Relating Language to Perception, Action, and Feelings

Arun K. Majumdar and John F. Sowa

International Conference on Conceptual Structures, 2013

Slides revised, 15 March 2022

Relating Language to Perception, Action, and Feelings

Outline:

1. Neural Foundations for Language

Language is a late development in evolutionary time.

The systems of perception and action were developed millions of years before some early hominin began to talk.

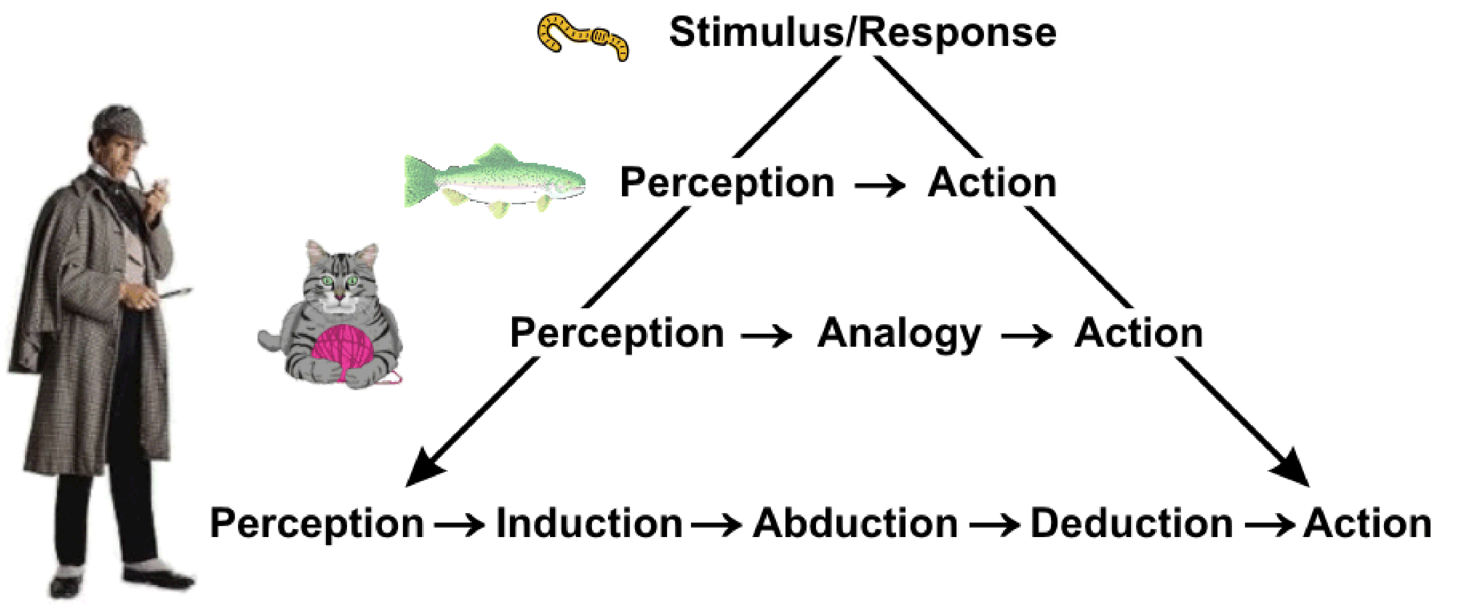
People and higher mammals use the mechanisms of perception and action as the basis for mental models and reasoning.

Language understanding and generation use those mechanisms.

Logic and mathematics are based on abstractions from language.

For any notation – natural or artificial – semantics depends on the mapping to the world by means of perception and action.

Cognitive Complexity



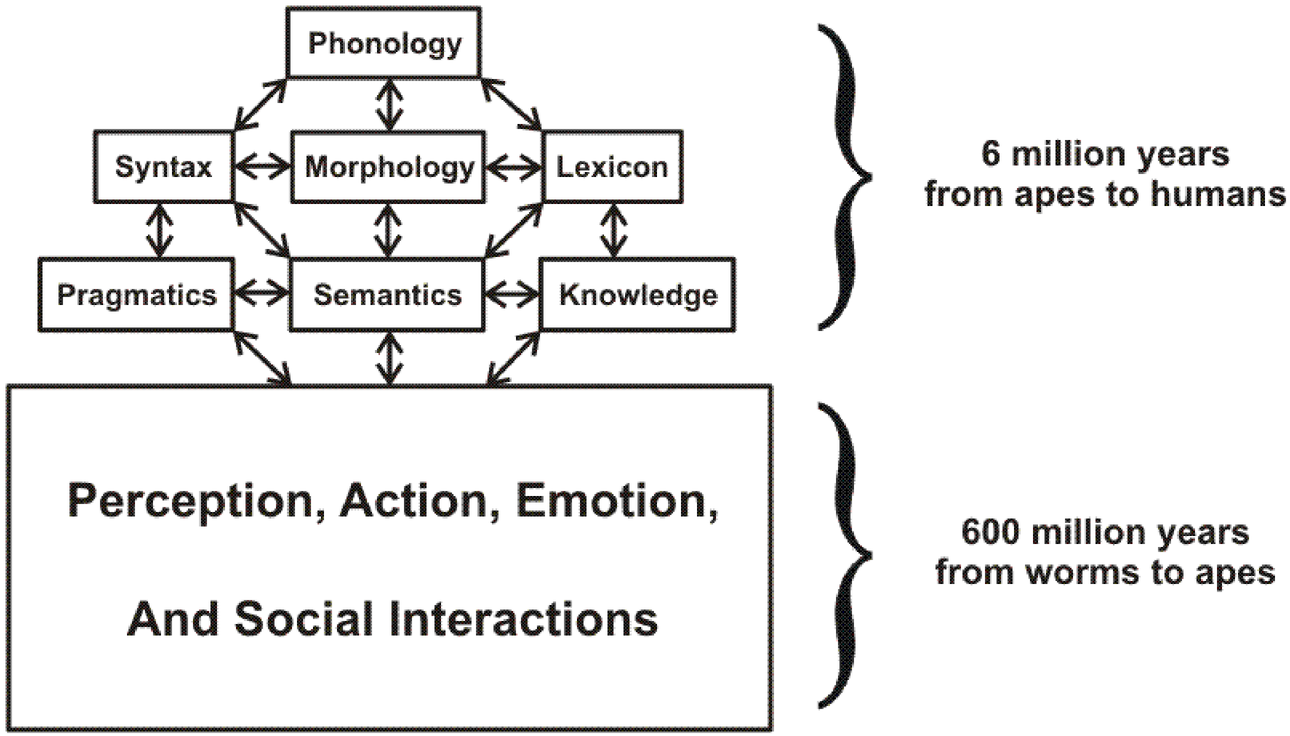
Each level inherits the abilities of all previous levels.

Fish already have complex perception and action.

Mammals have a much larger cerebral cortex.

But their more complex methods of reasoning are also designed to relate perception and action.

Evolutionary View of Cognition



Most human cognition except language is at the chimpanzee level.

Language is supported by and integrated with that level.

The huge increase in the size of the human cerebral cortex results from "the co-evolution of language and the brain" (Deacon 1997).

Brain Stem

The cerebral cortex is essential for all complex reasoning and language.

