavior Based Robotics* as an alternative to the computational theory of mind.

- Maja J. Mataric, "Don't Think, REACT!" in *The Robotics Primer* (Cambridge, MA: MIT Press, 2007), 161-176. ***(L)***
- Rodney Brooks, “Intelligence without Representation,” in ed. John Haugeland, *Mind Design II* (Cambridge, MA: MIT Press, 1997), 395-420. ***(L)***

Lecture 9. **BEHAVIOR BASED ROBOTICS II (Seminar Room)**
This session introduces Rodney Brooks' *subsumption architecture* and continues discussion of the behavior-based robotics approach in artificial intelligence that it spearheaded. Brooks by-passed the frame problem. His robots are designed to react directly to signal properties in the environment that are of value to their behavior. Brooks used this *insect intelligence strategy* to model complete elemental behaviors modularly, for instance simple locomotion and object avoidance, and then connected these modular behaviors in hierarchical structures to constructed robots that could operate autonomously in simple environments.

- Rolf Pfeifer and Josh Bongard, *How the Body Shapes the Way We Think* (Cambridge, MA: MIT Press, 2007), 123-137 ***(L)***
- Rodney Brooks, “Intelligence without Representation,” in ed. John Haugeland, *Mind Design II* (Cambridge, MA: MIT Press, 1997), 395-420. ***(L)***

Lecture 10. **BEHAVIOR BASED ROBOTICS III (Seminar Room)**
This session continues discussion of Rodney Brooks' *subsumption architecture* and the behavior-based robotics approach in artificial intelligence that it spearheaded. Brooks by-passed the frame problem. His robots are designed to react directly to signal properties in the environment that are of value to their behavior. Brooks used this *insect intelligence strategy* to model complete elemental behaviors modularly, for instance simple locomotion and object avoidance, and then connected these modular behaviors in hierarchical structures to constructed robots that could operate autonomously in simple environments.

- Evan Thompson, "The Ecological View," *Colour Vision* (New York: Routledge, 1995), pp. 215-220.
- George Monibot, "Bring Back the Wolf," *Feral: Rewilding the Land, the Sea, and Human Life* (Chicago: The University of Chicago Press, 2014), 77-93. ***(L)***
- Richard Levins and Richard C. Lewontin, "The Organism as the Subject and Object of Evolution," in eds. Richard Levins and Richard C. Lewontin, *The Dialectical Biologist* (Cambridge, MA: Harvard University Press, 1985), 89, 97-104. ***(L)***
- Rodney Brooks, “Intelligence without Representation,” in ed. John Haugeland, *Mind Design II* (Cambridge, MA: MIT Press, 1997), 395-420. ***(L)***

Lecture 11. **BRAITENBERG VEHICLES I (Imaging Center)**
The goal of this session is to introduce *Braitenberg Vehicles* and learn to program our own versions as a means to explore the concepts introduced in the discussion of embodied, behavior-based approaches to artificial intelligence.

- Valentino Braitenberg, *Vehicles: Experiments in Synthetic Psychology* (Cambridge, MA: MIT Press, 1986), 1-28. ***(V)***
- LEGO PROJECT: Braitenberg, *Vehicles* 2a/b.

Lecture 12. **BRAITENBERG VEHICLES II (Imaging Center)**
The goal of this session is to continue exploring the behaviors of Braitenberg Vehicles.

- LEGO PROJECT: Braitenberg, *Vehicles* 3a/b.
- Valentino Braitenberg, *Vehicles: Experiments in Synthetic Psychology* (Cambridge, MA: MIT Press, 1986), 1-28. ***(V)***
- Rodney Brooks and Anita Flynn, "Fast, Cheap, and Out of Control: A Robot Invasion of the Solar System," *Journal of The British Interplanetary Society*, Vol. 42, pp 478-485, 1989.

