Language Evolution

- Features of human language
- Evidence for a universal grammar
  - Language development
  - Pidgeons and creoles
  - Language disorders
  - Grammar gene (FoxP2)
- Language evolution
  - Animal language experiments
  - Fossil evidence
  - ESS approaches to language evolution
  - Language diversity

What is language for?

- Provides labels for categories of objects
- Permits us to form internal representations of objects in our minds
- Allows us to convey what we are thinking

Universal grammar

- All sentences contain a subject-verb phrase
- Verbs have argument structure
  - "John sleeps"
  - "John hit Mary"
  - "John gave Mary a present"
- Meaning depends on order (syntax)
  - "John is hungry" ≠ "Is John hungry?"
- No more than two branches spring from the same node, but phrases can be stacked together like Chinese boxes

Sentences can be infinitely long, but have hierarchical structure

" This is the man all tattered and torn, who loved the maiden all forlorn, who milked *the cow with the crumpled horn*, that kicked the dog that chased the cat that killed the rat that ate the malt that lay in the house that Jack built"

Noun phrase structure

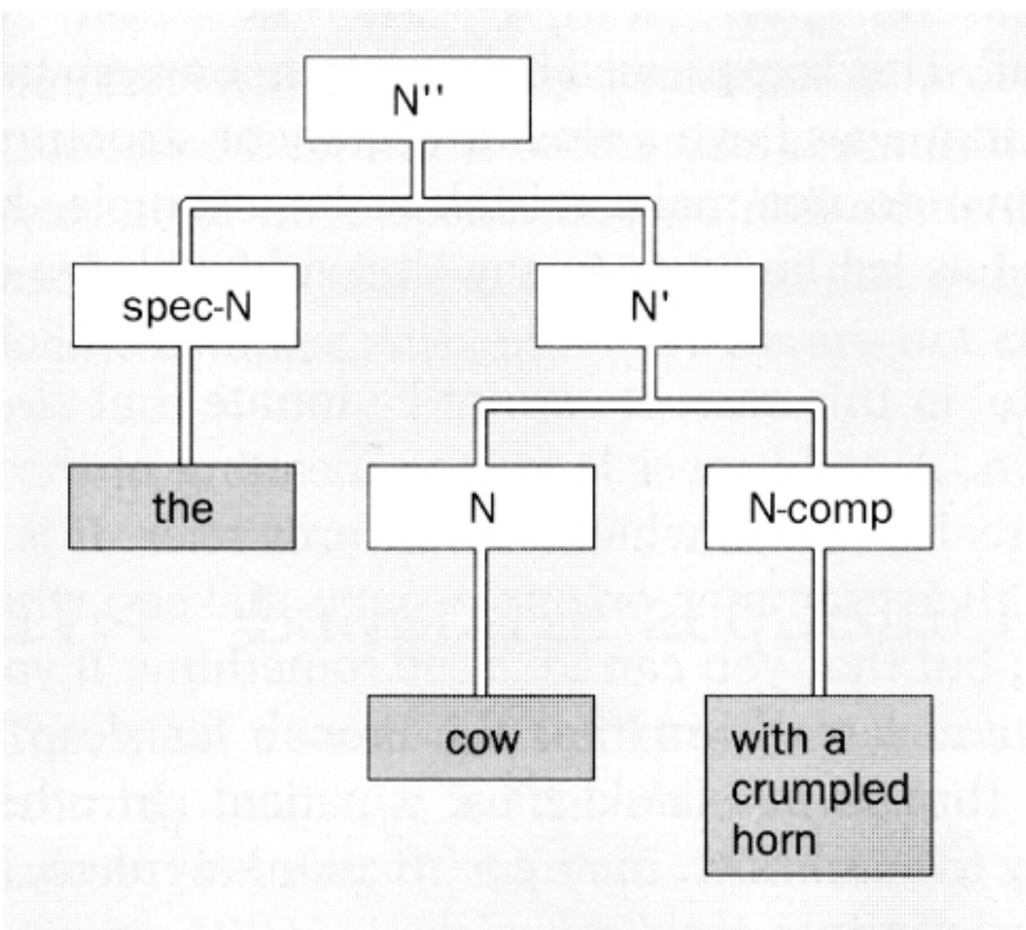
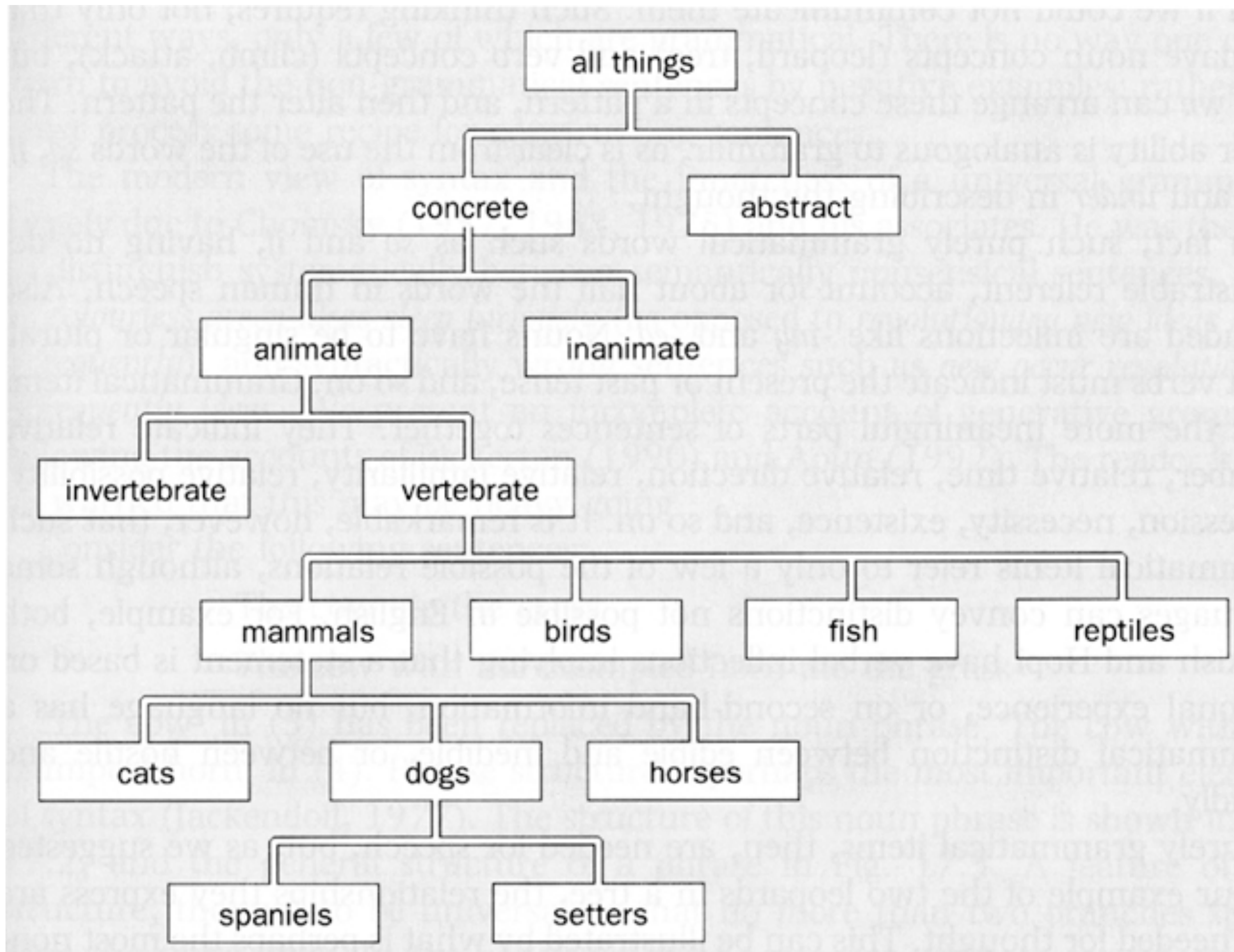


Fig. 17.2 The structure of a noun phrase (after Bickerton, 1990). N (*cow*) is the head of the phrase, and must be a single word. It is first linked to its complement (*with a crumpled horn*) via the node N′, and N′ is then linked to the specifier (*the*) via the node N″, representing the full phrase. Although the head, N, must be a single word, the complement may itself be a phrase, as it is in this example. Thus phrases are like chinese boxes, stacked inside one another.

Words also form hierarchies



Consequences of grammar

- All 6500+ known languages utilize a structurally similar grammar
- Due to combinatoric structure can produce an infinite number of sentences with only a few rules
- Words must be learned and associated with objects, actions and relationships. The list of words used in a language is the lexicon.

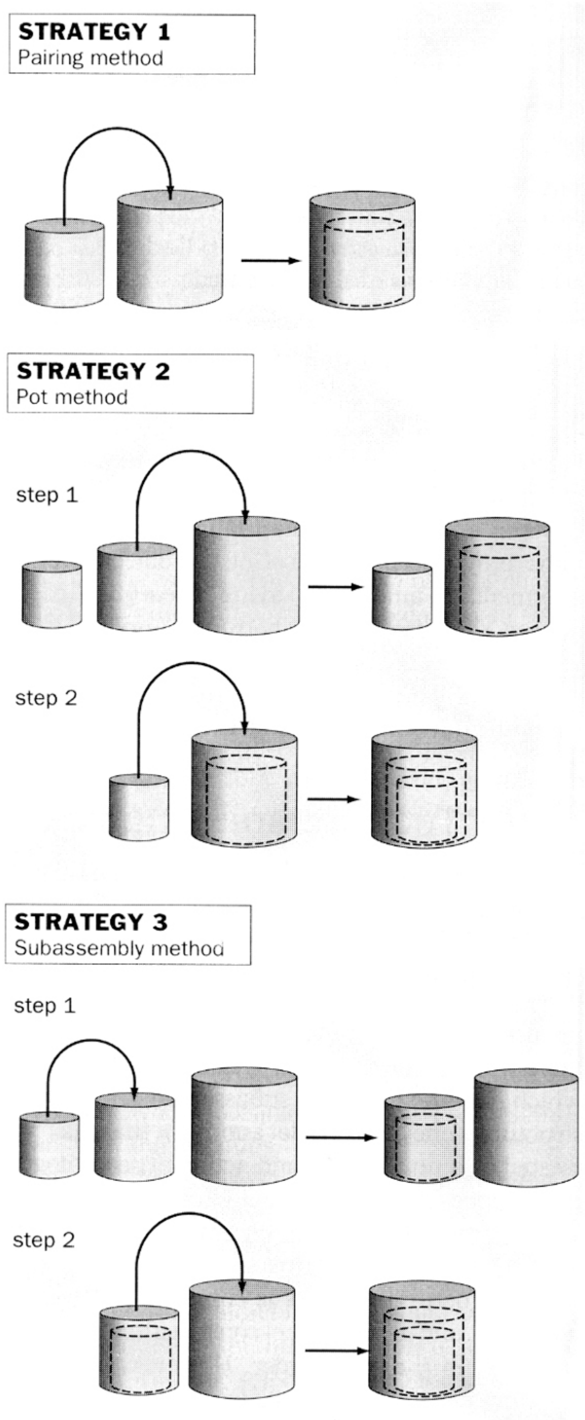
Evidence for universal grammar

- Children follow consistent patterns of language development independent of culture
- Caspar Hauser children and apes exhibit protolanguage
- Creole languages have evolved in a single generation from pidgeons in many parts of the world
- Evidence for neuroanatomical modularity
  - Language disorders disrupt grammar, but not overall mental competency
- Single gene influences grammar

