# 6.863J Natural Language Processing
# Lecture 14: Word semantics I

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# The Menu Bar

- Administrivia:
- Lab 4 due April 9
- *Agenda:*
- Lexical semantics: the meanings of words: how hard can it be?
- Tense and time (if there's time)

# Word sense

- The benevolent alien race that visits earth.
- Their great book is entitled *How to Serve Humans*

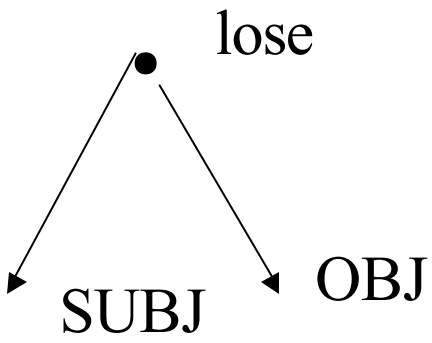
# Predicate-arguments to thematic roles

- Use *linking rules*
- These say whether, e.g, Subject is the agent…
- Is there a theory for this?
- How do we build this knowledge?

# Predicate-argument structures for *lose*

lose1 (*Agent*: animate,
*Patient*: physical-object)

lose2 (*Agent*: animate,
*Patient*: competition)




Agent <=> subj
Patient <=> obj

# Machine Translation Lexical Choice- Word Sense Disambiguation

Iraq lost the battle.

*Ilakuka centwey ciessta.*

[Iraq ] [battle] [lost].

John lost his computer.

*John-i computer-lul ilepelyessta.*

[John] [computer] [misplaced].

# Word sense disambiguation with Source Language Semantic Class Constraints (co-occurrence patterns)

lose1(*Agent, Patient*: competition) <=> ciessta

lose2 (*Agent, Patient*: physobj) <=> ilepelyessta

# Is there enough data?

- Break

# Levin classes (3100 verbs)

- 47 top level classes, 150 second and third level
- Based on pairs of syntactic frames.

  *John broke the jar. / Jars break easily. / The jar broke.*
  *John cut the bread. / Bread cuts easily. / *The bread cut.*
  *John hit the wall. / *Walls hit easily. / *The wall hit.*

- Reflect underlying semantic components

  **contact, directed motion,**
  **exertion of force, change of state**

- Synonyms, syntactic patterns, relations

# Another alternation example

- Another example: Causative/inchoative
- The window broke
- John broke the window
- The rabbit suddenly appeared
- *The magician appeared the rabbit

- Benefactive:
- Sue carved a toy out of wood for Hansel
- Sue carved hansel a toy out of wood
- Sue carved some wood into a toy for Hansel
- *Sue carved Hansel some wood into a toy

- Middle formation:
- The whale frightens easily
- *The whale sees easily

# Alternations..

- Sue broke the vase/ The vase broke (change-of-state)
- The vase broke easily
- Conative: *Sue broke at the vase

- Bill cut the bread/ *The bread cut (change-of-state, no “telic” endpoint)
- The bread cut easily
- Bill cut at the bread

- Mary touched the cat / *The cat touched
- *The cat touched easily (no change-of-state)
- *Mary touched at the cat

- Joe kicked the tire / *The tire kicked
- *The tire kicked easily
- Joe kicked at the tire
- Alternations can be lang-specific: "break" is a causative/inchoative in English, but not Italian.

# Lexical Gaps: English to Chinese

| | | |
|---|---|---|
| break | → | **?** |
| smash | → | da po - *irregular pieces* |
| shatter | → | da sui - *small pieces* |
| snap | → | pie duan -*line segments* |

# Intersective Levin classes

# So we want…

# Thematic Roles

- E w,x,y,z Giving (x) ^ Giver(w,x) ^ Givee(z, x)
  ^ Given(y,x)
- E w,x,z Breaking (x) ^ Breaker(w,x) ^
  Broken(z,x)
- A set of roles:
  - agent, experiencer, force, theme, result, content, instrument, beneficiary, source, goal,...

The dog ate the cheeseburger.

What is cheeseburger?

The sniper shot his victim with a rifle.

What is rifle?

