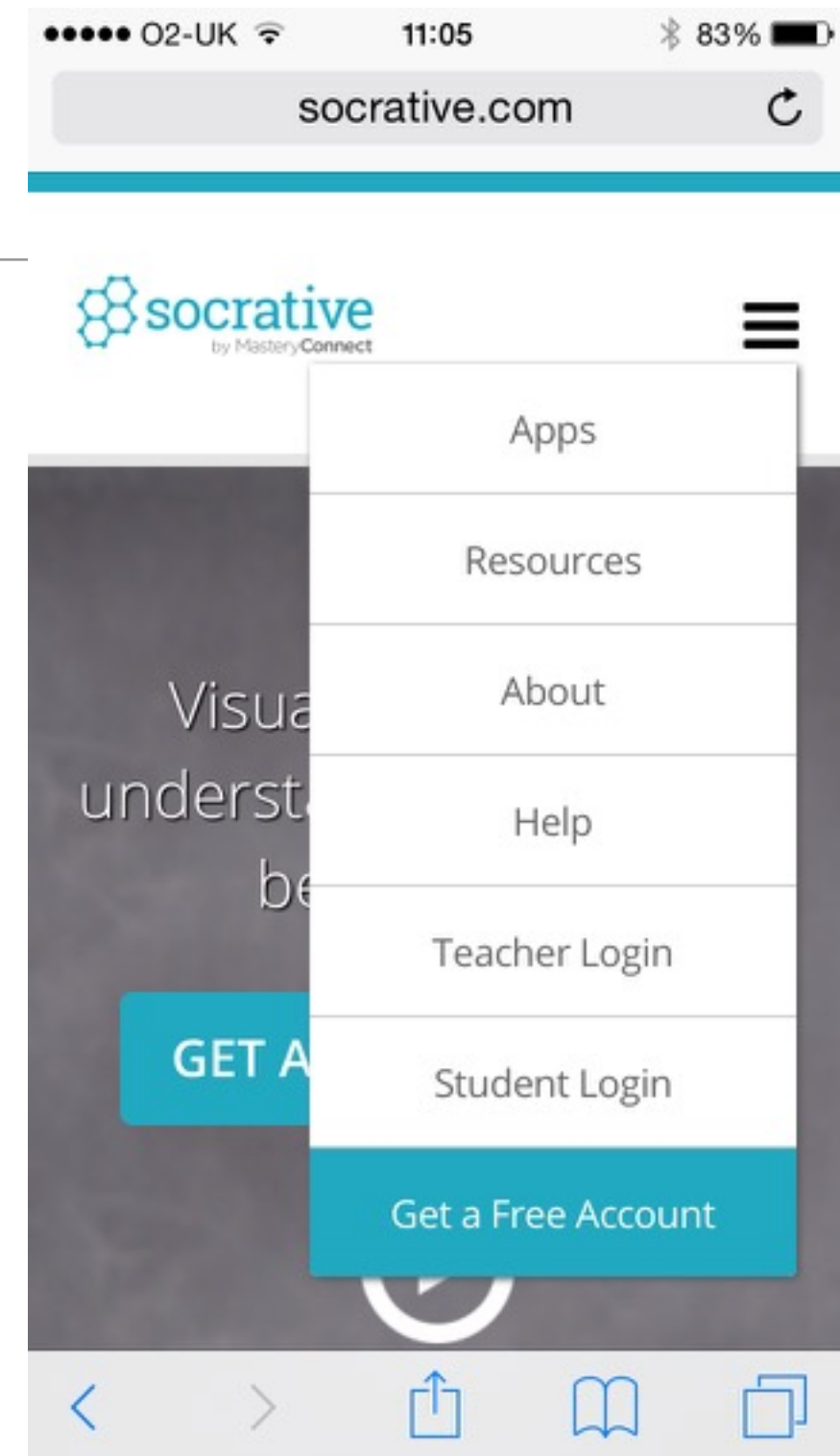


While you are waiting...

