DENOTATION, TRUTH, MEANING

C-MG ch. 2
Overall review (so far)

• Semantics: meaning at various levels
• Evaluating meaning: an empirical approach
  • Denotation/referentiality
  • Models, processes, compositionality
• Sentential meaning: subject + predicate; truth-value of assertions
• Meaning relationships: implication, implicature, entailment, presupposition, …
• Interpretive procedure: read semantics off of prior syntactic representation
  • For now: minimal fragments (vocabulary, syntax, semantics)
• Represent relationships between entities (and groups), properties, events, …
• Issues: ambiguity, granularity, deliberate violation of the assumptions
Set theory: review

• Let $S$ be the set of people in this class.
  $S = \{BA, BD, SN, CR, DL\}$ (extensional description)
  $S = \{x \mid x$ is a person in this class$\}$ (intensional description)

• Let $M = \{DL, BD\}$ be the (sub)set of males.  ($M \subseteq S$ i.e. $S \supseteq M$)

• Let $M$'s complement in $S$ be the set $F$ of females.  ($F = S - M$)

• Use set theory to evaluate the truth of the following sentences:
  • There are seven people in this class.
  • The people in this class are either male or female.
  • There are more males than females in this class.
  • More than half of the people in this class are female.
  • There are more than twice as many males in this class as females.

• Linguistics is doing language usage in slow motion, identifying and explicating the steps, and describing the basic objects and procedures used.
Denotation

- Linguistic expressions refer to real-world objects
  - The real-world object: denotation, denotatum, reference, or semantic value
- This is the most fundamental semantic relation.

- Proper nouns are the most straightforward examples of denotation
  - The word *Trump* denotes (refers to) the real-world person
  - Don’t change reference over time: sometimes called rigid designators

- NP’s are most often referential
  - Individuals, pluralities, substances, actions, abstract entities, etc.
  - Occasionally they are non-referential
Predication

- Assertion: subject + predicate
  - What you’re talking about + what you’re saying about it
- Situation or state of affairs (SoA): the result of predication
- A notion we can use in empirical support for semantic relations (e.g. entailment)
A puzzle

• We can substitute one linguistic expression in a sentence with its synonym.
  • Doesn’t change the sentence’s truth value
• If we define the reference of a sentence as its truth value \{T,F\}, any pair of true
  sentences have the same denotation/reference.

• Frege’s approach
  • Sentences have a reference (Bedeutung) and a sense (Sinn)
  • Reference: meaning on a given occasion of an expression’s use; situational (moon)
  • Sense: way in which reference is presented; objective (moon on telescope’s lens; doesn’t
    vary w/r.t observer)
  • Retinal image of viewer: subjective (mental image may vary w/r.t observer)
Frege’s solution

- Venus is Venus. (trivially true; tautology)
- The morning star is the morning star. (same)
- Venus is the morning star. (common knowledge)
- The morning star is the evening star. (took much empirical investigation)

- Primary reference: based on an identity relation to the same object
  - Objects with primary reference can be interchanged without altering the sentence’s meaning
  - Both stars have the same primary reference.

- Secondary reference: sense
  - Objects with secondary reference can’t be interchanged w/out altering meaning
  - Both stars have different senses (i.e. different situations, modes of presentation, etc.)
  - “The evening star” and “the morning star” have the same reference but differ in sense since they present Venus in different ways.
Related concepts

- de Saussure: signification vs. signifié

- Proposition: the sense of a sentence

- Carnap: sense $\approx$ intension, and reference/denotation $\approx$ extension

- Quine: opaque contexts
  - *Fred believes that this winter is a cold one.*
  - The truth value of the embedded proposition may not determine that Fred believes.
  - We can use the notion of sense for such sentences.
<table>
<thead>
<tr>
<th>Expression</th>
<th>Reference</th>
<th>Sense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Referential NP’s</td>
<td>Individuals</td>
<td>Individual concepts</td>
</tr>
<tr>
<td>VP’s</td>
<td>Classes of individuals</td>
<td>Concepts</td>
</tr>
<tr>
<td>S’s</td>
<td>T/F</td>
<td>Thoughts</td>
</tr>
</tbody>
</table>
Sentence truth value and meaning

• S is true in v iff p.
  • S: the sentence/utterance
  • v: the state of the world, or (at least) a model thereof
  • p: the proposition encoded by the sentence
• S means p: S is true in v iff p