# Schank's Conceptual Dependency

- Eleven predicate primitives represent all predicates
- Objects decomposed into primitive categories and modifiers
- But few predicates result in very complex representations of simple things

Ex,y Atrans(x) ^ Actor(x,John) ^
Object(x,Book) ^ To(x,Mary) ^ Ptrans(y) ^
Actor(y,John) ^ Object(y,Book) ^ To(y,Mary)

John caused Mary to die vs. John killed Mary

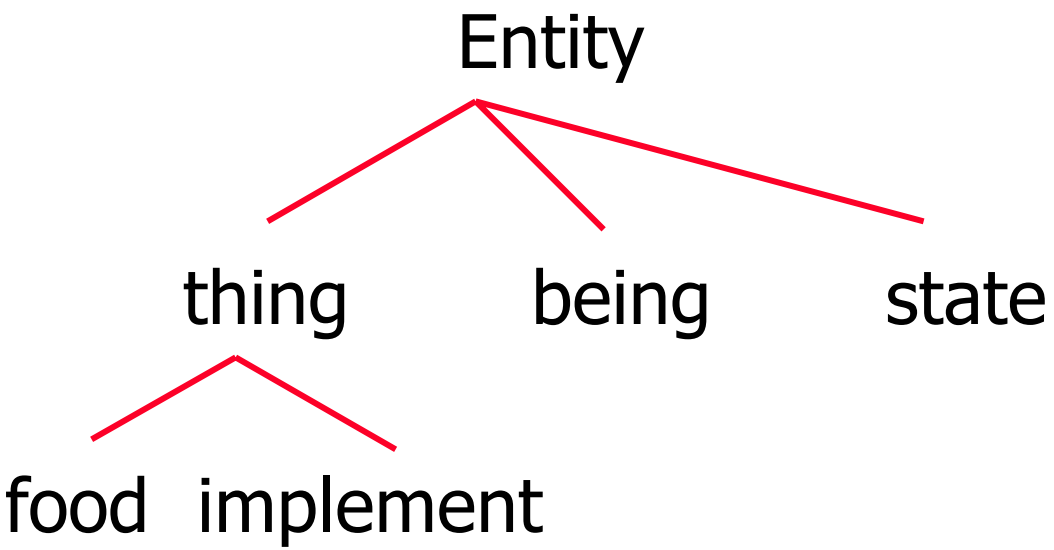
# Selection via sortal hierarchy

- John ate a clam
- They served clams

- "logical" form: ∃ x,y,e[eat(e) & eater(e,y) & eaten(e,x) & john(y) & clam(x) & past(e)]

- So…

# Sortal hierarchy ('ontology')



# Selection via sortal hierarchy

1. eater([Eating],[Being])
2. eat([Eating])
3. eaten([Eating],[Food])
4. server([Serving],[Being])
5. $serve_1$([Serving])
6. served([Serving],[Food])
7. john([Person])
8. they([Person])
9. $mussel_1$([Food])
10. $mussel_2$([Creature])

# But…

- Which airlines serve Denver?
- You ate glass on an empty stomach
- Metonomy: What airlines fly to Boston?

# But how can we/computer learn this?

- Two parts: pred-arg linking to thematic roles – which verbs do what
- Selectional restrictions

# *pour* vs. *fill*

- Different linking entails semantic difference - when in Object position, the Goal seems "affected" in a way not so in the PP
- *Fill*: Cause X to become full of Y by means of causing Y to be in X
- *Pour*: Cause X to go in a downward stream into Y
- *Fill* has two events: a state change (the glass) and a location change (the water)
- *Pour* has one event: location change
- The Main-change argument gets Old-Info structure and main event status. Main event of *Fill*: state change of glass

Look! He's sebbing!

Look! A seb!

Look, some seb!

/seb/ means MIXING

/seb/ means BOWL

/seb/ means STUFF

# **KEY** HUMAN COMPETENCE:

- One-shot integration of syntax & semantics

# The Problem of Ambiguity


**Possible Hypotheses**

- **Rabbit (whole object)**
- **Animal (superordinate)**
- **Flopsie (individual)**
- **Furry (property)**
- **Ear (part)**
- **Walk by (activity)**
- **Undetached rabbit parts .....**

# Two Bootstrapping Proposals

- Children use syntactic cues to verb meaning (Gleitman 1990)
- Children use (verb) meaning to figure out how its arguments are realized in the syntax of the language (Pinker 1989)

# Semantic Bootstrapping

(Pinker 1984)

***Semantic* Bootstrapping involves the pairing of a situational context with some syntactic pattern.**

- Kids learn syntax by first learning the semantic argument structure of the verb.
  - SWIM = one participant (the "swimmer")
  - EAT = two participants ("eater", "eatee")
  - TAKE = two/three participants ("taker", "takee", and "person taken from"...)

# Gleitman: Not So Fast, Pinker...

Temporal ambiguity

Situation ambiguity

Mental unobservable!

