# Evolution

Hauser, Chomsky & Fitch 2002

Fitch, Hauser & Chomsky 2005

Levitin 2006

Patel 2008 Chapter 7

# The evolution of language

Hauser, Chomsky & Fitch 2002
"The Faculty of Language: What is it, Who has it, and How did it evolve?"
Science 298. 1569-1579.

We argue that an understanding of the faculty of language requires substantial interdisciplinary cooperation. We suggest how current developments in linguistics can be profitably wedded to work in evolutionary biology, anthropology, psychology, and neuroscience. We submit that a distinction should be made between the faculty of language in the broad sense (FLB) and in the narrow sense (FLN). FLB includes a sensory-motor system, a conceptual-intentional system, and the computational mechanisms for recursion, providing the capacity to generate an infinite range of expressions from a finite set of elements. We hypothesize that FLN only includes recursion and is the only uniquely human component of the faculty of language. We further argue that FLN may have evolved for reasons other than language, hence comparative studies might look for evidence of such computations outside of the domain of communication (for example, number, navigation, and social relations).

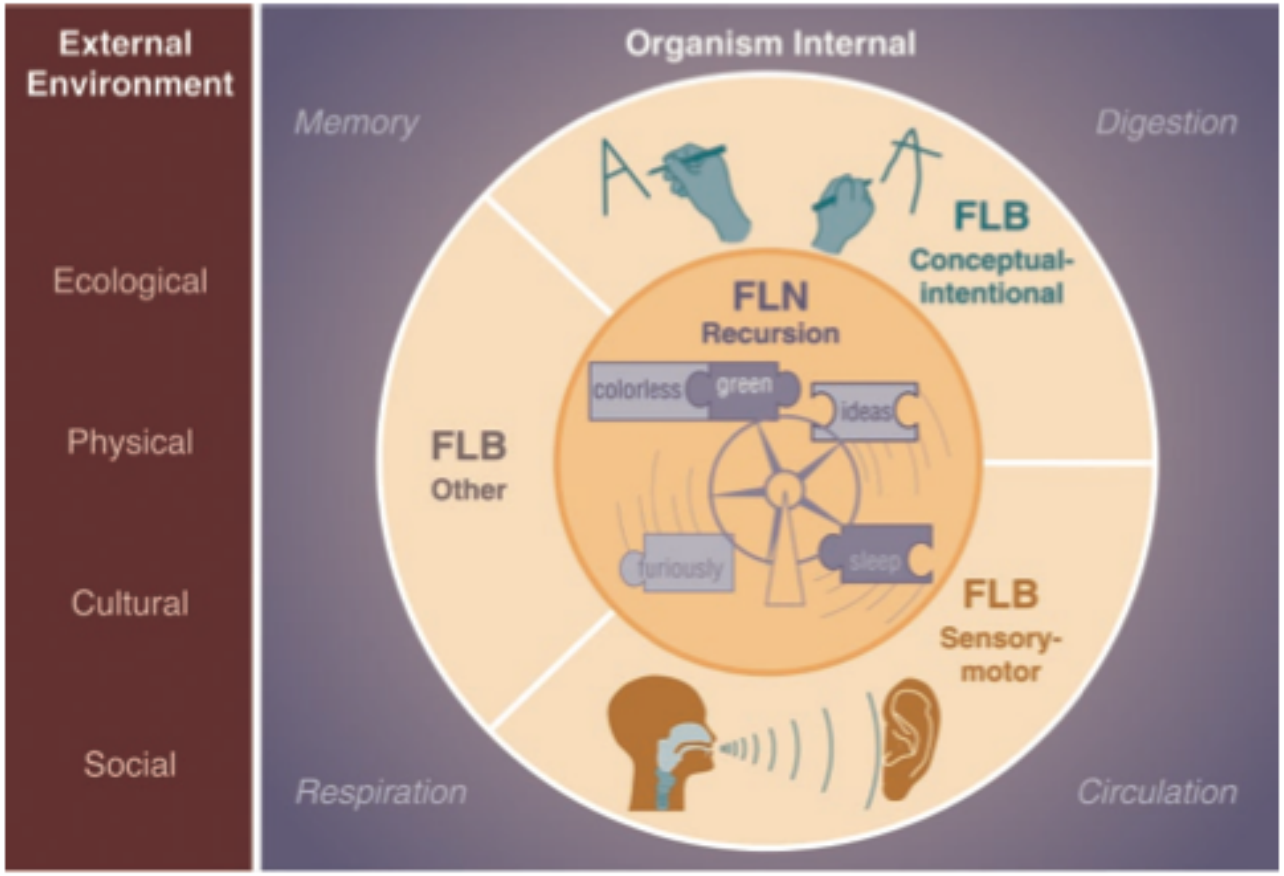



**Fig. 2.** A schematic representation of organism-external and -internal factors related to the faculty of language. FLB includes sensory-motor, conceptual-intentional, and other possible systems (which we leave open); FLN includes the core grammatical computations that we suggest are limited to recursion. See text for more complete discussion.

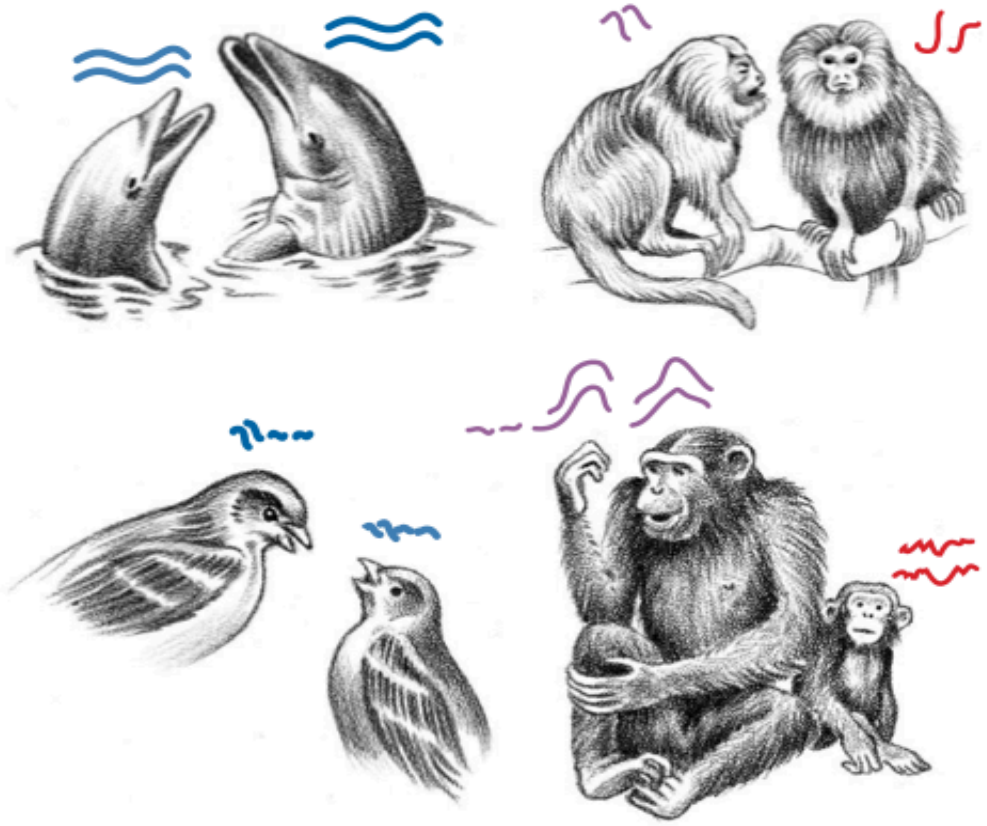


**Fig. 4.** The distribution of imitation in the animal kingdom is patchy. Some animals such as songbirds, dolphins, and humans have evolved exceptional abilities to imitate; other animals, such as apes and monkeys, either lack such abilities or have them in a relatively impoverished form. [Illustration: John Yanson]


