Kamp & Reyle 1993, Ch. 5 (1)
DRS Construction for Simple Tensed Sentences

• EVENTUALITIES VS. TIMES, EVENTS VS. STATES

(1)	Mary **call***ed* Sue *on Sunday*.	$t < n$, on_Sunday(t), $e \subseteq t$
(2)	Mary *will* **call** Sue *tomorrow*.	$n < t$, on_Sunday(t), $e \subseteq t$
(3) #	Mary **call***s* Sue (*right now*).	$n = t$, $e \subseteq t$
(4)	Mary was [= **be** + *ed*] ill *on Sunday*.	$t < n$, on_Sunday(t), $s \bigcirc t$
(5)	Mary *will* **be** ill *tomorrow*.	$n < t$, on_Sunday(t), $s \bigcirc t$
(6)	Mary is [= **be** + *s*] ill (*right now*).	$n = t$, $s \bigcirc t$

• LOCATION TIME INTRODUCED AT S'_{TNS}, EVENTUALITY AT S_{ST} (contra K&R pp. 543, 554)

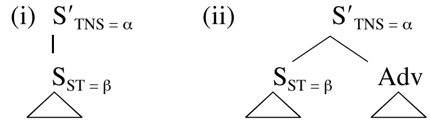
(7)	Mary [*will* not **call** Sue] *tomorrow*.	$n < t$, tomorrow(t), $\neg\exists e(e \subseteq t \ldots)$
(8)	Mary [*did* not **know** Sue] *last year*.	$t < n$, last_year(t), $\neg\exists s(s \bigcirc t \ldots)$
(9)	Mary [*did* not **call** Sue]. (Partee 1973 problem — still a problem for K&R.)	$t < n$, $\neg\exists e(e \subseteq t \ldots)$

Problems with DRS construction:
K&R's rule on p. 543 — CR.S'_{TA}, for tensed sentences without negation — is very complicated because it deals with all temporal dref's at once. This rule is also hard to reconcile with the rule on p. 554 — CR.VP'_{TA}, for negation — because it fails to generate the required triggering configuration.

Solution (2nd guess):
Introduce temporal dref's one at a time — specifically, introduce the location time dref (t) by TNS at S$'$, and the eventuality dref (e or s) by ST (short for STAT) at S. This can be done by the rules that follow — specifically, CR.TNS and CR.ST below. These generate the DRSs that K&R want for sentences like (1)–(9) but are much simpler and interact with each other and with CR.NEG (revised as below) in the right way.

CR.TNS (for discourse initial sentences)

Triggering configurations $\gamma \in$ Con$_K$:



(S and Adv in any order)

Introduce in U$_K$: new discourse referent **t** for a time

Introduce in Con$_K$:

- new condition $\alpha(\mathbf{t}, n)$,

where			
	$pst(\mathbf{t}, n)$	stands for	$\mathbf{t} < n$
	$fut(\mathbf{t}, n)$	stands for	$n < \mathbf{t}$
	$prs(\mathbf{t}, n)$	stands for	$\mathbf{t} = n$

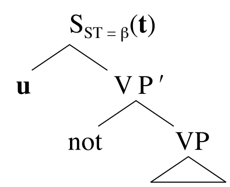
- new condition Adv($\mathbf{t}$), if γ = (i)

Replace γ by: $S_{ST = \beta}(\mathbf{t})$ $_1$

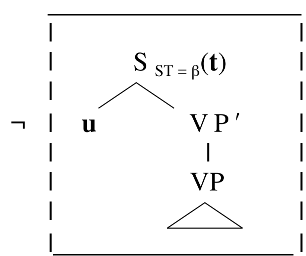
where $S_{ST = \beta}$ $_1$ is obtained from $S_{ST = \beta}$ by changing the form of the main V to the infinitive and deleting any tensed AUX (*will* or *do*-TNS).

CR.NEG

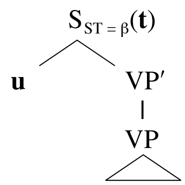
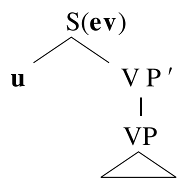
Triggering configuration $\gamma \in$ Con$_K$:



Replace γ by:



CR.ST (for discourse initial sentences)

Triggering configuration $\gamma \in Con_K$:	
Introduce in U_K:	new discourse referent **ev** for an eventuality, where **ev** ranges over states if $\beta = +$, and over events otherwise
Introduce in Con_K:	• new condition $\beta(\mathbf{ev}, \mathbf{t})$, where $-(\mathbf{ev}, \mathbf{t})$ stands for $\mathbf{ev} \subseteq \mathbf{t}$ $+(\mathbf{ev}, \mathbf{t})$ stands for $\mathbf{ev} \circ \mathbf{t}$
Replace γ by:	

Kamp & Reyle 1993, Ch. 5 (2)
Extending DRT to Simple Tensed Sentences

DRT Syntax (cf. K&R df 5.6.4, p. 676)

(i) A *Discourse Representation Structure* (*DRS*) K *confined to a vocabulary* V and *dref set* R is a pair, consisting of a possibly empty subset $U_K \subseteq R$ and a possibly empty set Con_K of DRS-conditions confined to V and R.

