

Origins and Evolution of Language

Week 10: Gene-culture co-evolution

Kenny Smith

kenny.smith@ed.ac.uk

Reminder: the human package

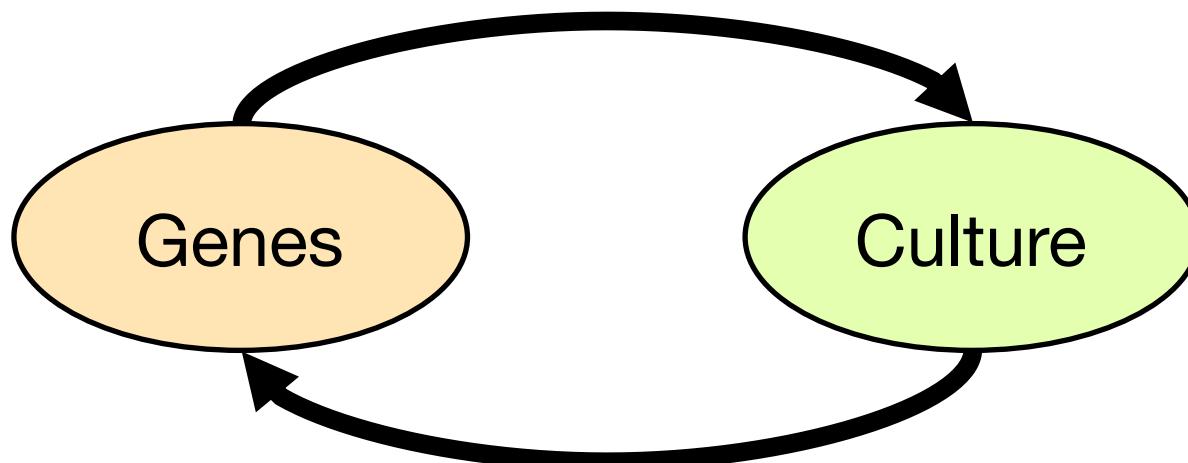
Somehow, we ended up with

- The ability to learn complex grammars
 - capacity for complex vocal imitation
 - ability to learn complex sequencing constraints
 - ability to learn compositional meaning-form mappings
- The ability and motivation to mindread and mindshare

This sets up the preconditions for the **cultural transmission of learned, meaning-bearing communication**

- Once that's in place, exciting stuff happens

Gene-culture co-evolution



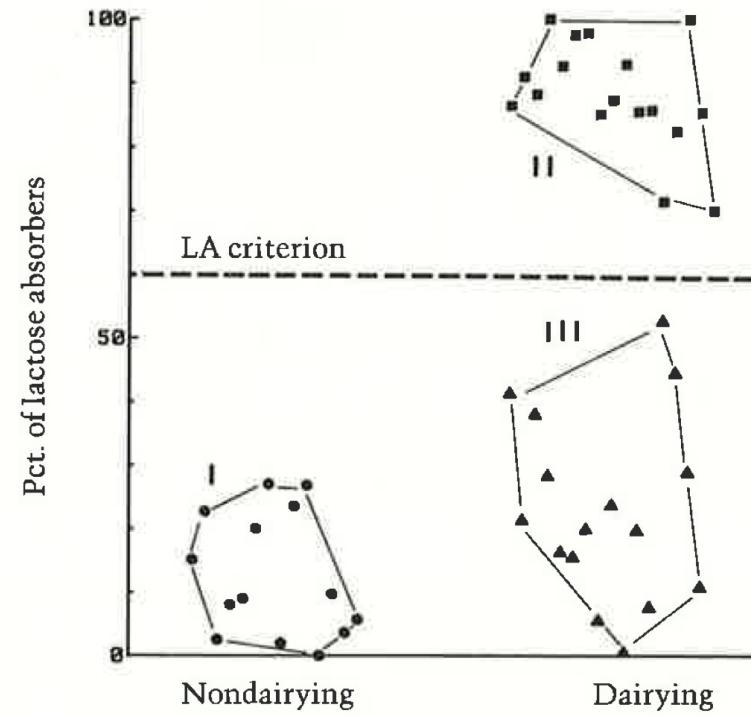


Has culture ended human evolution?



