

# Representations for KBS: Semantic Networks

6.871 Lecture 7

# Outline

- Quillian's foundations: associations
- Implicit meanings for uniform links
- Knowledge-related primitives [eg. CDs]
- Concern for semantics of the language
- Structured inheritance networks [eg. KL-ONE]
- Where the field is today

# Preview

- Semantic networks have evolved:
  - Shift in motivation from modeling cognitive processes to addressing computational issues.
  - Shift in representation goals from "all human memory" to certain types of knowledge [eg. definitions vs. assertions, classes vs. instances]
  - Semantics of links have become less intuitive and more formally defined.
  - Shift in reasoning mechanisms suited to more careful definitions of primitives.

# What is a Semantic Net?

- What's a net?
- What a semantic net?
- Where do the semantics come from?

# Questions for Semantic Nets

- Regarding the original motivation
  - How should we view the world?
  - What are the recommended inferences?
- Regarding the representation formalism:
  - (What) are the(re) primitives?
    - The primitives of a KR technology are those things “the interpreter is programmed in advance to understand” [Brachman]
  - What knowledge can we express?
  - What does a concept mean?
    - May be what the machine infers
    - May be a formal answer
- Regarding the reasoning mechanism:
  - What are the easy/automatic inferences?
  - How efficient can we make these?

# Semantic Memory [Quillian, 1966]

- Motivations
  - Understand the structure of human memory, and its use in language understanding
  - What sort of representational format can permit the “meanings” of words to be stored, so that humanlike use of these meanings is possible?
- Psychological evidence that memory uses associative links in understanding words

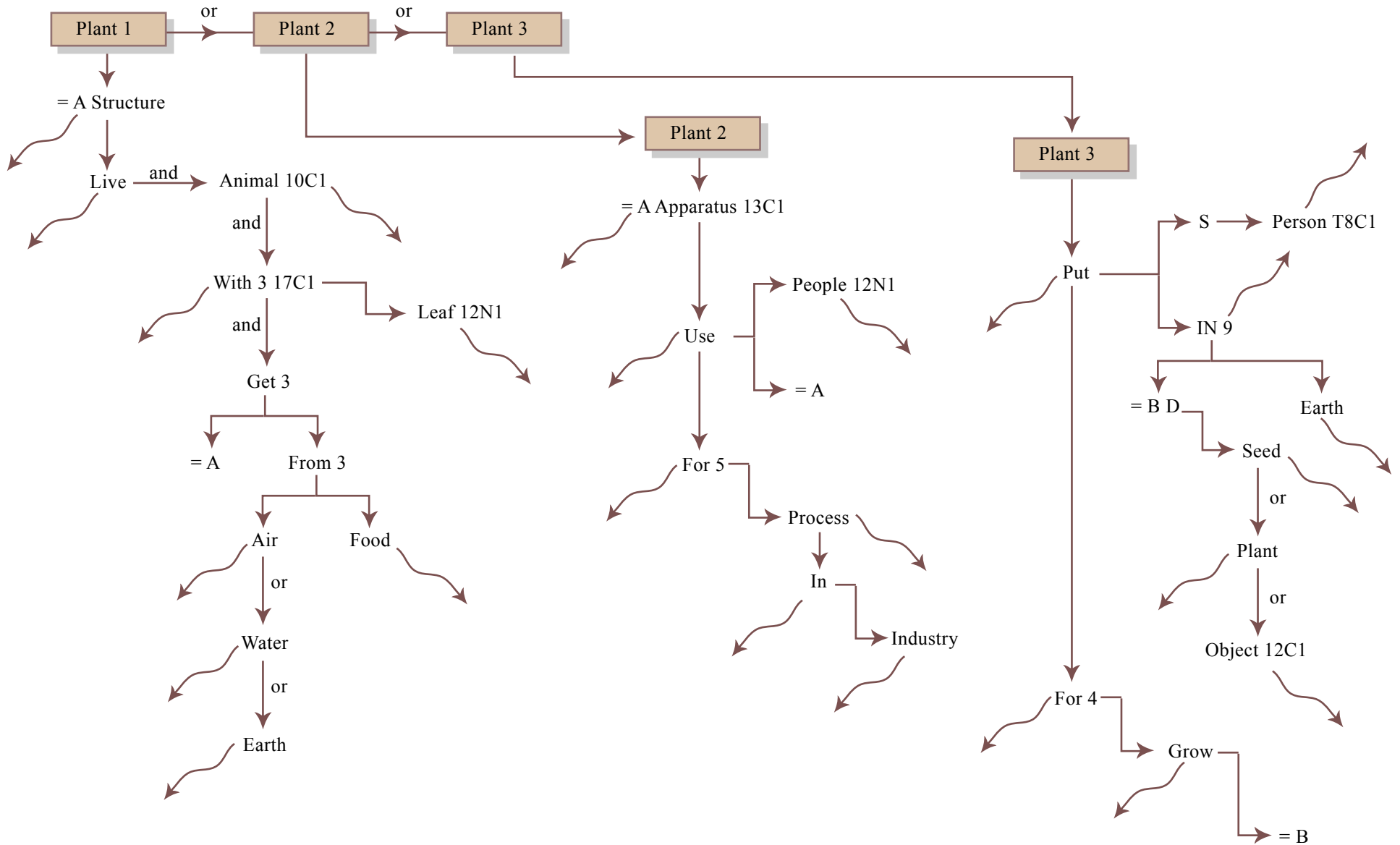
# Semantic Memory [Quillian, 1966]

