Generative Lexicon Theory: Theoretical and Empirical Foundations

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Brandeis University CS 135
(with Martha Palmer
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Course Outline

- Introduction: Motivation and Objectives.
- What is Generative Lexicon About? Basic Architecture of GL.
- Treatment of Compositionality. Selection and Coercion.
Lecture 1

Framing the problem: Encoding meaning creation in context

Sept. 9, 2014
Outline of Lecture 1
Motivation and Objectives

Questions

- How do words combine to make meanings?
- How do words meanings change in composition?
- How do we explain creative word use?
More Questions

- What conditions does a predicate impose on its arguments, and how are these conditions realized?
- How many meanings are needed for a word appearing in multiple syntactic contexts (i.e., polysemy)?
- What are the sources of polysemy? underspecified meanings?
- Where do interpretations for unarticulated constituents come from?
- Given these facts, how can we maintain a compositional semantics?
The Principle of Compositionality

The meaning of a complex expression is determined by its structure and the meanings of its constituents.
Starting Assumptions

- Language meaning is **compositional**.
- **Compositionality** is a desirable property of a semantic model.
- Many linguistic phenomena appear **non-compositional**.
- **Generative Lexicon** exploits richer representations and rules to enhance compositional mechanisms.
- Richer representations involve **Lexical Decomposition**.
- Richer rules involve **Coercion, Subselection, Co-composition**.
Outline of Lecture 1
Language Data

- What is the motivation for the theory? Lots of relevant data!
- Let’s look at the data!
Outline of Lecture 1
Two Types of Ambiguity

- **Homonymy**: unrelated senses of a word
  - bank vs. bank
  - chair vs. chair

- **Polysemy**: conceptually related senses of a word
  - book vs. book
  - door vs. door

- How are these to be represented in the lexicon?
Lexical and Structural Ambiguity

Language is highly ambiguous, and the ambiguity is due to different factors:

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- Local high school dropouts cut in half / polysemy
Two Types of Polysemy

- **Inherent polysemy**: where multiple interpretations of an expression are available by virtue of the semantics inherent in the expression itself.

- **Selectional polysemy**: where any novel interpretation of an expression is available due to contextual influences, namely, the type of the selecting expression.

   b. John doesn’t agree with the new Obama book. (inherent)

2. a. Mary left after her cigarette. (selectional)
   b. Mary left after her smoking a cigarette.

– We would like to represent different types of polysemy differently
Systematic (Logical) Polysemy

1. There’s chicken in the salad. (GRINDING)
2. We’ll have a water and two beers. (PACKAGING)
3. Roser finished her thesis. (finished doing what?)
4. Mary began the novel. (began doing what?)
5. Mary believes John’s story. (PROPOSITION)
6. Mary believes John. (PROPOSITION?)
Outline of Lecture 1
Underspecification of Meaning I

How many meanings for *good*?

1. good car
2. a good meal
3. a good knife

What does *noisy* select for?

1. a noisy\textsubscript{1} car
2. a noisy\textsubscript{1} dog
3. a noisy\textsubscript{2} room
4. a noisy\textsubscript{2} cafeteria

1. a fast typist
2. a fast train
3. a fast highway
Underspecification of Meaning II

- This ironing board is flat.
- My neighborhood is flat.
- My country is flat.
- The water is boiling.
- The pot is boiling.
Language Data: Motivation for the Theory

- We are looking at a lot of very diverse examples.
- They illustrate the mutability of meaning.
- And! The representation proposed within the GL theory is capable of modeling it very simply and elegantly.
Outline of Lecture 1
Flexibility of Interpretation

- Flexibility of Subject Interpretation
- Flexibility of Object Interpretation
- Flexibility of Experiencing
- Flexibility of Perceiving
- Flexibility of Aspectuals
- Flexibility of Arguments: Concealed Questions
Flexibility of Subject Interpretation

Subject of *kill*:

- John killed Mary.
- The gun killed Mary.
- The shot killed Mary.
- The bullet killed Mary.
- John’s pulling the trigger killed Mary.
- *The trigger killed Mary.*
Causation and Intention

- John rolled down the hill as fast as he could.
- John cooled off with an iced latte.

**Subject Rule** (Wechsler, 2005): Optionally interpret subject as AGENTIVE.

- kill vs murder:
  - John killed the flowers accidently / intentionally.
  - John murdered Mary.
  - *John murdered Mary intentionally / accidentally.

– This distinction can be lexicalized
Flexibility of Object Interpretation


- John swept \([\text{the dirt}]_{\text{material}}\).
- John swept \([\text{the room}]_{\text{region}}\).
- The man shoveled \([\text{the snow}]_{\text{material}}\).
- The man shoveled \([\text{the driveway}]_{\text{region}}\).
Flexibility of Arguments: Experiencers

1. That book bored me terribly.
   That movie bored me terribly.
   – bore selects for EVENT in the subject position
   – reading vs. watching

2. The movie frightened Mary.
   The dog frightened Mary.

3. The newspaper article angered the Republicans.

4. Listening to Mary irritated Alice.
   The narrow streets have always irritated Alice.

Exactly how it bores, frightens, or irritates us varies depending on the subject!
Flexibility of Arguments: Perception

- The boy heard a cat / a dog.
- They heard a bang / cry / rumor / shout / rain.
- !John heard the cloud/star/light.
- The crowd listened to the poem/speaker/speech.
Flexibility of Arguments: Attitudes, Factives

- Mary believes the rumor.
- No one believes the newspaper.
- She found the book hard to believe.
- They denied the actual conditions of the prisons.
- The graduate student regrets his last homework assignment.
- The hacker acknowledged the spam.
Flexibility of Arguments: Aspectuals

The verb *begin* is syntactically *polymorphic*:  
- Mary *began* [to eat her breakfast].  
- Mary *began* [eating her breakfast].  
- Mary *began* [her breakfast].

but semantically *underspecified*:  
- Mary *began*  
  her beer/thesis/dinner/class/homework/bath  
- John *enjoyed*  
  his coffee/movie/cigar/discussion/appointment

– The result is combinatorial explosion in the number of sense specifications!
Flexibility of Arguments: Concealed Questions

• John knows [that the earth is round].
• John told Mary [that she is an idiot].
• Mary realizes [that she is mistaken].

• Mary knows [what time it is].
• John knows [how old she is].
• Mary told John [where she lives].
• John told me [how old he is].

• Mary knows the time.
• John knows her age.
• Mary told John her address.
• John told me his age.
Outline of Lecture 1
Sense Enumerative Lexicon (SEL)

1. Different senses of a word are separate lexical entries.
2. Different senses behave differently in composition.
3. Lexical entry encodes both syntactic and semantic properties.

**semantics**

\[ \text{love}: \text{love}(\theta_1, \theta_2) \]

\[ \theta_1: \text{HUMAN}, \theta_2: \text{HUMAN} \]

1. John loves Mary.
2. Apply \(\text{love}(\theta_1, \theta_2)\) to Mary.
3. \(\Rightarrow \text{love}(\theta_1, \text{Mary})\)
4. Apply \(\text{love}(\theta_1, \text{Mary})\) to John.
5. \(\Rightarrow \text{love}(\text{John}, \text{Mary})\)
Lexical ambiguity is handled through separate lexical entries 1/2

1. **bake** (change-of-state): \( \text{bake}(\theta_1, \theta_2) \)

2. **bake** (create): \( \text{bake}(\theta_1, \theta_3) \)

John baked a potato.

1. Apply \( \text{bake}(\theta_1, \theta_2) \) to a potato

2. \( \text{bake}(\theta_1, \text{a\_potato}) \)

3. Apply \( \text{bake}(\theta_1, \text{a\_potato}) \) to John

4. \( \text{bake}(\text{John, a\_potato}) \)
Lexical ambiguity is handled through separate lexical entries 2/2

1. **bake** (change-of-state): bake($\theta_1, \theta_2$)
2. **bake** (create): bake($\theta_1, \theta_3$)

1. John baked a cake.
2. Apply bake($\theta_1, \theta_3$) to a cake
3. $\implies$ bake($\theta_1$, a_cake)
4. Apply bake($\theta_1$, a_cake) to John
5. $\implies$ bake(John, a_cake)
Outline of Lecture 1


Introducing Generative Lexicon Theory

- A lexical semantic theory that can do better!
- Addresses the generative expressiveness of language
- Lexical meaning is fundamentally decompositional, i.e., based on the idea that words encode complex concepts that may be decomposed into simpler notions
Traditional View of Decomposition

- Decomposing the meaning into features/components/primitives
  - e.g. table: inanimate, concrete, with-legs
- Other primitives:
  - animate, artifact, countable, portable, part-of(x)
  - act, cause, result, manner, motion
- But: does the verb like have two different meanings, and if so, how do you represent them?
  - John likes ice cream.
  - John likes my sister.
Generative Lexicon Theory

- The method adopted in GL to define the meaning of words is inverted!
- Instead of concentrating on how a word meaning may be decomposed, GL examines how a word meaning may compose with other meanings, and how it changes in the different contexts.
- GL draws insights about the meaning of a word by looking at the range of its contextual interpretations, and by examining how this range can be predictably derived from the underlying meanings.
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Outline of Lecture 1
Lexical Data Structures

(1) a. **Lexical Typing Structure**: giving an explicit type for a word positioned within a type system for the language;
b. **Argument Structure**: specifying the number and nature of the arguments to a predicate;
c. **Event Structure**: defining the event type of the expression and any subeventual structure it may have;
d. **Qualia Structure**: a structural differentiation of the predicative force for a lexical item.
Event Types

STATE : John loves his mother.
ACCOMPLISHMENT : Mary wrote a novel.
ACCOMPLISHMENT : John found a Euro on the floor.
PROCESS : Mary played in the park for an hour.
POINT : John knocked on the door (for 2 minutes).

Accomplishment vs. achievement:
- Mary finished writing a novel.
- *Mary wrote a novel at 5 pm.
- *John finished finding a Euro on the floor.
- John found a Euro on the floor at 5 pm.
Event Structure

In order to account for some internal aspects of event, some events need to be decomposed into subevents:

1. **kill**:
   \[ \lambda y x e_1 e_2 [\text{act}(e_1, x, y) \land \neg \text{dead}(e_1, y) \land \text{dead}(e_2, y) \land e_1 < e_2] : \]
   The gardener killed the flower.

**Event Headedness**: A way of indicating a foregrounding and backgrounding of sub-event. The arguments of a headed event must be expressed.

1. **arrive**: \( e' < e \)
2. **build**: \( e < e' \)

Subevents can be combined into a single event in different ways:

1. **accompany**: simultaneous subevents
2. **arrive**: one subevent precedes the other
Argument Structure Types

1. True Arguments (ARG): Syntactically realized parameters of the lexical item;

2. Default Arguments (D-ARG): Parameters which participate in the logical expressions in the qualia, but which are not necessarily expressed syntactically; e.g. John built the house with bricks.

3. Shadow Arguments (S-ARG): Logical parameters which are semantically incorporated into the lexical item. They can be expressed only by operations of subtyping; e.g. Mary buttered her toast with an expensive butter.