- Go to **socrative.com**
- Log in as a student, enter room number **SIMLANG2016**



Simulating Language

Lecture 2: Modelling signalling systems

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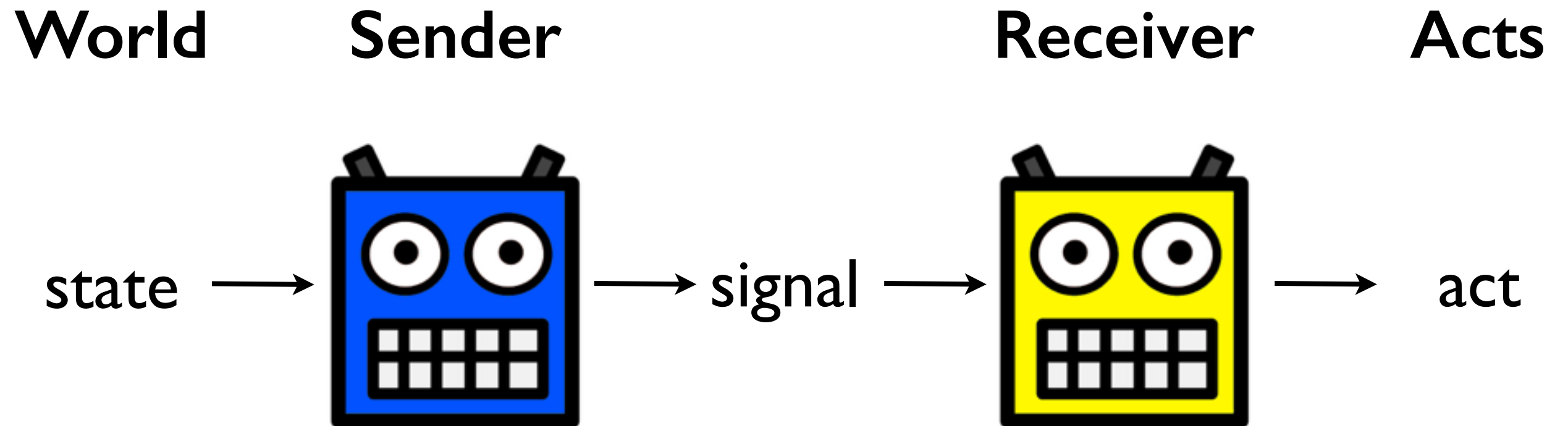


Starting simple: signalling

- We want a simple starting point for our effort to model the evolution of language
- Look not at language, but communication more broadly. Particularly, the kind of communication we see in many species: (**innate**) signalling
- Example: vervet monkey alarm calls
<http://www.youtube.com/embed/3lsF83rHKFc>
- Calls (and appropriate responses) for:
Leopard, eagle, snake