• Simplifying assumptions:
  • Declaratives only
  • Fixed context (indexicality is known)
• Principle: S is t/f in a given situation
• Sentential truth-value can be evaluated
• Felicitous criteria can be determined
Tarskian analysis

- Computing truth-value for any sentence
- For any S in L and any v, S is true in v iff p.
  - S: a sentence
  - L: a language
  - v: a given situation or circumstance
  - p: truth conditions for the sentence
- Compositional account is possible
- Start with fragments, gradually enhance
- Bottom-up, interpreted from syntax
Compositionality

• Apply syntactic PS rules, compose structure
• Interpret each structure
  • Intransitive verb: set of individuals
    \[ \text{is hungry}^v = \{x | x \text{ is hungry in } v \} \]
  • Transitive verb: set of ordered pairs of individuals <subject, object>
    \[ \text{loves}^v = \{<x, y> | x \text{ loves } y \text{ in } v \} \]
### Specifying semantic relations

<table>
<thead>
<tr>
<th>Syntactic category</th>
<th>Semantic relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Truth value {T,F} or {0,1}</td>
</tr>
<tr>
<td>N</td>
<td>Individuals</td>
</tr>
<tr>
<td>(V_i, VP)</td>
<td>Sets of individuals</td>
</tr>
<tr>
<td>(V_t)</td>
<td>Sets of ordered pairs of individuals</td>
</tr>
<tr>
<td>conj</td>
<td>Function: maps two truth values to one</td>
</tr>
<tr>
<td>neg</td>
<td>Function: maps one truth value to one</td>
</tr>
</tbody>
</table>
Fragment $F_1$

- Fragment: set of syntactic/semantic specifications that permit compositional derivation of semantic interpretations

- $F_1$: a very basic fragment (i.e. training wheels, sandbox)

- Vocabulary: (some) English words
- Syntax: phrase-structure rules, parse tree (phrase-marker)
- Semantics: denotation with respect to entities, sets, relations, functions, truth values for the circumstance $\nu$
  - $[\beta]^\nu$ means semantic value (denotation) of $\beta$ in circumstance $\nu$
  - $[S]^\nu = 1$ means “$S$ is true in $\nu$”
Syntax in $F_1$

- Crude approximation of what you’ve done in earlier classes
- Context-free phrase structure grammar
- Lexical items: categories

(21) a. $S \rightarrow N \ VP$
    
    b. $S \rightarrow S \ conj \ S$
    
    c. $S \rightarrow neg \ S$
    
    d. $VP \rightarrow V_iN$
    
    e. $VP \rightarrow V_i$
    
    f. $N \rightarrow Pavarotti, \ Sophia \ Loren, \ James \ Bond$
    
    g. $V_i \rightarrow$ is boring, is hungry, is cute
    
    h. $V_i \rightarrow$ likes
    
    i. $conj \rightarrow$ and, or
    
    j. $neg \rightarrow$ it is not the case that

(23) $a.$

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Pavarotti is hungry and it is not the case that Bond likes Pavarotti
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b. $[S \ [S \ [N \ Pavarotti] \ [VP \ [V_i \ is \ hungry]]] \ [conj \ and] \ [S \ [neg \ it \ is \ not \ the \ case \ that] \ [S \ [N \ Bond] \ [VP \ [V_i \ likes] \ [N \ Pavarotti]]]]$
Semantics in $F_1$

- Think denotation!
- Circumstance/situation $\nu$

\[(25)\] For any situation (or circumstance) $\nu$,

\[\begin{align*}
[Pavarotti]^{\nu} &= Pavarotti \\
[Loren]^{\nu} &= Loren \\
[Bond]^{\nu} &= Bond \\
[is\ boring]^{\nu} &= \text{the set of those individuals that are boring in } \nu \\
(in\ symbols,\ \{x : x\ \text{is boring in } \nu\}) \\
[is\ hungry]^{\nu} &= \{x : x\ \text{is hungry in } \nu\} \\
[is\ cute]^{\nu} &= \{x : x\ \text{is cute in } \nu\} \\
[likes]^{\nu} &= \text{the set of ordered pairs of individuals such that } \text{the first likes the second in } \nu \text{ (in symbols, } \{(x, y) : x\ \text{likes } y \text{ in } \nu\})
\]
Our model of the world: \( \nu \)