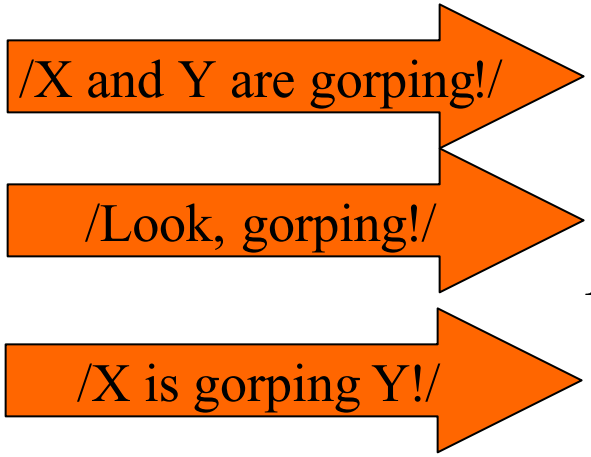
***... more than <u>just</u> real-world observation...***

# Syntactic Bootstrapping

(Landau and Gleitman 1986, Naigles 1990)

Syntactic frames provide *evidence* for meaning:

$H_1$: arm wheel




$H_2$: cause to squat

# Verbs Classes Grouped by Cause Feature

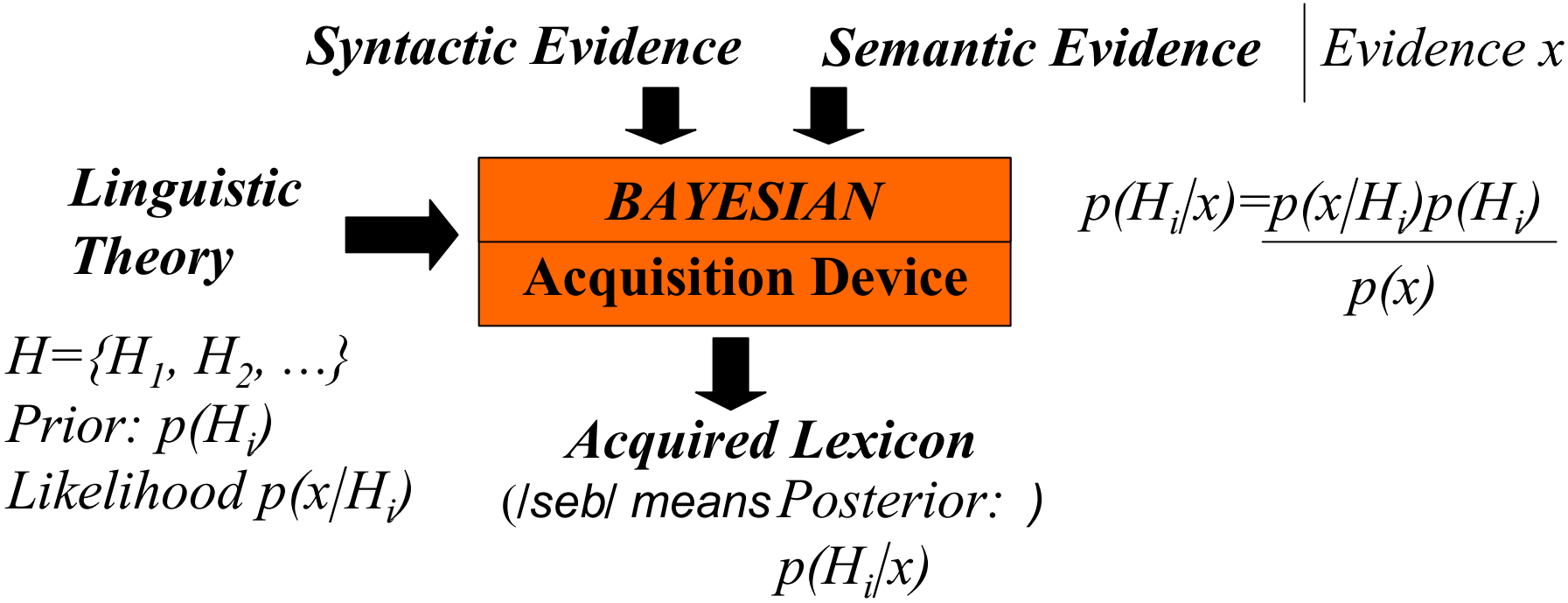
| $H_i$ | *Verb Class* |
|---|---|
| $H_1$ | Externally Caused (*touch*, *load*) |
| | *F1: He touched the glass.*<br>* *F0: The glass touched.* |
| $H_0$ | Internally Caused *(laugh, glimmer)* |
| | * *F1: He laughed the child.*<br>*F0: He laughed.* |
| $H_*$ | Externally Causable *(open, break)* |
| | *F1: He opened the door.*<br>*F0: The door opened.* |