(ii) A *DRS-condition confined to* V *and* R is an expression of one of the following forms:

(a) $\mathbf{u} = \mathbf{v}$, where **u** and **v** are drefs of the same type.
$\mathbf{t} < \mathbf{t}'$, where **t** and **t**′ are temporal drefs.
$\mathbf{ev} \subseteq \mathbf{t}$, $\mathbf{ev} \bigcirc \mathbf{t}$, where **ev** is an event or state dref and **t** is a temporal dref.

(b) $\pi(\mathbf{x})$, where **x** is an individual dref and π is an individual constant from V.
$\tau(\mathbf{t})$, where **t** is a temporal dref and τ is a temporal functor from V.

(c) $\eta(\mathbf{x})$, where **x** is an individual dref and η is a 1-place nominal predicate from V.
$\eta(\mathbf{t})$, where **t** is a temporal dref and η is a 1-place temporal predicate from V.

(d) $\zeta(\mathbf{e}, \mathbf{x})$, where **e** is an event dref, **x** an individual dref and ζ is a 1-place event predicate from V.
$\zeta(\mathbf{s}, \mathbf{x})$, where **s** is a state dref, **x** an individual dref and ζ is a 1-place state predicate from V.

(e) $\zeta(\mathbf{e}, \mathbf{x}, \mathbf{y})$, where **e** is an event dref, **x** and **y** are individual drefs and ζ, a 2-place event predicate from V.
$\zeta(\mathbf{s}, \mathbf{x}, \mathbf{y})$, where **s** is a state dref, **x** and **y** are individual drefs and ζ, a 2-place state predicate from V.

(f) $\neg$K, where K is a DRS confined to V and R.

DRT Models (cf. K&R pp. 664–678)

A *model* M *for a vocabulary* V is a 9-tuple $\langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M\rangle$ consisting of:

(i) non-empty pairwise disjoint sets U_M (of *individuals*), E_M (of *events*), and S_M (of *states*).

(ii) an *instant structure* $\mathbf{I}_M = \langle I_M, <\rangle$, where

- I_M is a non-empty set (of *instants*), pairwise disjoint from U_M, E_M and S_M.
- < (*precedence*) is a strict linear order over I_M, i.e.
  - (Ax_1) $i_1 < i_2 \rightarrow \neg\, i_2 < i_1$ (asymmetric)
  - (Ax_2) $i_1 < i_2 \wedge i_2 < i_3 \rightarrow i_1 < i_3$ (transitive)
  - (Ax_3) $i_1 \neq i_2 \rightarrow i_1 < i_2 \vee i_2 < i_1$ (connected)

(iii) the *interval structure* $\mathbf{T}_M = \langle T_M, <_T, \bigcirc_T\rangle$ induced by the instant structure $\mathbf{I}_M = \langle I_M, <\rangle$ as follows:

- T_M (set of *intervals*) is the set of non-empty convex subsets of I_M, i.e.,
  $T_M := \{t: \varnothing \subset t \subseteq I_M \wedge \forall i, i', i''(i \in t \wedge i'' \in t \wedge i < i' < i'' \rightarrow i' \in t)\}$
- $t <_T t'$ iff $\forall i, i'(i \in t \wedge i' \in t' \rightarrow i < i')$ (T-*precedence*)
  $t \bigcirc_T t'$ iff $\exists i(i \in t \wedge i \in t')$ (T-*overlap*)

(iv) a function Loc_M which assigns a time interval (*location time*) in T_M to each eventuality in $E_M \cup S_M$.

(v) a function $Name_M$ which assigns
- an individual in U_M to each individual constant in {*Bill*, *Mary*, …} ⊆ V.

(vi) a function Fun_M which assigns
- a function from instants in I_M to intervals in T_M to each temporal functor in {*tomorrow*, *last_year*, …} ⊆ V.

(vii) a function $Pred_M$ which assigns:
- a subset of U_M to each 1-place nominal predicate in {*man*, *car*, …} ⊆ V.
  a subset of T_M to each 1-place temporal predicate in {*Sunday*, *on_Sunday*, …} ⊆ V.
- a subset of $E_M \times U_M$ to each 1-place eventive predicate in {*arrive*, …} ⊆ V.
  a subset of $S_M \times U_M$ to each 1-place stative predicate in {*be_ill*, …} ⊆ V.
- a subset of $E_M \times U_M \times U_M$ to each 2-place eventive predicate in {*call*, *write*, …} ⊆ V.
  a subset of $S_M \times U_M \times U_M$ to each 2-place stative predicate in {*know*, *like*, …} ⊆ V.