The cerebellum learns and controls fine tuned, but automatically executed skills.

But the brain stem controls all basic functions necessary for maintaining life.

It also integrates all inputs and outputs to and from the cerebral cortex.

The superior colliculus integrates vision with eye movements and head position.

It also relates vision to the auditory inputs processed by the inferior colliculus.

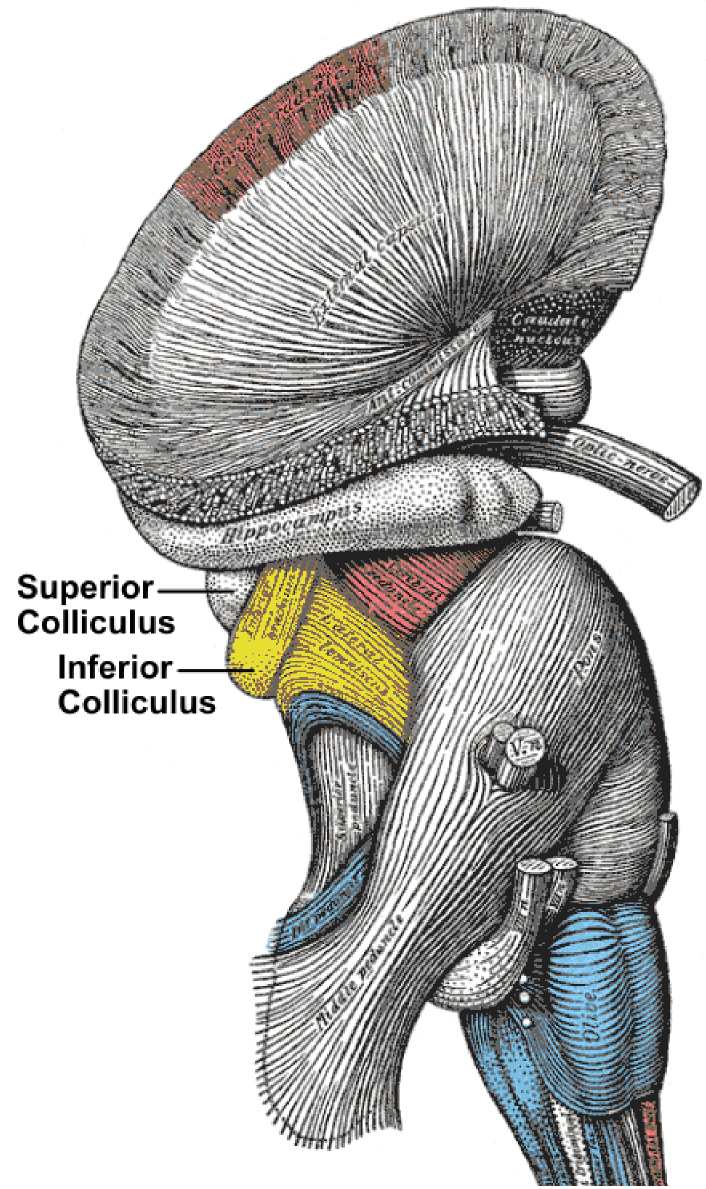
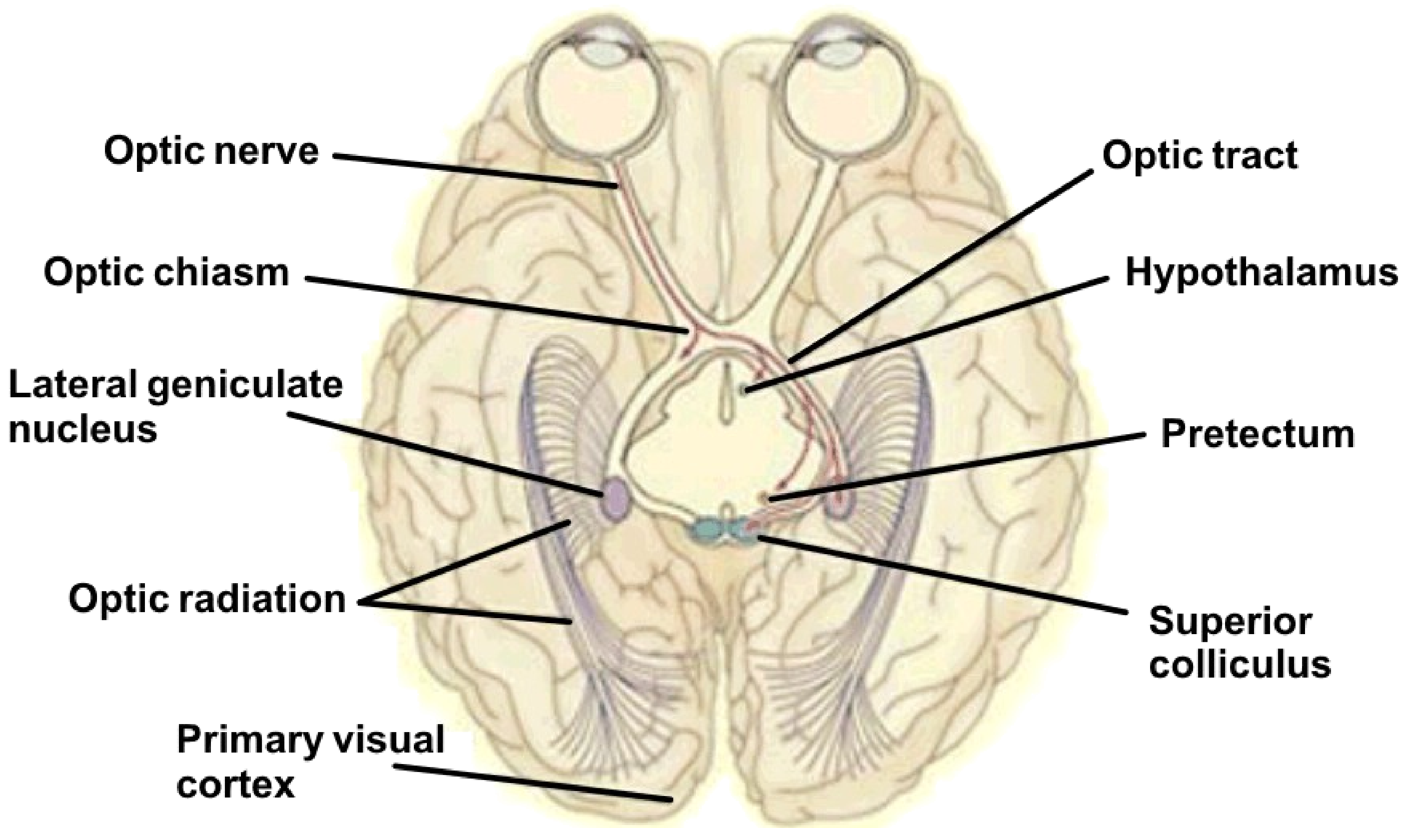


