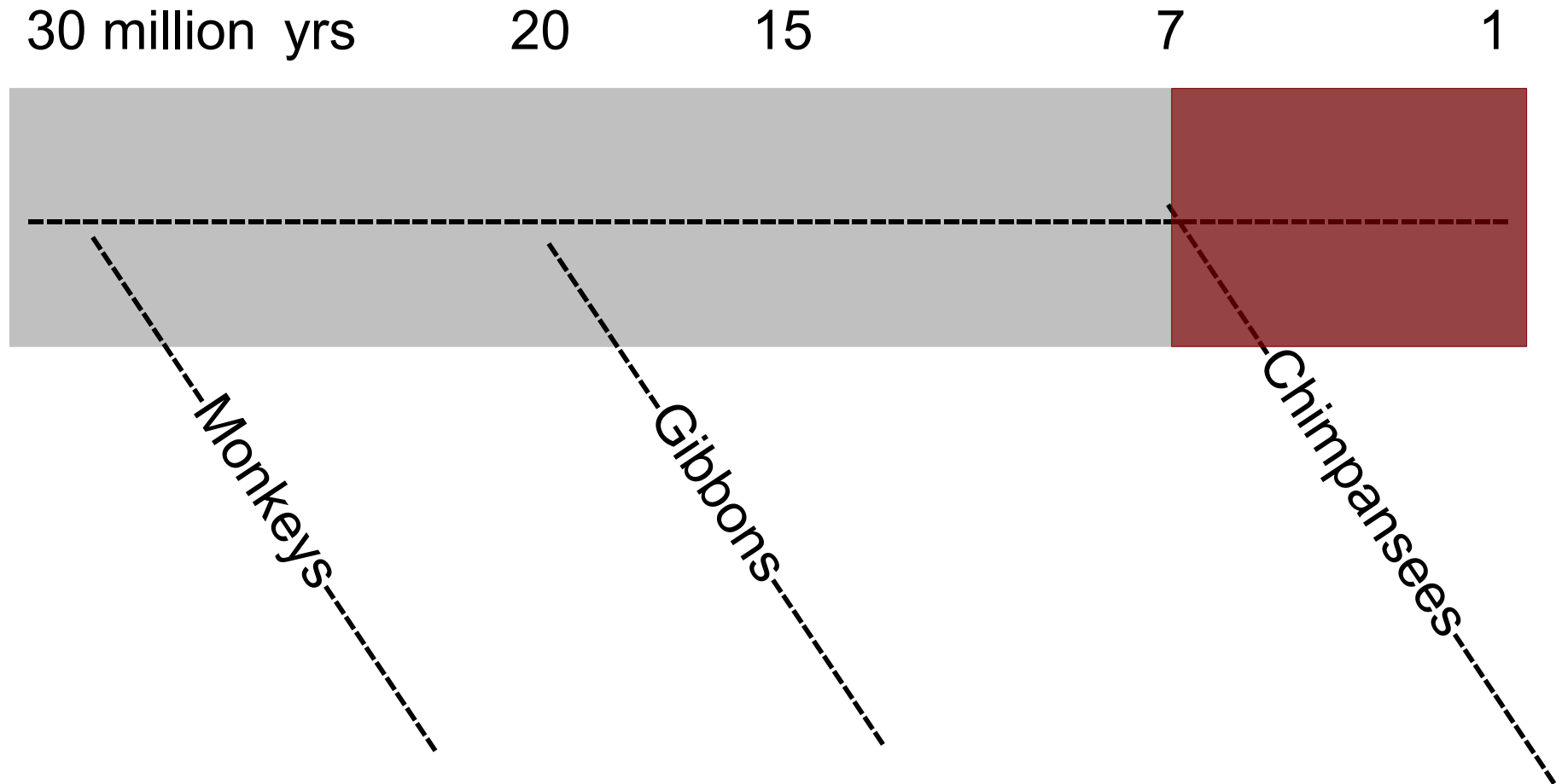


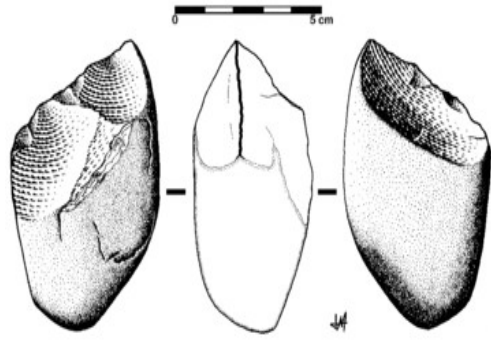
Story of human evolution



Cognition, Language & Computation
MSc Brain & Cognitive Science
2013

Lecture 8: Language, cooperation, cognition

Jelle Zuidema