4. Optional Arguments: Parameters which modify the logical expression, but are part of situational or propositional interpretation, not any particular lexical item’s semantic representation. These include adjunct expressions of temporal or spatial modification.
Qualia Structure

(2) a. **FORMAL**: the basic category of which distinguishes the meaning of a word within a larger domain; encodes taxonomic information about the lexical item; *is-a* relation.
b. **CONSTITUTIVE**: the relation between an object and its material, constituent parts; *part-of* or *made-of* relation.
c. **TELIC**: the purpose or function of the object, if there is one; *used-for* or *functions-as* relation.
d. **AGENTIVE**: the factors involved in the object’s origins or “coming into being”; *created-by* relation.
GL Feature Structure

\[
\begin{align*}
\alpha & \\
\text{ARGSTR} & = \begin{bmatrix} \text{ARG1} = x \\
\ldots \end{bmatrix} \\
\text{EVENTSTR} & = \begin{bmatrix} \text{EVENT1} = e_1 \\
\text{EVENT2} = e_2 \end{bmatrix} \\
\text{QUALIA} & = \begin{bmatrix} \text{CONST} = \text{what } x \text{ is made of} \\
\text{FORMAL} = \text{what } x \text{ is} \\
\text{TELIC} = e_2: \text{function of } x \\
\text{AGENTIVE} = e_1: \text{how } x \text{ came into being} \end{bmatrix}
\end{align*}
\]
Qualia at Work

Mary began
her beer / thesis / dinner / class / book / bath

John enjoyed
his coffee / movie / cigar / discussion / appointment

Jessica started the car
Jessica locked the car
GL Solution

- In GL, identifying the meaning of words requires a system of lexical representation that allows words to change their meaning in different contexts.
- But! Maintains the distinction between word meaning and world knowledge: this is what qualia structure aims to accomplish.
Generative Lexicon Model

GL uses argument typing and qualia structure to model compositionality.

Main analytic tools:

- Qualia Structure
- Coercion Mechanisms (type shifting operations)

In GL, we look at the way the meanings are put together, and use these tools to understand analytically how it is done.
Lecture 2


September 9, 2014
Outline of Lecture 2
Lexical Data Structures

(3) a. **Lexical Typing Structure**: giving an explicit type for a word positioned within a type system for the language;
b. **Argument Structure**: specifying the number and nature of the arguments to a predicate;
c. **Event Structure**: defining the event type of the expression and any subeventual structure it may have;
d. **Qualia Structure**: a structural differentiation of the predicative force for a lexical item.
(4) a. **FORMAL**: the basic category of which distinguishes the meaning of a word within a larger domain; encodes taxonomic information about the lexical item; *is-a* relation.
b. **CONSTITUTIVE**: the relation between an object and its material, constituent parts; *part-of* or *made-of* relation.
c. **TELIC**: the purpose or function of the object, if there is one; *used-for* or *functions-as* relation.
d. **AGENTIVE**: the factors involved in the object’s origins or “coming into being”; *created-by* relation.
GL Feature Structure

\[
\alpha
\]

ARGSTR = \[
\begin{bmatrix}
\text{ARG1} &= x \\
\ldots
\end{bmatrix}
\]

EVENTSTR = \[
\begin{bmatrix}
\text{EVENT1} &= e_1 \\
\text{EVENT2} &= e_2
\end{bmatrix}
\]

QUALIA = \[
\begin{bmatrix}
\text{CONST} &= \text{what x is made of} \\
\text{FORMAL} &= \text{what x is} \\
\text{TELIC} &= e_2 : \text{function of x} \\
\text{AGENTIVE} &= e_1 : \text{how x came into being}
\end{bmatrix}
\]
Mary began her beer / thesis / dinner / class / book / bath

John enjoyed his coffee / movie / cigar / discussion / appointment

Jessica started the car
Jessica locked the car
In GL, identifying the meaning of words requires a system of lexical representation that allows words to change their meaning in different contexts.

But! Maintains the distinction between word meaning and world knowledge: this is what qualia structure aims to accomplish.
Generative Lexicon Model

GL uses argument typing and qualia structure to model compositionality.

Main analytic tools:

- **Qualia Structure**
- **Coercion Mechanisms** (type shifting operations)

In GL, we look at the way the meanings are put together, and use these tools to understand analytically how it is done.
Outline of Lecture 2
Motivation for Qualia

Motivation for Qualia relations comes from the idea that there is a hidden event in the lexical representation associated with nouns denoting objects made for a particular purpose:

(5) a. a door is for walking through  
    b. a window is for seeing through  
    c. a book is for reading  
    d. a beer is for drinking  
    e. a cake is for eating  
    f. a car is for driving  
    g. a table is for putting things on  
    h. a desk is for working on  
    i. a pen is for writing with
Motivation for Qualia

In certain syntactic contexts an event appears to be present in the interpretation of a noun, without being expressed in the syntax:

(6) a. They finished the beer. (drinking / TELIC)
    b. They finished the house. (building / AGENTIVE)

(7) a. a comfortable chair (to sit on)
    b. comfortable shoes (to wear, to walk in)
    c. a comfortable bed. (to sleep on)

(8) a. a dinner dress (wearing)
    b. a dessert wine (drinking)
    c. the dinner table (eating at)

This event is not arbitrary, but depends on the semantics of noun.
Light Verbs and Noun-to-Verb Transformations

- Light verb specifications:
  - Take a tablet (TELIC = ingest)
  - Take a train (TELIC = travel with)

- Noun-to-Verb transformations:
  - fax a document: (TELIC = send)
  - microwave the chicken: (TELIC = cook)
  - lace the shoes: (TELIC = tie)
Required Adjuncts?

Required adjuncts in short passives, middles and past participle constructions:

(9) Short passives (AGENTIVE(picture) = paint):
   a. *This picture was painted.
   b. This picture was painted in 1604.

(10) Middles (TELIC(book) = read):
   b. This book reads easily.

(11) Adjectival Use of Past Participles (AGENTIVE(house) = build):
   a. *a built house;
   b. a recently built house.
Qualia roles capture different properties of objects insofar as they are reflected in the language:

(12) a. **FORMAL**: taxonomic information, i.e. information about its basic conceptual category.
b. **CONSTITUTIVE**: information about material and parts of objects.
c. **TELIC**: information about the purpose and function of the object.
d. **AGENTIVE**: information about the origin / creation of the object.
World Knowledge vs. Lexical Specification

Not world knowledge, but just the knowledge relevant for understanding linguistic expressions:

- Our knowledge that bread as something that is brought about through baking is considered a Quale of the word bread;
- This knowledge is exploited in our understanding of linguistic expressions, such as fresh bread, meaning bread which has been baked recently.
Unspecified Qualia Roles

Not all lexical items carry a value for each qualia role:
- Some are left unspecified
- Others are populated with more than one value.

Natural objects (e.g., rock, fish, air, sea) typically do not have a value for the Agentive Quale, since the objects they reference are not products of human creation.
Artifacts are created by humans, for a purpose:

\[
\text{QUALIA} = \begin{bmatrix}
\text{letter} \\
\text{read} \\
\text{write}
\end{bmatrix}
\]
Qualia Roles for house

(14) a. He owns a two-story house. (house as artifact (F))
b. Lock your house when you leave. (part of house, door (C))
c. We bought a comfortable house. (purpose of house (T))
d. The house is finally finished. (origin of house (A))

\[
\text{QUALIA} = \begin{bmatrix}
F &= \text{building} \\
C &= \{\text{door, rooms, ...}\} \\
T &= \text{live in} \\
A &= \text{build}
\end{bmatrix}
\]
Constitutive Quale for car

(15) a. John started the car. / engine
b. You should warm your car up in winter. / engine
c. Did you lock the car? / door
d. The car screeched down the road. / tires
e. I’m going to fill up the car. / tank

\[
\text{QUALIA} = \begin{bmatrix}
car \\
\text{QUALIA} = \\
F = \text{vehicle} \\
C = \{\text{engine, door, wheels, ...}\}
\end{bmatrix}
\]
Criteria for Identifying Qualia Value

Distribution of nouns in context is the key:

(16) a. The rock shattered the window.
    b. Wooden windows are prone to rotting.

\[
\text{window}
\]

\[
\text{QUALIA} = \begin{bmatrix} C = \{\text{pane, frame, ...}\} \end{bmatrix}
\]
What’s Encoded in Lexical Entry?

When language accesses the component parts of a word’s meaning with systematic regularity, there is reason to think that those parts are encoded in the lexical semantics for that word.

E.g. **Car** in subject position occurs with verbs denoting human actions:

(17)  
   a. The **car** is **waiting** in the driveway.  
   b. A **car** **honked** from behind.
Cars and Drivers

Sense extension from the car to its driver (metonymy) suggests that this information is not only part of our world knowledge but is in fact encoded in the lexical entry (as an argument to the the Telic) and available for syntactic selection:

\[
\begin{bmatrix}
\text{car} \\
\text{QUALIA} = \begin{bmatrix}
F = \text{vehicle} \\
T = \text{drive(human,vehicle)}
\end{bmatrix}
\end{bmatrix}
\]
Lexically Encoded Metonymy

House and café are often used to refer to the people who live in or work there:

(18) a. Do you want to wake up the whole house?
    b. The rest of the house was sleeping.
    c. You had the whole café laughing.

Such data provide evidence for specific TELIC values for these noun concepts:

- live_in(human, building)
- eat_in(human, building).

\[
\begin{align*}
\text{QUALIA} &= \begin{bmatrix}
F = \text{building} \\
T = \text{live\_in(human, building)}
\end{bmatrix}
\end{align*}
\]
Relevant Linguistic Phenomena

- Contextual modulations of noun meaning: start/lock the car
- Implicit predicates in syntactic constructions:
  - Verb-Noun: finish the beer/house
  - Adjective-Noun: comfortable chair/shoes
  - Noun-Noun: dinner dress/table
- Flexibility of light verbs support verb constructions:
  - take a tablet/a train
- Noun-to-Verb transformations:
  - microwave = cook
- Required adjuncts in short passives, middles and past participle constructions
Formal Quale

Formal quale establishes a relation between the entity denoted by a word (e.g., dog) and the category it belongs to (i.e., ANIMAL):
Lexical Type Taxonomy
Formal Attributes for Concrete Entities

Salient properties of the entity are inherited along the is-a relations in this lexical hierarchy:

(19) a. Spatial characteristics, intrinsic orientation;
    b. Size and dimensional properties;
    c. Shape and form;
    d. Color.
**Const / part-of Relation**

**CONST** Quale specifies only those parts of an entity that are relevant for the linguistic behavior of the noun:

(20) a. John was going to paint his room ([**CONST** = walls]).
    b. She has swept the room ([**CONST** = floor]).

\[
\begin{align*}
\text{room} & \\
\text{QUALIA} & = \left[ \begin{array}{c}
F = \text{space} \\
C = \{ \text{walls, floor, ceiling, ...} \} \\
C_I = \text{building}
\end{array} \right]
\end{align*}
\]

a. Parts are available in discourse as individual units;
b. Parts make a functional contribution to the entity;
c. Parts are cognitively salient.
Genitive Construction for part-of Constitutive Quale

Nouns may express one of the default values of CONST syntactically, as in a genitive construction:

a. John was going to paint the room’s walls.
b. John was going to paint the walls of the room.
**Constitutive material / made-of Relation**

**FORMAL** role can be both modified and referenced by spatial predicates:

(21) a. They crossed the river. ([FORMAL = space])
    b. The river is wide. ([FORMAL = space])

The **CONSTITUTIVE** value can be referenced directly:

(22) a. The river had frozen during the severe weather.  
    **CONST** = water
    b. The river became polluted. 
    **CONST** = water

\[
\begin{bmatrix}
\text{river} \\
\text{QUALIA} = \\
F = \text{space} \\
C = \text{water}
\end{bmatrix}
\]
Expressing made-of Constitutive Quale

Adjectival modifiers:

(23)  a. a golden ring;
    b. a wooden floor;
    c. a metallic paint.