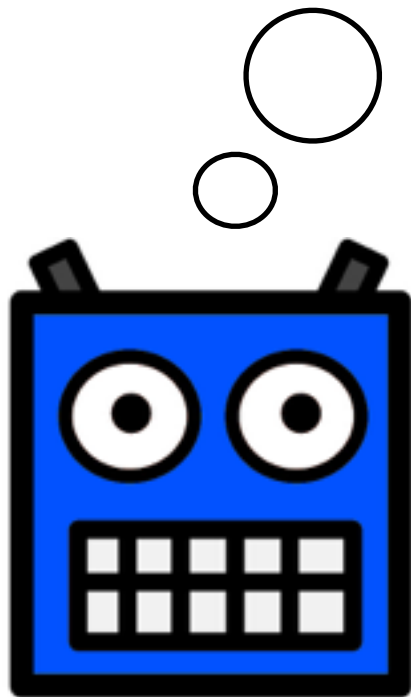
Sender-receiver games



Sender strategy

- Specifies, for every state, the signal to send

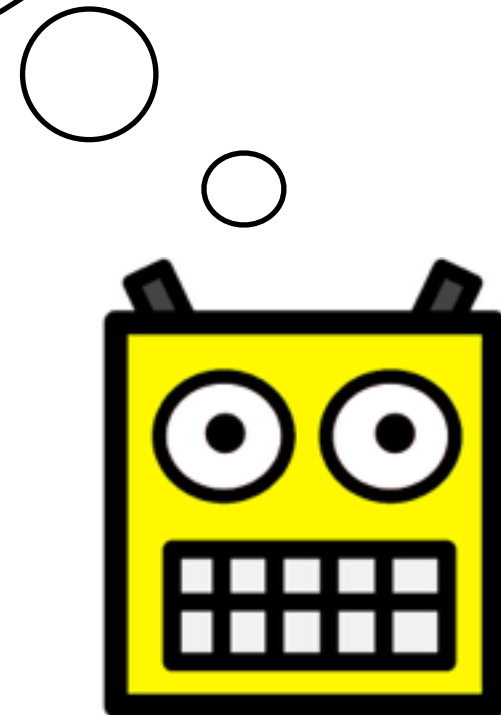
state 1 \longrightarrow signal a
state 2 \longrightarrow signal b
...



Receiver strategy

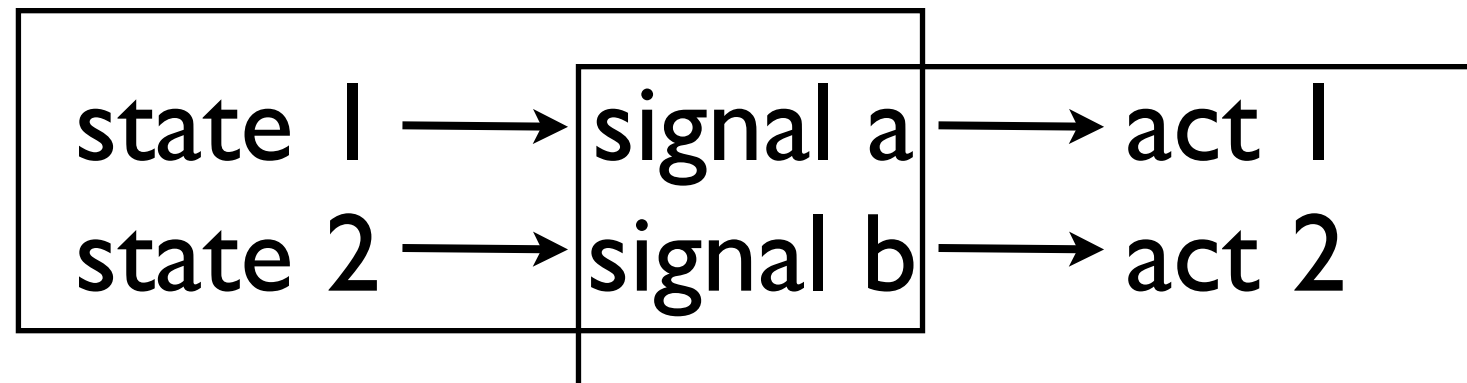
- Specifies, for every signal, the act to perform

signal a \longrightarrow act 1
signal b \longrightarrow act 2
...