- Motivations:
  - Claim that people use same memory structure for a variety of tasks
- Wish to encode dictionary definition of words.
- And then:
  - Comparing and contrasting meanings of two words
  - Generating quasi-English sentences to describe the comparison

# Semantic Memory Formalism

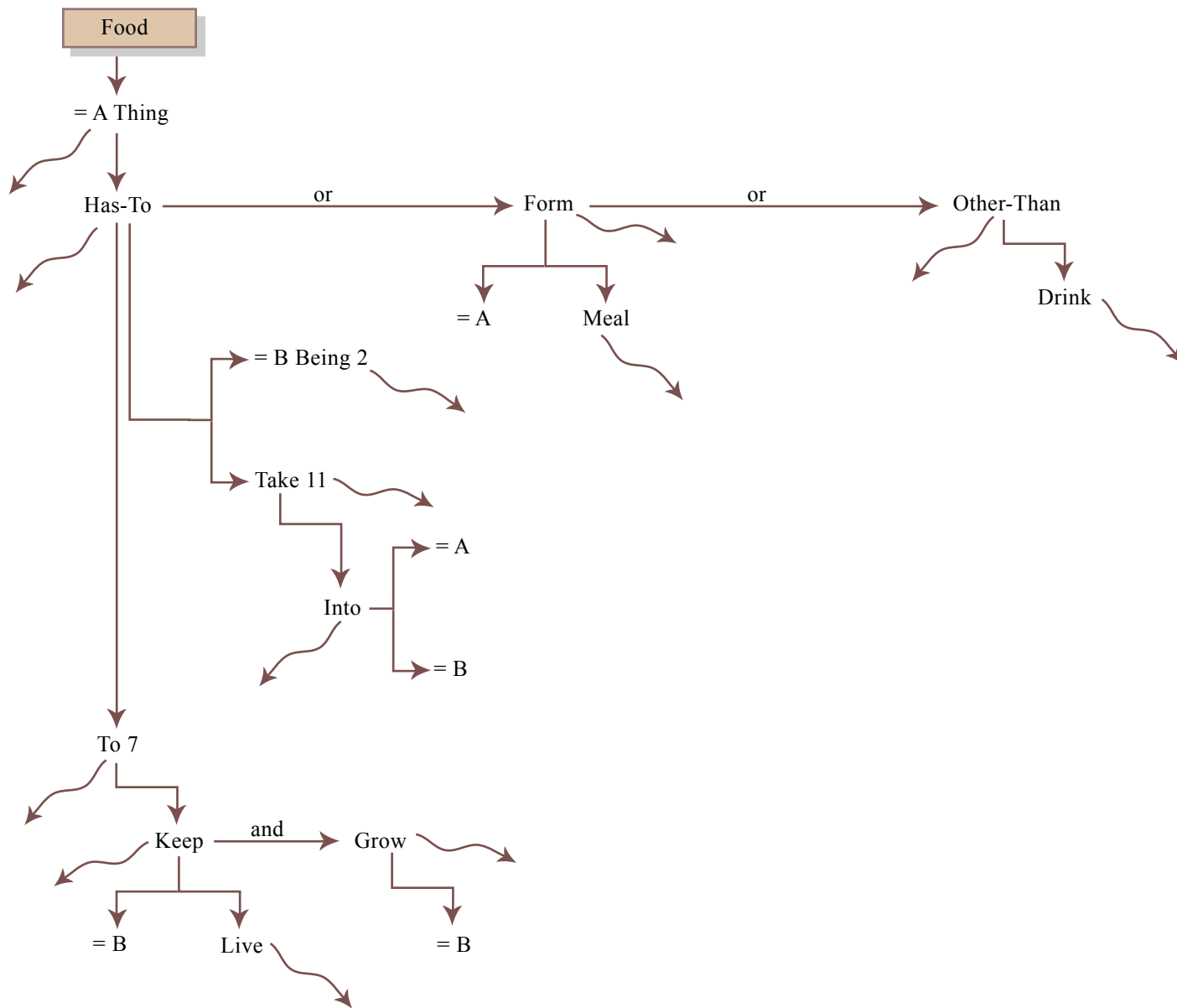
- Plane: A network of nodes and links for representing the definition of a word "concept"
- Nodes:
  - Type nodes: Direct representation of word [one per plane]
  - Token nodes: Denote a type node in some other plane
- Link types
  - Type node (A) is a subclass of B
  - A, B, and C disjunctive [conjunctive]
  - A relates B and C
  - A is a token associated with type node (A)
  - A modifies B [an "escape hatch"]





