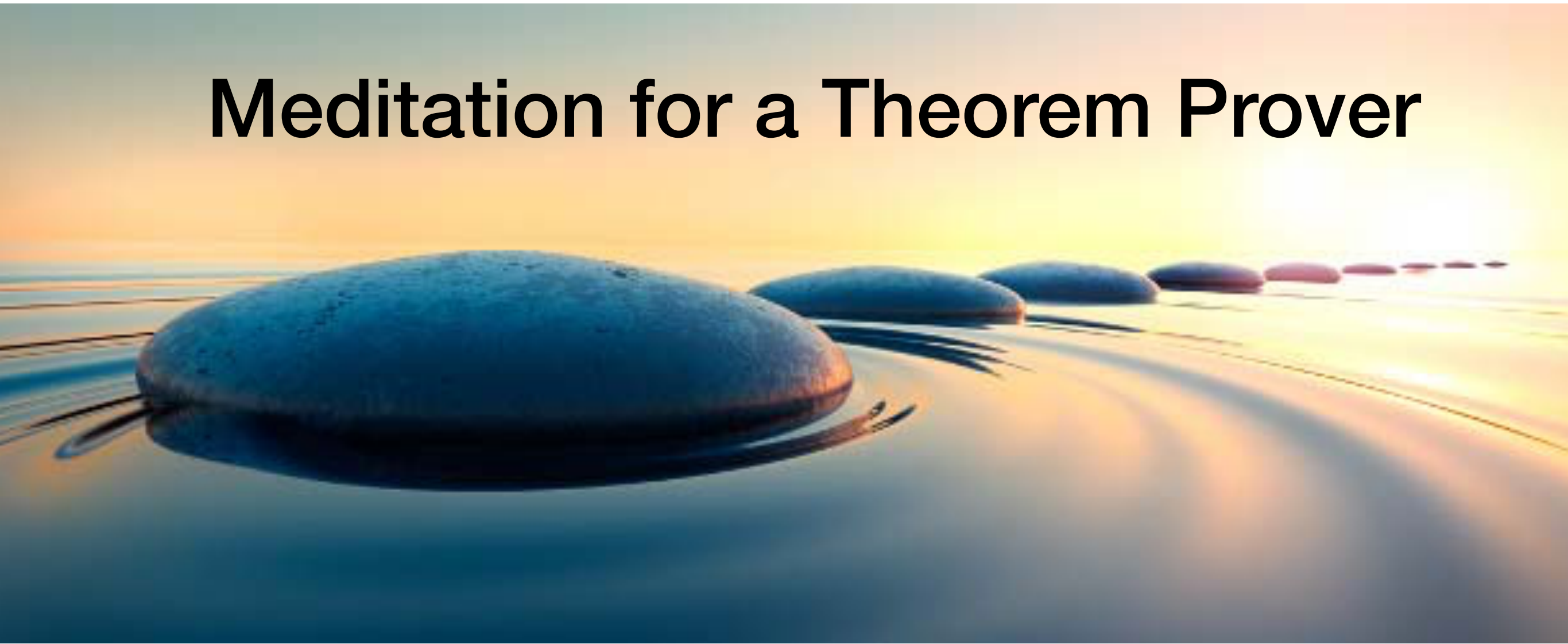


# Meditation for a Theorem Prover



# Reasoning and Consciousness

## Teaching a Theorem Prover to let its Mind Wander

Ulrich Furbach   Claudia Schon

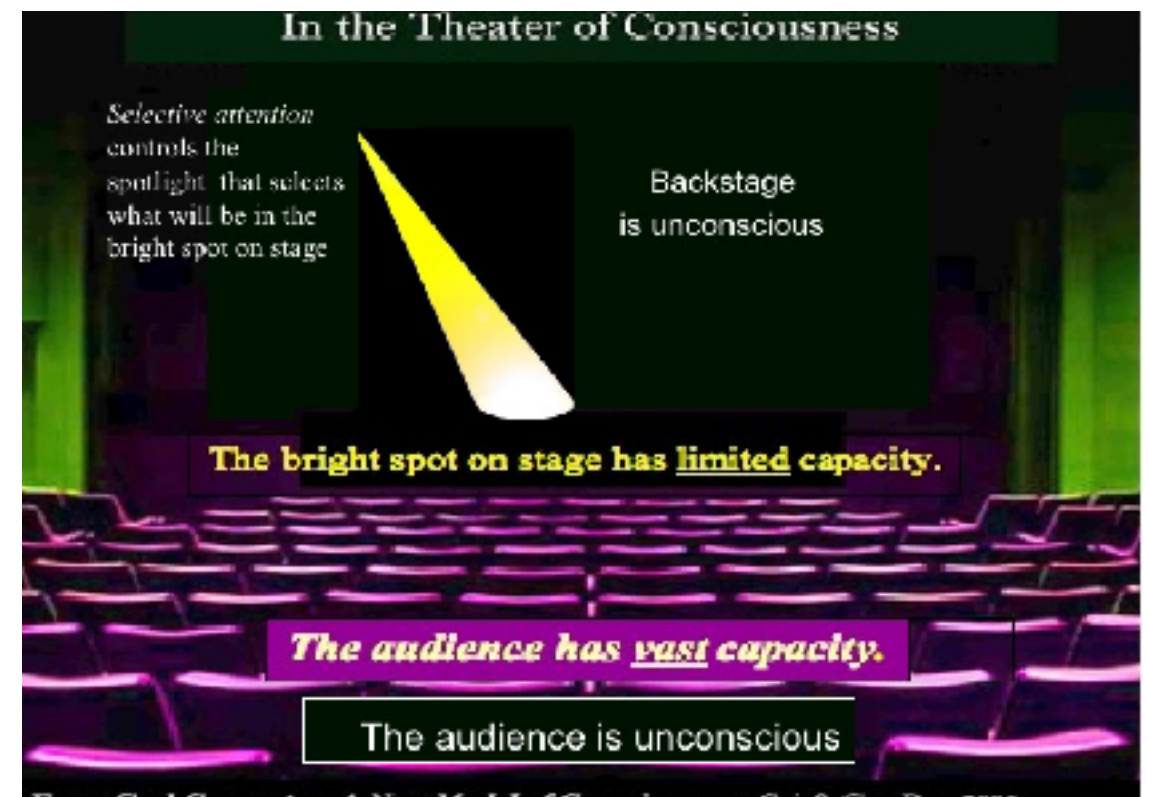
Univ. Koblenz - DFG Project ,Cognitive Reasoning‘

# Reasoning and Consciousness

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Ulrich Furbach   Claudia Schon

Univ. Koblenz - DFG Project ‚Cognitive Reasoning‘

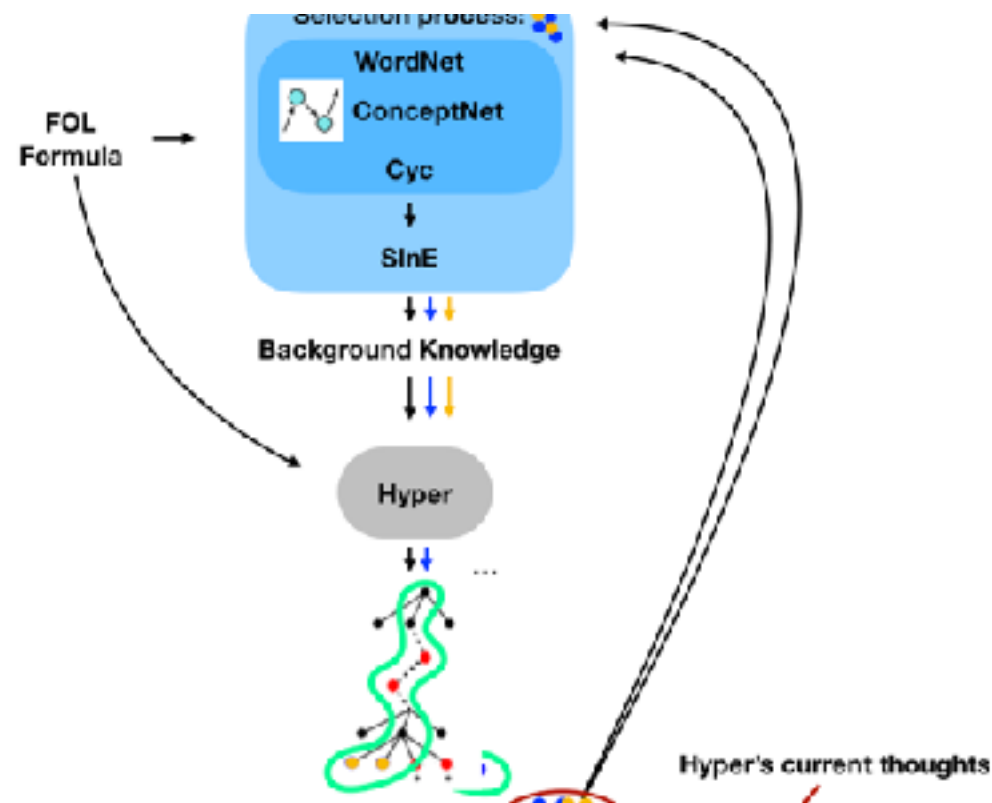


# Reasoning and Consciousness

## Teaching a Theorem Prover to let its Mind Wander

Ulrich Furbach Claudia Schon

Univ. Koblenz - DFG Project 'Cognitive Reasoning'



**My body cast a shadow over the grass. What was the CAUSE of this?**

**a) The sun was rising.**

**b) The grass was cut.**

COPA Benchmarks

**My body cast a shadow over the grass. What was the CAUSE of this?**

**a) The sun was rising.**

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Boxer

COPA Benchmarks

**My body cast a shadow over the grass. What was the CAUSE of this?**

**a) The sun was rising.**

**b) The grass was cut.**

COPA Benchmarks



Boxer

$$\begin{aligned} &\exists A, B((n1grass(A) \wedge n1sun(B)) \wedge \exists C, D, E((r1over(C, A) \wedge \\ &(r1Theme(C, D) \wedge (r1Actor(C, E) \wedge (v1cast(C) \wedge (n1shadow(D) \wedge \\ &(n1body(E) \wedge (r1of(E, D) \wedge n1person(D)))))))) \wedge \\ &\exists F((r1Actor(F, B) \wedge v1rise(F)) \wedge \exists G(r1Theme(G, A) \wedge v1cut(G)))) \end{aligned}$$

FO-representation  
of COPA problem:

$\exists A, B((n1grass(A) \wedge n1sun(B)) \wedge \exists C, D, E, G(r1lover(C, A) \wedge$   
 $(r1Theme(C, G) \wedge (r1Actor(C, E) \wedge (v1cast(C, D) \wedge (n1shado$   
 $(n1body(E) \wedge r1of(E, D) \wedge n1grass(B) \wedge$   
 $\exists F((r1Actor(F, D) \wedge v1isc(1)) \wedge \exists G(r1Theme(G, A) \wedge v1$

*v1cast(D)*

Background  
Knowledge:

OpenCyc

*project(X)*



## WordNet Search - 3.1

- [WordNet home page](#) - [Glossary](#) - [Help](#)

Word to search for:

Display Options:

Key: "S:" = Show Synset (semantic) relations, "W:" = Show Word (lexical) relations  
Display options for sense: (gloss) "an example sentence"

### Noun

- [S:](#) (n) **cast**, [cast of characters](#), [dramatis personae](#) (the actors in a play)
- [S:](#) (n) [mold](#), [mould](#), **cast** (container into which liquid is poured to create a given shape when it hardens)
- [S:](#) (n) **cast**, [mold](#), [mould](#), [stamp](#) (the distinctive form in which a thing is made) *"pottery of this cast was found throughout the region"*
- [S:](#) (n) [form](#), [shape](#), **cast** (the visual appearance of something or someone) *"the delicate cast of his features"*
- [S:](#) (n) **cast**, [plaster cast](#), [plaster bandage](#) (bandage consisting of a firm covering (often made of plaster of Paris) that immobilizes broken bones while they heal)
- [S:](#) (n) **cast**, [casting](#) (object formed by a mold)
- [S:](#) (n) **cast**, [roll](#) (the act of throwing dice)
- [S:](#) (n) [casting](#), **cast** (the act of throwing a fishing line out over the water by means of a rod and reel)
- [S:](#) (n) [hurl](#), **cast** (a violent throw)

### Verb

- [S:](#) (v) [project](#), **cast**, [contrive](#), [throw](#) (put or send forth) *"She threw the flashlight beam into the corner"; "The setting sun threw long shadows"; "cast a spell"; "cast a warm light"*

# Bridging Formulae

$$\forall X(v1cast(X) \leftrightarrow project(X))$$

# WordNet

FO-representation  
of COPA problem:

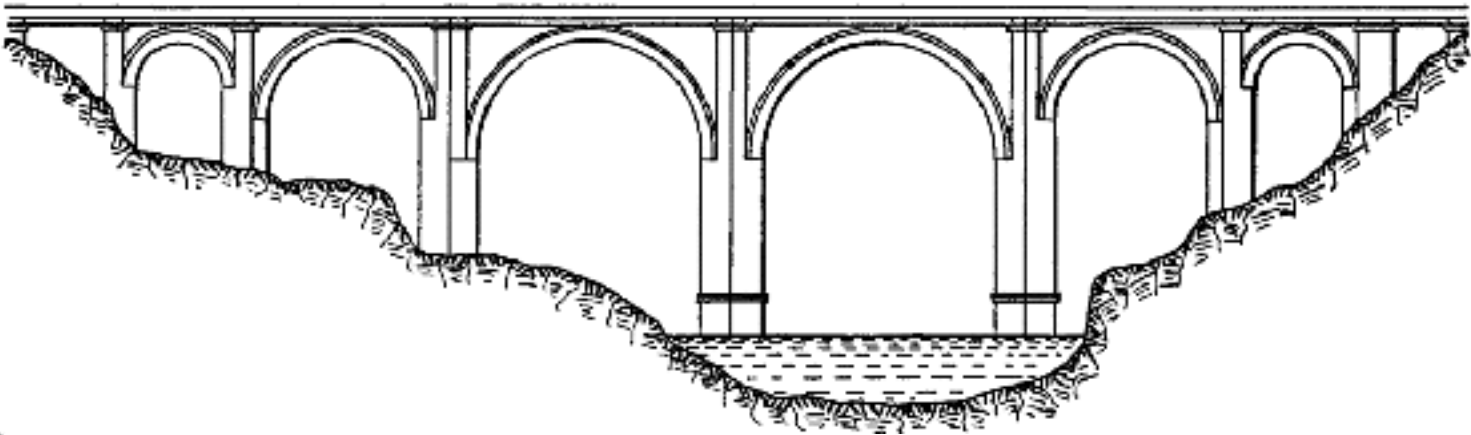
$\exists A, B((n1grass(A) \wedge n1sun(B)) \wedge \exists C, D, E, F(r1lover(C, A) \wedge$   
 $(r1Theme(C, E) \wedge (r1Actor(C, E) \wedge (v1cast(C) \wedge (n1shado$   
 $(n1body(E) \wedge (r1of(E, D) \wedge n1grass(D) \wedge$   
 $\exists F((r1Actor(C, D) \wedge v1isc(17)) \wedge \exists G(r1th(G, A) \wedge v1$