Infant vocal development

The Early Stages of Vocal Development in Human Infants (Oller and Eilers 1992)

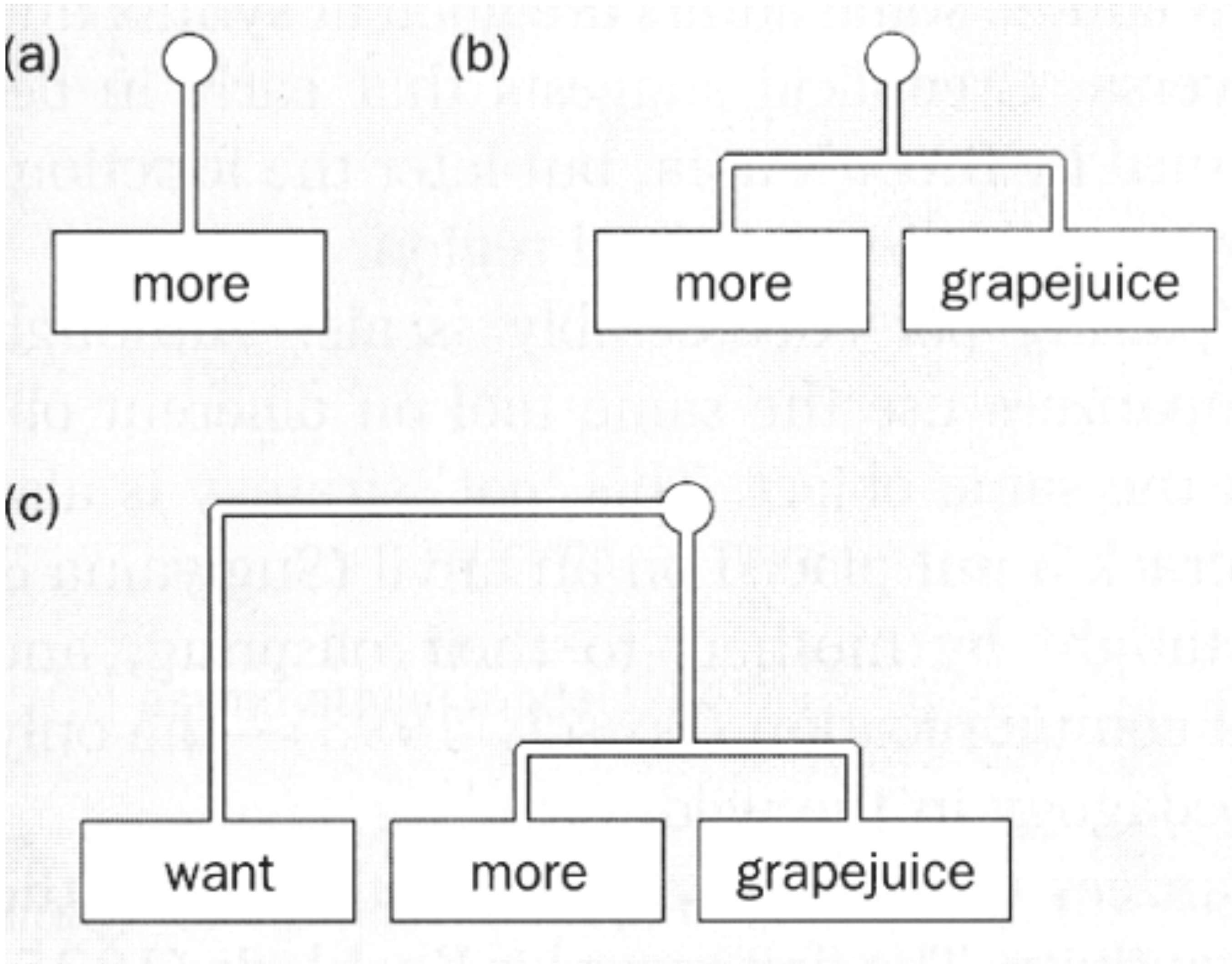
Stage	Label	Age (months)	Description
1	Phonation	0–2	Quasi-vocalic sounds produced with normal phonation. The vocal tract is typically open, with minimal movement of the tongue and mandible.
2	Primitive articulation	1–4	Combination of quasi-vocalic and protoconsonantal utterances (i.e., primitive syllables) produced at the back of the throat. These sounds therefore indicate the first sign of normal phonation together with articulation.
3	Expansion	3–8	Full vocalic sounds (i.e., vowel precursors) produced repetitively. Squeals, growls, yells, whispers, raspberries, and grunts produced, indicating control of pitch, amplitude, and articulatory movement. Initiation of babbling, known as *marginal babbling*, characterized by protoconsonantal margins (i.e., sound that starts or terminates an utterance) and nucleus (resonant vowels); formant transitions for such utterances are not quite adultlike.
4	Canonical	5–12	First signs of clearly articulated reduplicated syllables such as "mama" and "dada," and later on (11–12 mos) variegated syllables such as "bada." Margins and nuclei are produced in the adult form. Infants will occasionally produce words of the native language, but without necessarily recognizing the fact that they have a specific meaning.



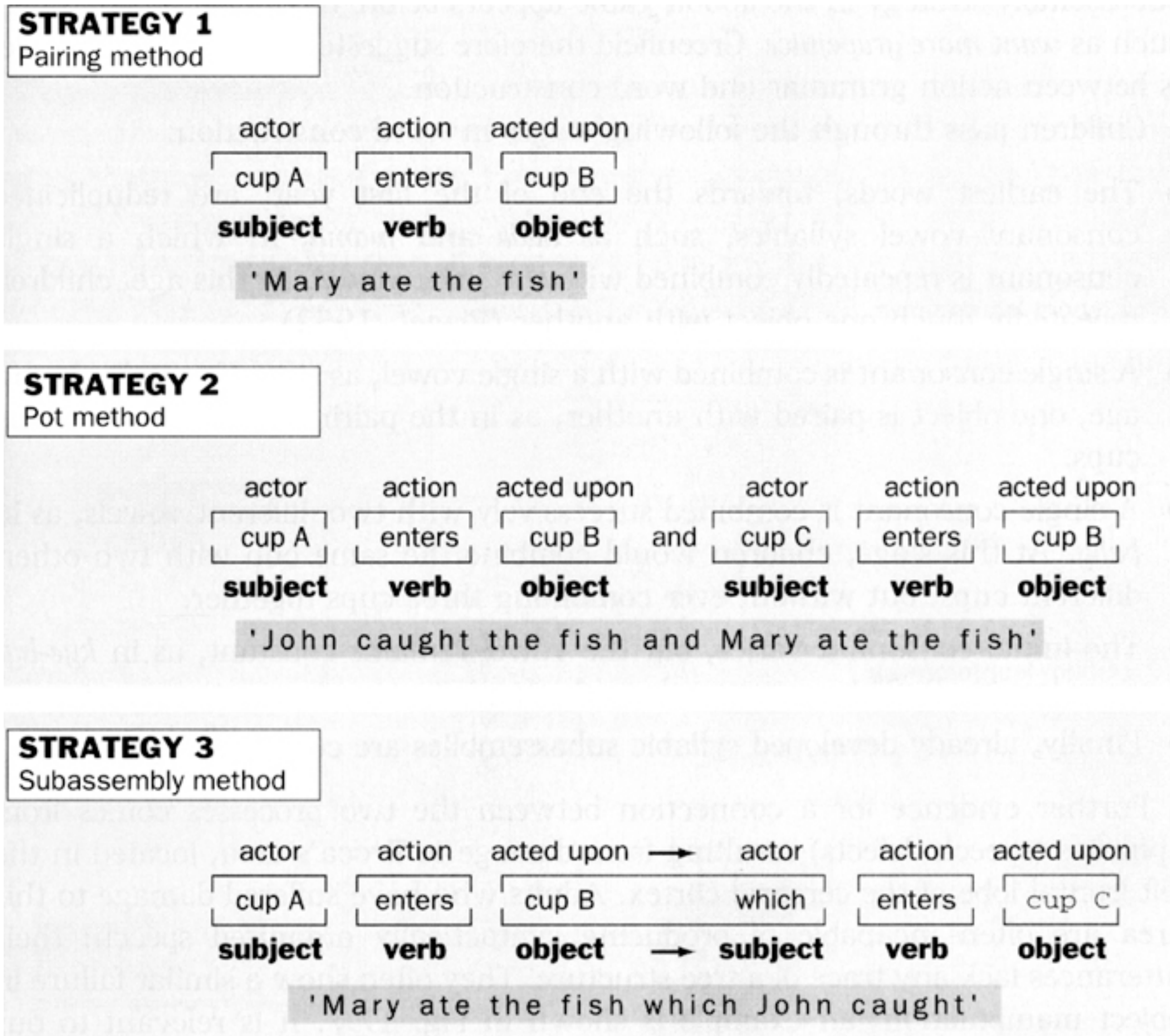
Word development follows object manipulation patterns

- Single consonant combined with single vowel: na (for no)
- Reduplicated consonant-vowel syllables: dada, mama
- Single consonant combined with different vowels: baby
- Initial consonant varies, but vowel remains constant: kye-bye (car bye-bye)
- Syllabic subassemblies are combined: ball

Syntax ontogeny



Grammar also follows an ontogenetic pattern of object manipulation



Protolanguage

- Big train; Red book
- Adam checker; Mommy lunch
- Walk street; Go store
- Adam put; Eve read.
- Put book; Hit ball.

2-year old child

- Drink red; Comb black.
- Clothes Mrs G; You hat.
- Go in; Look out.
- Roger ticket; You drink.
- Tickle Washoe; Open blanket.

Trained chimpanzee

Animal language studies

Linguistic Tool	Species	Reference
Formal ASL	Chimpanzee, gorilla	1
''Pidgin'' ASL	Chimpanzee	2
''Pidgin sign English''	Orangutan	3
Arbitrary gestures and sounds	Dolphin, sea lion	4
Color/shape symbols	Chimpanzee	5
Lexigrams (abstract symbols)	Chimpanzee, bonobos	6
Comprehension of spoken English	Bonobo	7
Production and comprehension of spoken English	African gray parrot	8

References: 1 (Gardner and Gardner 1969; Gardner, Gardner, and Van Cantfort 1989; F. Patterson 1979, 1987); 2 (Terrace 1979); 3 (Miles 1978); 4 (Herman, Richards, and Wolz 1984; Schusterman et al. 1993); 5 (Premack 1971, 1986; Premack and Premack 1983); 6 (Rumbaugh 1977; Savage-Rumbaugh 1986); 7 (Savage-Rumbaugh et al. 1993); 8 (Pepperberg 1987a, 1991).

For a detailed but highly critical review of this literature, see Wallman (1992).

