Psychology of Learning: Animals, Humans and Machines

- Syllabus online:
  - www.psych.rutgers.edu/~jose/courses
  - Midterm 3/7
  - Final May 1-8
  - Paper Due May
What's Learning?

- Define Learning
Learning

Plasticity, then, in the wide sense of the word, means the possession of a structure weak enough to yield to an influence, but strong enough not to yield all at once.

Each relatively stable phase of equilibrium in such a structure is marked by what we may call a new set of habits. Organic matter, especially nervous tissue, seems endowed with a very extraordinary degree of plasticity of this sort; so that we may without hesitation lay down as our first propositions the following, that the phenomena of habit in living beings are due to the plasticity of the organic materials of which their bodies are composed.

--William James, Principles of Psychology, *Habit*, Chapter 4, 1890.
Nature vs Nurture

- Plato & Nativism  born with knowledge in a dormant state—simply needs to be “awakened”
- John Locke's “Blank Slate”
- Fodor- Modularity “swiss army knife theory of the brain”
- Watson & Skinner “Beyond Freedom and Dignity”
- Chomsky- LAD “.. language module is like a kidney”
- Pinker (Chomsky “mini-me”) biological determinism

“There's no point in attempting to control cultural influences on violence and aggression since genes will be the primary determinate of who commits crimes in society.” Pinker-- The Language Instinct.
Genes and Behavior

• Bio 101
• Each cell contains Directions for development of Brain/body etc..
• Chromosomes—strands of DNA packaging all the DNA
• Genome is the set of genes on the chromosomes that describes the organism (gene!=trait)
• Huge variation chromosome number and gene number
Genes

• Chromosomes 46 for Humans, 4 Fruit flys, 104 Carp, 16 Onion.
• Genes-- Worms 15k, flies 14k, Humans 30k Rice 60k
• Yikes. Genes==Traits?
•
  − Genes for tennis? Genes for chess?
  − Genes for language? Genes for dancing
• How come there's so few..?
50 Gene different between Humans Cognitive function...and

- .1% of genome
- But interactions matter
- So Gene(i) affects Gene(j) by either <enhance, inhibit, not at all>
- $3^{((n-1)*n)/2}$
- Super exponential
- 5 gene = 60,000 outcomes
- 7 genes = 10Billion
- 50 = way big.
But the Brain is really big too!

THE BRAIN IS BIG:

* $10^{12}$ NEURONS 10s of BILLIONS
* Different Functions regions $10^4$ to $10^7$
* Average Cell has $10^3$ connections
* $10^{14}$ SYNAPSES!! 10-50 TRILLION!!
Natural Selection

- Fitness
- Reproductive Success
- Selfish Genes
- Selection of Individuals that possess genes that maximize fitness and hence increase SPECIES VIABILITY.
The case of the color changing Moths

• Before the Industrial Revolution

• Before the Industrial Revolution in Great Britain, the trees in Manchester, England were covered with white lichens, which made the tree appear whitish-gray. The peppered moths which resided in this area were generally white. There were a few cases of black versions of the peppered moth, which were widely sought after by collectors.

• During the Industrial Revolution

• Then, during the start of the Industrial Revolution, soot from nearby factories began to darken the trees. This caused the white version of the peppered moth to stand out against the bark of the trees and to become visible to predators (birds). Consequently, the white moths began to lessen in number, while the black moths began to blend in more with the trees. The environment was changing for the peppered moth.

• Towards the end of the Industrial Revolution

• Later in the Industrial Revolution, the soot darkened the trees even more. The black moths became abundant because they could reproduce and hide from predators. Survival of the fittest worked because before the Industrial Revolution, the fittest of the black moths had to survive to change later on.
Tropisms—Fixed Responses
Little or no fitness uncertainty

- Environment is fixed and predictable.
- Direction of Stimulation matters. polarity matters intensity matters
Cost of being Chameleon

- Fixed adaptations are good:
- IF environmental complexity is high but finite
- AND
- Response Cost is relatively Low
- Then there is no limit to local complexity of adaptation
Chameleon Skin

A system of moving pigment from melanophore cells into different layers of the skin creates the varied colorations.
The Mechanism

- Chameleons have specialized cells, collectively called chromatophores, that lie in layers under their transparent outer skin. The cells in the upper layer, called xanthophores and erythrophores, contain yellow and red pigments respectively. Below these is another layer of cells called iridophores (or guanophores), and they contain the colorless crystalline substance guanine. These reflect amongst others the blue part of incident light. If the upper layer of chromatophores appear mainly yellow, the reflected light becomes green (blue plus yellow). A layer of dark melanin containing melanophores is situated even deeper under the reflective iridophores. The melanophores influence the 'lightness' of the reflected light. All these different pigment cells can rapidly relocate their pigments, thereby influencing the color of the chameleon.
Nastic Motion: fitness uncertainty thresholds reducing errors

- Venus Flytrap
- 2 or more stimuli..(what does a bug feel like walking around in your “mouth”?)
Blow flies: The Danger of fixed actions

- Dethier's Blow flies

Sugar on feet

Proboscis response

Feed

Gut distends

If FULL—STOP Proboscis

If FULL—YES

FULL? NO.
Behavior Modification: fitness uncertainty high.