Anchored DRT models (cf. K&R pp. 247–248)

An *anchored model* is a pair $\langle M, \phi\rangle$ of a model $M = \langle U_M, E_M, S_M, \langle I_M, <\rangle, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M\rangle$ and an (*indexical*) M-*anchor* $\phi = \{\langle n, \{i\}\rangle\}$ where $i \in I_M$.

DRT Semantics (cf. K&R p. 678)

Let $K = \langle U_K, Con_K\rangle$ be a proper DRS confined to V and R,
$M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M\rangle$, a model for V,
$\phi = \{\langle n, \{i\}\rangle\}$, an M-anchor
f, a ϕ-extending embedding from R into M
(i.e. $\phi \subseteq f$ and, for any dref $\mathbf{u} \in Dom(f)$, we require $f(\mathbf{u}) \in U_M$ if $\mathbf{u}$ is an individual dref, $f(\mathbf{u}) \in E_M$ if $\mathbf{u}$ is an event dref, $f(\mathbf{u}) \in S_M$ if $\mathbf{u}$ is a state dref, and $f(\mathbf{u}) \in T_M$ if $\mathbf{u}$ is a temporal dref).

(i) for any DRS condition $\gamma \in Con_K$, f *verifies* γ in $\langle M, \phi\rangle$ iff

(a) γ is of the form $\mathbf{u} = \mathbf{v}$ and $f(\mathbf{u}) = f(\mathbf{v})$.
γ is of the form $\mathbf{t} < \mathbf{t}'$ and $f(\mathbf{t}) <_T f(\mathbf{t}')$.
γ is of the form $\mathbf{ev} \subseteq \mathbf{t}$ and $Loc_M(f(\mathbf{ev})) \subseteq f(\mathbf{t})$.
γ is of the form $\mathbf{ev} \circ \mathbf{t}$ and $Loc_M(f(\mathbf{ev})) \circ_T f(\mathbf{t})$.

(b) γ is of the form $\pi(\mathbf{x})$ and $f(\mathbf{x}) = Name_M(\pi)$
γ is of the form $\tau(\mathbf{t})$ and $f(\mathbf{t}) = Fun_M(\tau)(i)$

(c) γ is of the form $\eta(\mathbf{x})$ and $f(\mathbf{x}) \in Pred_M(\eta)$.
γ is of the form $\eta(\mathbf{t})$ and $f(\mathbf{t}) \in Pred_M(\eta)$.

(d) γ is of the form $\zeta(\mathbf{e}, \mathbf{x})$ and $\langle f(\mathbf{e}), f(\mathbf{x})\rangle \in Pred_M(\zeta)$.
γ is of the form $\zeta(\mathbf{s}, \mathbf{x})$ and $\langle f(\mathbf{s}), f(\mathbf{x})\rangle \in Pred_M(\zeta)$.

(e) γ is of the form $\zeta(\mathbf{e}, \mathbf{x}, \mathbf{y})$ and $\langle f(\mathbf{e}), f(\mathbf{x}), f(\mathbf{y})\rangle \in Pred_M(\zeta)$.
γ is of the form $\zeta(\mathbf{s}, \mathbf{x}, \mathbf{y})$ and $\langle f(\mathbf{s}), f(\mathbf{x}), f(\mathbf{y})\rangle \in Pred_M(\zeta)$.

(f) γ is of the form $\neg K'$ and there is no extension g of f such that
- $Dom(g) = Dom(f) \cup U_{K'}$
- g verifies K' in $\langle M, \phi\rangle$

(ii) f *verifies* the DRS K in $\langle M, \phi\rangle$ iff f verifies each condition $\gamma \in Con_K$ in $\langle M, \phi\rangle$.

(iii) K is *true in* $\langle M, \phi\rangle$ iff there is a ϕ-extending embedding f from R into M such that $Dom(f) = U_K$ and f verifies K in $\langle M, \phi\rangle$.

DRS Subordination (as in K&R Ch. 1)

Let K and K′ be DRSs.

(i) K is *immediately subordinate to* K′ iff $\neg K \in Con_{K'}$

(ii) K is *subordinate to* K′, $K < K'$, iff either (a) or (b):
(a) K is immediately subordinate to K′
(b) K is immediately subordinate to some $K'' < K'$.

(iii) K is *weakly subordinate to* K′, $K \leq K'$, iff $K = K'$ or $K < K'$.

Dref Accessibility (as in K&R Ch. 1)

Let K be a DRS, $\mathbf{u}$ a dref, and γ a DRS-condition.
We say that $\mathbf{u}$ is *accessible from* γ in K iff, for some $K'' \leq K' \leq K$, $\gamma \in Con_{K''}$ and $\mathbf{u} \in U_{K'}$.

Kamp & Reyle 1993, Ch. 5 (3)
Verifying DRSs for Simple Tensed Sentences

- SIMPLE EVENTIVE SENTENCES

(1) Mary called Sue on Sunday.

