Simulating Language
Lecture 3: Evolving innate signalling systems

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Recap on signalling and communication

- Computational models allow us to bridge between theory and prediction for understanding complex dynamic systems with many interacting components
    - Or they allow us to play with those systems and figure out how they work
- First example: communication in animals with innate signalling systems
- Treat signalling system as a mapping between a fixed set of *meanings* and a fixed set of *signals*
- Modelled as (innately-determined) matrices of weighted associations
- Different matrices give different production and reception behaviours
- Communicative accuracy for a speaker and hearer can be defined as the proportion of utterances where hearer converges on same meaning as speaker

Comments on the worksheets

Where do these signalling matrices come from?

- If they are innately specified, they are somehow the result of the organism's genes

- How would an organism end up with a set of genes that gives them a good communicative accuracy score?

- **Theory**: natural selection will give us organisms with genes that specify signalling systems which have high communicative accuracy

- But can we be sure this is right?

- We need to model it...

- ...but first, some basic theory

Evolution by natural selection: preconditions

- Favourable heritable traits become more common over time, due to differential reproduction

- Three conditions:
  - Variation
  - Heredity
  - Selection

Variation

- different bodies
- different properties
- different abilities
- different phenotypes

Heredity

- These traits are passed on from parent to offspring

Selection

- Not all traits are equal
- Some traits improve your chances of passing those traits on, some don’t
- Differential reproduction
  - “The difference that makes a difference”

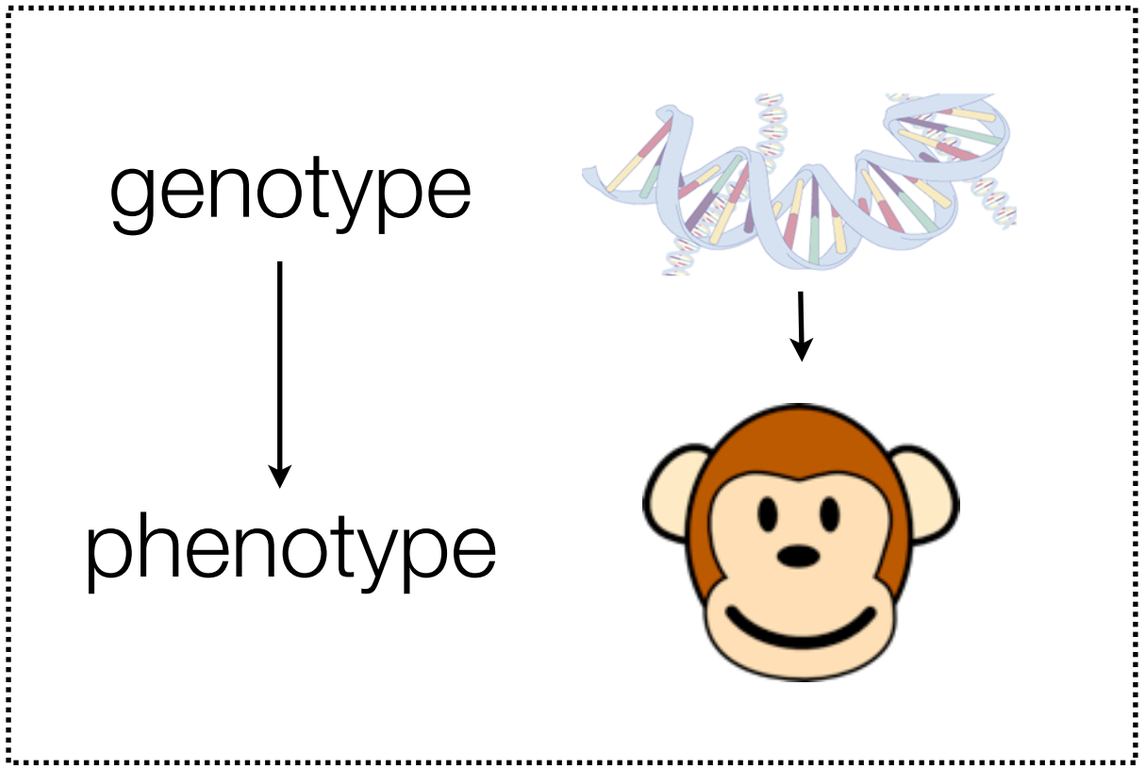
Evolution by natural selection, adaptation and the appearance of design

- Through this process, organisms tend to become well-suited to the pressures that operate on them
    - Relatively good at finding food, avoiding predators, attracting mate(s), rearing young, communicating, ...
- This is adaptation
    - “‘design’ in life - those properties of living things that enable them to survive and reproduce in nature.” (Ridley, 1996, p. 5)

Modelling evolution

- Many ways of modelling evolution. One approach: *genetic algorithms* (see reading for this week - Mitchell, 1998)

- Key ingredients:



Modelling evolution

- Many ways of modelling evolution. One approach: *genetic algorithms* (see reading for this week - Mitchell, 1998)

- Key ingredients:

1. A population of organisms
2. A task they are trying to succeed at
3. A measure of how *fit* they are at this task
4. A way of selecting the fittest
5. A way of allowing the genes of the fittest to survive
6. A mechanism for introducing variation into the gene pool

Our model

- Simplify things a bit: Treat genes and phenotype as equivalent and get rid of sex

- The simulation:

1. Create a population of random signal matrices
2. Assess each member of population for fitness
3. Pick a parent based on fitness
4. Copy parent (with chance of mutation) to create new offspring
5. Do 3 & 4 enough times to come up with a new population that's the same size as the old one
6. Replace old population with new one
7. Repeat steps 2 to 6 many times

Main research question

- Under what conditions will we see the emergence of “optimal” communication systems? (i.e. when will we see a stable population of agents in which any pair of agents would have a communicative accuracy of 1.0)

- Main parameter: *how do we assess fitness?*

- **What is the *fitness function*?**

- Key considerations:

  How do you pick communicative partners?
  Who gets rewarded for successful communication?

- Find out answers in the labs on Monday and Thursday (and in the reading - Oliphant, 1996)

Readings

- Oliphant, M. (1996) The dilemma of Saussurean communication. *Biosystems*, 37:31-38

- Mitchell, M. (1998) An introduction to genetic algorithms. pp. 1-16.