Can a TAG Semantics Be Compositional?

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Outline

Review of synchronous TAG for semantics

What compositionality is and isn't

- What it ought to mean to be worth worrying about
- Why it is a subjective notion

Relation to bimorphisms

Where synchronous TAG semantics are and aren't compositional

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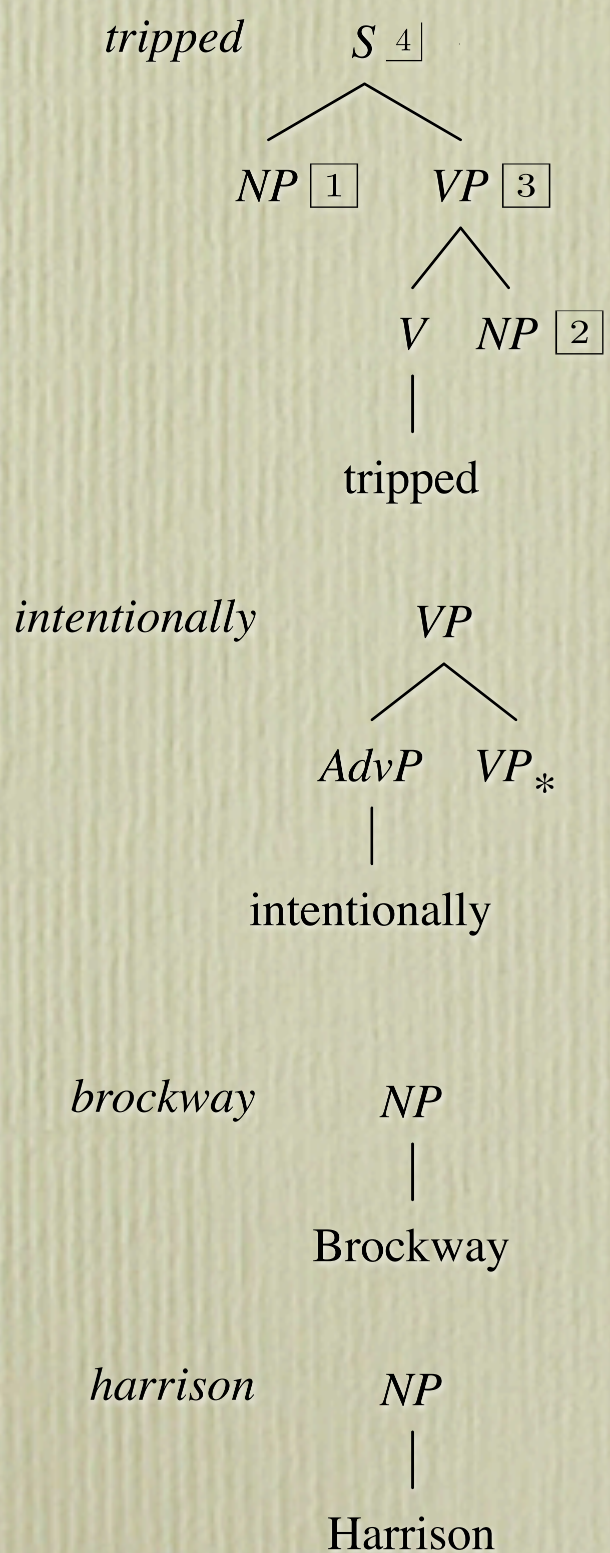
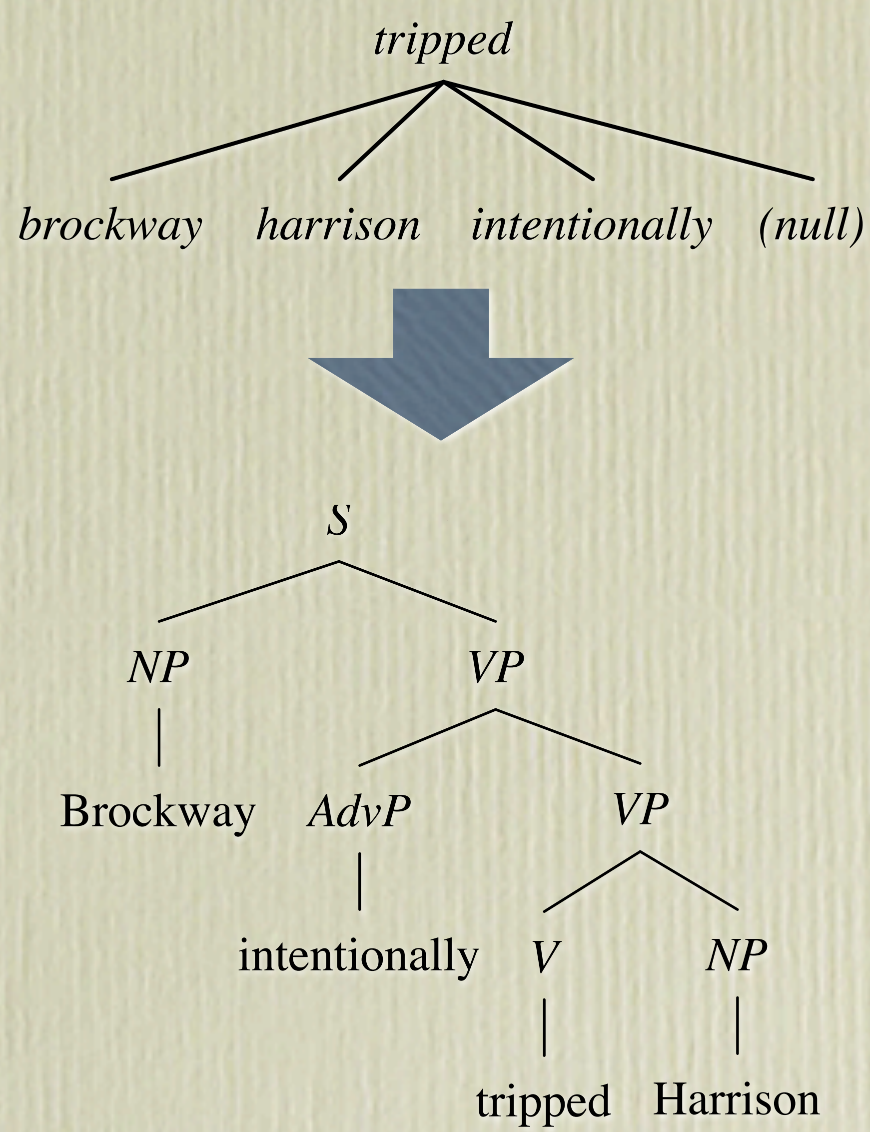
Synchronous TAG Semantics

TAG Syntax





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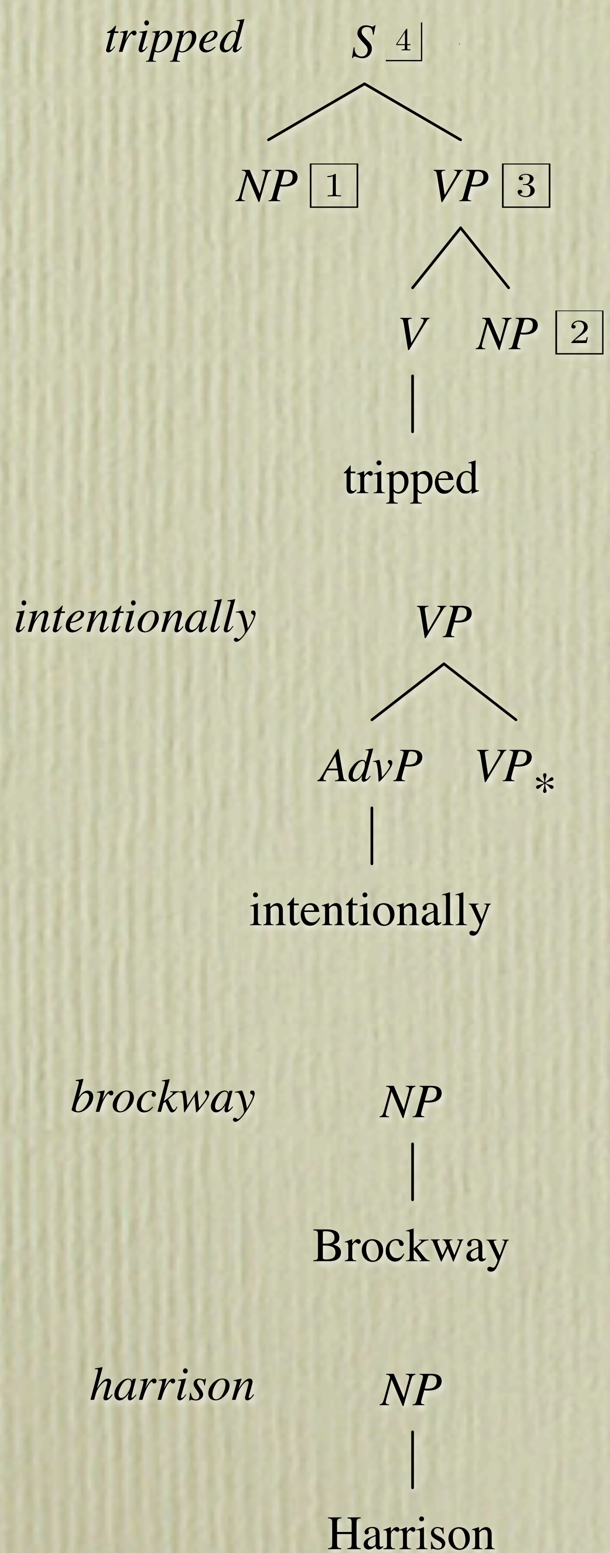
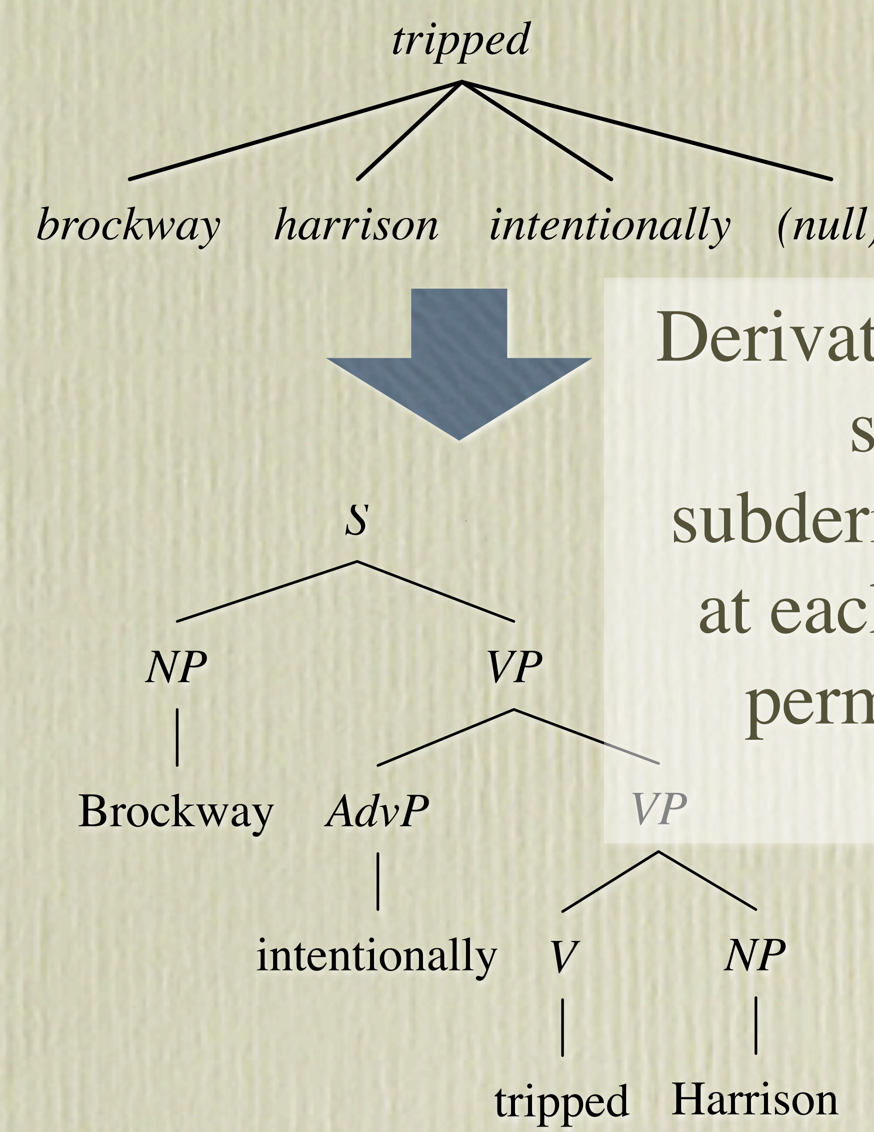


Numbered "links" mark and provide a permutation of adjunction and substitution sites



Derivation tree specifies subderivations at each site in permutation order.