- *DRS* K_1 for (1):

n t x y e
t < n on_Sunday(t) Mary(x) Sue(y) e ⊆ t call(e, x, y)

- K_1 is *true* in the anchored DRT model $\langle M, \phi_1\rangle$, where

$M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M\rangle$

$U_M = \{a, b, c\}$ $E_M = \{\varepsilon_0, \varepsilon_1, \ldots\}$ $\mathbf{I}_M = \langle\{i_0, i_1, \ldots\}, <\rangle$, where $i_0 < i_1 < \ldots$

$Loc_M(\varepsilon_0) = \{i_2, i_3\}$ $Name_M \supseteq \{\langle Mary, a\rangle, \langle Sue, b\rangle\}$ $Pred_M(call) = \{\langle\varepsilon_0, a, b\rangle, \ldots\}$

$Pred_M(on\_Sunday) = \{\{i_2, i_3, i_4\}, \{i_{12}, i_{13}, i_{14}\}\}$

$\phi_1 = \{\langle n, \{i_{10}\}\rangle\}$

Proof:

K_1 is verified in $\langle M, \phi_1\rangle$ by the ϕ_1-extension $f = \{\langle n, \{i_{10}\}\rangle, \langle t, \{i_2, i_3, i_4\}\rangle, \langle x, a\rangle, \langle y, b\rangle, \langle e, \varepsilon_0\rangle\}$.
For by the definition of DRT semantics,

't < n' is verified, by clause (i.a), because $f(t) = \{i_2, i_3, i_4\} <_T \{i_{10}\} = f(n)$

'on_Sunday(t)' is verified, by clause (i.c), because $f(t) = \{i_2, i_3, i_4\} \in Pred_M(on\_Sunday)$

'Mary(x)' is verified, by clause (i.b), because $f(x) = a = Name_M(Mary)$

'Sue(y)' is verified, by clause (i.b), because $f(y) = b = Name_M(Sue)$

'e ⊆ t' is verified, by clause (i.a), because $Loc_M(f(e)) = Loc_M(\varepsilon_0) = \{i_2, i_3\} \subseteq \{i_2, i_3, i_4\} = f(t)$

'call(e, x, y)' is verified, by clause (i.e), because $\langle f(e), f(x), f(y)\rangle = \langle\varepsilon_0, a, b\rangle \in Pred_M(call)$

So K_1 has a ϕ_1-extending embedding which verifies it in $\langle M, \phi_1\rangle$ (to wit f, by clause (ii)) and so is true in $\langle M, \phi_1\rangle$ (by clause (iii)). □

- Diagram:

```
          ('last_Sunday')                    ('PRS')  ('next_Sunday')
                                              φ1(n)
                 f(t)                         f(n)
________|||||||||||||||||||||||_____________________|||||____||||||||||||||||||||||__________
  i0   i1   i2   i3   i4   i5   i6   i7   i8   i9   i10  i11  i12  i13  i14  i15
        |----ε0----|
         ('call')
```

(2) Mary will call Sue tomorrow.

- *DRS* K_2 for (2):

n t x y e
n < t tomorrow(t) Mary(x) Sue(y) $e \subseteq t$ call(e, x, y)

- K_2 is *true* in the anchored DRT model $\langle M, \phi_2\rangle$, where

  $M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M\rangle$

  $U_M = \{a, b, c\}$ $\quad$ $E_M = \{\varepsilon_0, \varepsilon_1, \ldots\}$ $\quad$ $\mathbf{I}_M = \langle\{i_0, i_1, \ldots\}, <\rangle$, where $i_0 < i_1 < \ldots$

  $Loc_M(\varepsilon_0) = \{i_2, i_3\}$ $\quad$ $Name_M \supseteq \{\langle Mary, a\rangle, \langle Sue, b\rangle\}$ $\quad$ $Pred_M(call) = \{\langle\varepsilon_0, a, b\rangle, \ldots\}$

  $Fun_M(tomorrow)(i_0) = \{i_2, i_3, i_4\}$

  $\phi_2 = \{\langle n, \{i_0\}\rangle\}$

  Proof:

  K_2 is verified in $\langle M, \phi_2\rangle$ by the ϕ_2-extension $f = \{\langle n, \{i_0\}\rangle, \langle t, \{i_2, i_3, i_4\}\rangle, \langle x, a\rangle, \langle y, b\rangle, \langle e, \varepsilon_0\rangle\}$.
  For by the definition of DRT semantics,

  ‘n < t’ is verified, by clause (i.a), because $f(n) = \{i_0\} <_T \{i_2, i_3, i_4\} = f(t)$

  ‘tomorrow(t)’ is verified, by clause (i.b), because $f(t) = \{i_2, i_3, i_4\} = Fun_M(tomorrow)(i_0)$