*v1cast(D)*

Background  
Knowledge:

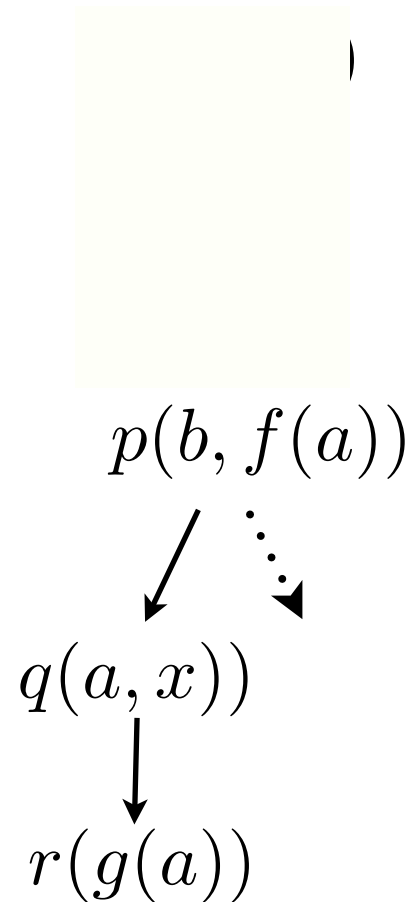
OpenCyc

*project(X)*



# Hypertableau 1st order

Cade 07



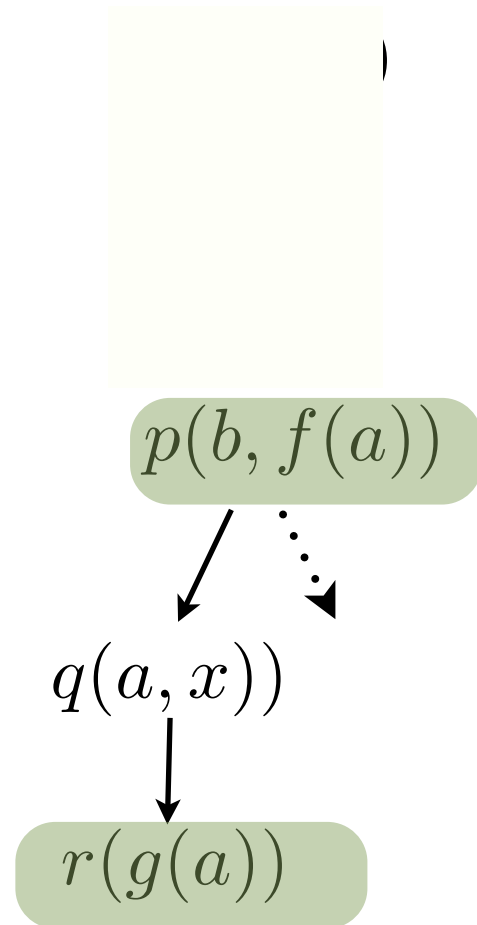
$$p(z, f(a)) \wedge r(g(a)) \rightarrow p(x, y) \vee q(f(x), z)$$

no backtracking

branches can be considered  
isolated - equality handling!

# Hypertableau 1st order

Cade 07



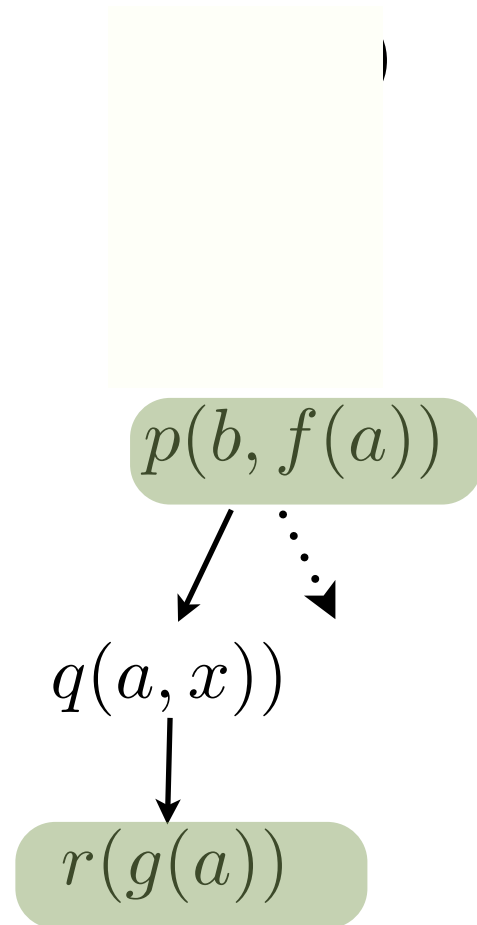
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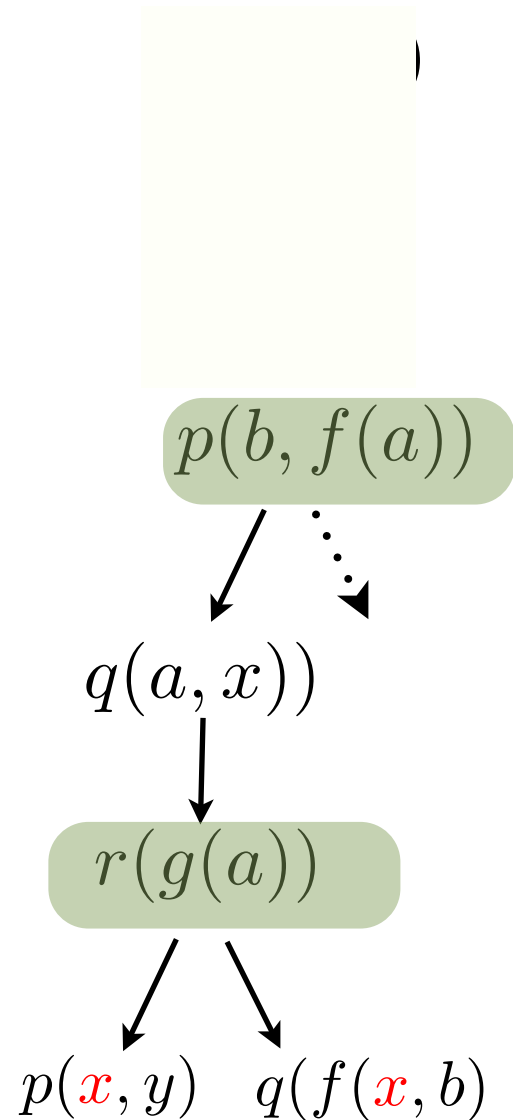
$$\downarrow \sigma = \{z \leftarrow b\}$$

$$p(b, f(a)) \wedge r(g(a)) \rightarrow p(x, y) \vee q((f(x), b)$$

branches can be considered  
isolated - equality handling!

# Hypertableau 1st order

Cade 07



no backtracking

$$p(z, f(a)) \wedge r(g(a)) \rightarrow p(x, y) \vee q((f(x), z)$$

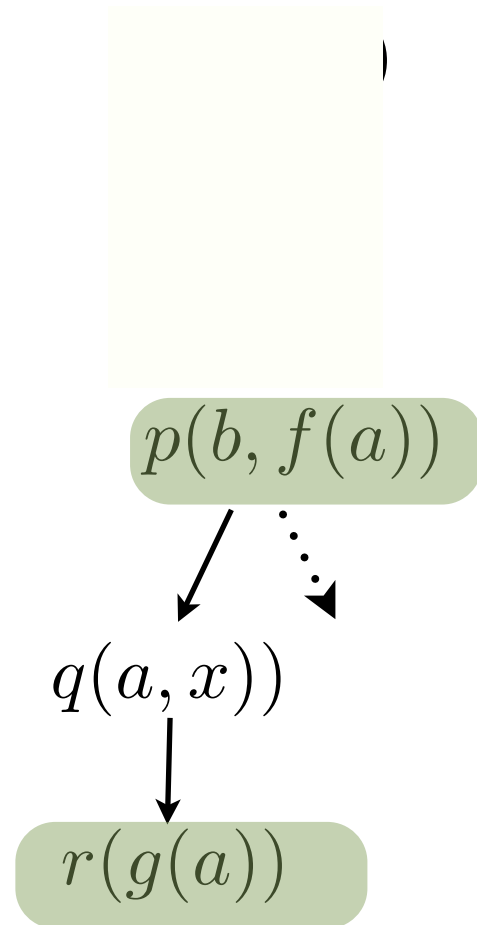
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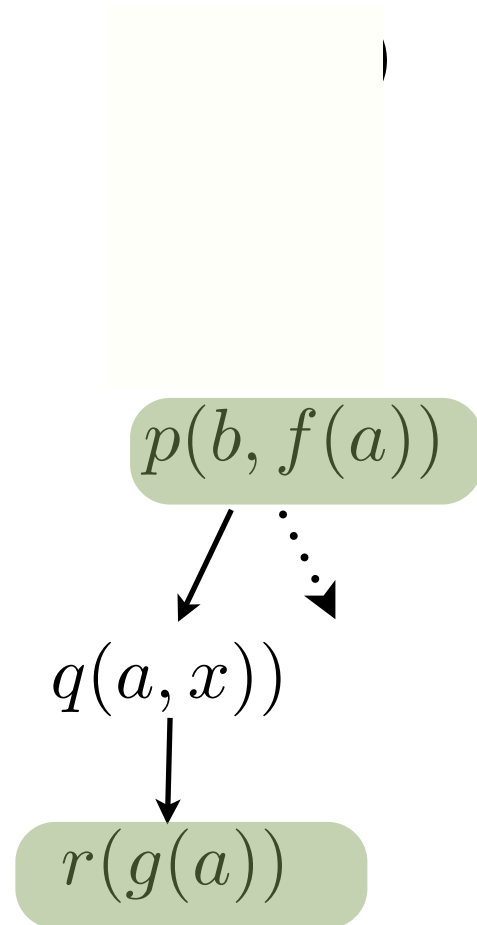
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# Hypertableau 1st order

Cade 07



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$$\downarrow \sigma = \{z \leftarrow b\}$$

$$p(b, f(a)) \wedge r(g(a)) \rightarrow p(x, y) \vee q((f(x), b)$$

$$\pi = \{x \leftarrow a\}$$

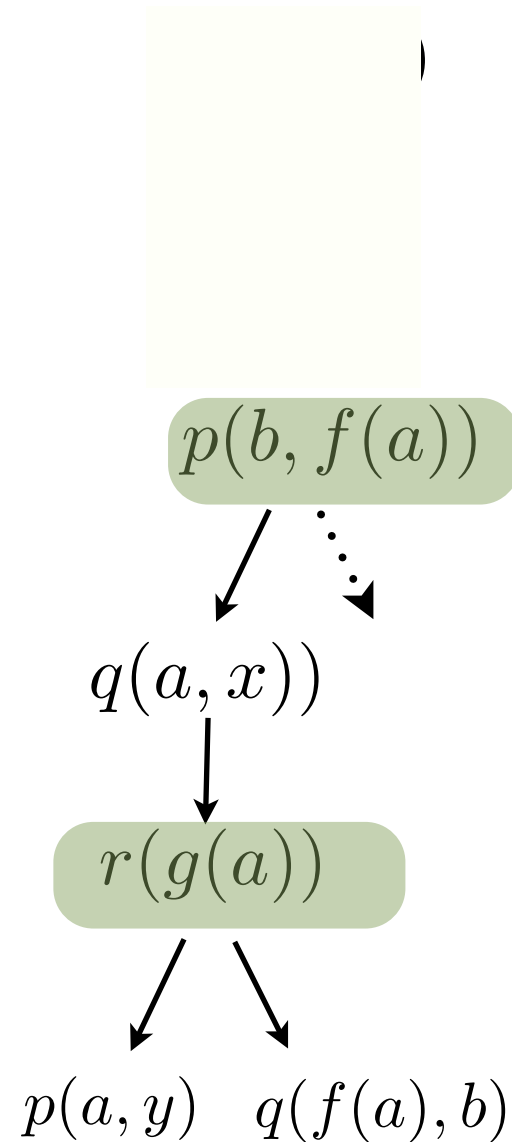
no backtracking

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# Hypertableau 1st order

Cade 07



no backtracking

$$p(z, f(a)) \wedge r(g(a)) \rightarrow p(x, y) \vee q((f(x), z)$$

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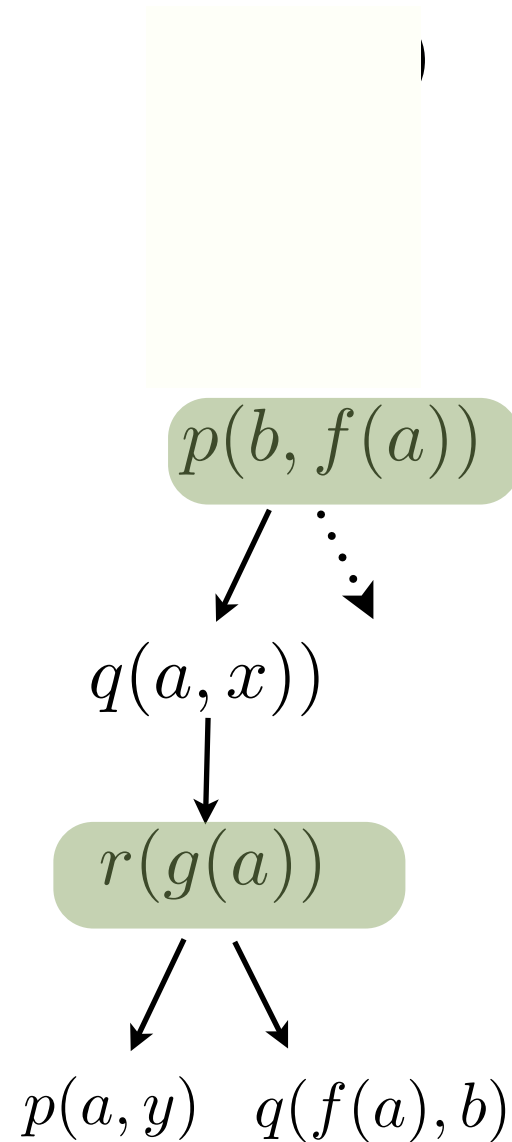
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$$p(z, f(a)) \wedge r(g(a)) \rightarrow p(x, y) \vee q((f(x), z)$$