Nominal compounds:

(24)  a. plastic bag
    b. paper cup
    c. leather shoes
    d. milk chocolate

\[
\begin{align*}
\text{plastic bag} \\
\text{QUALIA} = \\
F = \text{bag} \\
C = \text{plastic}
\end{align*}
\]
Telic Quale

Information about intended use of objects (potential, characteristic activity) is encoded in the noun:

(25) a. This pen does not work well. (does not write)
    b. Can I use your pen? (for writing)
    c. We skipped (eating) the cake and settled for (drinking) another coffee.

(26) a. This is a difficult problem (to solve)
    b. This is a difficult question (to answer)

(27) a. Your lunch is ready (to eat).
    b. Your car is ready (to drive).
Telic Quale with -able Adjectives

-able adjectives to impose a specific interpretation on the Telic activity of the noun:

(28) a. There is no drinkable water here. (good for drinking)
   b. This is a very readable text-book. (easy to read)

– NB: Not water than can be drunk!
Natural Telic

Telic of nouns like human, dog, water, encodes information about the properties and actions they engage in, not intension or purpose:

    b. Rivers flow.
    c. The heart pumps blood.

– It is not the intentional purpose of a heart to pump blood, but it is a necessary activity for the object so defined. Likewise, a river does not intentionally flow, but this is a necessary property of a body of water if it is to qualify as a river.

(30) a fast/rapid/slow/lazy river (flowing)
    a slow/lazy student
Agentive Quale

Distinguishes between **created** and **naturally** occurring objects:

```
coffee
QUALIA = [ F = liquid 
T = drink 
A = brew ]
```

```
water
QUALIA = [ F/C = liquid 
A = nil ]
```

a. **fresh coffee** (**AGENTIVE** = brew)
b. **fresh water** (in contrast to “salt water”)
Agentive Quale for Abstract Entities

\[
\text{idea} \quad \begin{bmatrix}
\text{QUALIA} &=& \begin{bmatrix}
\text{F} &=& \text{proposition} \\
\text{A} &=& \text{think}
\end{bmatrix}
\end{bmatrix}
\]
Redundancy of Modification by Quale

Modifications of a noun by its quale is ungrammatical due to redundancy:

(31) a. *baked bread (AGENTIVE = bake) / a freshly baked bread
    b. *a built house (AGENTIVE = build) / a well-built house
    c. *a written book (AGENTIVE = write) / a beautifully written book

This effect is similar to the effect of properties inherited via the is-a hierarchy of FORMAL relations:

(32) a. *a male bachelor
    b. *a female woman
Extended Qualia

- **Telic**
  - Direct telic: the entity is the object of activity
    e.g. *beer* is the object of *drinking*
  - Indirect telic: the entity is not a direct object
    - Instrument telic:
      e.g. One *cuts with a knife*
    - Agentive noun telic (natural telic?):
      e.g. *drummer* is someone who *plays drums*

- **Constitutive**
  - Constitutive: *has-part, made-of* relation
    e.g. *spoon* is made out of *silver*
    e.g. *crowd* consists of *people*
  - Inverse constitutive: *is-part* relation
    e.g. engine is part of a car
Extended Qualia

**Telic**

- **Direct telic**: the entity is the object of activity
e.g. beer is the object of drinking
- **Indirect telic**: the entity is not a direct object
  - **Instrument telic**:  
e.g. One cuts with a knife
  - **Agentive noun telic** (natural telic?):
e.g. drummer is someone who plays drums

**Constitutive**

- **Constitutive**: has-part, made-of relation
  e.g. spoon is made out of silver
e.g. crowd consists of people
- **Inverse constitutive**: is-part relation
  e.g. engine is part of a car
Qualia Exploitation in Direct Object Position

- **chi dawan** 'eat a big bowl'
  - use a big bowl to eat
  - **INSTRUMENT TELIC**

- **chi shitang** 'eat the dining hall'
  - eat at the dining hall
  - **INDIRECT TELIC**
Conventionalized attributes

Conventionalized attributes (CA) extend qualia structure:

- **Conventional, prototypical use**: conventional way of experiencing something.
  
  e.g. *water is used for drinking; but it’s not its function*

Customary, habitual, stereotypical activities:

a. Mary sat out and **enjoyed the sun**. (warming up)

b. It’s a great place to **enjoy the sea**. (viewing, swimming, walking)
Telic Quale vs. Conventionalized Attribute

**Telics:**

a. Mary is a fast typist. \((\text{Telic} = \text{type})\)
b. This Porsche is a fast car. \((\text{Telic} = \text{drive})\)

Conventionalized or customary activities:

a. The tuna is one of the fastest fish in the sea. \((\text{swimming})\)
b. John was the fastest boy in the school. \((\text{running})\)
Perception predicates exploit CA

- hear the dog (barking)
- hear the rain (falling, hitting the roof)
- hear the wind (blowing)
- listen to the birds (singing)
  – but they are not FOR singing; cf. weak quale by Busa
- hear the car (pull in, making noise)
- hear the door (doorbell ring)
Outline of Lecture 2
Argument Structure

Argument types:
- true, default, shadow arguments

Type of the predicate is defined by virtue of the arguments it selects.

Argument structure specification:
- **Predicates and predicative nouns:**
  - number, type, syntactic expression of the arguments
- **Non-predicative nouns:** no argument structure specified.
- **Sortal nouns** would take referential arguments:
  - chair(x)
Compositionality as a Function Application

1. What is the nature of the function?
2. What does it apply to; i.e., what can be an argument?

- John loves Mary. *John loves.
- love(Arg₁, Arg₂)
- Apply love(Arg₁, Arg₂) to Mary
  \[\Rightarrow\] love(Arg₁, Mary)
- Apply love(Arg₁, Mary) to John
  \[\Rightarrow\] love(John, Mary)

Lambda notation

- Meaning for John loves Mary \[\Rightarrow\] love(John, Mary)
- Meaning for love \[\Rightarrow\] \(\lambda xy.\) love(x, y)
Selection in a Compositional Theory

1. What elements can select?
2. What is an argument?
3. What does it mean for a predicate to select an argument?
4. How does selection relate to composition and lexical decomposition?
Verb Meaning

(1) a. Verb: V How do we decompose the meaning?
   b. Arguments: x, y, z, ...

(2) a. Body: the predicate, with bound variables.
   b. Arguments: the parameter list.
Verb Meaning

(1) a. **Verb**: V How do we decompose the meaning?
b. **Arguments**: x, y, z, ...

(2) a. **Body**: the predicate, with bound variables.
b. **Arguments**: the parameter list.

\[
\text{Args} \quad \text{Body} \\
\lambda x_i \ [\Phi]
\]
Decomposition Strategies

1. atomic predication: do nothing, $P(x_1)$
2. add arguments: $P(x_1) \implies P(x_1, x_2)$
3. split the predicate: $P \implies P_1, P_2$
4. add and split: $P(x_1) \implies P(x_1, x_2), P_2(x_2)$
Atomic Predication

Syntax mirrors argument structure:

\[ \text{Verb} (\text{Arg}_1, \ldots, \text{Arg}_n) \iff \lambda x_n \ldots \lambda x_1 [\Phi] \]

1. \( \lambda x [\text{die}(x)] \)
The flower died.

2. \( \lambda y \lambda x [\text{hit}(x, y)] \)
The car hit the wall.
Add Arguments

Parameter structure adds additional arguments for interpretation in the model:

$$\lambda x_m \ldots \lambda x_{n+1} \lambda x_n \ldots \lambda x_1[\Phi] \Rightarrow \text{Verb}(\text{Arg}_1, \ldots, \text{Arg}_n)$$

1. $$\lambda y \lambda x \lambda e[\text{kill}(e, x, y)]: \text{(Davidson, 1967)}$$
The gardener killed the flower.

2. $$\lambda l_2 \lambda l_1 \lambda x \lambda e[\text{go}(e, x, l_1, l_2)]: \text{(Hobbs, 1993)}$$
Nicholas went to China.

3. $$\lambda t_2 \lambda t_1 \lambda l \lambda y \lambda x[\text{teach}(x, y, t_1, t_2, l)]: \text{(TimeML'07)}$$
Graham taught for an hour in Boston.
Split The Predicate

$P$ is defined as a complex expression of subpredicates over the parameter:

$$\text{Verb(}\text{Arg}_1\text{)} \implies \lambda x[\Phi_1, \ldots, \Phi_k]$$

1. **die:** $\lambda x[\text{alive}(x) \land \text{Become}(\neg \text{alive}(x))]$
   
The flower died.

2. **bachelor:** $\lambda x[\text{male}(x) \land \text{person}(x) \land \text{adult}(x) \land \neg \text{married}(x)]$
Add and Split

Parameter structure is enhanced, and $P$ is defined as a complex of subpredicates:

$$\text{Verb}(\text{Arg}_1, \ldots, \text{Arg}_n) \implies \lambda x_m \ldots \lambda x_{n+1} \lambda x_n \ldots \lambda x_1[\Phi_1, \ldots, \Phi_k]$$

$\text{kill}:$

$$\lambda y x e_1 e_2[\text{act}(e_1, x, y) \land \neg \text{dead}(e_1, y) \land \text{dead}(e_2, y) \land e_1 < e_2]:$$

The gardener killed the flower.
Argument Typing as Abstracting from the Predicate

Richer typing for arguments:

1. Identifies specific predicates in the body of the expression that are characteristic functions of an argument;

2. Pulls this subset of predicates out of the body, and creates a *pretest* to the expression as a restricted quantification over a domain of sorts, denoted by that set of predicates.
Types from Predicative Content

\[ \lambda x_2 \lambda x_1 [\Phi_1, \ldots, \Phi_{x_1}, \ldots, \Phi_{x_2}, \ldots, \Phi_k] \]

\[ \lambda x_2 : \sigma \lambda x_1 : \tau [\Phi_1, \ldots, \Phi_k - \{\Phi_{x_1}, \Phi_{x_2}\}] \]

\(\sigma\) and \(\tau\) have now become reified as types on the arguments.
A Flexible Strategy of Selection

Arguments can be viewed as encoding pretests for performing the action in the predicate.