Caspar Hauser children

- Want milk,
- Mike paint.
- Applesauce buy store
- At school wash face
- Very sad, climb mountain
- I want Curtiss play piano

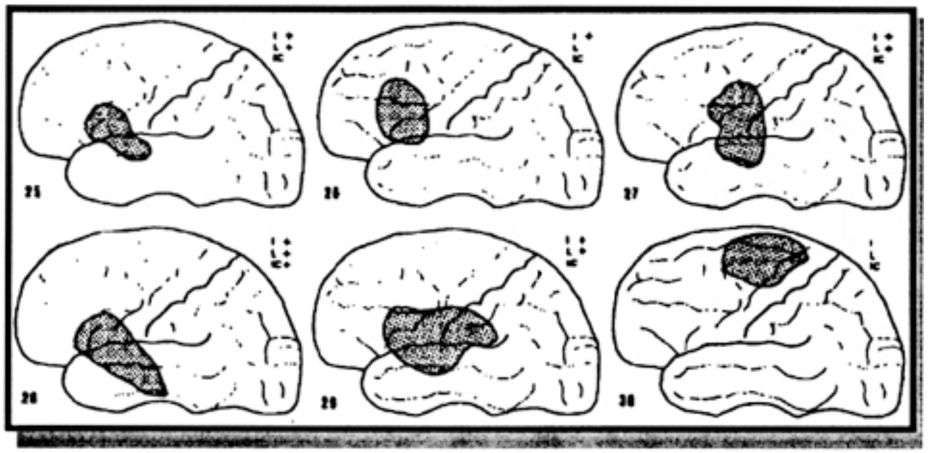
- 13 year old girl who was imprisoned by her father at 18 months
- Never learned to speak
- Normal ability to form concepts

Pidgeons and Creoles

- Pidgeon languages are formed by people who do not share a language, e.g. traders or slaves in island colonies
  - "Forman, who carry? Carry all, cut all"
- Children of pidgeon-speaking parents form Creole languages, which have complete grammatical structure, in 1 generation. These have developed in many parts of the world with similar grammars

Language aphasias

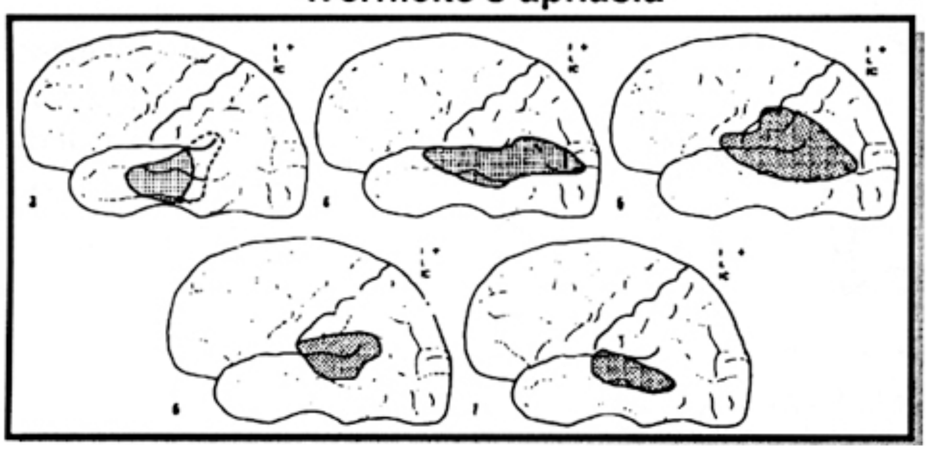
Broca's aphasia



Disrupts grammar structure, but have full comprehension

http://video.google.com/videosearch?q=language+aphasia&hl=en&client=firefox-a&emb=0&aq=f#

Wernicke's aphasia



Sentences are grammatically correct, but meaningless

Both forms disrupt ability to reproduce drawings

A Sample of Language Aphasias, Their Putative Locus of Damage, and Apparent Functional Consequences

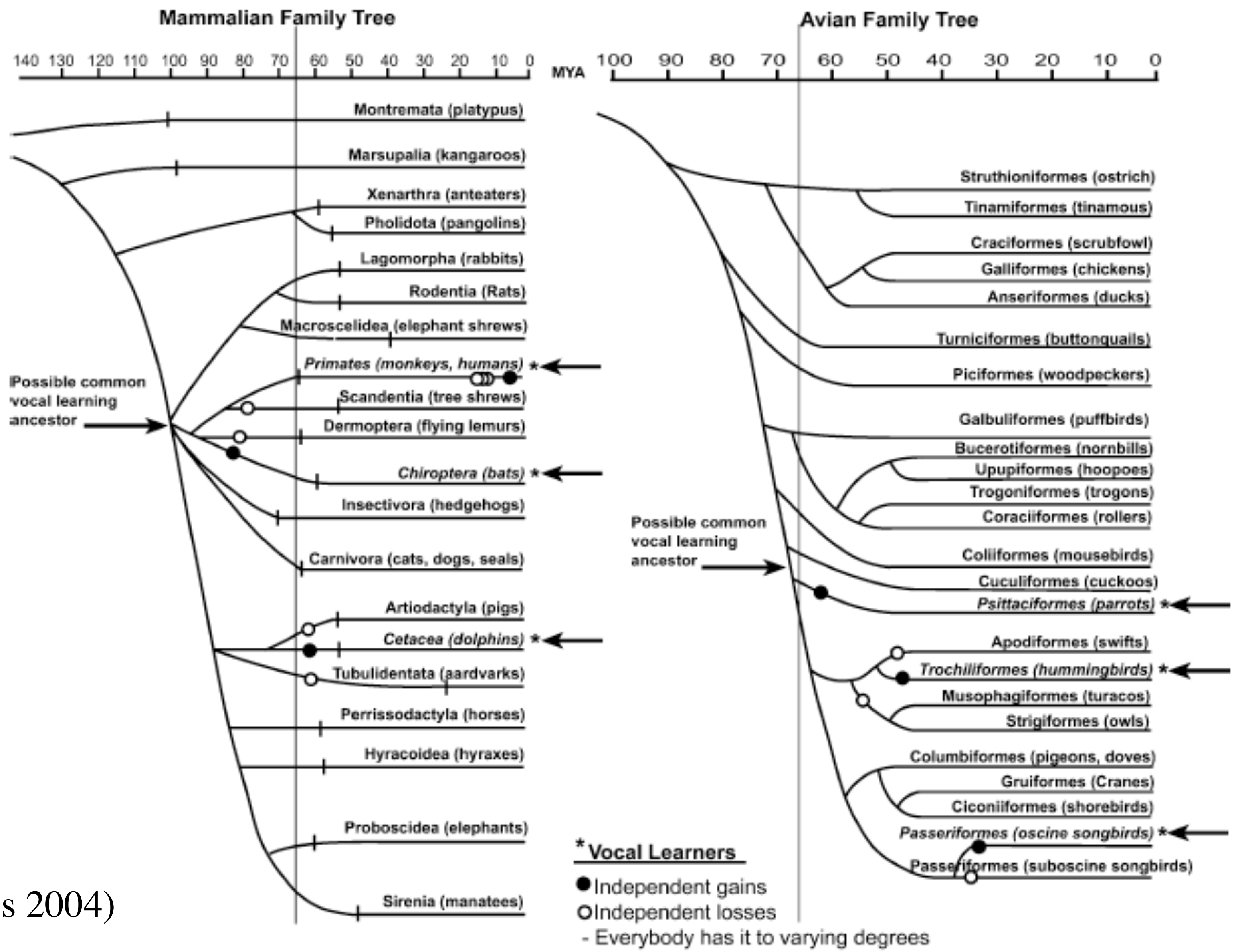
Type of Aphasia	Locus of Damage	Description
Global aphasia	Left perisylvian region	Propositional speech is either completely or almost completely absent, including oral production, oral comprehension, reading, and writing.
Mixed transcortical aphasia	A border surrounding the perisylvian	Comprehension in the auditory and visual speech domains is lost, though subjects can repeat what they hear.
Transcortical sensory aphasia	Temporo-parietal-occipital junction, posterior to Wernicke's	Comprehension is impaired, but speech repetition and production are unaffected.
Transcortical motor aphasia	Prefrontal area rostral and dorsal to Broca's	Speech production is impaired, but speech repetition and comprehension are unaffected.
Broca's aphasia	Broca's area (posterior regions of the second and third divisions of the inferior frontal gyrus)	Spontaneous speech is often poorly articulated, nonfluent, effortful, and can be characterized by loss of grammatical words. Speech repetition is poor, and naming can also be impaired. Comprehension is typically unaffected.
Wernicke's aphasia	Wernicke's area	No articulatory impairments for spontaneous speech, but there often is difficulty with selection of appropriately meaningful words. Repetition and naming are poor. Comprehension of both spoken and written words is significantly impaired.
Conduction aphasia	Arcuate fasciculus	Occasional difficulties with articulation. Repetition is heavily impaired. Naming and comprehension in the auditory domain show slight impairments.

Information on aphasias obtained from reviews by Caplan (1987, 1992), Demonet, Wise, Frackowiak (1993), Dronkers and Pinker (in press), Gordon (1990), and Maratsos and Matheny (1994).

Language origins: vocal learning?

- Mammals
  - Young animals learn call context, not call type
  - Examples of vocal learning typically involve call convergence for group recognition
- Birds
  - Vocal mimicry is widespread and male-limited in oscines
  - Repertoires function in sexual advertisement and territorial encounters
    - Why species differ in repertoire size is unclear
  - Parrots exhibit call convergence of group calls
  - We know little about hummingbird vocal learning

Is vocal learning a single trait?



(Jarvis 2004)

FOXP2 - a grammar gene?