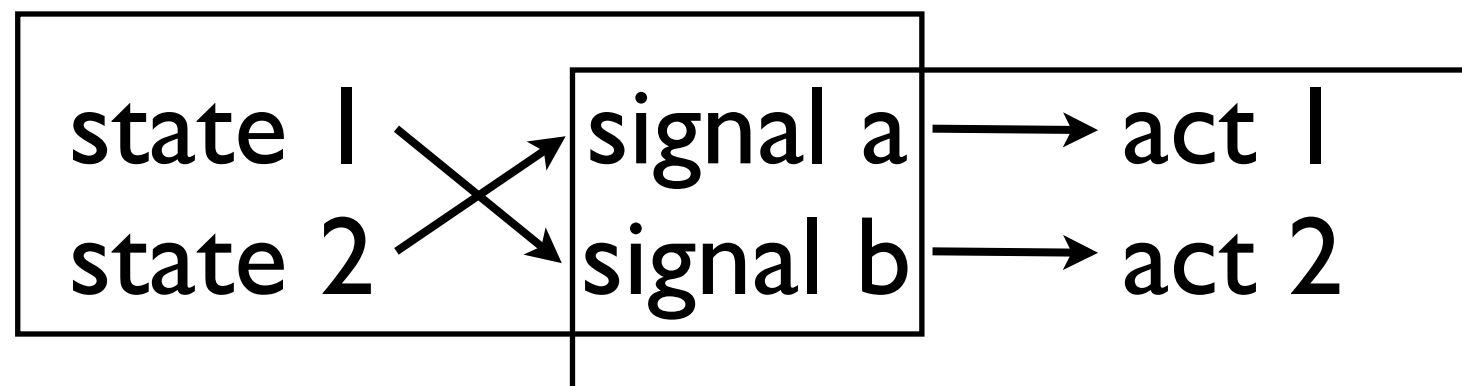
Communication and payoff

Sender



Receiver

Sender



Receiver

The vervet system

Sending

eagle → grunt

snake → chatter

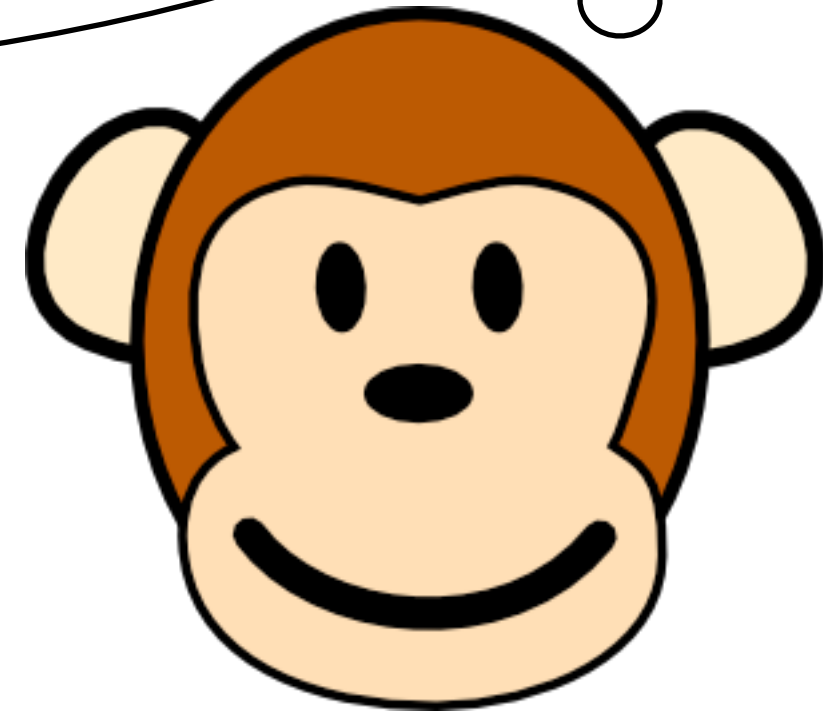
leopard → bark

Receiving

grunt → eagle

chatter → snake

bark → leopard



What's **missing** from this as a model of language?