Diagram adapted from Wikipedia, Gray719.png

The Visual System

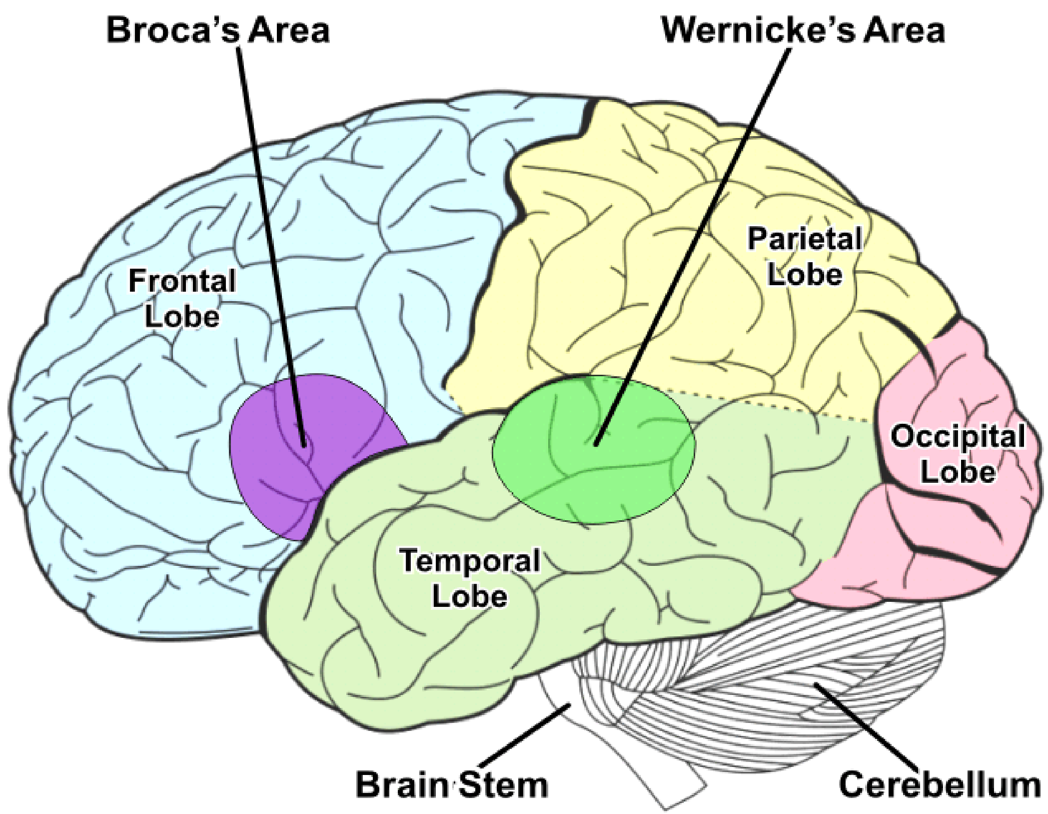


Rich connections between the brain stem and the visual cortex.

They relate vision to other sensory and motor modalities.

Even people who are blind from birth use the visual cortex to maintain "views" of their body and its relationship to the environment.

Language Areas in the Left Hemisphere



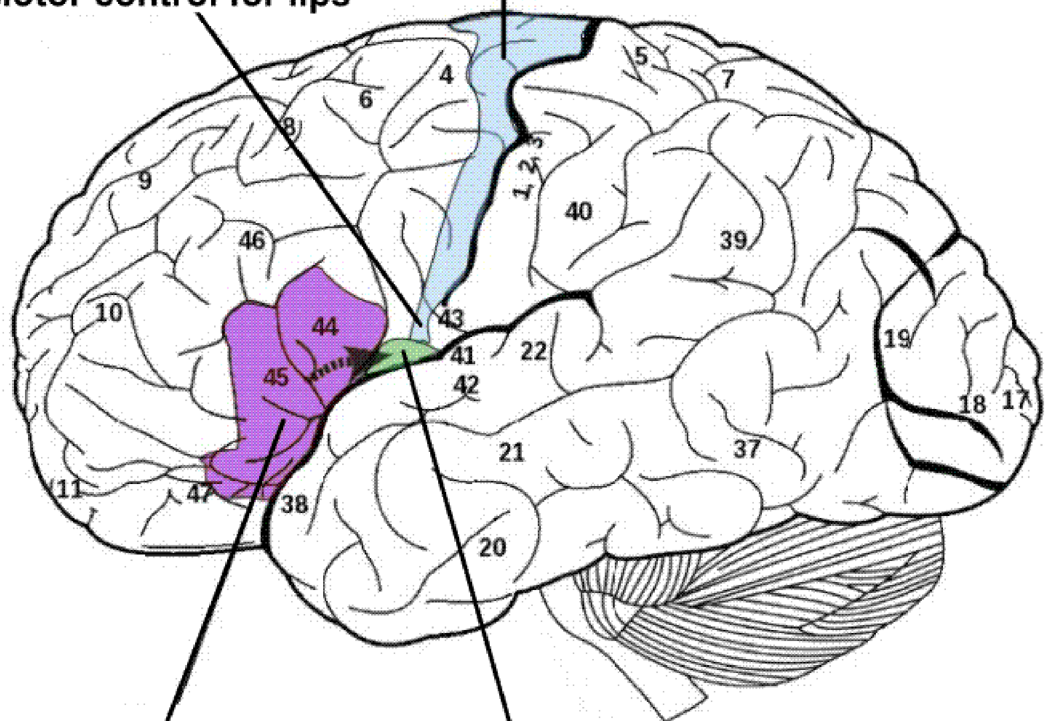
Broca's area and Wernicke's area are essential for language.

Lesions in Broca's area disrupt syntax in speech generation.

Lesions in Wernicke's area disrupt language understanding.

Diagram adapted from Wikipedia.