- Barbara Webb, "Robots in Invertebrate Neuroscience," *Nature* 417, 359-363.

optional supplemental readings:

- Rodney Brooks and Anita Flynn, "Fast, Cheap, and Out of Control: A Robot Invasion of the Solar System," Journal of The British Interplanetary Society, Vol. 42, pp 478-485, 1989.
- Barbara Webb, "Robots in Invertebrate Neuroscience," Nature 417, 359-363.
- Dario Floreano, Auke Jan Ijspeert, and Stefan Schaal, "Robotics and Neuroscience," Current Biology 24, 2014: R910-R920.
- Rolf Pfeifer, Max Lungarella, and Fumiya Lida, "Self-Organization, Embodiment, and Biologically Inspired Robots," *Science* 318, 2007: 1088-1093.
- Rolf Pfeifer, Fumiya Lida, and Max Lungarella, "Cognition from the Bottom Up: On Biological Inspiration, Body Morphology, and Soft Materials," Trends in Cognitive Sciences August 2014, Vol. 18, No. 8: 404-413.

FALL BREAK: October 19 – October 23!!!!

Lecture 13. **DIDABOTS (Imaging Center)**
The goal of this session is to use the *Braitenberg Vehicles* platform we have developed with our LEGO robots to explore *stimergy* as a mechanism for coordinating cooperative group behaviors that can be interpreted as intelligent at a group level, but not the individual level. This session extends our discussion of the different ways morphology and the structure of the local environment can be used to scaffold information processing.

- Marinus Maris and René te Boekhorst, "Exploiting Physical Constraints: Heap Formation through Behavioral Error in a Group of Robots," in ed. M. Asada, *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems*, 1996, 1655-1660. ***(L)***
- Michael Dawson, Brian Dupuis, and Michael Wilson, Embodiment, Stimergy, and Swarm Intelligence (http://www.aupress.ca/books/120175/ebook/08_Dawson_et_al_2010-From_Bricks_To_Brains.pdf), *From Bricks to Brains: The Embodied Cognitive Science of LEGO Robots* (Calgary, Alberta: Athabasca University Press, 2008): 226-237. ***(Onl)***
  - *Optional:* Verena Hafner. “An Example for (Reactive) Cooperative Behavior: The Swiss Robots." Retrieved August 31, 2014: http://www.verena-hafner.de/teaching/didabots.pdf ***(Onl)***
    http://www.verena-hafner.de/teaching/didabots.pdf
- LEGO PROJECT: Didabots.

Lecture 14. **FLOCKING (Imaging Center)**
This session continues our exploration of emergent collective intelligence. Social behaviors, like the flocking behaviors of birds would seem to have to be carefully coordinated. However the complex global behaviors of flocks can be shown to emerge from very simple local behaviors of individuals. We will meet in Coram and then take our robots over to the Grey Cage to experiment with flocking behaviors.

- Reynolds, BOIDS & flocking behaviors: http://www.red3d.com/cwr/boids/
- LEGO PROJECT: Line Followers, Wanderers, & Flockers.

Lecture 15. **ARTIFICIAL NEURAL NETWORKS I: BASIC CONCEPTS (Seminar Room)**
Behavior Based Robots often exhibit more flexibility than symbol systems. However, they are still engineered. Their behaviors are still constrained by the range of reflexes an engineer has chosen to implement in their programming. We might, therefore, wonder whether they are truly situated agents. The trick is to devise a strategy to allow the robots to *self-organize*. Artificial neural networks employ *learning algorithms* to develop sensitivity to those aspects of the environment that support their behaviors. The resulting control system is self-organized rather than engineered. The goal of this session is to introduce students to the fundamental concepts underwriting artificial neural network approaches to autonomous robots.

- Rolf Pfeifer and Christian Scheir, "Neural Networks for Adaptive Behavior," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 140-152. ***(L)***
- The Mind Project: Connectionism, Parts 1, 2, & 3. ***(Onl)***
  (http://www.mind.ilstu.edu/curriculum/connectionism_intro/connectionism_1.php)
- LEGO PROJECT: Artificial Neural Networks in Excel.

Lecture 16. **ARTIFICIAL NEURAL NETWORKS I: BASIC CONCEPTS (Seminar Room)**
Behavior Based Robots often exhibit more flexibility than symbol systems. However, they are still engineered. Their behaviors are still constrained by the range of reflexes an engineer has chosen to implement in their programming. We might, therefore, wonder whether they are truly situated agents. The trick is to devise a strategy to allow the robots to *self-organize*. Artificial neural networks employ *learning algorithms* to develop sensitivity to those aspects of the environment that support their behaviors. The resulting control system is self-organized rather than engineered. The goal of this session is to introduce students to the fundamental concepts underwriting artificial neural network approaches to autonomous robots.

