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Recursion as derivation layering

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SCIENCE'S COMPASS • REVIEW

REVIEW: NEUROSCIENCE

The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?

Marc D. Hauser,[1]* Noam Chomsky,[2] W. Tecumseh Fitch[1]

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).

If a martian graced our planet, it would be struck by one remarkable similarity among Earth's living creatures and a key difference. Concerning similarity, it would note that all living things are de-

tures; it might further note that the human faculty of language appears to be organized like the genetic code—hierarchical, generative, recursive, and virtually limitless with

question of language evolution, and of how humans acquired the faculty of language.

In exploring the problem of language evolution, it is important to distinguish between questions concerning language as a communicative system and questions concerning the computations underlying this system, such as those underlying recursion. As we argue below, many acrimonious debates in this field have been launched by a failure to distinguish between these problems. According to one view (*1*), questions concerning abstract computational mechanisms are distinct from those concerning communication, the latter targeted at problems at the interface between abstract computation and both sensory-motor and conceptual-intentional interfaces. This view should not, of course, be taken as a claim against a relationship between compu-

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- **Chomsky: recursion is Merge**

modify the ensuing discussion. All approaches agree that a core property of FLN is recursion, attributed to narrow syntax in the conception just outlined. FLN takes a finite set of elements and yields a potentially infinite array of discrete expressions. This capacity of FLN yields discrete infinity (a property that also characterizes the natural numbers). Each

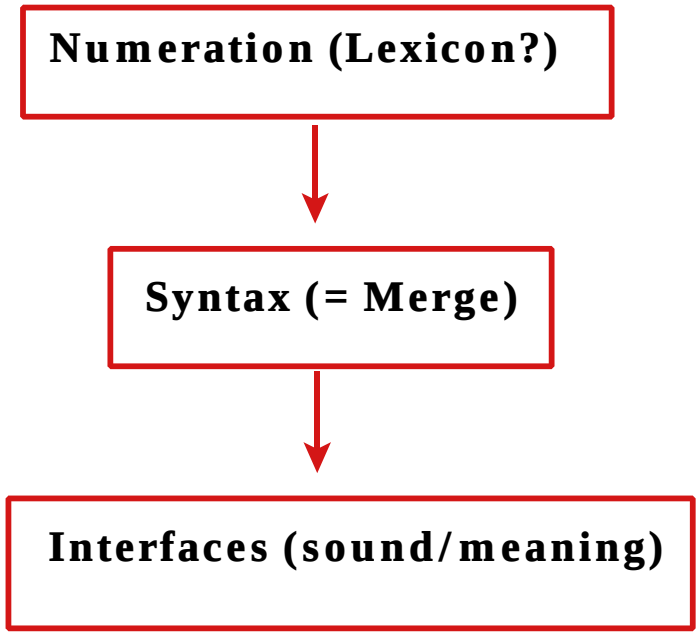
(Hauser/Chomsky/Fitch 2002:1571)

- **Chomsky: recursion is Merge**

> The core property of discrete infinity is intuitively familiar to every language user. Sentences are built up of discrete units: There are 6-word sentences and 7-word sentences, but no 6.5-word sentences. There is no longest sentence (any candidate sentence can be trumped by, for example, embedding it in "Mary thinks that . . ."), and there is no non-

(ibid.)

- **Model of grammar**



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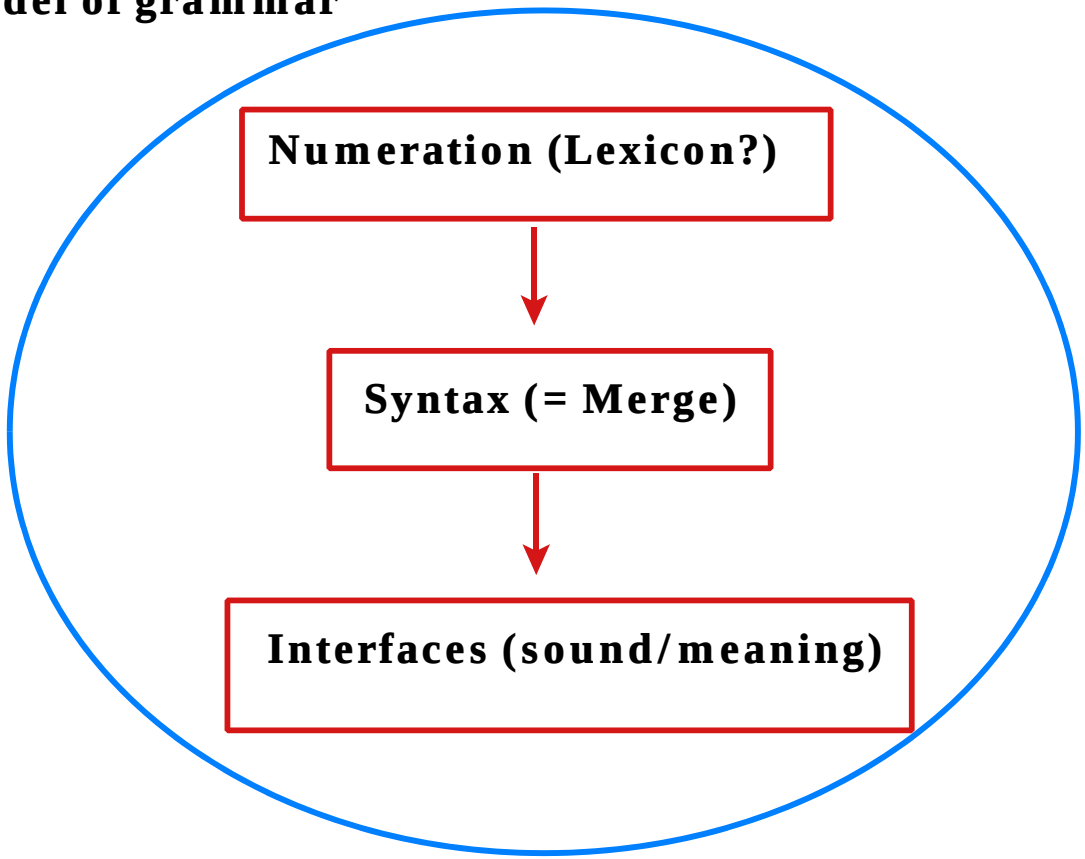
FLB