PLANT

1. Living structure which is not an animal, frequently with leaves, getting its food from air, water, earth.
2. Apparatus used for any process in industry.
3. Put (seed, plant, etc.) in earth for growth.



FOOD 1. That which living being has to take in to keep it living and for growth. Things forming meals, especially other than drink.

# Semantic Memory Formalism

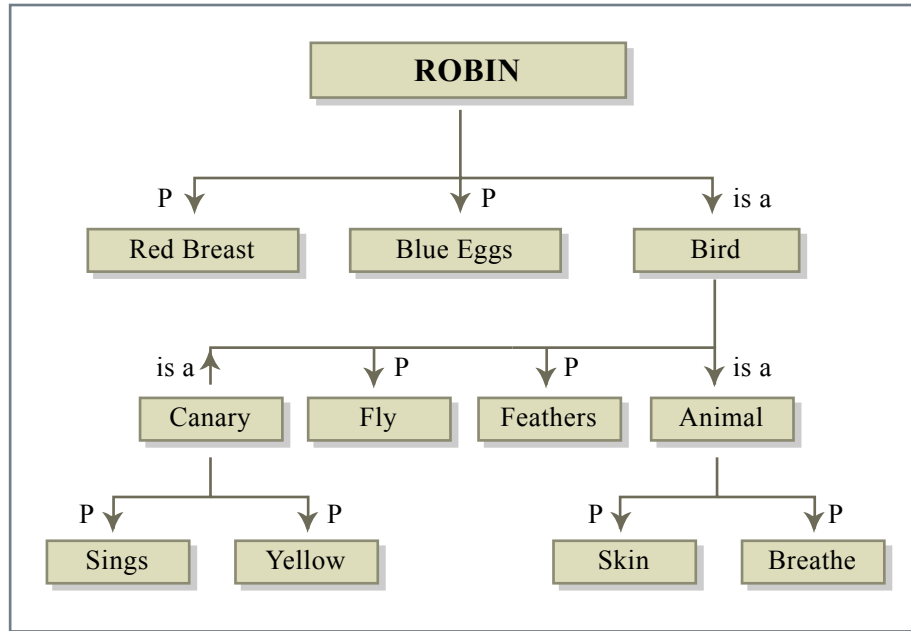
- Expressiveness: Any word with a dictionary definition
- Meaning of a concept: two answers
  - dictionary definition in its plane.
  - "full concept": transitive closure of all links
    - Size ??
- Focus is on nodes: in use links are merely connections

