LING/C SC 581:
Advanced Computational Linguistics

Lecture 26

Prof. Sandiway Fong

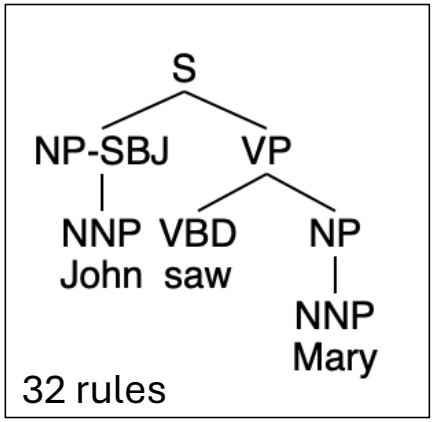
Today's Topics

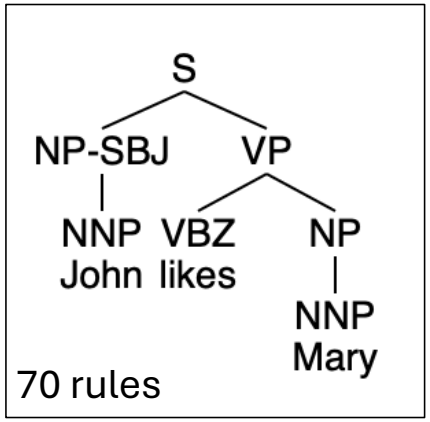
- Homework 11 Review

- Let's try something different!
  - Fall Semester: Mondays 2:30PM-5PM
  - I'm teaching **LING696A**, a Seminar on *Syntax + Computation*
  - *Very much hope some of you will sign up for it!*

Homework 11 Review

- "*John saw Mary*" vs. "*John likes Mary*"
- **Q1-2**: which grammar is smaller and why?





Frequence of occurrence:
PAST Tense (VBD) vs.
PRES Tense (VBZ)

Homework 11 Review

```
>>> find_scfg("John saw Mary")
["NNP -> 'Mary'", "NNP -> 'John'", "VBD -> 'saw'"]
Begin CFG grow
Parses: 1, # syntax rules: 32 (minus 0 blocked), # lexical rules: 3
(S (NP-SBJ (NNP John)) (VP (VBD saw) (NP (NNP Mary))))
grow CFG time: 0.01 (s)
```

```
>>> find_scfg("John likes Mary")
["NNP -> 'Mary'", "NNP -> 'John'", "VBZ -> 'likes'"]
Begin CFG grow
Parses: 1, # syntax rules: 70 (minus 3 blocked), # lexical rules: 3
(S (NP-SBJ (NNP John)) (VP (VBZ likes) (NP (NNP Mary))))
grow CFG time: 0.04 (s)
```

Homework 11 Review

```
>>> find_scfg("John likes Mary", printgrammar=True)
["NNP -> 'Mary'", "NNP -> 'John'", "VBZ -> 'likes'"]
Parses: 1, # syntax rules: 70 (minus 3 blocked), # lexical rules: 3
(S (NP-SBJ (NNP John)) (VP (VBZ likes) (NP (NNP Mary))))
```

1. S -> NP-SBJ VP
2. PP -> IN NP
3. NP-SBJ -> NONE
4. NP -> DT NN
5. NP-SBJ -> PRP
6. NP -> NP PP
7. VP -> TO VP
8. NP -> NN
9. NP -> NONE
10. PP-LOC -> IN NP
11. ADVP -> RB
12. NP -> DT JJ NN
13. NP -> NNS
14. VP -> MD VP
15. SBAR -> WHNP S
16. NP -> NNP
17. VP -> VB NP
18. NP -> PRP
19. PP-TMP -> IN NP
20. SBAR -> NONE S
21. PP-CLR -> IN NP
22. NP -> NNP NNP
23. NP-SBJ -> DT NN
24. NP -> JJ NNS
25. NP -> NP SBAR
26. SBAR -> IN S
27. NP-SBJ -> NP PP
28. VP -> VBD VP
29. NP-SBJ -> NNP
30. VP -> VBD SBAR
31. ADVP-TMP -> RB
32. **VP -> VBD NP**
33. PP -> TO NP
34. QP -> CD CD
35. WHNP -> WDT
36. NP -> DT NNS
37. VP -> VBZ VP
38. VP -> VBG NP
39. NP-SBJ -> NNP NNP
40. NP -> NP CC NP
41. NP -> JJ NN
42. NP -> PRPS NN
43. VP -> VP CC VP
44. NP -> NP PP-LOC
45. VP -> VBD S
46. NP -> QP NONE
47. NP -> DT NN NN
48. S-NOM -> NP-SBJ VP
49. PRT -> RP
50. VP -> VBP VP
51. WHNP -> WP
52. NP -> CD
53. NP -> NP VP
54. ADJP-PRD -> JJ
55. VP -> VB VP
56. NP -> NNP POS
57. S -> S CC S
58. WHADVP -> WRB
59. VP -> VBN NP
60. NP-SBJ -> NNS
61. NP -> NN NNS
62. SBAR-ADV -> IN S
63. S-ADV -> NP-SBJ VP
64. NP -> CD NNS
65. VP -> VBN NP PP
66. PP -> IN NP-LGS
67. VP -> VBZ NP
68. NNP -> 'Mary'
69. NNP -> 'John'
70. VBZ -> 'likes'