**Fig. 5.** Human and nonhuman animals exhibit the capacity to compute numerosities, including small precise number quantification and large approximate number estimation. Humans may be unique, however, in the ability to show open-ended, precise quantificational skills with large numbers, including the integer count list. In parallel with the faculty of language, our capacity for number relies on a recursive computation. [Illustration: John Yanson]

| | *FLN—recursion* | |
|---|---|---|
| Spontaneous and training methods designed to uncover constraints on rule learning | Studies of serial order learning and finite-state grammars in tamarins and macaques | (*114, 116, 117, 129*) |
| Sign or artificial language in trained apes and dolphins | Studies exploring symbol sequencing and open-ended combinatorial manipulation | (*130, 131*) |
| Models of the faculty of language that attempt to uncover the necessary and sufficient mechanisms | Game theory models of language acquisition, reference, and universal grammar | (*72–74*) |
| Experiments with animals that explore the nature and content of number representation | Operant conditioning studies to determine whether nonhuman primates can represent number, including properties such as ordinality and cardinality, using such representations in conjunction with mathematical operands (e.g., add, divide) | (*102–106, 132*) |
| Shared mechanisms across different cognitive domains | Evolution of musical processing and structure, including analyses of brain function and comparative studies of music perception | (*133–135*) |

## Music references:

Lerdahl & Jackendoff. 1983. A Generative Theory of Tonal Music.
Wallin, Merker & Borwin (eds.) 2000. The Origin of Music.
Zatorre & Peretz. (eds.) 2000. The Biological Foundation of Music.

# Debate resulting from HCF 2002

- Hauser, Chomsky & Fitch 2002. The faculty of language: What is it, who has it, and how has it evolved?. Science 298. 1569-1579.
- Pinker & Jackendoff 2005. The faculty of language: What's special about it? Cognition 95. 201–223.
- Fitch, Hauser & Chomsky 2005. The evolution of the language faculty: Clarifications and implication. Cognition 97. 179-210.
- Jackendoff & Pinker 2005. The nature of the language faculty and its implications for evolution of language. Cognition 97. 211-225.

# Clarifications emerging from FHC 2005

- The "language" capacity is to be identified with FLB—much is shared with other species and other capacities in humans.
  - FLB as a whole or in parts could be adaptive.
- Hypothesis 3: Recursion is unique to humans and unique to language, hence could be the only capacity in FLN.
  - Empirically testable:
    - Perhaps word-learning (fast mapping) could be in FLN.
    - Perhaps recursion is not unique to humans.
    - Perhaps recursion in humans is not unique to language.
      - Number, music.
      - Perhaps arose originally for navigation or social intelligence.

# Another debate

- There is another, more far-reaching, debate within linguistics between generativists and emergentists, especially in the area of syntax.
  - Generativists follow Chomsky and emphasize the importance of formal grammars, assuming that such grammars are instantiated in the brain, and arise in people through a largely innate and computationally optimal Universal Grammar (UG) capacity.
  - Minimalism ("Biolinguistics"), Formal semantics.
- Emergentists are less concerned with formally specifying grammars, and don't believe in an innately highly specific or optimal UG.
  - Instead language learning emerges through domain-general mental capacities interacting with the world, statistical learning, etc.
  - Cognitive grammar, Construction grammar.

# Some prominent papers advocating the emergentist perspective

- Christiansen, Morten H. & Nick Chater. 2008. Language as shaped by the brain. Behavioral and Brain Sciences 31. 489-558.
  - The brain isn't shaped by/for language (e.g. recursion), but rather language is shaped by the brain.
  - Languages have evolved in such a way that makes it easy for humans to learn and use them.
- Evans, Nicholas & Steven C. Levinson. 2009. The myth of language universals: Language diversity and its importance for Cognitive Science. Behavioral and Brain Sciences 32. 429-492.
  - There are very few language universals; diversity is the norm.
  - Recurrent patterns represent engineering solutions satisfying multiple design constraints.
  - Linguists and cognitive scientists should embrace this diversity and explore how it arises and how it is handled by the brain.
- Emphasis on cultural evolution: e.g. the discovery of fire has lead to cooking, and the invention of the alphabet has led to literacy.