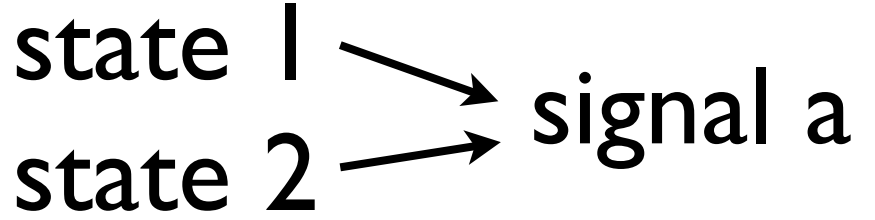
Two questions about the evolution of communication

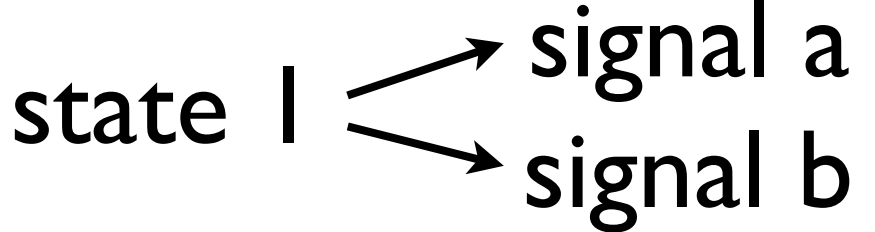
- How are communicative **conventions** established?
- What ensures those conventions are **communicatively useful**?

Convention and communication

- Rough definition: A convention is a system of behaviour that is **shared** among members of a population
- Two (related) ways in which communication requires convention:
 - Agreement between sender and receiver about what each signal 'means'
 - Agreement across a population about how to send and how to receive

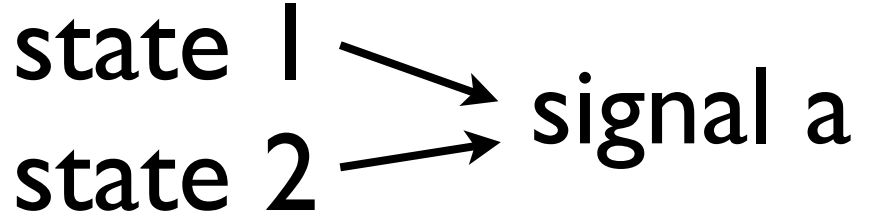
Communication, homonymy, synonymy

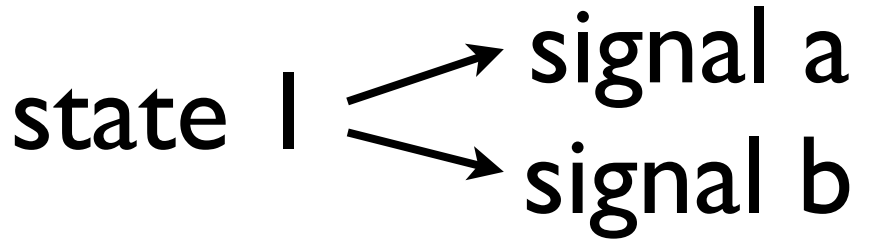
- **Homonymy:** multiple states map to a single signal


```
graph LR; state1[state 1] --> signal_a[signal a]; state2[state 2] --> signal_a;
```
- **Synonymy:** a state maps to multiple signals


```
graph LR; state1[state 1] --> signal_a[signal a]; state1 --> signal_b[signal b];
```
- **What determines the communicative functionality of a signalling system (in addition to conventionality)?**
 - A:** homonymy (more is bad)
 - B:** homonymy (more is good)
 - C:** synonymy (more is bad)
 - D:** synonymy (more is good)
 - E:** both synonymy and homonymy (more is bad)