Motor Control Areas for Producing Speech



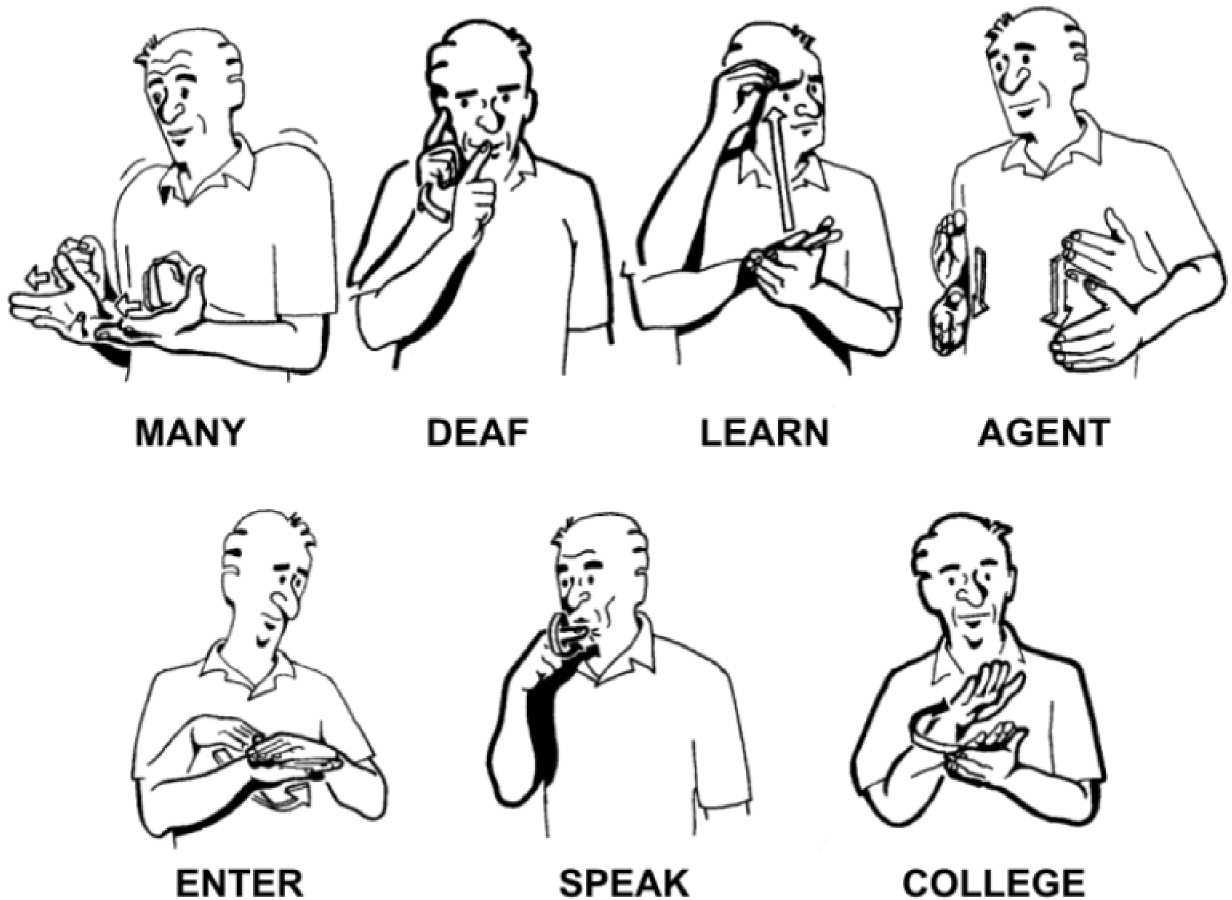
Broca's area overlaps Broadmann's areas BA44 and BA45.

BA44 is active in controlling the mouth for speech and eating.

BA45 is active in producing both spoken and signed languages.

See Horwitz et al. (2003) Activation of Broca's area during the production of spoken and signed language:

American Sign Language



Many deaf students enter hearing colleges.

The order of signs in ASL is similar to English word order.

But many syntactic features are absent; others use 3-D space.

Diagram adapted from Lou Fant (1983) ***The American Sign Language Phrase Book.***

Spoken and Signed Language

The same neural mechanisms are used to produce and interpret spoken and signed languages. (Petitto 2005)

Studies of bilingual infants of parents with different languages:

- **All pairs of four languages: English, French, American Sign Language (ASL), and Langue des Signes Québécoise (LSQ).**
- **Monolingual and bilingual babies go through the same stages and at the same ages for both spoken and signed languages.**
- **Hearing babies born to profoundly deaf parents babble with their hands, but not vocally.**
- **Babies bilingual in a spoken and a signed language babble in both modalities – vocally and with their hands.**
- **And they express themselves with equal fluency in their spoken and signed language at every stage of development.**
- **Petitto's conclusion: Any hypothesis about a Language Acquisition Device (LAD) must be independent of modality.**

Spatio-Temporal Syntax

Signed and spoken languages have a time-ordered sequence.

But signed languages can also take advantage of 3-D space:

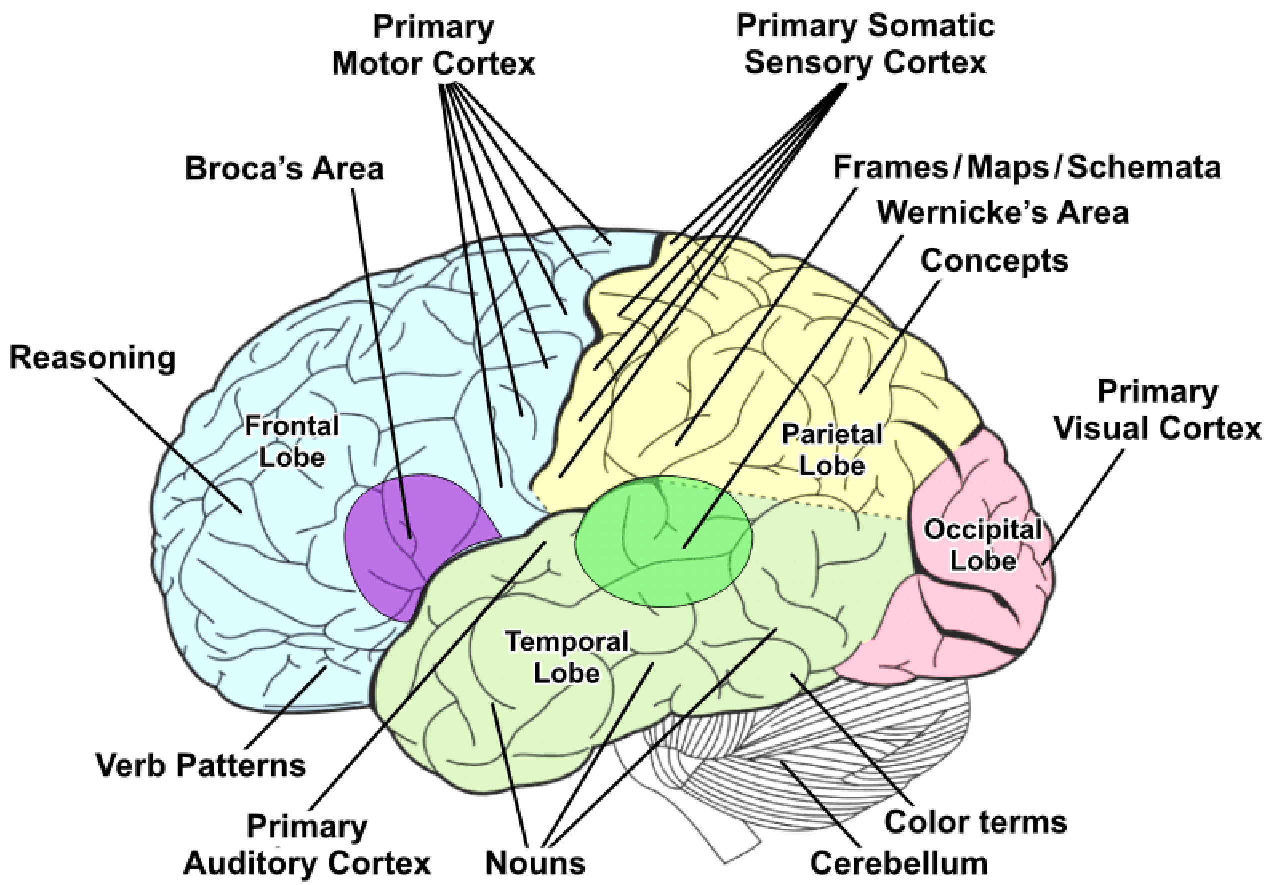
- **For anything visible, pointing serves the role of pronouns.**
- **But references to people and things that left the scene are also possible by pointing to where they had been.**
- **The signer can also introduce new people and things, place them in fixed locations in the air, and refer to them by pointing.**
- **For spatial relations, signing is more “natural” than spoken language.**

Observation: The index finger is the most natural indexical.