***Hypothesis space* H**
**Hi in H**

**Evidence x in X = {0, 1}**

# One-shot learning

*within a Bayesian framework.*



# Learning Value of Verbs Cause Feature

***Syntactic Evidence:***

*/He glipped the balloon/*

*x=F1*

***Syntactic Theory:***

***H***$=\{H_1, H_0, H_*\}$

*Prior:*

$p(H_i) = .333$

$$p(H_i|x)=\frac{p(x|H_i)p(H_i)}{p(H_i)}$$

*Likelihood*

$p(x|H_i)$

| | x=F0 | x=F1 |
|---|---|---|
| $H_1$ | .05 | .95 |
| $H_0$ | .95 | .05 |
| $H_*$ | .50 | .50 |

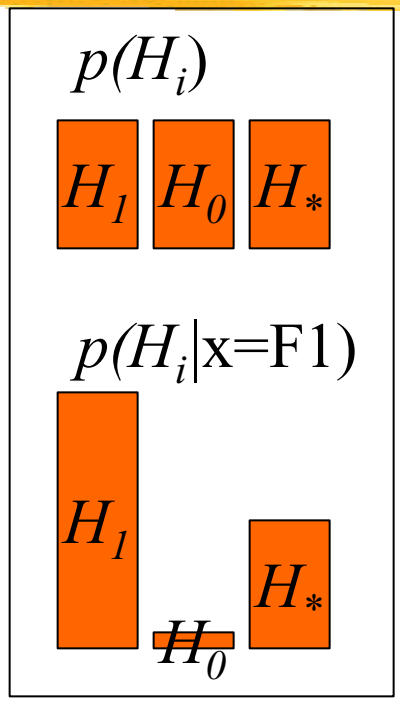
***Acquired Lexicon***

*Posterior* $p(H_i|x)$

$p(H_1|x=F1) = .633$

$p(H_0|x=F1) = .033$

$p(H_*|x=F1) = .333$




$$= \frac{(.95)(.33)}{(.05+.95+.50)(.33)}$$

**Syntactic Evidence X:**

*/He glipped the balloon/*
*/X gorped Y/, /X gorped Y/*
*/X sebbed Y/, /Y sebbed/*
*/X meefed Y/[5], /Y meefed/*
*/Y foomed/[6]*

**Syntactic Theory:**

**H**=$\{H_1, H_0, H_*\}$
*Prior* $p(H_i)$
*Likelihood* $p(x|H_i)$

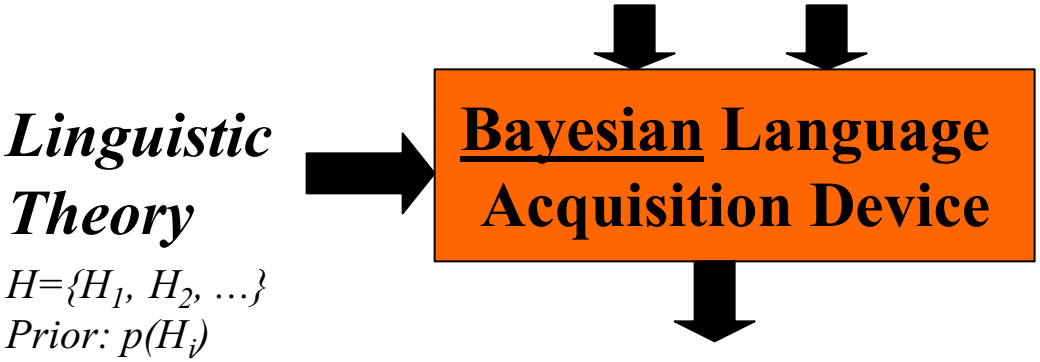
**Bayesian Language Acquisition Device**

**Acquired Syntactic Knowledge**

| **Lexicon:** | **Evidence X** | $p(H_1\|X)$ | $p(H_0\|X)$ | $p(H_*\|X)$ |
|---|---|---|---|---|
| */glip/* | *F1* | *.633* | *.033* | *.333* |
| */gorp/* | *F1, F1* | *.781* | *.002* | *.217* |
| */seb/* | *F1, F0* | *.137* | *.137* | *.724* |
| */meef/* | *F1[5], F0* | *.712* | *5e-6* | *.288* |
| */foom/* | *F0[6]* | *2e-8* | *.979* | *.021* |