$$\downarrow \sigma = \{z \leftarrow b\}$$

$$p(b, f(a)) \wedge r(g(a)) \rightarrow p(x, y) \vee q((f(x), b)$$

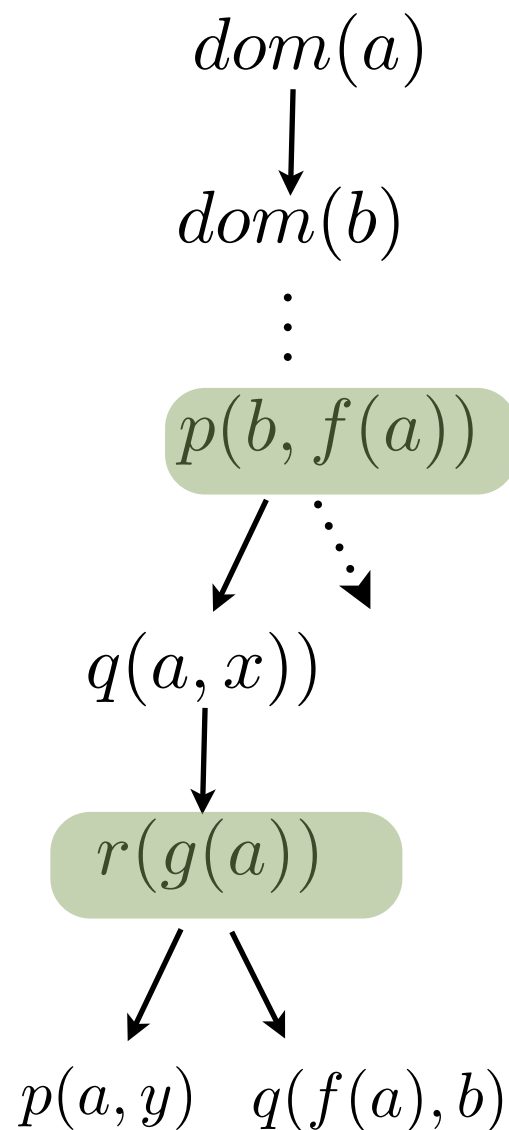
$$\pi = \{x \leftarrow a\}$$

$$\rightarrow dom(a) \quad dom(a) \rightarrow dom(f(a))$$

branches can be considered  
isolated - equality handling!

# Hypertableau 1st order

Cade 07



no backtracking

$$p(z, f(a)) \wedge r(g(a)) \rightarrow p(x, y) \vee q((f(x), z)$$

$$\downarrow \sigma = \{z \leftarrow b\}$$

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$$\pi = \{x \leftarrow a\}$$

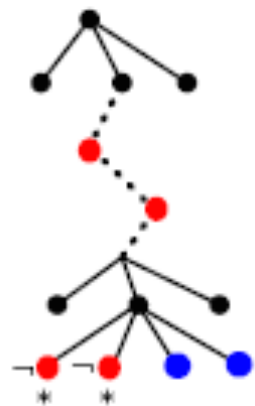
$$\rightarrow dom(a) \quad dom(a) \rightarrow dom(f(a))$$

branches can be considered  
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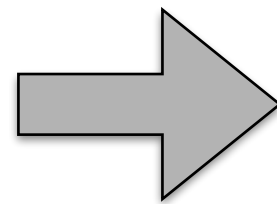
**My body cast a shadow over the grass. What was the CAUSE of this?**

**a) The sun was rising.**

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Hyper  
Tableau

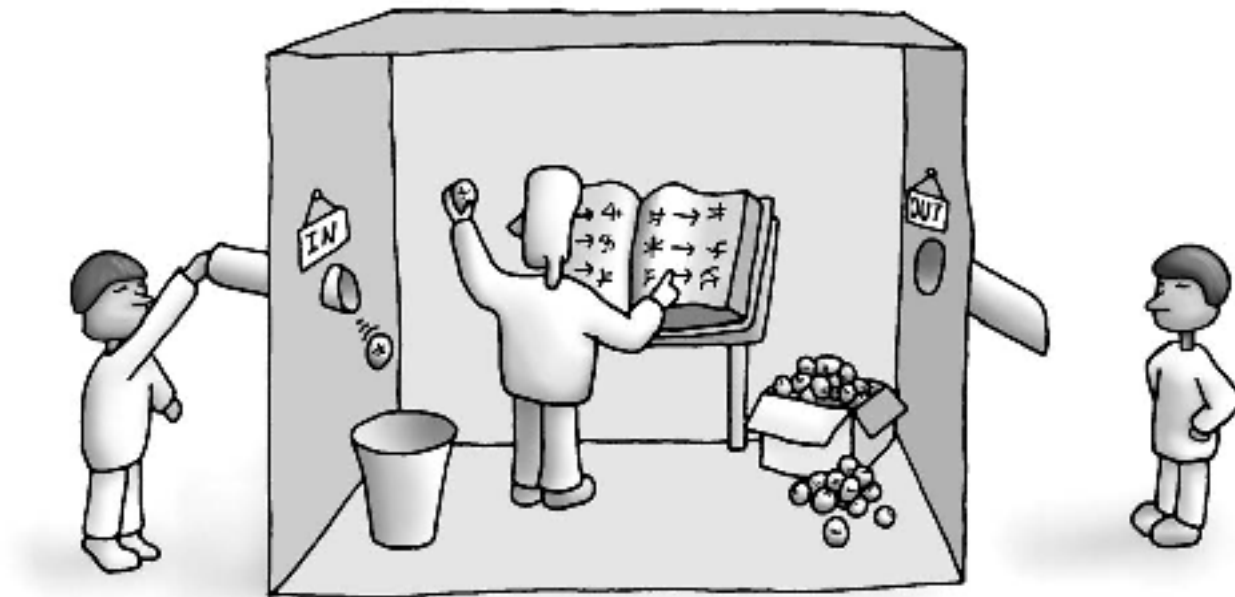


ML

What is 'closer'  
to a logical  
consequence?  
a) or b)?

a)!

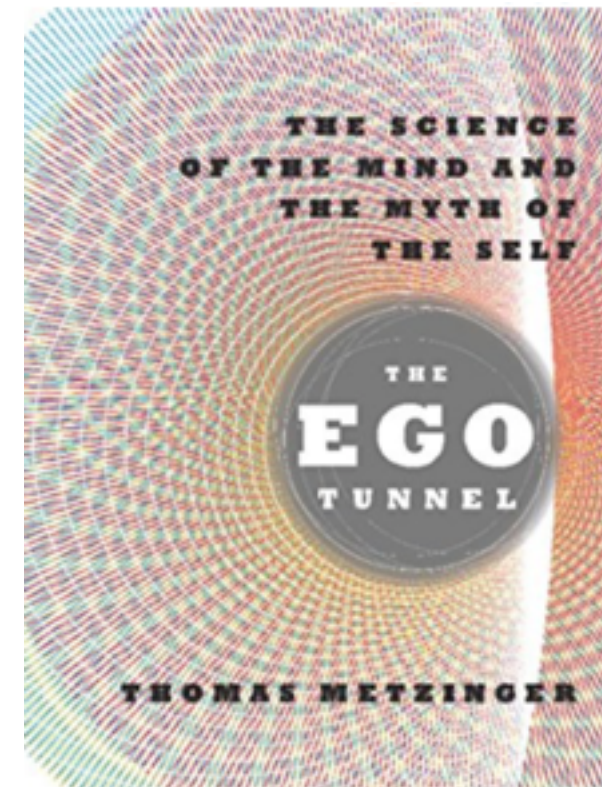
# Chinese Room - John Searl



jolyon.co.uk

## Thomas Metzinger

Postbiotic consciousness



# Bernhard Baars

- Global Workspace Theorie
- Theatre metaphor





# Bernhard Baars

- Global Workspace Theorie
- Theatre metaphor
- Consciousness is a gateway to vast domains of knowledge and control
- we can create access to any part of the brain using consciousness



# Bernhard Baars

- Global Workspace Theorie
- Theatre metaphor
- Consciousness is a gateway to vast domains of knowledge and control
- we can create access to any part of the brain using consciousness

**„Consciousness may be considered as the gateway to these unconscious sources of knowledge.“**





# Bernhard Baars

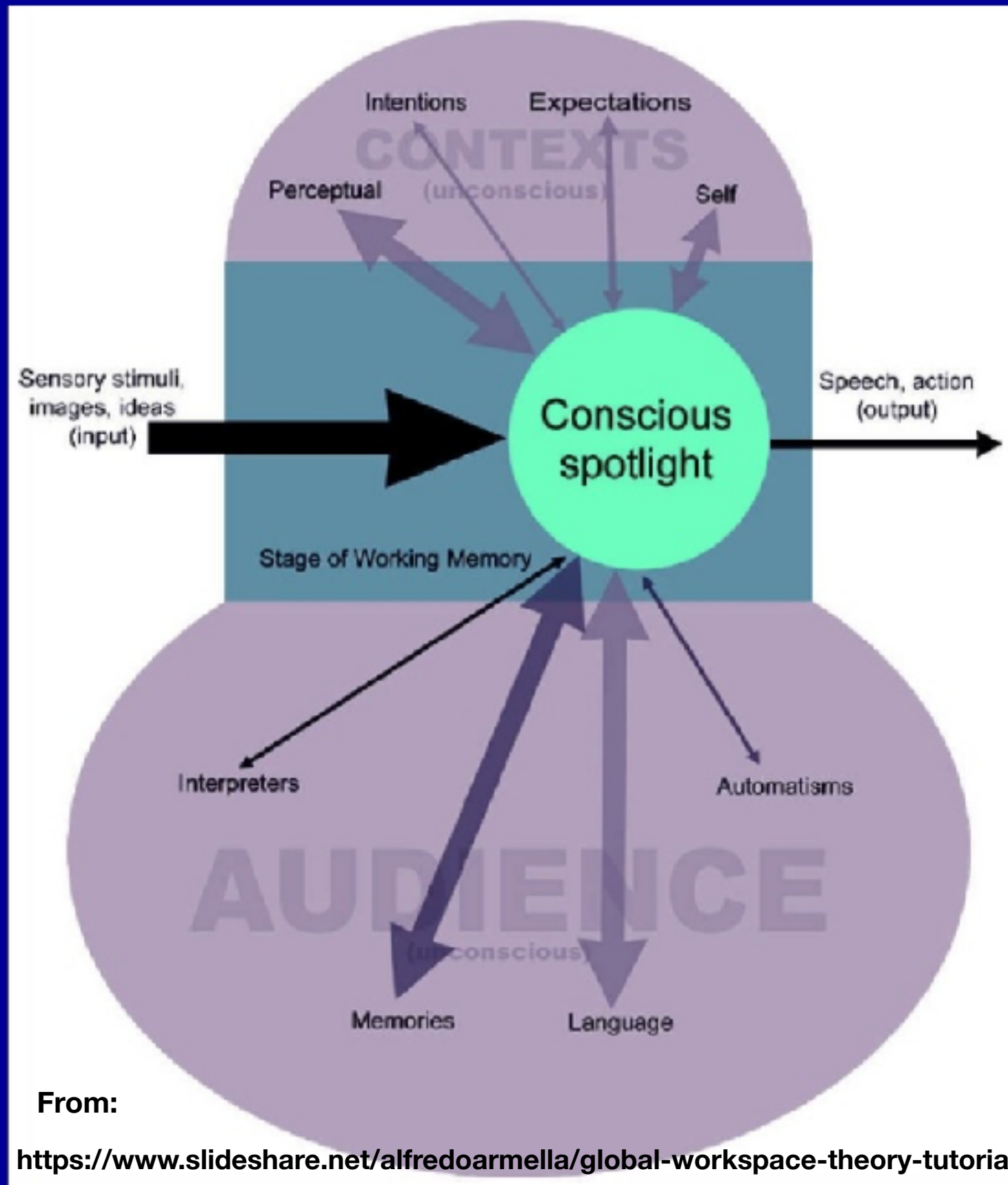
- Global Workspace Theorie
- Theatre metaphor
- Consciousness is a gateway to vast domains of knowledge and control
- we can create access to any part of the brain using consciousness

**„Consciousness may be considered as the gateway to these unconscious sources of knowledge.“**



„This is ostensibly based on GWT, but the idea is easily understood without the psycho-babble. The work is very suitable for the AITP workshop.“

# In the Theater of Consciousness - a useful theoretical metaphor



From:

<https://www.slideshare.net/alfredoarmella/global-workspace-theory-tutorial>

--- only the bright spot on stage is conscious (because consciousness is very limited in capacity)

--- sensory inputs compete for access to the conscious bright spot; so do output plans;

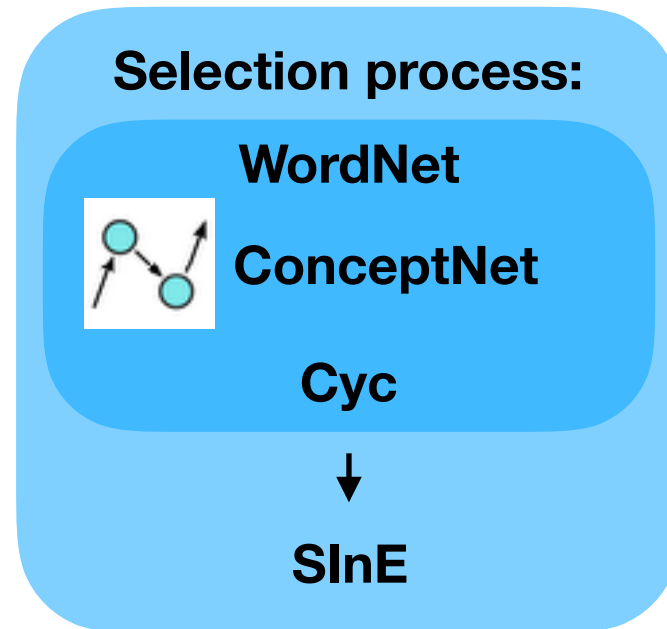
--- the "theater stage" corresponds to Working Memory;

--- all other parts are unconscious, including longterm memory, the automatic processes of language, and events going on backstage. (The capacity of unconsciousness is enormous.)