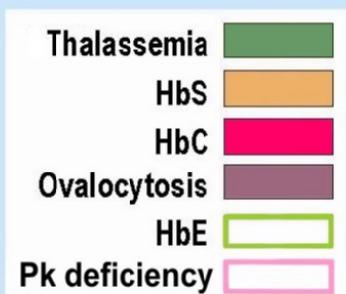
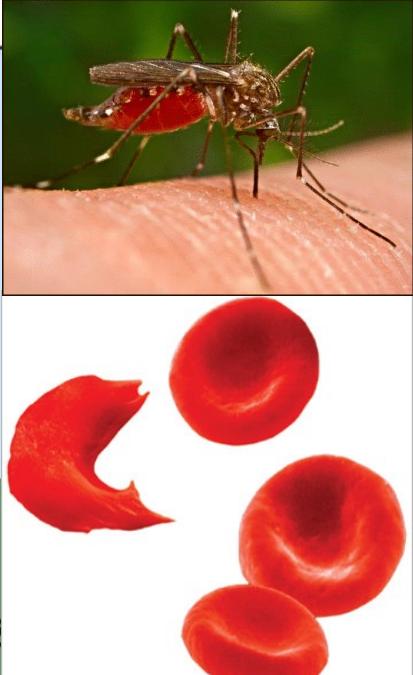
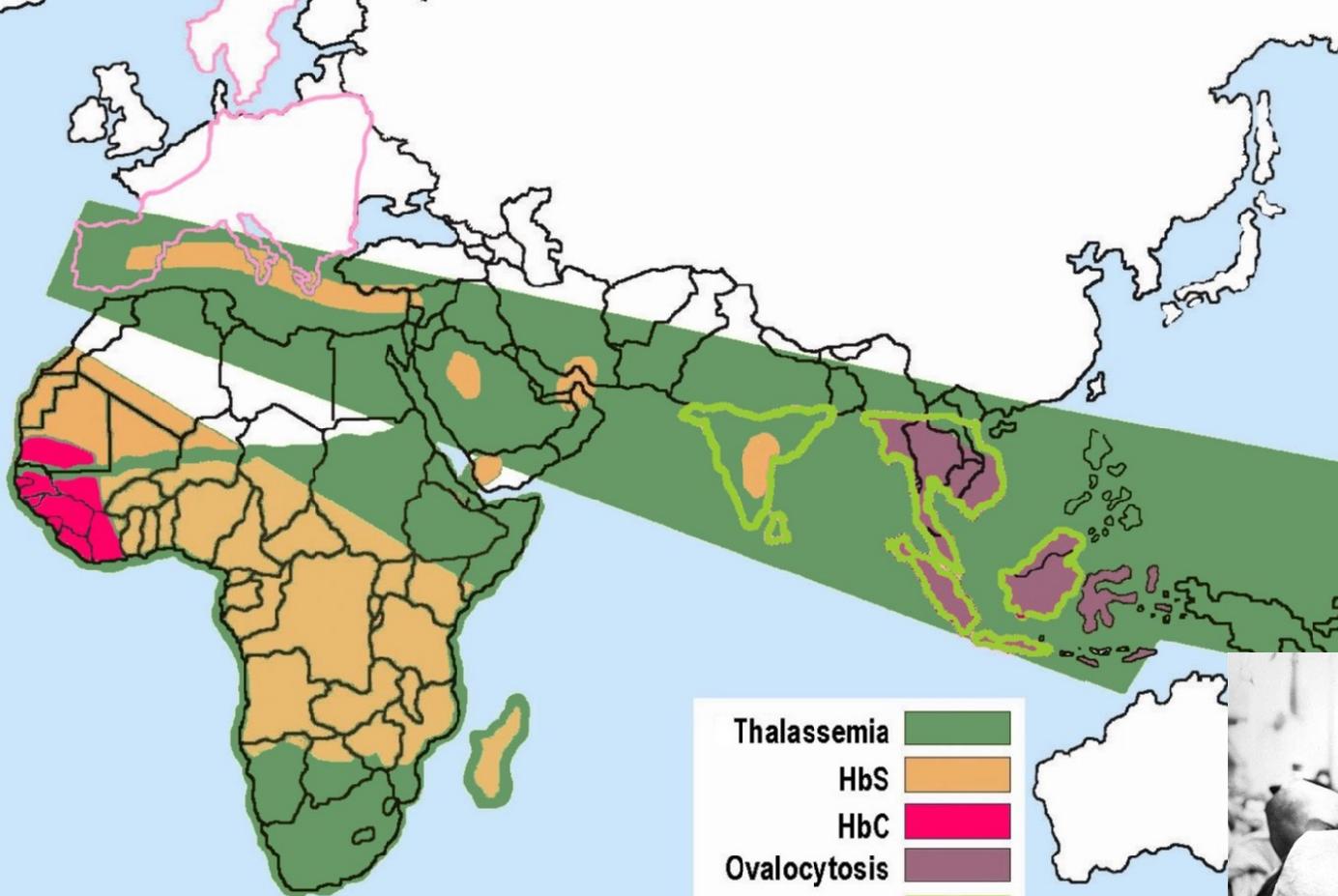


Dairying and lactase persistence

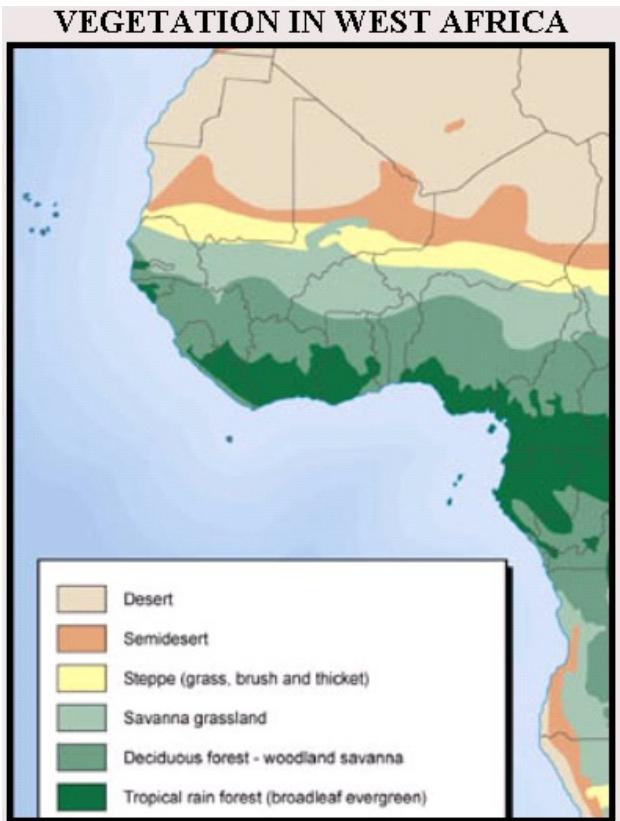


Gerbault, P., et al. (2011). Evolution of Lactase Persistence: an example of human niche construction. *Philosophical Transactions of the Royal Society of London B*, 366, 863-878.

Figure 5.4 from Durham, W. (1991). *Coevolution: Genes, Culture, and Human Diversity*. Stanford, CA: Stanford University Press.