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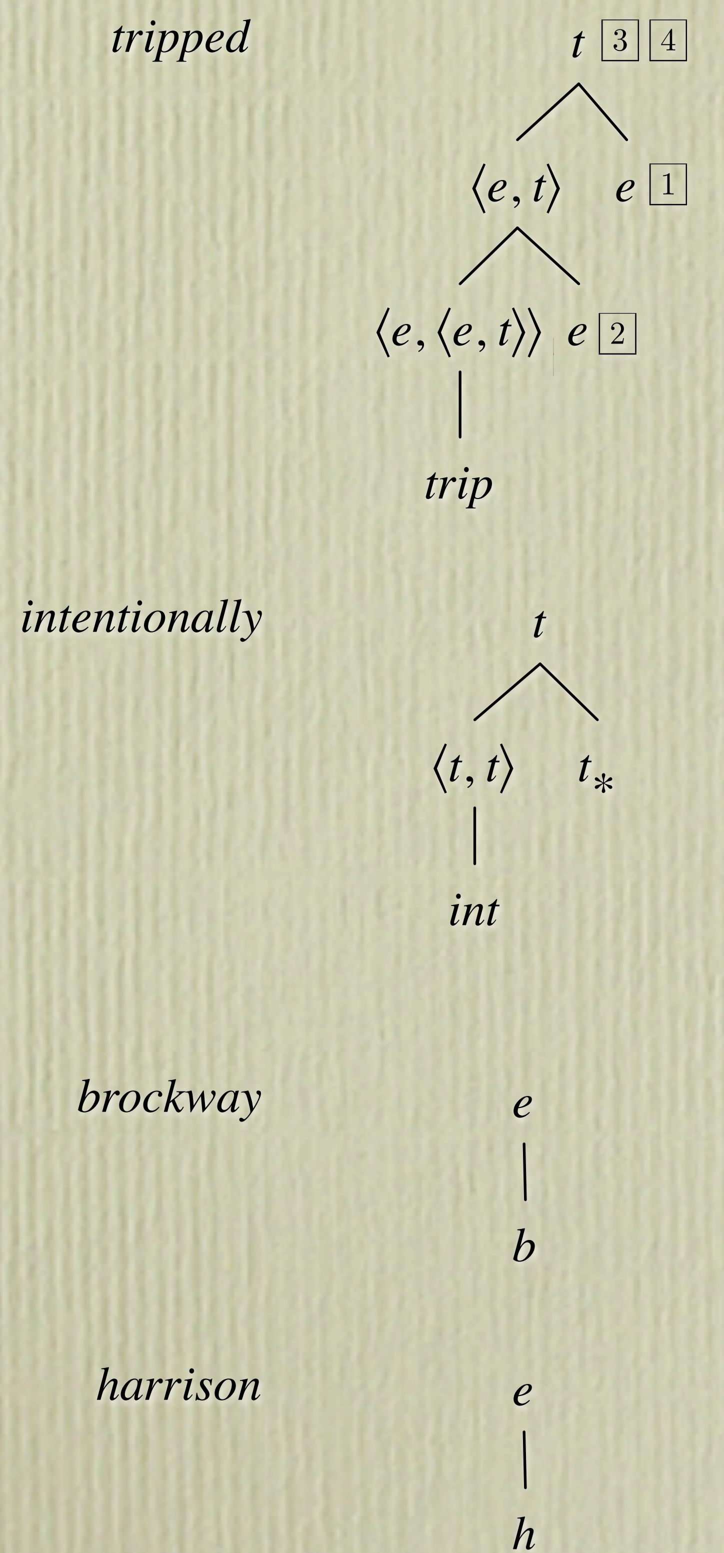
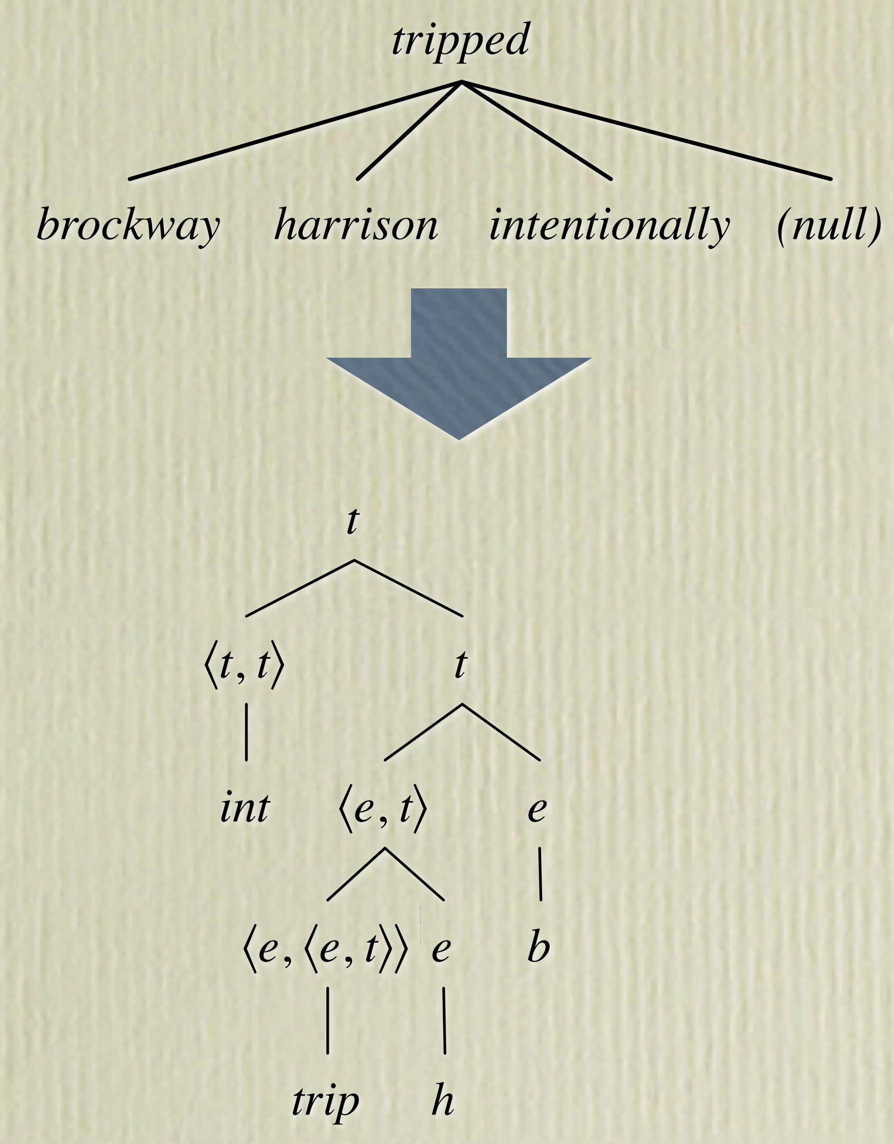
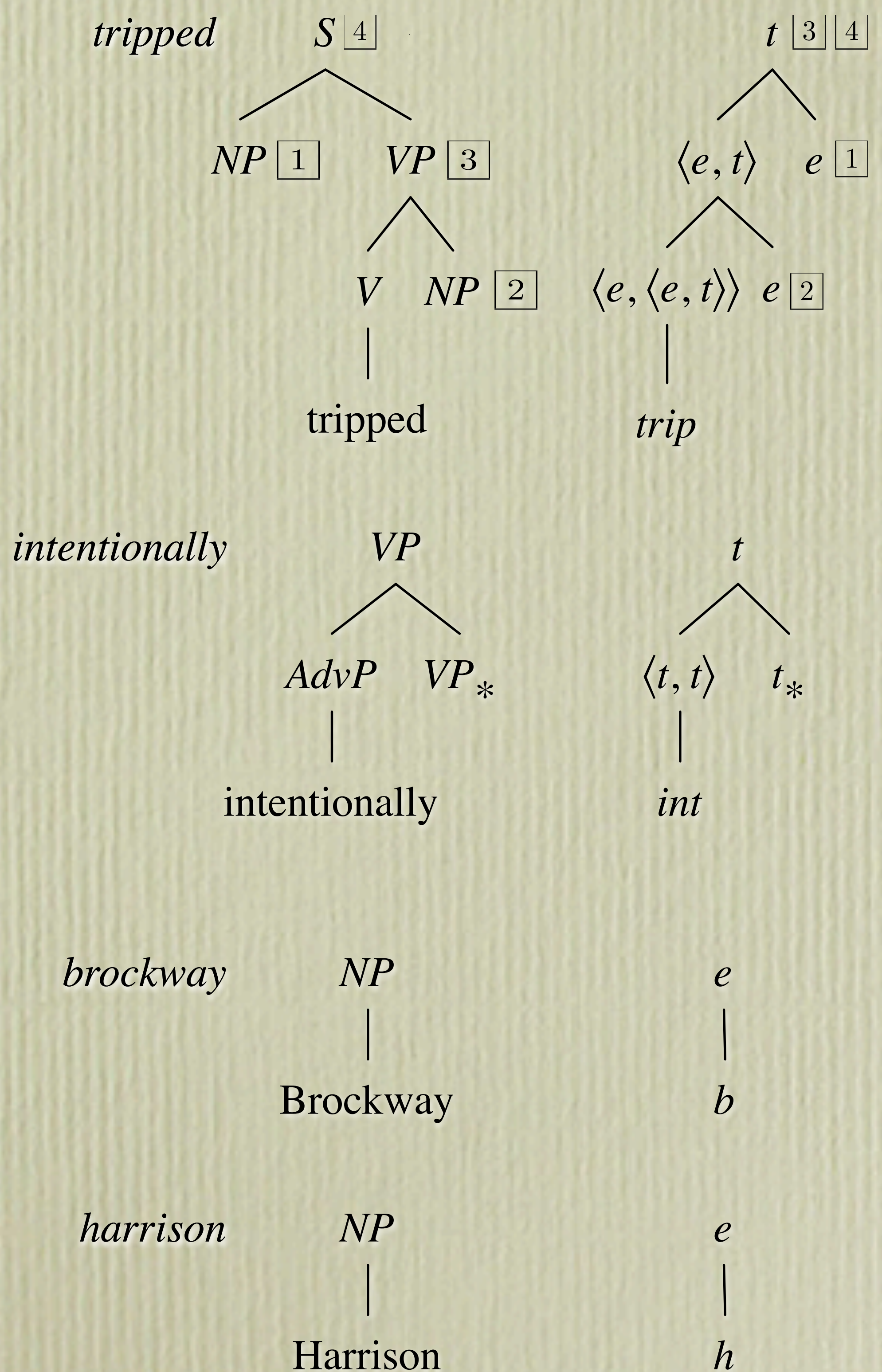
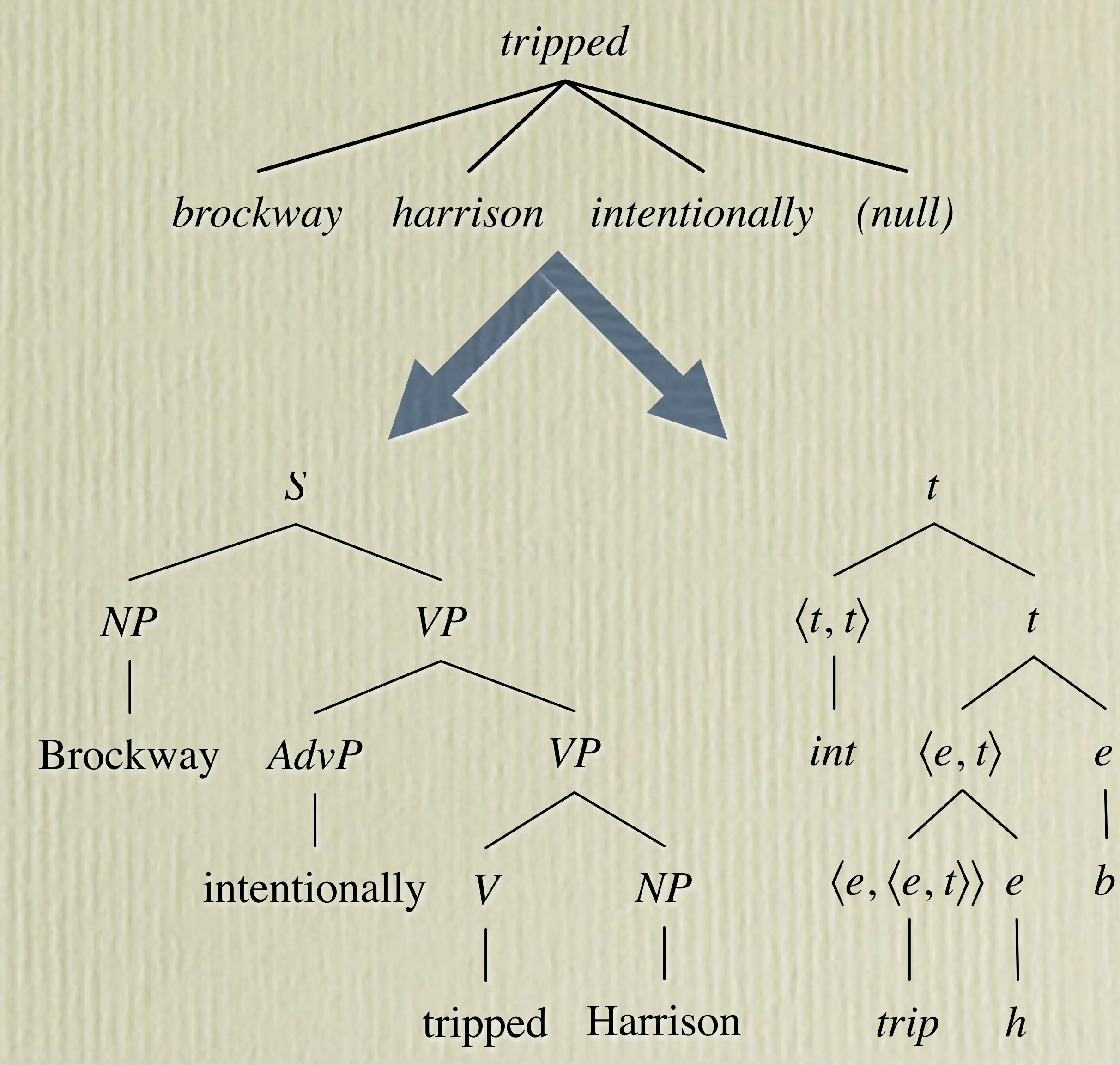
TAG Semantics