Questions:

- **Must a language of thought include geometry of the environment?**
- **If so, should it still be called a “language” of thought?**
- **A better term might be “cognitive map” or “mental model.”**

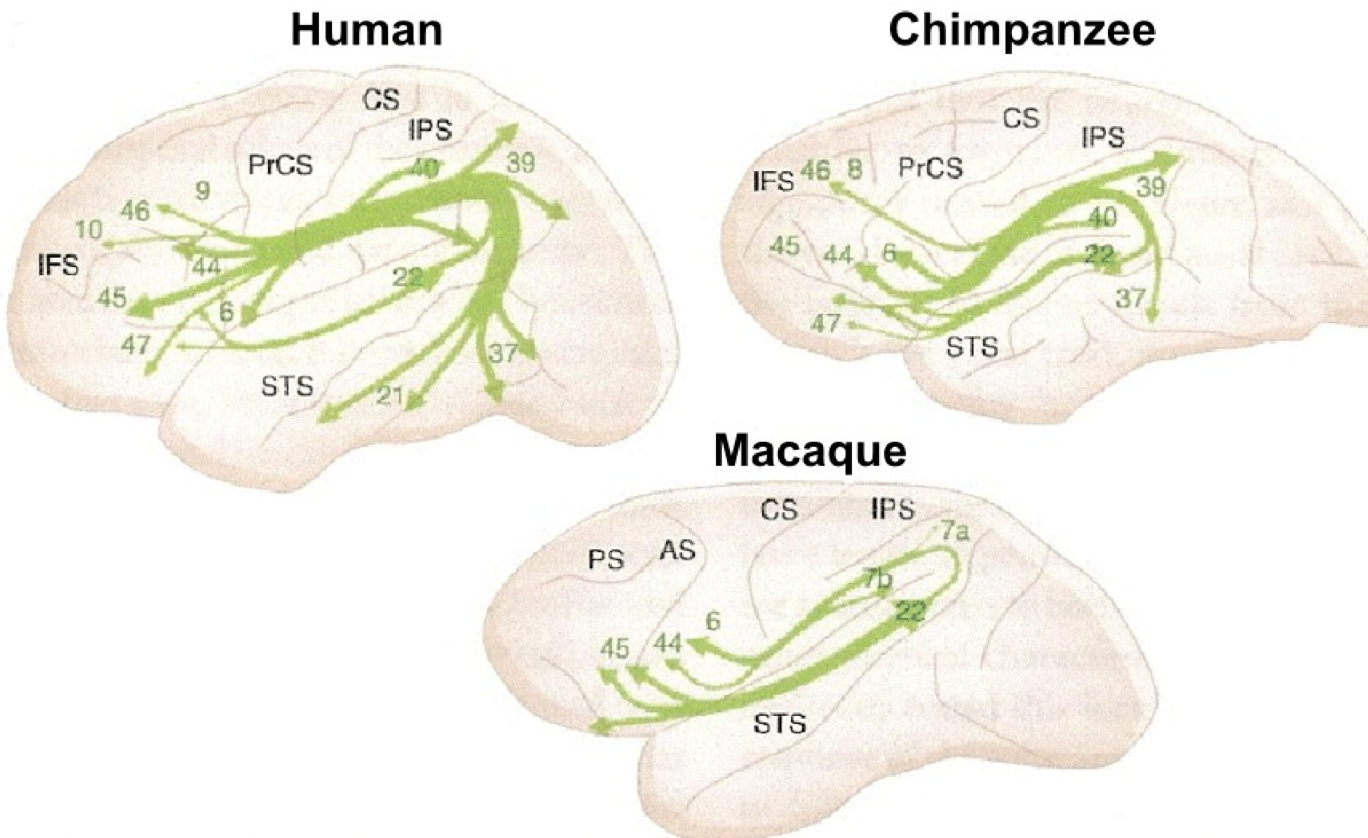
Areas Involved in Language Processing



The entire brain is active in language processing:

- **Nouns and adjectives are represented in the temporal lobe.**
- **Frames, maps, and semantic schemata are in the parietal lobe.**
- **Verb patterns are in BA47, close to Broca's area and the motor areas.**
- **The frontal lobes, which are dedicated to action, control reasoning.**

Arcuate Fasciculus

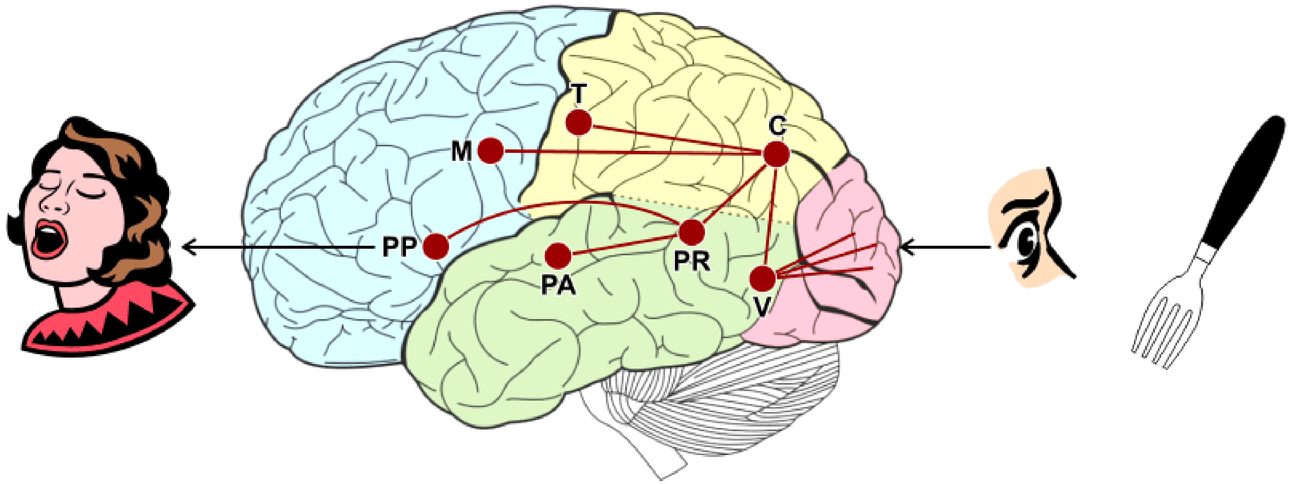


The arcuate fasciculus is a bundle of fibers that connect Broca's area and Wernicke's area in the human brain.

It has branches that link to verb patterns (BA47), cognitive maps in the parietal lobe, and nouns in the temporal lobe.

Diagram adapted from Lamb (2011).

Neurocognitive Network for the Word 'fork'



Network of locations in the LH, adapted from Lamb (2011):

- **C: Concept of a fork in the parietal lobe has links to all other areas.**
- **V: Visual recognition in the temporal lobe links to the visual cortex.**
- **T: Tactile feel of a fork in the sensory area of the parietal lobe.**
- **M: Motor schemata for manipulating a fork in the frontal lobe.**
- **PR: Phonology for recognizing the word 'fork' in Wernicke's area.**
- **PA: Phonology for the sound /fork/ in the primary auditory cortex.**
- **PP: Phonology for producing the articulation of /fork/ in Broca's area.**

Action and Perception

Frontal lobes control action, process, sequence, and planning:

- Contain the primary projection areas for motor neurons,
- Control reasoning about the contents in all other lobes,
- Use Broca's area to generate spoken, signed, and written language.