Construction of a malarial niche



Evidence of gene-culture co-evolution

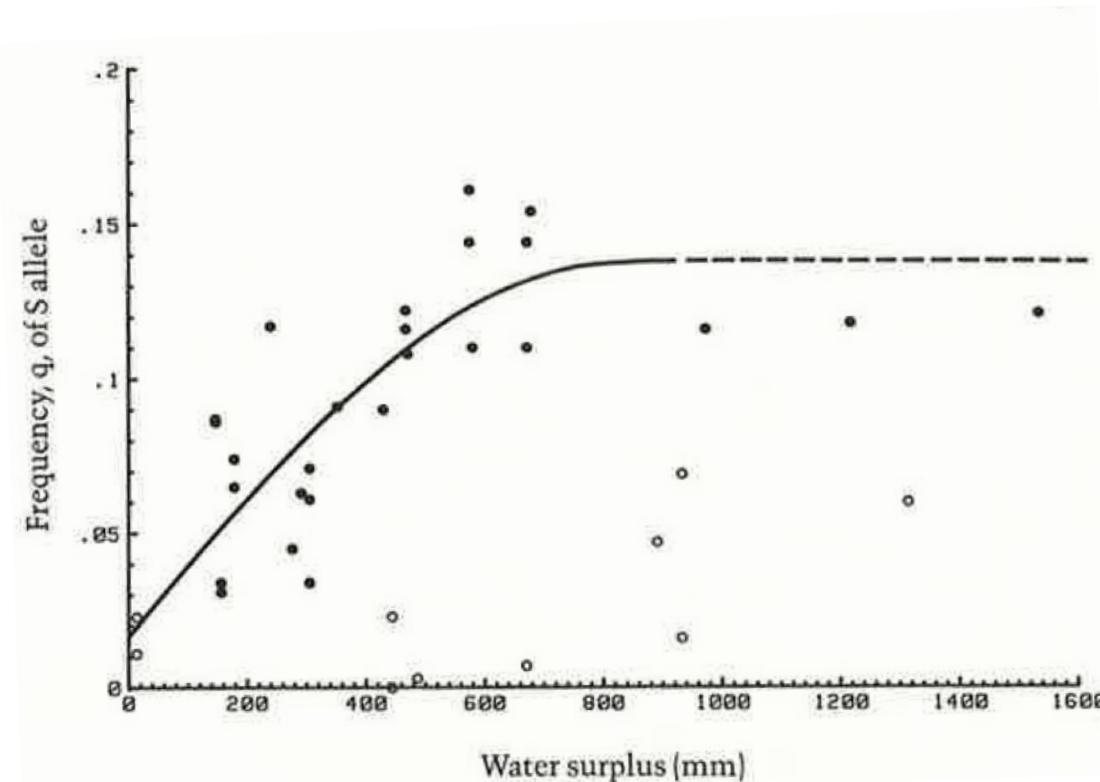
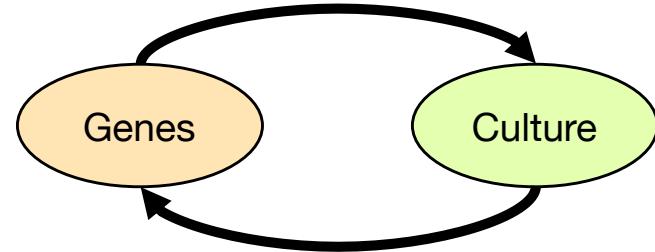
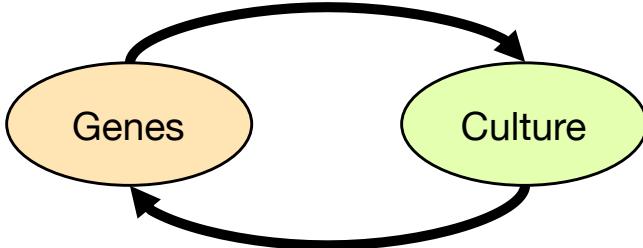


Figure 3.10 from Durham, W. (1991). *Coevolution: Genes, Culture, and Human Diversity*. Stanford, CA: Stanford University Press.

Other possibilities?



“In the space below, briefly (1 short paragraph max!) give an example of a human cultural practice other than language (i.e. some non-linguistic behaviour that humans acquire through social learning, imitation, teaching etc) that you think plausibly changes the selection pressures acting on human genes - say what this cultural practice is, and what selection pressure it exposes us to / insulates us from. This could be an example from the reading, or an idea you have yourself.”



How could this work for language?

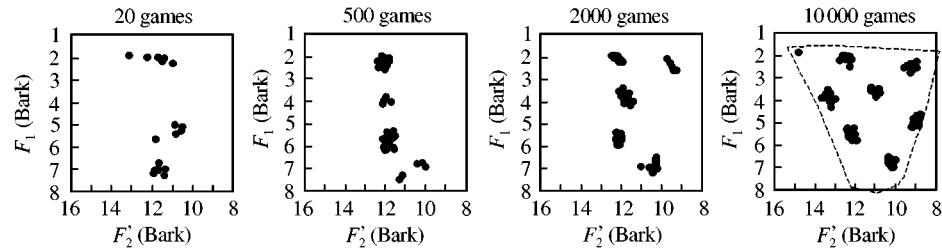
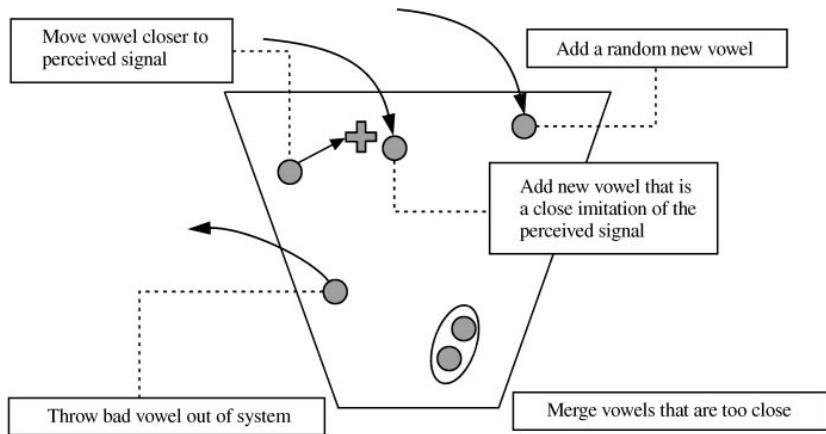
- Biological adaptations (rudimentary vocal learning, sequence and compositionality learning, mindreading) set scene for cultural transmission
- Cultural evolution begins to create structured (proto-)linguistic system
- Presence of structured, functional language creates/increases selection pressures for language-relevant skills, natural selection ensues
 - Enhanced vocal learning, better sequence/grammar learning, better mindreading
 - **Other things? Discuss in a moment**
- Enhanced linguistic capacities allow cultural transmission to do more
 - New functions, more complex structures, ...
- And repeat