Synchronous TAG Syntax-Semantics





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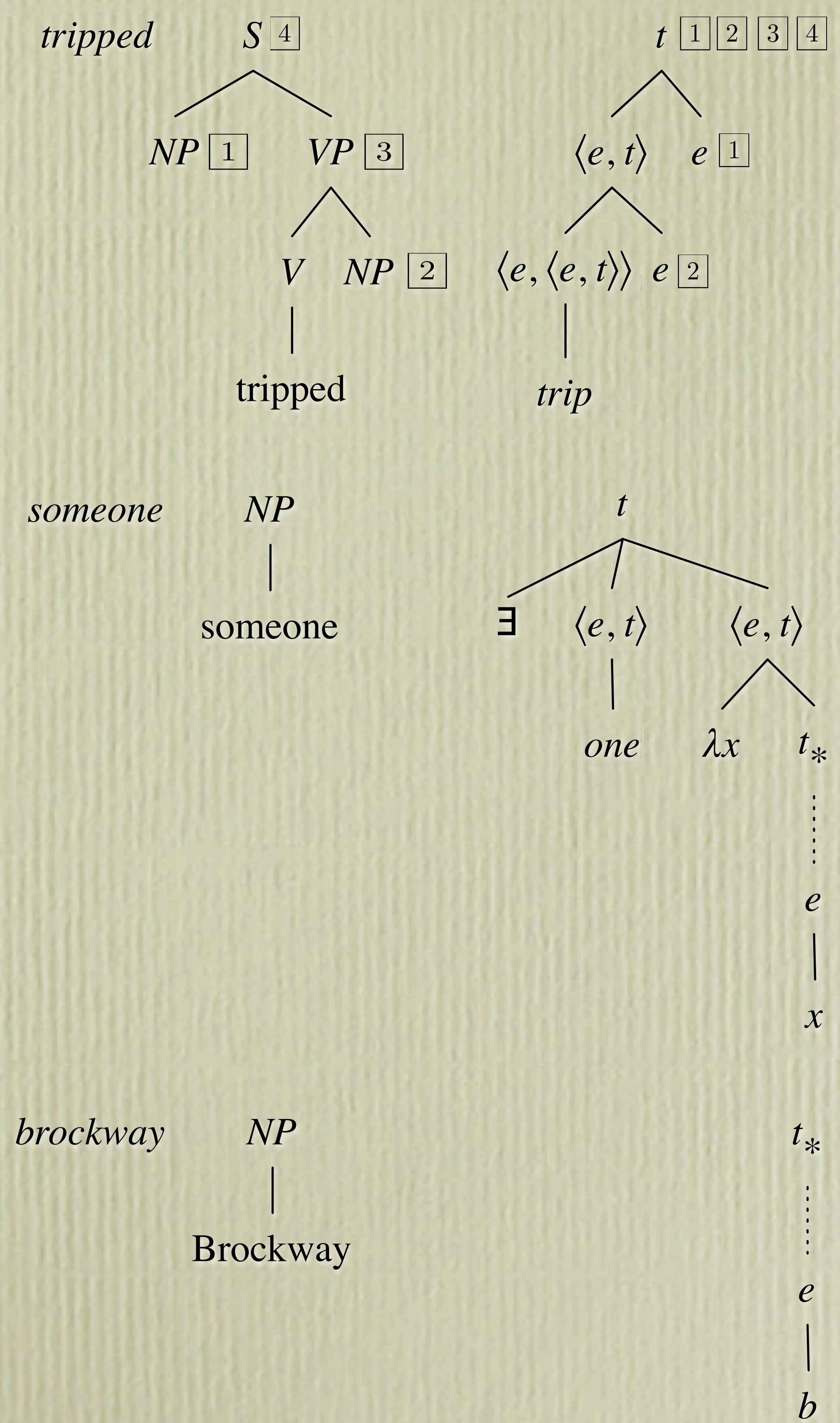
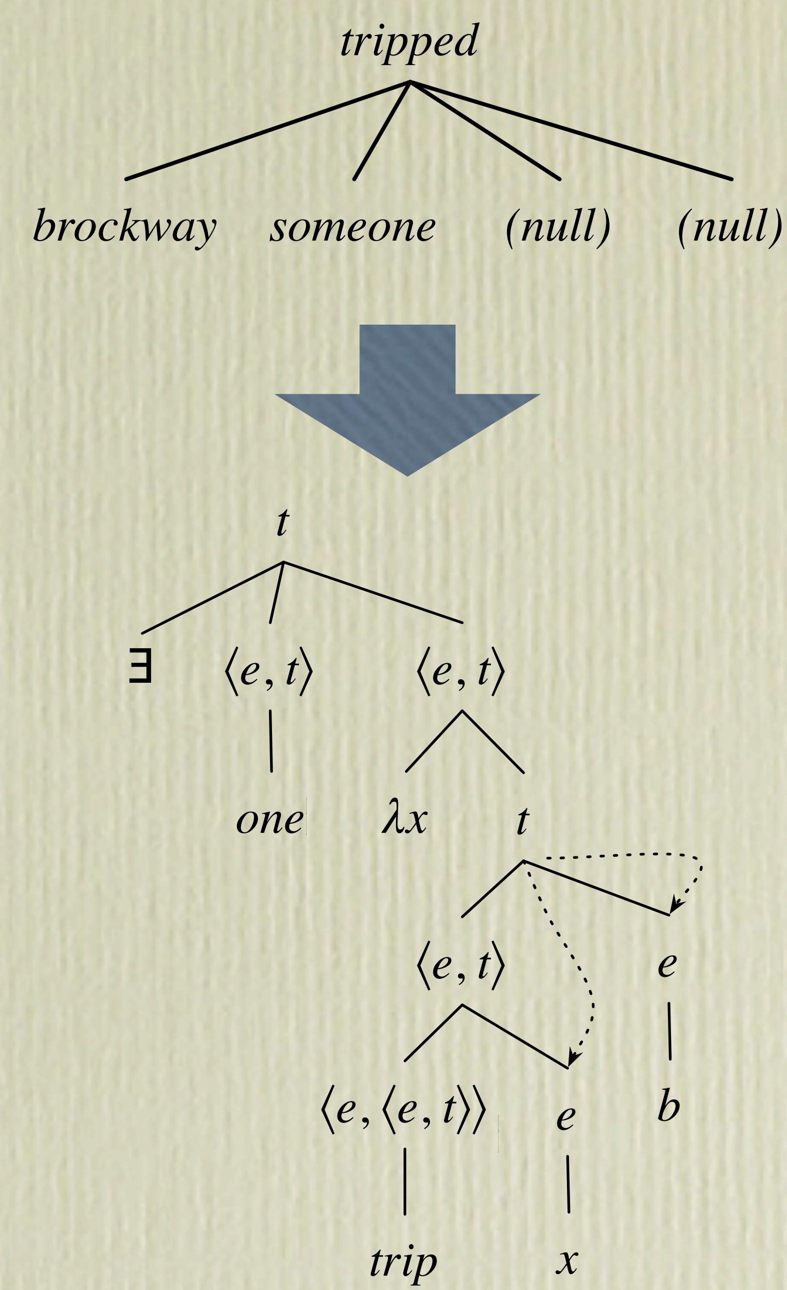
Quantifiers