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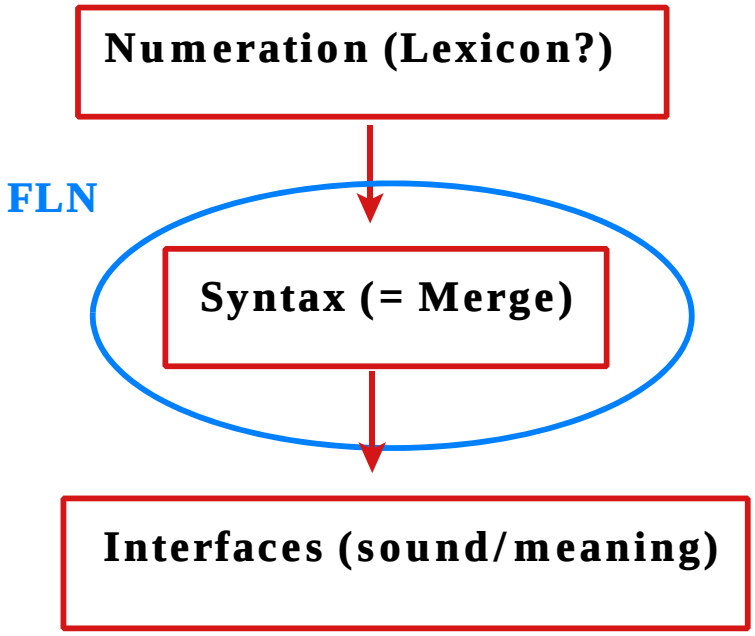

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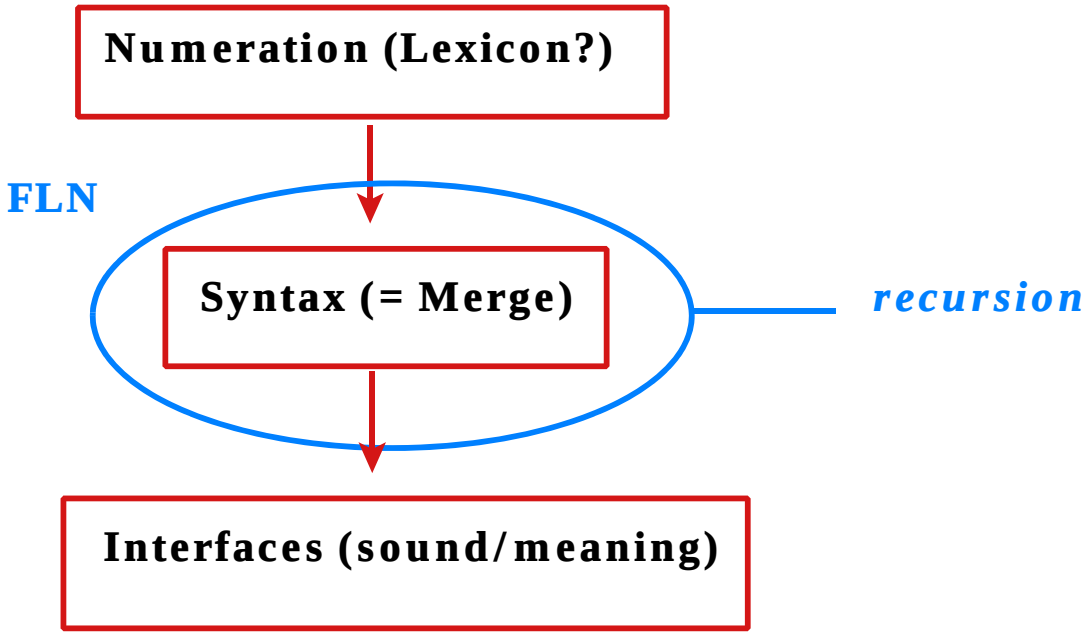

- **questioning the idea that FLN = recursion:**

Abstract

We examine the question of which aspects of language are uniquely human and uniquely linguistic in light of recent suggestions by Hauser, Chomsky, and Fitch that the only such aspect is syntactic recursion, the rest of language being either specific to humans but not to language (e.g. words and concepts) or not specific to humans (e.g. speech perception). We find the hypothesis problematic. It ignores the many aspects of grammar that are not recursive, such as phonology, morphology, case, agreement, and many properties of words. It is inconsistent with the anatomy and

(Pinker & Jackendoff, 2005, The faculty of language: what's special about it?, *Cognition* 95, 201-236.)