Oldowan

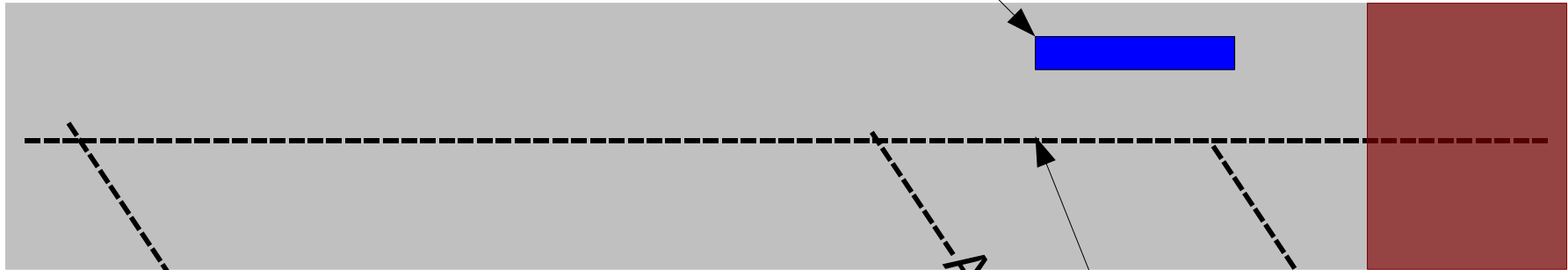
7 million yrs

3

2.5

1.5

1

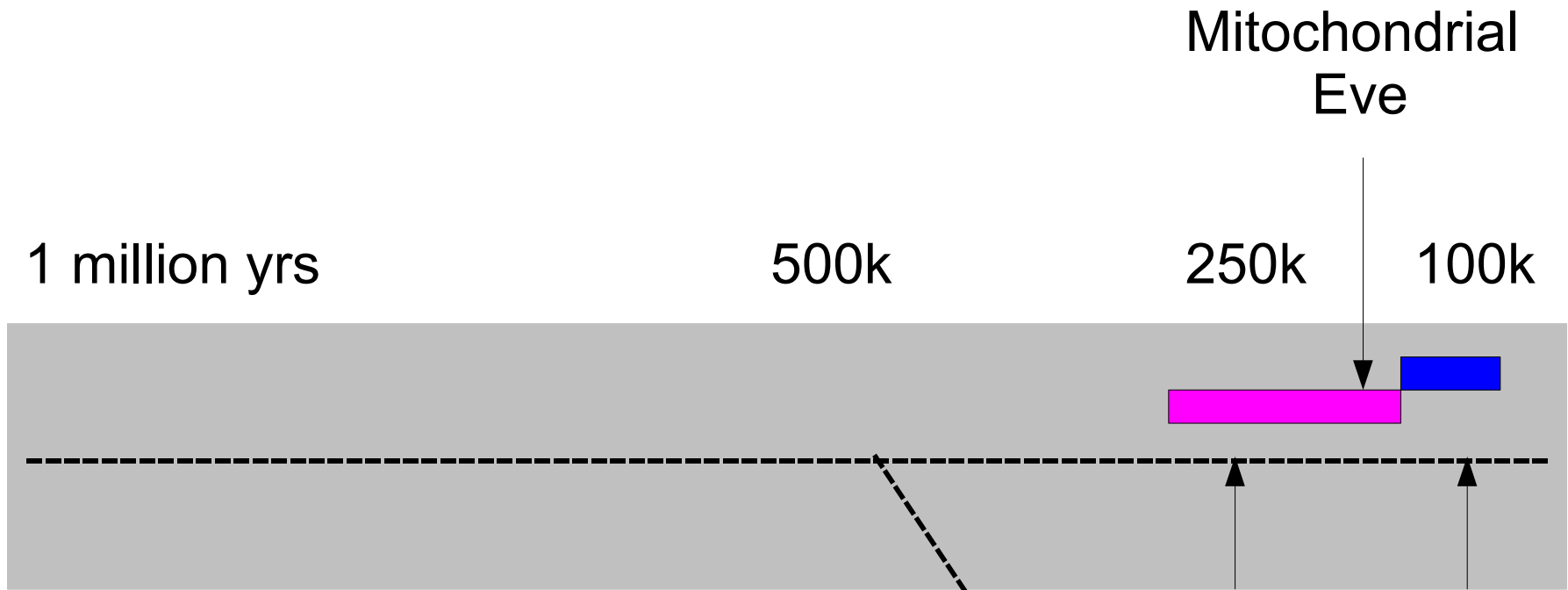


Chimpansees

Australopithecus

Homo
genus

Ergaster



Neanderthals





painting, Lascaux, France, 15,000 to 10,000 B.C.