Homework 11 Review

- "*Mary saw the boy who I saw* " vs. " *Mary saw the boy I saw* "
- **Q3-4**:
  - which grammar is smaller? Parses correct?

Both report 151 rules

Homework 11 Review

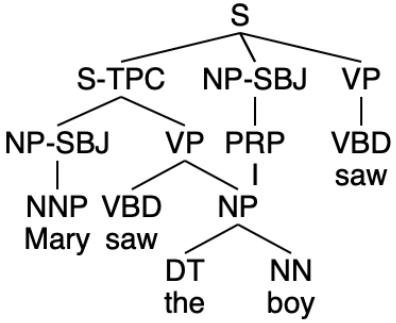
```
>>> find_scfg("Mary saw the boy")
["DT -> 'the'", "NN -> 'boy'", "NNP -> 'Mary'", "VBD -> 'saw'"]
Parses: 1, # syntax rules: 32 (minus 0 blocked), # lexical rules: 4
(S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (DT the) (NN boy))))
grow CFG time: 0.02 (s)
```

```
>>> find_scfg("Mary saw the boy I saw")
["NNP -> 'Mary'", "VBD -> 'saw'", "PRP -> 'I'", "DT -> 'the'", "NN -> 'boy'"]
Parses: 2, # syntax rules: 151 (minus 5 blocked), # lexical rules: 5
(S (S-TPC (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (DT the) (NN boy)))) (NP-SBJ (PRP I)) (VP (VBD saw)))
(S (S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (DT the) (NN boy)))) (S (NP-SBJ (PRP I)) (VP (VBD saw))))
grow CFG time: 0.16 (s)
```

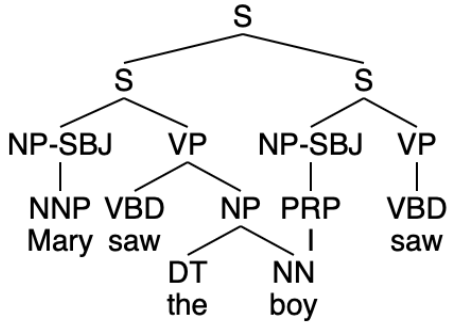
```
>>> find_scfg("Mary saw the boy who I saw")
["WP -> 'who'", "NNP -> 'Mary'", "VBD -> 'saw'", "PRP -> 'I'", "DT -> 'the'", "NN -> 'boy'"]
Parses: 1, # syntax rules: 151 (minus 5 blocked), # lexical rules: 6
(S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (NP (DT the) (NN boy)) (SBAR (WHNP (WP who)) (S (NP-SBJ (PRP
  I)) (VP (VBD saw)))))))
grow CFG time: 0.16 (s)
```

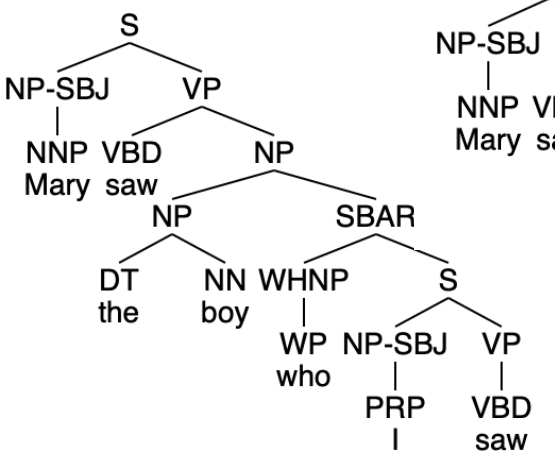
Homework 11 Review

```
(S (S-TPC (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (DT the) (NN boy)))) (NP-SBJ (PRP I)) (VP (VBD saw)))
```




```
(S (S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (DT the) (NN boy)))) (S (NP-SBJ (PRP I)) (VP (VBD saw))))
```






```
(S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (NP (DT the) (NN boy)) (SBAR (WHNP (WP who)) (S (NP-SBJ (PRP I)) (VP (VBD saw)))))))
```

Homework 11 Review

- *Mary saw the boy who I saw* " vs. " *Mary saw the boy I saw* "
  - parameter `ec: True, permits –NONE– –> ''`
- **Q5-6**: which grammar is smaller? Why? Parses correct?