- For now:
  - The relevant individuals/entities
  - The relevant predicates/attributes
  - A set of mappings, aka operators
    - Negation
    - Conjunction
    - Disjunction

(30) For any situation \( \nu \),

\[
\begin{bmatrix}
\text{it is not the case that} \\
\text{\( \nu \)} \\
\end{bmatrix} = \begin{bmatrix}
1 & 0 \\
0 & 1 \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\text{\( \mu \)} \\
\text{\( \nu \)} \\
\end{bmatrix} = \begin{bmatrix}
\langle 1, 1 \rangle & 1 \\
\langle 1, 0 \rangle & 0 \\
\langle 0, 1 \rangle & 0 \\
\langle 0, 0 \rangle & 0 \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\text{\( \gamma \)} \\
\text{\( \nu \)} \\
\end{bmatrix} = \begin{bmatrix}
\langle 1, 1 \rangle & 1 \\
\langle 1, 0 \rangle & 1 \\
\langle 0, 1 \rangle & 1 \\
\langle 0, 0 \rangle & 0 \\
\end{bmatrix}
\]
The crucial semantics of a sentence

• The denotation of a sentence is 1 iff the denotation of the subject is an element of the denotation of the predicate
  • Otherwise it’s 0
• The denotation of conjoined sentences is the denotation of both conjuncts mapped by the denotation of the conjunction
• The denotation of a transitive verb is the set of ordered pairs satisfying the denotation of the verb

\[(31)\]

\[a. \quad \llbracket S \ N \ VP \rrbracket^V = 1 \text{ iff } \llbracket N \rrbracket^V \in \llbracket VP \rrbracket^V \text{ and 0 otherwise}\]

\[b. \quad \llbracket S_1 \ \text{conj} \ S_2 \rrbracket^V = \llbracket \text{conj} \rrbracket^V(\llbracket S_1 \rrbracket^V, \llbracket S_2 \rrbracket^V)\]

\[c. \quad \llbracket S \ \text{neg} \ S \rrbracket^V = \llbracket \text{neg} \rrbracket^V(\llbracket S \rrbracket^V)\]

\[d. \quad \llbracket VP \ V_t \ N \rrbracket^V = \{x : \langle x, \llbracket N \rrbracket^V \rangle \in \llbracket V_t \rrbracket^V\}\]

\[e-j. \quad \text{If } A \text{ is a category and } a \text{ is a lexical entry or a lexical category and } \Delta = [A \ a], \text{ then } \llbracket \Delta \rrbracket^V = [a]^V\]
The interpretive procedure

(32) 1 S
     /   \
    2 S   3 conj
     |     |     |
   4 S   7 neg
     |     |     |
   5 N   6 VP
     |     |     |
  9 V_i

Pavarotti is hungry and it is not the case that Bond likes Pavarotti

(51) a. Pass-up If Λ is a nonbranching node that dominates a, then \([Λ]^v = [a]^v\).
    b. Functional application If Λ is a branching node with daughters a and b and \([a]^v\) is a function whose domain contains \([b]^v\), then \([Λ]^v = [a]^v([b]^v)\).

Our interpretive procedure works bottom up. Here is a step by step derivation of the truth conditions associated with (22a):

(33) [5]^v = Pavarotti, by (31e)
    [9]^v = \{x : x is hungry in v\}, by (31e)
    [6]^v = \{x : x is hungry in v\}, by (31e)
    [2]^v = 1 if Pavarotti ∈ \{x : x is hungry in v\}, by (31a)
    [13]^v = Pavarotti, by (31e)
    [12]^v = \{\langle x, y \rangle : x likes y in v\}, by (31e)

In (53) we give a derivation of the truth conditions of (52).