# The evolution of music

# Pinker 1997: *How the Mind Works:* Music as "auditory cheesecake"

- "As far as biological cause and effect go, music is useless. It shows no signs of design for attaining a goal such as long life, grandchildren, or accurate perception and prediction of the world. Compared with language, vision, social reasoning, and physical know-how, music could vanish from our species and the rest of our lifestyle would be virtually unchanged. Music appears to be a pure pleasure technology, a cocktail of recreational drugs that we ingest through the ear to stimulate a mass of pleasure circuits at once. [p. 528].
- "But if music confers no survival advantage, where does it come from and how does it work? I suspect that music is auditory cheesecake, an exquisite confection crafted to tickle the sensitive spot of at least six of our mental faculties." [p. 534]
  - Language (heightened speech), Auditory scene analysis (localized source), Emotional calls, Habitat selection (e.g. tone painting, movie scores), Motor control (e.g. dance) Something else (something more).

# Spandrel

- Wikipedia:  In evolutionary biology, a Spandrel is a phenotypic* characteristic that is the byproduct of the evolution of some other characteristic, rather than a direct product of adaptive selection.
  - *Phenotype: the set of observable characteristics of an individual resulting from the interaction of its genotype with the environment (Apple dictionary).
- Wikipedia: In architecture, a spandrel is the space between two arches or between an arch and a rectangular enclosure.

Spandrel figures

# Levitin's arguments for the adaptive value of music

- Sexual selection (Darwin's hypothesis).
  - Music may indicate biological and sexual fitness, serving to attract mates.
    - Rock stars have a lot of sexual partners.
    - Interest in music peaks in adolescence, when humans are close to their sexual peak.
    - At the peak of monthly fertility, women said they'd prefer a creative but poor artist to a not creative but rich man as a short-term mate.
  - Stamina in song and dance may indicate stamina for hunting and warfare.
  - Time to devote to song/dance may indicate sufficient wealth and shelter.
  - Improvisation and novelty may indicate creativity.

# Levitin's arguments for the adaptive value of music

- Music has been around a long time.
  - "Any activity that has low adaptive value is unlikely to be practiced very long in the species's history."
  - Music is likely older than the 50,000-year-old bone flute.
  - Drums, rattles and shakers were likely used before flutes.
  - Picture from McDermott & Hauser 2005.

FIG 1. The oldest known putative musical instrument, from a Neanderthal campsite.

# Levitin's arguments for the adaptive value of music

- Music is ubiquitous: It has been accompanied by movement and dance by all members of societies historically.
  - "When a behavior or trait is widely distributed across members of a species, we take it to be encoded in the genome."
- Social bonding and cohesion may be a selective factor.
  - Collective music making encourages social cohesion.
    - Promotes feelings of group togetherness and synchrony.
    - Patients with Williams syndrome are gregarious and highly musical.
    - Double dissociation with Autism Spectrum Disorder where patients are withdrawn and only attracted to structural aspects of music.
    - Cerebellum larger than normal in WS, and smaller than normal in ASD.

# Levitin's arguments for the adaptive value of music

- Music may have evolved because it promoted cognitive development.
  - Paves the way for speech and language.
    - Both evolutionarily and developmentally.
    - It is a cultural universal that mother-infant interactions involve singing and rhythmic movement---rocking and caressing.
    - The infant brain is unable to distinguish the source of sensory inputs—music helps imprint these.
- Other species use vocalizations for courtship and to warn others of particular predators.
  - Birds, whales, gibbons, frogs, chimpanzees, prairie dogs.

# Levitin's arguments for the adaptive value of music

- There may be a genetic basis of music cognition in mirror neurons.
  - Rizzolatti, et al. (2001?) found neurons in monkeys that responded both when reaching for food and when observing another monkey reaching for food.
  - Since found in primates, birds and humans.
  - Some neuroscientists speculate that our mirror neurons may be firing when we see or hear musicians perform.
  - Many musicians can play back a musical part on their instruments when they've heard it only once.