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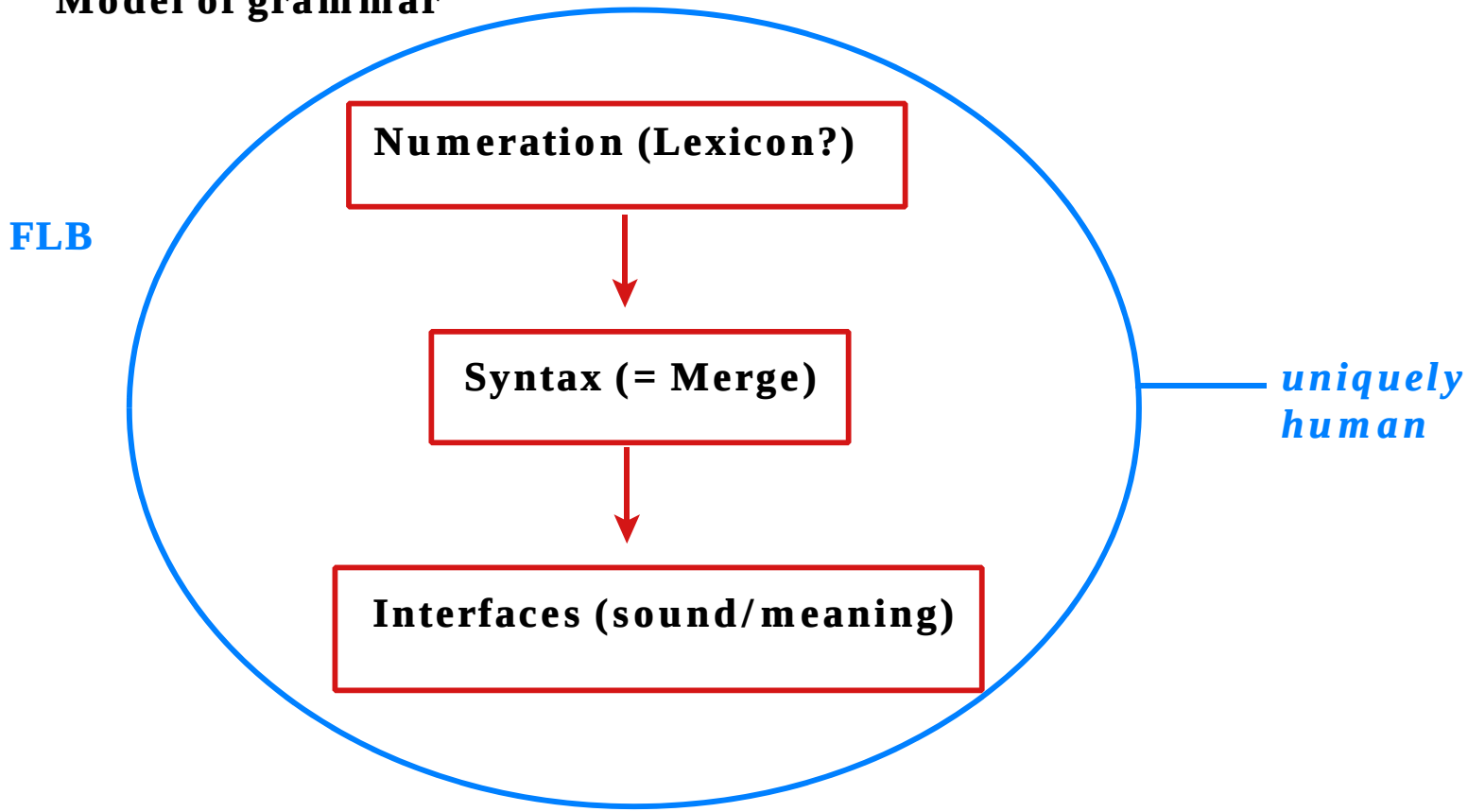
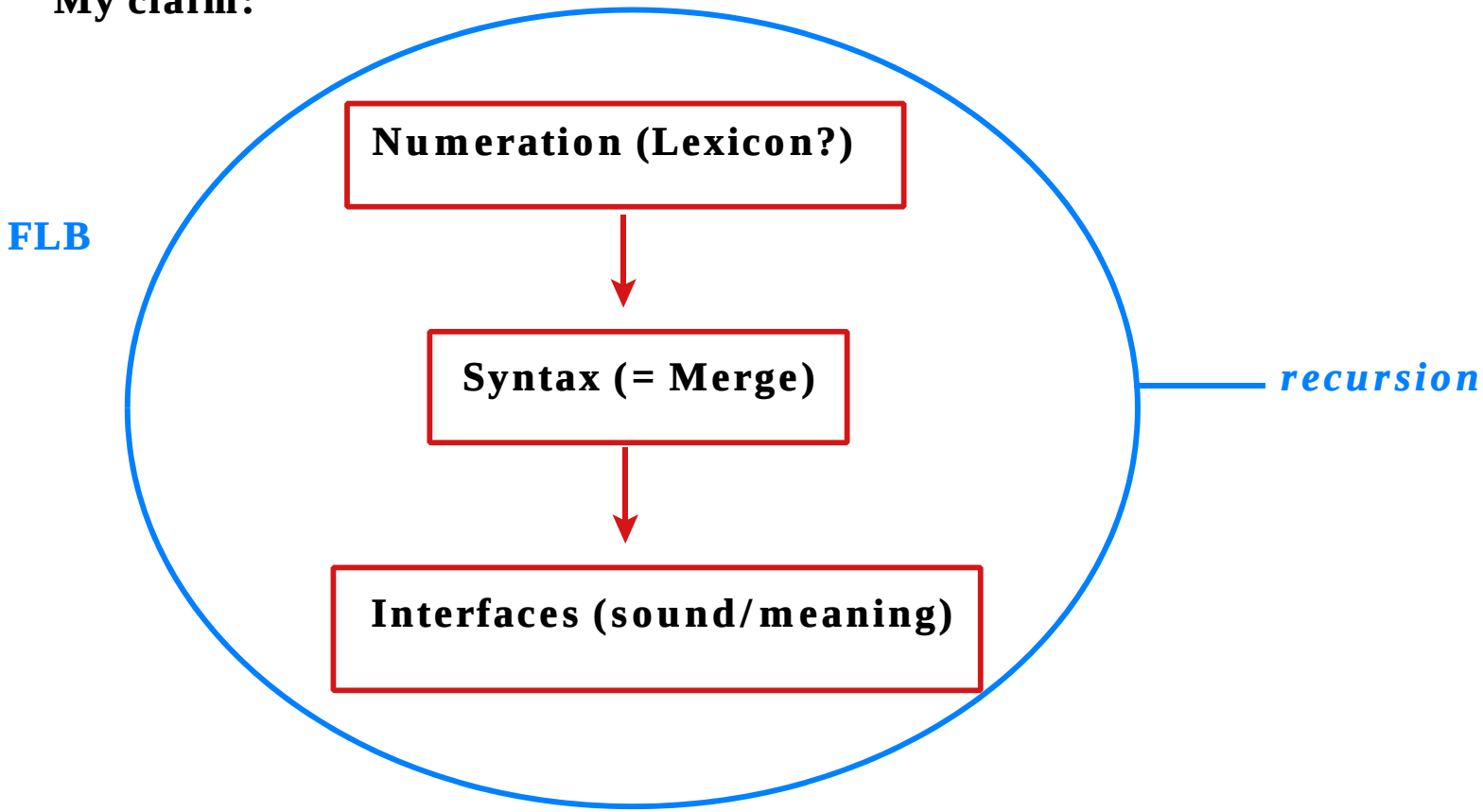