- Rolf Pfeifer and Christian Scheir, "Neural Networks for Adaptive Behavior," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 152-159. ***(L)***
- The Mind Project: Connectionism, Parts 1, 2, & 3. ***(Onl)*** (http://www.mind.ilstu.edu/curriculum/connectionism_intro/connectionism_1.php)
- LEGO PROJECT: Artificial Neural Networks in Excel.

Lecture 17. **ARTIFICIAL NEURAL NETWORKS III: PROGRAMMING SIMPLE HEBB (Imaging Center)**
The goal of this session is to learn to program a simple artificial neural network for the LEGO robots that uses a Hebbian learning algorithm to train itself to avoid obstacles.

- Rolf Pfeifer and Christian Scheir, "Neural Networks for Adaptive Behavior," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 159-164. ***(L)***
- LEGO PROJECT: Simple Hebb (bump learner)

Lecture 18. **ARTIFICIAL NEURAL NETWORKS III: EVALUATING SIMPLE HEBB (Imaging Center)**
The goal of this session is to learn to evaluate the behavior of our simple Hebb learner and discuss solutions to any of its shortcomings.

- Rolf Pfeifer and Christian Scheir, "Neural Networks for Adaptive Behavior," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 159-164. ***(L)***
- LEGO PROJECT: 4 Sonar Hebb

Lecture 19. **ARTIFICIAL NEURAL NETWORKS III: FORGETFUL HEBB (Imaging Center)**
The goal of this session is to introduce active forgetting into our network architecture to try to stave off the effects of overlearning in Hebbian learning algorithms.

- Rolf Pfeifer and Christian Scheir, "Neural Networks for Adaptive Behavior," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 159-164. ***(L)***
- LEGO PROJECT: Forgetful Hebb

Lecture 20. **NO CLASS – Independent Robot Work**

THANKSGIVING BREAK: November 18 – October 27!!!!

Lecture 21. **GENETIC ALGORITHMS (Imaging Center)**
The goal of this session is to introduce students to fundamental concepts in evolutionary robotics: what are genetic algorithms and how can they be used to evolve neural network controllers for autonomous robots.

- Rolf Pfeifer and Christian Scheir, "Artificial Evolution and Artificial Life," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 227-237. ***(L)***

- LEGO PROJECT: 4 Sonar Explorer

Lecture 22. **GENETIC ALGORITHMS (Imaging Center)**
The goal of this session is to learn how to implement a genetic algorithm in Excel that can be used to evolve a neural network controller for our 4 Sonar Explorers.

- Rolf Pfeifer and Christian Scheir, "Artificial Evolution and Artificial Life," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 227-237. ***(L)***

- LEGO PROJECT: Genetic Algorithms for Neural Network Controllers in Excel

Lecture 23. **GENETIC ALGORITHMS (Imaging Center)**
The goal of this session is to test the genetic algorithm we have implemented in Excel by running generations on our 4 Sonar Explorers.

- Rolf Pfeifer and Christian Scheir, "Artificial Evolution and Artificial Life," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 227-237. ***(L)***

- LEGO PROJECT: 4 Sonar Explorer

Lecture 24. **GENETIC ALGORITHMS (Imaging Center)**
The goal of this session is to test the genetic algorithm we have implemented in Excel by running generations on our 4 Sonar Explorers.

- Rolf Pfeifer and Christian Scheir, "Artificial Evolution and Artificial Life," *Understanding Intelligence*, Cambridge, MA: MIT Press, 1999, 227-237. ***(L)***

- LEGO PROJECT: 4 Sonar Explorer

ASSIGNMENTS: All assignments must be handed in electronically via the dropbox for that assignment on LYCEUM. See the schedule of readings below for assignment due dates.