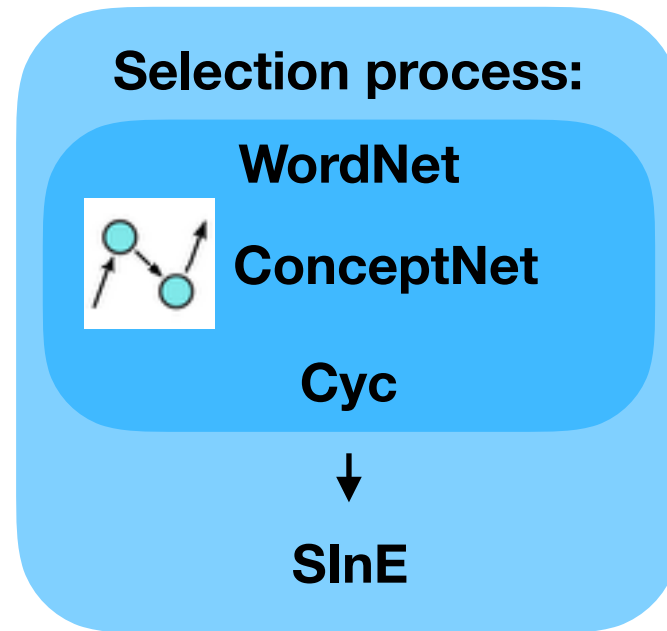
-- the theater metaphor has been turned into several testable models?