- **My claim:**


FLB
Numeration (Lexicon?)
Syntax (= Merge)
Interfaces (sound/meaning)
recursion

- **Origin of the idea that Recursion = Merge**
  - **'Aspects' model:**

    "[Recursion is] the introduction, by the rules of the base component, of the initial symbol S into strings of category symbols" [1]

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- **Origin of the idea that Recursion = Merge**
  - **'Aspects' model:**

    "[Recursion is] the introduction, by the rules of the base component, of the initial symbol S into strings of category symbols"

    » **gives you embedding structures**

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    "[Recursion is] the introduction, by the rules of the base component, of the initial symbol S into strings of category symbols"

    became acategorial (X-bar theory)
  - **Government & Binding model:**

    "Recursion is the embedding, by the rules of the X-bar theory, of an XP within XP."

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  - **Minimalism:** **became Merge**

    "Recursion is the application of Merge to the output of the previous application of Merge."

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    "Recursion is the embedding, by the rules of the X-bar theory, of an XP within XP."
  - **Minimalism:**
    "Recursion is the application of Merge to the output of the previous application of Merge."

    » *recursion is embedding*

aside:

Discussion on recursion in Pirahã	
Everett (2005, 2009)	**Nevins/Pesetsky/Rodrigues (2009)**
Aspects/GB view ***recursion = NP/S embedding***	**Minimalist view** ***recursion = Merge***
» recursion is embedding	

- **earliest generative ideas about recursion:**

  "[Recursion is] the introduction of S into another S by embedding transformation" [1]

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  - **Generalized transformation**

    "An optional embedding transformation which operates on two underlying strings at once (...)

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    the output of phrase structure rules