Free Writing Assignment (700-900 words): Please construct an argument in support of your thoughts about the nature of intelligence. Be sure to clearly articulate what you think intelligence is, provide your reasons in support of this concept of intelligence, and provide some common sense evidence in support of your view from the everyday behaviors of humans and other animals. *See Lyceum page for due date and full assignment.*

Free Writing Assignment Argument Exercise: Please re-construct the position you defended in your free writing assignment as an argument, or a schematic set of reasons given in support of your thesis. Your strategy should resemble the strategy we adopt on the board or in slides in class when we are analyzing the position presented in a text – identify your position (here the view of what intelligence is that you were defending) and list the reasons or exidence you provided in support of this view. the goal of this exercise is to reflect on the strength of the argument that you provided in the text of your paper. *See Lyceum page for due date and full assignment.*

Descriptive Writing & rewrite (700-900 words): The goal of this assignment is to recreate the argument in a reading. Your task is to describe the issue in question, the argument provided by the authors for their position, and the key points of evidence used in their argument. Your description of the argument should model the reading notes you would take to prepare a text for class discussion or the entry you would prepare for the reading for an annotated bibliography. *See Lyceum page for due date and full assignment.*

> *Descriptive Writing Question:* Reconstruct Darwin's argument in support of the claim that earthworms are flexible and adaptive autonomous problem solvers…or the argument that the burrow plugging behavior of earthworms reflects their natural intelligence.

Analysis Paper (1000 words): Choose one of the following prompts. The goal of this paper is to critically evaluate the argument presented in syllabus reading identified by the prompt (it may take some sleuthing to identify the reading). This paper should be treated as an extended version of your descriptive writing assignments. However, extra focus should be placed on critically evaluating the reasoning and evidence presented in support of the argument in the reading. Remember: Use ***the principle of charity*** to generate a ***rational reconstruction*** of the author's argument and then critically evaluate his or her reasoning. Please choose one of the following prompts for your paper. *See Lyceum page for due date and full assignment.*

> *Analysis Paper Question (1):* Is the *Chinese Room Argument* sound?
>
> *Analysis Paper Question (2):* Does the robot reply add anything to the *outdoor version* of the *Chinese Room argument*?

Robot Journals: Although we will work in robot teams, each of you will be asked to keep your own robot journal as the semester unfolds to keep track of your work outside of class with the robots. You will be provided with a worksheet concerning the format of your robot journals before the midterm and a series of prompts addressing questions about each of our robotics assignments. In general your journal entries should:

a) identify the philosophical issue a robotics exercise is designed to explore
b) describe and evaluate the results of your work in the exercise (how did the behavior of the robot illustrate the philosophical issue)
c) explain how this behavior emerged from your programming/d3esign efforts
d) make note of any challenges encountered in the process and how you brainstormed to solve them.

Compare-Contrast-Synthesize (1800-2000 words): The purpose of this paper is to demonstrate that you can identify & evaluate a range of standard arguments in the literature, compare and contrast these positions, and synthesize the diverse range of material covered on the syllabus into a coherent position of your own. A list of potential topics for this paper will be distributed after Fall Break. *See Lyceum page for due date and full assignment.*

Documentation, Final Robot Journal, & Robot Rodeo: You are responsible for submitting a complete robot journal to your Etna student file at the end of the semester. This copy of your complete robot journal should include: a text file copy (*.txt) of each of your final programs "commented out" so that your choices, decisions, and programming strategies are transparent to the reader; video documentation of 1 successful run of each of your robots; and a complete set of corrected robot journal entries that take into account my comments throughout the semester.

Some Miscellaneous Notes and Guidelines:

Moral behavior is the grounds for, and the framework of, a healthy society. In this regard it is each of our responsibility as an individual within the community of our classroom to act responsibly. This includes following the rules and guidelines set out by Bates College for academic behavior. Plagiarism is a serious matter. It goes without saying that each of you is expected to do his or her own work and to cite EVERY text that is used to prepare a paper for this class.

Please familiarize yourself with the guidelines for academic integrity posted on the Bates Website:
http://www.bates.edu/entering/policy/judicial-affairs/code-of-student-conduct/academic-misconduct/

This is a seminar. This means that the content of the course, and our progress through the syllabus, should ideally be student driven. I have designed the course to allow us some flexibility so that we can spend more time on issues of interest to the class. I reserve the right to make changes to the syllabus as we go along in order to accommodate our interests as they emerge in class discussions. I will also occasionally upload supplementary materials to *Lyceum* for students interested in pursuing particular issues beyond class discussion.