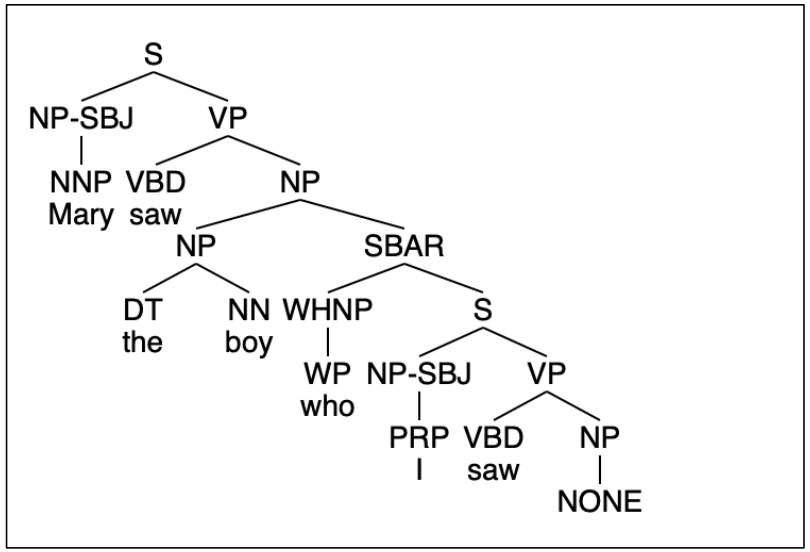
53 vs. 32 rules

Homework 11 Review

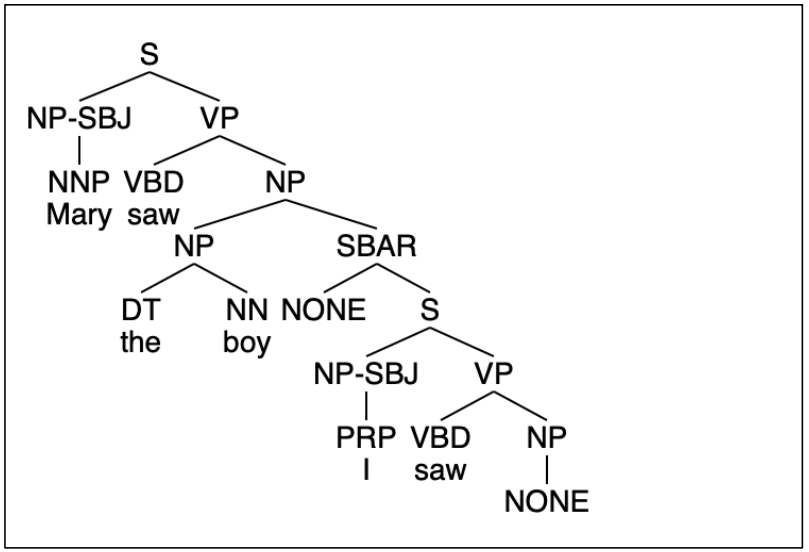
```
>>> find_scfg("Mary saw the boy who I saw",ec=True)
["WP -> 'who'", "NNP -> 'Mary'", "VBD -> 'saw'", "PRP -> 'I'", "DT -> 'the'", "NN ->
  'boy'", 'NONE ->']
Begin CFG grow
Parses: 1, # syntax rules: 53 (minus 2 blocked), # lexical rules: 7
(S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (NP (DT the) (NN boy)) (SBAR (WHNP (WP who)) (S
  (NP-SBJ (PRP I)) (VP (VBD saw) (NP (NONE ))))))))
grow CFG time: 0.06 (s)

>>> find_scfg("Mary saw the boy I saw",ec=True)
["NNP -> 'Mary'", "VBD -> 'saw'", "PRP -> 'I'", "DT -> 'the'", "NN -> 'boy'", 'NONE ->']
Begin CFG grow
Parses: 1, # syntax rules: 32 (minus 0 blocked), # lexical rules: 6
(S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (NP (DT the) (NN boy)) (SBAR (NONE ) (S (NP-SBJ
  (PRP I)) (VP (VBD saw) (NP (NONE ))))))))
grow CFG time: 0.03 (s)
```