    - **'ready made' syntactic object**

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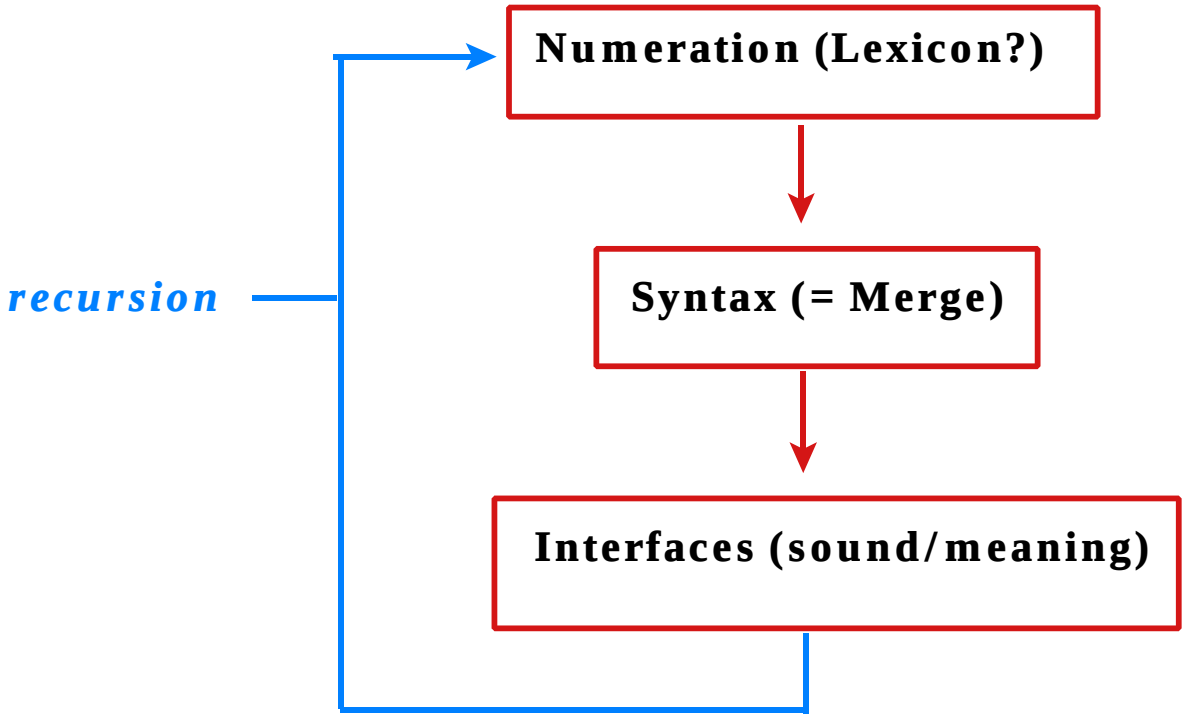
- **adapting this to modern terminology:**

» **“Recursion is the combination of previously construed elements.”**

» **“Recursion is merger of a complex element.”**

» **“Recursion arises when the output of a derivation is included in the Numeration for the next derivation.”**

- **Model of grammar**



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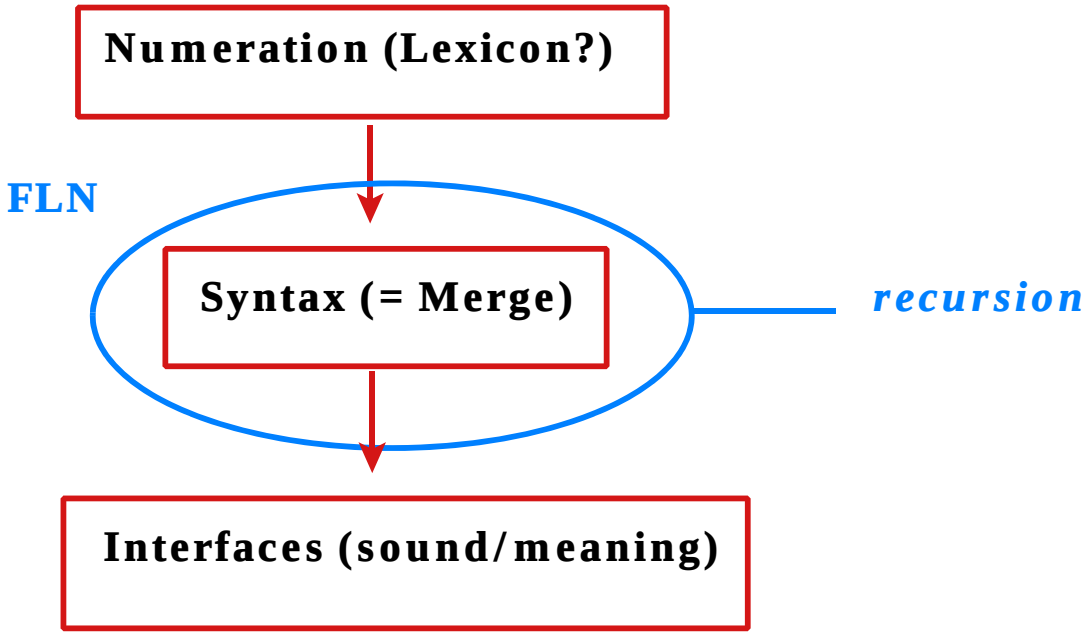