Two examples

- Niche construction in perceptual/articulatory capacity
- Unmasking and masking in the evolution of innate constraints

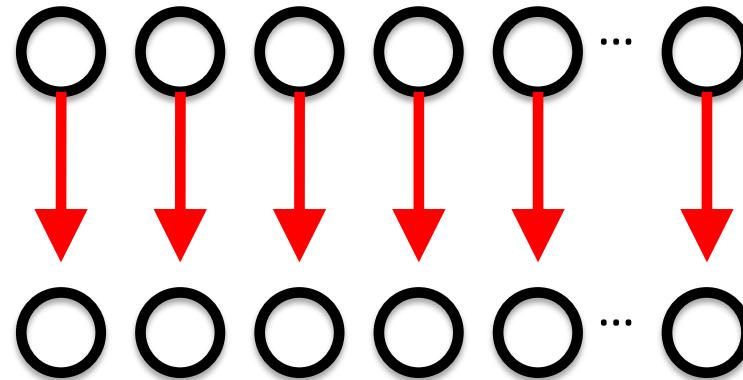
(Reviewed in Smith, K. (2020). How Culture and Biology Interact to Shape Language and the Language Faculty. *Topics in Cognitive Science*, 12, 690–712.)

Example 1: could co-evolution produce increasingly sophisticated linguistic capacities?

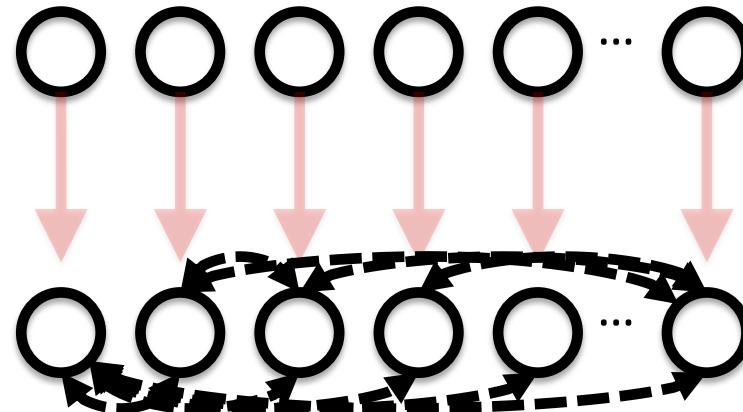


de Boer, B. (2000). Self-organization in vowel systems. *Journal of Phonetics*, 28, 441–465.
de Boer, B. (2016). Modeling co-evolution of speech and biology. *Topics in Cognitive Science*, 8, 459–468.