Communication, homonymy, synonymy

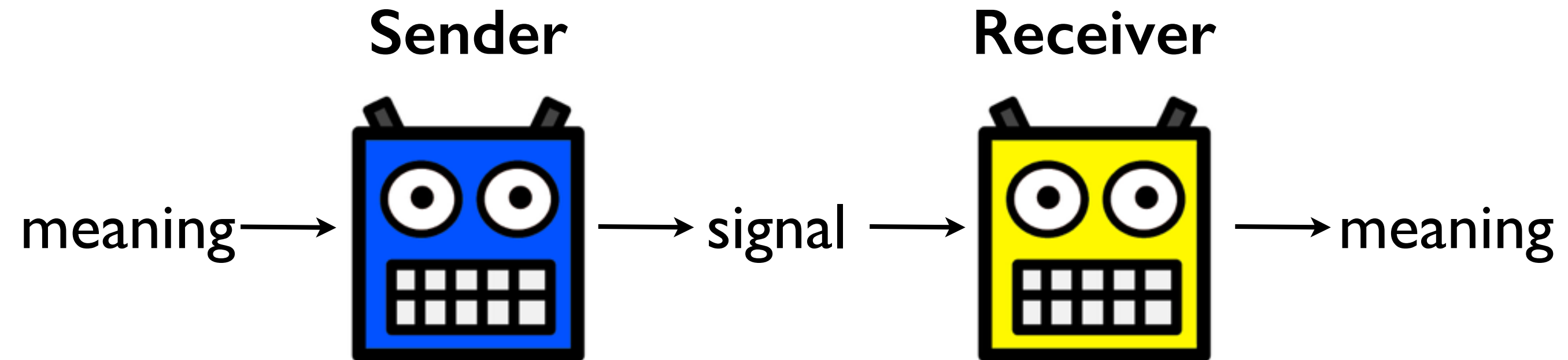
- **Homonymy:** multiple states map to a single signal


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graph LR; state1[state 1] --> signal_a[signal a]; state2[state 2] --> signal_a;
```
- **Synonymy:** a state maps to multiple signals