  ‘Mary(x)’ is verified, by clause (i.b), because $f(x) = a = Name_M(Mary)$

  ‘Sue(y)’ is verified, by clause (i.b), because $f(y) = b = Name_M(Sue)$

  ‘$e \subseteq t$’ is verified, by clause (i.a), because $Loc_M(f(e)) = Loc_M(\varepsilon_0) = \{i_2, i_3\} \subseteq \{i_2, i_3, i_4\} = f(t)$

  ‘call(e, x, y)’ is verified, by clause (i.e), because $\langle f(e), f(x), f(y)\rangle = \langle\varepsilon_0, a, b\rangle \in Pred_M(call)$

  So K_2 has a ϕ_2-extending embedding which verifies it in $\langle M, \phi_2\rangle$ (to wit f, by clause (ii))
  and so is true in $\langle M, \phi_2\rangle$ (by clause (iii)). □

- Diagram:

```
('PRS')   ('tomorrow')
φ2(n)
 f(n)          f(t)
_||||||_____||||||||||||||||||||||||||_______________________________________________
  i0   i1   i2   i3   i4   i5   i6   i7   i8   i9   i10   i11   i12   i13   i14   i15
            |----ε0----|
             ('call')
```

(3) # Mary calls Sue.

- *DRS* K_3 for (3):

n t x y e
$n = t$
Mary(x)
Sue(y)
$e \subseteq t$
call(e, x, y)

- Since n must be anchored to an instant, this DRS can only be verified if there are instantaneous calling events. Arguably, there aren't any such things in realistic models. This would account for the oddity of (3) — i.e., on this view, (3) is odd because its DRS K_3 can never be verified (in any realistic anchored model).

- SIMPLE STATIVE SENTENCES

(4) Mary was ill on Sunday.

- *DRS* K_4 for (4):

n t x s
t < n on_Sunday(t) Mary(x) s ○ t be_ill(s, x)

- K_4 is *true* in the anchored DRT model $\langle M, \phi_4 \rangle$, where

$M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M \rangle$

$U_M = \{a, b, c\}$ $S_M = \{\sigma_0, \sigma_1, \ldots\}$ $\mathbf{I}_M = \langle \{i_0, i_1, \ldots\}, < \rangle$, where $i_0 < i_1 < \ldots$

$Loc_M(\sigma_1) = \{i_4, i_5, i_6\}$ $Name_M(Mary) = a$ $Pred_M(be\_ill) = \{\langle \sigma_1, a \rangle, \ldots\}$

$Pred_M(on\_Sunday) = \{\{i_2, i_3, i_4\}, \{i_{12}, i_{13}, i_{14}\}\}$

$\phi_4 = \{\langle n, \{i_6\} \rangle\}$

Proof:

K_4 is verified in $\langle M, \phi_4 \rangle$ by the ϕ_4-extension $f = \{\langle n, \{i_6\} \rangle, \langle t, \{i_2, i_3, i_4\} \rangle, \langle x, a \rangle, \langle s, \sigma_1 \rangle\}$.
For by the definition of DRT semantics,

'$t < n$' is verified, by clause (i.a), because $f(t) = \{i_2, i_3, i_4\} <_T \{i_6\} = f(n)$

'on_Sunday(t)' is verified, by clause (i.c), because $f(t) = \{i_2, i_3, i_4\} \in Pred_M(on\_Sunday)$

'Mary(x)' is verified, by clause (i.b), because $f(x) = a = Name_M(Mary)$

'$s \bigcirc t$' is verified, by clause (i.a), because $Loc_M(f(s)) = Loc_M(\sigma_1) = \{i_4, i_5, i_6\} \bigcirc_T \{i_2, i_3, i_4\} = f(t)$

'be_ill(s, x)' is verified, by clause (i.d), because $\langle f(s), f(x) \rangle = \langle \sigma_1, a \rangle \in Pred_M(be\_ill)$

So K_4 has a ϕ_4-extending embedding which verifies it in $\langle M, \phi_4 \rangle$ (to wit f, by clause (ii)) and so is true in $\langle M, \phi_4 \rangle$ (by clause (iii)). □

- Diagram:

('last_Sunday') ('PRS') ('next_Sunday')

$\phi_4(n)$

f(t) f(n)

________||||||||||||||||||||||______|||||______________________||||||||||||||||||||||__________

i_0 i_1 i_2 i_3 i_4 i_5 i_6 i_7 i_8 i_9 i_{10} i_{11} i_{12} i_{13} i_{14} i_{15}

|===σ_1===|

('be_ill')

(5) Mary will be ill tomorrow.