**FOL**  
**Formula**

**FOL  
Formula**



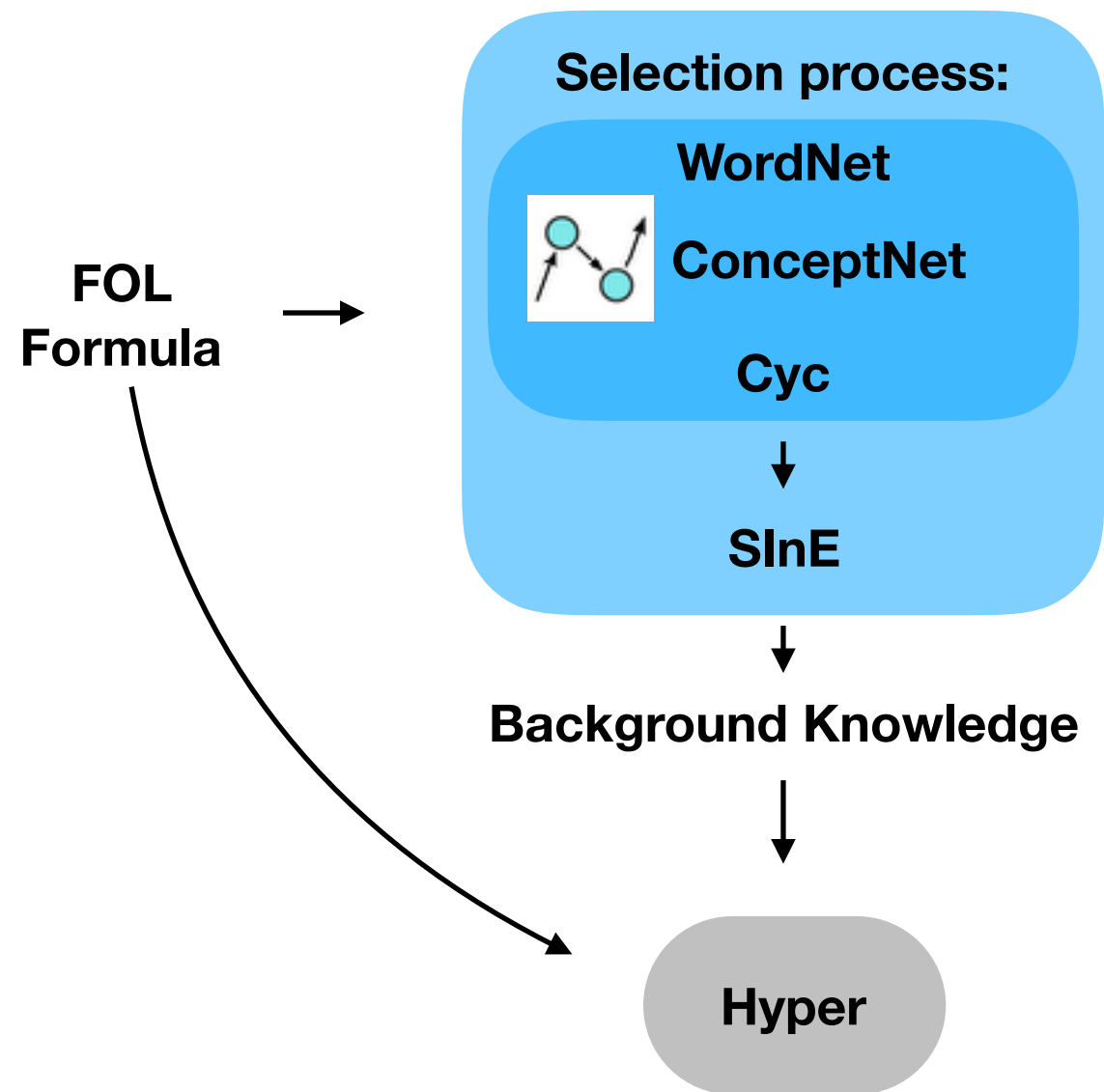
**FOL  
Formula**

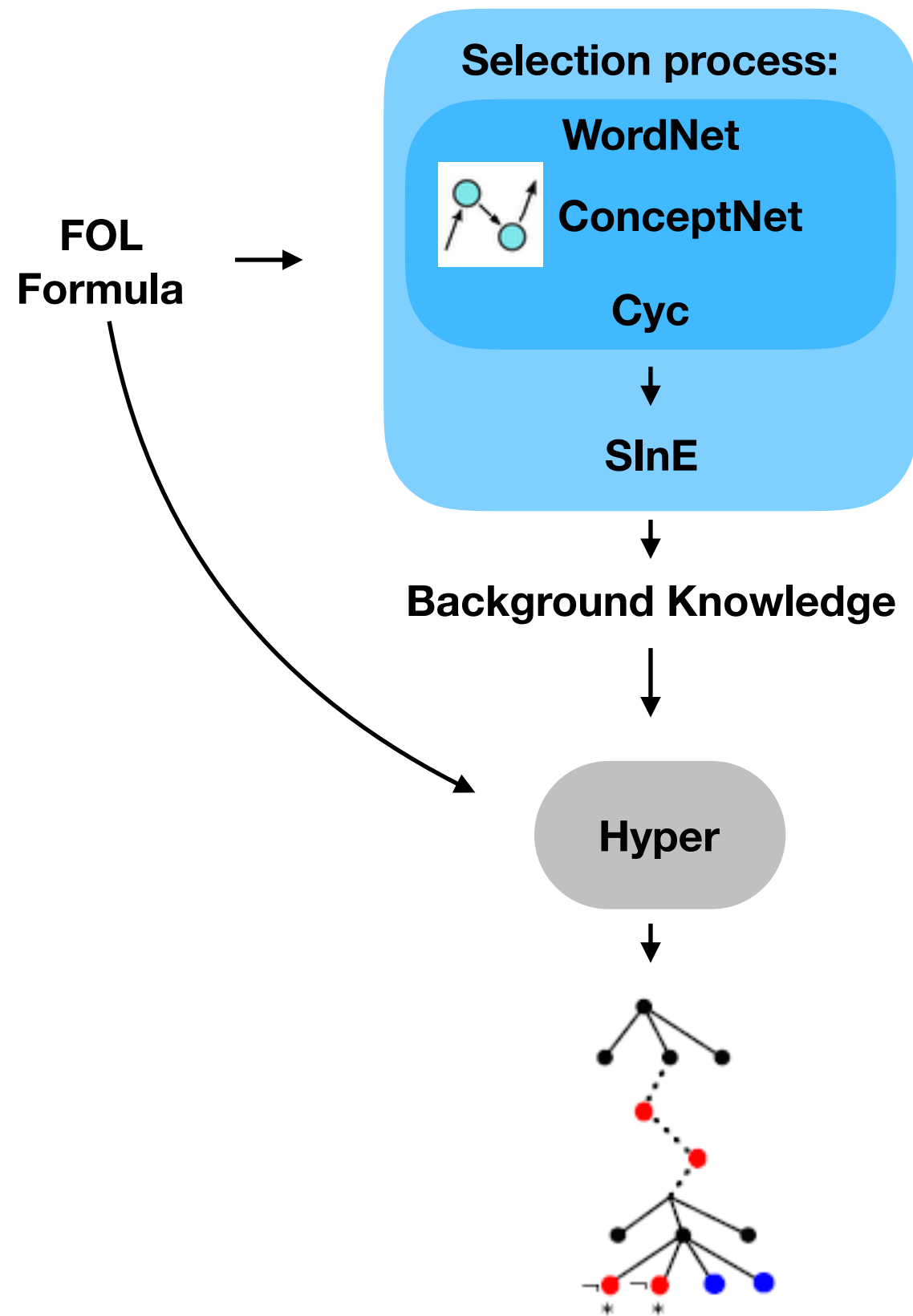


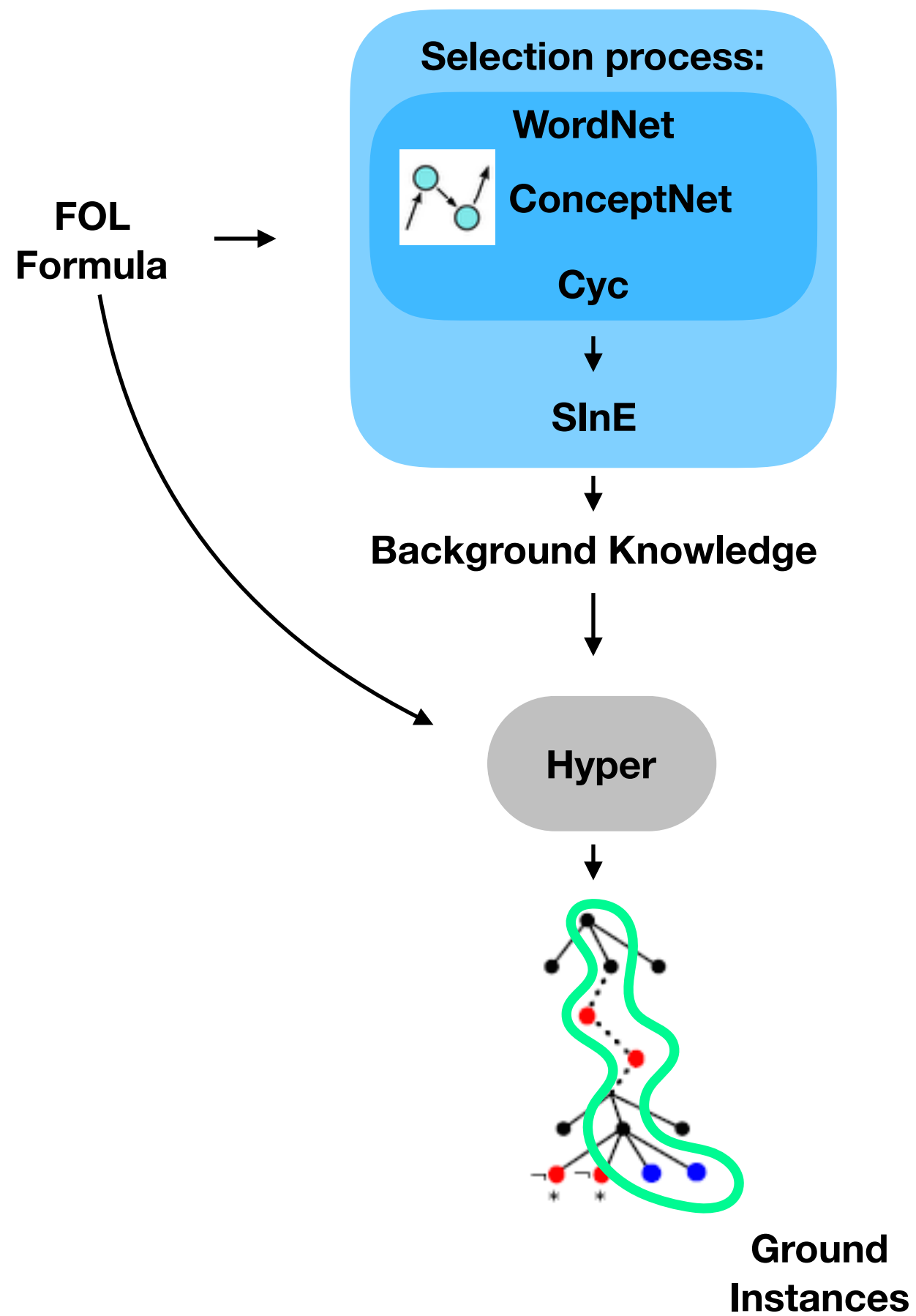
**SInE**



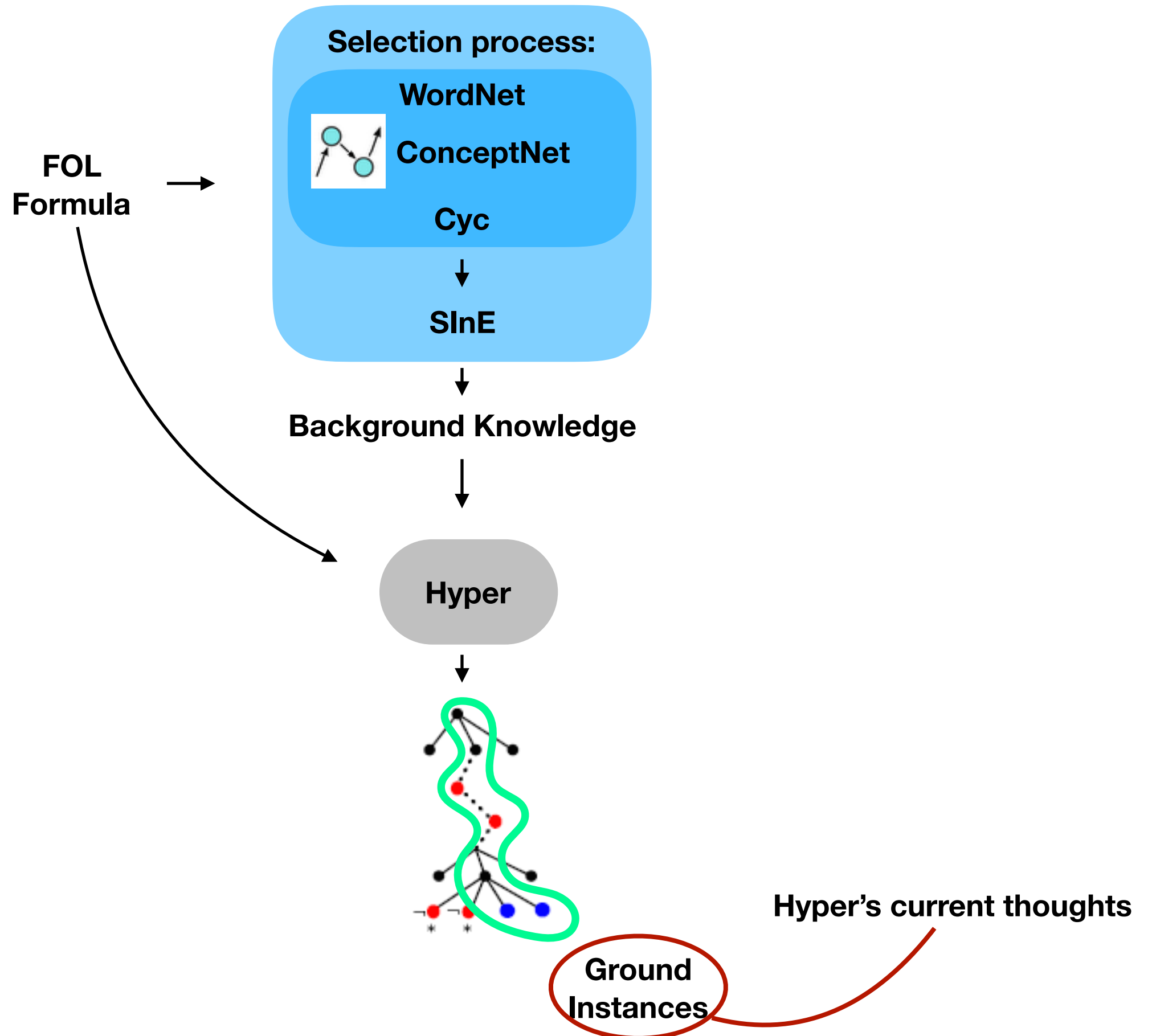
**Background Knowledge**

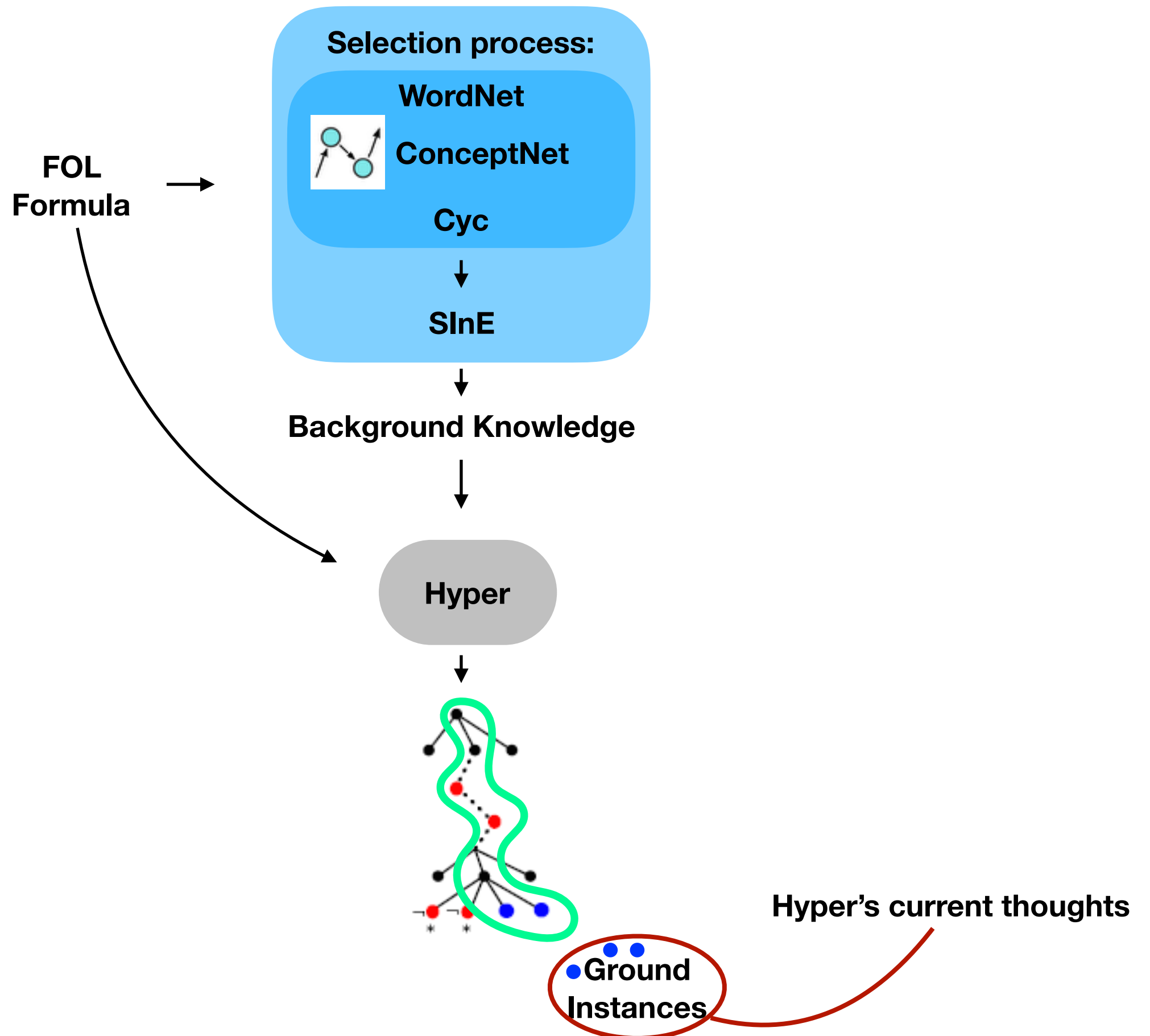


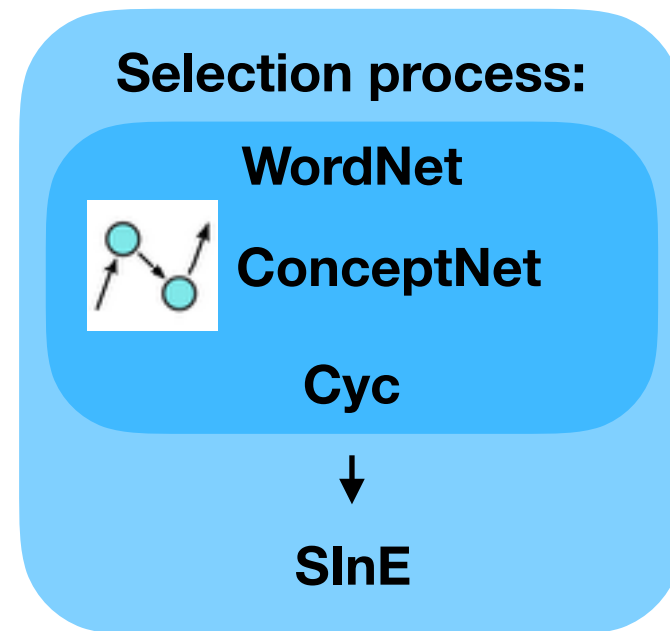




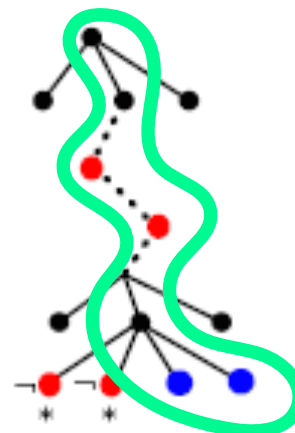




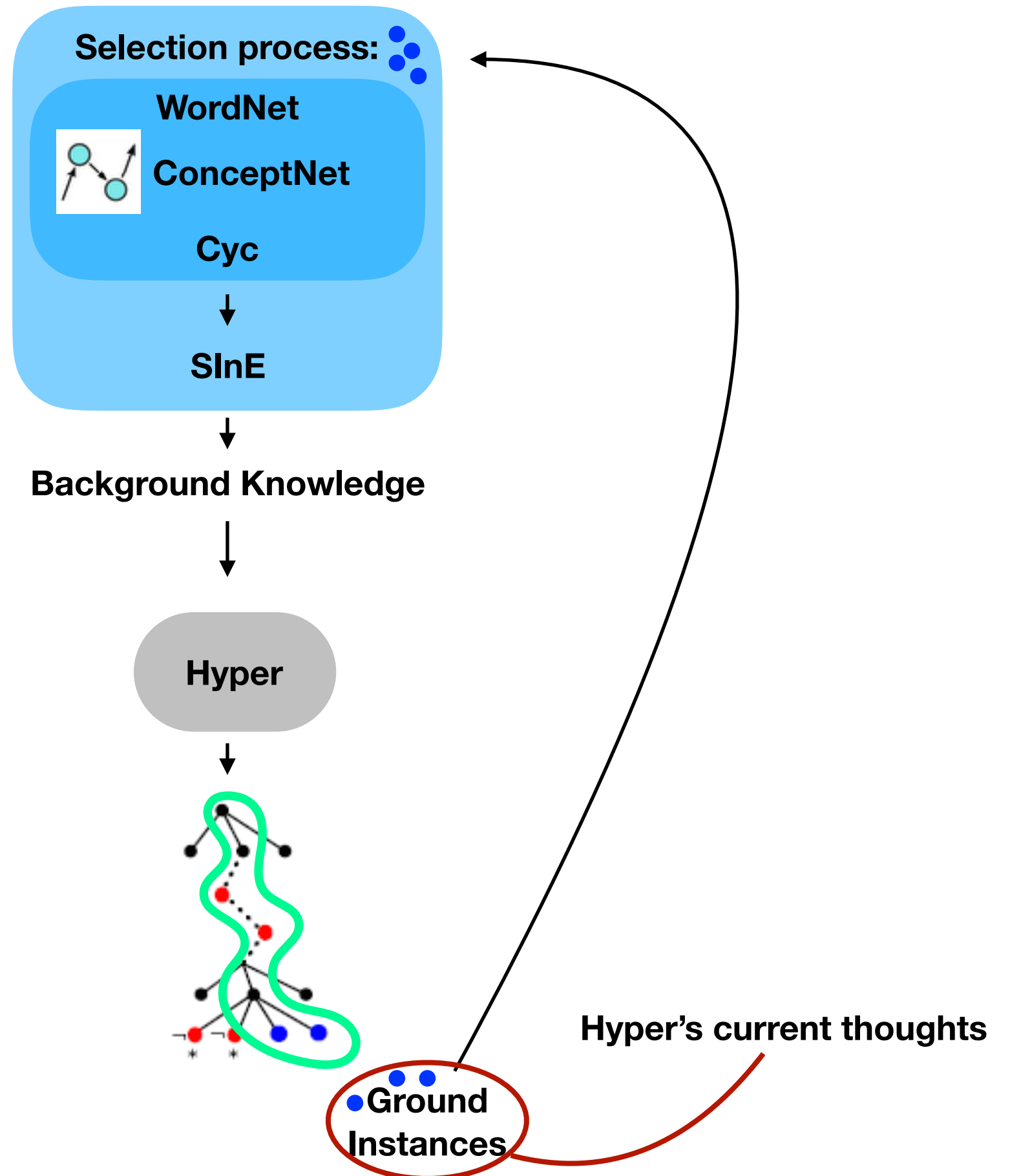


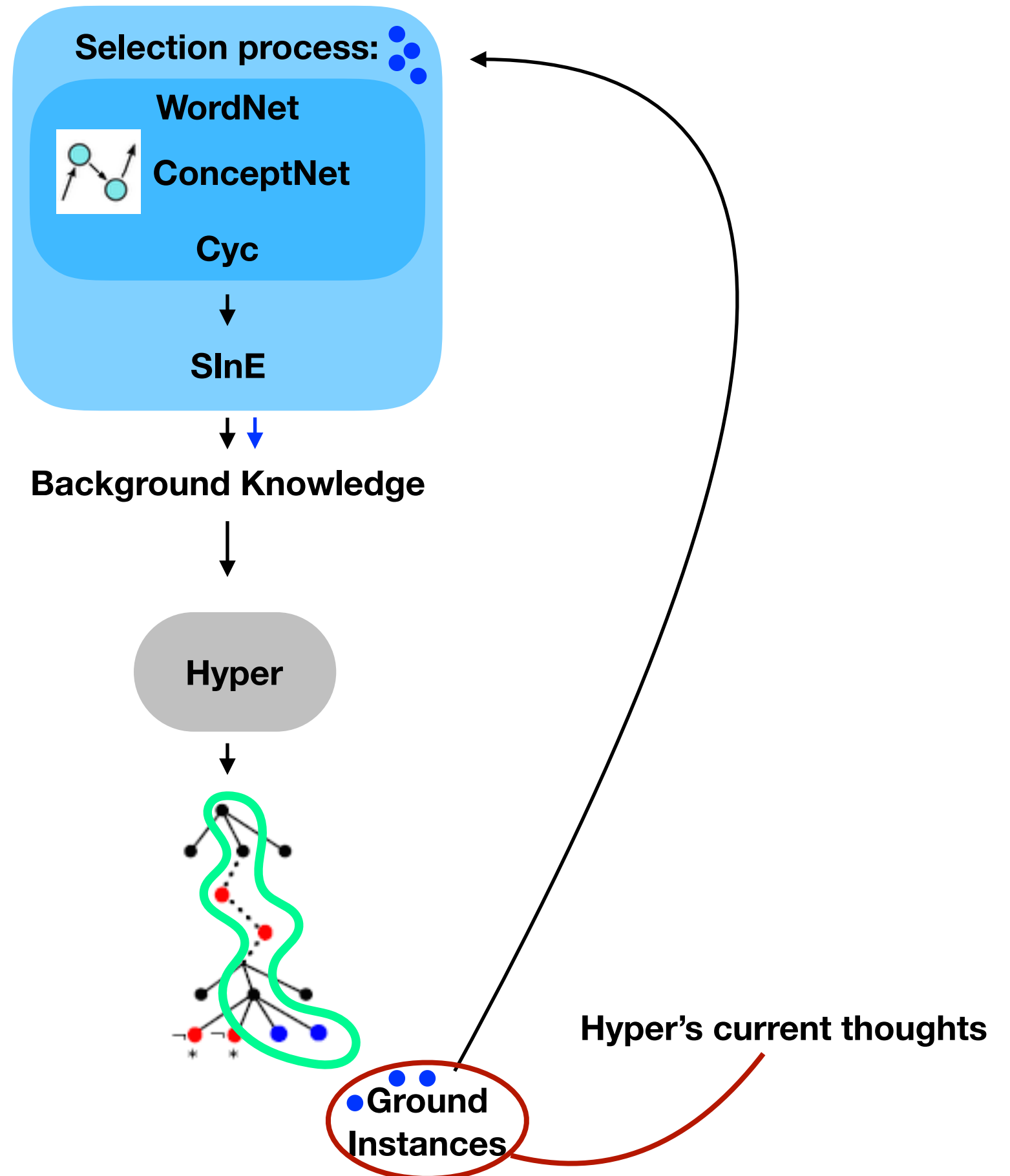


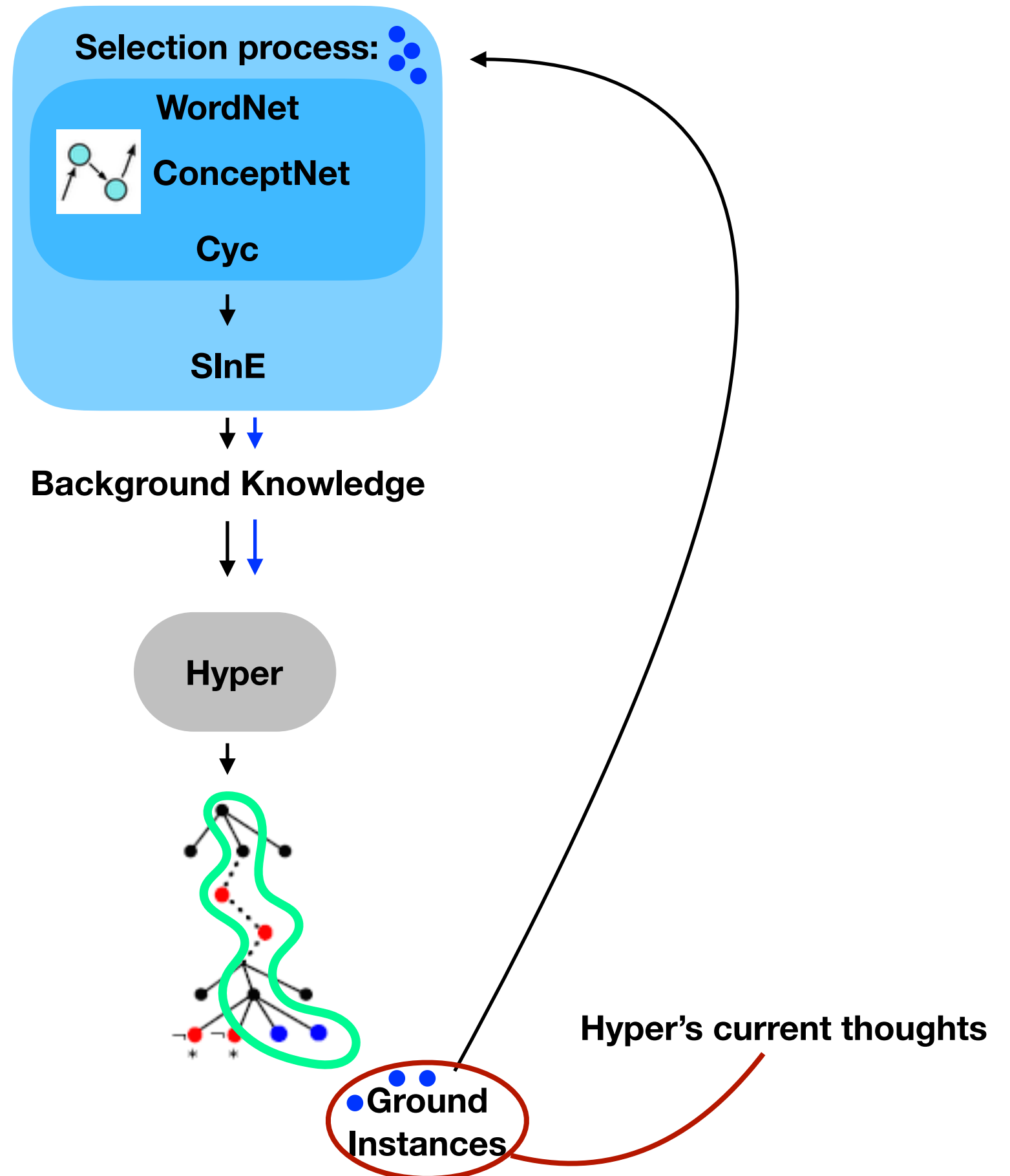