If the argument condition (i.e., its type) is not satisfied, the predicate either:

- **fails** to be interpreted (strong selection);
- **coerces** its argument according to a given set of strategies.
Formal foundations. The notion of types
Outline of Lecture 3
Outline of Lecture 3
Function Application

(1) a. Verb: V How do we decompose the meaning?
   b. Arguments: x, y, z, ...

(2) a. Body: the predicate, with bound variables.
   b. Arguments: the parameter list.

\[ \lambda x_i [\Phi] \]
\textbf{\textit{\lambda}-Function Formalism}

- \lambda y : p \bullet i \lambda x : e_N[\textit{read}(x,y)]
- \lambda x : f(x)
- \lambda x : x^2
- \lambda x : 0 : \sqrt{x}
- \lambda x \lambda y : x < y

\text{MEANING}(\textit{read}) = \lambda y : p \bullet i \lambda x : e_N[\textit{read}(x,y)]
**λ-Function Formalism**

- $\lambda y : p \bullet i \lambda x : e_N[read(x,y)]$
- $\lambda x : f(x)$
  - $\lambda x : x^2$
  - $\lambda x > 0 : \sqrt{x}$
  - $\lambda x \lambda y : x < y$
- $\text{MEANING}(\text{read}) = \lambda y : p \bullet i \lambda x : e_N[read(x,y)]$
\(\lambda\)-Function Formalism

- \(\lambda y : p \bullet i \lambda x : e_N[\text{read}(x,y)]\)
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\textbf{\textit{\textlambda}-Function Formalism}

- Function typing:
  - \( e \rightarrow t \): a function that takes an entity (\( e \)) and returns a truth value (\( t \))
  - \( e_N \rightarrow (e_A \rightarrow t) \): a function that takes a natural entity type (\( e_N \)) and returns another function

- We want a similar representation for
  - \( \text{sleep} = \lambda y : e_N \) [\( \text{sleep}(x) \)]
  - \( \text{love Mary} = \lambda y : e_N \) [\( \text{love}(x, \text{Mary}) \)]

- both are functions of one argument, typed \( e_N \).


**λ-Function Formalism**

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Outline of Lecture 3

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Formal Quale

Formal quale specifies an is-a relation between the entity denoted by a word (e.g., dog) and the category it belongs to (i.e., ANIMAL).

- The basic category associated with the word (i.e., its semantic type);
- The position of the word in the hierarchy of types following from this association;
- The salient properties which enter into the definition of the type, which are inherited by the word along the Formal role.
Formal Attributes for Concrete Entities

Salient properties of the entity are inherited along the is-a relations in this lexical hierarchy:

(33) a. Spatial characteristics, intrinsic orientation;
    b. Size and dimensional properties;
    c. Shape and form;
    d. Color.

Each attribute may be filled with a value – e.g. long red dress
Formal Subsumption Relations Expressed in Language

FORMAL-specific Constructions:

(34) a. NP such as NP: events such as lectures, walks, tours and meetings;
b. such NP as NP: such areas as children’s playground;
c. NP and other NP: rum and other spirits;
d. NP or other NP: insects or other animals
e. NP, including NP: recyclable materials including glass;
f. NP, especially NP: cool temperate countries especially Europe and North America;
g. favorite NP is NP: Mario’s favorite food is pasta.
Inheritance of Formal Attributes

- Lexical meaning often provides default values for the different Formal factors or attributes.
- Default values are inherited properties of entities, that distinguish them within larger domain:

  → Size value associated with the noun ant is small, when evaluated relative to the superordinate class for the noun insect.
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Inheritance of Formal Attributes

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  \[ \text{Size} \text{ value associated with the noun } \text{ant} \text{ is small, when evaluated relative to the superordinate class for the noun } \text{insect}. \]
Update of Default Formal Attribute Values

Default values may be updated from discourse context in composition:

large ant, context makes us update the value of the Size factor from small (default) to large (for an ant)

Category and ontological classification information specified in the Formal role gives us a way to constrain the interpretation of relative interpretations of Size:

a large ant vs. a small dog,
Outline of Lecture 3
Outline of Lecture 3
Lexical Data Structures

(35) a. **LEXICAL TYPING STRUCTURE**: giving an explicit type for a word positioned within a type system for the language;
b. **ARGUMENT STRUCTURE**: specifying the number and nature of the arguments to a predicate;
c. **EVENT STRUCTURE**: defining the event type of the expression and any subeventual structure it may have;
d. **QUALIA STRUCTURE**: a structural differentiation of the predicative force for a lexical item.
(36) a. **FORMAL**: the basic category of which distinguishes the meaning of a word within a larger domain; encodes taxonomic information about the lexical item; *is-a* relation.
b. **CONSTITUTIVE**: the relation between an object and its material, constituent parts; *part-of* or *made-of* relation.
c. **TELIC**: the purpose or function of the object, if there is one; *used-for* or *functions-as* relation.
d. **AGENTIVE**: the factors involved in the object’s origins or “coming into being”; *created-by* relation.
GL Feature Structure

\[
\begin{align*}
\alpha & = \begin{bmatrix}
\text{ARG1} & = & x \\
\ldots & & \\
\end{bmatrix} \\
\text{ARGSTR} & = \\
\text{EVENTSTR} & = \begin{bmatrix}
\text{EVENT1} & = & e_1 \\
\text{EVENT2} & = & e_2 \\
\end{bmatrix} \\
\text{QUALIA} & = \begin{bmatrix}
\text{CONST} & = & \text{what x is made of} \\
\text{FORMAL} & = & \text{what x is} \\
\text{TELIC} & = & e_2: \text{function of } x \\
\text{AGENTIVE} & = & e_1: \text{how x came into being} \\
\end{bmatrix}
\end{align*}
\]
**Type Composition Logic** (Asher and Pustejovsky, 2006)

1. $e$ the general type of entities; $t$ the type of truth values. 
   (σ, τ range over all simple types, and subtypes of $e$.)

2. If $\sigma$ and $\tau$ are types, then so is $\sigma \rightarrow \tau$.

3. If $\sigma$ and $\tau$ are types, then so is $\sigma \otimes_R \tau$; $R$ ranges over $A$ or $T$.

4. If $\sigma$ and $\tau$ are types, then so is $\sigma \bullet \tau$. 
Qualia Types

\[
\chi : \alpha \\
\otimes_c \beta \\
\otimes_t \tau \\
\otimes_a \sigma
\]
Outline of Lecture 3
Three Categories of Types

- **Natural Types**: Carry only **FORMAL** and **CONST** qualia specifications;
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Typing for Major Categories

1. Noun
   N: rock, water, woman, tiger, tree
   A: knife, beer, husband, dancer
   C: book, lunch, university, temperature

2. Verb
   N: fall, walk, rain, put, have
   A: donate, spoil, quench
   C: read, perform

3. Adjective
   N: red, large, flat
   A: useful, good, effective
Natural Types

Entities formed from the application of the FORMAL and/or CONST qualia roles:

1. For the predicates below, \( e_N \) is structured as a taxonomy:
2. *physical, human, stick, lion, pebble*
3. *water, sky, rock*
Taxonomy of Natural Entity Types
Motivating the Notion of Natural Kind

a. Nominal Predication: How the common noun behaves predicatively;

b. Adjectival Predication: How adjectives modifying the the common noun can be interpreted;

c. Interpretation in Coercive Contexts: How NPs with the common noun are interpreted in coercive environments.
Motivating Evidence

Natural kinds seem to behave similarly to artifacts in adjectival constructions or as nominal heads:

- Mary saw every **dog/pet**.
- John visited a **man/doctor**.
- Birds/planes can fly.
- a sick **dog/pet**
- an American **man/doctor**
- white **birds/planes**
Motivating Evidence

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Predicative Uniqueness

Natural kinds appear to require predicative uniqueness:

a. Otis is a dog.
b. Otis is a poodle.
b. Eno is a cat.
a. Otis is a dog and an animal.
b. That is a dog and a cat.
c. Otis is a dog and therefore an animal.

–and-therefore construction is acceptable for sortal terms of which the first is a subcategory of the second.
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– *and*-*therefore* construction is acceptable for sortal terms of which the first is a subcategory of the second.
Predicative Uniqueness Elsewhere

For adjectives, restriction on co-predication is only present for terms in the same domain:

a. This box is large and small. (size)
b. Your gift is round and square. (shape)
c. bright and red; long and thin; flat and smooth
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Co-Predication in Artifactuals

Artifactuals, occupational terms, agentive nominals co-predicate easily:

a. This is both a pen and a knife.
b. The substance is a stimulant and an anti-inflammatory.

a. Mary is a housewife and a doctor.
b. Bernstein was a composer and a conductor.
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Predicative Uniqueness

This restriction on co-predication suggests that natural kind terms are structured in a taxonomy, obeying a complementary partitioning of the conceptual space.

1! That is a dog and a cat.
Multiple Inheritance

Subsumption constructions indicate multiple inheritance:

a. This object is a *knife* and therefore *a weapon*.
b. Emanuel Ax is a *pianist* and therefore *a musician*.
c. Emanuel Ax is a *pianist* and therefore *a human*. 
Multiple Inheritance for Naturals and Artifactuals
Ambiguity of Adjectival Modification

For artifactuals and agentives, adjectival modification can be ambiguous (e.g. between physical and non-physical attribute):

a. a blue pen (ink or material? CONST or FORMAL?)
b. a bright bulb
c. a long CD

a. a very old friend
b. a good professor
c. such a beautiful dancer

No such ambiguity is possible for natural kinds:

a. very old gold
b. a new tree
c. a young tiger
d. such a beautiful flower
Availability of Default Interpretation

a. Mary enjoyed drinking her beer.
b. Mary enjoyed her beer.

a. John began to write his thesis.
b. John began writing his thesis.
c. John began his thesis.

b. !John finished the tree.
b. !Mary began a tiger.
Natural Predicate Types

Predicates formed with Natural Entities as arguments:

1. **fall**: \( e_N \rightarrow t \)
2. **touch**: \( e_N \rightarrow (e_N \rightarrow t) \)
3. **be under**: \( e_N \rightarrow (e_N \rightarrow t) \)

Expressed as typed arguments in a lambda-expression:

a. \( \lambda x : e_N[fall(x)] \)

b. \( \lambda y : e_N \lambda x : e_N[touch(x,y)] \)

c. \( \lambda y : e_N \lambda x : e_N[be-under(x,y)] \)
Outline of Lecture 3
Artifactual Entity Types

Entities formed from the Naturals by adding the AGENTIVE or TELIC qualia roles:

1. **Artifact Entity**: $x : e_N \otimes_a \sigma$
   $x$ exists because of event $\sigma$

2. **Functional Entity**: $x : e_N \otimes_t \tau$
   the purpose of $x$ is $\tau$

3. **Functional Artifactual Entity**: $x : (e_N \otimes_a \sigma) \otimes_t \tau$
   $x$ exists because of event $\sigma$ for the purpose $\tau$

a. **beer**: $(\text{liquid} \otimes_a \text{brew}) \otimes_t \text{drink}$

b. **knife**: $(\text{phys} \otimes_a \text{make}) \otimes_t \text{cut}$

c. **house**: $(\text{phys} \otimes_a \text{build}) \otimes_t \text{live\_in}$
Human Functional Entity Types

**TELIC** and **AGENTIVE** constraints on the Natural Type **HUMAN**:

a. boss, friend;
b. dancer: *human* $\otimes_t$ *dance*
c. wife, husband: *human* $\otimes_a$ *marry*
Artifactual Predicate Types

Predicates formed with Artifactual Entities as arguments:

1. **spoil**: $e_N \otimes_t \tau \rightarrow t$
2. **fix**: $e_N \otimes_t \tau \rightarrow (e_N \rightarrow t)$

a. $\lambda x : e_A[spoil(x)]$

b. $\lambda y : e_A \lambda x : e_N[fix(x,y)]$

- The beer spoiled.
- Mary fixed the watch.
Complex Entity Types

Entities formed from the **Naturals** and **Artifactuals** by a **product type** between the entities, i.e., the dot, \( \cdot \).