```
graph LR; state1[state 1] --> signal_a[signal a]; state1 --> signal_b[signal b];
```
- **What does the lexicon of natural languages look like?**
 - A:** homonymy and synonymy are rare
 - B:** homonymy is rare, synonymy is common
 - C:** homonymy is common, synonymy is rare
 - D:** homonymy and synonymy are common

A simplification

- Forget about the distinction between states and acts - *meanings* and *signals*



How to model an agent

- Need to represent the mapping between meanings and signals somehow
- Store *matrices* of associations

Producing

	s1	s2	s3
m1			
m2			
m3			

Receiving

	m1	m2	m3
s1			
s2			
s3			

Use the matrix for production and reception

- How do we take a matrix like this and get it to **produce** signals?

- One way: *winner take all*

- **Production:** Look along row for meaning and pick signal with highest association strength

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4

Use the matrix for production and reception

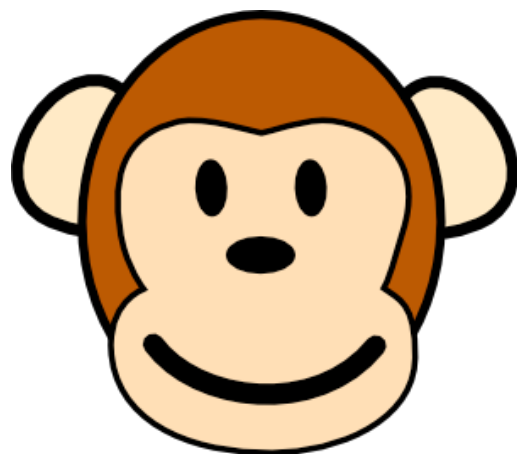
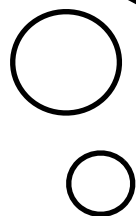
- How do we take a matrix like this and get it to **receive** signals?
- One way: *winner take all*
- **Reception**: Look along row for signal and pick meaning with highest association strength

	m1	m2	m3
s1	1	0	0
s2	2	1	3
s3	0	1	4

How can we measure communication success?

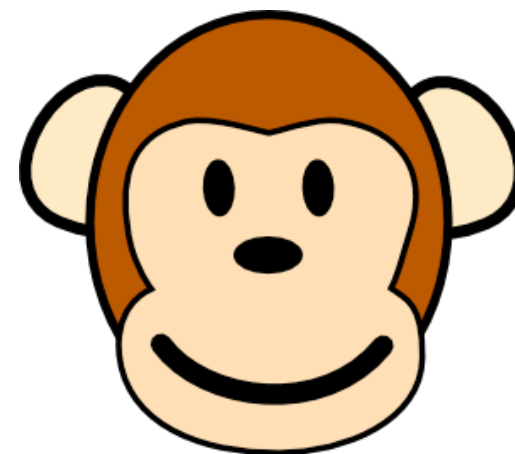
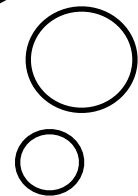
- Now we have a model of signalling, how do we measure how good a signalling system is for communication?

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4



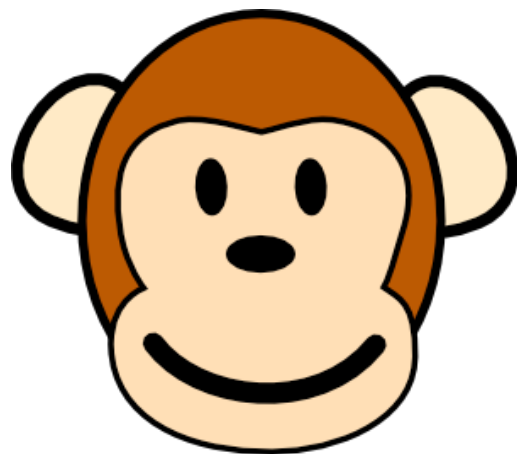
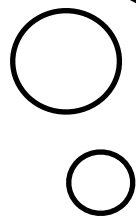
Producer

	m1	m2	m3
s1	1	0	0
s2	2	1	3
s3	0	1	4



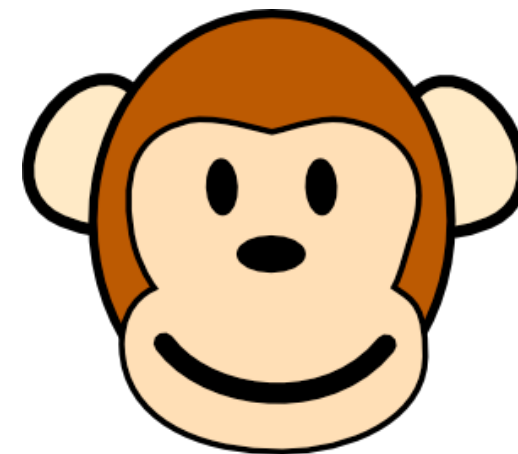
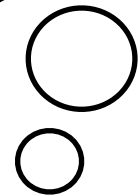
Receiver

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4



Producer

	m1	m2	m3
s1	1	0	0
s2	2	1	3
s3	0	1	4



Receiver

On average, how often will they communicate successfully?

A: Never

B: One third of the time

C: Two thirds of the time

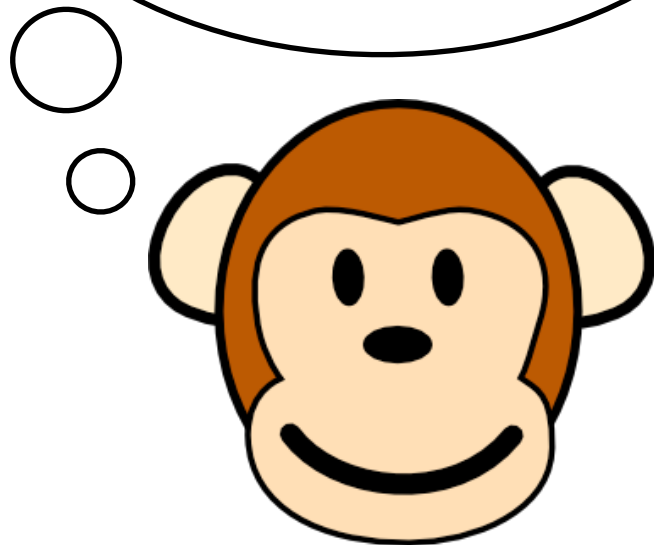
D: Always

Another way of evaluating communicative accuracy: Monte Carlo simulation

- Build a simulation of thousands of communication events between two agents, a producer and a receiver.
- For a particular producer and receiver, do the following:
 1. Pick a random meaning
 2. Use winner take all to generate a signal for that meaning according to the producer's production matrix
 3. Use winner take all again to see what meaning corresponds to that signal in the receiver's reception matrix
 4. If the receiver's meaning is the same as the original one, count as success
- Repeat 1-4 thousands of times and return the proportion of these “trials” that were successful. This is your *communicative accuracy score*.

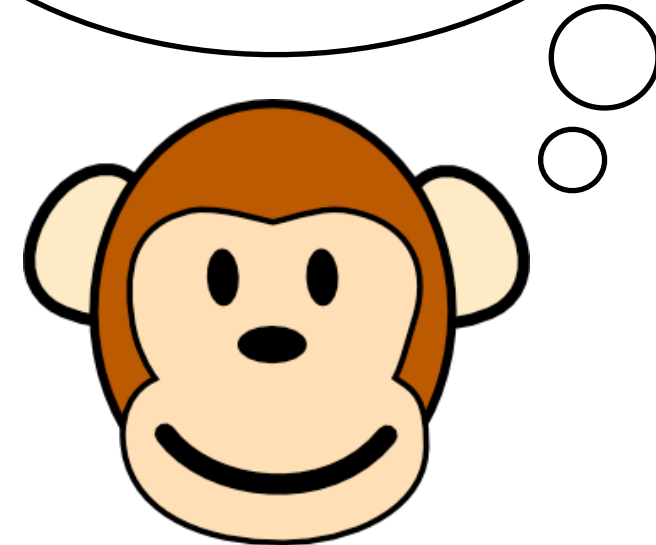
Communicative accuracy

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4



Producer

	m1	m2	m3
s1	1	0	0
s2	2	1	3
s3	0	1	4



Receiver

Communicative accuracy: 0.33

One way to model matrices in Python

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4