Homework 11 Review

```
(S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (NP
(DT the) (NN boy)) (SBAR (WHNP (WP who)) (S
(NP-SBJ (PRP I)) (VP (VBD saw) (NP (NONE
))))))))
```




```
(S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (NP (DT
the) (NN boy)) (SBAR (NONE ) (S (NP-SBJ (PRP I))
(VP (VBD saw) (NP (NONE ))))))))
```



Homework 11 Review

```
>>> find_scfg("Mary saw the boy who I saw", ec=True, printgrammar=True)
["WP -> 'who'", "NNP -> 'Mary'", "VBD -> 'saw'", "PRP -> 'I'", "DT -> 'the'", "NN -> 'boy'", 'NONE ->']
Parses: 1, # syntax rules: 53 (minus 2 blocked), # lexical rules: 7
(S (NP-SBJ (NNP Mary)) (VP (VBD saw) (NP (NP (DT the) (NN boy)) (SBAR (WHNP (WP who)) (S (NP-SBJ (PRP I)) (VP (VBD saw)
(NP (NONE ))))))))
```

1. S -> NP-SBJ VP
2. PP -> IN NP
3. NP-SBJ -> NONE
4. NP -> DT NN
5. NP-SBJ -> PRP
6. NP -> NP PP
7. VP -> TO VP
8. NP -> NN
9. NP -> NONE
10. PP-LOC -> IN NP
11. ADVP -> RB
12. NP -> DT JJ NN
13. NP -> NNS
14. VP -> MD VP
15. SBAR -> WHNP S
16. NP -> NNP
17. VP -> VB NP
18. NP -> PRP
19. PP-TMP -> IN NP
20. SBAR -> NONE S
21. PP-CLR -> IN NP
22. NP -> NNP NNP
23. NP-SBJ -> DT NN
24. NP -> JJ NNS
25. NP -> NP SBAR
26. SBAR -> IN S
27. NP-SBJ -> NP PP
28. VP -> VBD VP
29. NP-SBJ -> NNP
30. VP -> VBD SBAR
31. ADVP-TMP -> RB
32. VP -> VBD NP
33. PP -> TO NP
34. QP -> CD CD
35. WHNP -> WDT
36. NP -> DT NNS
37. VP -> VBZ VP
38. VP -> VBG NP
39. NP-SBJ -> NNP NNP
40. NP -> NP CC NP
41. NP -> JJ NN
42. NP -> PRPS NN
43. VP -> VP CC VP
44. NP -> NP PP-LOC
45. VP -> VBD S
46. NP -> QP NONE
47. NP -> DT NN NN
48. S-NOM -> NP-SBJ VP
49. PRT -> RP
50. VP -> VBP VP
51. **WHNP -> WP**
52. WP -> 'who'
53. NNP -> 'Mary'
54. VBD -> 'saw'
55. PRP -> 'I'
56. DT -> 'the'
57. NN -> 'boy'
58. NONE ->

Let's pivot!

- Just saw how grammar complexity could be reduced
  - **the device:** empty categories
  - a reduction in grammar size is always welcome
  - dependency grammars don't use empty categories

- What if we could go beyond basic PS rules?
  - to something potentially more satisfying
  - generalize further …

Explanation vs. Description

Noam Chomsky - Genuine Explanation & the Strong Minimalist Thesis (MIT Linguistics Colloquium 2022)

Description and (Im)possible Languages

Minimalist Theories of Language

- It's perhaps the **MOST** you can do!

Strong Minimalist Thesis (SMT)

- Chomsky's latest take on how language works
  - (*70 years of research into this question*)
  - *informed by child language research, genetics, etc.*