1. a. Mary doesn’t believe **the book**.
   b. John sold **his book** to Mary.

2. a. **The exam** started at noon.
   b. The students could not understand **the exam**.
Motivating Dot Objects

When a single word or phrase has the ability to appear in selected contexts that are *contradictory* in type specification:

We had a *delicious leisurely* lunch.
Dot Object Inventory: 1

1. **Act•Proposition**: promise, allegation, lie
   - I doubt John’s promise of marriage.
   - John’s promise of marriage happened while we were in Prague.

2. **Attribute•Value**: temperature, weight, height, tension, strength
   - The temperature is rising.
   - The temperature is 23.
Dot Object Inventory: 2

1. **Event•(Information • Phys)**: lecture, play, seminar, exam, quiz, test
   
   a. My lecture lasted an hour.
   b. Nobody understood my lecture.

2. **Event•Music**: sonata, symphony, song, performance, concert
   
   a. Mary couldn’t hear the concert.
   b. The rain started during the concert.
Dot Object Inventory: 3

1. **Event** • **Physical**: lunch, breakfast, dinner, tea
   a. My lunch lasted too long today.
   b. I pack my lunch on Thursdays.

2. **Information** • **Physical**: book, cd, dvd, dictionary, diary, mail, email, mail, letter
   a. Mary burned my book on Darwin.
   b. Mary believes all of Chomsky’s books.
Dot Object Inventory: 4

1. **Organization** • (Information • Physical): magazine, newspaper, journal
   - a. The magazine fired its editor.
   - b. The cup is on top of the magazine.
   - c. I disagreed with the magazine.

2. **Process** • **Result**: construction, depiction, imitation, portrayal, reference
   - a. Linnaeus’s classification of the species took 25 years.
   - b. Linnaeus’s classification contains 12,100 species.
Distinct Principles of Individuation in Dot Objects


2. a. Mary answered every question in the class.
   b. Mary repeated every question in the class.
Today’s lunch$_2$ was longer than yesterday’s lunch$_1$. 

lunch2-eps-converted-to.pdf
Today’s lunch$_2$ was longer than yesterday’s [___]$^1$. 

1 lunch-.eps-converted-to.pdf
Copredication with Different Dot Object Elements

1 Today’s lunch\textsubscript{2} was longer than yesterday’s [__]\textsubscript{1}.
Complex Predicate Types

Predicates formed with a **Complex Entity Type** as an argument:

1. $\text{read}: \text{phys} \bullet \text{info} \rightarrow (e_N \rightarrow t)$

2. Expressed as typed arguments in a $\lambda$-expression:
   $\lambda y : \text{phys} \bullet \text{info} \ \lambda x : e_N[\text{read}(x,y)]$

3. Mary read the book.
Complex Predicate Types

Predicates formed with a Complex Entity Type as an argument:

1. \( \text{read: phys \bullet info} \rightarrow (e_N \rightarrow t) \)
2. Expressed as typed arguments in a \( \lambda \)-expression:
   \[ \lambda y : \text{phys \bullet info} \lambda x : e_N [\text{read}(x,y)] \]
3. Mary read the book.
Complex Predicate Types

Predicates formed with a **Complex Entity Type** as an argument:

1. \( \text{read}: \text{phys} \bullet \text{info} \rightarrow (e_N \rightarrow t) \)
2. Expressed as typed arguments in a \( \lambda \)-expression:
   \[
   \lambda y : \text{phys} \bullet \text{info} \ \lambda x : e_N[\text{read}(x,y)]
   \]
3. Mary read the book.
Mechanisms of Compositionality

September 12, 2014
Outline of Lecture 4
Three Categories of Types

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Three Categories of Types

- **Natural Types:**
  - Entities: formed from the application of the **FORMAL** and/or **CONST** qualia roles:
    - physical, human, lion, stone, pebble
  - Predicates: formed with **Natural Entities** as arguments:
    - fall: $e_N \rightarrow t$
    - touch: $e_N \rightarrow (e_N \rightarrow t)$

- **Artifactual Types:**
  - Entities: formed from Naturals by adding an **AGENTIVE** and/or **TELIC** qualia roles: **CONST** qualia roles:
    - beer: $(\text{liquid} \otimes a \text{ brew}) \otimes t \text{ drink}$
    - wife, husband: $\text{human} \otimes a \text{ marry}$
  - Predicates: formed with Artifactual Entities as arguments:
    - spoil: $e_N \otimes i \tau \rightarrow t$
    - fix: $e_N \otimes i \tau \rightarrow (e_N \rightarrow t)$
Three Categories of Types

- **Natural Types:**
  - Entities: formed from the application of the `FORMAL` and/or `CONST` qualia roles:
    - physical, human, lion, stone, pebble
  - Predicates: formed with Natural Entities as arguments:
    - fall: \( e_N \rightarrow t \)
    - touch: \( e_N \rightarrow (e_N \rightarrow t) \)

- **Artifactual Types:**
  - Entities: formed from Naturals by adding an `AGENTIVE` and/or `TELIC` qualia roles:
    - beer: \((\text{liquid} \otimes_a \text{brew}) \otimes_t \text{drink}\)
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Dot Objects / Complex Types

1. If \( \sigma \) and \( \tau \) are types, then so is \( \sigma \bullet \tau \).

2. When a single word or phrase has the ability to appear in selected contexts that are contradictory in type specification:

   We had a delicious leisurely lunch.

3. Each component type of the dot object has its own separate qualia specification, providing available interpretations in selection.

Book

CONST for INFO: chapters, paragraphs, ..
CONST for PHYS: pages, cover, paper, ...

University

CONST for ORGANIZATION: schools, departments, faculties, ..
CONST for LOCATION: buildings, rooms, ..
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Complex Predicate Types

Predicates formed with a Complex Entity Type as an argument:

1. \( \text{read}: \text{phys} \bullet \text{info} \rightarrow (e_N \rightarrow t) \)

2. Expressed as typed arguments in a \( \lambda \)-expression:
   \[
   \lambda y : \text{phys} \bullet \text{info} \lambda x : e_N[\text{read}(x,y)]
   \]

3. Mary read the book.
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Predicates formed with a **Complex Entity Type** as an argument:

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## Dot Type Inventory

<table>
<thead>
<tr>
<th>Dot type</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACTION</strong></td>
<td>promise, allegation, lie, charge</td>
</tr>
<tr>
<td><strong>STATE</strong></td>
<td>belief</td>
</tr>
<tr>
<td><strong>ATTRIBUTE</strong></td>
<td>temperature, weight, height, strength</td>
</tr>
<tr>
<td><strong>EVENT</strong></td>
<td>lecture, play, seminar, exam, quiz, test</td>
</tr>
<tr>
<td><strong>(INFO ● PHYSObj)</strong></td>
<td>concert, sonata, symphony, song</td>
</tr>
<tr>
<td><strong>EVENT</strong></td>
<td>lunch, breakfast, dinner, tea</td>
</tr>
<tr>
<td><strong>(INFO ● SOUND)</strong></td>
<td>article, book, CD, DVD, dictionary, diary, email, essay, letter, novel, paper</td>
</tr>
<tr>
<td><strong>ORGANIZATION</strong></td>
<td>newspaper, magazine, journal</td>
</tr>
<tr>
<td><strong>(INFO ● PHYSObj)</strong></td>
<td>university, city</td>
</tr>
<tr>
<td><strong>LOCATION</strong></td>
<td>class</td>
</tr>
<tr>
<td><strong>HUMANGROUP</strong></td>
<td>door, window</td>
</tr>
</tbody>
</table>

**Pustejovsky (Brandeis University)**
## Dot Type Inventory

<table>
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<td><strong>PROCESS • RESULT</strong></td>
<td>construction, imitation, portrayal, reference, decoration, display documentation, drawing, enclosure, entry, instruction, invention, simulation, illustration, agreement, approval, recognition, damage, compensation, contribution, discount, donation, acquisition, deduction, endowment, classification, purchase</td>
</tr>
<tr>
<td><strong>PRODUCER • PRODUCT</strong></td>
<td>Honda, IBM, BMW</td>
</tr>
<tr>
<td><strong>TREE • FRUIT / TREE • WOOD</strong></td>
<td>apple, orange, coffee / oak, elm, pine</td>
</tr>
<tr>
<td><strong>ANIMAL • FOOD</strong></td>
<td>anchovy, catfish, chicken, eel, herring, lamb, octopus, rabbit, squid, trout</td>
</tr>
<tr>
<td><strong>CONTAINER • CONTENTS</strong></td>
<td>bottle, bucket, carton, crate, cup, flask, keg, pot, spoon</td>
</tr>
</tbody>
</table>
Today’s lunch$_2$ was longer than yesterday’s [___]$_1$. 

lunch2-eps-converted-to.pdf
Today’s lunch$_2$ was longer than yesterday’s [___]$_1$. 

lunch-eps-converted-to.pdf
Today’s lunch\textsubscript{2} was longer than yesterday’s [\_\_\_]\textsubscript{1}. 

\texttt{lunch3-eps-converted-to.pdf}
Gating Predicates for Complex Types

For some complex types there are gating predicates that specify a transition between two simple types that make up the complex type:

She dictated a letter.