SCHEDULE OF READINGS

The reading schedule that follows is a loose guideline for our progress through the syllabus.
It is open to change at the Professor's discretion contingent on the pace of the class and evolving interests of the group.

Date	Readings	Assignments
0: 08/30	General Discussion: Thinking? Intelligence? watch: The Cognitive Science Song watch: Rolf Pfeifer: Embodied Cognition watch: Michael Dawson: Legos & Synthetic Psychology	
1: 09/07	Darwin: *The Formation of Vegetable Mould Through the Actions of Worms, with Observations on Their Habits*,The Habits of Worms II (excerpt): 55-98. ***(ebook, Ladd Library)*** Darwin's Worms: http://www.naturalhistorymag.com/htmlsite/master.html?http://www.naturalhistorymag.com/htmlsite/editors_pick/1958_11_pick.html	
2: 09/12	Kohler: *The Mentality of Apes*: 7-9; 39-45; 135-139. ***(L)*** Wynne: *Do Animals Think?*, Modern Logic for Primates: 60-64. ***(L)***	
3: 09/14	Dennett, True Believers (excerpt). ***(L)***	**Free Writing Assignment due Sunday 09/14 @ midnight:** *what is the nature of intelligence?*
4: 09/19	Hobbes, The Elements of Philosophy, Ch.1: pp. 5-9. ***(ebook)*** Hobbes, *Leviathan,* Ch. 5: 48-50. ***(ebook)*** Haugeland, What is Mind Design?: 8-21. ***(L)***	
5: 09/21	Hobbes, The Elements of Philosophy, Ch.1: pp. 5-9. ***(ebook)*** Hobbes, *Leviathan,* Ch. 5: 48-50. ***(ebook)*** Haugeland, What is Mind Design?: 8-21. ***(L)***	**Descriptive Writing Assignment due Sunday 09/ 21 @ midnight:** *reconstruct Darwin's argument for the intelligence of worms*
6: 09/26	Searle, Minds, Brains, and Programs: 183-204. ***(L)*** Pfeifer & Scheir, *Understanding Intelligence*: 69-71. **(L)** The Mind Project: The Chinese Room Argument, Parts 1 & 2. ***(Onl)***	**Free Writing Argument Exercise due Sunday 09/25 @ midnight:** *what is the nature of intelligence?*

7: 09/28	Pfeifer & Schier, *Understanding Intelligence*: 64-69. ***(L)*** Copeland, *Artificial Intelligence*: 91-92.	**Descriptive Writing rewrites due Friday 09/30 @ 5pm.**
8: 10/03	Mataric, Don't think, REACT!: 161-176. ***(L)*** Brooks, Intelligence without Representation: 395-420. ***(L)***	
9: 10/05	Pfeifer & Bongard, *How the Body Shapes…*: 123-137. ***(L)*** Brooks, Intelligence without Representation: 395-420. ***(L)***	
10: 10/10	Thompson, The Ecological View: 215-220. ***(L)*** Levins & Lewontin, the Organism as… 97-104. ***(L)*** Monibot, Bringing Back the Wolf: 77-93. ***(L)*** Brooks, Intelligence without Representation: 395-420. ***(L)***	
11: 10/12	LEGO PROJECT: *Vehicles* 2a/b Braitenberg, *Vehicles*, Vehicles 1-6: 1-28. ***(B)***	**Analysis Paper due Friday 10/14 @ 5pm:** *is The Chinese Room Argument sound?*
12: 10/17	LEGO PROJECT: *3a/b* Braitenberg, *Vehicles*, Vehicles 1-6: 1-28. ***(B)***	
Fall Recess: 10/19 – 10/23		
13: 10/24	LEGO PROJECT: Didabots - Tidy Robots - Hafner, An example of cooperative behavior: 1-3. ***(Onl)*** - Maris & te Boekhorst, Exploiting Physical Constraints: 1-6. ***(L)***	
14: 10/26	LEGO PROJECT: Flockers - Reynolds, BOIDS: Flocks, Herds, and Schools: http://www.red3d.com/cwr/boids/ - Dawson et al, *From Bricks to Brains,* Embodiment, Stimergy, and Swarm Intelligence: 253-262. ***(Onl)***	**Robot Journal I due Friday 10/28 @ 5pm.**
15: 10/31	Pfeifer & Schier, *Understanding Intelligence*: 140-152. ***(L)*** The Mind Project: Connectionism, Parts 1, 2, &3. ***(Onl)***	
16: 11/02	LEGO PROJECT: Artificial Neural Networks (Simple Hebb) Pfeifer & Schier, *Understanding Intelligence*: 152-159. ***(L)***	
17: 11/07	LEGO PROJECT: Artificial Neural Networks (Simple & Forgetful Hebb) Pfeifer & Schier, *Understanding Intelligence*: 159-164. ***(L)***	
18: 11/09	LEGO PROJECT: Artificial Neural Networks (Forgetful Hebb) Pfeifer & Schier, *Understanding Intelligence*: 159-164. ***(L)***	**Robot Journal I due Sunday 11/13 @ 5pm.**
19: 11/14	LEGO PROJECT: Genetic Algorithms (Concepts) Pfeifer & Schier, *Understanding Intelligence*: 227-237. ***(L)***	
20: 11/16	***No Class***	**Free Writing Assignment & Argument Exercise due Friday 11/18 @ 5pm.**