- *DRS* K_5 for (5):

n t x s
n < t tomorrow(t) Mary(x) s ○ t be_ill(s, x)

- K_5 is *true* in the anchored DRT model $\langle M, \phi_2 \rangle$, where

$M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M \rangle$

$U_M = \{a, b, c\}$ $S_M = \{\sigma_0, \sigma_1, \ldots\}$ $\mathbf{I}_M = \langle \{i_0, i_1, \ldots\}, < \rangle$, where $i_0 < i_1 < \ldots$

$Loc_M(\sigma_1) = \{i_4, i_5, i_6\}$ $Name_M(Mary) = a$ $Pred_M(be\_ill) = \{\langle \sigma_1, a \rangle, \ldots\}$

$Fun_M(tomorrow)(i_0) = \{i_2, i_3, i_4\}$

$\phi_2 = \{\langle n, \{i_0\} \rangle\}$

Proof:

K_5 is verified in $\langle M, \phi_2 \rangle$ by the ϕ_2-extension $f = \{\langle n, \{i_0\}\rangle, \langle t, \{i_2, i_3, i_4\}\rangle, \langle x, a\rangle, \langle s, \sigma_1\rangle\}$.
For by the definition of DRT semantics,

'n < t'	is verified, by clause (i.a), because $f(n) = \{i_0\} <_T \{i_2, i_3, i_4\} = f(t)$
'tomorrow(t)'	is verified, by clause (i.b), because $f(t) = \{i_2, i_3, i_4\} = Fun_M(tomorrow)(i_0)$
'Mary(x)'	is verified, by clause (i.b), because $f(x) = a = Name_M(Mary)$
's ○ t'	is verified, by clause (i.a), because $Loc_M(f(s)) = Loc_M(\sigma_1) = \{i_4, i_5, i_6\} \bigcirc_T \{i_2, i_3, i_4\} = f(t)$
'be_ill(s, x)'	is verified, by clause (i.d), because $\langle f(s), f(x)\rangle = \langle \sigma_1, a\rangle \in Pred_M(be\_ill)$

So K_5 has a ϕ_2-extending embedding which verifies it in $\langle M, \phi_2 \rangle$ (to wit f, by clause (ii))
and so is true in $\langle M, \phi_2 \rangle$ (by clause (iii)). u

- Diagram:

```
('PRS')   ('tomorrow')
φ2(n)
 f(n)          f(t)
_||||||_____|||||||||||||||||||||||||_____________________________________________
  i0   i1   i2   i3   i4   i5   i6   i7   i8   i9   i10  i11  i12  i13  i14  i15
                    |===σ1===|
                     ('be_ill')
```

(6) Mary is ill.

- *DRS* K_6 for (6):

n t x s
n = t Mary(x) s ○ t be_ill(s, x)

- K_6 is *true* in the anchored DRT model $\langle M, \phi_4 \rangle$, where

  $M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M \rangle$

  $U_M = \{a, b, c\}$ $S_M = \{\sigma_0, \sigma_1, \ldots\}$ $\mathbf{I}_M = \langle \{i_0, i_1, \ldots\}, < \rangle$, where $i_0 < i_1 < \ldots$

  $Loc_M(\sigma_1) = \{i_4, i_5, i_6\}$ $Name_M(Mary) = a$ $Pred_M(be\_ill) = \{\langle \sigma_1, a \rangle, \ldots\}$

  $\phi_4 = \{\langle n, \{i_6\} \rangle\}$

  Proof:

  K_6 is verified in $\langle M, \phi_4 \rangle$ by the ϕ_4-extension $f = \{\langle n, \{i_6\} \rangle, \langle t, \{i_6\} \rangle, \langle x, a \rangle, \langle s, \sigma_1 \rangle\}$.
  For by the definition of DRT semantics,

  'n = t' is verified, by clause (i.a), because $f(n) = \{i_6\} = f(t)$

  'Mary(x)' is verified, by clause (i.b), because $f(x) = a = Name_M(Mary)$

  's ○ t' is verified, by clause (i.a), because $Loc_M(f(s)) = Loc_M(\sigma_1) = \{i_4, i_5, i_6\} \bigcirc_T \{i_6\} = f(t)$

  'be_ill(s, x)' is verified, by clause (i.d), because $\langle f(s), f(x) \rangle = \langle \sigma_1, a \rangle \in Pred_M(be\_ill)$

  So K_6 has a ϕ_4-extending embedding which verifies it in $\langle M, \phi_4 \rangle$ (to wit f, by clause (ii))
  and so is true in $\langle M, \phi_4 \rangle$ (by clause (iii)). □

- Diagram:

```
                         ('PRS')
                           φ2(n)
                           f(n)
                           f(t)
_________________________|||||||____________________________________________
  i0  i1  i2  i3  i4  i5  i6  i7  i8  i9  i10  i11  i12  i13  i14  i15
                  |===σ1===|
                  ('be_ill')
```

- TENSE AND NEGATION

(7) Mary will not call Sue tomorrow.