$$\exists(one, \lambda x.trip(b, x))$$

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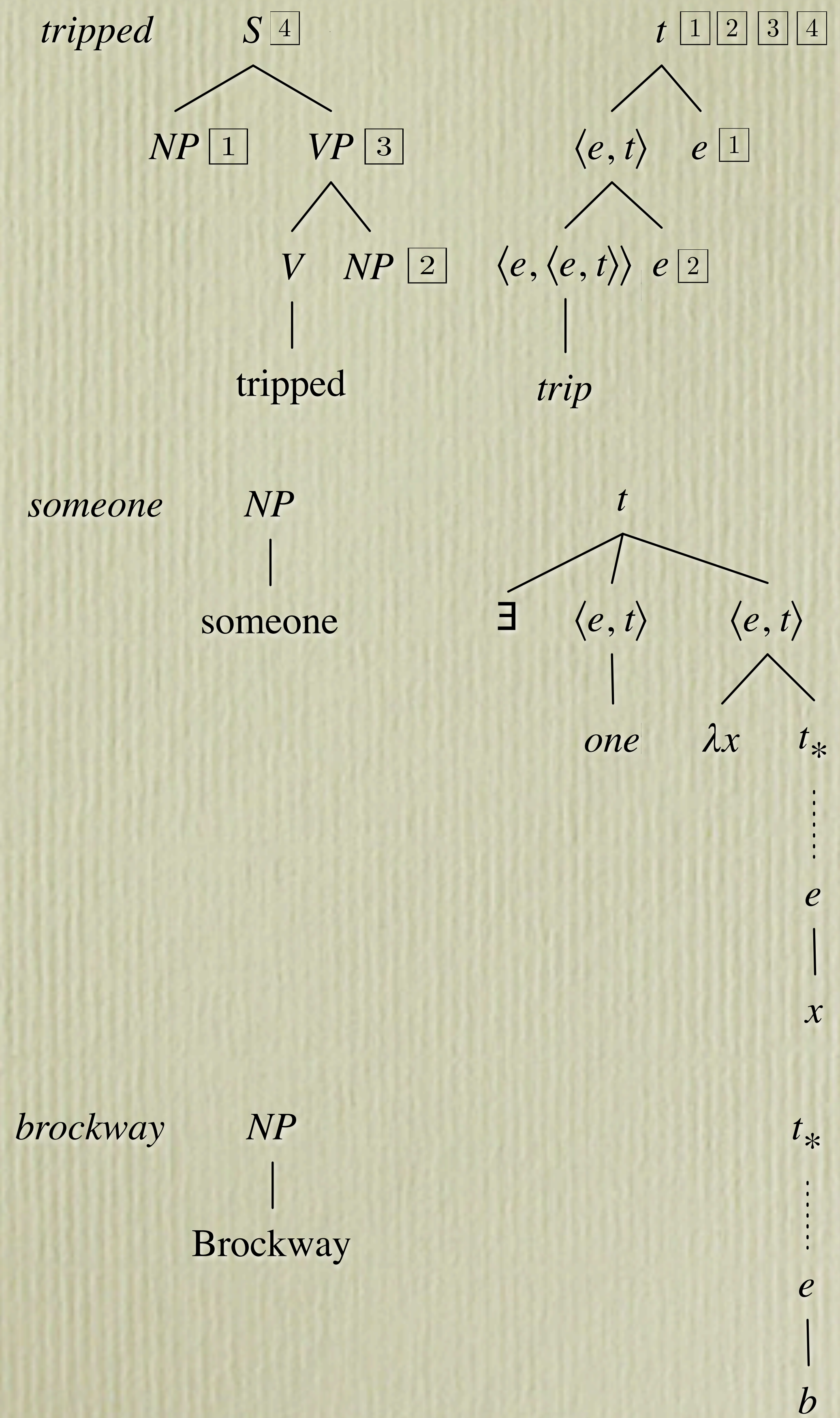
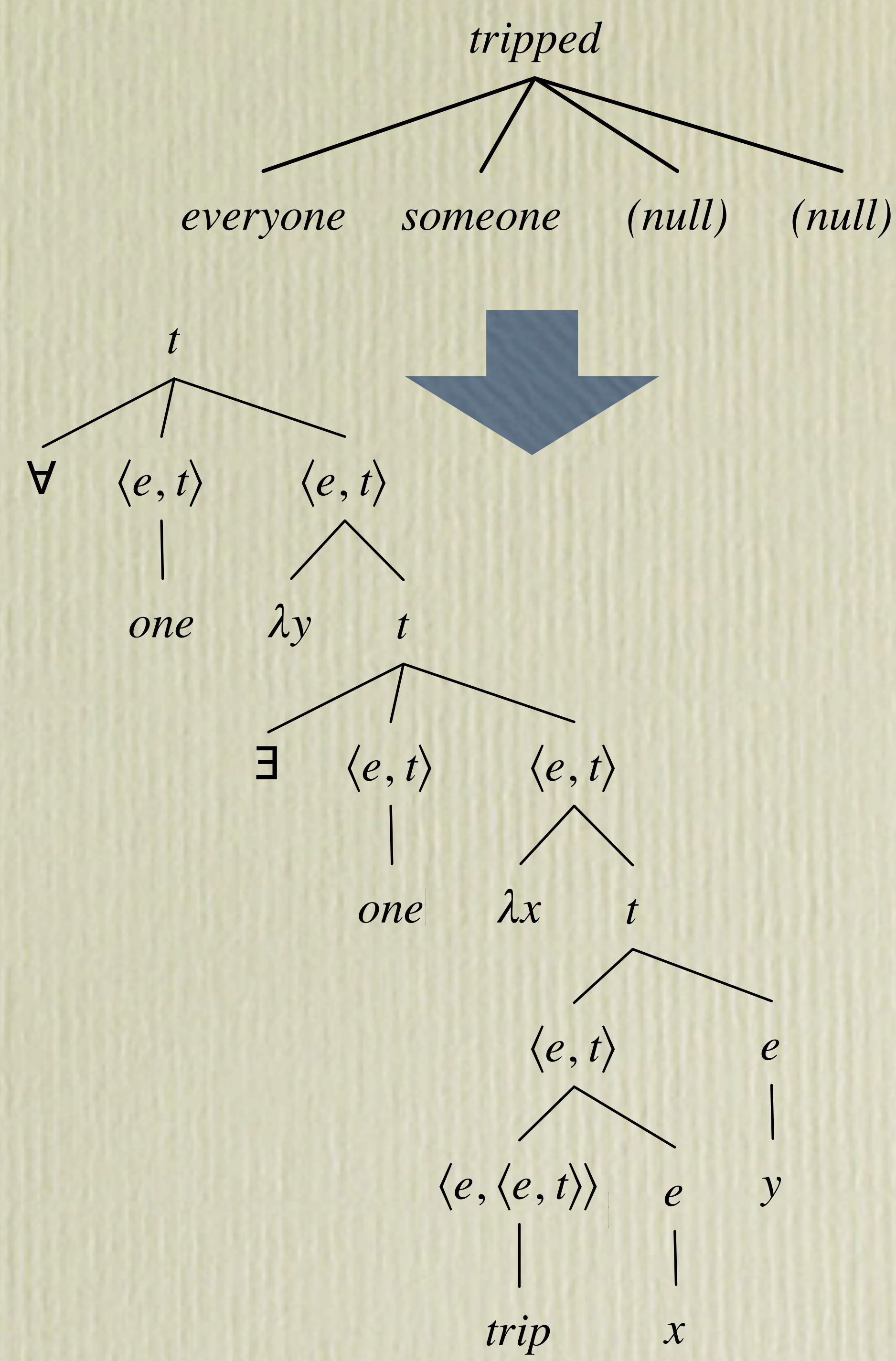
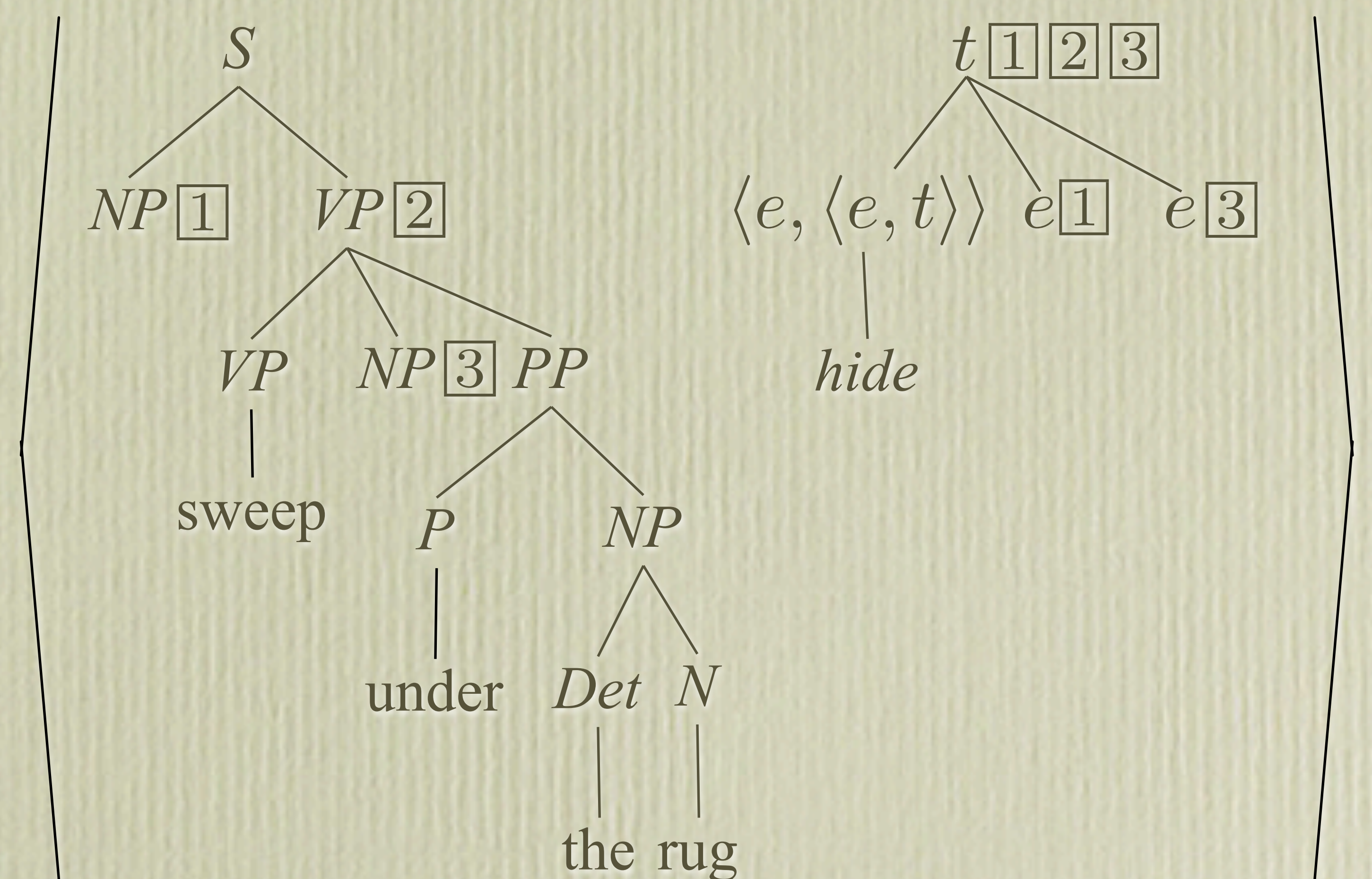
Quantifiers