Patel

Hummel

Spelke,
Carey

Music

Art

Numerical
& spatial
Cognition

Relational
Reasoning

Social
Cognition

Cooperation

General
Intelligence

Language

Planning

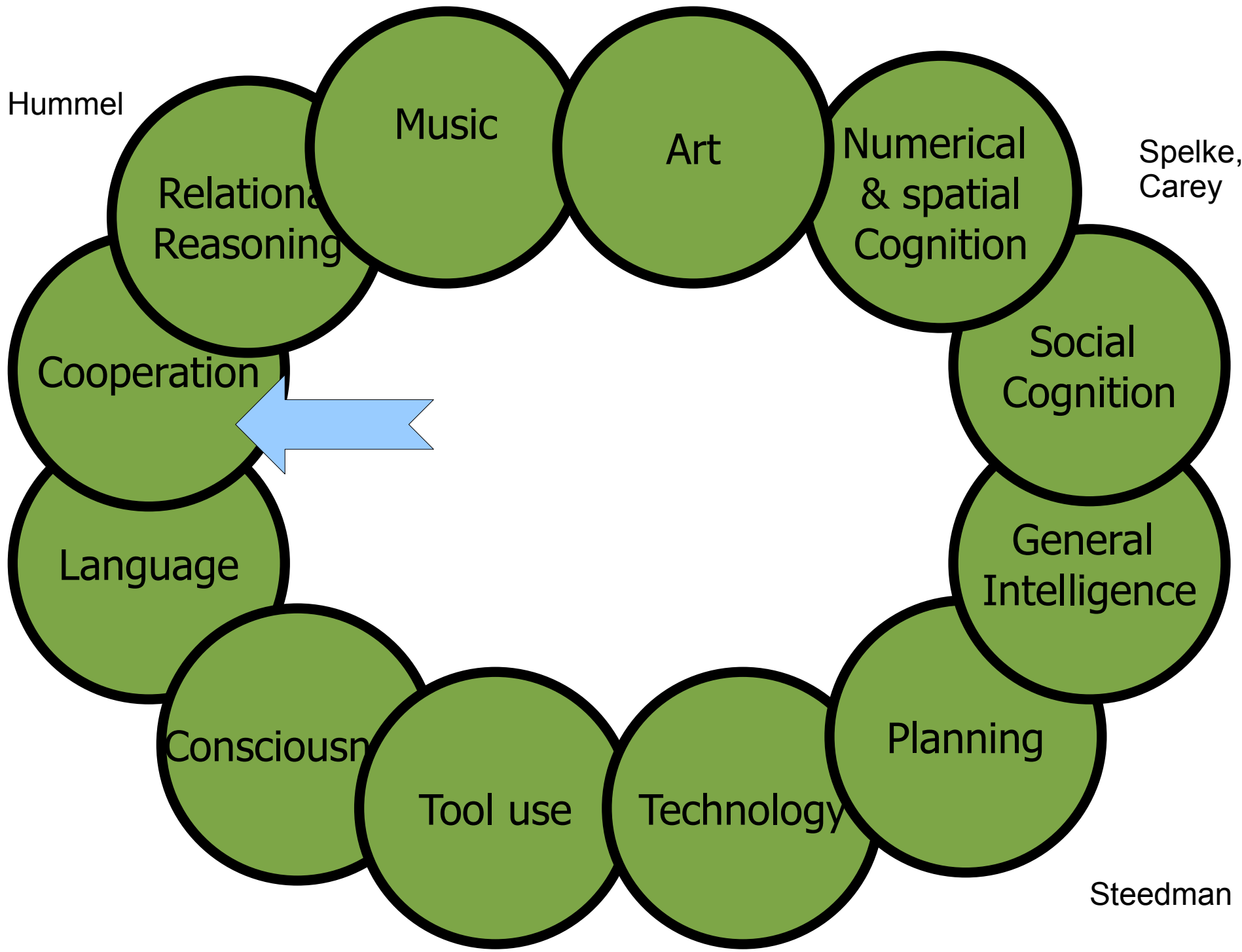
Consciousness

Tool use

Technology

Steedman

Steele

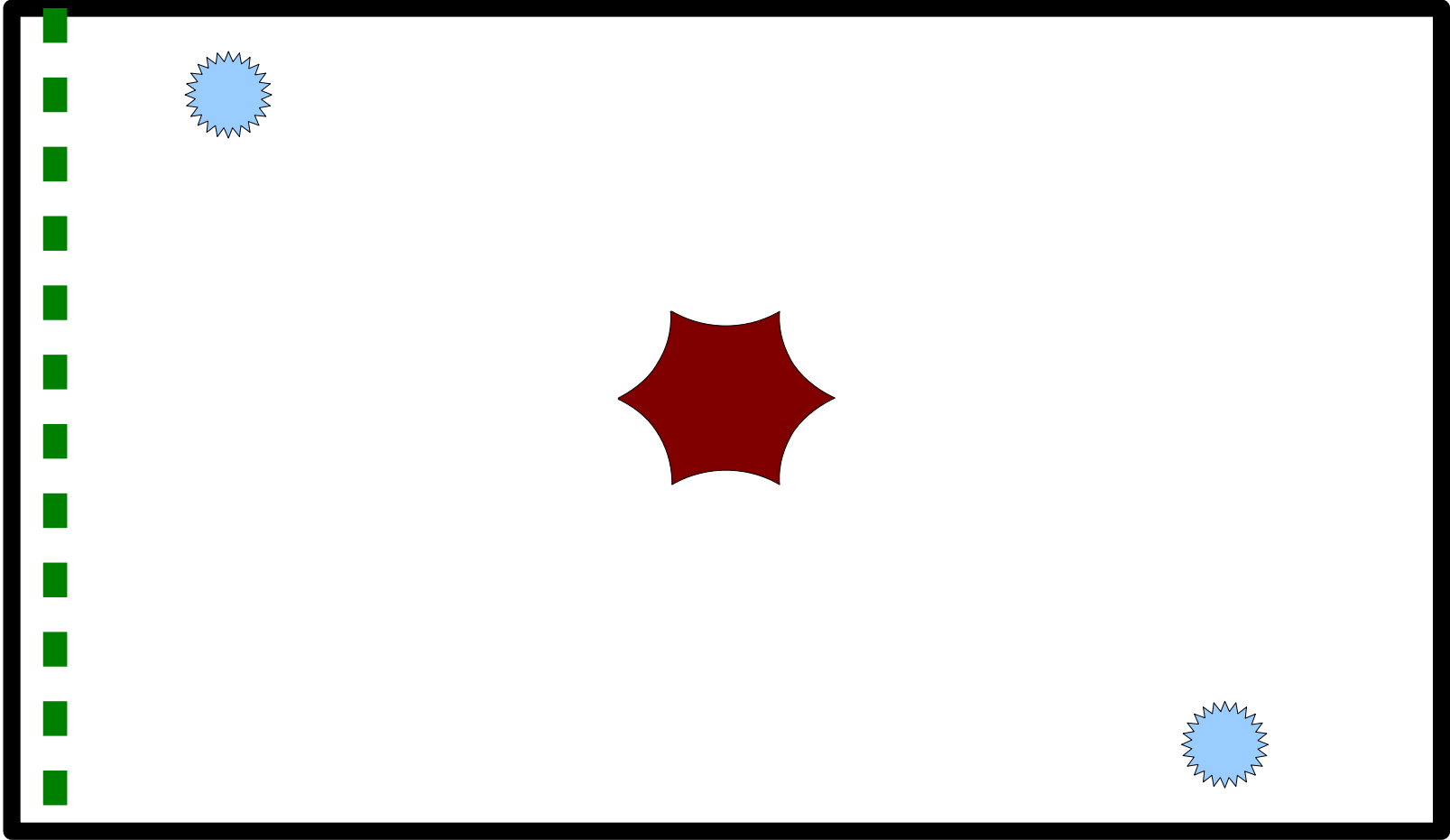


Language & cognition

- Reasoning: logic \leftrightarrow language (not, and, or, if, then, all, every, some, X is Y, ...)
- Planning: hierarchical plans \leftrightarrow hierarchical phrase-structure
- Theory of mind: intentional embedding \leftrightarrow sentential embedding
- Mathematics: number words, context-free syntax of algebra
- Music: pitch, rhythm, phrasal structure, cultural transmission
- Consciousness: inner voice