- *DRS* K_7 for (7):

```
n  t  x  y

n < t
tomorrow(t)
Mary(x)
Sue(y)
      ______________
     | e            |
  ¬  | e ⊆ t        |
     | call(e, x, y)|
     |______________|
        N
```

- K_7 is *true* in the anchored DRT model $\langle M, \phi_1\rangle$, where

$M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M\rangle$

$U_M = \{a, b, c\}$ $E_M = \{\varepsilon_0, \varepsilon_1, \dots\}$ $\mathbf{I}_M = \langle\{i_0, i_1, \dots\}, <\rangle$, where $i_0 < i_1 < \dots$

$Loc_M(\varepsilon_0) = \{i_2, i_3\}$ $Name_M \supseteq \{\langle Mary, a\rangle, \langle Sue, b\rangle\}$ $Pred_M(call) = \{\langle\varepsilon_0, a, b\rangle\}$

$Fun_M(tomorrow)(i_{10}) = \{i_{12}, i_{13}, i_{14}\}$

$\phi_1 = \{\langle n, \{i_{10}\}\rangle\}$

Proof:

K_7 is verified in $\langle M, \phi_1\rangle$ by the ϕ_1-extension $f = \{\langle n, \{i_{10}\}\rangle, \langle t, \{i_{12}, i_{13}, i_{14}\}\rangle, \langle x, a\rangle, \langle y, b\rangle\}$.
For by the definition of DRT semantics,

‘n < t’	is verified, by clause (i.a), because $f(n) = \{i_{10}\} <_T \{i_{12}, i_{13}, i_{14}\} = f(t)$
‘tomorrow(t)’	is verified, by clause (i.b), because $f(t) = \{i_{12}, i_{13}, i_{14}\} = Fun_M(tomorrow)(i_{10})$
‘Mary(x)’	is verified, by clause (i.b), because $f(x) = a = Name_M(Mary)$
‘Sue(y)’	is verified, by clause (i.b), because $f(y) = b = Name_M(Sue)$
'¬N'	is verified, by clause (i.f), because there is no f-extension which verifies N in $\langle M, \phi_1\rangle$.

For suppose there was one, call it g. Then, to verify 'call(e, x, y)', clause (i.e) would require $\langle g(e), g(x), g(y)\rangle \in Pred_M(call) = \{\langle\varepsilon_0, a, b\rangle\}$. So $g(e) = \varepsilon_0$. But then 'e ⊆ t' cannot be verified, by clause (i.a), because $Loc_M(g(e)) = Loc_M(\varepsilon_0) = \{i_2, i_3\}$ ‹ $g(t) = f(t) = \{i_{12}, i_{13}, i_{14}\}$.

So K_7 has a ϕ_1-extending embedding which verifies it in $\langle M, \phi_1\rangle$ (to wit f, by clause (ii)) and so is true in $\langle M, \phi_1\rangle$ (by clause (iii)). u

- Diagram:

```
                                              ('PRS')    ('tomorrow')
                                               φ1(n)
                                               f(n)            f(t)
______________________________________________|||||______||||||||||||||||||__________
 i0   i1   i2   i3   i4   i5   i6   i7   i8   i9   i10  i11  i12  i13  i14  i15
          |----ε0---|
           ('call')
```

(8) Mary did not know Sue last year.

- *DRS* K_8 for (8):

```
┌──────────────────────────────┐
│   n  t  x  y                 │
│                              │
│   t < n                      │
│   last_year(t)               │
│   Mary(x)                    │
│   Sue(y)                     │
│       ________________       │
│      | s              |      │
│   ¬  | s ○ t          |      │
│      | know(s, x, y)  |      │
│      |________________|      │
│        N                     │
└──────────────────────────────┘
```

- K_8 is *true* in the anchored DRT model $\langle M, \phi_1\rangle$, where

$M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M\rangle$

$U_M = \{a, b, c\}$ $\quad S_M = \{\sigma_0, \sigma_1, \ldots\}$ $\quad \mathbf{I}_M = \langle\{i_0, i_1, \ldots\}, <\rangle$, where $i_0 < i_1 < \ldots$

$Loc_M(\sigma_0) = \{i_8, i_9, i_{10}\}$ $\quad Name_M \supseteq \{\langle Mary, a\rangle, \langle Sue, b\rangle\}$ $\quad Pred_M(know) = \{\langle\sigma_0, a, b\rangle\}$

$Fun_M(last\_year)(i_{10}) = \{i_1, i_2, i_3, i_4, i_5, i_6\}$

$\phi_1 = \{\langle n, \{i_{10}\}\rangle\}$

Proof:

K_8 is verified in $\langle M, \phi_1\rangle$ by the ϕ_1-extension $f = \{\langle n, \{i_{10}\}\rangle, \langle t, \{i_1, i_2, i_3, i_4, i_5, i_6\}\rangle, \langle x, a\rangle, \langle y, b\rangle\}$.
For by the definition of DRT semantics,

't < n'	is verified, by clause (i.a), because $f(t) = \{i_1, i_2, i_3, i_4, i_5, i_6\} <_T \{i_{10}\} = f(n)$
'last_year(t)'	is verified, by clause (i.b), because $f(t) = \{i_1, i_2, i_3, i_4, i_5, i_6\} = Fun_M(last\_year)(i_{10})$
'Mary(x)'	is verified, by clause (i.b), because $f(x) = a = Name_M(Mary)$
'Sue(y)'	is verified, by clause (i.b), because $f(y) = b = Name_M(Sue)$
'¬N'	is verified, by clause (i.f), because there is no f-extension which verifies N in $\langle M, \phi_1\rangle$.