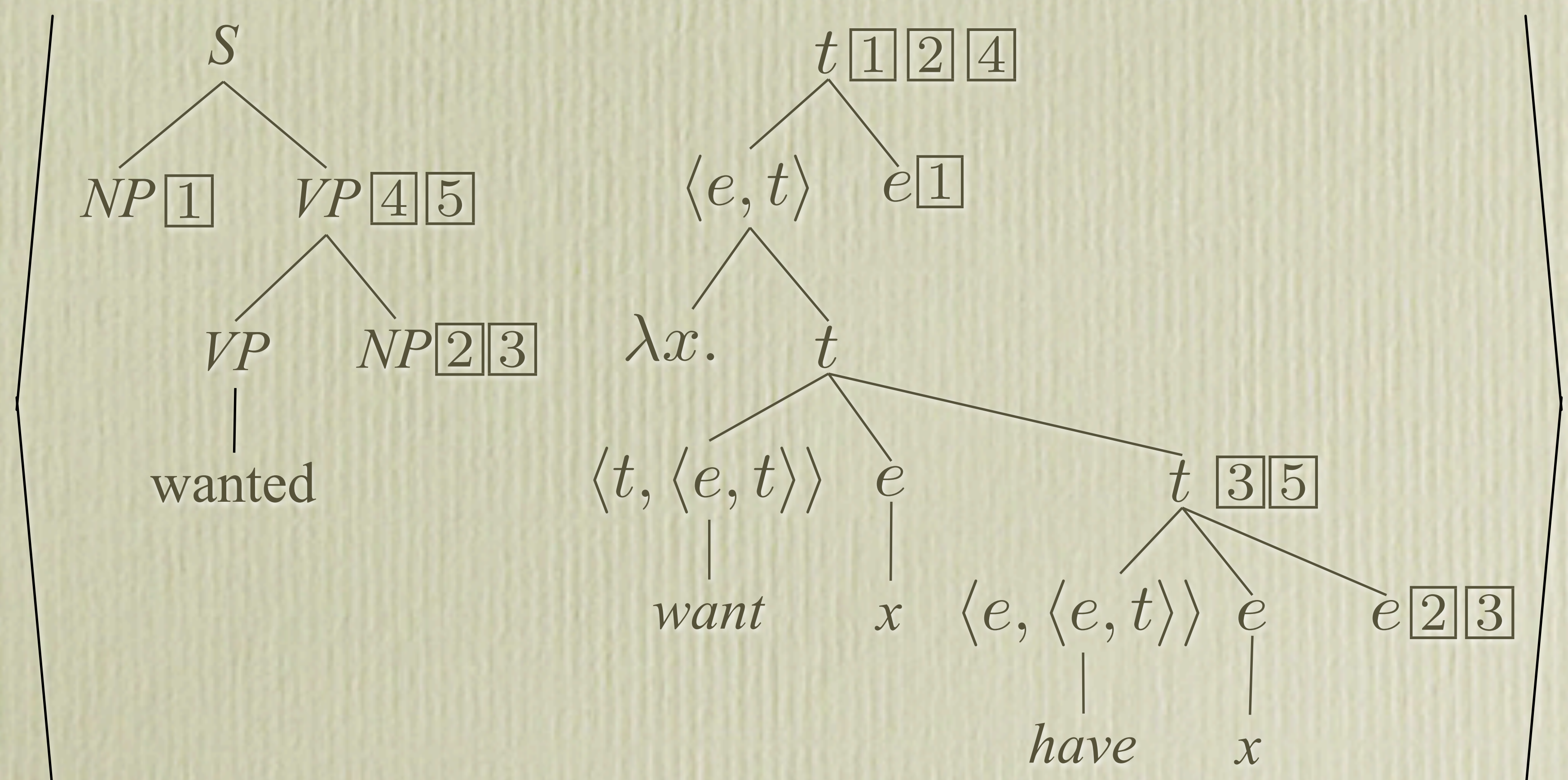
Complex Syntax with Simple Semantics: Idioms



Simple Syntax with Complex Semantics: Semantic Decomposition

Kim wanted the report tomorrow.

- $want(k, tomorrow(have(k, the\text{-}report)))$
  $= [\lambda x.want(x, tomorrow(have(x, the\text{-}report)))]k$



— McCawley, 1979, pages 84-86

Coverage

Can handle several putatively hard cases without additional machinery (with reservations...):

- Scope ambiguities
  Everyone loves someone.
- Scope interactions of VP-modifiers and quantifiers
  Sandy usually likes everyone.
- No scope out of finite clause
  Sandy thinks everyone loves someone.
- Pied-piped relative clauses
  A problem whose solution was difficult stumped Bill.
- Embedded quantifiers in prepositional phrases
  Two politicians spy on someone from every city.

— Kallmeyer, Romero, Joshi

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Compositionality

Compositionality

A means for guaranteeing the systematicity of the syntax-semantics relation.

Compositionality (informal): The meaning of an expression is determined by the meanings of its immediate parts along with their method of combination.

"The meaning of a compound expression is a function of the meaning of its parts and of the syntactic rule by which they are combined." (Partee et al., 1990, p. 318, as cited by Janssen, 1997)

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A Compositional Semantics

$$
\begin{array}{lcl}
Num & \rightarrow & Num\ Digit \\
Num & \rightarrow & Digit \\
Digit & \rightarrow & \underline{0} \\
Digit & \rightarrow & \underline{1}
\end{array}
$$

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A Compositional Semantics

$$
\begin{array}{rcll}
Num & \rightarrow & Num\ Digit & 10 \times [\![Num]\!] + [\![Digit]\!] \\
Num & \rightarrow & Digit & [\![Digit]\!] \\
Digit & \rightarrow & \underline{0} & 0 \\
Digit & \rightarrow & \underline{1} & 1
\end{array}
$$

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A Compositional Semantics

$$\begin{array}{lclr} Num & \rightarrow & Num\ Digit & 10 \times [\![Num]\!] + [\![Digit]\!] \\ Num & \rightarrow & Digit & [\![Digit]\!] \\ Digit & \rightarrow & \underline{0} & 0 \\ Digit & \rightarrow & \underline{1} & 1 \end{array}$$

$$\begin{array}{rcl} [\![\underline{101}]\!] & = & 10 \times [\![\underline{10}]\!] + [\![\underline{1}]\!] \\ & = & 10 \times (10 \times [\![\underline{1}]\!] + [\![\underline{0}]\!]) + [\![\underline{1}]\!] \\ & = & 10 \times (10 \times 1 + 0) + 1 \\ & = & 101\ (5) \\ [\![\underline{0011}]\!] & = & 3 \end{array}$$

Near Misses

Precompositionality: The meaning of an expression is determined by its parts.

Representational compositionality: The meaning representation of an expression is determined by the meaning representations of its parts along with their method of combination.

Near Misses

Precompositionality: The meaning of an expression is determined by its parts.

$$\begin{array}{rcll} A & \rightarrow & B\,C & [_A\, [\![B]\!]\, [\![C]\!]] \\ S^* & \rightarrow & S & \mu([\![S]\!]) \end{array}$$

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$$

Representational compositionality: The meaning representation of an expression is determined by the meaning representations of its parts along with their method of combination.

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Montague’s Approach

Montagovian compositionality: The meaning of an expression is a homomorphic image of the expression’s syntactic derivation.

$$h(\textsc{op}(P, Q)) = \hat{h}_{\textsc{op}}(h(P), h(Q))$$

$$\begin{aligned} [\![Num\ Digit]\!] &= 10 \times [\![Num]\!] + [\![Digit]\!] \\ \hat{h} &= \lambda x, y.10 \times x + y \end{aligned}$$

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An Example: Relative Clauses

S3: If $\zeta \in P_{CN}$ and $\phi \in P_t$, then $F_{3,n}(\zeta, \phi) = \zeta$ **such that** ϕ', and ϕ' comes from ϕ by replacing each occurrence of he_n or him_n by [the gender-appropriate unsubscripted pronoun].

T3: If $\zeta \in P_{CN}, \phi \in P_t$, and ζ, ϕ translate into ζ', ϕ' respectively, then $F_{3,n}(\zeta, \phi)$ translates into $\lambda x_n.\zeta'(x_n) \wedge \phi'$.

(Montague, 1970, PTQ)

Dispensibility of Logical Form

Montague's relative clause translation rule: "If $\zeta \in P_{CN}, \phi \in P_t$, and ζ, ϕ translate into ζ', ϕ' respectively, then $F_{3,n}(\zeta, \phi)$ translates into $\lambda x_n.\zeta'(x_n) \wedge \phi'$."

Thomason's clarificatory footnote: "To avoid collision of variables, the translation must be $\lambda x_m.\zeta(x_m) \wedge \psi$, where ψ is the result of replacing all occurrences of x_n in ϕ' by occurrences of x_m, where m is the least even number such that x_m has no occurrences in either ζ' or ϕ'."

Janssen's correction: "Thomason's reformulation is an operation on representations, and not on meanings. . . . The operation on meanings can be represented in a much simpler way, using a polynomial, viz.:

$$[\lambda P.(\lambda x_n.P(x_n) \wedge \phi')](\zeta') \qquad "$$

An Example: Relative Clauses

S3: If $\zeta \in P_{CN}$ and $\phi \in P_t$, then $F_{3,n}(\zeta, \phi) = \zeta$ **such that** ϕ', and ϕ' comes from ϕ by replacing each occurrence of he_n or him_n by [the gender-appropriate unsubscripted pronoun].

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"man such that he left"

- "man" • "such that he$_2$ left"
- *man* • *left*(x_2)
- $\lambda x_2.man(x_2) \wedge left(x_2)$
- $[\lambda P.(\lambda x_2.P(x_2) \wedge left(x_2))](man)$

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Is Compositionality Possible?

$$\begin{array}{rcl} Num & \rightarrow & Num\ Digit \\ Num & \rightarrow & Digit \\ Digit & \rightarrow & \underline{0} \\ Digit & \rightarrow & \underline{1} \end{array}$$

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$$
\begin{array}{lcl@{\qquad}lcl}
Num & \rightarrow & Num\ Digit & Num & \rightarrow & Digit\ Num \\
Num & \rightarrow & Digit & Num & \rightarrow & Digit \\
Digit & \rightarrow & \underline{0} & Digit & \rightarrow & \underline{0} \\
Digit & \rightarrow & \underline{1} & Digit & \rightarrow & \underline{1}
\end{array}
$$

Impossibility of compositional semantics for this language:

$$
\begin{aligned}
[\![\underline{101}]\!] &= f([\![\underline{1}]\!], [\![\underline{01}]\!]) \\
&= f([\![\underline{1}]\!], [\![\underline{1}]\!]) \\
&= [\![\underline{11}]\!]
\end{aligned}
$$

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Is Compositionality Vacuous?