# Semantic Memory Reasoning

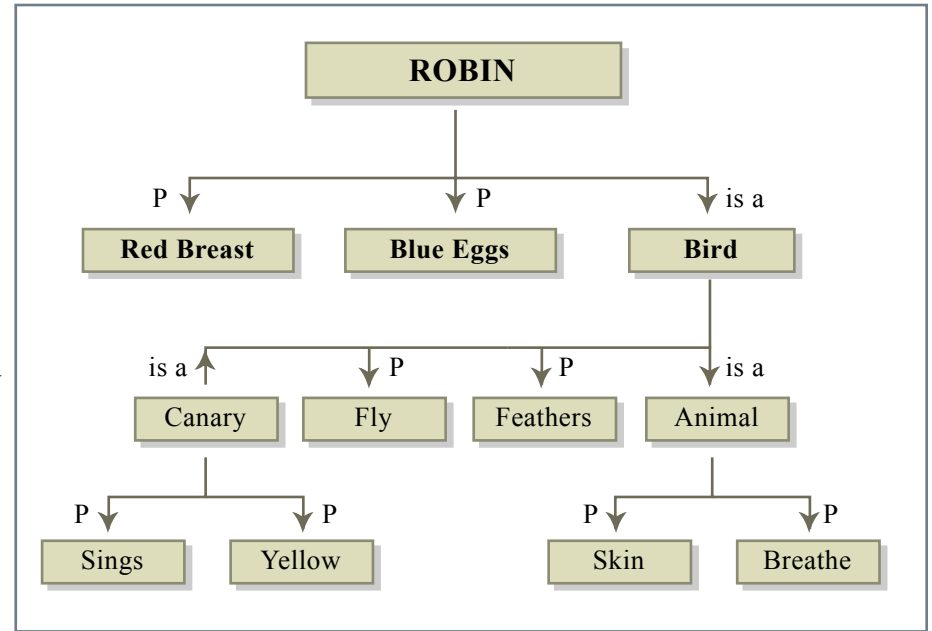
- Comparing meanings of two words: via “spreading activation”
  - Intersections in unguided breadth-first search
    - General purpose
    - Is this “closest path” the shared meaning?
- Describing the comparison:
  - Trace the links leading to the intersections.

# Spreading Activation

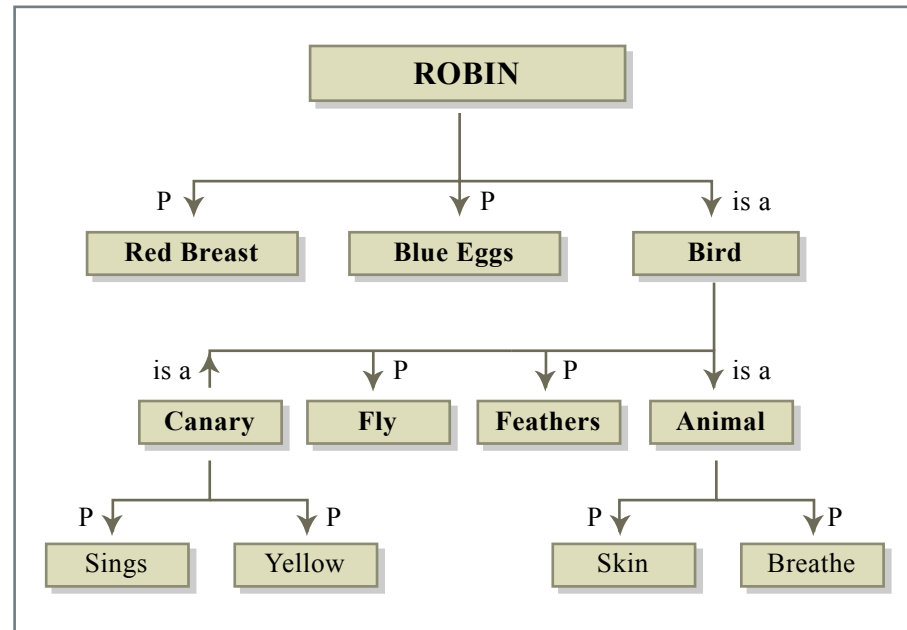
(A) Robin is activated



(B) Robin primes its associates



(C) Continued priming from Robin



# Primitives?

- What's primitive in Quillian?
- Why primitives?
- Approaches to primitives:
  - Language independent: Conceptual dependencies
  - Language [English] dependent: OWL

# Conceptual Dependency

- A strongly reductionist approach
- Five primitive categories of knowledge
  - Actions [Eg. Propel, Ingest, Ptrans, Mtrans]
  - Tenses [Eg. Present, Past, Future]
  - Objects [any noun]
  - Modifiers of actions: case frames [eg. object, subject, recipient]
  - Modifiers of objects
- Combining primitives yields standard scenarios
  - building blocks world knowledge.