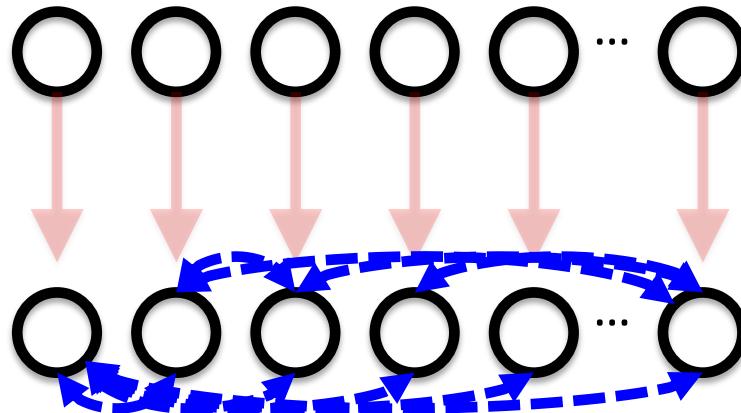
TRANSMISSION



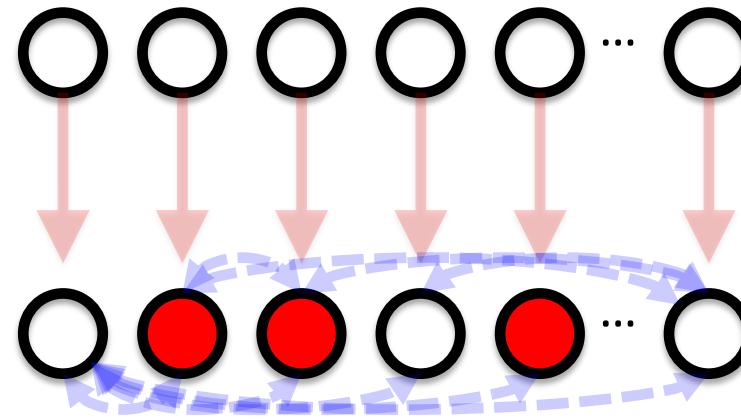
ADAPTATION IN
COMMUNICATION



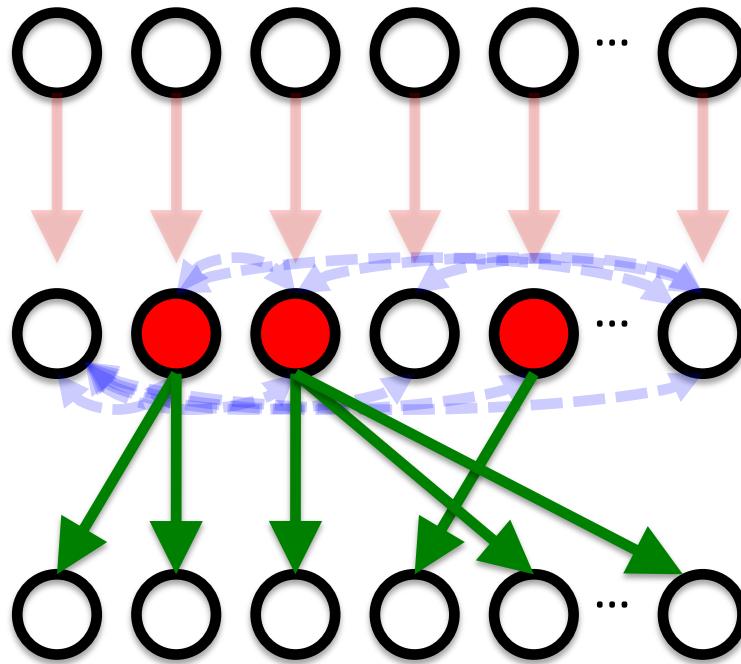
FITNESS
ASSESSMENT



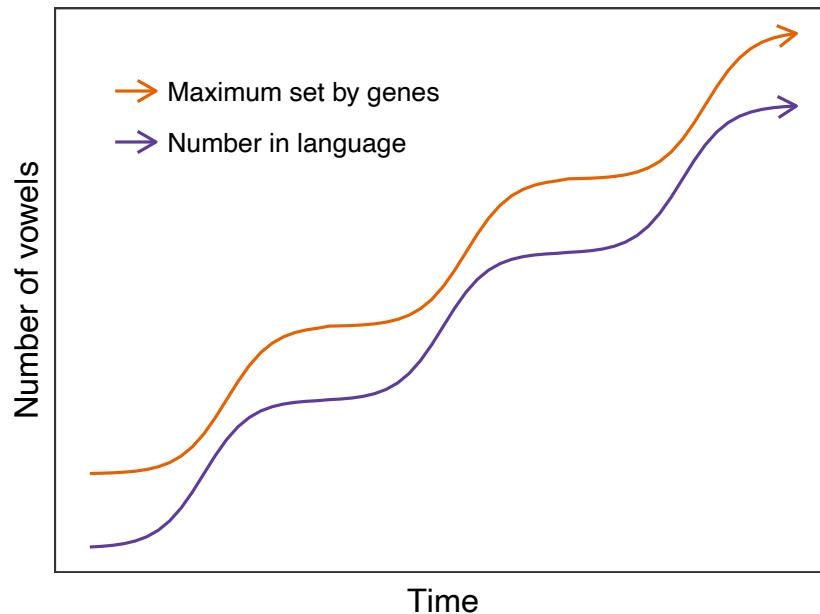
SELECTION



REPRODUCTION
+ MUTATION



Result: niche construction leads to increasingly complex vowel systems

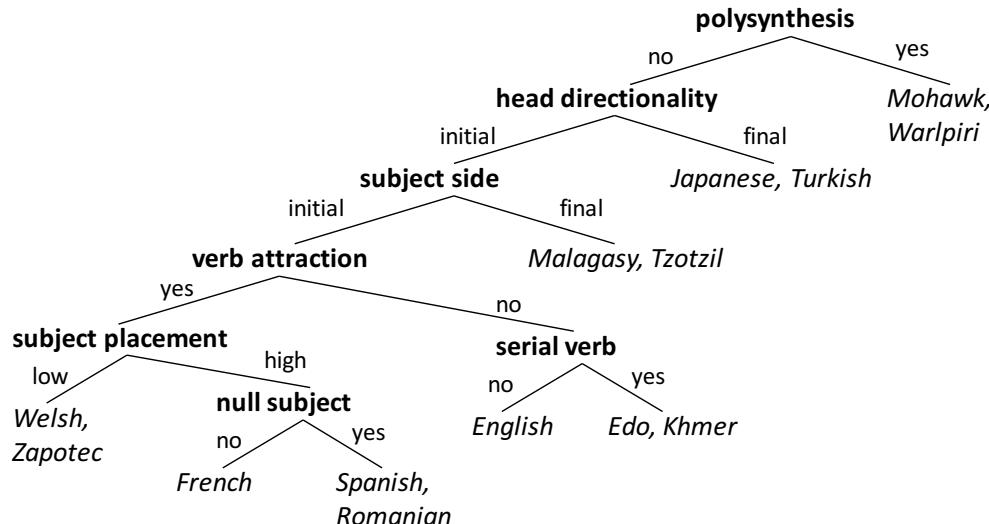


Schematic illustration of results from Smith, K. (2020). How Culture and Biology Interact to Shape Language and the Language Faculty. *Topics in Cognitive Science*, 12, 690–712.

Example 2: could co-evolution produce arbitrary constraints on learning?

Central idea in many linguistic theories: **arbitrary innate constraints** on learning