For arbitrary language L and meaning function $[\![\cdot]\!] : L \to M$, there is a function $\mu : L \to M'$ such that

$$
\begin{aligned}
\mu(P\ Q) &= \mu(P)(\mu(Q)) \\
\mu(P \dashv) &= [\![P]\!]
\end{aligned}
$$

(Zadrozny, 1994)

The Counterexample Revisited

$$\begin{array}{rcl} Num & \rightarrow & Num\ Digit \\ Num & \rightarrow & Digit \\ Digit & \rightarrow & \underline{0} \\ Digit & \rightarrow & \underline{1} \end{array} \qquad \begin{array}{rcl} Num & \rightarrow & Digit\ Num \\ Num & \rightarrow & Digit \\ Digit & \rightarrow & \underline{0} \\ Digit & \rightarrow & \underline{1} \end{array}$$

$$\begin{array}{rcll} Num & \rightarrow & Digit\ Num & \langle 10^{[\![Num]\!]_2} \times [\![Digit]\!]_1 + [\![Num]\!]_1, \\ & & & \quad [\![Digit]\!]_2 + [\![Num]\!]_2 \rangle \\ Num & \rightarrow & Digit & [\![Digit]\!] \\ Digit & \rightarrow & \underline{0} & \langle 0, 1 \rangle \\ Digit & \rightarrow & \underline{1} & \langle 1, 1 \rangle \\ S & \rightarrow & Num\ \dashv & [\![Num]\!]_1 \end{array}$$

Montague’s Approach

Montagovian compositionality: The meaning of an expression is a homomorphic image of the expression’s syntactic derivation.

Contextual non-synonymy:

- I believe Lewis Carroll is the greatest children’s book author.
- I believe Charles Dodgson is the greatest children’s book author.

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Adjust denotations: $e \Rightarrow \langle s, e \rangle$

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Subjectivity of Compositionality

Compositionality (informal): The meaning of an expression is determined by the meanings of its immediate parts along with their method of combination.

- What are appropriate meanings?
  - $[\![\underline{101}]\!] = 5$
    $[\![\underline{101}]\!] = \langle 5, 3 \rangle$
    $[\![\underline{101}]\!] = [\ \underline{1}\ [\ \underline{0}\ [\ \underline{1}\ ]\ ]\ ]$
  - $[\![\text{Lewis Carroll}]\!] : e$
    $[\![\text{Lewis Carroll}]\!] : \langle s, e \rangle$

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    ~~$[\![\underline{101}]\!] = [\ \underline{1}\ [\ \underline{0}\ [\ \underline{1}\ ]\ ]\ ]$~~
  - $[\![\text{Lewis Carroll}]\!] : e$

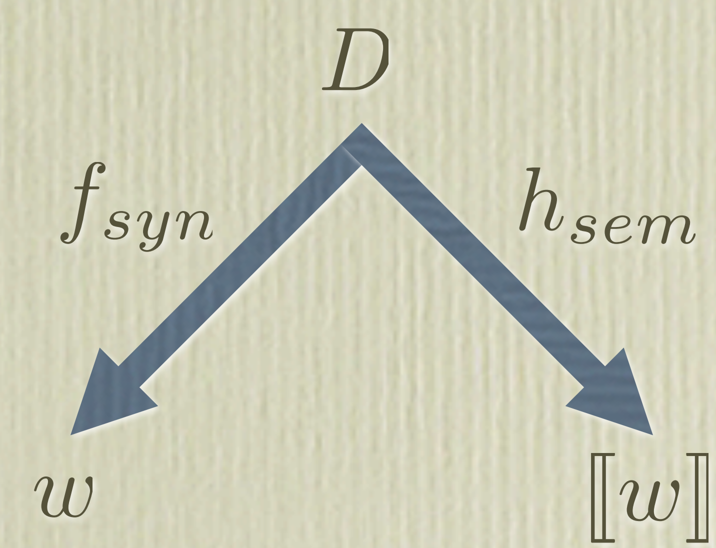
    $[\![\text{Lewis Carroll}]\!] : \langle s, e \rangle$

Compositionality of STAG Semantics

Compositionality

Montagovian compositionality: The meaning of an expression is a homomorphic image of the expression's syntactic derivation.

$$
\begin{aligned}
w &= f_{syn}(D) \\
[\![w]\!] &= h_{sem}(D)
\end{aligned}
$$



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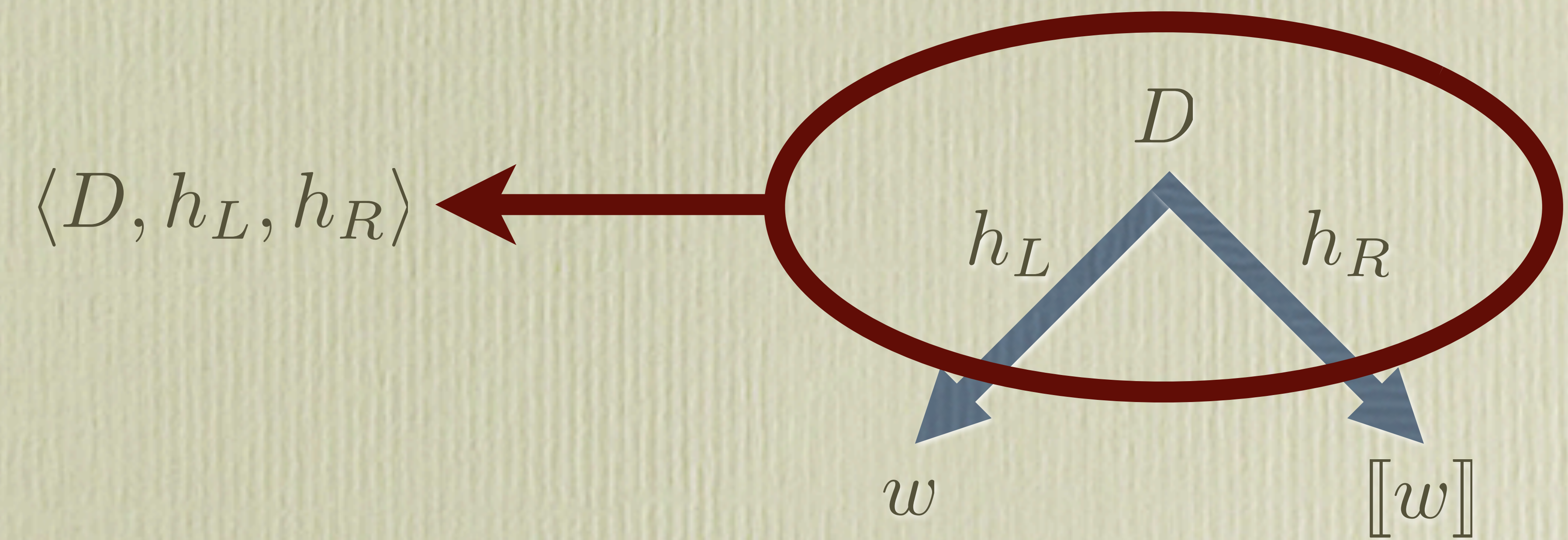
Compositionality and Bimorphisms



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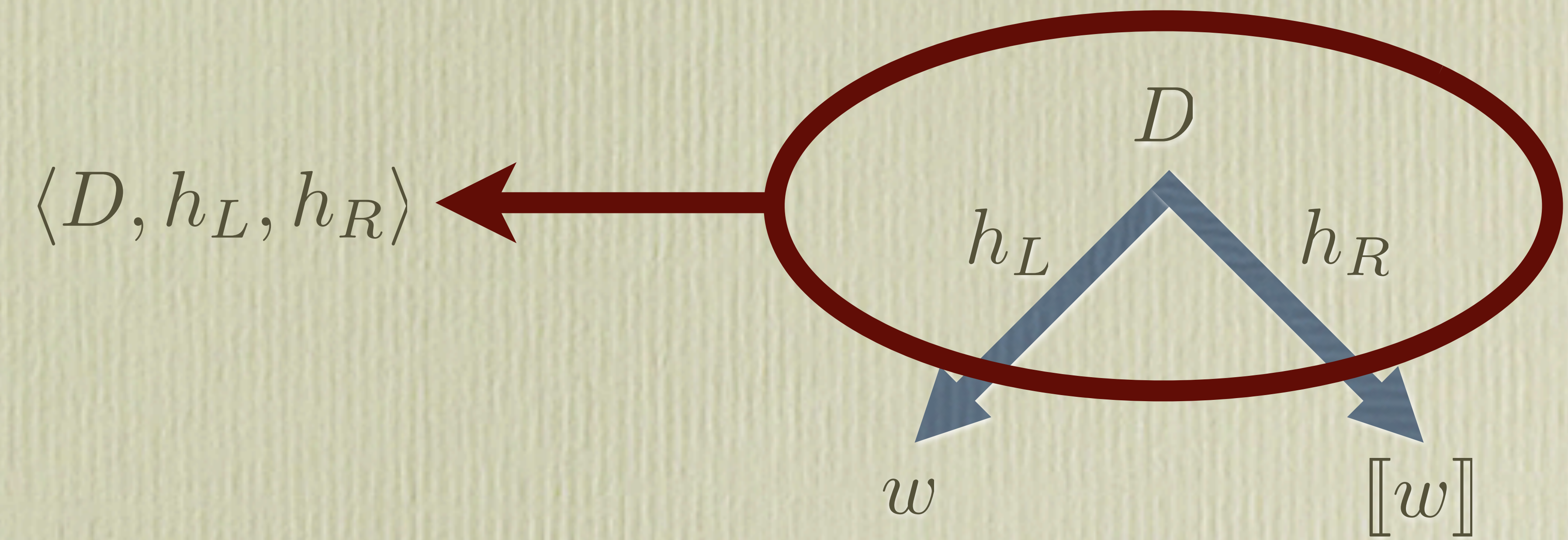
Compositionality and Bimorphisms



$B(L, R)$	
$B(D, M)$	tree transduction
$B(LC, LC)$	STSG
$B(ELC, ELC)$	STAG
$B(arb, M)$	compositional relation

Summary

Compositional relation defined by

- A generalized bimorphism
  - Input function is arbitrary
  - Output function is a homomorphism
    - to a pretheoretically appropriate domain