(53) a. [5]^v = Loren, by pass-up and (25)
    b. [4]^v = the function f in \langle a, t \rangle such that f(x) = 1 if x ∈ \{x : x is hungry in v\} and = 0 otherwise, by pass-up and the value assigned in exercise 5
    c. [3]^v = the function f in \langle a, t \rangle such that f(x) = 1 if x ∈ \{x : x is hungry in v\} and = 0 otherwise, by pass-up and the proceeding calculation of [4]^v
    e. [3]^v([2]^v) = 1 if Loren e \{x : x is hungry in v\} if Loren is hungry in v and = 0 otherwise
Definitions for semantic relations

- **S1 entails S2** (relative to analyses $A_{S1}$ and $A_{S2}$ respectively) iff for every situation $v$, if $[[S1]]^v=1$, then $[[S2]]^v=1$.
- **S1 is logically equivalent to S2** (relative to $A_{S1}$, $A_{S2}$) iff S1 entails S2 and S2 entails S1 (both w/rt $A_{S1}$, $A_{S2}$).
- **S is contradictory** (relative to analysis $A_S$) iff there is no situation $v$ where $[[S]]^v=1$
- **S is logically true (or valid)** relative to analysis $A_S$ iff there is no situation where $[[S]]^v=0$
- A set of sentences…entails…
- A set of sentences…is contradictory…
Conjunction and disjunction

• Conjunction
  • Combines truth of both conjuncts
  • Often implies sequentiality in English

• Disjunction
  • Exclusive: both disjuncts cannot be true
  • Inclusive: both disjuncts can be true

• Binary, ternary, n-ary
Semantic relations again

• Now we have empirical tools for the relations we’ve seen before.

• $S$ entails $S'$ (relative to analyses $\Delta_s$ and $\Delta_{s'}$) iff for every situation $v$, if $[[\Delta_s]]^v = 1$, then $[[\Delta_{s'}]]^v = 1$.

• $S$ is logically equivalent to $S'$ (relative to analyses $\Delta_s$ and $\Delta_{s'}$) iff $S$ entails $S'$ (relative to analyses $\Delta_s$ and $\Delta_{s'}$) and vice-versa.

• $S$ is contradictory (relative to analysis $\Delta_s$) iff there is no situation $v$, such that $[[\Delta_s]]^v = 1$.

• $S$ is logically true (or valid) relative to analysis $\Delta_s$ iff there is no situation $v$, such that $[[\Delta_s]]^v = 0$.

• Similarly for relationships between sets of sentences.
Specifying semantic relations using types

<table>
<thead>
<tr>
<th>Syntactic category</th>
<th>Semantic type</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>t</td>
</tr>
<tr>
<td>N</td>
<td>e</td>
</tr>
<tr>
<td>V_i, VP</td>
<td>&lt;e,t&gt;</td>
</tr>
<tr>
<td>V_t</td>
<td>&lt;e,&lt;e,t&gt;&gt;</td>
</tr>
<tr>
<td>conj</td>
<td>&lt;t,&lt;t,t&gt;&gt;</td>
</tr>
<tr>
<td>neg</td>
<td>&lt;t,t&gt;</td>
</tr>
</tbody>
</table>
Why types?

• Map from individuals to truth values, other semantic relations.
• Abstract away from (reduce burden of) some of the complexity of syntax
• Semantic constraints on ill-formed syntactic constructions
  • *He sneezed Fred. *Fred requires.
• Later: will allow us to shift between categories
  • yesterday: both an adverb and a noun
    Fred sneezed yesterday.
    Yesterday was fun.
  • [ John and every woman ] passed the exam with distinction.
• Mary considers John competent in math and an authority on verbs.
• Later: allows for reinterpretation (coercion) when a mismatch occurs between an assigner and a receiver
  • This morning Tom began a book. → …reading or writing or…
Issues for later

• Impoverished states of affairs
• (Ir)relevance of truth-values
  • Prevarication, speech acts, nondeclaratives
• Underspecification, vagueness
Propositional logic

- Representing propositions as atomic symbols
  e.g. p: John is hungry.
  q: John eats Cheerios.
  r: Ottawa is the capital city of Canada.
  s: Paris is the capital city of France.
  t: Orem is the center of the universe.
- Connectives: & (and), V (or), ¬ (not), → (if-then)
  p → q
  ¬p → ¬q
  s & q
  ¬¬p
- Truth value: true or false: r is true, t is false, p is ???
Logical inferences

- Modus Ponens:
  \[ p \rightarrow q \]
  \[ p \]
  \[ \quad \]
  \[ q \]

- Modus Tollens:
  \[ p \rightarrow q \]
  \[ \neg q \]
  \[ \quad \]
  \[ \neg p \]