She cooked a frog.
Dot Object Disambiguators

The verb `dictate` has two main senses:
(1) verbalize to be recorded, and
(2) control

Direct objects for the first sense:
(37) a. passage, story, letter, memoirs, novel
    b. message, words, work, point

The nouns in (a) can not be dictated in the "control" sense.
The nouns in (b) are ambiguous between two senses.
The good disambiguators are actually dot objects of type `INFO • PHYSOBJ`, with `dictate` functioning as a gating predicate, which requires for the information to be given physical form.
Asymmetry of Dots

The use of complex types in text suggests that there is an inherent asymmetry in the way dot objects are used. This asymmetry is consistent with the systematic relation between the senses, where each sense corresponds to one of the component types. For example, for the ANIMAL • FOOD nominals, the subject position tends to disprefer the FOOD sense, whereas in the object position, such nominals occur both with the FOOD- and the ANIMAL-selecting predicates, as well as with the gating predicates. In the object position, the FOOD selectors and the gating predicates tend to dominate:

(38) chicken.n
subject
a. ANIMAL: peck, look, wander, come, cross, follow, die
object
a. ANIMAL: count, chase, kill, shoot, slaughter, skin, pluck, sacrifice, throw
b. FOOD: eat, serve, prefer, turn, dip, stuff, carve, baste, roast, simmer
c. ANIMAL • FOOD: poach, cook
Asymmetry of Dots

A similar asymmetry can be seen with respect to different argument positions for such dot types as PROCESS ● RESULT, EVENT ● PROPOSITION, etc. For example, adjectival modifiers for construction (PROCESS ● RESULT) tend to select for RESULT, whereas the predicates that take construction as direct object tend to select for PROCESS. Similarly, for allegation (EVENT ● PROPOSITION), the PROPOSITION interpretation is preferred in the object position.
Asymmetry of Dots

(39) **construction.n**
    **object**
    **EVENT**: finance, oversee, complete, supervise, halt, permit, recommend enable, delay, stimulate
    **PHYSOBJ**: examine, build, inaugurate, photograph
    **adjectival modifier**
    **PHYSOBJ**: logical, syntactic, passive, solid, all-metal, geometric, hybrid, rugged, sturdy, artificial, cultural, imaginative
Asymmetry of Dots

(40) allegation.n

object

EVENT: face, fuel, avoid, deflect

PROPOSITION: deny, refute, counter, contain, substantiate, rebut, confirm, believe, corroborate, hear, dispute, broadcast, prove
Asymmetry of Dots

Generic asymmetry of use (i.e. the asymmetry across all argument positions) is also a common property of some dot nominals. For example, such PROCESS • RESULT nominals as building, invention, acquisition show a distinct preference for one of the types in all argument positions. For building and invention, the RESULT/PhysObj interpretation is much more frequent, whereas for acquisition, the PROCESS/Event interpretation dominates the use in all argument positions.

NB. For building, for example, plan selects for the complex type Event • RESULT in the object position, while abandon may select for either of the component types.
Asymmetry of Dots

(41) invention n

object
a. RESULT: produce, explain, protect, adopt, develop, combine, patent, license, display, neglect, export, exploit
b. PROCESS: welcome, avoid, stimulate, spark, trace, facilitate, demand

subject
a. RESULT: simplify, impress, consist, popularize, appear, comprise

adjectival modifier
a. RESULT: finest, original, comic, successful, British, latest, patented, brilliant
Asymmetry of Dots

(42) building.n

object
a. PHYSOBJ: erect, demolish, construct, occupy, restore, enter, convert, design, destroy, lease, own, renovate, surround, damage, complete
b. EVENT: allow, finish, oppose, accelerate, initiate, halt, commence, stop, undertake
c. EVENT ● RESULT: plan
d. EVENT, RESULT: arrange, abandon

subject
a. PHYSOBJ: house, stand, collapse, contain, survive, belong, remain, overlook, surround, fall, replace, dominate
b. EVENT: begin, continue, commence
c. EVENT ● PHYSOBJ: date
d. EVENT, PHYSOBJ: accompany
Asymmetry of Dots

(43) acquisition n
object
a. EVENT: finance, fund, complete, announce, authorize, commence, facilitate, oversee, control, approve, undertake
b. RESULT: identify, secure, seize, store, stalk
subject
a. EVENT: occur, boost, result, strengthen, increase, depend, form, take, continue, affect, result
b. RESULT: turn out, offer, comprise, bore, allow
c. EVENT • RESULT: put, increase, mean, represent, complement
Outline of Lecture 4
Outline of Lecture 4
Compositionality in Language

**Principle of Compositionality** (Frege 1892):

The meaning of an expression is a function of the meanings of its parts and the way they are syntactically combined.

**Strong Compositionality**: allowing no semantic operations that aren’t syntactic:

Meaning of an expression is fully determined by the meanings of its constituents and by the way they combine syntactically.
Outline of Lecture 4
Tools for introducing unexpressed meanings

How do you maintain strong compositionality in the face of phenomena such as polymorphism, underspecified meanings?

Syntactic level solutions

- Adding null-elements
  - empty verbs, agentive markers to the subject, etc.
- Syntactic movement
  - Give the book to John
  - Give John the book

- polymorphism accounted for via transformations
Polymorphisms via transformations

- Give the book to John
- Give John the book

This is an enumerative technique: you have to put in two grammar rules, disjunctively:

\[ VP \rightarrow VP \text{ PP} \]
\[ VP \rightarrow V \text{ NP NP} \]

But what about

- \text{begin} to-VP
- \text{begin} NP

  - Is it the same kind of polymorphism? Do we associate semantics for NP with to-VP? Normal composition can not do that! So: you need two \text{semantic} begins, as well as two \text{syntactic} begins.
Semantic representation solutions

Weak Compositionality:

If all you have for composition is function application, then you need to create as many lexical entries for an expression as there are environments it appears in.

– senses multiply infinitely to account for generative expressiveness

Two ways to overcome this:

Overcoming Infinite Multiplication of Senses

**Type Shifting Rules:**
Dynamically generate the sense that would otherwise be cached in the sense-enumerative lexicon.

- shift *begin* to something that takes an NP.

**Type Coercion Operations:**
Type-shift the arguments!

- coerce NP to activity relating to the object.

– interpretation arises out of the semantics of the object.
Outline of Lecture 4
A Flexible Strategy of Selection

Arguments can be viewed as encoding pretests for performing the action in the predicate.

If the argument condition (i.e., its type) is not satisfied, the predicate either:

- fails to be interpreted (strong selection);
- coerces its argument according to a given set of strategies.
Argument Typing as Abstracting from the Predicate

Richer typing for arguments:

1. Identifies specific predicates in the body of the expression that are characteristic functions of an argument;

2. Pulls this subset of predicates out of the body, and creates a pretest to the expression as a restricted quantification over a domain of sorts, denoted by that set of predicates.
Types from Predicative Content

\[ \lambda x_2 \lambda x_1 [\Phi_1, \ldots, \Phi_{x_1}, \ldots, \Phi_{x_2}, \ldots, \Phi_k] \]

\[ \lambda x_2 : \sigma \lambda x_1 : \tau [\Phi_1, \ldots, \Phi_k - \{\Phi_{x_1}, \Phi_{x_2}\}] \]

\(\sigma\) and \(\tau\) have now become reified as types on the arguments.
Outline of Lecture 4
Outline of Lecture 4
Modes of Composition

a. **PURE SELECTION (TYPE MATCHING):** the type a function requires is directly satisfied by the argument;

b. **ACCOMMODATION:** the type a function requires is inherited by the argument;

c. **TYPE COERCION:** the type a function requires is imposed on the argument type. This is accomplished by either:
   
   i. **Exploitation:** taking a part of the argument’s type to satisfy the function;
   
   ii. **Introduction:** wrapping the argument with the type required by the function.
Direct Argument Selection

- The spokesman denied the statement (PROPOSITION).
- The child threw the ball (PHYSICAL OBJECT).
- The audience didn’t believe the rumor (PROPOSITION).
Paradigm Sentences

(44) Target = Natural
    a. The rock fell. (Source = Natural)
    b. The beer fell. (Source = Artifactual)
    c. The book fell. (Source = Complex)

(45) Target = Artifactual
    a. The water spoiled. (Source = Natural)
    b. The beer spoiled. (Source = Artifactual)
    c. The bottle spoiled. (Source = Complex)

(46) Target = Complex
    a. Mary read the idea. (Source = Natural)
    b. Mary read the rumor. (Source = Artifactual)
    c. Mary read the book. (Source = Complex)
Pure Selection / Type Matching

Pure selection happens for naturals, artifactuals, and complex types alike:

- The rock fell. (NATURAL)
- The beer spoiled. (ARTIFACTUAL)
- John read the book. (COMPLEX)
The rock fell.

\[ \lambda x : e_N[fall(x)] \]
Pure Selection / Type Matching: Natural Type II

(47) a. “fall” is of type $phys \rightarrow t$;
b. “the rock” is of type $phys$ (modulo GQ type shifting);
c. Function Application (TM) applies;
   $\rightarrow$ fall(the-rock)

(48) a. “fall” is of type $phys \rightarrow t$;
b. “some water” is of type $liquid$ (modulo GQ type shifting);
c. Accommodation Subtyping applies, $liquid \sqsubseteq phys$:
   $\rightarrow$ “some water” is of type $phys$:
d. Function Application (TM) applies;
   $\rightarrow$ fall(some-water)
Pure Selection / Type Matching: Artifactual Type

1. The beer spoiled.

\[
S \\
\sigma \otimes_T \tau
\]

\[
NP \quad \text{liquid} \otimes_T \text{drink} : e_A
\]

\[
VP \quad \text{the beer}
\]

\[
V \quad \text{spoiled}
\]

\[
\lambda x : e_A[\text{spoil}(x)]
\]
(49) a. “spoil” is of type $\text{phys} \otimes_T \tau \rightarrow t$;
b. “the beer” is of type $\text{liquid} \otimes_T \text{drink}$ (modulo GQ type shifting);
c. Accommodation Subtyping applies to the head, $\text{liquid} \sqsubseteq \text{phys}$:
   $\Longrightarrow$ “the beer” has head type $\text{phys}$:
d. Accommodation Subtyping applies to the TELIC, $\text{drink} \sqsubseteq \tau$:
   $\Longrightarrow$ “the beer” has TELIC type $\tau$
e. “the beer” has type $\text{phys} \otimes_T \tau$;
f. Function Application (TM) applies:
   $\Longrightarrow$ spoil(\text{the-beer})
John read the book.

\[ \begin{array}{c}
\text{VP} \\
\text{V} \quad p \bullet i \\
\text{NP: phys} \bullet info \\
\text{read} \quad \text{Det} \\
\text{the} \quad \text{N} \\
\text{book} \\
\end{array} \]

\[ p \bullet i \lambda x : e_N[read(x,y)] \]
Type Matching: Complex Types II

(50)  a. “read” is of type \( p \bullet i \rightarrow (e_N \rightarrow t) \);
     b. “the book” is of type \( p \bullet i \) (modulo GQ type shifting);
     c. Function Application (TM) applies;
         \[ \implies \lambda x \ [\text{read}(x, \text{the-book})] \]
Outline of Lecture 4
Two Kinds of Coercion in Language

- **Domain-shifting**: The domain of interpretation of the argument is shifted;
- **Domain-preserving**: The argument is coerced but remains within the general domain of interpretation.
Domain-Shifting Coercion

1. Entity shifts to event:
   I enjoyed the beer

2. Entity shifts to proposition:
   I doubt John.
Domain-Preserving Coercion

1. **Count-mass shifting**: There’s chicken in the soup.
2. **NP Raising**: Mary and every child came.
3. **Natural-Artifactual shifting**: The water spoiled.
4. **Natural-Complex shifting**: She read a rumor.
5. **Complex-Natural shifting**: John burnt a book.
6. **Artifactual-Natural shifting**: She touched the phone.
Type Shifting in Coercion

- The president denied the attack.
  \[\text{EVENT} \rightarrow \text{PROPOSITION}\]

- The White House denied this statement.
  \[\text{LOCATION} \rightarrow \text{HUMAN}\]