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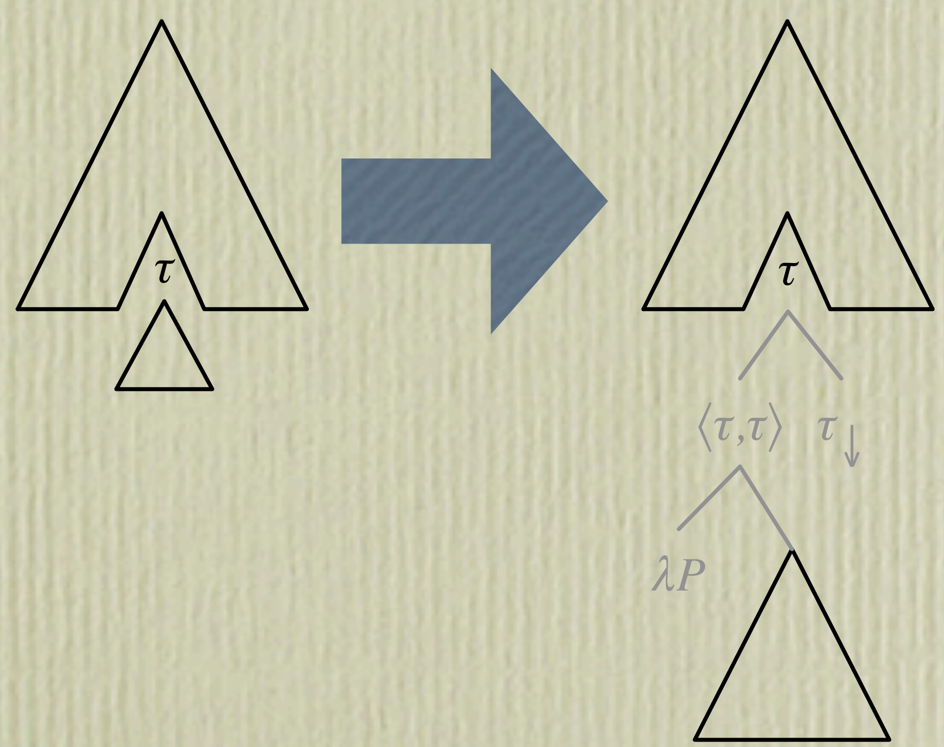
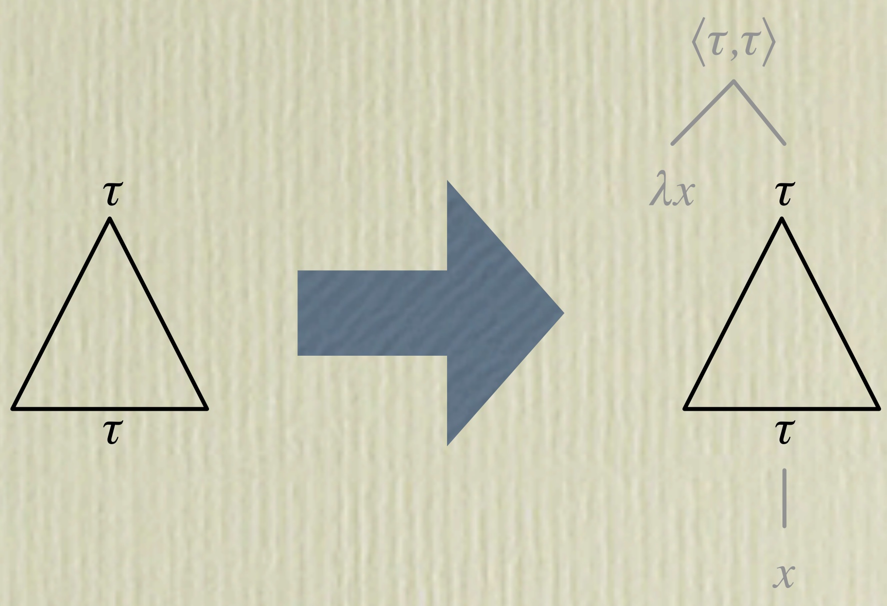
TAG to TSG





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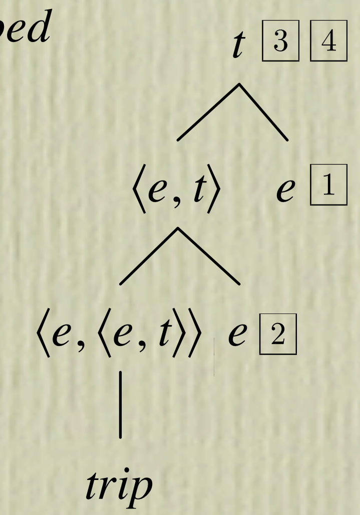
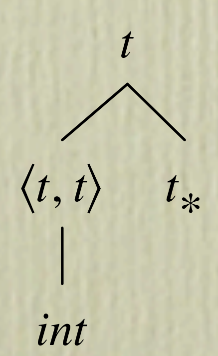
TAG to TSG

tripped



intentionally



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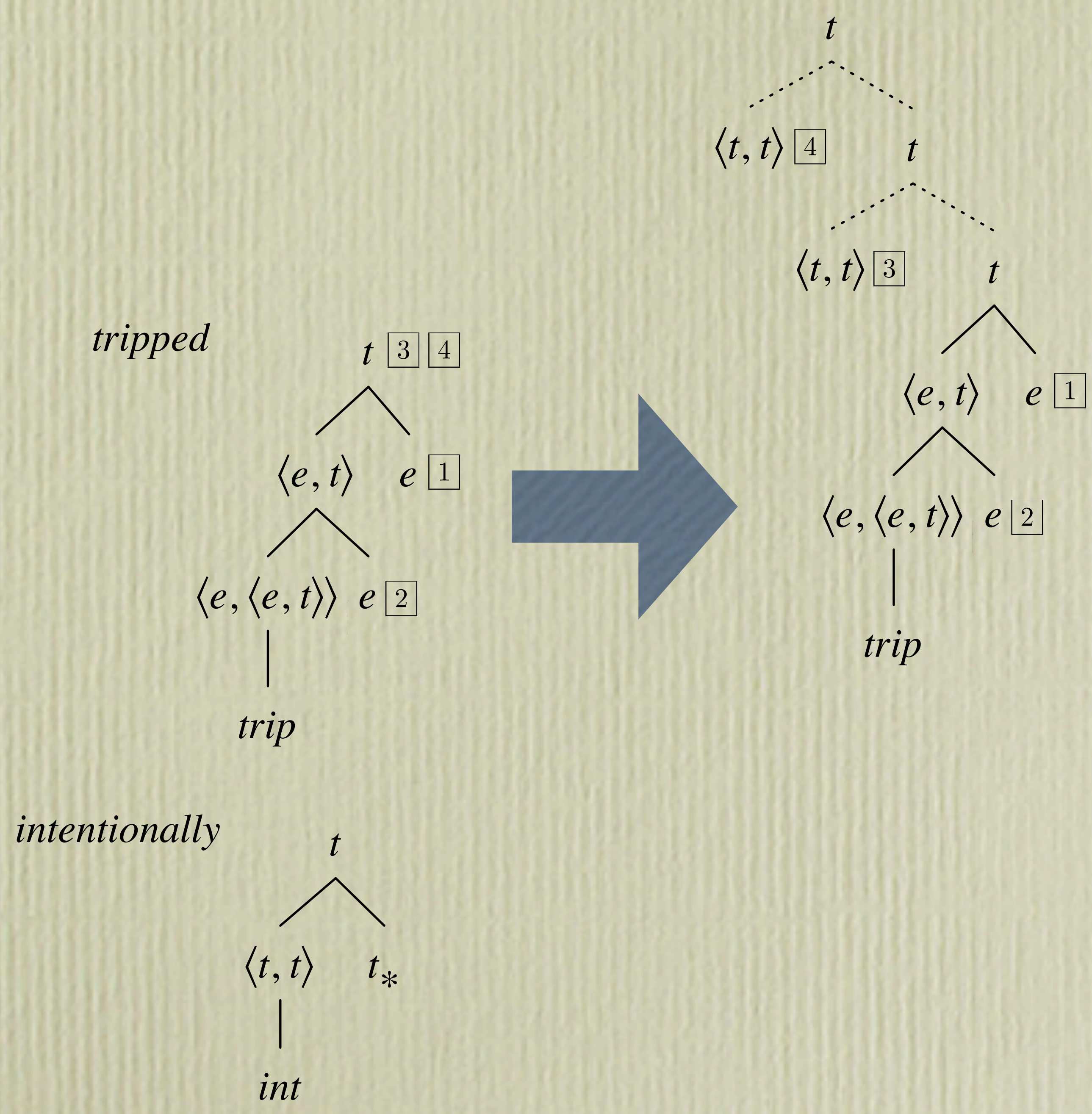

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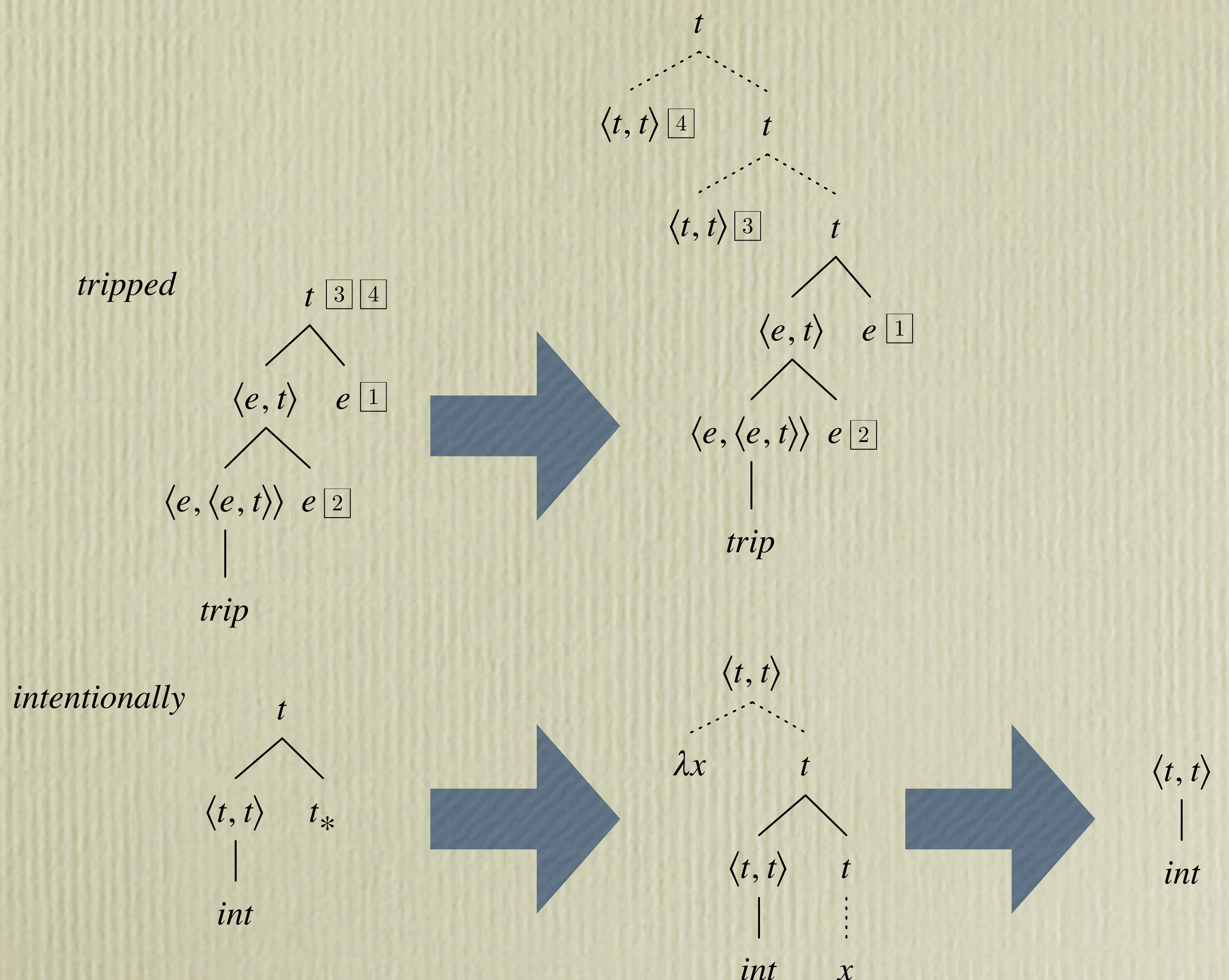
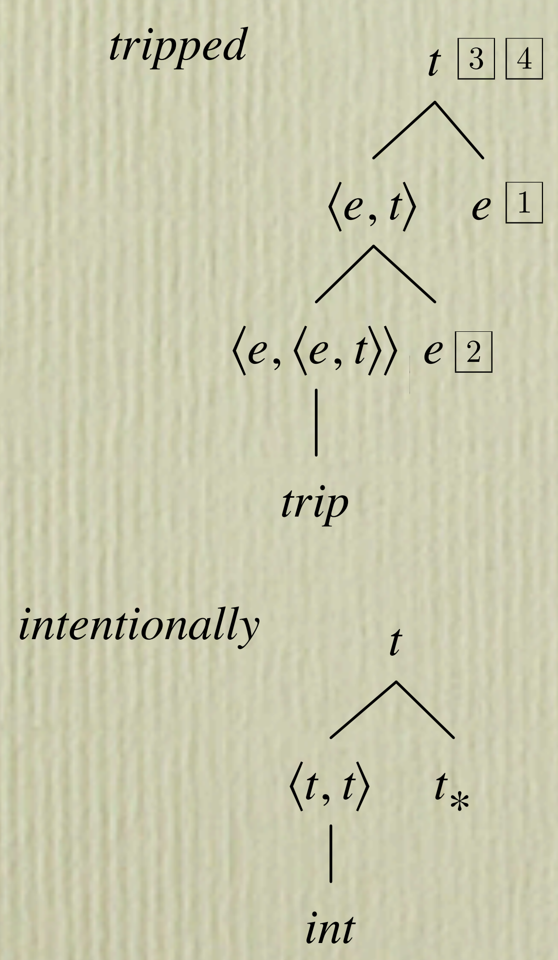
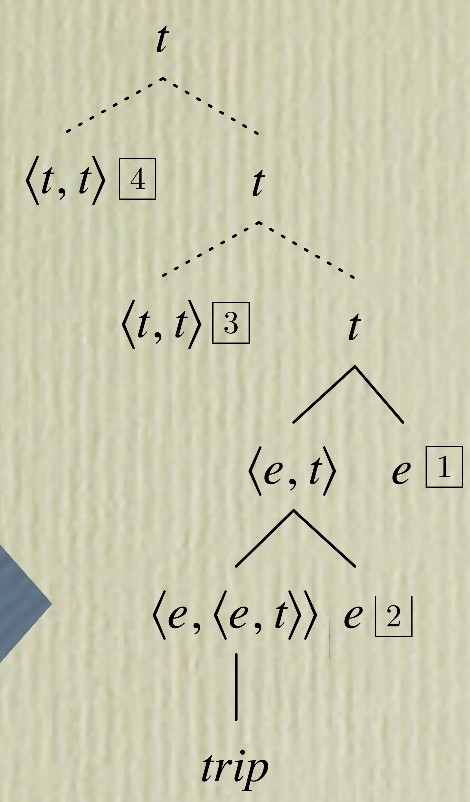