**Background Knowledge**

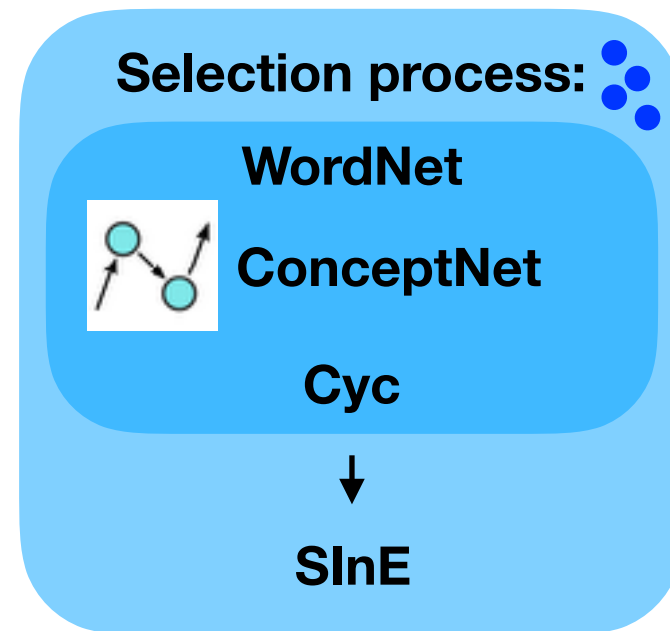


**Hyper's current thoughts**





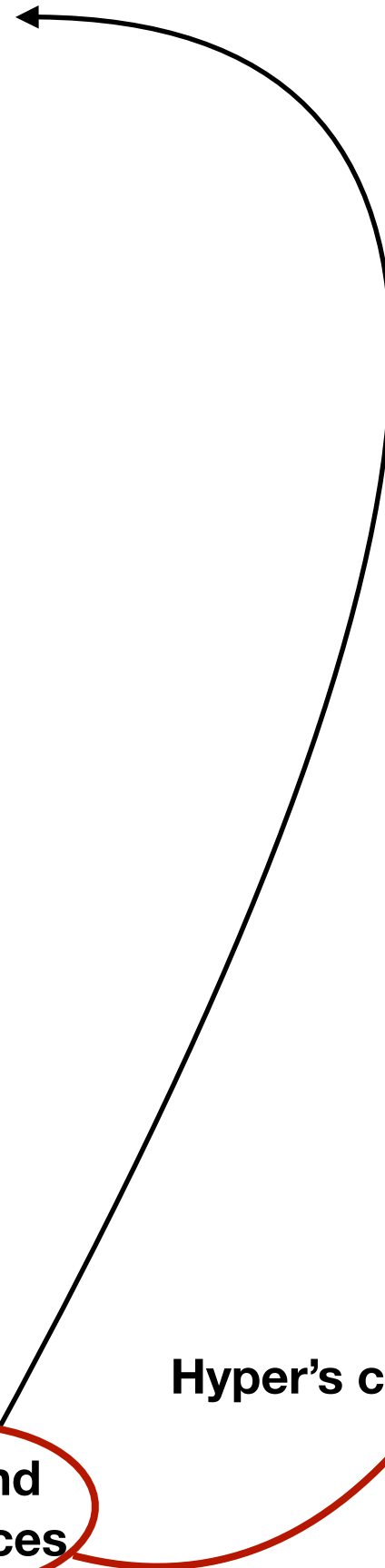


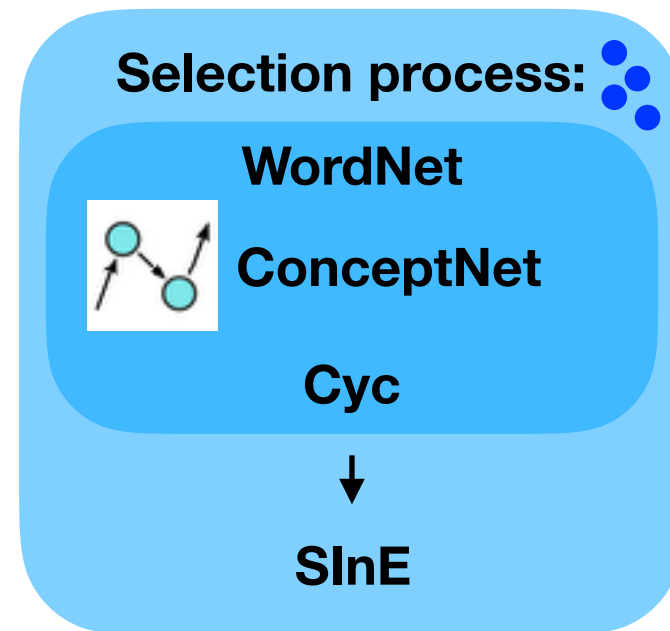


**Background Knowledge**

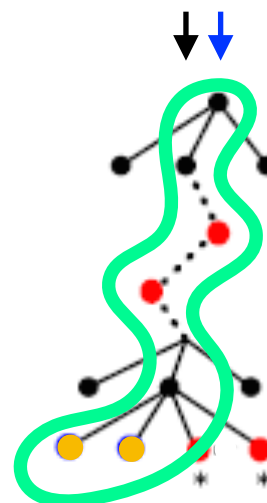


**Hyper's current thoughts**

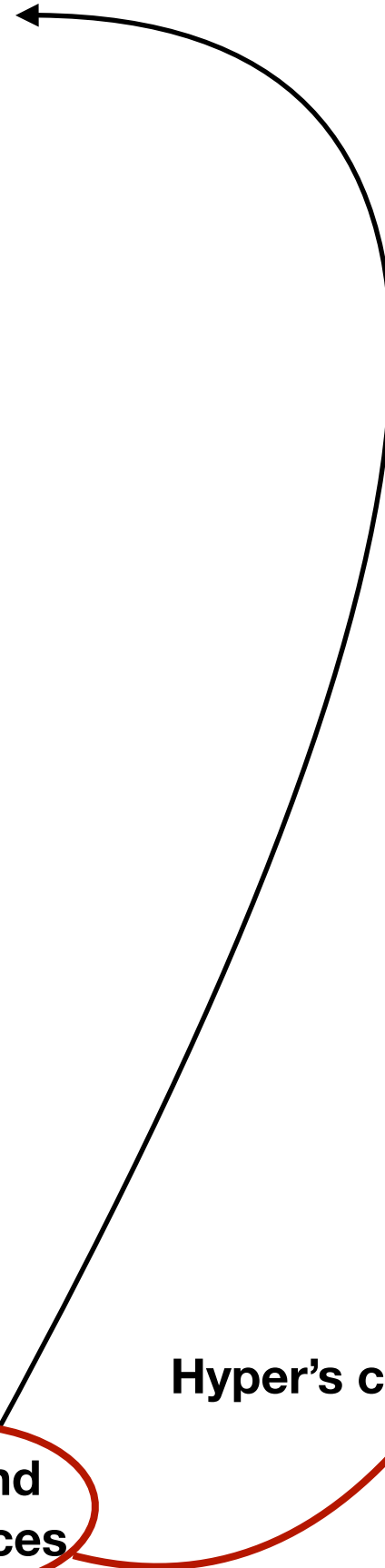




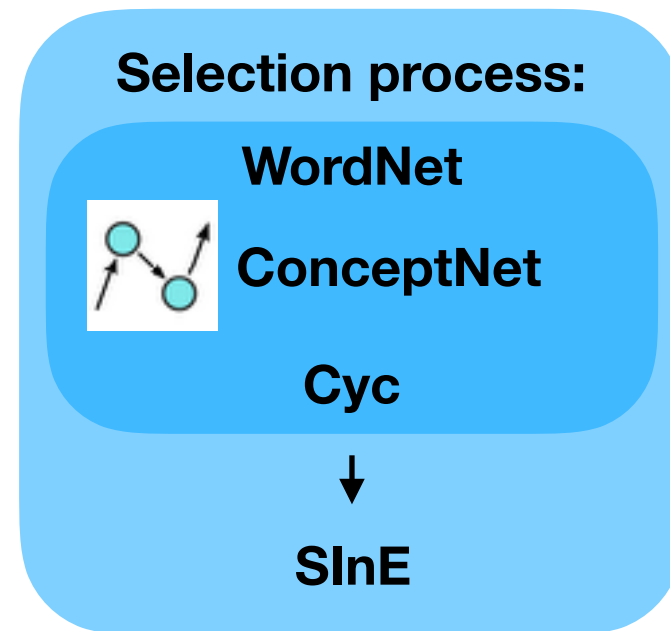
**Background Knowledge**



**Hyper's current thoughts**

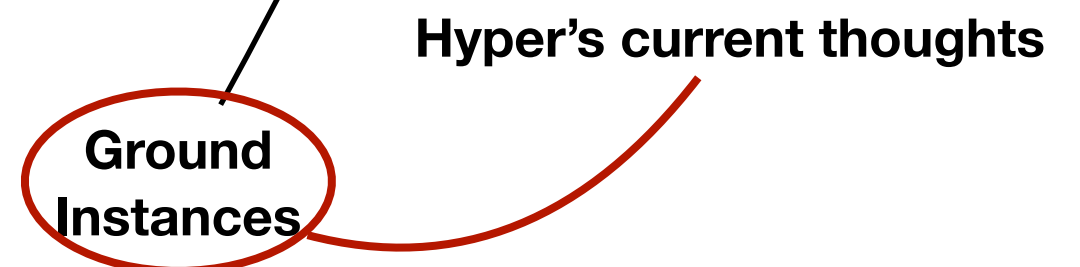
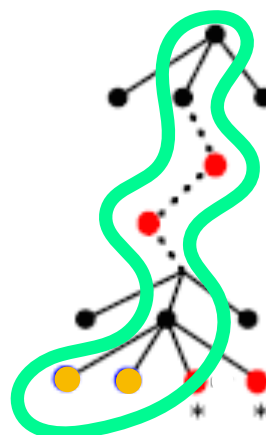