- Chickens learning to “bowl”.
- 
- Fitness variability larger then necessary?
- Was cognitive function and language in the “overhead” of the learning capacity?
“Robot Crawling” Learning

• Sutton's classic learning task
• Reinforcement Learning
Children talking

- Why language?
- Why so complex?
- Why so symbolic: referential?
- Why so productive?
Learning is a Species Response

- Given environmental constraint
- Behave as to increase individual fitness
- If Fitness is linear with behavior
  - Simple solution:
    - More foraging—better
    - More energy – better
    - More mates – better
    - More everything that is good is ...better!
Learning

- Principle of Diminishing Return
- NONLINEAR fitness
- Cost of action increases pressure for diversity
Fitness Uncertainty

- If action leads to diminishing returns
- If action leads to fitness variability
- Two possibilities: Accuracy vs Precision
Lecture 2: Nature of learning

- In lecture 2 we continue to define the scope and framework for learning theories.
Things We've learned – So far
Trade-off between Species Learning and Individual Learning by:

- Minimize action cost & complexity
- Maximize diversity of actions (in response to environmental constraints)
- While optimizing fitness!
Now can we define learning?

- So given the biological framework we have—what's Learning?
- It must include both Individuals and Species
- It must include environmental constraint on access to basic needs
- It must include fixed action patterns and human language: Scope of actions
- So what do you think?—Students say something here.....hint...hint..
Definitions of Learning

- Hull argued that:

- ...learning turns out upon analysis to be either a case of differential strengthening of one from a number of responses evoked by a situation of need, or the formation of receptor-effector connections de novo; the first occurs typically in simple selective learning and the second in conditioned reflex learning.
Operational definitions

• some authors found it useful to define learning by exception. What came from that approach was a list of phenomena which learning was

• Learning refers to the change in a subject's behavior to a given situation brought about by his repeated experiences in that situation, provided that the behavior change cannot be explained on the basis of native response tendencies, maturation or temporary states of the subject (e.g., fatigue, drugs).
Summary of definitions (1890-1960)

- the importance of the motivation on the part of subject,
- the necessity of activity resulting from obstruction of motivated activity,
- a multiplicity of responses to stimuli,
- a gradual selection of appropriate responses and elimination of extraneous responses
- reinforcement of the appropriate responses, and
- variations in improvement from gradual to sudden solutions.
Learning: What does it do for the individual?

- (1) the control of environmental variance,
- (2) efficient handling of new events in updating memory,
- (3) reducing overhead -- effectively increasing the number of "cycles",
- (4) generative -- able to recover specific experiences and justifications for behaving,
- (5) simulating and deriving consequences from limited data prior to action.
Problems in learning

• What can and can't be learned?
  
  – Species Level
    
    • how abstract can the trait be that is passed to offspring?
      
      – athletic abilities?
      – math abilities?
      – tennis? can your parents be good at tennis and pass those abilities to you?
      – political preference-- republican/democrat
      – specific knowledge-- memories of culture or historical events?
Problems in learning: Limits?

- Individual Level
  - can we learn to
    - count all the leaves on a tree by looking at it?
    - multiply two large numbers together
      \[39539939494411 \times 99938383848586=\]
    - there are roughly 3000 languages on earth.. can we learn them all?
    - could we learn to jump 35 feet in the air?
    - learn to solve different problems with both hands at the same time?
Problems in Learning-2

• The Generalization Problem
  - if you learn a rule –what is the generality of the rule? Who do you know it applies in all similar situations?
  - My son—4 years old and the restaurant..
  - CUPS—what's a cup?
  - Cats and Dogs.. what's a Cat?
CUPS?
Cats?
Shepard's Theory

• Suppose an animal is foraging and finds food near a pecan tree. What should the animal infer from this event? If “O” is where the food was found, what should the animal assume about “X” another nearby pecan tree?
Generalization Error?

- The Universe: Cats
So what should a Learning Machine do?

Given Generalization SET of examples what should a LEARNING SYSTEM respond?

Concept 1 which includes examples from Training and Generz.
Concept 2 which includes ONLY Generz.
Concept 3 which includes half of training & Generz.
Causality Detection

- What rules are the most general?
- What Features are most predictive?
  - the feature game...
- What examples are best?
- What is the causality of the world?
Problems in Learning

• How many kinds of learning are there?
• How many kinds should there be?
  - Species level-- Natural Selection/Evolution
  - Individual Level—causality detection?
  - WHAT OTHER KINDS?
  -
Things we've learned

- Minimize action cost
- Maximize diversity of actions
- Minimize cost of error
- Minimize prediction error
- Minimize variability
- Maximize casuality detection
- While optimizing fitness!
Learning: The problems
Managing environmental Variability
Prediction vs Cost of Adaptation
Extreme cases (moths, chameleon,..)

Tradeoff between Generalization (sampling error) and environmental complexity

The Biological paradox: When to adapt and when to fixate-- the Nature/Nurture debate
Nature vs nurture

Where did this debate come from?