- Encodes a transcription factor containing a polyglutamine tract and a forkhead DNA-binding domain
- Causes a severe speech and language disorder that is transmitted as an autosomal-dominant trait
- Comparison of sequences between humans and great apes has revealed changes in amino-acid coding and a pattern of nucleotide polymorphism, which suggest that this gene has been the target of selection during recent human evolution
- Differential expression of FoxP2 in avian vocal learners is associated with vocal plasticity

FoxP2 structure

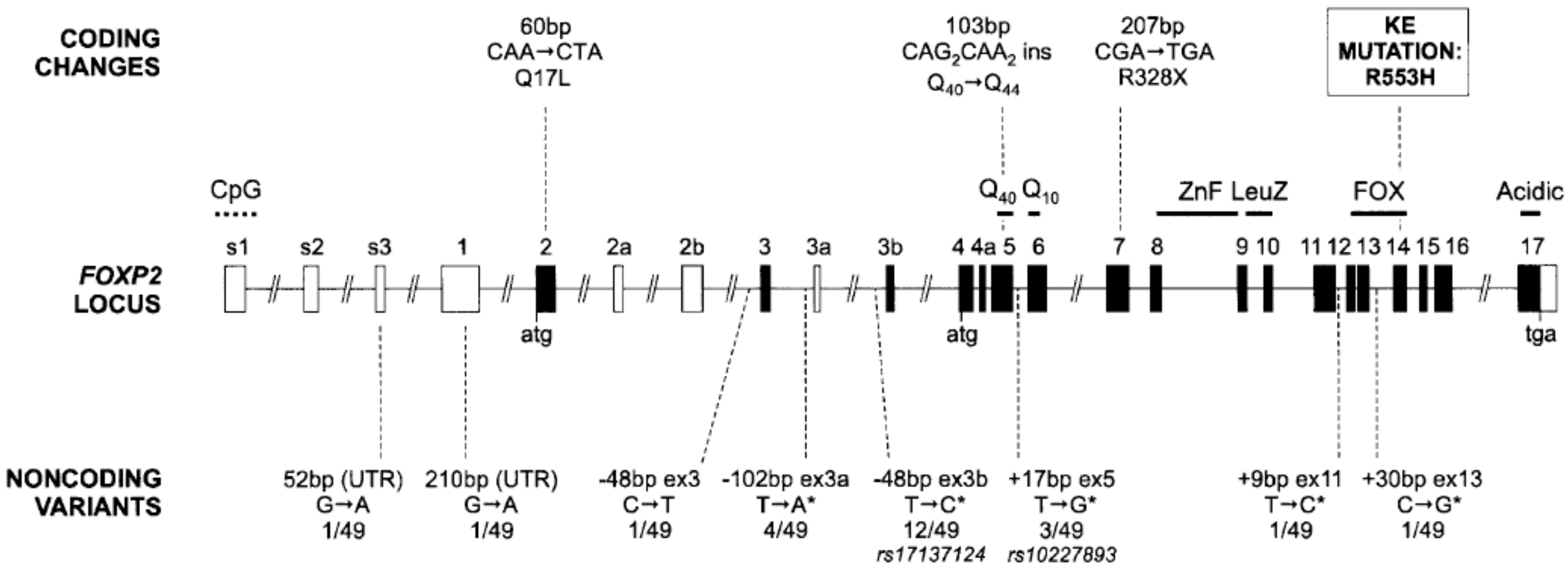
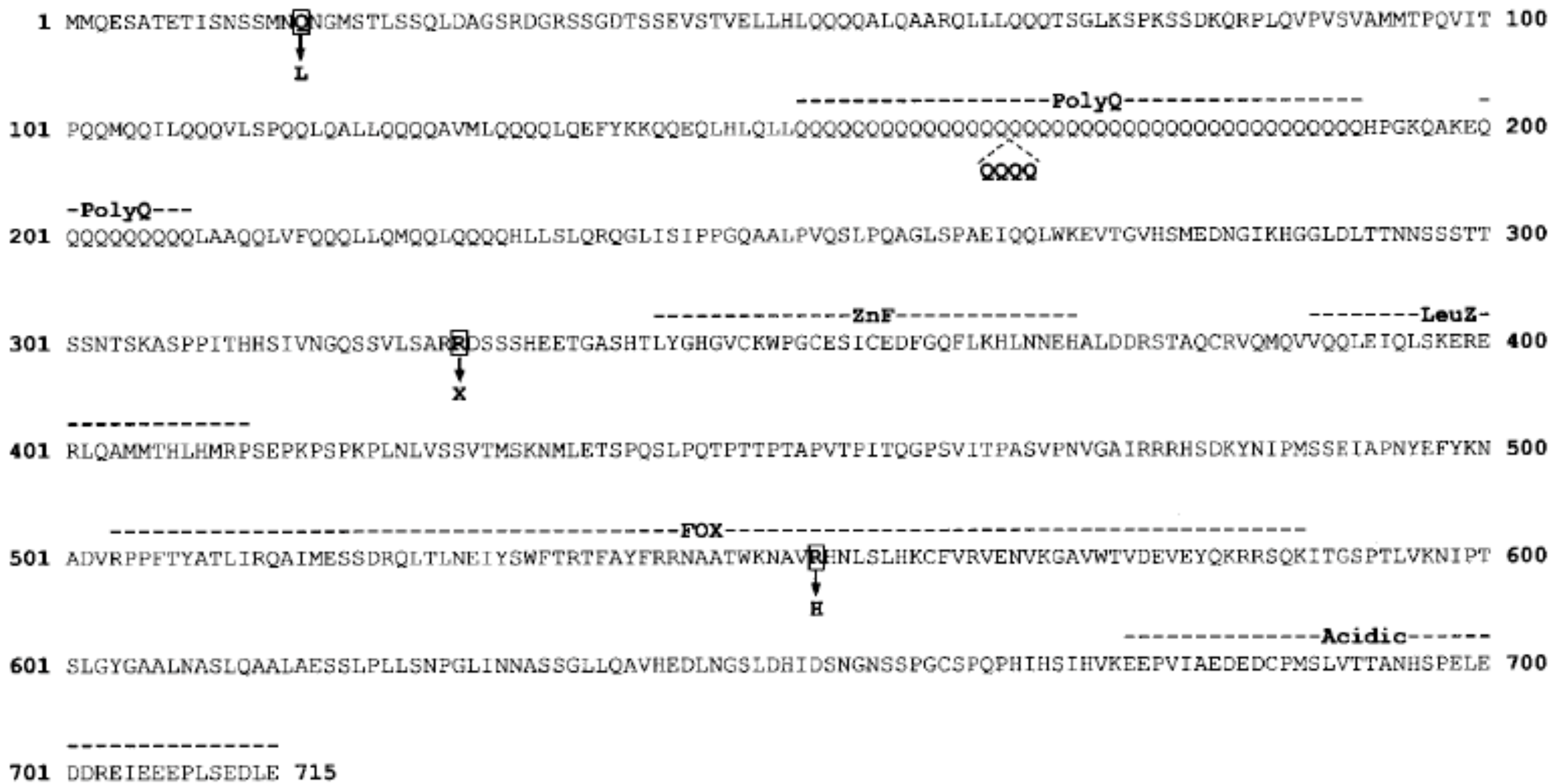


Figure 1 Schematic of the human *FOXP2* locus, which spans >600 kb of genomic DNA, showing sequence variants identified in subjects with verbal dyspraxia. Black shading indicates translated exons; "atg" and "tga" denote positions of initiation and termination codons. Known domains encoded by exons include polyglutamine tracts (Q_{40} and Q_{10}), a zinc-finger motif (ZnF), a leucine zipper (LeuZ), the forkhead domain (FOX), and an acidic C-terminus (Acidic). Exons 3b and 4a are alternatively spliced coding exons yielding amino acid insertions, whereas alternatively spliced exons 2a, 2b, and 3a are predicted to be noncoding. Exons s1–s3 and 1 represent alternative 5′ UTR regions that have not been found in the same human transcript; the position of the 5′ end of exon 1 is based on currently available EST data. For more information on splicing and isoforms, see Lai et al. (2001) and Bruce and Margolis (2002). All known exons were screened for mutations, with the exception of two noncoding exons: s1 (5′ CpG-rich UTR) and 2a (alternatively spliced and untranslated). Coding variants are shown above the locus, with resulting codon and amino acid changes indicated. For reference, the KE mutation is also included. Noncoding variants are shown below the locus, with information regarding relative position (with respect to the exon in question) and frequency in probands (number of heterozygous probands/total probands screened). An asterisk (*) denotes intronic variants that correspond to those previously detected by Newbury et al. (2002), and rs numbers are indicated for polymorphisms also present in dbSNP. Locus schematic is adapted from Fisher et al. (2003).

All human FoxP2 AA variants (Macdermot 2005)



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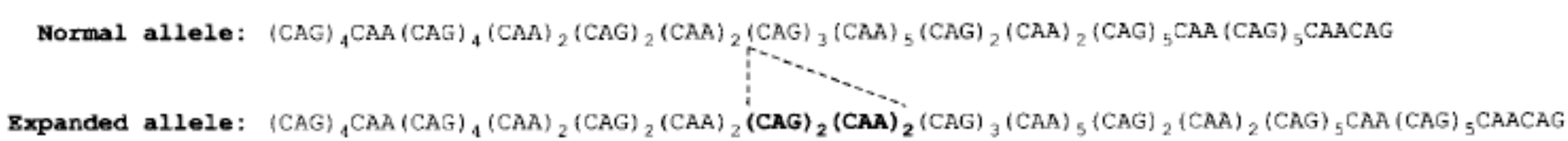


Alternative ideas regarding when language evolved

- Evolved in steps from primate ancestors
  - Due to direct competition among hominoids?
  - Need to maintain social relationships in large groups?
- Approx. 1 MYBP
  - Tool kit became sophisticated, persisted for nearly 1 million years
- Approx 40,000 YBP
  - Cave paintings indicate sophisticated symbolic communication

The social brain hypothesis

- Brain size increases with group size across species
- Old world primates and apes use grooming to maintain social bonds
- Grooming time increases with group size
- In large groups, there isn't enough time to use grooming to support social networks.

Grooming time increases with group size in Old World monkeys and apes

Dunbar: Language evolution

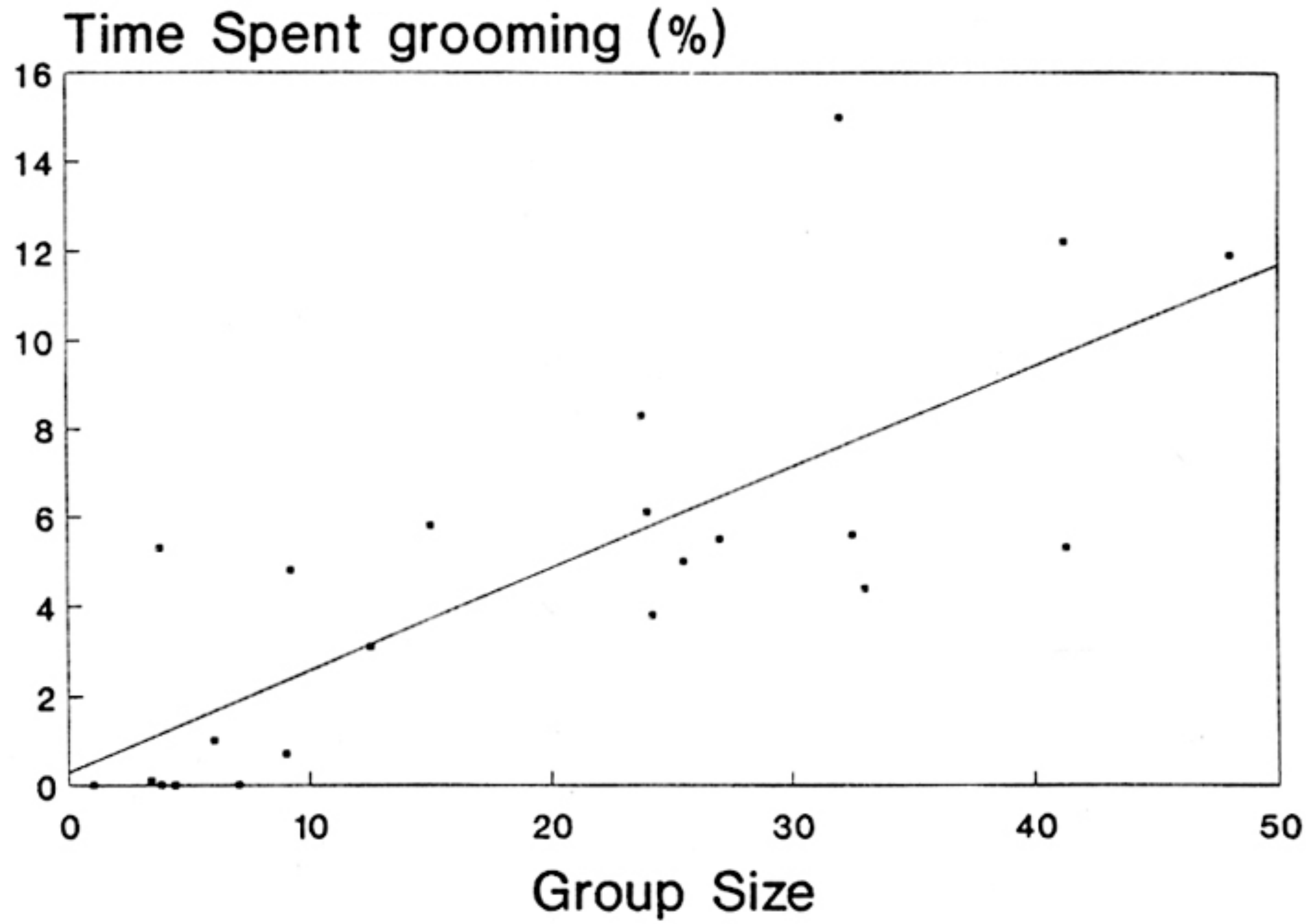


Figure 3. Mean percentage of time spent grooming plotted against mean group size for Old World monkeys and apes that do not have fission-fusion societies (based on data in Dunbar 1991).