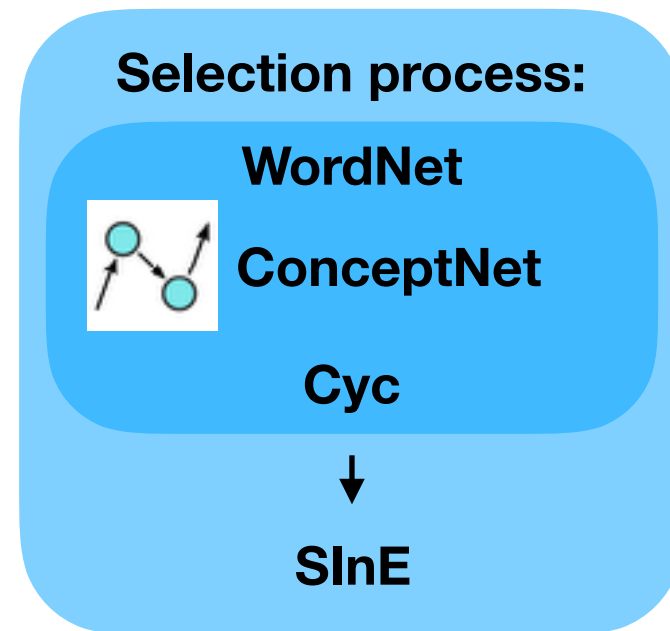




↓ ↓

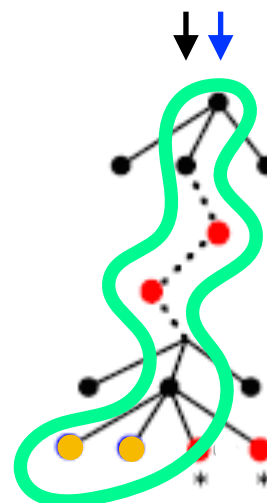
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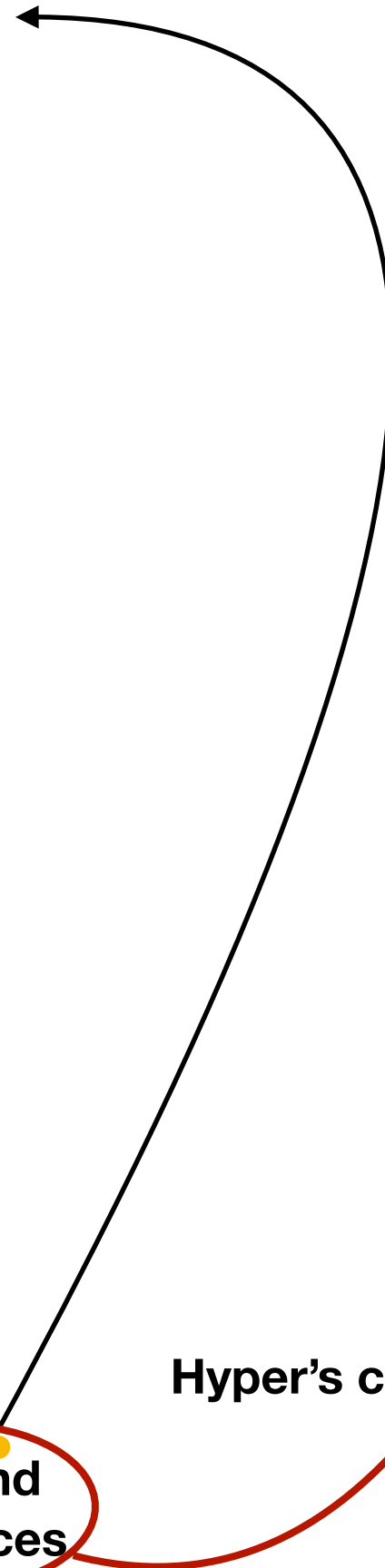


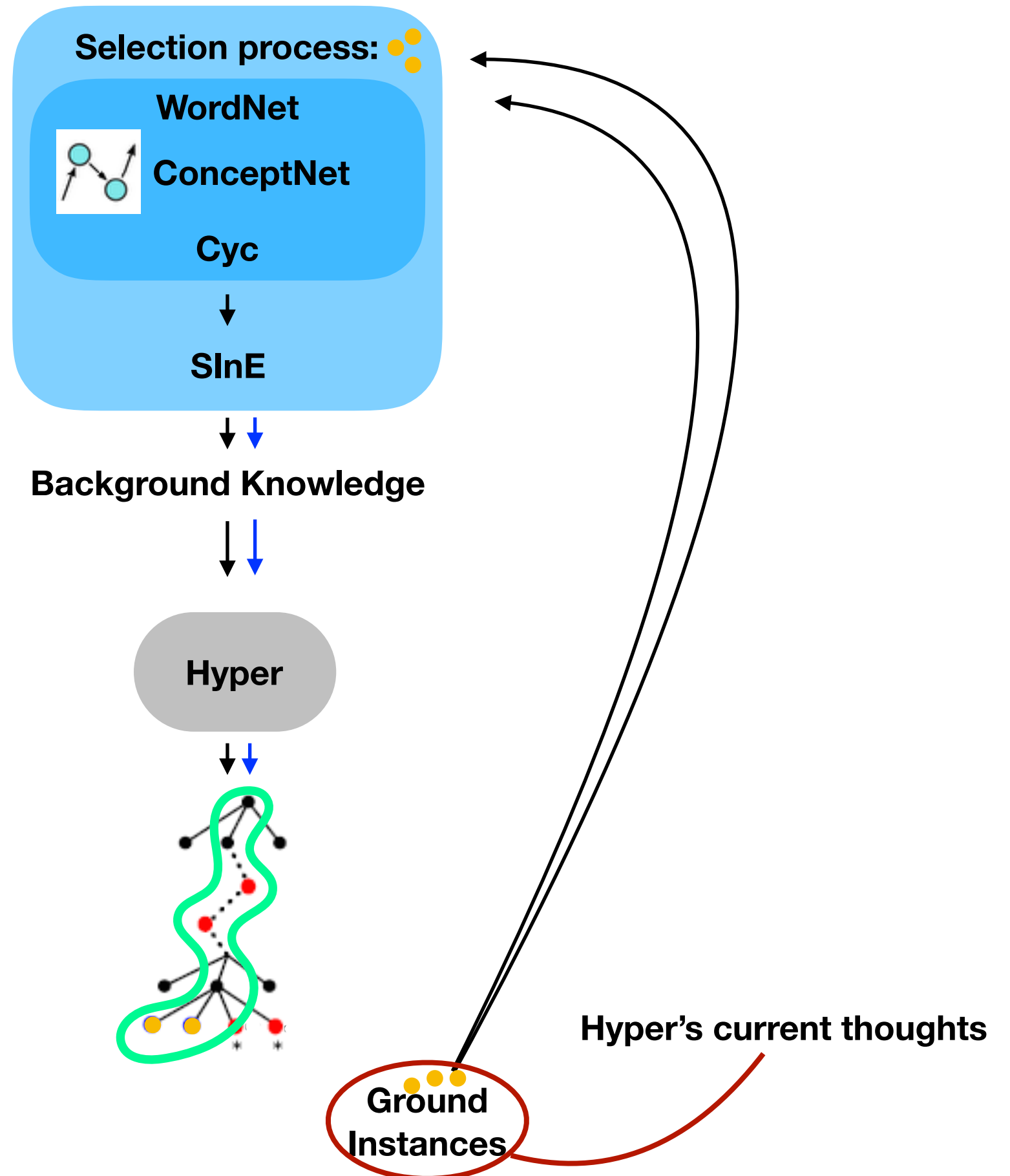
↓ ↓

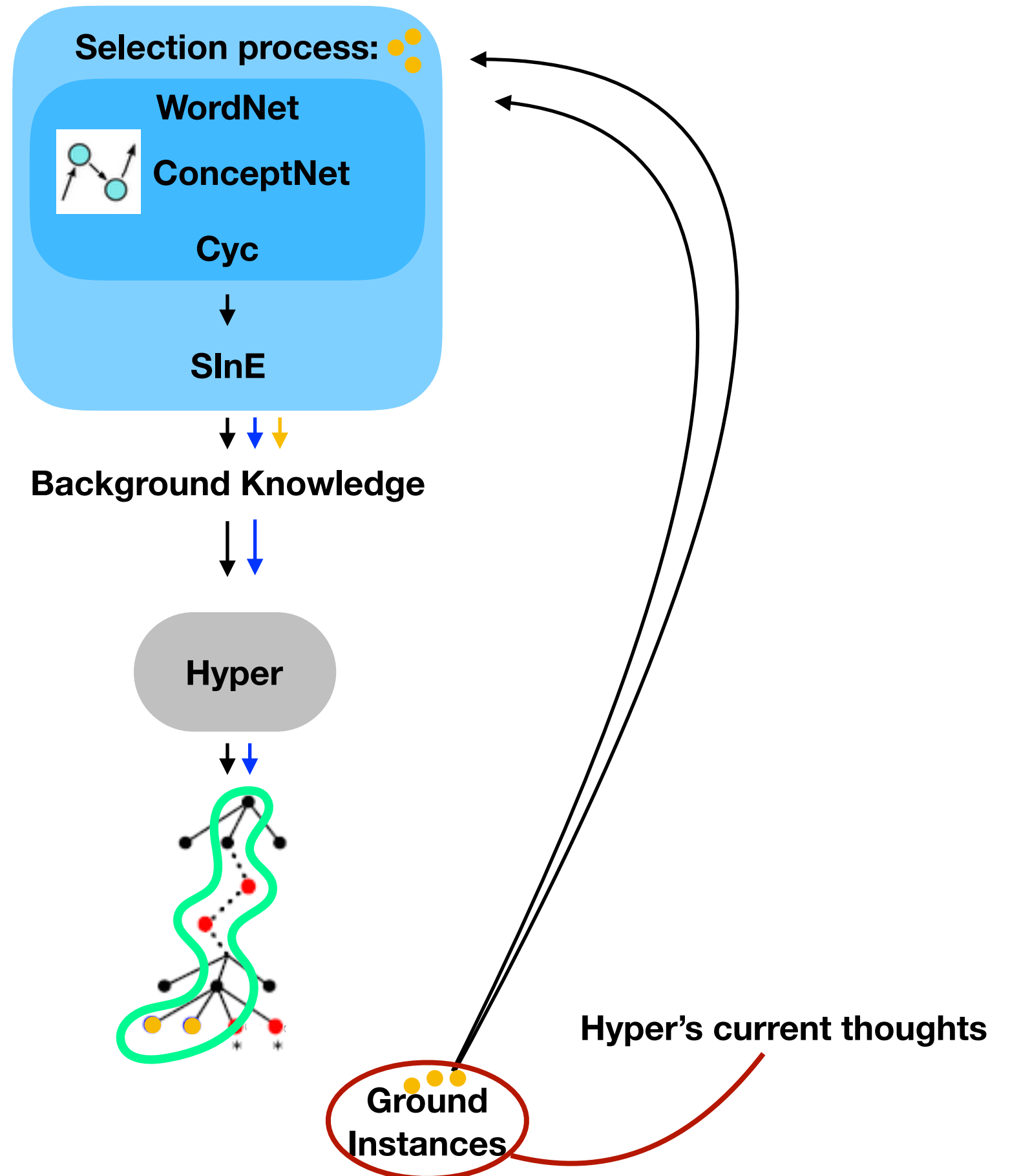
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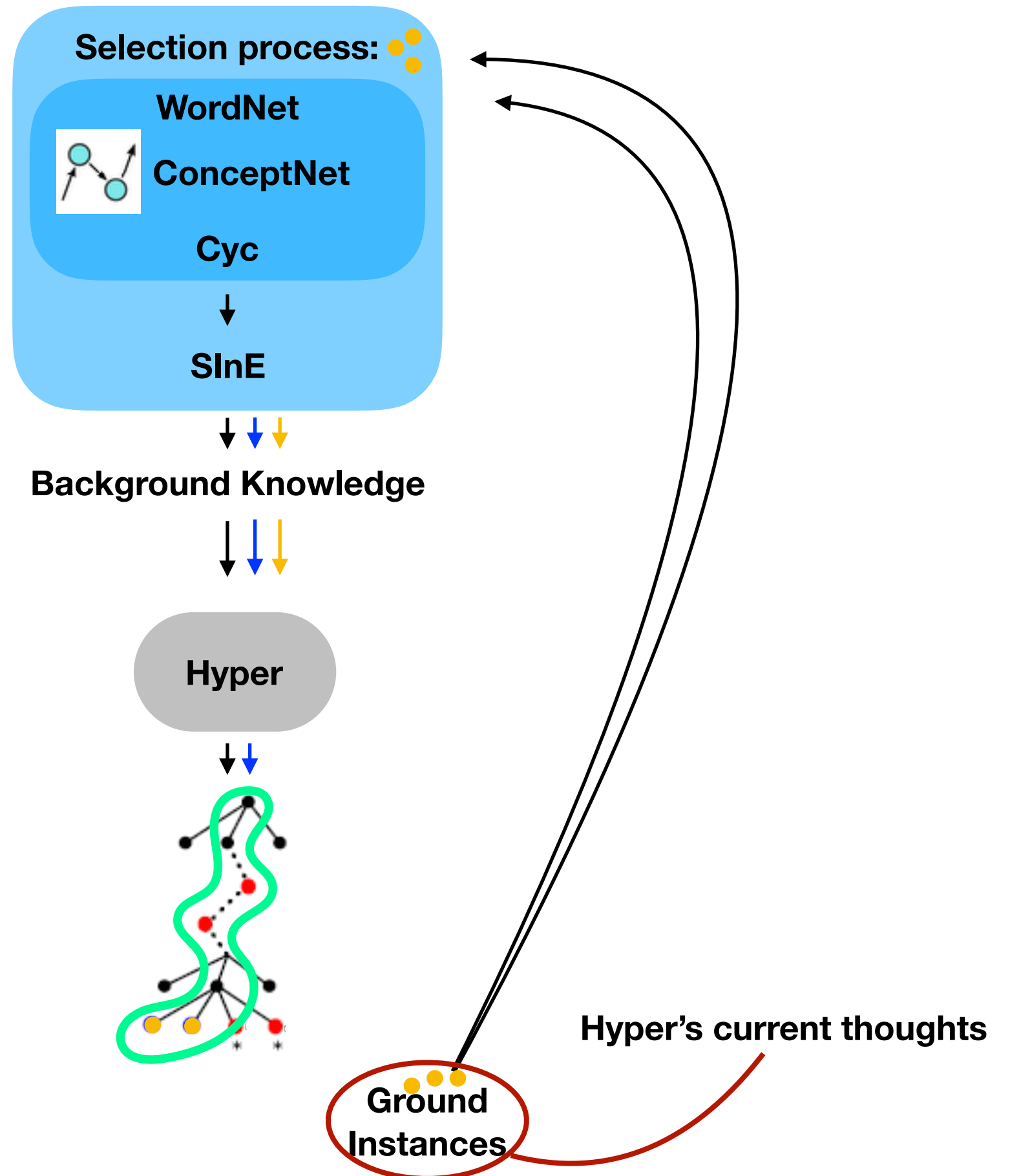