- Society/technology: eg, Pizarro's capture of Atahualpa

Key questions

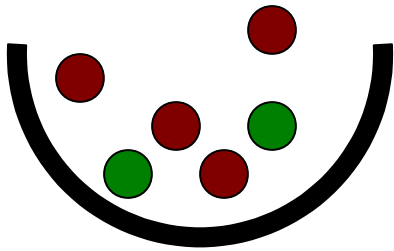
- Is language involved in the uniquely human components of other cognitive skills?
- Is language the 'cause', or did the influence go the other way around (eg, general intelligence)?
 - Spelke: core knowledge & language
 - Social cognition
 - Sequence learning
 - Number cognition



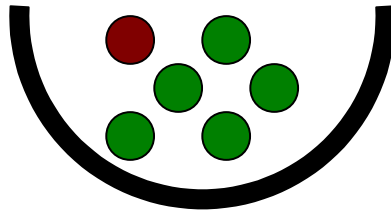
Language & cooperation

- Accounting for the evolution of cooperation/ altruism is challenging;
- Language use often *requires* cooperativity;
- Language might also *facilitate* cooperativity;
- Evolution of cooperation requires unusual conditions:
 - Kin selection: interaction w/kin, competition w/nonkin
 - Reciprocal altruism: repeated interactions, memory
 - Multilevel evolution: alternating grouping/dispersing
 - Altruistic punishment: solution to 2nd order problem

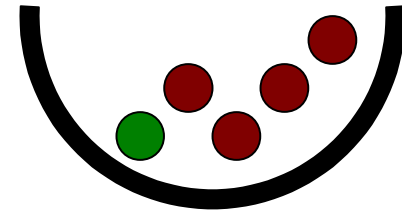
Evolution in structured populations



2:4

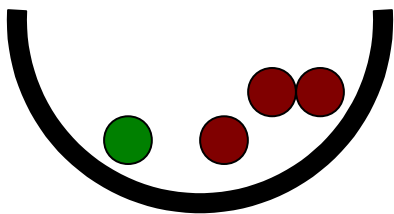


5:1

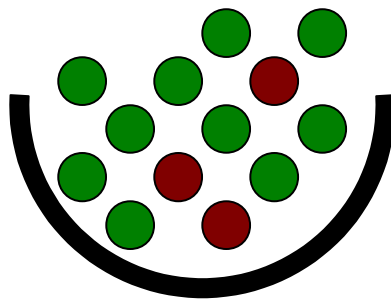


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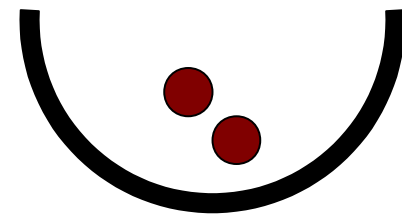
8:9



1:3



10:3



0:2

11:8

Language facilitating cooperation

- Language can help identifying kin (*kin selection*)
- Language facilitates memory and theory of mind (*reciprocal altruism*)
- Language facilitates gossip / reputation (*punishment*)
- Language marks group membership (*multilevel*)