# Levitin's arguments for the adaptive value of music

- The previous slides were adapted from Levitin's 2006 book, *This is Your Brain on Music: The Science of a Human Obsession*.
- He has a more recent book, *The World in Six Songs: How the Musical Brain Created Human Nature*, 2008.
- Here, he proposes to explain how the evolution of the brain created music, art, science and society.
- Songs of:
  - Friendship (and war).
  - Joy
  - Comfort
  - Knowledge
  - Religion
  - Love

# Patel's arguments for the adaptive value of language but not music

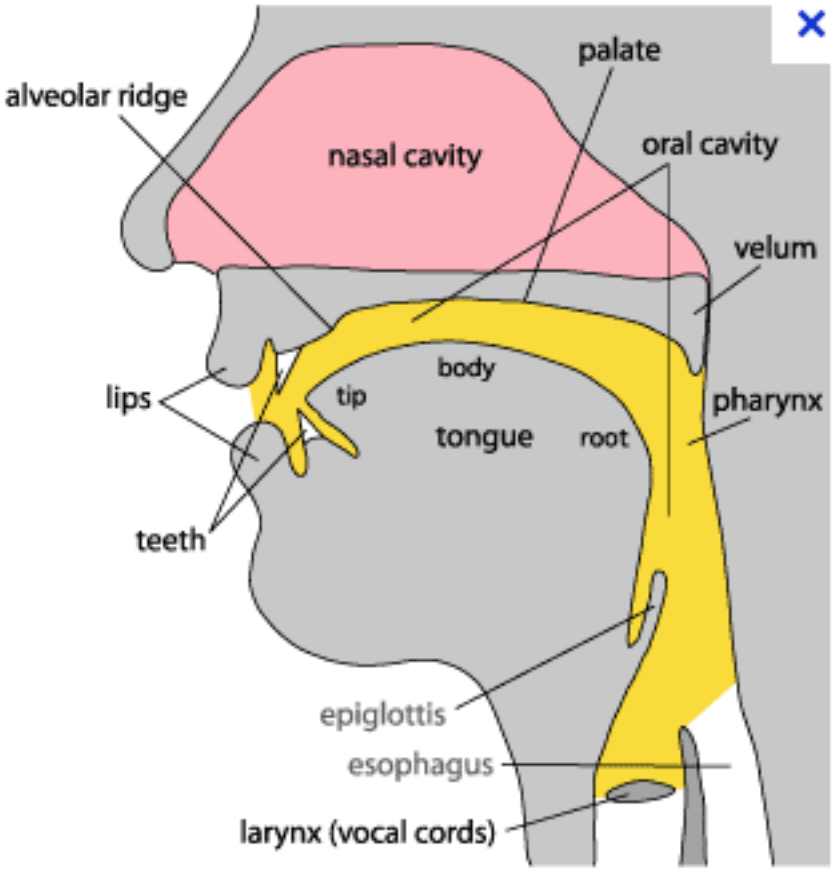
1. Babbling.
2. Anatomy of the human vocal tract.
3. Vocal learning.
4. Precocious learning of linguistic sound structure.
5. Critical periods for language acquisition.
6. Commonalities of structure and development in spoken and signed languages.
7. Robustness of language acquisition.
8. Adding complexity to impoverished linguistic input.
9. Fixation of a language-relevant gene.
10. Biological cost of a failure to acquire language.
11. Other evidence.

# 1. Babbling

- Patel: Supports both language and music as adaptive.
- At 7 months, babies begin to produce nonsense syllables like /ba/ and /da/ in repetitive sequences.
- Even deaf babies babble orally.
- Deaf babies also babble manually.
- Young birds babble (subsong).
- Babbling helps tune the perceptual-motor skills they will use in acquiring their species' communication system.
- Because its emergence is spontaneous and not simply an imitation of adult speech, it provides evidence that selection has acted on language acquisition (or music acquisition).
- Baby twins babbling.