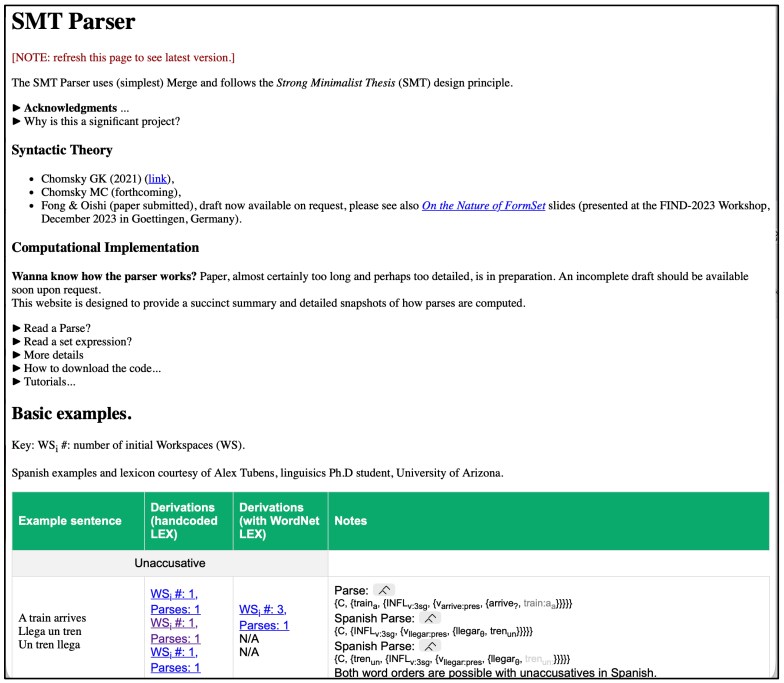
  - at its heart, there's a very "simple" theory of language
  - maximum (*mathematical*) simplicity in possible operations
  - considers evolutionary plausibility
  - *asks difficult questions*
  - *pose new challenges for explanatory theory*

Noam Chomsky - Genuine Explanation & the Strong Minimalist Thesis (MIT Linguistics Colloquium 2022)

Deep Learning: GPT Parameter Space

My contribution to the **SMT**

- Investigate computational modeling of I-Language
- There's a parser!
- sandiway.arizona.edu/smtparser/



SMT Parser

[NOTE: refresh this page to see latest version.]

The SMT Parser uses (simplest) Merge and follows the *Strong Minimalist Thesis* (SMT) design principle.

▶ **Acknowledgments** ...
▶ Why is this a significant project?

Syntactic Theory

- Chomsky GK (2021) (link),
- Chomsky MC (forthcoming),
- Fong & Oishi (paper submitted), draft now available on request, please see also *On the Nature of FormSet* slides (presented at the FIND-2023 Workshop, December 2023 in Goettingen, Germany).

Computational Implementation

Wanna know how the parser works? Paper, almost certainly too long and perhaps too detailed, is in preparation. An incomplete draft should be available soon upon request.
This website is designed to provide a succinct summary and detailed snapshots of how parses are computed.

▶ Read a Parse?
▶ Read a set expression?
▶ More details
▶ How to download the code...
▶ Tutorials...

Basic examples.

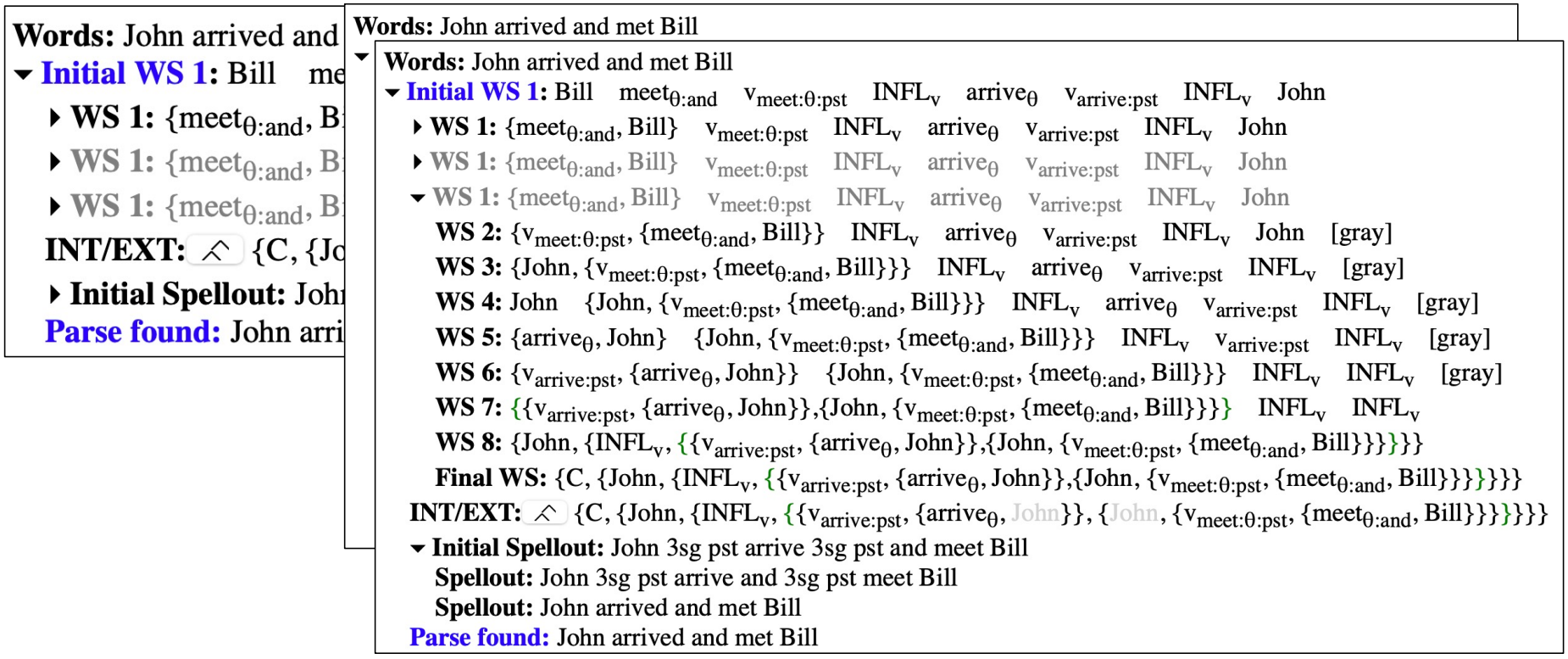
Key: WS_i #: number of initial Workspaces (WS).