# Example CDs

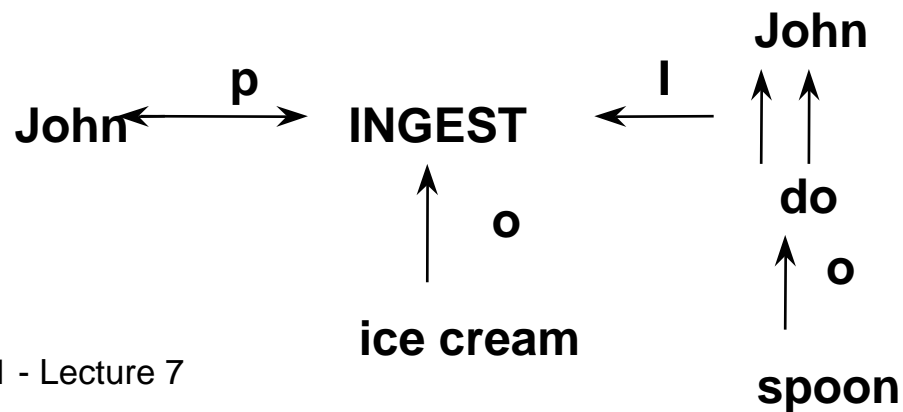
## Basic dependency

John  $\longleftrightarrow$  PTRANS

## Combining 2 dependencies

John  $\longleftrightarrow$  PROPEL  $\longleftarrow$  cart

## More Complex:





# Conceptual Dependency

- Motivation: Provide a canonical form for world knowledge expressible in any natural language.
- Why a canonical form is valuable
  - Deciding whether two expressions have the same meaning.
    - If not, how close are they?
  - Understanding complex text [eg. stories]

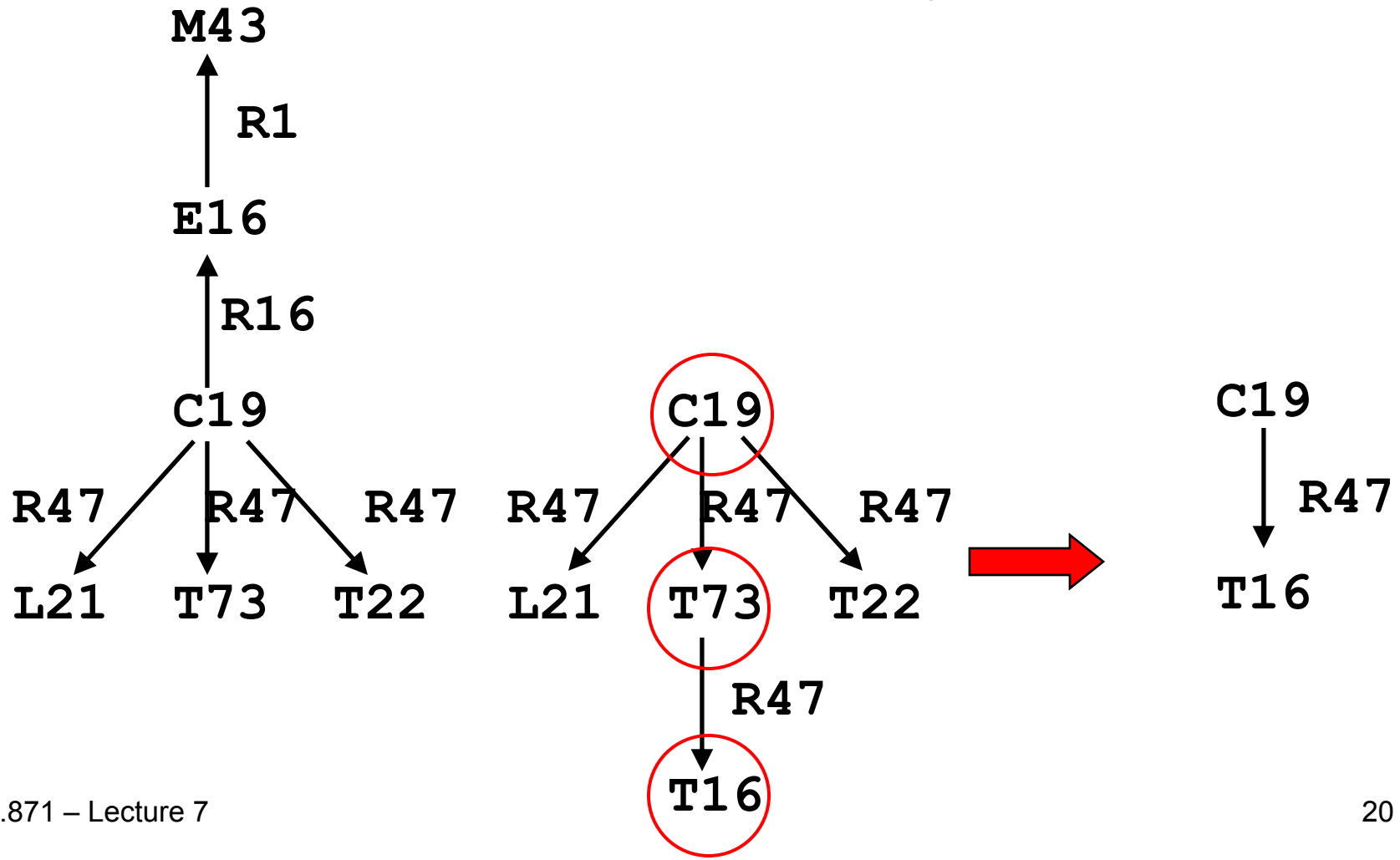
# Conceptual Dependencies

- Expressiveness: All world knowledge?
- Not an intuitive means of communication, for us.