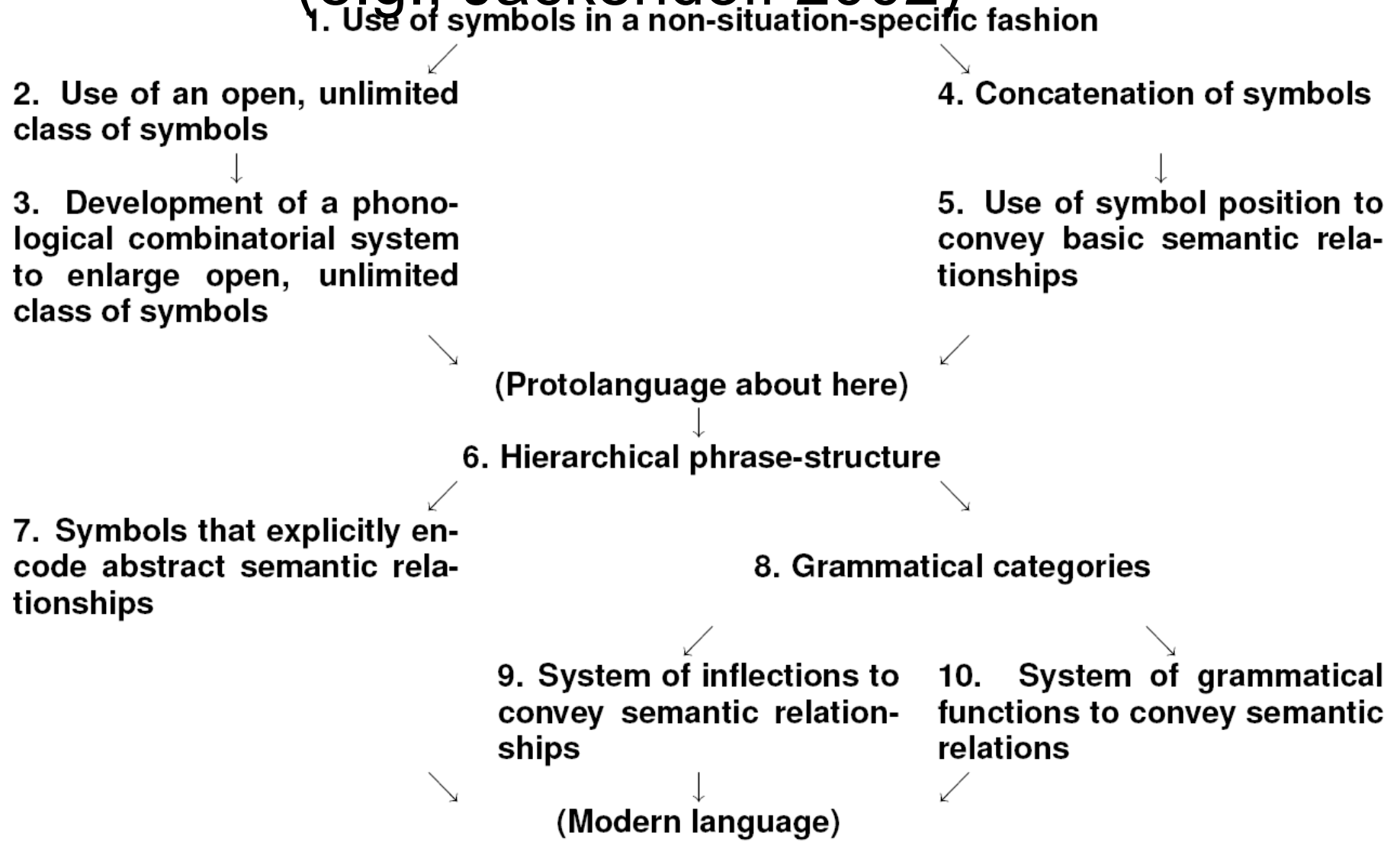


Evolution of Language & cognition

- “Language-first scenario”: humans discovered language, and language made us smart
- “Intelligence-first scenario”: human intelligence increased and affected many other human cognitive traits (once it reached a threshold)
- “Massive modularity scenario”: human specific traits are modules, evolved one by one under selection pressure of savannah life

Gradualist/adaptationist scenario

(e.g., Jackendoff 2002)



Gradualist/adaptationist scenario

(e.g., Jackendoff 2002)

- Language
 - Vocal learning, speech production/perception, symbolism, compositionality, comb. phonology, hier. phrase-structure, synt. categories, inflections
- Reasoning
 - Counterfactual reasoning, n^{th} order theory of mind, mathematical skills
- Music
 - Harmony, beat induction
- Consciousness, planning, culture, ...