Spanish examples and lexicon courtesy of Alex Tubens, linguisics Ph.D student, University of Arizona.

Example sentence	Derivations (handcoded LEX)	Derivations (with WordNet LEX)	Notes
Unaccusative			
A train arrives Llega un tren Un tren llega	WS_i #: 1, Parses: 1 WS_i #: 1, Parses: 1 WS_i #: 1, Parses: 1	WS_i #: 3, Parses: 1 N/A N/A	Parse: {C, {train$_a$, {INFL$_{v:3sg}$, {v$_{arrive:pres}$, {arrive$_?$, train:a$_a$}}}}} Spanish Parse: {C, {INFL$_{v:3sg}$, {v$_{llegar:pres}$, {llegar$_0$, tren$_{un}$}}}} Spanish Parse: {C, {tren$_{un}$, {INFL$_{v:3sg}$, {v$_{llegar:pres}$, {llegar$_0$, tren$_{un}$}}}}} Both word orders are possible with unaccusatives in Spanish.

SMT Parser

sandiway.arizona.edu/smtparser



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Inquiry of Language: Two levels

well-formed thought but not externalizable

[pg.39, (Chomsky 2013)]

{C_Q, {INFL, {{eagles, {C_{rel}, {INFL, ~~{eagles}~~, {v_θ, fly}}}}}, {v_θ, swim}}}}

can

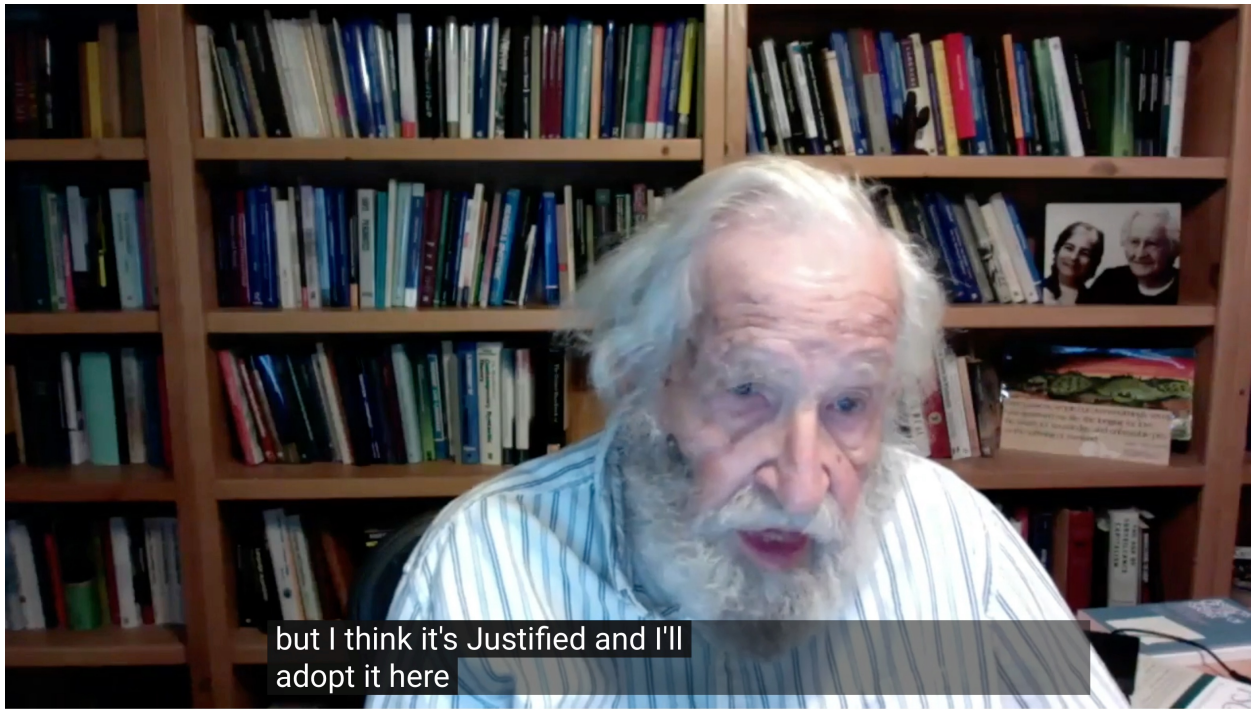
- Eagles that fly swim
- Eagles that fly *can* swim **?** (*turn into a question: front modal verb*)
- *Can* eagles that fly *swim*? C_Q: question about *swim* (not *fly*)