# Links: What Do They Mean?

- IS-A
  - **Clyde is-a elephant**
  - **Elephant is-a mammal**
- The World Wide (Non-Semantic) Web
  - What does a hyperlink *mean*?
    - What does *that* mean?
    - Eg: books on the web
- Need to think about the semantics of the network notation, to minimize the “intuitive” meanings of links
  - Similarity to semantics in logic sense
  - Meaning arises from:
    - what the interpreter does (procedural semantics)
    - formal definitions

# Links: What Do They Mean?



# SI-Nets: Epistemologically Explicit

- Representational primitives with formal, logical meanings.
- Strict definitions of concepts: necessary and sufficient conditions, giving the essence of the concept's intension.
  - Some representations are concerned with the definition of terms - the “T-box”
  - Other representations use terminology to say what’s true in the world at the moment - the “A-box”
  - A-box reasoning can use T-box reasoning as a fast subroutine for certain queries.

# SI-Nets: Epistemologically Explicit

- Importance of subsumption: one concept as more general than a second concept.
  - Eg. Animal subsumes Dog.
  - Allows inheritance of definitional properties
  - Allows recognizing new concepts and instances as members of concepts.
  - Subsumption is the recommended inference.
- (In logical inference, the most general unifier is the key computation, here it's the most specific subsumer).

# KL-ONE

- Logic-like notation:
  - Concepts: One place logical predicates:  $C(x)$ .
    - Eg.  $\text{Animal}(x)$ .
- Subsumption links:  $C1$  subsumes  $C2$  if and only if for all  $X$ ,  $C2(x) \rightarrow C1(x)$ 
  - Eg.  $\text{Dog}(x) \rightarrow \text{Animal}(x)$ .
  - Subsumption links create a taxonomy.

# KL-ONE

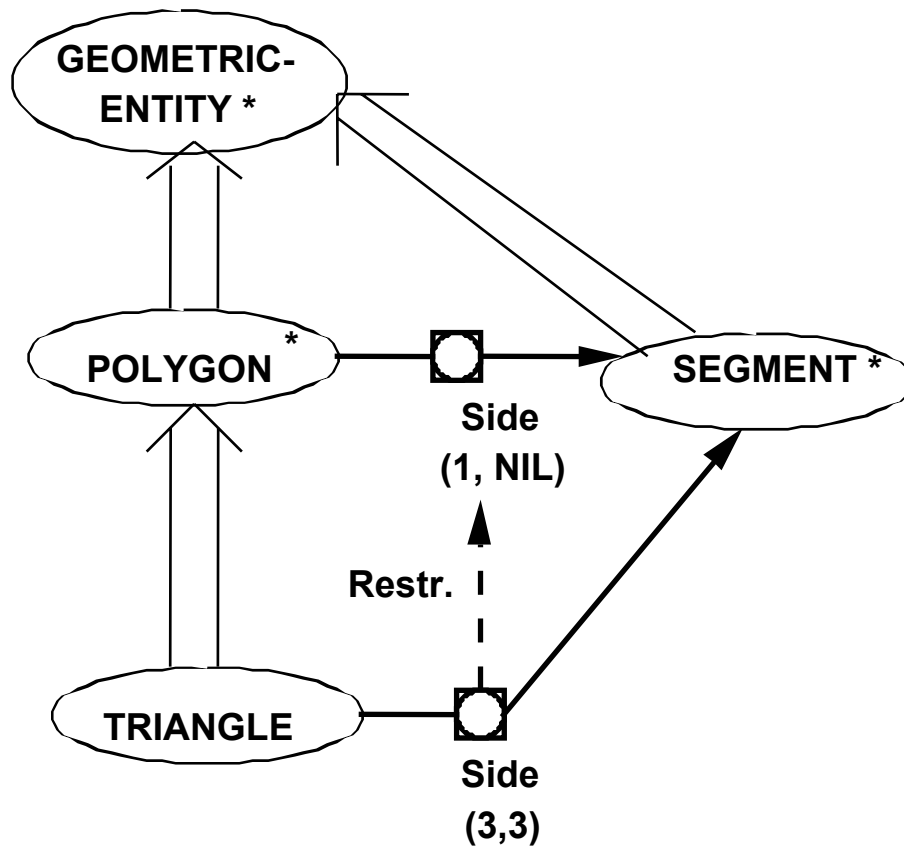
- Distinction between individuals and generics
- Roles: Two place relations  $R(x,y)$ .
  - E.g.  $\text{Color}(x,y)$
  - Defined by domain and range; have their own taxonomy
- Role restrictions: consist of
  - Value Restrictions - the class of the role fillers for that concept
  - Number Restrictions - min. and max. number of instances filling the role.