Thanksgiving Break, 11/18-11/27		
21: 11/28	LEGO PROJECT: Genetic Algorithms (Concepts) Pfeifer & Schier, *Understanding Intelligence*: 227-237. ***(L)***	
22: 11/30	LEGO PROJECT: Genetic Algorithms (Excel Generations) Pfeifer & Schier, *Understanding Intelligence*: 227-237. ***(L)***	**Robot Journal II due Friday 12/02 @ 5pm.**
23: 12/05	LEGO PROJECT: Genetic Algorithms (Testing in Robots) Pfeifer & Schier, *Understanding Intelligence*: 227-237. ***(L)***	
24: 12/07	LEGO PROJECT: Genetic Algorithms (Testing in Robots) Pfeifer & Schier, *Understanding Intelligence*: 227-237. ***(L)***	**Compare-Contrast-Synthesize Assignment due 12/09 @ 5pm.**
Final 12/13	1:15-3:15 Robot Rodeo ***(Coram)***	**Final robot journals and documentation due on Etna**

Other Resources and Materials

Lawrence Barsalou:

How we think: grounded cognition shakes up psychology
https://www.youtube.com/watch?v=JZsckkdFyPM

Language and Simulation in the Representation of Abstract Concepts:
https://www.youtube.com/watch?v=WA0K4xpHs24

David Chalmers

Is your phone part of your mind?
https://www.youtube.com/watch?v=ksasPjrYFTg

Soft Robots:
https://www.youtube.com/watch?v=A7AFsk40NGE

Printable Hydraulic Robots:
http://www.csail.mit.edu/node/2753

Robocup
http://www.robocup.org/

Octopus IP
http://www.octopusproject.eu/

Poseidrone
http://sssa.marinerobotics.it/research/activegrants/01_PoseiDRONE.php

Robolobster
http://www.neurotechnology.neu.edu/

RoboticFish.net
http://www.robotic-fish.net/index.php?lang=en&id=robots

OpenWorm
http://www.openworm.org/

STIFF-Flop
http://www.stiff-flop.eu/index.php/en/

Robots and Us
http://www.bbc.co.uk/programmes/p01m366d

Natural Born Robots – PBS Scientific American Frontiers (Chedd Angiers)
http://www.chedd-angier.com/frontiers/season10.html

Rolf Pfeifer Ted Talk
https://www.youtube.com/watch?v=mhWwoaoxIyc

EUcog – Rolf Pfeifer: Tutorial on Embodiment
http://www.eucognition.org/index.php?page=tutorial-on-embodiment

Lego C. Elegans model
Open Worm, Lego *C. Elegans*, http://www.cnn.com/2015/01/21/tech/mci-lego-worm/

Robotic Ray
https://www.youtube.com/watch?v=-D_XrRo0h20
https://www.youtube.com/watch?v=1-iyPHse8uk