{C_Q, {INFL, {{eagles, {C_{rel}, {INFL, {can, ~~{eagles}~~, {v_θ, fly}}}}}}, {v_θ, swim}}}}

- Eagles that *can fly* swim (*let's try turning it into a question*)
- *****Can* eagles that *fly* swim? **well-formed thought** (no EXT)

"*... that is a fine thought, but it cannot be expressed by* [*this sentence*]."

Faculty of Language (FL) & Poverty of Stimulus



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FL: Contradictory Conditions; UG theory of FL

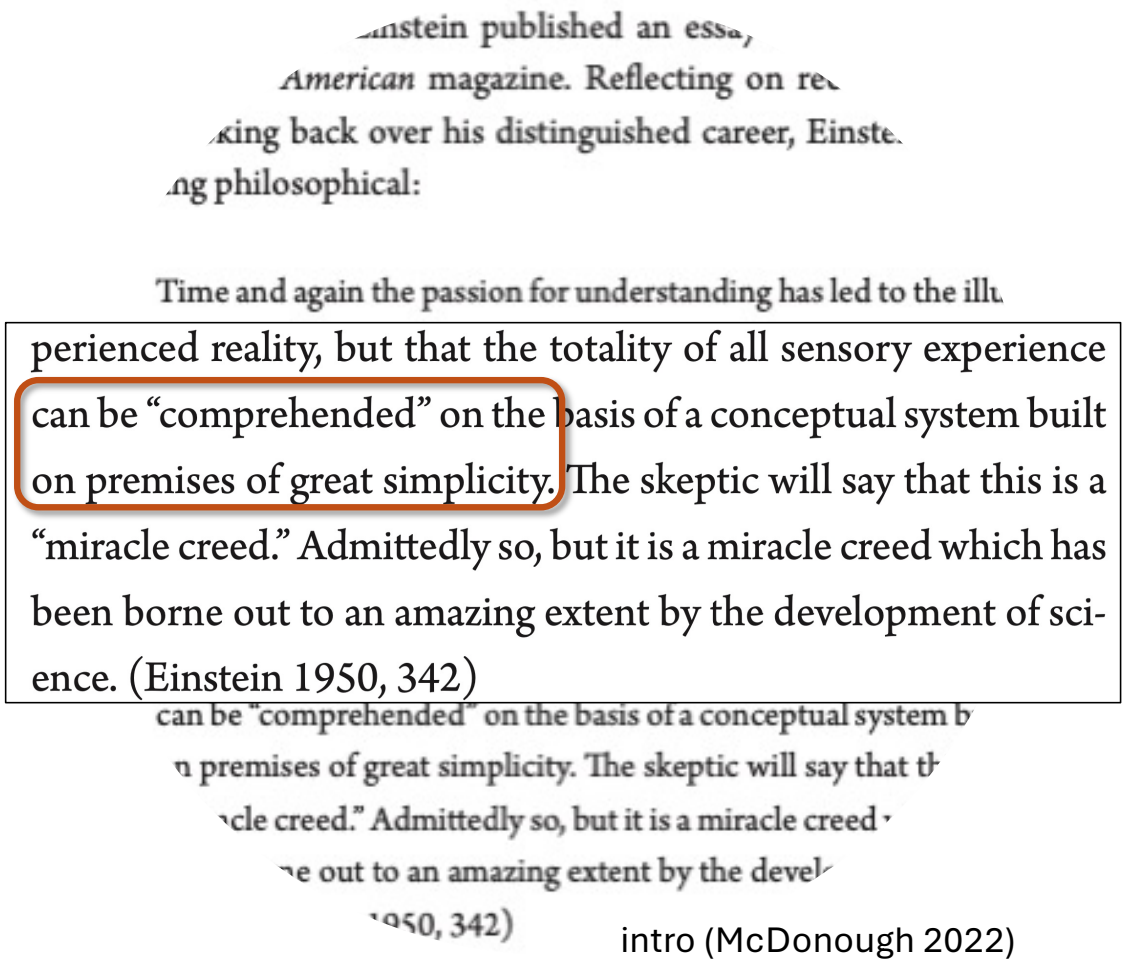
Recent Human Evolution

- Explosion of symbolic works in the fossil record
  - *coincides with the appearance of modern humans* (200-300 tya)
  - … until the emergence of behaviorally modern *H. sapiens*: **in general, technological innovations have been sporadic and rare**. The most-striking evidence for a distinct cognitive contrast between modern humans and all their predecessors, however, comes from Europe. *H. sapiens* came late to this continent and brought a new kind of stone tool based on striking long thin "blades" from a carefully prepared long core. **In short order these Europeans, the so-called Cro-Magnons, left a dazzling variety of symbolic works of prehistoric art**. (Tattersall in *Encyclopaedia Britannica*)

    Last Updated: Aug. 29, 2025
  - *we can fashion tools that amplify these inherent abilities that we have to spectacular magnitudes*, *e.g. wrt. locomotion, computation, medicine*

Recent Human Evolution

- (Berwick & Chomsky 2016)
  - *Vocal learning and production aspect of* [***EXT***] *is not human-specific* (ancient)
- (Chomsky 2021)
  - Language/thought, **I-Language**, an authentic species property (recent)
  - *Our closest relatives, otherwise intelligent apes, cannot begin to grasp the most elementary rudiments of language even with intensive training. They have about the same auditory system as humans, but acquire nothing from the sounds that lead a human infant, almost reflexively, to develop complex systems for constructing and expressing thought.*
- Basic structure of I-Language should be simple (**Merge**):
  - *the result of some […] small rewiring of the brain […] and has not changed […] since.*
- Modern human ~20K protein coding genes (*1.5% human genome*)