Occipital lobes recognize and generate visual images:

- Contain the primary projection areas for vision,
- Maintain a panoramic view of the current situation,
- Build mental models under the control of the frontal lobes.

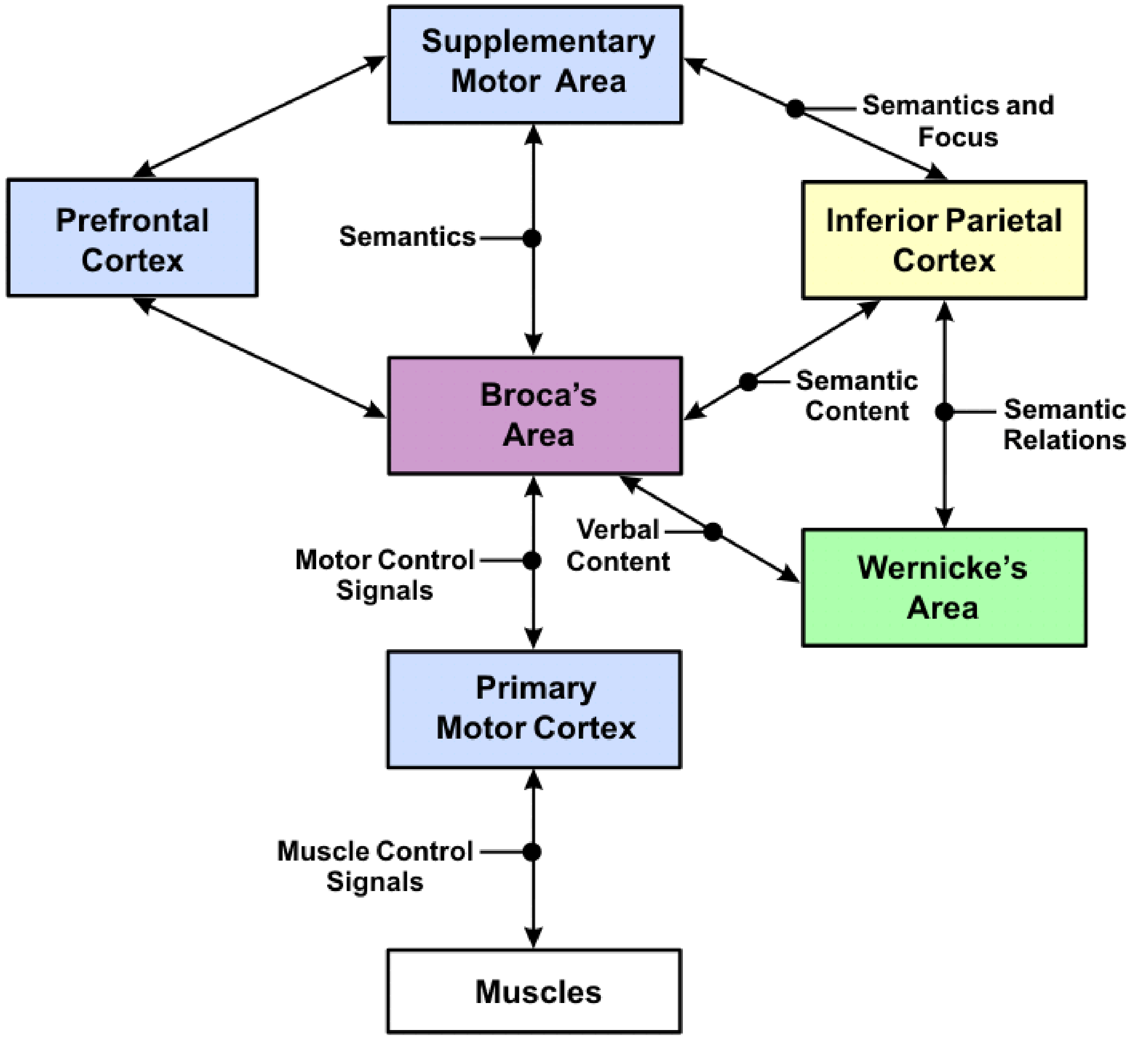
Temporal lobes recognize sounds and relate them to words:

- Contain the auditory projection areas and Wernicke's area,
- Relate nouns to objects recognized by the sensory areas.

Parietal lobes integrate information from all sources:

- Build and store patterns that organize and relate all content.
- The patterns are also called frames, maps, or schemata.

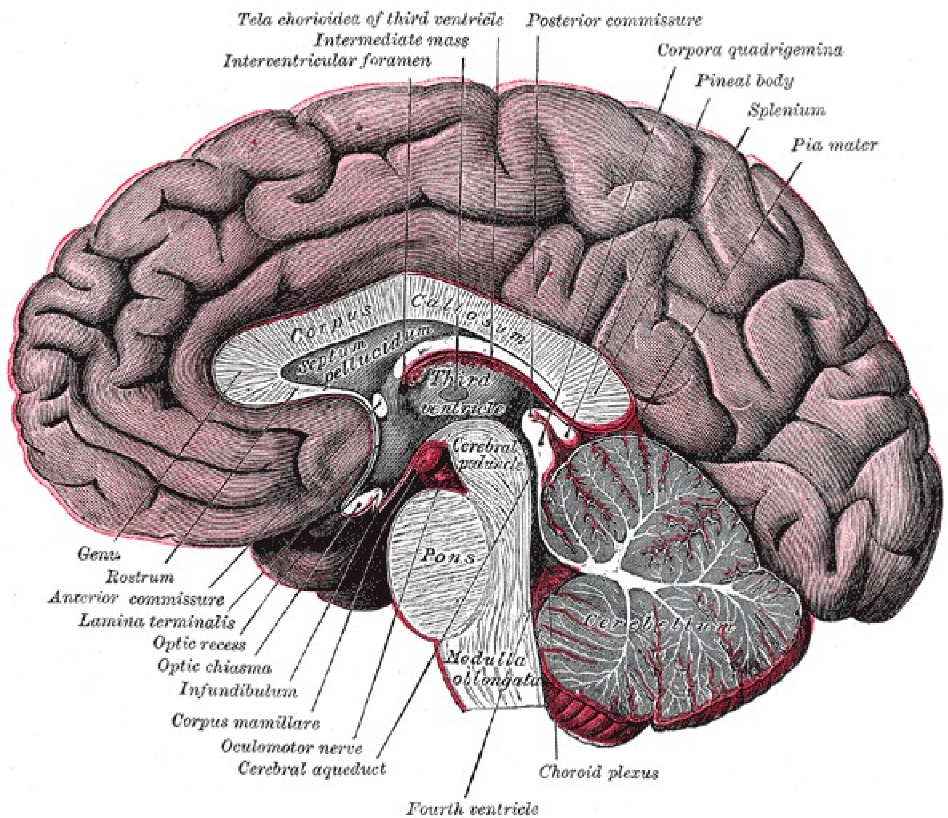
Information Flow in Speech Generation



Speech is generated from information in multiple areas of the brain. It is not translated from some "language of thought".

Diagram adapted from MacNeilage (2008). The colors are keyed to the brain areas.