# Bayesian Learning at the Syntax-Semantics Interface

| ***Syntactic Evidence*** | ***Semantic Evidence*** |
|---|---|
| **/X is gorping Y into Z/** | **Person pours water into a glass, filling it** |
| **/X is pilking Z with Y/** | **Person pours water into a glass, filling it** |
| **/Look! jebbing!/** | **Person pours water into a glass, filling it** |




***Acquired Lexicon*** *p(Hi|x)*

| | *p(POUR\|x)* | *p(FILL\|x)* | *p(MOVE\|x)* |
|---|---|---|---|
| */gorp/* | ***.880*** | *.000* | *.101* |
| */pilk/* | *.001* | ***.989*** | *.000* |
| */jeb/* | ***.463*** | ***.463*** | *.005* |

# How to get ‘real semantics’ in?

# Verb meanings are logic programs (LPs):

General: cause(e)

One args x: move(x), rotate(x), move-dn(x), move-up(x)
supported(x), liquid(x), container(x)

Two args x,y: contact(x,y), support(x,y), attach(x,y)
(if cause(e)=1)

| **Verb** | **Logic Program** |
|---|---|
| /lower/ | 1 1*101** 11* |
| /raise/ | 1 1*011** 11* |
| /rise/ | 0 1*01*** |
| /fall/ | 0 1*10*** |

Hypothesis space **H**: All LPs
Evidence *X*: Bit Vector Examples
(e.g. 1 1010100 110)

# Learning Semantic Features

***Semantic "Theory":*** (3 bits)

Hypothesis space **H**: 27 LPs

| **q** | $H_i$ |
|---|---|
| 0 | 000, 001, 010, 011 |
| | 100, 101, 110, 111 |
| 1 | 00*, 01*, 10*, 11* |
| | 0*0, 0*1, 1*0, 1*1 |
| | *00, *01, *10, *11 |
| 2 | 0**, 1**, *0*, *1*, **0, |
| 3 | *** |

Priors $p(H_i) = 1/27$

Likelihood $p(x|H_i) = \{2^{-q}$ if $x$ in $\boldsymbol{H_i}$

$p(x=000|H_{000}) = 1$
$p(x=000|H_{00*}) = .5$
$p(x=000|H_{0**}) = .25$
$p(x=000|H_{***}) = .125$

***Semantic Evidence:***

/Look! Glipping!/ X1=000
/Look! Gorping!/ X2=000,001
/Look! Sebbing!/ X3=000,000,000
/Look! Meefing!/ X4=000,101,010,111,000


***Acquired Semantic Knowledge***

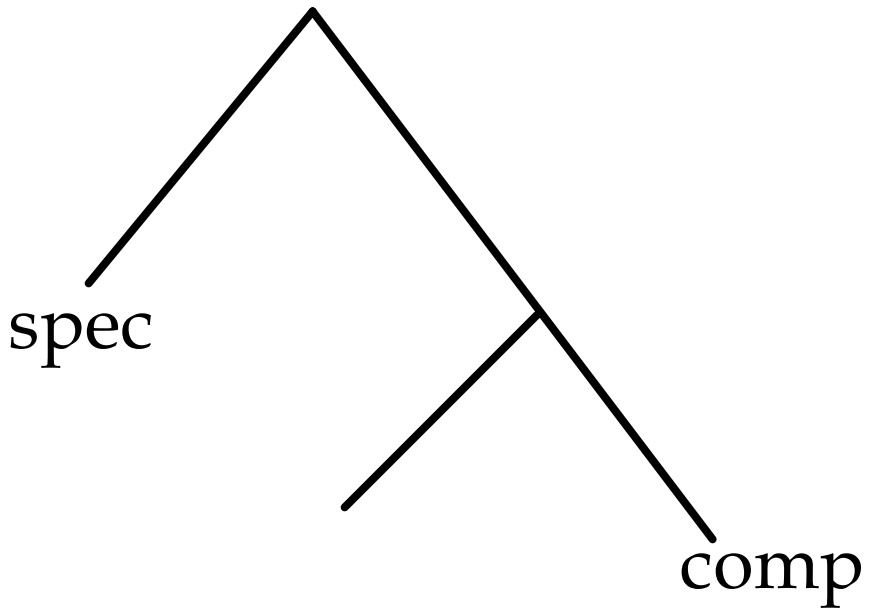
| ***Lexicon:*** | $p(H_{000}\|X)$ | $p(H_{00*}\|X)$ | $p(H_{0**}\|X)$ | $p(H_{***}\|X)$ |
|---|---|---|---|---|
| */glip/* | *.30* | *.15* | *.07* | *.03* |
| */gorp/* | *.00* | *.64* | *.16* | *.04* |
| */seb/* | *.70* | *.09* | *.01* | *.001* |
| */meef/* | *.00* | *.00* | *.00* | *1.0* |