# 2. Anatomy of the human vocal tract

- Descended larynx.
- Happens between 3 months and 3 years.
- Aids in speech but  can lead to choking (in other primates, the larynx connects with the nasal passages, allowing simultaneous swallowing and breathing).
- Increases the range and discriminability of speech sounds because it gives the tongue room to move both vertically and horizontally.



- Lieberman et al. 1969: Argued that it shows natural selection for language.
- Patel: Could also support music as an adaptation.
- Fitch et al. 2005.
  - Happens in other species like deer.
  - Happens again in adolescent humans but only for males.
  - The triggering function was size exaggeration.

# 3. Vocal learning

- Learning to produce vocal signals based on auditory experience and sensory feedback.
- Has arisen in only a few species (songbirds, parrots, cetaceans), but in no other primates.
- Part of an ensemble of characteristics shaped by natural selection to favor children's acquisition of a complex acoustic communication system.
- Patel:  could also support music, or a musical protolanguage.

# Hauser, Chomsky & Fitch 2002

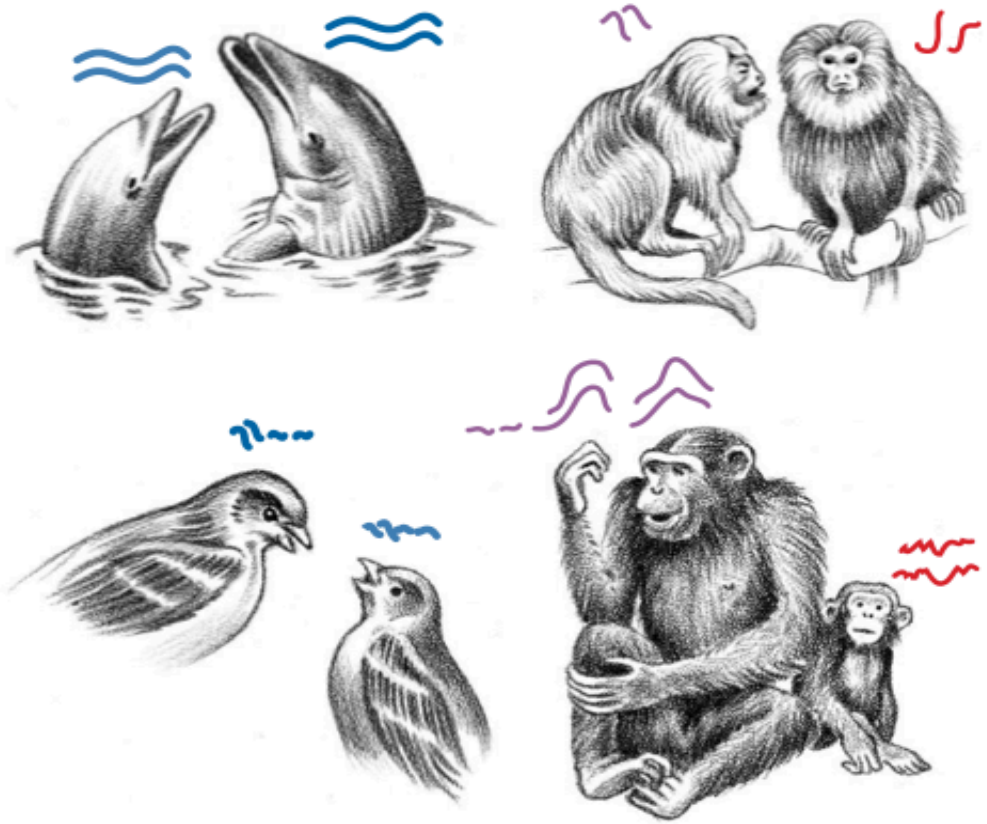


**Fig. 4.** The distribution of imitation in the animal kingdom is patchy. Some animals such as songbirds, dolphins, and humans have evolved exceptional abilities to imitate; other animals, such as apes and monkeys, either lack such abilities or have them in a relatively impoverished form. [Illustration: John Yanson]