Neocortex size and group size in primates

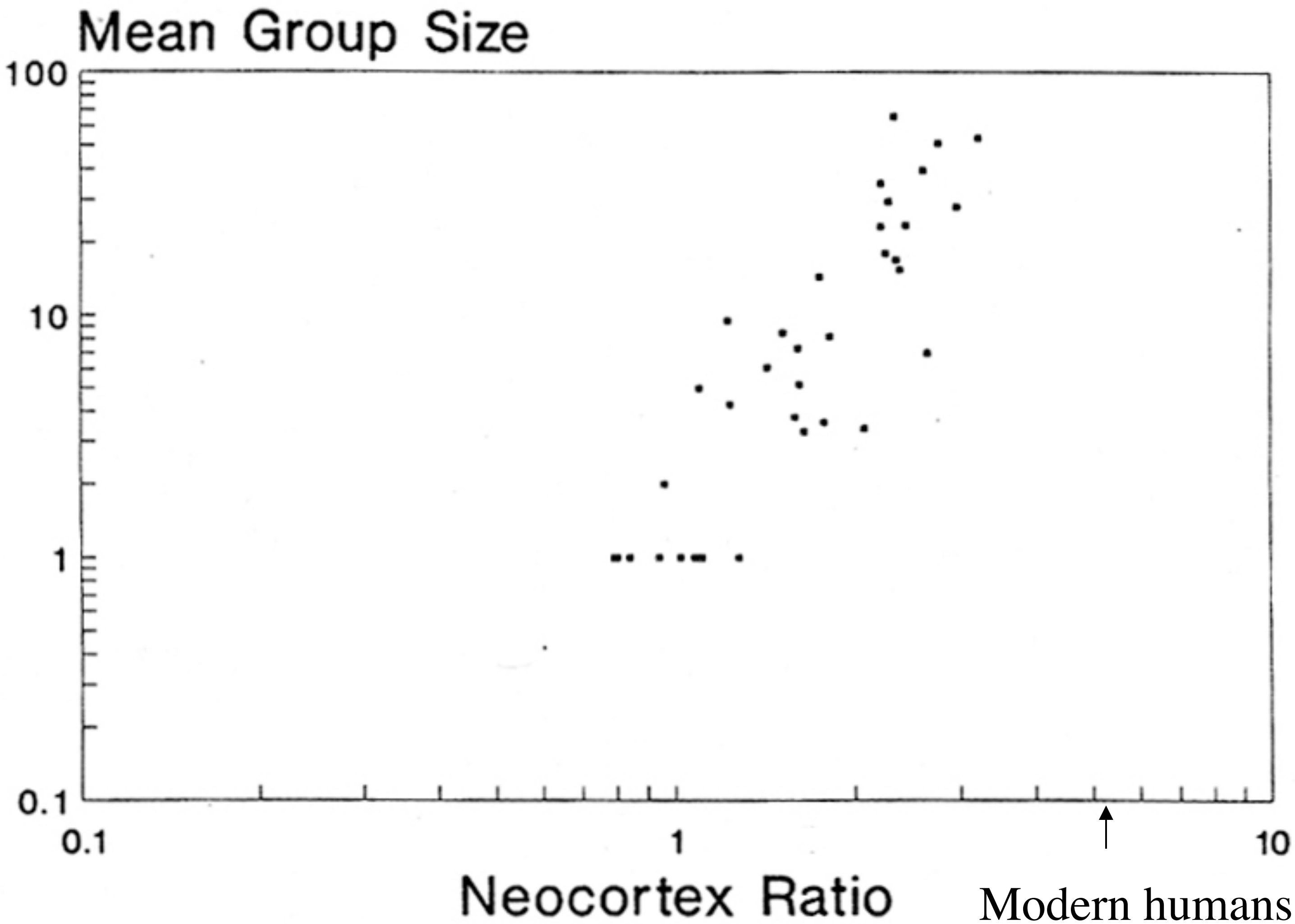


Figure 1. Group size plotted against neocortex ratio for nonhuman primates (redrawn from Dunbar 1992a).

Traditional society group sizes

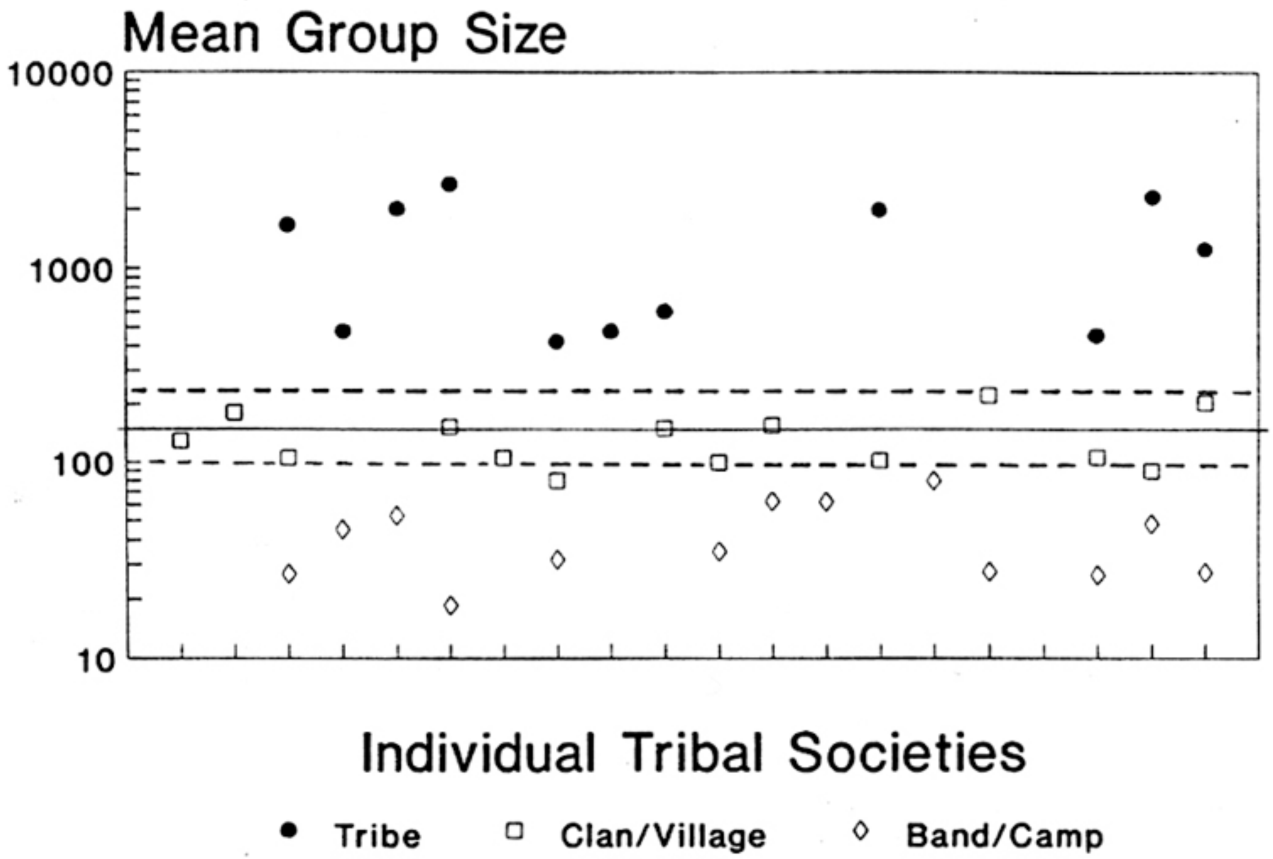


Figure 2. Distribution of group sizes for traditional societies. Individual societies are placed along the abscissa in arbitrary order. The group size predicted by equation (1) is indicated by the horizontal line; 95% confidence limits around this value are indicated by the dotted lines (*source:* Table 1).