# But… what are the possible arguments?

- Predicate-arguments can be complicated…can we crank it out?
- Argument structure is syntax
- There are no specialized mechanisms of 'thematic role assignment'
- Everything is really predication

# Hale-Keyser: arguments are syntax

# The basic form



# H & K: The framework

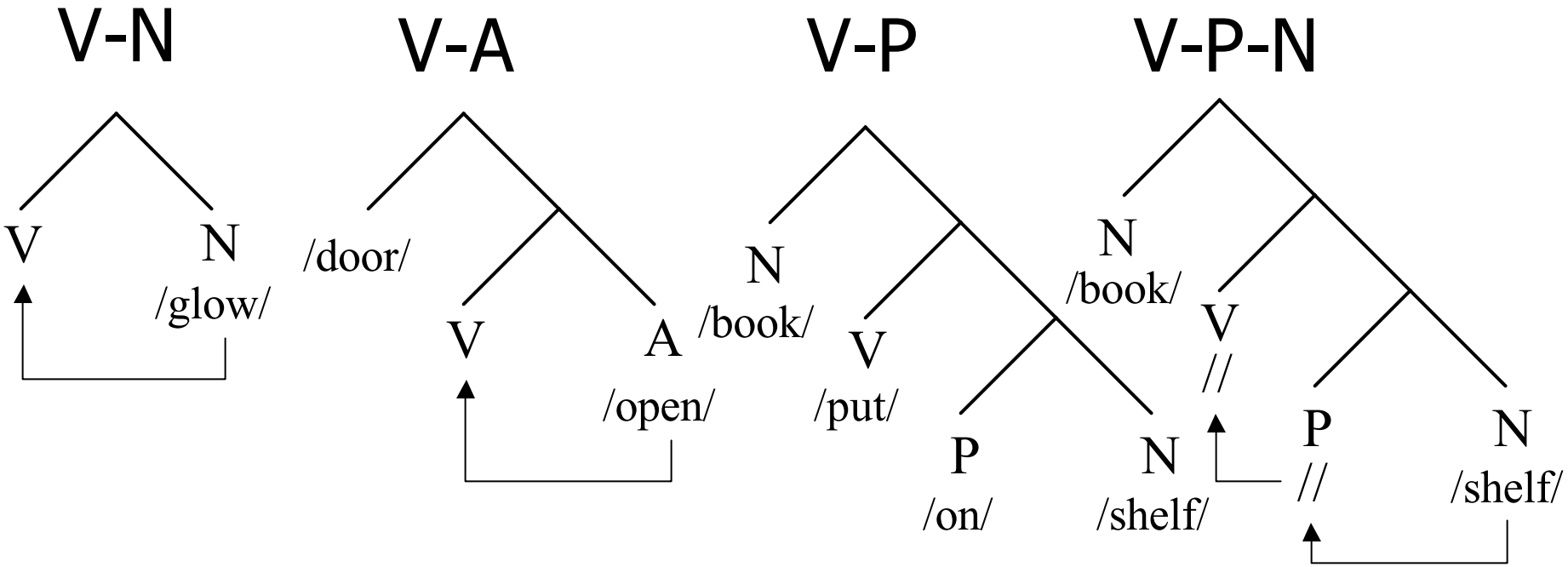
- There are only three places a verb argument can come from
  - The complement or specifier of a "basic" lexical item
  - An external "addition"
  - As for "basic lexical items" there are four types: N, V, A, P
  - Why so few thematic roles? Because so few basic lexical items (entity/instance, event, state, relation)

# N,V,A,P

- N takes no arguments
- V are predicational, and take one argument, a complement.
- P are relational, and take two arguments
- A are predicational, and take one argument, but require some help; thus an A is always the complement of a verb, which then projects for an external arg.