# 4. Precocious learning of linguistic sound structure

- By 6 months, infants begin to learn their languages sounds, and lose the ability to distinguish other languages' sounds shortly thereafter.
- Infants recognize the same speech sound across gender, speaker and speech rate differences—still hard for computers.
- Master speech production by 3-4 years, but not ball throwing and shoe tying.
- English-speaking college students were better at producing Spanish unaspirated stops /p, t, k/ if they had overheard informal Spanish for a few years before the age of 6 (Au et al. 2002).
- However, sensitivity to key membership in music develops rather slowly. It is not in place at 8 months but is in place by 5 years.
  - Trainor & Trehub 1992: 4 semitone in-key change vs. 1 semitone out-of-key change: infants but not adults detected out-of-key changes equally well.
  - Dowling 1988: 3 year-olds who sang in tune (and most don't) were barely able to distinguish tonal from atonal melodies.
- Infant's sensitivity to contour and preference for consonant intervals may be byproducts of attunement to speech or of general auditory processing.

# 5. Critical period effects

- A time window when developmental processes are especially sensitive to environmental input.
- Songbirds will never acquire full proficiency when not permitted to hear the song of an adult before a certain age.
- Mechanism: Perhaps over time, the rate of neural proliferation in specific brain areas reduces.
- Lenneberg 1967: human critical period for language ends at puberty.
- Evidence from second-language acquisition and from first-language sign language.
- There doesn't seem to be a critical period for music.
  - Many accomplished musicians start learning their instrument after 10.
- More white matter (connecting different brain areas) correlates with more musical practice in childhood, but this doesn't reflect a critical period.
- Absolute pitch in musicians is rare if they began training beyond 6, but AP is rare anyway and isn't necessary for music proficiency.

# 6. Commonalities of structure and development in spoken and signed languages

- Sign languages like ASL (American Sign Language) and BSL (British Sign Language) are true languages with structural organization distinct from that of spoken languages.
  - ASL and BSL are not mutually intelligible
  - They have phonology, morphology, syntax, semantics.
  - Deaf children learn them just like hearing children learn oral languages.
- The fact that language can "jump modalities" suggests a role for natural selection to have played a role in shaping the language acquisition process.
- But there doesn't seem to be signed music.
  - A nonreferential but richly organized system of visual signs with discrete elements and principles of syntax, created and shared for aesthetic ends by an appreciative community.

# 7. Robustness of language acquisition

- Children acquire language equally well despite wide variation in how much input they get.
  - De Weijer found that a Dutch infant heard about 2.5 hours of speech per day, only 37 minutes directed at the infant.
  - Adults barely talk to infants in some cultures (e.g. Kaluli of Papua New Guinea).
- There is more variability in musical abilities.
  - Nonmusicians were unable to tap to the beat on over 10% of trials (Drake et al. 2000).
- Again lack of signed music.
- Seems to indicate that there has been no specific selection for music in humans.

# 8. Adding complexity to impoverished linguistic input

- Nicaraguan Sign Language was spontaneously created by children in a school for the deaf in 1977.
- As the language develops from generation to generation it is becoming increasingly grammaticalized.
  - The second cohort systematized the use of spatial locations to signal grammatical relationships.
  - They showed a strong preference for breaking holistic gestures ito discrete components and arranging these in sequences.
- These findings complement earlier work on creolization.
- Suggestive of learning predispositions that have been shaped by natural selection.

# 9. Fixation of a language-relevant gene.

- FOXP2
  - When one copy of the gene is damaged, individuals exhibit deficits in oral movements, difficulties in manipulating phonemes, and problems with grammar and lexical judgments (Marcus & Fisher 2003).
  - Some individuals have nonverbal abilities in the normal IQ range.
  - FOXP2 occurs in many other species-- chimpanzees, birds, crocodiles--but the exact DNA sequence is unique to humans and shows almost no variation, suggesting that this language-relevant gene has been a target of selection.
  - This gene appears to be involved in circuits that support speech and musical rhythm.

# 10. Biological cost of failure to acquire language

- We can't do experiments, but it seems likely that a human being without language abilities would be at a severe disadvantage in terms of survival and reproduction in any human society, past or present.
- Tone-deaf or rhythm-deaf individuals seem to get along fine.