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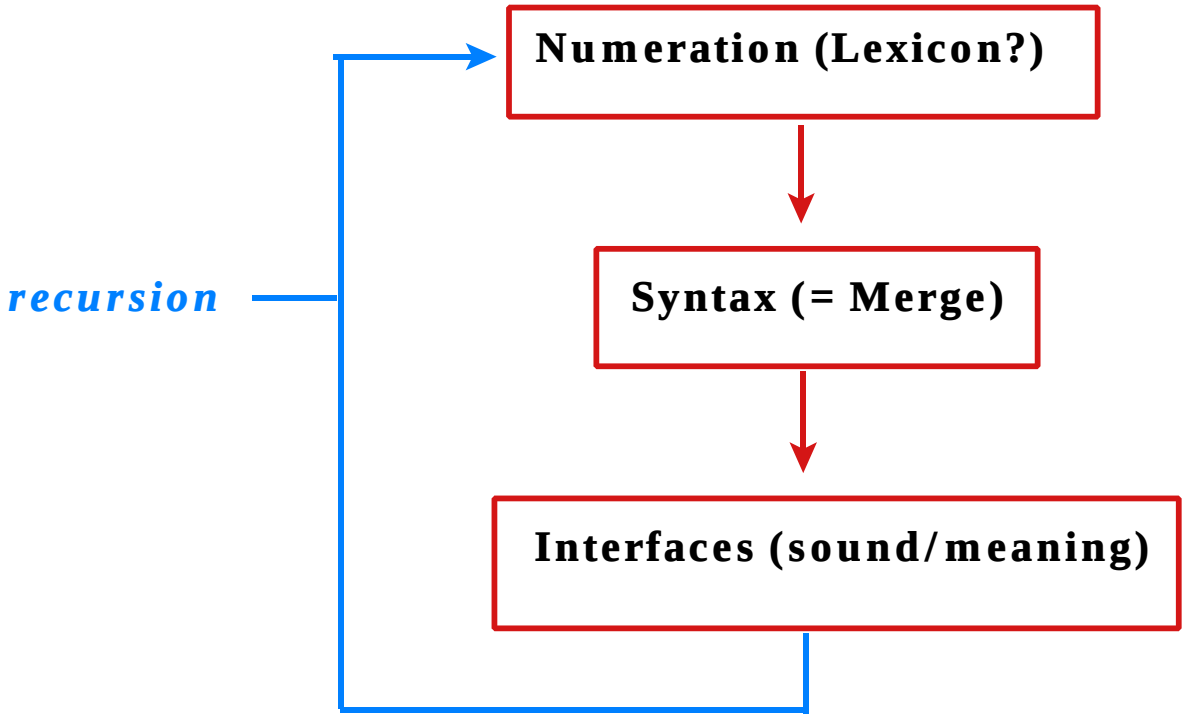

- **Arguments for thinking that recursion = derivation layering**
  - **the nature of the Numeration;**
  - **derivation layering is independently needed;**
  - **Merge/embedding need not be recursive but may be iterative; conversely, derivation layering is recursive by definition.**

- **the nature of the Numeration**

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  - **what's in a Numeration?**
    - **(implicit assumption:) words**
    - **but words are/may be complex**
      - **compounds**
      - **derived words**
      - **nominalizations**
      - **hybrids ('[stay-in-bed-and-do-nothing]-ish')**
      - **results of incorporation/conflation (*shelve*)**
    - **we want these to be composed (via Merge)**

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      - **results of incorporation/conflation (*shelve*)**
    - » **we want these to be composed (via Merge)**
  - **the Numeration is nonhomogeneous (so: ≠ Lexicon)**
    - » **features, morphemes, roots, stems, words, phrases, clauses**

- **derivation layering is independently needed**

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  - **theoretical (configurational) argument**
  - **empirical arguments**

- derivation layering is independently needed
  - theoretical (configurational) argument

(i) The man saw the woman

Let Numeration = { the, man, saw, the, woman }
Merge = bottom-up set creation
Constituent = output of Merge

- derivation layering is independently needed
  - theoretical (configurational) argument

(i) The man saw the woman

Let Numeration = { the, man, saw, the, woman }
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Constituent = output of Merge

1. { the, woman }
2. { saw, the_woman }
3. { man, saw_the_woman }
4. { the, man_saw_the_woman }

- derivation layering is independently needed
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(i) The man saw the woman

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1. { the, woman }
2. { saw, the_woman }
3. { man, saw_the_woman } *not a constituent*
4. { the, man_saw_the_woman }

» [the man] must be in the Numeration

Numeration = { [the man], saw, the, woman }

aside

- **There is an alternative,**
  where Merge creates *the man* and *saw the woman* in parallel,
  and then merges them

  » **this alternative violates my Simplest Merge Hypothesis:**

  Simplest Merge
  Merge manipulates a single element only once

  - ***bottom-up implementation*:**
    Merge transfers one element
    from the Numeration to the workspace

  - ***top-down implementation*:**
    Merge splits the Numeration N
    into an element in its syntactic position and the residue of N

- **derivation layering is independently needed**
  - **theoretical (configurational) argument**
    - » **complex specifiers/adjuncts must be created in a separate derivation layer**

      (i.e. must be in the Numeration, barring parallel derivations)
    - » **complex complements may be created 'on the fly' (in a single derivation)**

      >> **left/right asymmetry relevant to locality in syntax (CED)**
      >> **hypothesis: 'phases' are just outputs of derivation layers**

- **derivation layering is independently needed**
  - **empirical arguments**

- **derivation layering is independently needed**
  - **empirical arguments**
    - » **complex elements with idiosyncratic sound/meaning properties must have passed through the interface components**
    - » **types of phenomena indicative of derivation layering:**
      - **idiomatic interpretation**
      - **reanalysis**
      - **idiosyncratic morphology**
      - **fixed linear order properties**

- derivation layering is independently needed
  - empirical arguments
    - » complex elements with idiosyncratic sound/meaning properties must have passed through the interface components
    - » one example:

(2) He is a little bit crazy

- reanalysis of a noun phrase ('a small quantity') as a degree marker ('to some degree')
- analysis:
  1. { a, little, bit } > a_little_bit (Merge)
  2. interfaces: reanalysis
  3. inclusion in the Numeration for a next derivation

- **derivation layering is independently needed**
  - **empirical arguments**
    - » **complex elements with idiosyncratic sound/meaning properties must have passed through the interface components**
    - » **another example:**