- e.g. Principles and Parameters



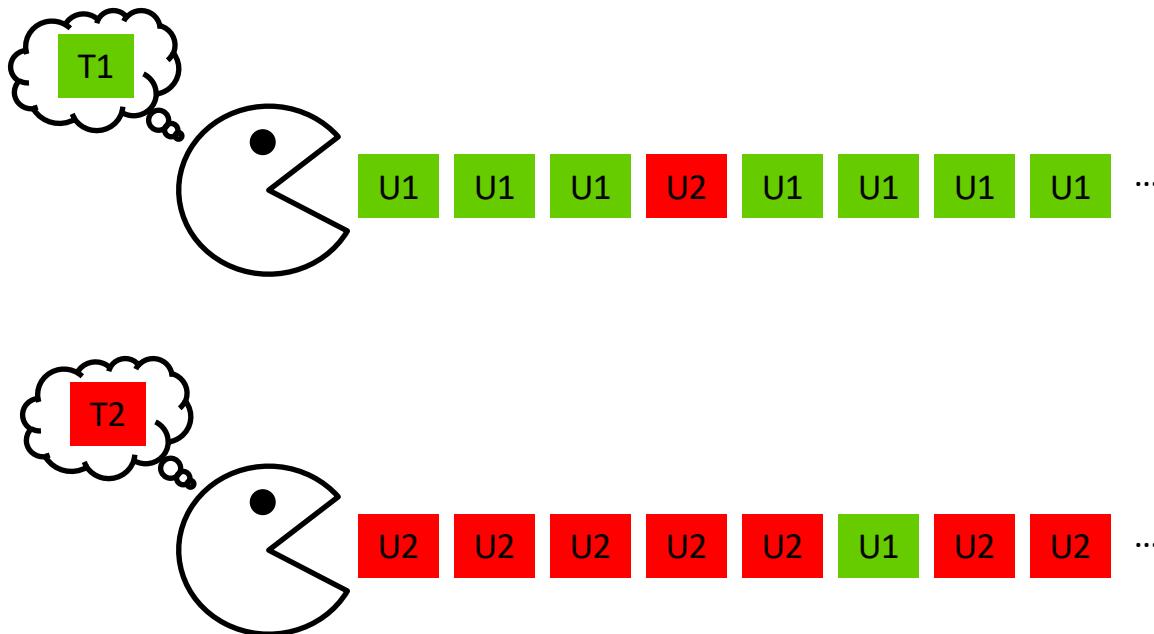


A candidate mechanism: the Baldwin effect

(aka genetic assimilation)

- Behaviour is initially learned
- Learning has some cost (time, **error**)
- Individuals whose genes reduce amount of learning required (e.g. by building in some aspects of the solution) are selected
- Eventually, learning minimized / nativised away

The simplest possible model of language



Smith, K., & Kirby, S. (2008). Cultural evolution: implications for understanding the human language faculty and its evolution. *Philosophical Transactions of the Royal Society B*, 363, 3591-3603.

Thompson, B., Kirby, S., & Smith, K. (2016). Culture shapes the evolution of cognition. *Proceedings of the National Academy of Sciences, USA*, 113, 4530-4535.

Learning

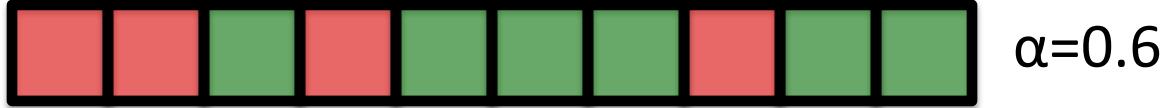
Learning: finding the most probable hypothesis (i.e. language) given some data (i.e. utterances).

$$P(h|d) \propto P(d|h)P(h)$$

Genes and selection

Genes: bias in favour of T1 (α) is polygenic

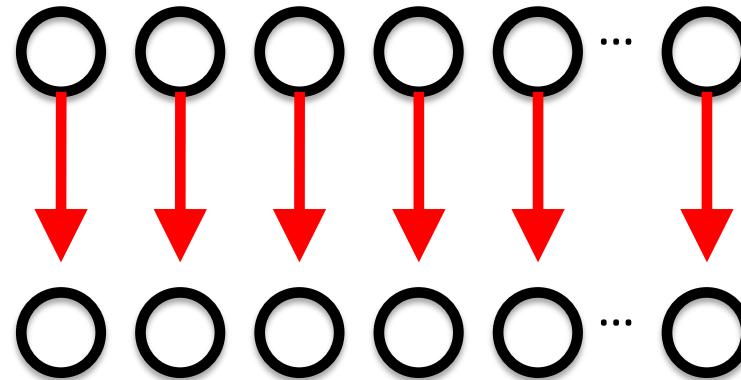
- Bias encoded by a string of genes
- Alleles either promote or inhibit T1



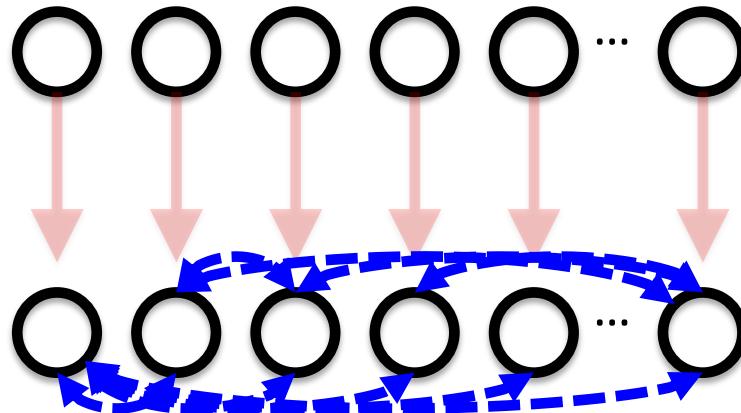
Selection: Individuals reproduce proportional to their communicative success in the population