- This book explains the theory of relativity.
  \[\text{PHYS} \bullet \text{INFO} \rightarrow \text{HUMAN}\]

- The Boston office called with an update.
  \[\text{EVENT} \rightarrow \text{INFO}\]
Different Kinds of Type Coercion

- **The water spoiled.**
  (Quality Introduction)

- **John read the rumor.**
  (Natural to Complex Introduction)

- **Mary enjoyed her coffee.**
  (Event Introduction)
  (Quality Exploitation)

- **The police burned the book.**
  (Dot Exploitation)

- **Mary believes the book.**
  (Dot Exploitation)
The water spoiled.

\[
\lambda x : e_A[\text{spoil}(x)]
\]
Qualia Introduction on Natural Type (II)

(51) a. “spoil” is of type $\text{phys} \otimes_T \tau \rightarrow t$;
b. “the water” is of type $\text{liquid}$ (modulo GQ type shifting);
c. Accommodation Subtyping applies to the head, $\text{liquid} \sqsubseteq \text{phys}$:
   \[ \implies \text{“the water” has type } \text{phys}; \]
d. Coercion by Qualia Introduction (CI-Q) applies to the type $\text{phys}$, adding a TELIC value $\tau$:
   \[ \implies \text{“the water” has type } \text{phys} \otimes_T \tau; \]
e. Function Application applies;
   \[ \implies \text{spoil(the-water)} \]
Type Coercion: Artifactual to Complex Qualia

Introduction

John read the rumor.

\[ y: \, p \cdot i \lambda x: \, e_N[\{\text{read}(x,y)\}] \]

\[ \text{Det} \quad \text{the} \quad \text{NP:info} \quad \text{VP} \quad \text{phys} \bullet \text{info} \]

\[ \text{read} \quad \text{Det} \quad \text{N} \quad \text{NP:info} \quad \text{VP} \]
(52)  a. “read” is of type $p \bullet i \rightarrow (e_N \rightarrow t)$;
b. “the rumor” is of type $i$, $i \sqsubseteq t$ (modulo GQ type shifting);
c. Coercion by Dot Introduction (CI-•) applies to the type $i$, adding the missing type value, $p$, and the relation associated with the •:
   $\Rightarrow$ “the rumor” has type $p \bullet i$;
e. Function Application applies;
   $\Rightarrow \lambda x[\text{read}(x, \text{the-rumor})]
Mary enjoyed her coffee.

\[
\lambda x. \text{Event}(x, \text{NP}) \quad \text{NP: liquid} \otimes_{T} \text{drink}
\]

[event]

[portion]

[mass]

enjoy

Det

N

VP

V

NP

Pustejovsky (Brandeis University)
Mary enjoyed her coffee.
Domain-Shifting Coercion

(53) a. “enjoy” is of type $event \rightarrow (e_N \rightarrow t)$;
b. “her coffee” is of type $liquid \otimes_T drink$, (modulo GQ type shifting);
c. Coercion by Introduction (CI) applies to the type $liquid \otimes_T drink$, returning $event$:
   $\implies$ “her coffee” has type $event$;
d. Coercion by Qualia Introduction (CI-Q) applies to the type $event$, adding a value $drink$ to the predicate, $P$:
   $\implies$ “her coffee” has type $event$, with $P$ bound to $drink$;
e. Function Application applies:
   $\implies \lambda y[enjoy(y, \lambda x \exists e[drink(e,x,her-coffee)])]$
Type Coercion: Dot Exploitation

1. The police burned the book.
2. Mary believes the book.

\[
\begin{align*}
\text{VP} & \xrightarrow{\text{phys}} \text{NP:phys • info} \\
\text{V} & \xrightarrow{\text{burn}} \text{Det} \xrightarrow{\text{the}} \text{N} \xrightarrow{\text{book}} \\
\end{align*}
\]
Data for Coercion by Exploitation

(54) a. The beer fell.
   b. The bottle spoiled.
   c. The book fell.
   (c’. Mary bought a book. )
(55)

\[
S \\
\downarrow phys \\
NP: liquid \otimes_T drink \\
\downarrow the beer \\
\downarrow V \\
\downarrow fell \\
\lambda x : phys[fall(x)]
\]
Exploitation over Artifactual 2/2

(56) a. “fall” is of type $\text{phys} \rightarrow t$;
b. “the beer” is of type $\text{phys} \otimes_T \tau$ (modulo GQ type shifting);
c. Coercion by Exploitation (CE) applies to $\text{liquid} \otimes_T \tau$:
   $\Rightarrow$ “the beer” has type $\text{liquid}$;
d. Accommodation Subtyping (AS) applies to head, $\text{liquid} \sqsubseteq \text{phys}$:
   $\Rightarrow$ “the beer” has type $\text{phys}$:
e. Function Application applies;
   $\Rightarrow$ fall(the-beer)
Coercion by Dot Exploitation 1/2

(57)

\[ \lambda y : \text{phys} \lambda x : e_N[buy(x,y)] \]

\[ \text{the} \]

\[ \text{book} \]
Coercion by Dot Exploitation 2/2

(58) a. “buy” is of type $\text{phys} \rightarrow (e_N \rightarrow t)$;
b. “the book” is of type $\text{phys} \bullet \text{info}$, (modulo GQ type shifting);
c. Coercion by Dot Exploitation (CE-$\bullet$) applies to the type $\text{phys} \bullet \text{info}$, returning $\text{phys}$:
   $\Rightarrow$ “the book” has type $\text{phys}$;
e. Function Application applies:
   $\Rightarrow \lambda x[\text{buy}(x,\text{the-book})]$
Coercion Chains

(59) The bottle spoiled.

(60) a. “spoil” is of type $phys \otimes_T \tau \rightarrow t$;
b. “the bottle” is of type $phys \bullet liquid$, (modulo GQ type shifting);
c. Coercion by Dot Exploitation (CE-•) applies to the type $phys \bullet liquid$, returning $liquid$:
   \[ \Rightarrow \text{“the bottle” has type } liquid \]
d. Coercion by Qualia Introduction (CI-Q) applies to the type $liquid$, adding a \text{Telic} value $\tau$:
   \[ \Rightarrow \text{“the bottle” has type } liquid \otimes_T \tau \]
e. Function Application applies:
   \[ \Rightarrow \text{spoil(the-bottle)} \]
### Verb-Argument Composition Table

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(61) a. The children heard a sound outside.
b. The villagers heard the bell / alarm.
c. John heard the neighbor’s dog last night.
(62) a. “hear” is of type \( \text{sound} \rightarrow (e_N \rightarrow t) \);
b. “a sound” is of type \( \text{sound} \) (modulo GQ type shifting);
c. Function Application (TM) applies;
\[ \lambda x[\text{hear}(x,(a\text{-sound})] \]
Functional Coercion 3/6

(63) a. John left Boston.
    b. Mary taught before noon.

(64) a. John left the party.
    b. Mary taught before the party.
(65) Attribute Functional Coercion (AFC):
a. Given an expression $\alpha$, typed as: $\tau \rightarrow \beta$
b. the type $\tau$ shifts to $e \rightarrow \tau$
c. $\alpha$ is now typed as: $(e \rightarrow \tau) \rightarrow \beta$
(66) a. \( \text{leave}: \lambda y: \text{loc} \ \lambda x: e_N[\text{leave}(x, y)] \)

Functional Coercion: \( \text{loc} \Rightarrow e \rightarrow \text{loc} \)

\( \text{leave}: \lambda y: e \rightarrow \text{loc} \ \lambda x: e_N[\text{leave}(x, y)] \)

\( = \lambda y: e \ \lambda x: e_N[\text{leave}(x, \text{loc}(y))] \)

b. \( \exists e \exists y[\text{leave}(j, y) \land \text{party}(e) \land \text{loc}(e) = y] \)
(67) a. “hear” is of type $\text{sound} \to (e_N \to t)$;
b. ‘the bell’ is of type $\text{phys} \otimes_T \text{ring}$ (modulo GQ type shifting);
c. Functional Coercion applies to $\text{sound}$: $\text{sound} \Rightarrow e \Rightarrow \text{sound}$
e. Function Application (TM) applies;
   $\Rightarrow \lambda x[\text{hear}(x,(\text{sound}(\text{the-bell})))]$
d. CE-Q applies to $\text{phys} \otimes_T \text{ring}$, returning $\text{ring}$:
   $\Rightarrow \lambda x[\text{hear}(x,(\text{ring}(\text{the-bell})))]$
Composition Mechanisms

hear (Body: ’perceive with the ear’, Arg: sound):
- hear voice, sound, whisper, thud, whistle, bang: sound ⊆ phys
- hear siren, bell, alarm clock: phys (formal) + telic = ring
  – hear(alarm clock) is about ringing, not ticking: Qualia Exp
  – bell awakened, warned, alerted: telic event = ringing, Qualia Exp

mind:
- I am sure David won’t mind sandwiches for a day.
  – mind event : Event Introduction
  – eat phys (sandwiches) : Qualia Exploitation
Empirical Applications: from Theory to Practice

September 12, 2014
Outline of Lecture 5
Outline of Lecture 5
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**mind**:
- I am sure David won’t mind sandwiches for a day.
  - mind event : Event Introduction
  - eat phys (sandwiches) : Qualia Exploitation
Wrapping Entity with an Attribute

(68) a. John heard the neighbor’s dog last night.
    b. I did not hear the alarm.
    c. I did not hear the door.

(69) a. “hear” is of type $\text{sound} \rightarrow (e_N \rightarrow t)$;
    b. Attribute becomes a function: $\text{sound} \Rightarrow e \rightarrow \text{sound}$
        $\Rightarrow \lambda y : e, \lambda x : e_{anim}[\text{hear}(x,(\text{sound}(y)))]$
Attribute → Function Coercion

(70) a. John left Boston.
   b. Mary taught before noon.

(71) a. John left the party.
   b. Mary taught before the party.

(72) a. \textit{leave}: \(\lambda y : \text{loc} \ \lambda x : \text{e}_N[\text{leave}(x, y)]\)
   b. Attribute becomes a function: \(\text{loc} \Rightarrow e \rightarrow \text{loc}\)
   c. \textit{leave}: \(\lambda y : e \rightarrow \text{loc} \ \lambda x : \text{e}_N[\text{leave}(x, y)]\)
      \((= \lambda y : e \ \lambda x : \text{e}_N[\text{leave}(x, \text{loc}(y))])\)
   d. \(\exists e \exists y[\text{leave}(j, y) \land \text{party}(e) \land \text{loc}(e) = y]\)
Outline of Lecture 5
Co-compositionality

- Bilateral functional application:
- Both predicate and argument act functionally to build the resulting meaning

Three Kinds of Co-composition

- Predicate Coercion:
  Subject acts functionally over its own predicate

- Predicate Cospecification:
  Verb and object create a new meaning

- Argument Cospecification
  Two arguments of the verb are related independently of the selecting predicate
Bi-directional Selection:

Verb: take on

Sense 1: tackle an adversary:
competition, rival, enemy, opponent, team, congress, world.

Sense 2: acquire a quality:
shape, meaning, color, form, dimension, reality, significance, identity, appearance, characteristic, flavor.