- Hypothetical syllogism:
  \[ p \rightarrow q \]
  \[ q \rightarrow r \]
  \[ \quad \]
  \[ p \rightarrow r \]

- Disjunctive syllogism:
  \[ p \lor q \]
  \[ \neg p \]
  \[ \quad \]
  \[ q \]
Propositional logic language

- Used for a coarse-grained analysis of propositions
- Formal system
- Allows for wide range of applications
- Usable crosslinguistically
- Has three parts: vocabulary, syntax, semantics
Propositional logic

(1)

- Vocabulary:
  - Atoms representing whole propositions: p, q, r, s, ...
  - Logic connectives: & (and), V (or), ¬ (not), ↔ (if and only if), → (implies), parentheses

- Syntax (well-formed formulas, wff's):
  - Any atomic proposition is a wff. If \( \varphi \) and \( \psi \) are wff's, then so are:
    - \( \neg \varphi \), \( (\varphi \& \psi) \), \( (\varphi \vee \psi) \), \( (\varphi \rightarrow \psi) \), and \( (\varphi \leftrightarrow \psi) \)
  - Nothing else is a wff.

- Examples
  - \( \neg \& pq \) is not a wff
  - \( ((p \rightarrow q) \& (p \leftrightarrow r)) \) is a wff
  - \( ((p \vee q) \rightarrow \neg s) \) is a wff
  - \( (((p \& q) \vee \neg r) \rightarrow s) \leftrightarrow t \) is a wff
Propositional logic

• Semantics:
  • $V$ is a function that assigns a truth value to a wff
  • $V(\neg \varphi) = 1$ iff $V(\varphi) = 0$.
    • $\varphi$: Orem is the center of the universe. $V(\neg \varphi) = 1$
  • $V(\varphi \land \psi) = 1$ iff $V(\varphi) = 1$ and $V(\psi) = 1$.
    • $\varphi$: BYU is a university. $\psi$: Orem is a city. $V(\varphi \land \psi) = 1$
  • $V(\varphi \lor \psi) = 1$ iff $V(\varphi) = 1$ or $V(\psi) = 1$.
    • $\varphi$: Utah is a state. $\psi$: Utah is a village. $V(\varphi \lor \psi) = 1$
  • $V(\varphi \rightarrow \psi) = 1$ iff $V(\varphi) = 0$ or $V(\psi) = 1$.
    • $\varphi$: Provo is a city. $\psi$: Provo has a mayor. $V(\varphi \rightarrow \psi) = 1$
  • $V(\varphi \leftrightarrow \psi) = 1$ iff $V(\varphi) = V(\psi)$.
    • $\varphi$: Sam is a BYU student. $\psi$: Sam paid his tuition. $V(\varphi \leftrightarrow \psi) = 1$
Propositional logic $\rightarrow$ predicate logic

- Propositional level representations only
  - No individuals
  - No predication (events, attributes, etc.)
  - No quantifiers
  - No way of representing universe of discourse, world(s), etc.
- Instead, use predicate logic
  - Allows for a finer-grained analysis than propositional logic
  - Predicates and their arguments are the prime focus (vs. propositions in propositional logic)
  - Has a:
    - Vocabulary
    - Syntax
    - Semantics

- Powerful, useful, but has its limits (especially for natural language); more about this later
First-order predicate logic

- Vocabulary:
  - Terms: refer to objects in the world
    - Constants: represent individuals
    - Variables: terms with no arguments: x, y
    - Functions: terms with a fixed number of arguments
      - locationOf(x), fatherOf(x,y)
  - Predicates: represent relations, predicates
    - Have a fixed number of arguments
    - Can be thought of as sets of tuples
      - isAt(x,y), gives(x,y,z), etc.
  - A binary identity predicate: =
  - Logic connectives: &, V, ¬, →, ↔
  - Quantifiers: ∀, ∃
  - Parentheses and brackets: (, ), [, ]
Quantifiers

- \(\forall\): universal quantifier; “for all”; mnemonic: upside-down A for “all”
  - \(\forall x\) dog(x)
  - means: for all x such that x has the property of being a dog

- \(\exists\): existential quantifier; “there exists”; mnemonic: backwards E for “exists”
  - \(\exists x\) dog(x)
  - means: there is/exists a/some x such that x has the property of being a dog

- \(\forall x [\text{dog}(x) \rightarrow \text{barks}(x)]\)
  - All dogs bark. Every dog barks. For all x, if x is a dog then x barks. If you’re a dog you bark.