- Communication = sharing same language type

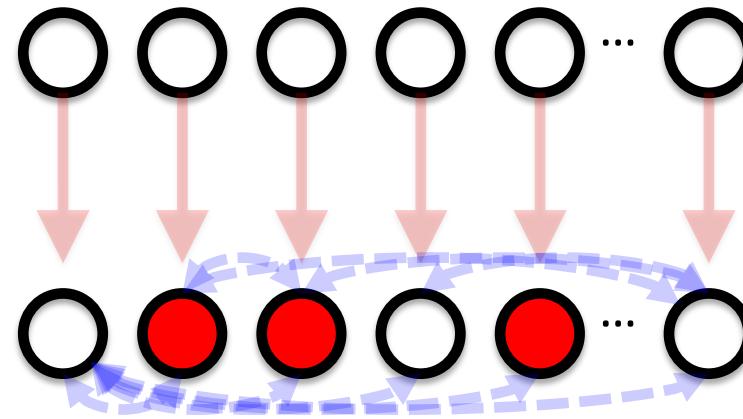
TRANSMISSION



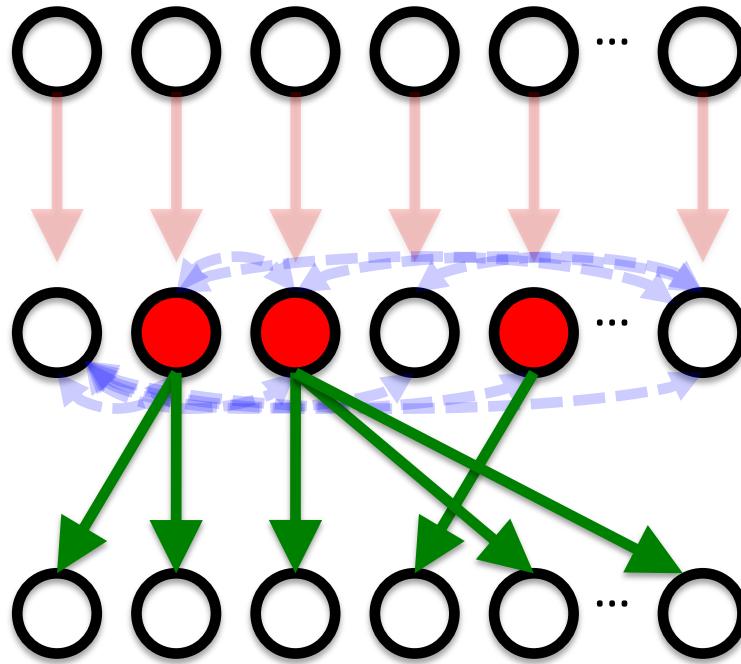
FITNESS
ASSESSMENT



SELECTION



REPRODUCTION
+ MUTATION



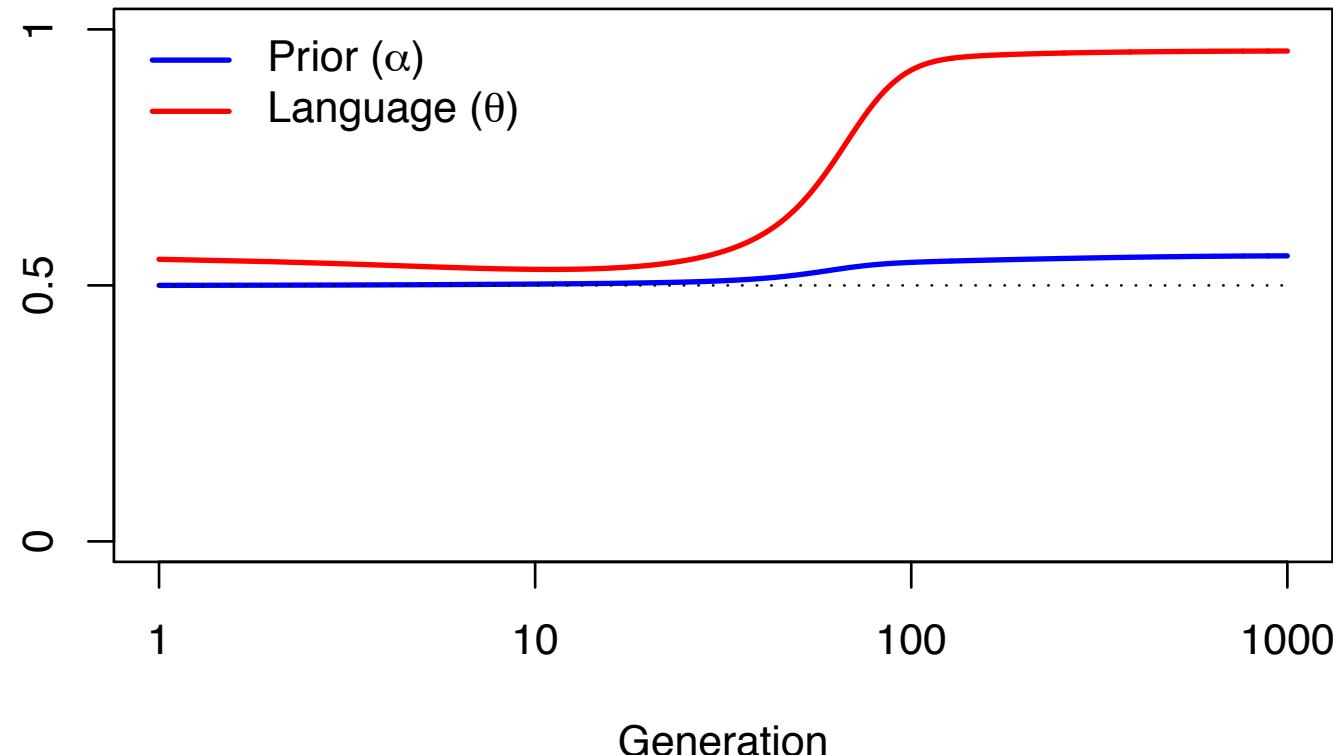
Predictions?

- A linguistic universal underpinned by highly informative/ strongly constraining prior (perhaps via the Baldwin effect)?