# Meaning in KL-One

- The meaning of a concept is either
  - A strict definition of necessary and sufficient conditions based on superclass[es], and role restrictions.
  - Or, a primitive: only necessary conditions.
    - Typically natural kinds [E.g. animal, water]

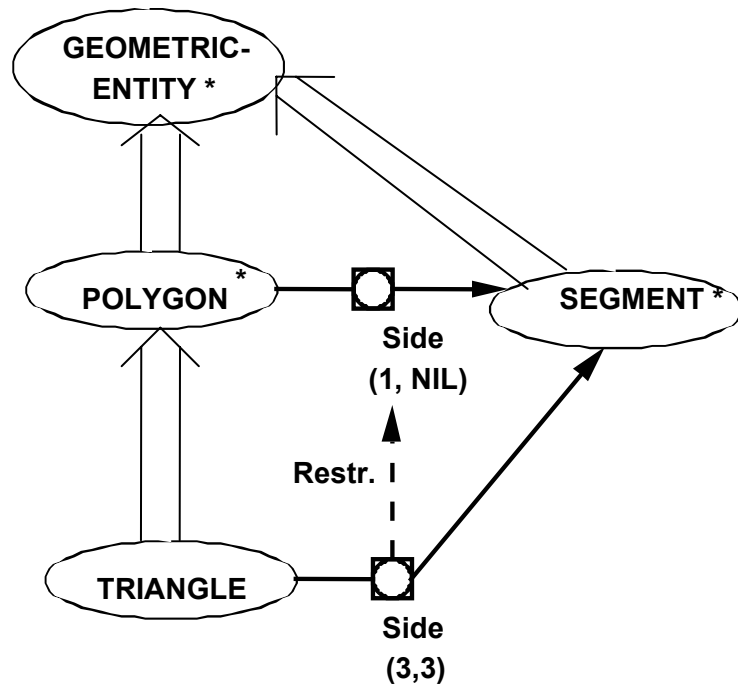
# KL-ONE Network



Triangle(x)  $\leftrightarrow$   
Polygon(x) AND  
Exists exactly 3 y s.t.  
Side(x, y) and  
Segment(y).

# Classification

Place a new concept underneath the *most specific generalizer*.



Triangle(x)  $\leftrightarrow$

Polygon(x) and

Exists exactly 3 y s.t.

Side(x, y) and Segment(y).

EquiTri  $\leftrightarrow$

Polygon and

Exists exactly 3 y st

Side (x, y) and Segment(y)

and Forall y1, y2 st Segment(y1) and Segment(y2):

Length(y1) = Length(y2)

# Expressiveness in SI Nets

- Very few cases of people actually using SI net languages like KL-One to encode large knowledge bases.
- In general, there are problems from limited expressiveness:
  - Cannot clearly define many important concepts in a domain.
    - Consider defining a right triangle, or isosceles triangle.
    - Consider defining a chair or a dog.
- Issues of different "boxes" to put knowledge in:
  - TBox - Definitions, usually about classes.
  - ABox - "Assertions" - non-definitional properties of concepts and instances.

# KL-One Descendants

- NIKL, KL-TWO, KRYPTON, KANDOR
- All Structured Inheritance Networks; same basic ontological commitment.
- Decisions made about:
  - Whether roles may also be in a definition hierarchy.
  - What expressions are allowed in TBox? In ABox?
  - Trading off the expressiveness of the language with efficiency of the classifier.