- \(\exists x [\text{dog}(x) \& \neg \text{barked}(x)]\)
  - Some dog didn’t bark. There is a dog x and it didn’t bark. X is a dog that didn’t bark. etc.
Other conventions

- **dog(Fido)**
  - Predicate name is “dog”; takes one parameter/argument, which (here) is a constant
  - i.e. Fido is a proper noun that denotes the dog named Fido
- **dog(x)**
  - Predicate name is “dog”; takes one parameter/argument, which (here) is a variable
  - i.e. x is a variable that can be instantiated to represent a constant (e.g. Fido)
- **Substituting a variable**
  - dog \[x ← Fido\]
  - Here we’re instantiated the variable x with the constant Fido

- \(x + 9 = 12\)
  - \(+ (x, 9) = 12\)
  - \(+ (x, 9)[x ← 3] = 12\)
  - \(x=3\)
First-order predicate logic

- Syntax (well-formed formula’s):

  - If \( t_1 \) and \( t_2 \) are terms, \( t_1=t_2 \) is a wff.

  - If \( P \) is an \( n \)-place predicate, and \( t_1, t_2, \ldots t_n \) are individual terms, \( P(t_1,t_2,\ldots t_n) \) is a wff.

  - If \( \phi \) and \( \psi \) are wff’s, then \( \neg \phi \), \( (\phi \& \psi) \), \( (\phi \lor \psi) \), \( (\phi \rightarrow \psi) \), and \( (\phi \leftrightarrow \psi) \) are wff’s.

  - If \( \phi \) is a wff and \( x \) is an individual variable, \( \forall x \phi \) and \( \exists x \phi \) are wff’s.
First-order predicate logic

• Semantics (interpretation):
  • $P(t_1, t_2, \ldots, t_n) = \text{True} \iff \langle[[t_1]], [[t_2]], \ldots, [[t_n]]\rangle \in P$
  • Algebraic rules of propositional logic
    • $\forall x \phi = \text{True} \iff \phi[x \leftarrow e] = \text{True} \text{ for all } e \in U$
    • $\exists x \phi = \text{True} \iff \phi[x \leftarrow e] = \text{True} \text{ for some } e \in U$
    • Where $U$ is the universe / world of discourse
Examples

- John is hungry; therefore, John is eating cheerios.
  - $\text{hungry}(J) \rightarrow \exists x \ \text{eats}(J,x) \ & \ \text{cheerios}(x)$
- John eats cheerios in the kitchen.
  - $\exists x \ \exists y \ \text{eats}(J,x) \ & \ \text{cheerios}(x) \ & \ \text{kitchen}(y) \ & \ \text{in}(x,y)$
- We can only specify where the cheerios are, not where John eats!
  - How can we fix that?
Events: arguments and roles

- Event arguments let us specify events as things that can be in separate relations with all of the participants.
  - Let e be a variable representing an event
  - Represent thematicity with thematic roles for predicates
- John eats cheerios in the kitchen.
  - $\exists e \exists x \exists y \text{eat}(e) \& \text{AGENT}(e,J) \& \text{PATIENT}(e,x) \& \text{LOC}(e,y) \& \text{cheerios}(x) \& \text{kitchen}(y)$
More examples

- The police chased the burglar.
  - $\exists e \exists x \exists y \text{chase}(e, x, y) \land \text{PAST}(e) \land \text{police}(x) \land \text{burglar}(y)$

- I gave the summons to Eric.
  - $\exists e \exists x \text{give}(e) \land \text{AGENT}(e, I) \land \text{BENEFACTOR}(e, E) \land \text{THEME}(e, x) \land \text{summons}(x) \land \text{PAST}(e)$

- It is unfortunate that the team lost.
  - $\exists e \exists x \text{lose}(e) \land \text{EXPERIENCER}(e, x) \land \text{team}(x) \land \lnot \text{fortunate}(e) \land \text{PAST}(e)$

- Everybody loves Raymond
  - $\forall x \text{person}(x) \rightarrow \text{loves}(x, R)$
Next class (first half of Chapter 3)

- Quantification
- FOPC
- C-command
- Variable binding
- $M_1$: our model for FOPC