- Are you willing to take on the competition?
- Are you willing to take on the Congress?
- It is much harder to take on the opponent you know personally.
- It is much harder to take on the student you know personally.
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Encoding Change through Selection

1. a. Mary fixed every leaky faucet.
   b. Mary fixed every brass faucet.

2. a. John drank a full glass of milk.
   b. !John drank an empty glass of milk.

3. John closed the open door.

4. People filled the empty hall.

5. a. Mary cleaned the dirty table.
   b. Mary cleaned the glass table.

6. a. [The audience]; left the theatre.
   b. *[It]; went home.
   c. [They]; went home.
Outline of Lecture 5
Selective Binding of Adjectives

NP

\[ \bar{A} \]

\[ \bar{N} \]

A

A

A

A

A

knife

\[ \text{sharp} \]

\[ \text{forged} \]

\[ \text{metal} \]

\[ \text{hunting} \]

\[ \text{F} \]

\[ \text{C} \]

\[ \text{A} \]

\[ \text{T} \]
How Adjectives Bind to Qualia: Constitutive

- **CONST**
  a. wooden house
  b. mountainous region
  c. clay tablets
How Adjectives Bind to Qualia: Formal

- FORMAL
  heavy, red, large, sweet, raw, rough, hard, simple, responsible, happy, short, narrow, poor, bitter, new
How Adjectives Bind to Qualia: Telic

TELIC

a. useful table
b. bright bulb
c. good knife
How Adjectives Bind to Qualia: Agentive

AGENTIVE

a. carved figure
b. hand-made shoes
c. synthetic material
d. natural light
Outline of Lecture 5
Bisetto and Scalise (2005)

Given a compound structure \([N_1 \ N_2]\):

- **SUBORDINATING**: the head acts functionally over \(N_1\), incorporating it as an argument.
- **ATTRIBUTIVE**: a general modification relation of \(N_1\) over \(N_2\).
- **COORDINATE**: the dvandva construction, with two elements without dependency holding between them.
Nominal Compounds

- Synthetic Compounds:
  Given a compound structure \([N_1 \ N_2]\): \(N_1\) is interpreted as an argument to \(N_2\)
  - bus driver
  - window cleaner

- Non-synthetic Compounds:
  - pastry chef
  - bread knife

Qualia-based meaning derivation: chef is someone who bakes pastries, knife is something that is used for cutting bread.
Compound Modification Relations

Given a compound \textbf{[A N]}:
A is the \textsc{telic} value of N:

- fishing rod
- magnifying glass
- swimming pool
- shopping bag
- drinking water
Compound Modification Relations

Given a compound \([N_1 \ N_2]\):

- party napkins
- kitchen table
- ipod speaker
- Christmas dinner
Compound Modification Relations

Given a compound $[N_1 \ N_2]$:
$N_1$ is the \text{CONST} of $N_2$:
- paper napkins
- metal cup
- gold filling
Compound Modification Relations

Given a compound $[N_1 N_2]$:

- $N_1$ is the AGENTIVE of $N_2$:
  - food infection
  - heat shock
  - university fatigue
  - automobile accident
  - sun light
Outline of Lecture 5
Outline of Lecture 5
GL AND CPA

Merging Two Traditions in Study of Language

- **Generative Lexicon:**
  Encoding lexical dynamic context for richer interpretation of natural language.

- **Corpus Language Philosophy:**
  Manipulation of usage situations associated with words and word tuples.
Consider the word *treat*:

- Peter treated Mary badly.
- Peter treated Mary with antibiotics.
- Peter treated Mary with respect.
- Peter treated Mary for her asthma.
- Peter treated Mary to a fancy dinner.
- Peter treated Mary to his views on George W. Bush.
- Peter treated the woodwork with creosote.
Analyzing Contexts of Usage

Consider the word **treat**:

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- Peter treated the woodwork with creosote.
Patterns for *treat*

69%  

$$[[\text{Human 1} \mid \text{Institution 1} \mid \text{Animal 1}]] \text{ treat } [[\text{Human 2} \mid \text{Animal 2} \mid \text{Entity} \mid \text{Event}]] \text{ [Adv[Manner]]}$$

$$\rightarrow [[\text{Human 1} \mid \text{Institution 1} \mid \text{Animal 1}]] \text{ behaves toward } [[\text{Human 2} \mid \text{Animal 2} \mid \text{Entity} \mid \text{Event}]] \text{ in the [Manner] specified}$$

17%  

$$[[\text{Human 1} = \text{Health Professional} \mid \text{Process} = \text{Medical} \mid \text{Drug}]] \text{ treat } [[\text{Human 2} = \text{Patient} \mid \text{Animal} = \text{Patient} \mid \text{Disease} \mid \text{Injury}]] \text{ [NO ADVL]}$$

$$\rightarrow [[\text{Human 1} = \text{Health Professional}]] \text{ applies a } [[\text{Drug}]] \text{ or } [[\text{Process} = \text{Medical}]] \text{ to } [[\text{Human 2} = \text{Patient}]] \text{ for the purpose of curing the patient’s } [[\text{Disease} \mid \text{Injury}]$$
Patterns for treat, cont’d

5%  [[Human]] treat [[Inanimate]] (with [[Stuff]] | by [[Process]])
→ The chemical or other properties of [[Inanimate]] are improved or otherwise changed by [[Process]] or the application of [[Stuff]]

5%  [[Human 1]] treat [[Human 2 | Self]] (to [[Eventuality = Good]])
→ [[Human 1]] gives or pays for [[Eventuality = Good]] as a benefit for [[Human 2 | Self]]
Outline of Lecture 5
Type Inheritance for Naturals and Artifacts
Corpus-Driven Type System

- Entity
- Eventuality
- Part
- Property
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Pustejovsky (Brandeis University)
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Corpus-Driven Type System

Eventuality $\rightarrow$ State $\rightarrow$ Abstract

- Privilege
- Psych
  - Attitude
  - Emotion
  - Goal
- Time Point
- Obligation
- Responsibility
- Power
- Uncertainty
- Concept
  - Proposition
  - Narrative
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Corpus-Driven Type System

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  - Proposition
  - Narrative
  - Information
  - Rule
Patterns for Specific Types

Type **Concept**:
- accept
- apprehend
- construct
- awaken
- arrive
- dignify
- ...

It is not what you’d expect!
Patterns for Specific Types

Type **Concept:**

- **awaken:**
  - 44% awaken [[Emotion | Attitude | Concept | Skill]] in [[Human]]
  - 11% awaken [[Human]] to [[Emotion | Attitude]]
  - e.g. awaken expectations, memories, feelings

- **arrive:**
  - 14% [[Human | Institution]] arrive at [[Concept = Considered Opinion]]
  - e.g. arrive at opinion, conclusion, design, solution, understanding
Patterns for Specific Types

Type Building Part:
- creak
- devote
- house
- plan
- ...

Type Vehicle Group:
- ambush
- crawl
Outline of Lecture 5
Are we working with invented examples?
Do these phenomena exist?
Can we account for what’s going on using the proposed solutions?

Let’s look at the real data!
## Corpus Data on Complex Types: book (as Obj)

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## Complex Types: book (modified by Adjective)

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Complex Type Structure is Exploited Differently in Different Grammatical Positions

- Book in Subject position exploits the information type
- Book in Object position exploits the physical type
Corpus Data on spoil

In both BNC and Associated Press, over 80% of **Direct Objects** of **spoil** are **Events**. Typically, they are **Events** that one would expect to enjoy. The implicature is that, by spoiling an Event, one kills the enjoyability of it. One might say that spoil is a **causative antonym** of enjoy. The lexical set of direct objects of spoil include: fun, enjoyment, magic, pleasure, holiday, party, Christmas, birthday, dinner, evening, morning, day, half-hour, event, occasion, view, performance, opera, game, match, ...
Corpus Data on Selection: \textit{believe} + \textit{clause}

\begin{tabular}{lll}
inf clause & 1996 & 0.6 \\
ing clause & 18 & 1.9 \\
that clause & 13974 & 2.6 \\
wh clause & 486 & 0.5 \\
\end{tabular}
**Corpus Data on Selection:** believe +NP

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<tr>
<td>propaganda</td>
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</tbody>
</table>
31 percent said they’d believe the newspaper, primarily because they had "more. He seems to have made the mistake of believing his own propaganda. Politicians are always at their most vulnerable when they believe their own propaganda. They weren’t quite so stupid as to believe wholly their own propaganda. The trouble with the hon. Gentleman is that he believes his own propaganda. The trouble is, the media is able to influence the public and unfortunately influential people in the trade union and labour movements, and maybe they believe the propaganda that socialism is dead and respond accordingly.
Corpus Data on Selection: doubt + NP

ability    validity
sincerity  sanity
existence correctness
accuracy  wisdom
viability truth
authenticity word
feasibility suitability
veracity
strength
seriousness
faith
value
presupposition
possibility
claim
commitment
## Corpus Data on Artifactual Selection: repair + NP

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<td>hernium</td>
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<td>16</td>
<td>13.52</td>
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</tbody>
</table>
Corpus Data on Complex Selection: read + NP

- book 772 43.31
- newspaper 205 35.76
- bible 82 34.24
- papers 144 32.61
- article 156 31.89
- letter 226 30.44
- poem 85 29.39
- novel 88 28.57
- paper 175 28.54
- text 112 26.93
- passage 82
- story 148 26.03
- comic 26 26.89

- magazine 85 25.38
- script 37 24.37
- poetry 46 24.12
- report 180 23.37
- page 89 23.25
- paragraph 38 22.92
- word 162 21.85

Pustejovsky (Brandeis University)
Generative Lexicon Theory
September 12, 2014
Corpus Data on Propositional Selection: \textit{tell + NP}

- story
- truth
- lie
- tale
- reporter
- inquest
- court
- Reuter
- conference
- fib
- joke
<table>
<thead>
<tr>
<th>Word</th>
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Corpus Data on Complex Types: lecture (as Obj)

- attend 75 38.84
- deliver 65 38.02
- give 226 35.18
- entitle 12 19.41
- organise 9 14.38
- Present 13 14.16
- sponsor 5 12.55
- illustrate 7 12.44
- finish 7 11.81
- include 13 11.4
- organize 5 11.21
- publish 8 10.99
- prepare 7 10.52
- get 22 9.82
- record 6 9.73
- hold 12 9.55
- arrange 5 9.46
- read 6 8.59
- write 8 8.54
- begin 6 6.4
## Corpus Data on Complex Types: seminar (as Obj)

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Driving Questions

- How do words combine to make meanings?
- What are the sources of polysemy and underspecified meanings?
- Can we explain how do words meanings change in composition?
What we have done?

- Developed a model for the lexicon that allow us to explain these phenomena generatively.
- Semantic load for an utterance is distributed between different elements (predicate, arguments, modifiers).
- No need for sense enumeration!
- Accounts for very large amounts of linguistic phenomena:
  - argument selection
  - adjectival modification
  - nominal compounds
  - light verb constructions
  - implicit predicates in V-N, A-N, N-N constructions
  - required adjuncts in short passives, middles, adj. use of participles
  - co-composition
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