```
my_matrix =  
[ [ 1, 2, 0 ],  
  [ 0, 1, 1 ],  
  [ 0, 3, 4 ] ]
```

- **How would you access the row of association strengths for m1?**

A: Hmm. I don't know.

B: `my_matrix[0]`

C: `my_matrix[1]`

One way to model matrices in Python

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4

```
my_matrix =  
[ [ 1, 2, 0 ],  
  [ 0, 1, 1 ],  
  [ 0, 3, 4 ] ]
```

- **How would you access the strength of association between m2 and s1?**

A: Hmm. I don't know.

B: `my_matrix[0][1]`

C: `my_matrix[1][0]`

One way to model matrices in Python

	s1	s2	s3
m1	1	2	0
m2	0	1	1
m3	0	3	4

```
my_matrix =  
[ [ 1, 2, 0 ],  
  [ 0, 1, 1 ],  
  [ 0, 3, 4 ] ]
```

- **Can you tell, by looking at the python code, that this is a production matrix rather than a reception matrix?**

A: No

B: Yes

Some questions for you

- Some signalling systems are better than others. How do animals end up with the best ones?
- What about signalling between two agents with *different* matrices of associations? Will there be different scores for sending versus receiving?
- What about a population of agents, each with different signal systems?

Next

- Monday: **lab** on modelling signalling and communication
- Thursday: first of our *optional* catch-up labs for anyone who is feeling overwhelmed
- Friday: lecture on evolving signalling systems - remember the pre-reading!