Corpus Callosum



A thick bundle of fibers that connect the left and right hemispheres.

Each area of LH has a direct connection to its mirror image in RH.

The connections relate and integrate operations in both hemispheres.

Diagram from Wikipedia, Gray720.png

Role of the Right Hemisphere

Processes for which RH is more active than LH:

- **Recognizing and classifying related items:** ***table, chair, bed, sofa.***
- **Synonyms and homonyms:** ***foot*** **as body part or unit of measure.**
- **Intonation pattern of speech, melody of music, and singing.**
- **Analogies, metaphors, and jokes.**

In Japanese subjects,

- **RH is better at reading kanji (Chinese characters).**
- **LH is better at reading kana (syllabic symbols).**

Global patterns vs. fine-grained details:

- **RH is better at broad outlines that quickly detect global patterns.**
- **LH is better at fine-grained details and precise distinctions.**
- **Precision is necessary for the details of logic, syntax, and tool making.**
- **But the global patterns are critical for making life and death decisions.**

RH recognizes the forest, while LH deals with the trees.

Mental Maps, Images, and Models

Observation by the neuroscientist Antonio Damasio (2010):

> **"The distinctive feature of brains such as the one we own is their uncanny ability to create maps... But when brains make maps, they are also creating images, the main currency of our minds. Ultimately consciousness allows us to experience maps as images, to manipulate those images, and to apply reasoning to them."**

Maps and images form mental models of the real world or the imaginary worlds of our hopes, fears, plans, and desires.

Language is generated and interpreted in terms of the maps.

They provide a "model theoretic" semantics for language that uses perception and action for testing models against reality.

Like Tarski's models, they determine truth, but they are flexible, dynamic, and situated in the daily drama of life.

2. Discrete and Continuous

Words are discrete, and patterns of words are discrete.

But the world is a continuum, and so are mental models.

Questions:

- **How can patterns of discrete words represent a continuum?**
- **How can discrete verbs represent continuous change?**
- **A three-year-old child quickly learns to relate language to perception and action. How could a computer do as well?**
- **How could a computer distinguish the forest (broad outlines) from the trees (details of logic and syntax)?**
- **How could it relate the outlines and the details?**
- **How could it learn as efficiently as a child?**

Discrete and Continuous Methods

Trees and graphs represent discrete structures:

- Rule-based parsers analyze sentences in trees and graphs.
- Statistical parsers construct similar trees and graphs.
- Logic and ontology are represented in discrete symbols that are combined and processed in strings, trees, and graphs.

These methods simulate operations performed in the LH.

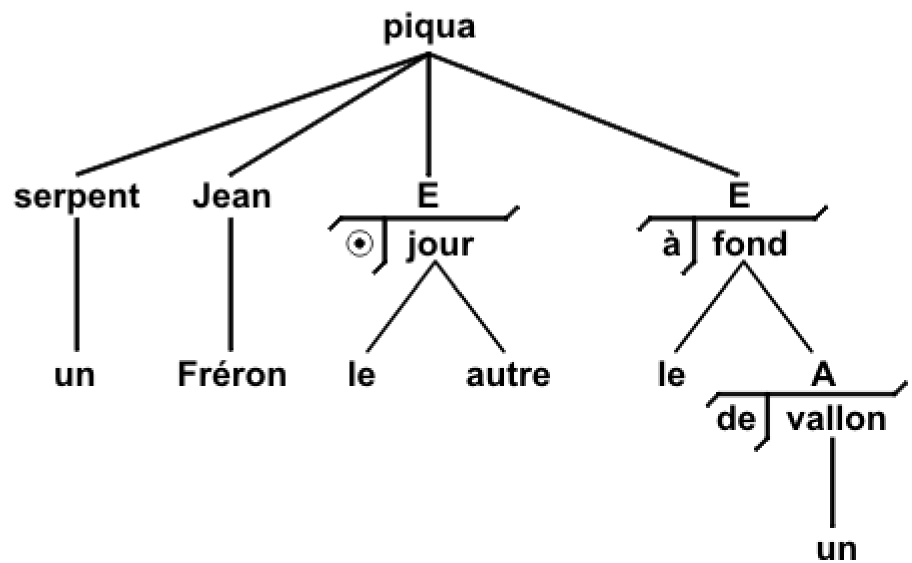
Some computational methods use continuous mathematics:

- Latent Semantic Analysis (LSA) and related vector-space methods.
- Continuous measures of semantic distance, fuzziness, etc.
- Neural networks with continuous weights on the nodes and arcs.

The continuous methods simulate global operations in the RH.

But we need methods that integrate the LH and RH processes.

Dependency Grammar



Theory and notation developed by Lucien Tesnière (1959).

An epigram written by Voltaire and analyzed by Tesnière:

> ***L'autre jour, au fond d'un vallon, un serpent piqua Jean Fréron.***
> ***Que pensez-vous qu'il arriva? Ce fut le serpent qui creva. ****

The verb is the focus of the clause. Nouns are participants (*actants*). Prepositions show circumstances (*circonstants*).

*** The other day, at the bottom of a valley, a snake stung Jean Fréron.***
What do you think happened? It was the snake that died.

“A Moving Picture of Thought”

A brilliant discovery by Charles Sanders Peirce:

- In 1885, Peirce published the algebraic notation for predicate calculus.
- In 1897, he invented existential graphs (EGs) as an equivalent notation.
- EG logic has no variables or complex substitutions and transformations.
- Peirce claimed that EG rules generate “a moving picture of thought.”
- The psychologist Philip Johnson-Laird (2002) agreed: EGs with Peirce’s rules of inference are a good candidate for a psychological theory.

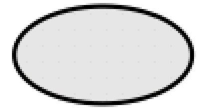
EG extensions to Sydney Lamb’s neurocognitive networks:

- A mechanism for treating any graph or subgraph as a single chunk.
- Inhibitory links for negating any chunk.
- Graphs with negated chunks can represent full first-order logic.

Mechanisms for supporting Peirce’s rules of inference:

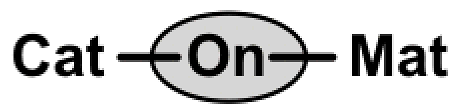
- Analogies for matching graphs and subgraphs.
- Some mechanism for inserting, erasing, or inhibiting links and chunks.