(3) He kicked the bucket

1. literal interpretation **Num = { he, PAST, kick, the, bucket }**

2. idiom interpretation **Num = { he, PAST, [kick the bucket] }**

output of previous subderivation

- **Merge/embedding may as well be iterative (not recursive)**

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(4) I think you know

Numeration = { I, think, you, know }

		Numeration	Workspace
Merge:	1.	{ I, think, you, know }	
	2.	{ I, think, you }	know
	3.	{ I, think }	you know
	4.	{ I }	think you know
	5.		I think you know

- **Merge/embedding may as well be iterative (not recursive)**

(4) I think you know

Numeration = { I, think, you, know }

(or, top-down)

1.		**{ I, think, you, know }**
2.	**I**	**{ think, you, know }**
3.	**think**	**{ you, know }**
4.	**you**	**{ know }**
5.	**know**	

- **Merge/embedding may as well be iterative (not recursive)**
  - **iteration of the same simple procedure**
    - » **filling up the workspace (bottom-up)**
    - » **depleting the Numeration (top-down)**
  - **Merge = recursion is not a virtual conceptual necessity**
    - » **but derivation layering is recursion by definition**

Conclusion of the argument

- the Numeration must be heterogeneous
- we independently need derivation layering
  - for complex left branch elements
  - for complex elements with idiosyncratic sound/meaning properties
- embedding can be done via iteration,
  but derivation layering is recursion by definition

Consequences

- **Is natural language grammar of the finite state type ?**
- **Do all languages have recursion ?**
- **Does recursion still define the human language faculty ?**

Consequences

- **Is natural language grammar of the finite state type ?**

Consequences

- **Is natural language grammar of the finite state type ?**
  - **History of the discussion:**
    (cf. *Syntactic structures*, 1957:18f)
    - **» the simplest grammars are finite state grammars**
    - **» but English is not a finite state language > we need a phrase structure grammar**

      (discussion about whether the phrase structure grammar must be context-free or context-sensitive)
    - **» but even a phrase structure grammar is not good enough > we need a transformational component**
    - **» beginnings of cartographic approach to syntax**

- **finite state grammar**
  - » **a sentence is a series of states**
  - » **the grammar is a machine that moves from one state to the next, producing an output at each move**
  - » **each state (or output) delimits the range of further states**
  - » **rewrite rules:**

    (i) A → a B | a **(where *a* is a terminal and *A/B* a nonterminal)**

- **context-free grammar**
  - » **rules replace a nonterminal by a string of (non)terminals**
- **context-sensitive grammar**
  - » **the same, but with context stipulated**

- **our simplest Merge grammar looks a lot like a finite-state grammar:**

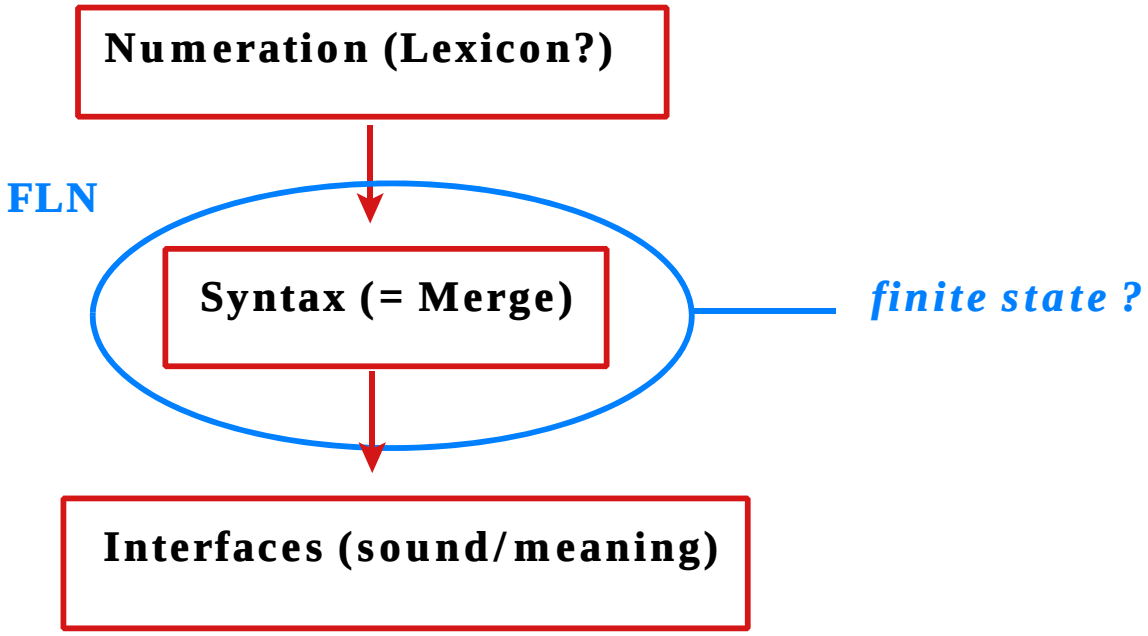
(4) **I think you know**

Numeration = { I, think, you, know }

1.		**{ I, think, you, know }**	***initial state***
2.	**I**	**{ think, you, know }**	
3.	**think**	**{ you, know }**	
4.	**you**	**{ know }**	
5.	**know**		***final state***

output

- **our simplest Merge grammar looks a lot like a finite-state grammar:**
  - » **hypothesis: FLN = finite state grammar**



- **Is English a finite state language?**
  - » ***wrong question*: 'English' involves the entire FLB, including the Numeration and the Interfaces (i.e. Lexicon, phonology, morphology, semantics), as well as the phenomenon of derivation layering (i.e. recursion)**
  - » **discussion should focus on the properties of FLN (i.e. Merge)**