Tribes form larger groups than predicted by brain size

Grooming times predicted by brain size for hominoids

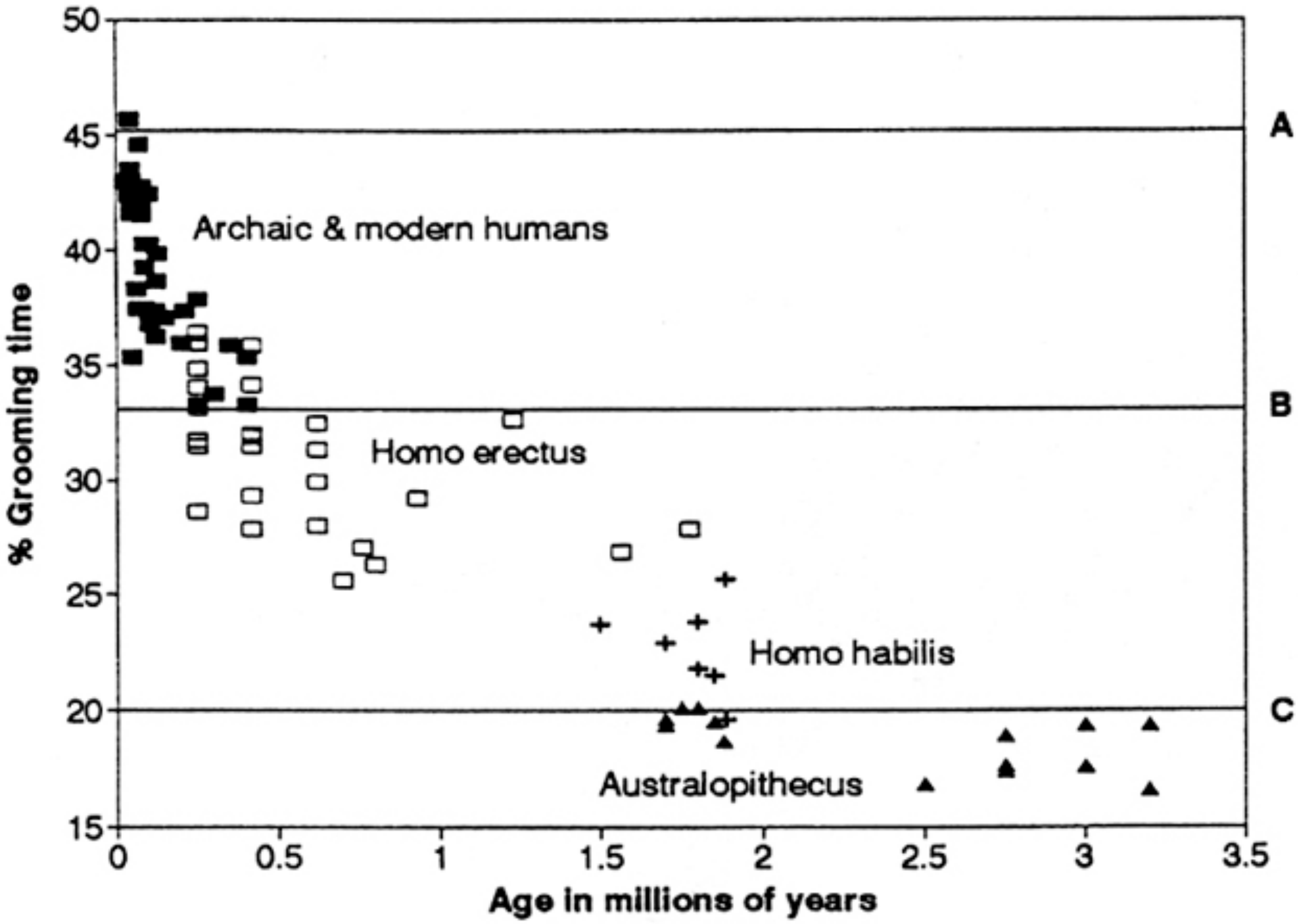
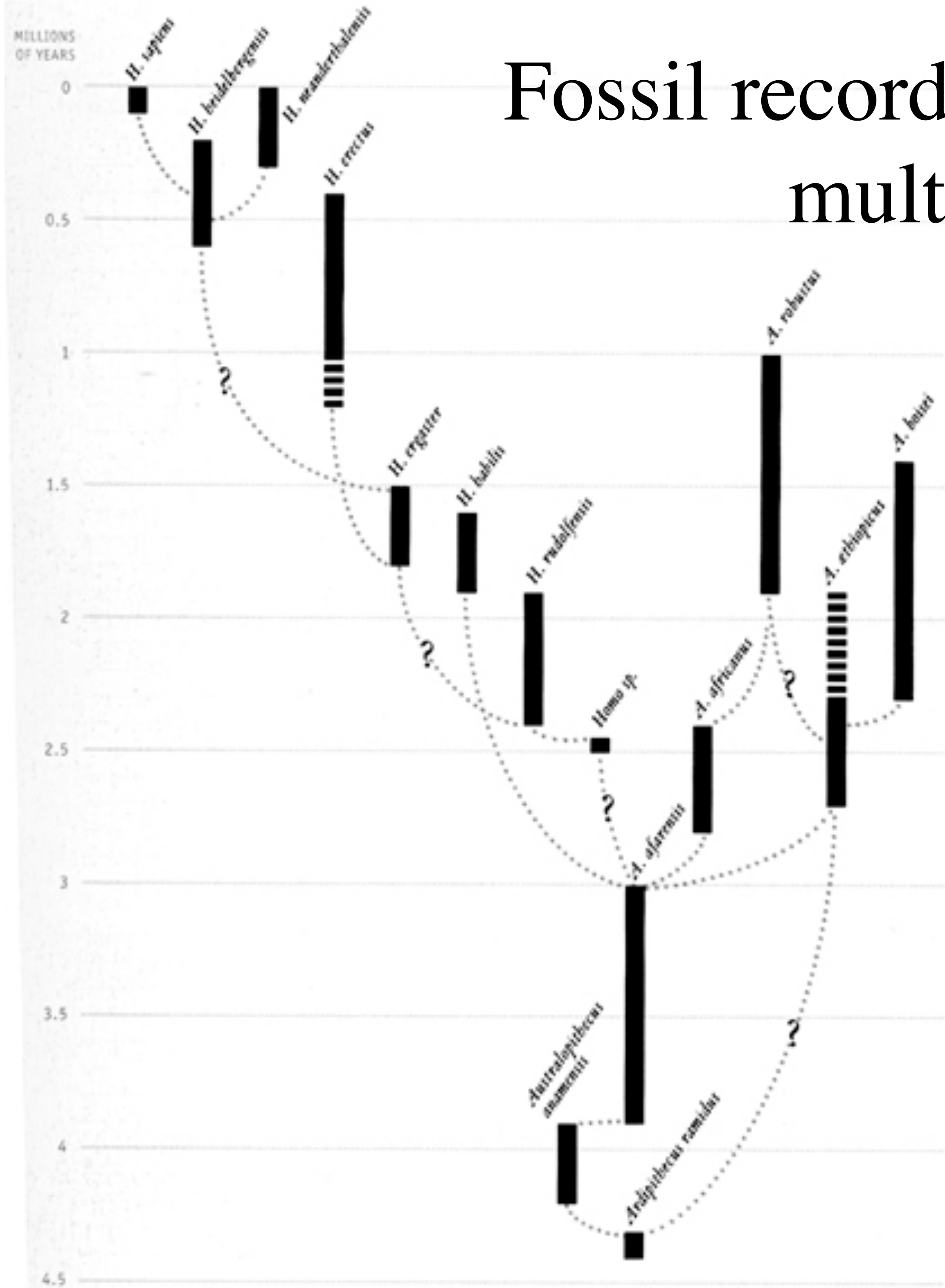


FIG. 3. *Predicted grooming time requirement and time.* ▲, *australopithecines;* +, H. habilis/rudolfensis; □, H. erectus; ■, *archaic* H. sapiens, *Neanderthals, early modern* H. sapiens. A *and* B, *95% confidence limits for predicted grooming time in living humans (A = two standard deviations above the modern human mean for males; B = two standard deviations below the modern human mean for females).* C, *maximum percentage grooming time observed in living primates (20%).*

Fossil record suggests presence of multiple hominids



Competitive hominds: Koobi Fora
1.5 MYA

Australopithecus boisei

Homo ergaster

Paleolithic technology

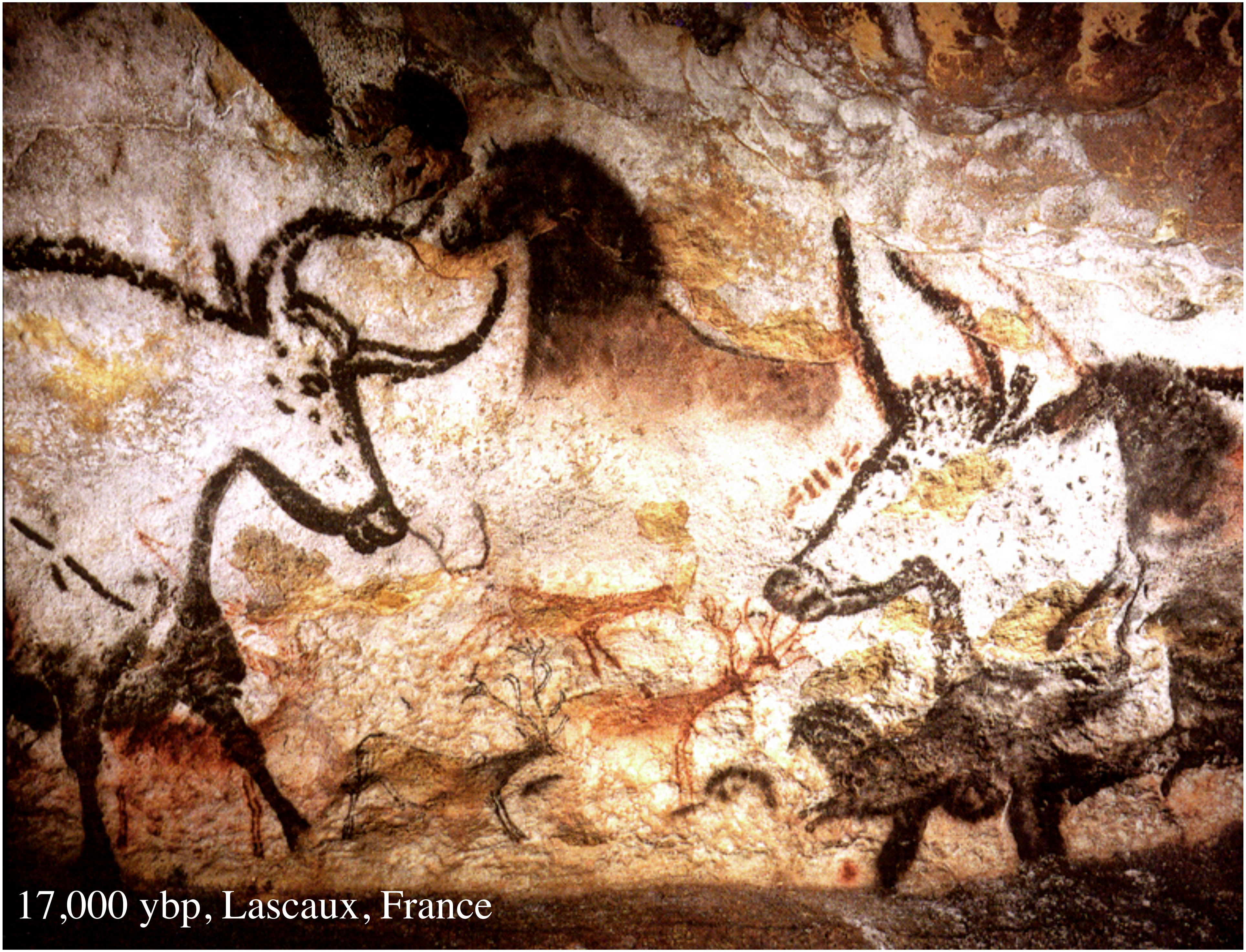
Oldowan, 2.4-1.5 MYA

Acheulean, 1.4-0.2 MYA

Cave and rock paintings

40,000 ybp, Kakadu NP, Australia

27,000 ybp, Cosquer, France



17,000 ybp, Lascaux, France

ESS approach to word evolution

- Relying on a different sound for every object requires multiple sounds which eventually become hard to distinguish
- Increase understanding by limiting number of sounds and stringing them into sequences, i.e. words
  - All languages utilize about 40 phonemes
- Expect words to evolve when there are a large number of things to name

ESS approach to syntax

- For a word to survive in a community, it must be used often enough to be heard and remembered.
- Memory is constraining if all concepts require unique words
- Can increase information using syntax (word order)
- In a combinatorial world, the number of words a syntactic communicator needs to know is the sum of objects and actions, whereas a nonsyntactic communicator needs to know the product.