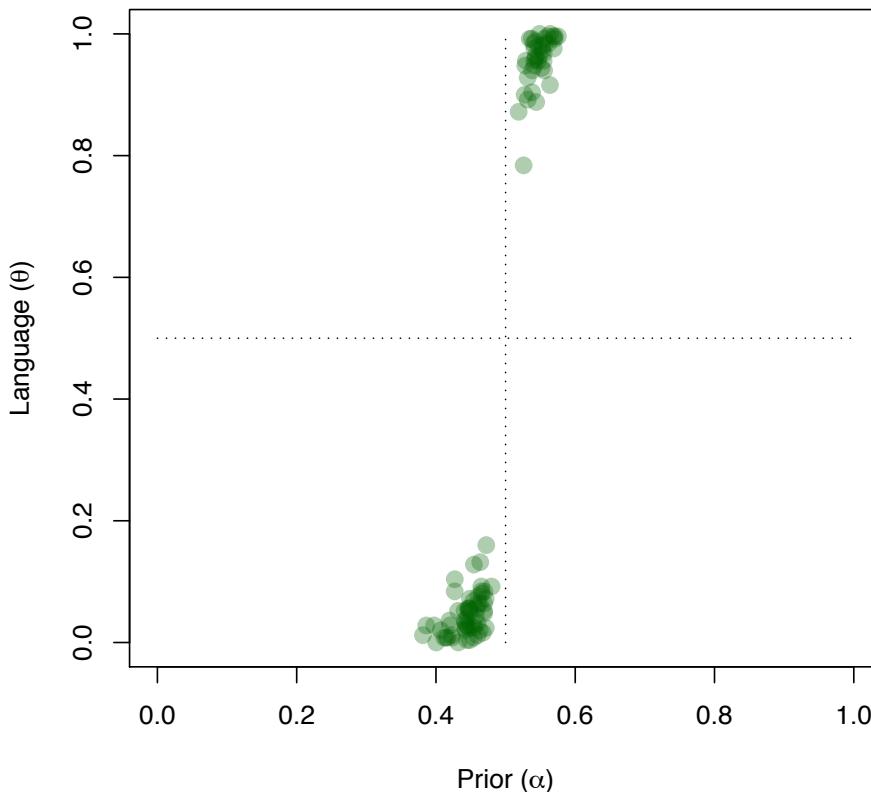
$$\alpha \approx \theta \approx 0 \text{ or } 1$$

(α : bias in favour of T1 language
 θ : proportion of population using T1 language)

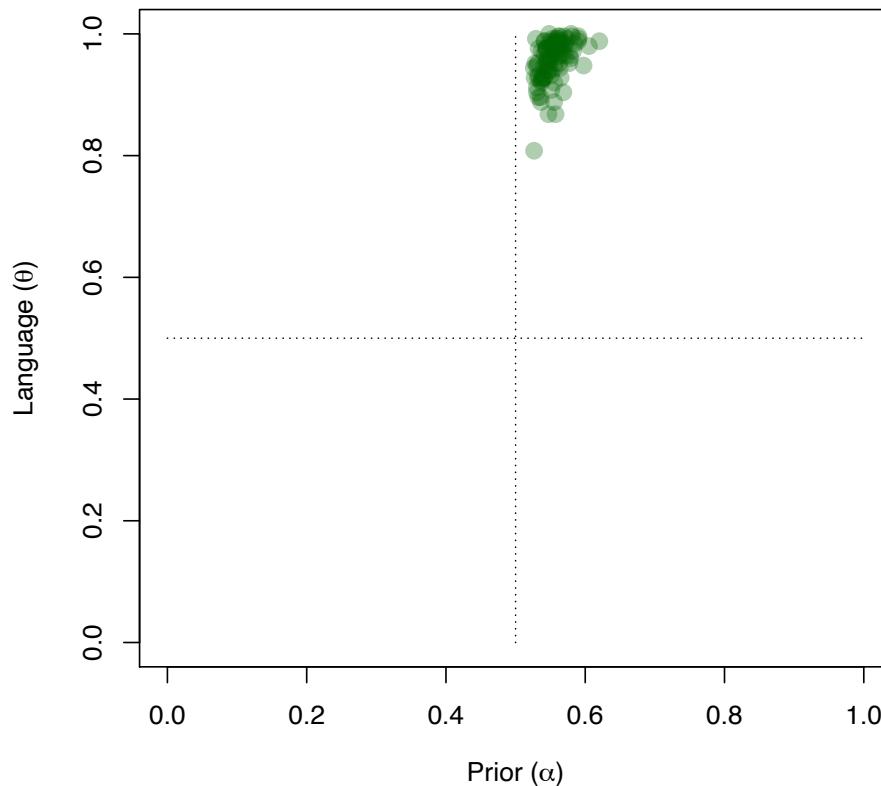
Result: strong universal, weak constraint



**Result: strong skew in languages, weak constraint
in learners**



Also works for functional features



Tiny genetic biases are **unmasked** by culture
Culture **masks** large differences in bias strength

Weak biases stabilize, fast.

Strongly constraining priors never evolve.

Gene-culture co-evolution: summary

- Humans are constructing environments which create new selection pressures and shape the evolution of our genes
- Language likely to be involved in the same process
- Should expect suite of genes underpinning learning and use of language to be under selection
- In some (most?) cases, can lead to cycles of niche construction producing increasingly sophisticated linguistic capacities
- Evolution of Universal Grammar unlikely though?

Course outline in retrospect

Week	Topic	
1	Introduction	
2	Natural selection, adaptation and language	↳ Produces adaptations
3	Intention and structure in animal communication	↳ Some but not much?
4	Social learning and cumulative culture	↳ Human social / technological niche
5	Evolution of vocal learning and grammar learning <i>Flexible learning week</i>	↳ Important cognitive innovations: vocal learning, sequence learning, compositional grammar learning
6	<i>No class (essay 1 due this week)</i>	
7	Evolution of social cognition	↳ Important cognitive innovation: mindreading
8	Cultural evolution of language	↳ How transmission produces linguistic structure
9	Sign language and language origins	
10	Gene-culture co-evolution	↳ Natural selection responds

Things I'd like to know

- Is mindreading really due to social and technological complexity?
- What are the selection pressures leading to the evolution of vocal learning and grammar learning capacities in humans?
- Why and how do languages get so complex?
- Once culture delivered linguistic structure, how did biological evolution respond?