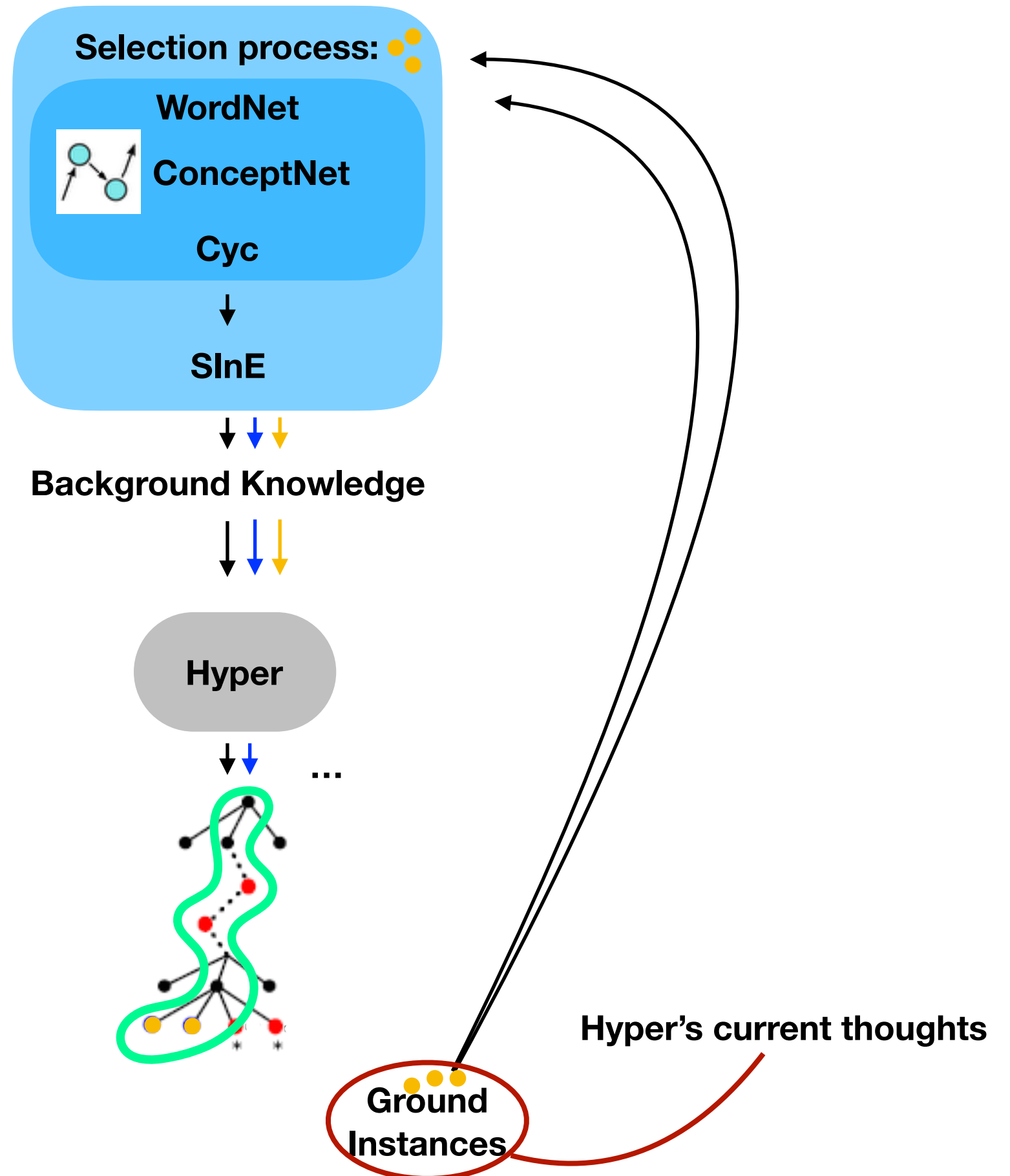
**Hyper's current thoughts**











# First Experiments

===== Copa test /40 =====

I pounded the nail with the hammer. What happened as a RESULT?  
The nail sunk into the wood.  
The nail became rusty.

<<----- Problembeschreibung

```
fof(b0,axiom,
  ( ? [A,B,C] :
    (? [D] :
      (r1with(D,A)
        & r1Theme(D,B)
        & r1Actor(D,C)
        & v1pound(D) )
      & n1hammer(A)
      & n1nail(B)
      & n1person(C) ) ) ).
```

<<----- Alternative 1

```
fof(b1,axiom,
  ( ? [A,B] :
    (? [C] :
      (r1into(C,A)
        & r1Actor(C,B)
        & v1sink(C) )
      & n1wood(A)
      & n1nail(B) ) ) ).
```

<<----- Alternative 2

```
fof(b2,axiom,
  ( ? [A] :
    (n1nail(A)
      & ? [B,C] :
        (? [D] :
          (r1Theme(D,A)
            & a1rusty(D) )
          & r1Topic(C,B)
          & r1Actor(C,A)
          & v1become(C) ) ) ) ).
```

# First Experiments



# First Experiments

===== Thought iteration 1 =====  
=====

```
fof(gr1,axiom,n1nail(sK1)).  
fof(gr2,axiom,n1person(sK2)).  
fof(gr3,axiom,thump(sK3)).  
fof(gr4,axiom,pound(sK3)).  
fof(gr5,axiom,poke(sK3)).  
fof(gr6,axiom,hit(sK3)).  
fof(gr7,axiom,hammer(sK0)).  
fof(gr15,axiom,crush(sK3)).
```

===== Thought iteration 2 =====  
=====

```
fof(gr1,axiom,pulverize(sK3)).  
fof(gr229,axiom,isa(sK3,c_pointyended)).  
fof(gr312,axiom,mortal(sK0)).  
fof(gr513,axiom,dig(sK3)).  
fof(gr514,axiom,touch(sK3)).  
fof(gr522,axiom,stab(sK3)).
```

# First Experiments

===== Thought iteration 3 =====

fof(gr104,axiom,defeat(sK1)).  
fof(gr741,axiom,n1heavy\_defeat(sK3)).  
fof(gr932,axiom,powerful\_blow(sK3)).  
fof(gr974,axiom,squeeze(sK1)).

===== Thought iteration 4 =====

fof(gr533,axiom,defeat\_decisively(sK1)).  
fof(gr587,axiom,ending(sK0)).  
fof(gr611,axiom,finish(sK0)).  
fof(gr617,axiom,sudden\_and\_intense(sK1)).  
fof(gr629,axiom,failure(sK1)).  
fof(gr641,axiom,the\_act\_of\_striking(sK1)).  
fof(gr653,axiom,crush\_thing(sK1)).

===== Thought iteration 5 =====

fof(gr4,axiom,disaster(sK0)).

===== Copa Dev 114 =====

The surfer caught the wave. What happened as a RESULT?  
The wave carried her to the shore.  
She paddled her board into the ocean.

===== Copa Dev 114 =====

The surfer caught the wave. What happened as a RESULT?  
The wave carried her to the shore.  
She paddled her board into the ocean.

===== Thought iteration 1 =====

=====

fof(gr0,axiom,catch(sK2)).  
fof(gr1,axiom,surprise(sK2)).  
fof(gr2,axiom,wave(sK0)).  
fof(gr3,axiom,surfer(sK1)).  
fof(gr4,axiom,surfboarder(sK1)).  
fof(gr5,axiom,swimmer(sK1)).  
fof(gr6,axiom,natator(sK1)).  
fof(gr7,axiom,bather(sK1)).  
fof(gr9,axiom,female(c\_tptpsquare)).  
fof(gr10,axiom,paddle(c\_tptpsquare)).

===== Copa Dev 114 =====

The surfer caught the wave. What happened as a RESULT?  
The wave carried her to the shore.  
She paddled her board into the ocean.

===== Thought iteration 2 =====

=====

fof(gr24,axiom,beauty(sK2)).  
fof(gr30,axiom,sweetheart(sK2)).  
fof(gr48,axiom,woman(sK2)).  
fof(gr51,axiom,adult\_female(sK2)).  
fof(gr74,axiom,aestheticquality(sK2)).

===== Thought iteration 3 =====

=====

fof(gr20,axiom,amazement(sK2)).  
fof(gr117,axiom,sweetie(sK0)).  
fof(gr133,axiom,truelove(sK0)).  
fof(gr141,axiom,lover(sK0)).  
fof(gr201,axiom,appearance(sK0)).  
fof(gr235,axiom,female\_person(sK0)).



===== Copa Dev 114 =====

The surfer caught the wave. What happened as a RESULT?

The wave carried her to the shore.

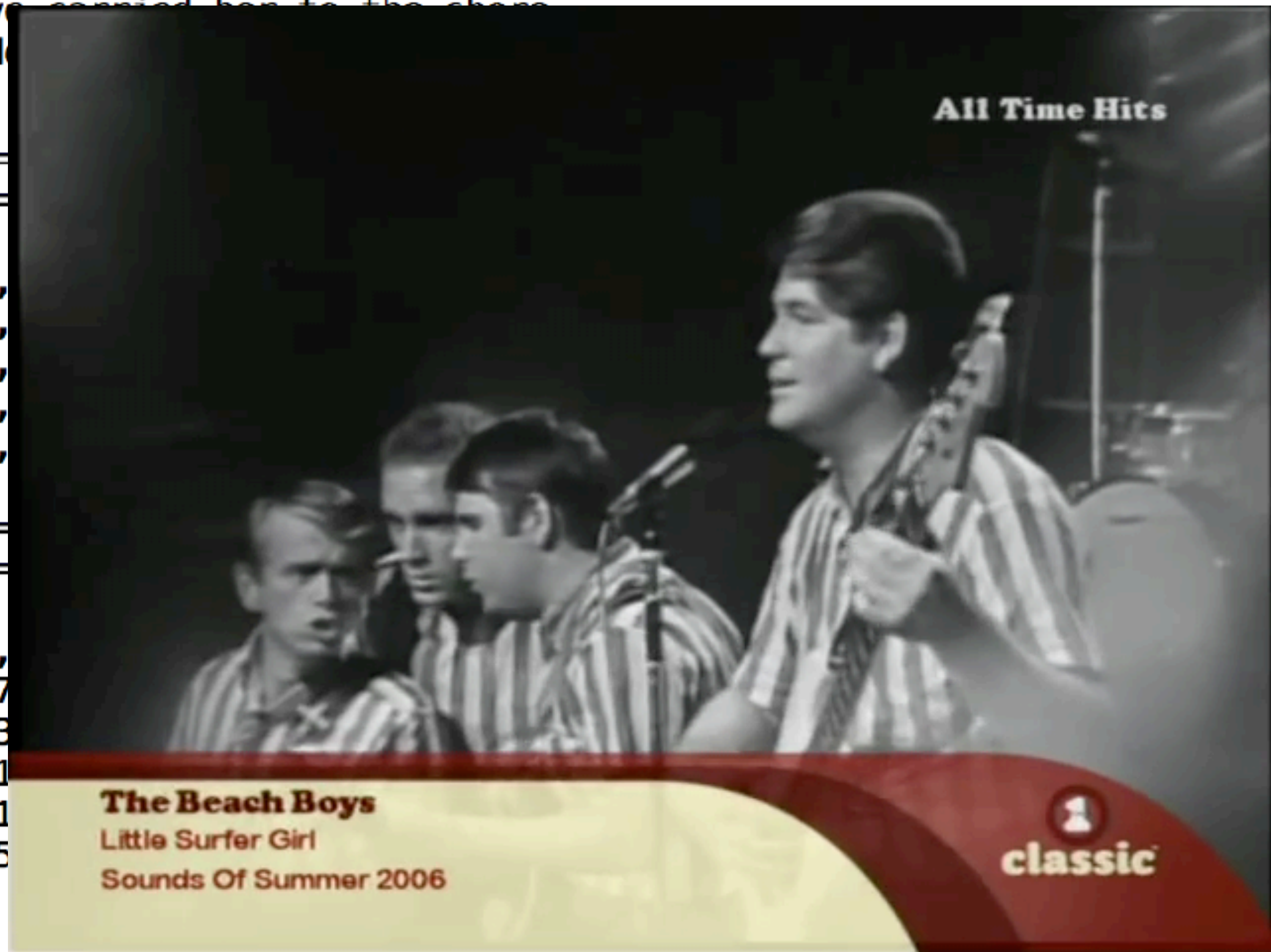
She paddled out.

=====

fof(gr24,  
fof(gr30,  
fof(gr48,  
fof(gr51,  
fof(gr74,

=====

fof(gr20,  
fof(gr117,  
fof(gr133,  
fof(gr141,  
fof(gr201,  
fof(gr235,



# todos

more different knowledge bases

what is interesting? (cf. AGInT-System)

how to remember?