tripped
t 3 4
⟨e, t⟩ e 1
⟨e, ⟨e, t⟩⟩ e 2
trip
t
⟨t, t⟩ 4 t
⟨t, t⟩ 3 t
⟨e, t⟩ e 1
⟨e, ⟨e, t⟩⟩ e 2
trip
intentionally
t
⟨t, t⟩ t*
int
⟨t, t⟩
λx t
⟨t, t⟩ t
int x
⟨t, t⟩
int

TAG to TSG

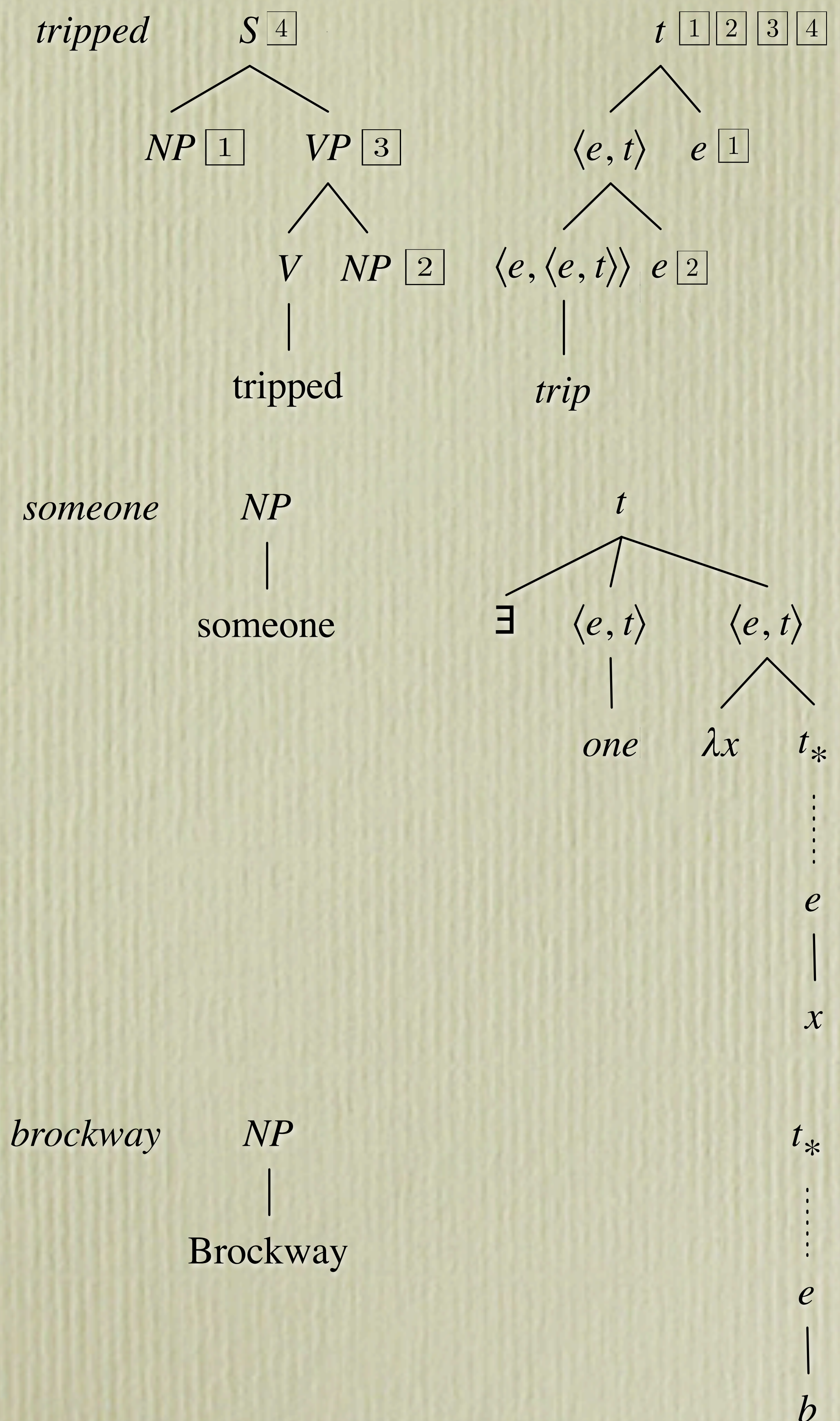


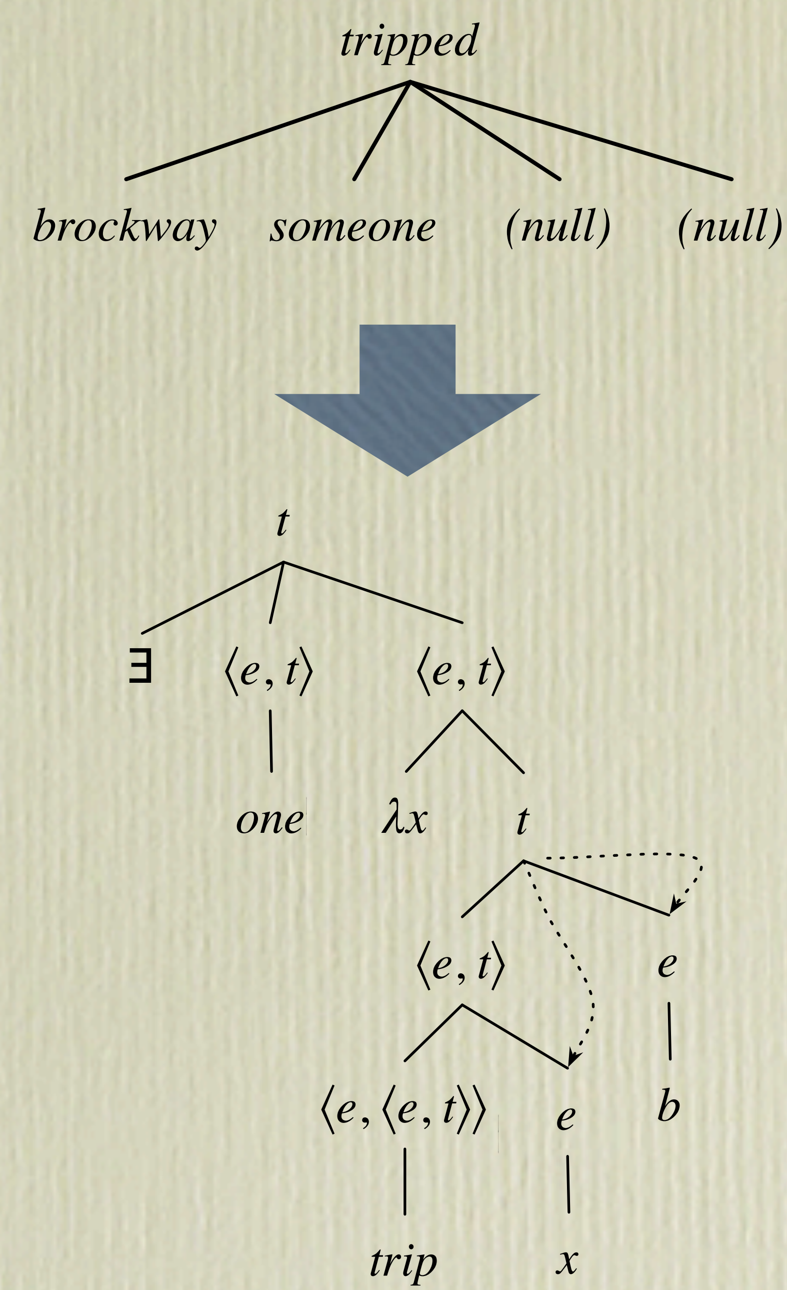


$$\boxed{4}(\boxed{3}(trip(\boxed{1}, \boxed{2})))$$

$$\lambda x_1, x_2, f_3, f_4 . f_4(f_3(trip(x_1, x_2)))$$

Quantifiers





$$\exists(one, \lambda x.trip(b, x))$$

Compositional STAG Quantifier Analyses

1. Reconstruct open meaning representations as self-contained semantic objects
2. Use an analysis with closed representations
   - “Variable-free semantics”
   - Hendriks, 1993

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Conclusion

Why compositionality?

- Pelletier: “Warm, fuzzy feeling”
- Janssen: As a guide for restrictive theorizing
- As a means for guaranteeing systematicity

Is STAG semantics compositional?

- More than you would have thought
- Less than completely

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