For suppose there was one, call it g. Then, to verify 'know(s, x, y)', clause (i.e) would require $\langle g(s), g(x), g(y)\rangle \in Pred_M(know) = \{\langle\sigma_0, a, b\rangle\}$. So $g(s) = \sigma_0$. But then 's ○ t' cannot be verified, by clause (i.a), because $Loc_M(g(s)) \cap g(t) = Loc_M(\sigma_0) \cap f(t) = \varnothing$.

So K_7 has a ϕ_1-extending embedding which verifies it in $\langle M, \phi_1\rangle$ (to wit f, by clause (ii)) and so is true in $\langle M, \phi_1\rangle$ (by clause (iii)). □

- Diagram:

```
              ('last year')                 ('PRS')
                                             φ1(n)
                  f(t)                        f(n)
______|||||||||||||||||||||||||||||||||||||______________||||||________________________
 i0   i1   i2   i3   i4   i5   i6   i7   i8   i9   i10  i11  i12  i13  i14  i15
                                   |===σ0====|
                                     ('know')
```

(9) Mary did not call Sue. (a la 'I didn't turn off the stove.' Partee 1973)

- *DRS* K_9 for (9):

$$
\boxed{
\begin{array}{l}
n \;\; t \;\; x \;\; y \\[4pt]
t < n \\
\text{Mary}(x) \\
\text{Sue}(y) \\[4pt]
\neg \; \boxed{\begin{array}{l} e \\ e \subseteq t \\ \text{call}(e, x, y) \end{array}} \\
\qquad N
\end{array}
}
$$

- K_7 is *true* in the anchored DRT model $\langle M, \phi_1 \rangle$, where

  $M = \langle U_M, E_M, S_M, \mathbf{I}_M, \mathbf{T}_M, Loc_M, Name_M, Fun_M, Pred_M \rangle$

  $U_M = \{a, b, c\}$ $\quad E_M = \{\varepsilon_0, \varepsilon_1, \ldots\}$ $\quad \mathbf{I}_M = \langle \{i_0, i_1, \ldots\}, < \rangle$, where $i_0 < i_1 < \ldots$

  $Loc_M(\varepsilon_0) = \{i_2, i_3\}$ $\quad Name_M \supseteq \{\langle \text{Mary}, a \rangle, \langle \text{Sue}, b \rangle\}$ $\quad Pred_M(\text{call}) = \{\langle \varepsilon_0, a, b \rangle\}$

  $\phi_1 = \{\langle n, \{i_{10}\} \rangle\}$

  Proof:

  K_9 is verified in $\langle M, \phi_1 \rangle$ by the ϕ_1-extension $f = \{\langle n, \{i_{10}\} \rangle, \langle t, \{i_5, i_6, i_7\} \rangle, \langle x, a \rangle, \langle y, b \rangle\}$.
  For by the definition of DRT semantics,

  ‘$t < n$’ is verified, by clause (i.a), because $f(t) = \{i_5, i_6, i_7\} <_T \{i_{10}\} = f(n)$

  ‘Mary(x)’ is verified, by clause (i.b), because $f(x) = a = Name_M(\text{Mary})$

  ‘Sue(y)’ is verified, by clause (i.b), because $f(y) = b = Name_M(\text{Sue})$

  '$\neg$N' is verified, by clause (i.f), because there is no f-extension which verifies N in $\langle M, \phi_1 \rangle$.

  For suppose there was one, call it g. Then, to verify 'call(e, x, y)', clause (i.e) would require $\langle g(e), g(x), g(y) \rangle \in Pred_M(\text{call}) = \{\langle \varepsilon_0, a, b \rangle\}$. So $g(e) = \varepsilon_0$. But then '$e \subseteq t$' cannot be verified, by clause (i.a), because $Loc_M(g(e)) = Loc_M(\varepsilon_0) = \{i_2, i_3\} \not\subseteq g(t) = f(t) = \{i_5, i_6, i_7\}$.

  So K_7 has a ϕ_1-extending embedding which verifies it in $\langle M, \phi_1 \rangle$ (to wit f, by clause (ii)) and so is true in $\langle M, \phi_1 \rangle$ (by clause (iii)). u

- Diagram:

```
                                      ('PRS')
                                      φ1(n)
                         f(t)         f(n)
_____________________|||||||||||||||||||________|||||______________________
  i0   i1   i2   i3   i4   i5   i6   i7   i8   i9   i10  i11  i12  i13  i14  i15
           |----ε0---|
            ('call')
```

PROBLEM: Too easy to verify this DRS -- any anchored model where M. doesn't call non-stop prior to n will do!