- **Is English a finite state language?**
  - » **Chomsky's argument (*Syntactic structures* and earlier):**

to account for the syntactic dependency between the words *if* and *then* in a sentence like *if it rains then it pours*, English grammar must contain a rule like $S \rightarrow$ *if* S *then* S. If so (..), then English also contains the sentences *if if it rains then it pours then it pours* and *if if if it rains then it pours then it pours then it pours*, but not **if it rains then it pours then it pours* nor **if if it rains then it pours*. That is, English contains every sentence of the form $\{(if)^m$ *it rains* $(then\ it\ pours)^n \mid m = n\}$, but no sentence of the form $\{(if)^m$ *it rains* $(then\ it\ pours)^n \mid m \neq n\}$. Hence English is not a finite-state language.

(Langendoen 2003: vol.2, 26-28)

$a^\frown b$
$a^\frown a^\frown b^\frown b$
$a^\frown a^\frown a^\frown b^\frown b^\frown b$
etc

- **but the structure is:**

  [[if it rains] [then [it [pours]]]]

  where if it rains is a complex left branch element, hence the output of a previous derivation layer

- **structurally:**

  (if S), then SUBJECT PREDICATE

  where *S* can be complex as well

- **in each cycle, there is just the local dependency between the *if*-clause and the consequent *then*-clause**

Consequences

- **Is natural language grammar of the finite state type ?**
  - » **should be asked of FLN only**
  - » **arguments should not involve the crucial property of derivation layering (which is outside FLN)**

aside

- **Interestingly, arguments showing that phrase structure grammars are insufficient (*Syntactic structures*, chapter 5)**
  - **either involve complex sentences (conjunction reduction) and hence must be reconsidered assuming layered derivations**
  - **or hinge on interface phenomena like inflectional morphology**

  (with the possible exception of the argument based on passivization).
- **This affects the evidence for transformations within FNL.**

even further aside

- **arguments showing that the grammar must be context-sensitive rather than context-free (or vice versa) typically focus on very complex structures (involving cross-serial dependencies)**

  - » **to remain valid, it must be shown that these structures are derived without derivation layering**

  - » **example**

    (that) we the children Hans the house

    let help paint

    das mer d'chiind em Hans es huus lönd helfe aastriiche

  - » **the argument becomes invalid if the cluster is the output of a separate derivation layer**

- **Is English a finite state language?**
  - » **obviously not**
  - » **but the narrow syntax part in each derivation layer might be**

Consequences 2

- **Do all languages have recursion ?**

Consequences 2

- Do all languages have recursion ?
  - Embedding is not the key
  - Indications of recursion:
    - » complex specifiers (subjects)
    - » idioms/reanalysis/compounds/clustering etc.

- **Pirahã (data from Everett 1986)**

subject

xoogiái	**hi**	**xapisí**	biga	aí	big-á
Xoogiái	3	arm	thick	be	thick-EMPH

'Xoogiái's arm is thick (i.e. strong), very strong.'

nominalization

tiobáhai	**hóoi**	**ai-sai**	xabahíoxoi
child	bow	make-NOM	incorrect

'Children's bow making is incorrect.'

compound

xabagisoixaoxoisai	<	xabagi +	soixaoxoisai
saw		toucan	beak

"All names for people are derived from verbal constructions, animal names, nominal phrases, etc. In about 90% of these cases, *-si* occurs optionally in morpheme final position, as though marking a change in the basic reference or function." (Everett 1986: 279-280)

- **Teiwa (Klamer 2010)**
  - **no embedding, no relative clauses, but signs of derivation layering**

subject

Quaf	*yas*	*nuk*	*ga'an*	*a*	*hafan*	*me'...*
grandmother	bad	one	3s	3s	village	be.in

'That one poor grandmother stayed in the village...'

compounds

xam	*yir*	'milk'
breast	water	

ga-fan iga'	'bury'
3s-face hide	

serial verbs

A	*ta*	*min-an*	*ba'.*
3s	TOP	[die- REAL	fall]

'He died falling [down]'

Consequences 3

- **Does recursion still define the human language faculty ?**

Consequences 3

- **Does recursion still define the human language faculty ?**
  - » **Arguably, yes, but recursion now refers not to embedding, but to the process of transforming/packaging complex items into simplex ones.**
  - » **Douglas Hofstadter thinks that this 'cognitive loop' is at the core of human cognition**

"A spectacular evolutionary gulf opened up at some point as human beings were gradually separating from other primates: their category systems became *arbitrarily extensible*. Into our mental lives there entered a dramatic open-endedness, an essentially unlimited extensibility, as compared with a very palpable limitedness in other species.

"Concepts in the brains of humans acquired the property that they could get rolled together with other concepts into larger packets, and any such larger packet could then become a new concept in its own right. In other words, concepts could *nest* inside each other hierarchically, and such nesting could go on to arbitrary degrees." [1]

[1] **Hofstadter, D. (2007) *I am a strange loop*, p. 83.**

» **example:**

OFFSPRING > FATHER/MOTHER > PARENT > GRANDFATHER > GRANDPARENT
CHILD GRANDCHILD
BROTHER/SISTER > SIBLING

>>> FAMILY > ETC.

derivation layering seems to me to be
the syntactic realization of Hofstadter's loop

Thank you !