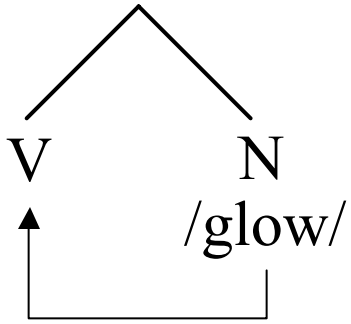
# Hale-Keyser Incorporation

- 4 Fundamental Primitives Yield Different Argument Structures

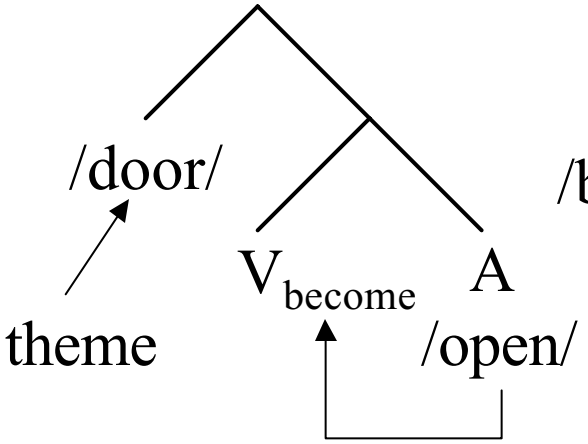


# HK Allows Us to Discard Thematic Roles

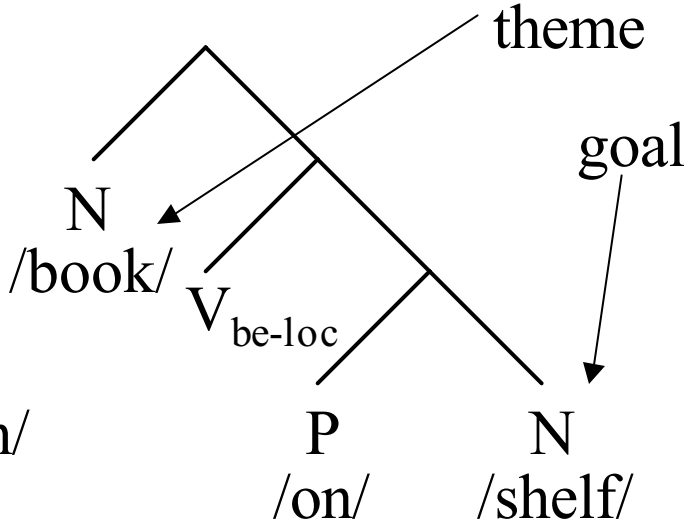
- Agent, Patient, Theme, Instrument, Goal, … *derived* from positions in structural configurations.
- V-N:




- V-A

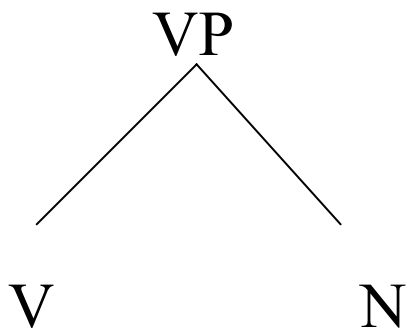



- V-P



# What can N get us?

- Intransitive verbs:




Nouns cannot project arguments. A noun (run, laugh, play, cough, snore, burp) incorporates into the verb. An external argument is adjoined to *v*. Thus, rather than having cognate N and V copies in the lexicon, verbs are derived by *syntax*.

# Unergatives vs. Simple Transitives

- Unergatives: no external agent *The child laughed*
  - [NP [*v* [V+N (N)]]]
- No verbs like **The clown laughed the child* / **The alfalfa sneezed the colt* (The N complement to V has incorporated, where would the "object NP" reside?)
  - [NP [V+N (N) NP?]]
- Simple transitive (non-creation) *The clown made the child laugh*
  - [NP [*v* [NP [V+N (N)]]]]
  - Extensions : *get+A (I got drunk, I got Josh drunk)*
    - But not for get+N (*I got the measles, *I got Josh the measles*)

# Explaining Gaps in the Lexicon

- *It cowed  a calf, *It dusted the horses blind, *It machined the wine into bottles (cf. The cow had a calf, the dust made the horses blind, the machines put the wine into bottles)
- The above items would be the result of the external subject incorporating into the verb, which is ruled out by the syntax elsewhere (items raise & incorporate up, but not down)
- If all "denominal" verbs are the result of incorporation of the complement to the V head, rather than unconstrained "category change", these  non-verbs are predicted

# V: Verbs of Creation: The simple case

- bake a cake, make trouble, build a house, have puppies

- V has a complement NP(=DP). External argument is projected and adjoined to *v*.