  - Neanderthal/Modern human Y-chromosome divergence ~588 tya (Mendez *et al*. 2016)
  - 14,042 regions of archaic DNA (Neanderthal/Denisovans) (Weiss et al. 2021)
  - *407 […] drove differential expression between the modern and archaic alleles*



...nstein published an ess...,
American magazine. Reflecting on re...
...king back over his distinguished career, Einste...
...ng philosophical:

Time and again the passion for understanding has led to the illu...
perienced reality, but that the totality of all sensory experience can be "comprehended" on the basis of a conceptual system built on premises of great simplicity. The skeptic will say that this is a "miracle creed." Admittedly so, but it is a miracle creed which has been borne out to an amazing extent by the development of science. (Einstein 1950, 342)
can be "comprehended" on the basis of a conceptual system b...
...n premises of great simplicity. The skeptic will say that t...
...cle creed." Admittedly so, but it is a miracle creed...
...e out to an amazing extent by the devel...
...950, 342)

intro (McDonough 2022)

What is the Strong Minimalist Thesis (SMT)?

- a theory design guideline (Chomsky 2024)
- **SMT**: **Language** satisfies Einstein's *Miracle Creed*

(Wikipedia) LLMs: "*largest models typically have 100 billion parameters*"
GPT-4 1,760 billion

What does it mean for *I-Language*?

- "The Strong Minimalist Thesis (SMT) holds that language too may satisfy the miracle creed **at its core**." (Chomsky 2024)
- At the core: **I-Language**
  - **I = internal**: the expressions computed by Merge
  - could be a **well-formed thought** but not (directly) externalizable

What does it mean for I-Language?

- "The Strong Minimalist Thesis (SMT) holds that language too may satisfy the **miracle creed** **at its core**." (Chomsky 2024)
- At the core: **I-Language**
  - internal: the expressions computed by Merge
  - could be a **well-formed thought** but not (directly) externalizable
  - Explains that orderly, see **Basic Property** (BP)
- **E-Language**:
  - Externalized I-Language (**EXT**), e.g. pronounced or signed or written
  - linear order imposed by the modality
  - word order and spellout parameterized *by particular (E-)language*

return to talk about this soon!