Linguistic sweep scenario

Pre-existing

- hierarchical, conceptual structure
- non-combinatorial communication
- limited cooperativity & social cognition
- hidden potential for more complex cognition

biological evolution



Biological adaptations to new niche

- larger social groups
- increases in social intelligence, cooperativity & communication
- increased reliance on learned, combinatorial signaling

cultural evolution



Cultural adaptations

- learned communication system adapts to preexisting biases of hominin brain (can thus be much more complex than random code)
- communication system becomes representational system for internal thought too
- knowledge transfer from previous generations unlocks potential for complex cognition

biological evolution



New cultural niche

- creates intense selection pressure for linguistic & cognitive skills

cultural evolution



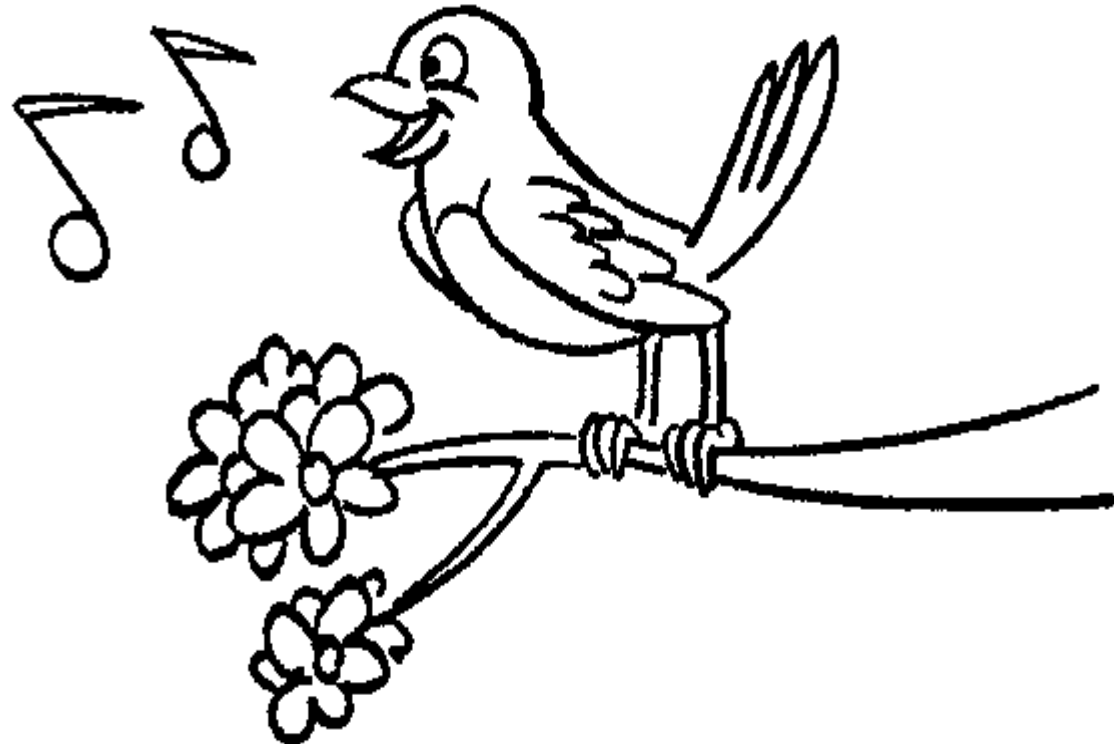
How did language evolve?

- In many different studies, we have shown that *cultural evolution* is a powerful mechanism...
- .. that can, in principle, shape languages such that they adapt to idiosyncracies of human brains & bodies (Kirby'00; de Boer'01, Zuidema'03; Verhoef'13)
- For explaining features of language, cultural evolution models assume a *hidden potential*. Is that reasonable?
 - hard to tell for many specifics of syntax, semantics, phonology; easier at level of 'design features'

(unique?) design features

(Hockett, 1960, etc; linguistic textbooks reviewed in Smith'03)