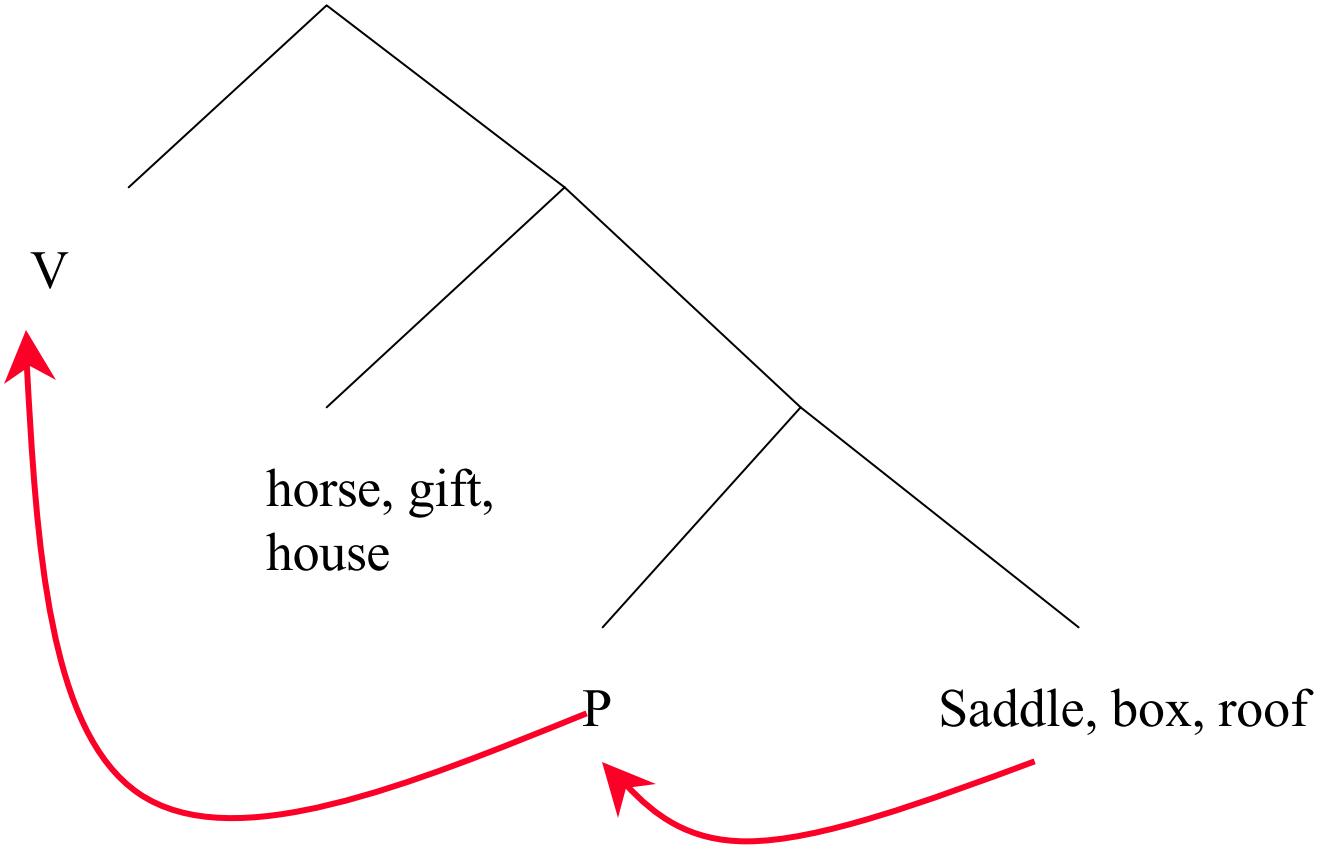
# P gives *put*-type Verbs

- The P frame has a specifier and complement. The whole P-complex is a verb complement. An external argument is projected and adjoined.

# P gives locatum-type verbs

- With a bare N as the PP complement, the N conflates with the P, which conflates with the V, giving *saddled the horse, boxed the gift, roofed the house* (all have P-meaning)

# Picture



# Implementation

```
(define-verb-class "PUT VERBS: put verbs (Section 9.1)"
  "putting entity at some location (but not to or from)"
  '(arrange immerse install lodge mount place position put set
    situate sling stash stow)
  (list '((* the water put into a bowl))
        '((+ he put the water into the bowl)
          (vp ()
              (v* (v put (feature CAUSE))
                  (pp (n the water)
                      (p* (p into (feature MOVELOCATION))
                          (n a bowl)))))))))
```

# Argument Structure: The Moral

- No specialized mechanism of "thematic role assignment". Everything is predication.
- Do these mechanisms of derived verbs happen in the syntax with everything else, or "prior to lexical insertion", e.g. "in the lexicon"? What do you think? Should this distinction *matter*?