Syntax evolution: the problem

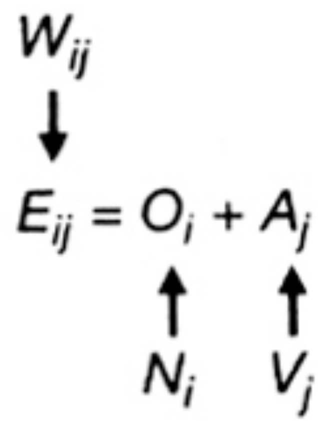


Figure 2 To understand the essence of the evolution of syntax, we imagine a world where each event consists of one object and one action. Event E_{ij} consists of object O_i and action A_j. A non-syntactic language has words, W_{ij}, that refer to events, E_{ij}. A syntactic language has words for objects and actions, N_i and V_j. Words for objects are called nouns, words for actions are called verbs. Our mathematical analysis can also be adapted to more complicated situations, where events consist of several objects, actions, places or times, but the equations become more clumsy. The principles remain the same.

Syntax evolution: the answer

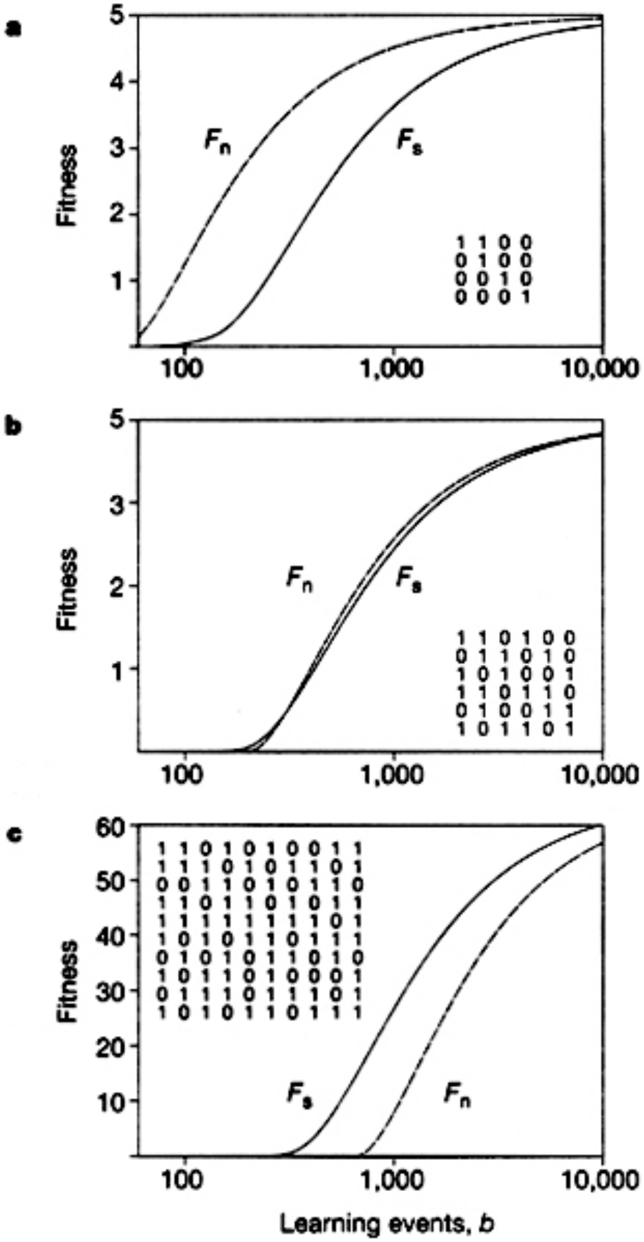


Figure 3 The fitness of non-syntactic and syntactic communication, F_n and F_s, as function of the total number of word learning events per individual, b, for three different choices of the event rate matrix, Γ. The entries of Γ are the numbers γ_{ij} which characterize the rates at which the various events occur. **a**, There are four objects and four actions. Each object is associated with a specific action; in addition object 1 also occurs with action 2. All possible events occur at the same rate. Thus the event rate matrix is a binary 4×4 matrix with 5 non-zero entries, $p = 5/16$. For b ranging from 50 to 10,000, F_n always exceeds F_s. **b**, There are six objects and six actions, the event rate matrix has 20 non-zero entries, $p = 5/9$. For values of b less than 400, syntactic communication has a higher fitness than non-syntactic communication. For values of b above 400, non-syntactic communication wins. Hence, for medium-sized systems the emergence of syntactic communication can be prevented by increasing the number of learning events per individual. **c**, There are 10 objects and 10 actions, 65 of 100 combinations occur, $p = 13/20$. In this case, syntactic communication wins for any choice of b. Each panel shows F_n and F_s as function of b and illustrates the chosen event rate matrix, Γ.

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ESS approach to universal grammar

- Considers fitness advantage when alternative grammars are in competition
- Acquisition of correct grammar requires learning from sample sentences
- Optimal learning period occurs at intermediate number of sentences to insure coherency
- Rule-based grammars are more efficient to learn than list-based grammars

Evolution of universal grammar

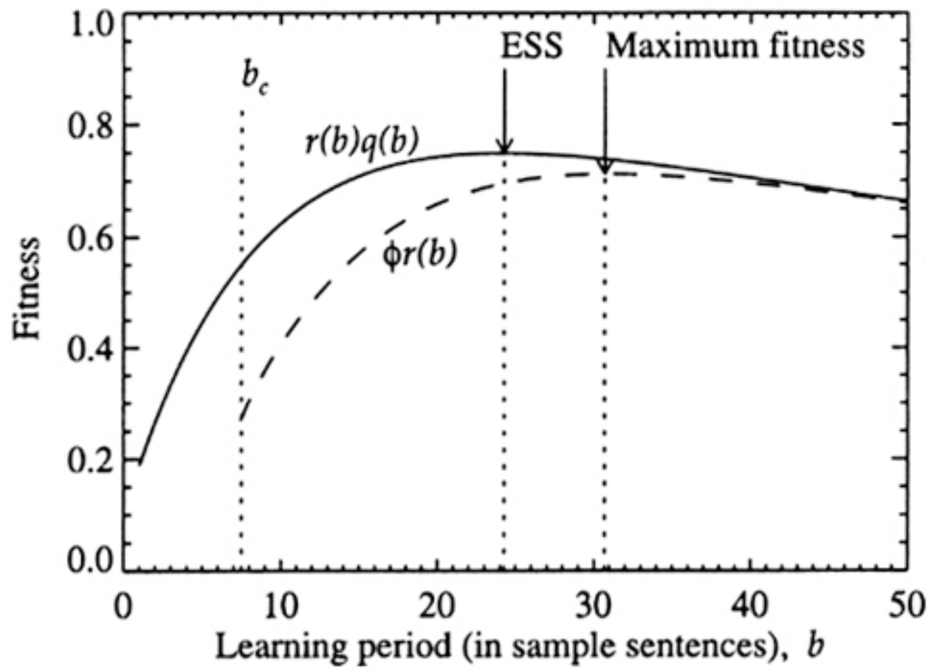


Fig. 3. Natural selection chooses a limited period of grammar acquisition. The time it takes to learn grammar is proportional to the number of sample sentences, b, that are being evaluated. The evolutionarily stable value of b maximizes the product $r(b)q(b)$ (solid line), which represents the rate of producing offspring that have acquired the correct grammar (same grammar as the parent). Here $r(b)$ is the rate of producing offspring that have acquired grammatical communication, and $q(b)$ is the probability of learning the correct grammar. The selected value of b is marked as ESS (evolutionarily stable strategy). The value b_c represents the coherence threshold. For this figure, we chose $r(b) = 1/(1 + 0.01b)$ and $q(b) = 1 - [1 - (1 - a)/n]^b$ (as defined for the memoryless learner). The evolutionary stability analysis uses the two–universal grammar equation of (*34*) and is exact for large values of n. The evolutionarily stable strategy does not maximize the fitness of the population, which is given by the product $r(b)\phi$ (dashed line). Parameter values are $n = 10$, $a_{ii} = 1$, and $a_{ij} = 0.1$ for $i \neq j$.

Human language diversity

- Cooperative trading requires a common language
- Conformity to a language could be used as an honest signal or group affiliation
- Expect linguistic uniformity when social networks are large, and distinct languages when networks are small and self-sustaining

Global linguistic diversity

TABLE 6.1. *Data on linguistic diversity for the nine continental and subcontinental areas of the world*

Area	Languages	Language density	Stocks	Phylogenetic density	Languages per stock
Africa	2,614	88.8	20	4.4	130.7
N. Eurasia	732	21.5	18	3.3	40.7
S. and SE Asia	1,998	110.4	10	3.8	199.8
Oceania	306	322.1	4	—	76.5
New Guinea	1,109	1,197.6	27	227.3	41.1
Australia	234	30.41	15	13.0	15.6
North America	243	12.3	50	16.9	4.9
Mesoamerica	381	144.2	14	71.7	27.2
South America	595	33.3	93	34.8	6.4

Note: Source for stocks and phylogenetic density is Nichols (1992), whose density figures have been converted from miles to kilometres. The density measures are units per million square kilometres. The language-density figures are obtained by summing the language counts for countries from Chapter 4. Languages spoken in several countries are thus counted several times, and so the figures, as absolute numbers of language in each continent, are inflated. However, this error affects each continent to about the same extent and so the figures remain useful for comparing continents.