# Where Field Is Today

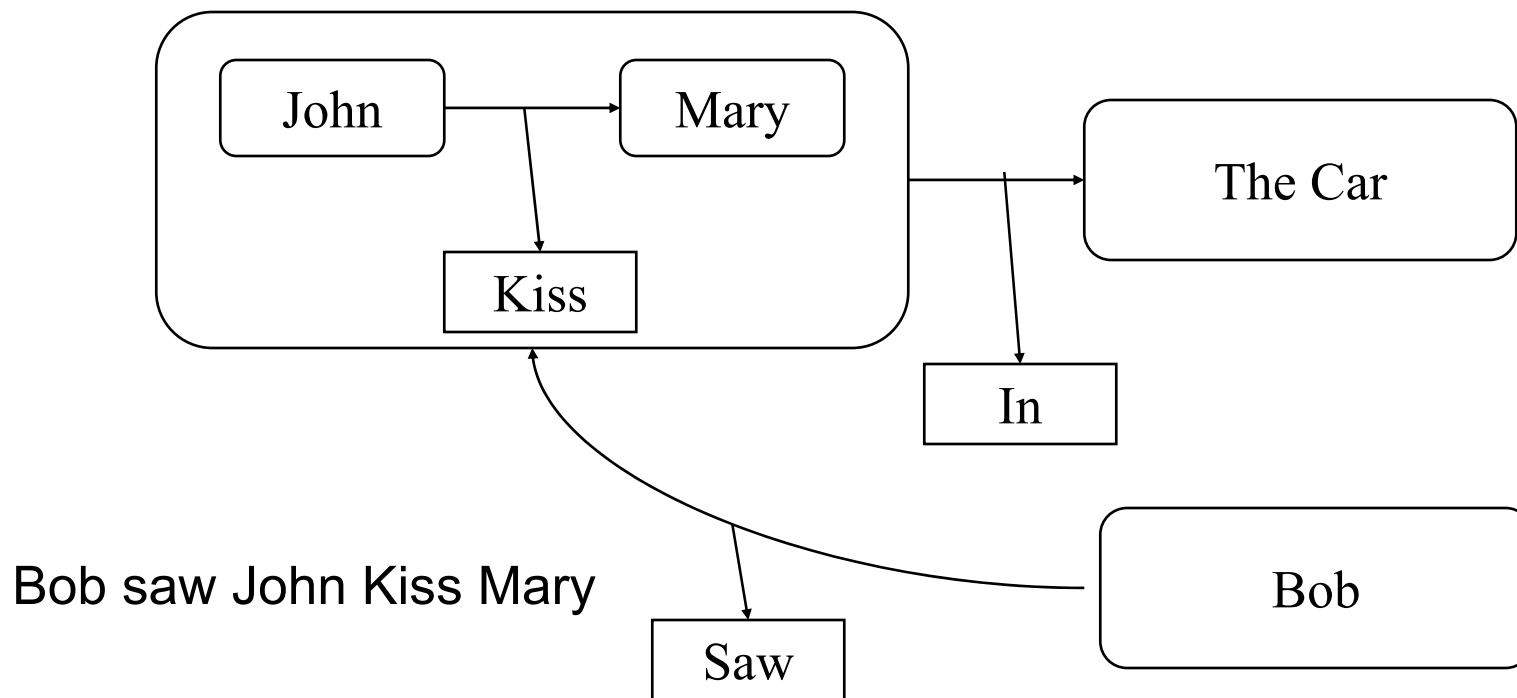
- Still much focus on structured inheritance networks
- Much focus on computational details of well-known network formalisms.
- Claim: Need to return to basic investigations of real world knowledge for new ideas

# Linguistically Motivated Networks

- The START NLP system (and some other earlier systems) use a triples representation
  - The link points to a relationship name and to the subject and object nodes.
  - Links may function as nodes
  - Relationship names and objects participate in inheritance relationships
- More complex relationships are decomposed into triples

# Example

- John kissed Mary in the car





# The Semantic Web

- Treat WWW Identifiers (URI's) as nodes
- Create a repository of triples describing these nodes semantically.
  - Traditional Meta-Data such as author, creation-date
  - Non traditional meta-data such as summary or peer review
- Use this network to retrieve Web resources based on their semantics
  - W3C standards are being evolved for this purpose:
  - RDF (resource description format), XML syntax

# Summary

- Semantic networks have evolved
  - Shift in motivation from modeling cognitive processes to addressing computational issues.
  - Shift in representation goals from "all human memory" to certain types of knowledge separately [eg. definitions vs. assertions, classes vs. instances]
  - Semantics of links have become less intuitive and more formally defined.
  - Shift in reasoning mechanisms suited to more careful definitions of primitives.
  - Possible impact on WWW.