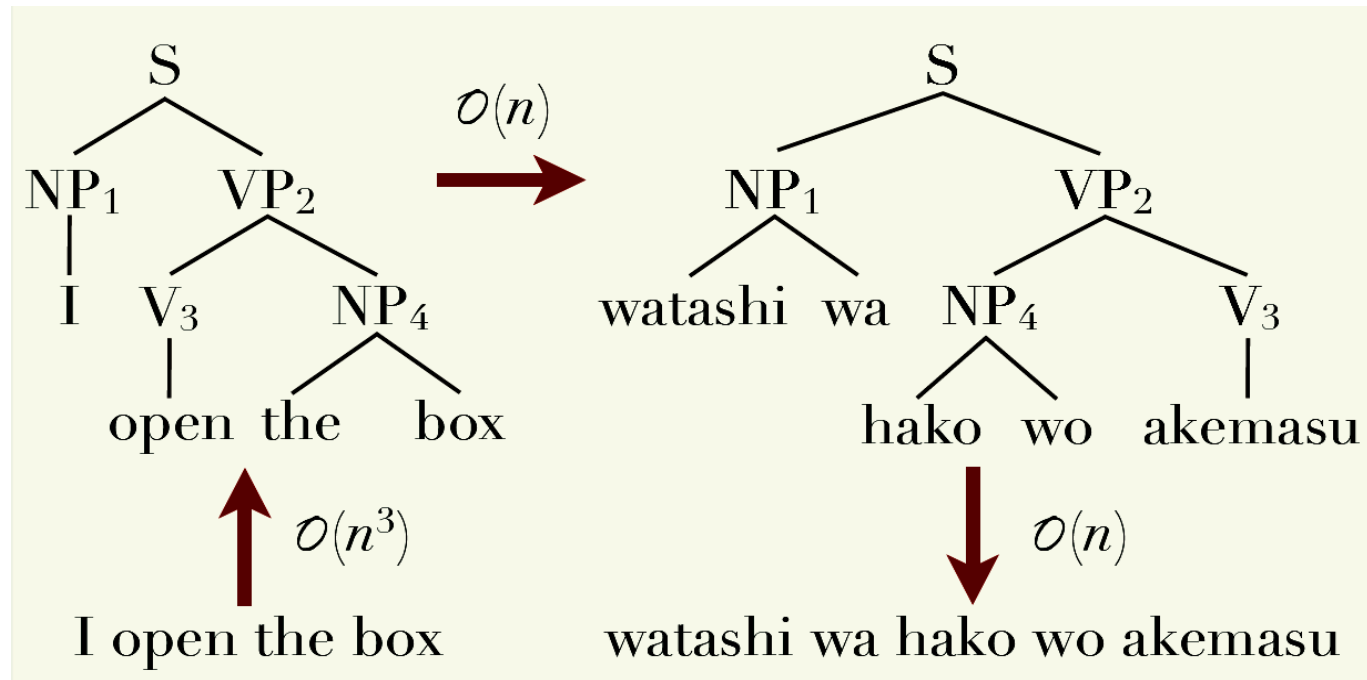
- **DISCRETENESS / COMBINATORIAL PHONOLOGY**
- **STIMULUS FREEDOM**
- **CULTURAL TRANSMISSION**
- **ARBITRARINESS**



(unique?) design features

- **SYMBOLISM**
- **DISPLACEMENT**
- **DUALITY OF PATTERNING**
- **OPEN-ENDEDNESS / RECURSION**
- **COMPOSITIONAL SEMANTICS**

HIERARCHICAL COMPOSITIONALITY



Working hypotheses

- Language was the key innovation in the evolution of human cognition;
 - Can we show a role for language in development of other uniquely human cognitive skills?
- Cultural evolution is key to understanding origin of many features of language;
 - Can we develop a quantitative theory of cultural evolution and help solve open issues in linguistics?
- Hierarchical compositionality is the key biological innovation in language evolution.
 - Can we identify the biological substrate of hierarchical compositionality?

Take home messages

- Language is a very complex behavior, that differs qualitatively from animal and nonlinguistic communication;
- Language *recruits* many of our advanced cognitive skills, and likely *facilitates* many of them;
- A key design features of language is its *categorical, hierarchical structure*
 - important open question whether it requires special neural substrate

Take home messages (ctd)

- Artificial Language Learning also provides a useful paradigm for investigating pattern learning abilities underlying music, planning, prediction, etc., and has clinical applications;
- ***Finite-state automata*** and ***contextfree grammars*** are used in many domains of cogsci (sequence learning, programming, process models, neural computation)
- Key challenge in cognitive science is combine ***models*** with ***observations*** and ***experiment***
 - *Foundations of Neural and Cognitive Modelling*