Latitudinal patterns of language diversity

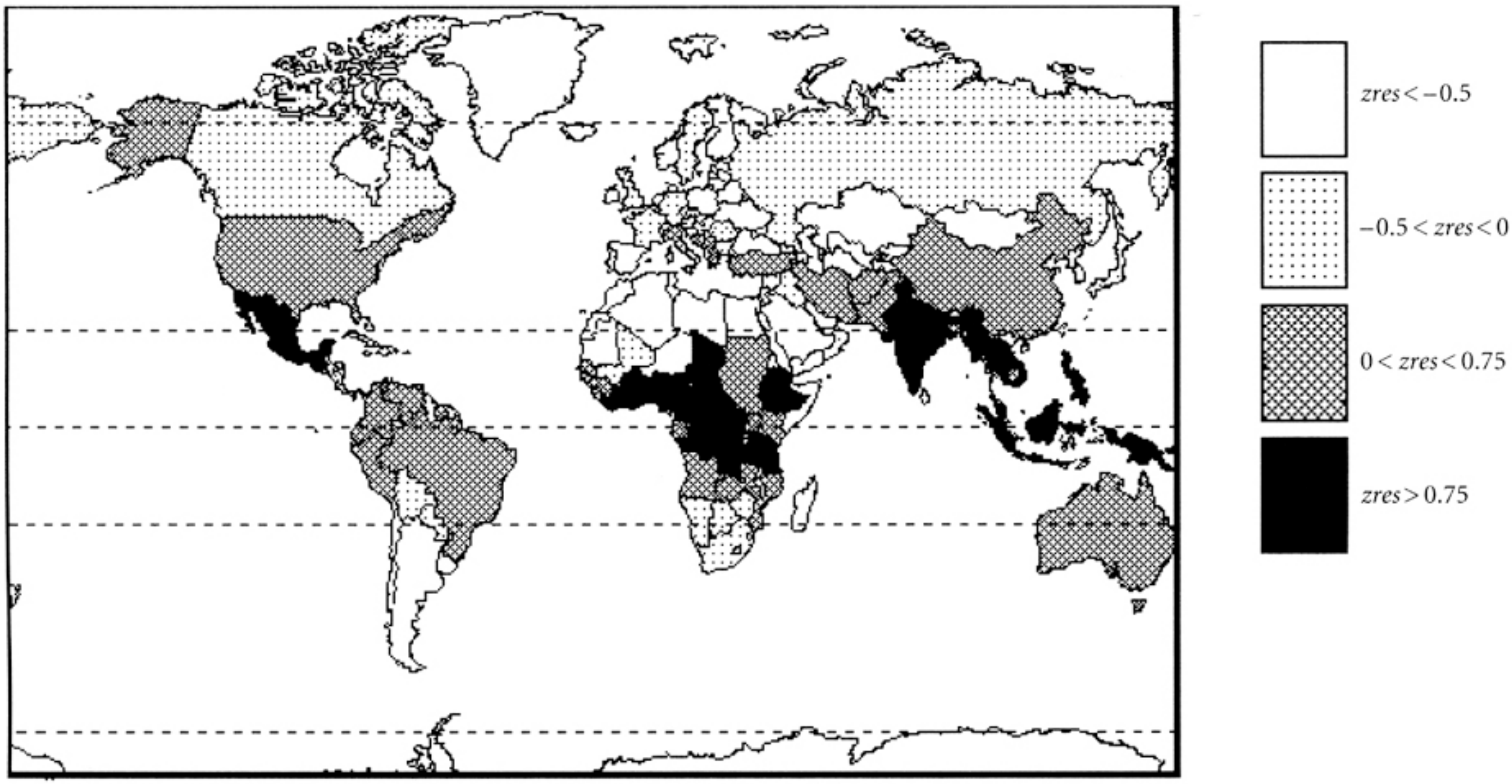


FIGURE 4.1. Map of the world showing the relative language diversity of the major countries.
Note: Language diversity is calculated by regressing the logarithm of the number of languages spoken in the country against the logarithm of the area of the country, and shading each country according to the value of the standardized residual.
Source: Nettle (1998*b*), by courtesy of Academic Press.

Language diversity and growing season

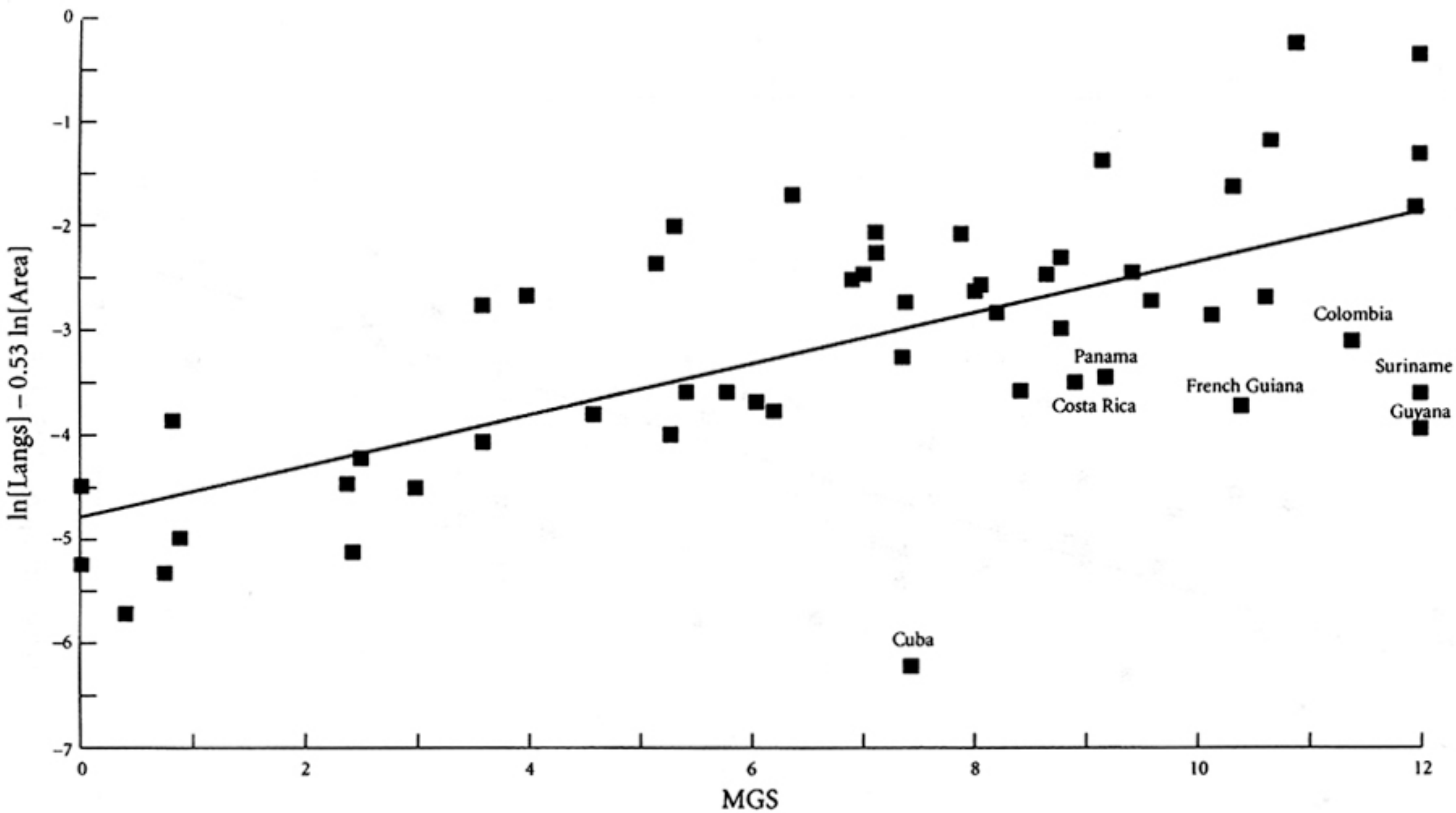


FIGURE 4.2. The number of languages in each country regressed against the Mean Growing Season once the effects of the country's size have been controlled for

Note: The South American countries are labelled.

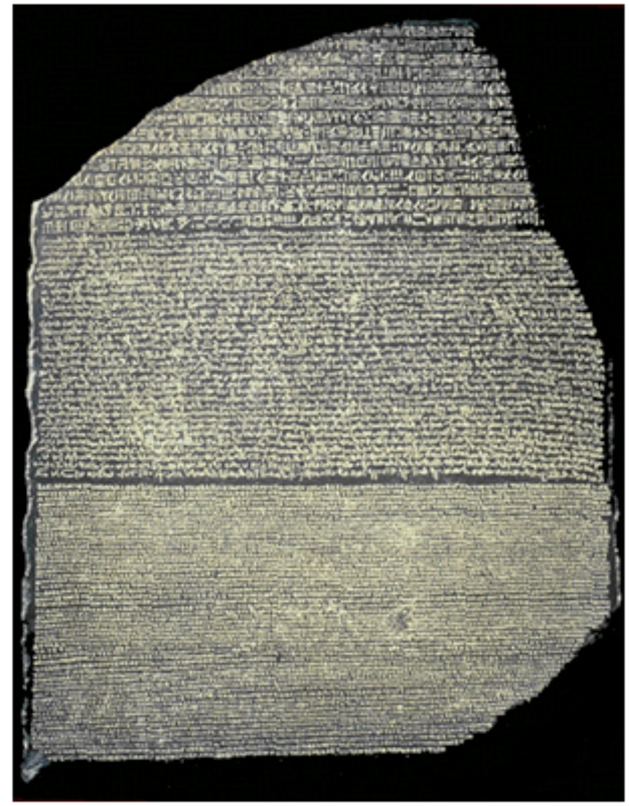
BIOL 608V, Spring 2008

Genetics and Evolution of Vocal Learning and Language

Dr. Gerald Wilkinson

Dr. Juan Uriagereka

Dr. Jim Reggia



Syllabus	Schedule
Readings	Library

http://www.life.umd.edu/faculty/wilkinson/BIOL608V/

Language evolution references

Aiello, L.C. and R.I.M. Dunbar 1993 Neocortex size, group size and the evolution of language. Current Anthropology 34:184-193.

Bickerton, D. 1990. Language and Species. Chicago: University of Chicago Press.

Bickerton, D. 1998. Catastrophic evolution: the case for a single step from protolanguage to full human language. In Hurtford, J.R., M. Studdert-Kennedy, and C. Knight (eds.) *Approaches to the evolution of language*. Cambridge: Cambridge University Press: 341-358.

Dunbar, R.I.M. 1993 Coevolution of neocortical size, group size and language in humans. Behavioral and Brain Sciences 16:681-735.

Enard, W., M. Przeworski, S. E. Fisher, C. S. L. Lai, V. Wiebe, T. Kitano, A. P. Monaco, and S. Paabo. 2002. Molecular evolution of FOXP2, a gene involved in speech and language. Nature 418:869-872.

Haesler, S., K. Wada, A. Nshdejan, E. E. Morrisey, T. Lints, E. D. Jarvis, and C. Scharff. 2004. FoxP2 expression in avian vocal learners and non-learners. Journal of Neuroscience 24:3164-3175.

Hurford, J.R. 1991. The evolution of the critical period for language acquisition. Cognition 40(3): 159-202.

Jackendoff, R. 2002. Foundations of Language. Oxford University Press, New York.

Lai, C. S. L., S. E. Fisher, J. A. Hurst, F. Vargha-Khadem, and A. P. Monaco. 2001. A forkhead-domain gene is mutated in a severe speech and language disorder. Nature 413:519-523.

Nettle, D. 1999. Linguistic Diversity. Oxford University Press: New York.

Nowak, M.A., D.C. Krakauer, and A. Dress. 1999. An error limit for the evolution of language. Proceedings of the Royal Society Biological Sciences Series B 266(1433): 2131-2136.

Nowak, M.A. and D.C. Krakauer. 1999. The evolution of language. PNAS 96(14): 8028-8033.

Nowak, M.A., J.B. Plotkin, and V.A.A. Jansen. 2000 The evolution of syntactic communication. Nature 404: 495-498.

Nowak, M.A., N.L. Komarova, and P. Niyogi 2001 Evolution of universal grammar. Science 291:114-118.

Pinker, S. and P. Bloom. 1990. Natural language and natural selection. Behavioral and Brain Sciences 13(4): 707-784.

Pinker, S. 1994 The Language Instinct. New York: Harper Perennial.

Pinker, S. 1997. Evolutionary biology and the evolution of language. In M. Gopnik (ed.) *The inheritance and innateness of grammars*. New York: Oxford University Press: 181-208

Smith, J.M. and E. Smathmary. 1995. Chapter 17: The evolution of language. In *The major transitions in evolution*. New York: W.H. Freeman and Co.: 281-309.