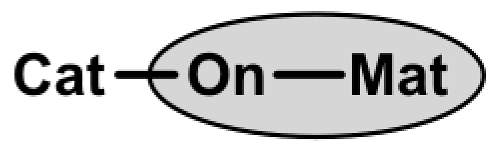
EGs With Negation Represent Full FOL

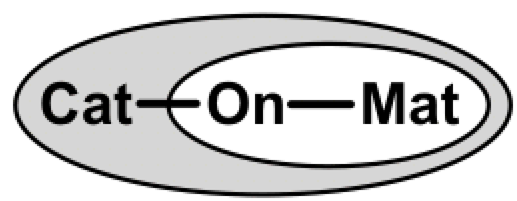
Existence: — *Negation:*  *Relations:* **Cat- -On- -Mat**

A cat is on a mat: **Cat—On—Mat**

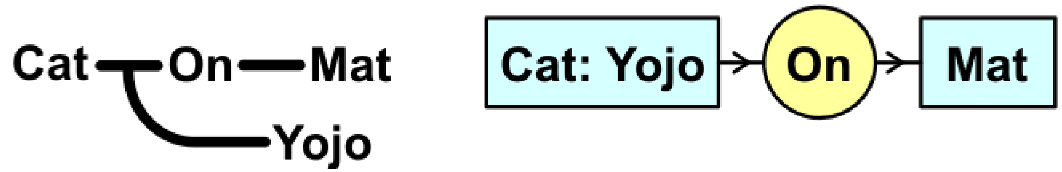
Something is on a mat: **—On—Mat**

Some cat is not on some mat: 

Some cat is not on any mat: 

If there is a cat, then it's on a mat: 

From EG to CG



Conceptual graphs add more features to the EG foundation:

- More symbols for Boolean operators and quantifiers.
- Point of quantification expressed by a concept box instead of a line.
- Concept box has a type field and a referent field, as in [Cat: Yojo].
- Types are represented by monadic relations or lambda expressions.
- Referent field may have names, indexicals, or generalized quantifiers.

A default ontology designed for mapping to and from NLs:

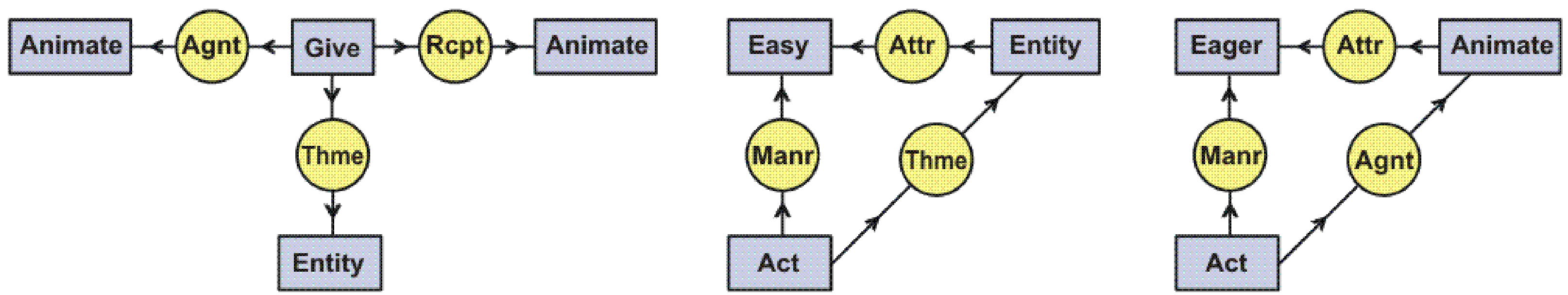
- Thematic roles or case relations used in linguistics.
- Context boxes for propositions and situations.
- Temporal, modal, causal, and intentional relations.

Operations adapted from various linguistic theories.

Canonical Graphs

A *canonical graph* is a conceptual graph that represents a pattern or *schema* that is typical for a given concept type.

Canonical graphs for the concept types Give, Easy, and Eager.



Canonical graphs encode typical patterns associated with each concept or relation type.

They can be linked to the default or expected knowledge relevant to subjects described by those concepts.

The canonical graphs for verbs specify the *case relations* or *thematic roles* and the constraints on concept types. See the IBM-CSLI verb ontology, http://lingo.stanford.edu/vso/

Mapping a Text to a CG

A very short story:

At 10:17 UTC, Yojo the cat and a mouse were in the basement of a house. Yojo chased the mouse. He caught the mouse. He ate the head of the mouse.

Context-free translation:

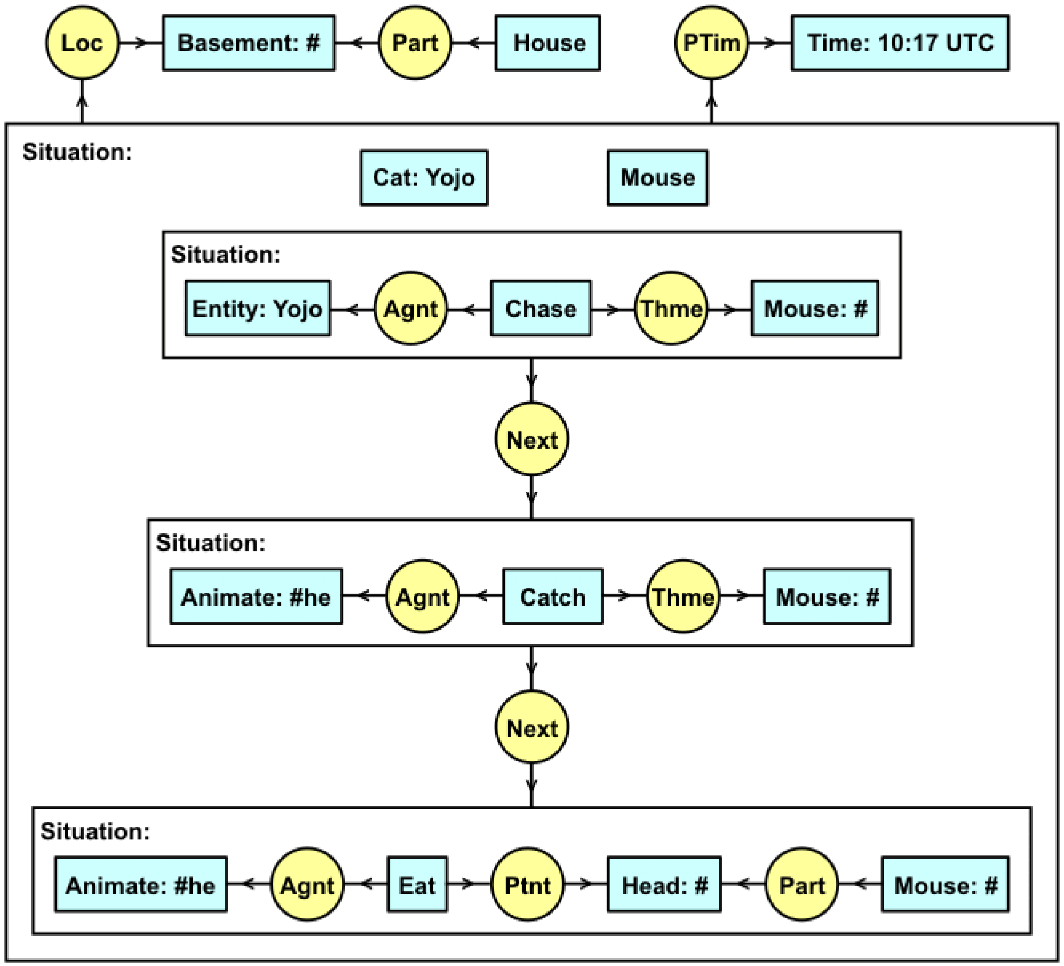
- **Translate each phrase of each sentence without considering the context.**
- **Leave some types and relations underspecified.**
- **Mark unresolved indexicals with the symbol #.**

As more information becomes available from the context,

- **Replace indexical markers with coreference labels.**
- **Specialize (or correct) the type labels on concepts and relations.**

CG contexts are isomorphic to the contexts of Discourse Representation Theory. DRT rules can be applied to CGs.

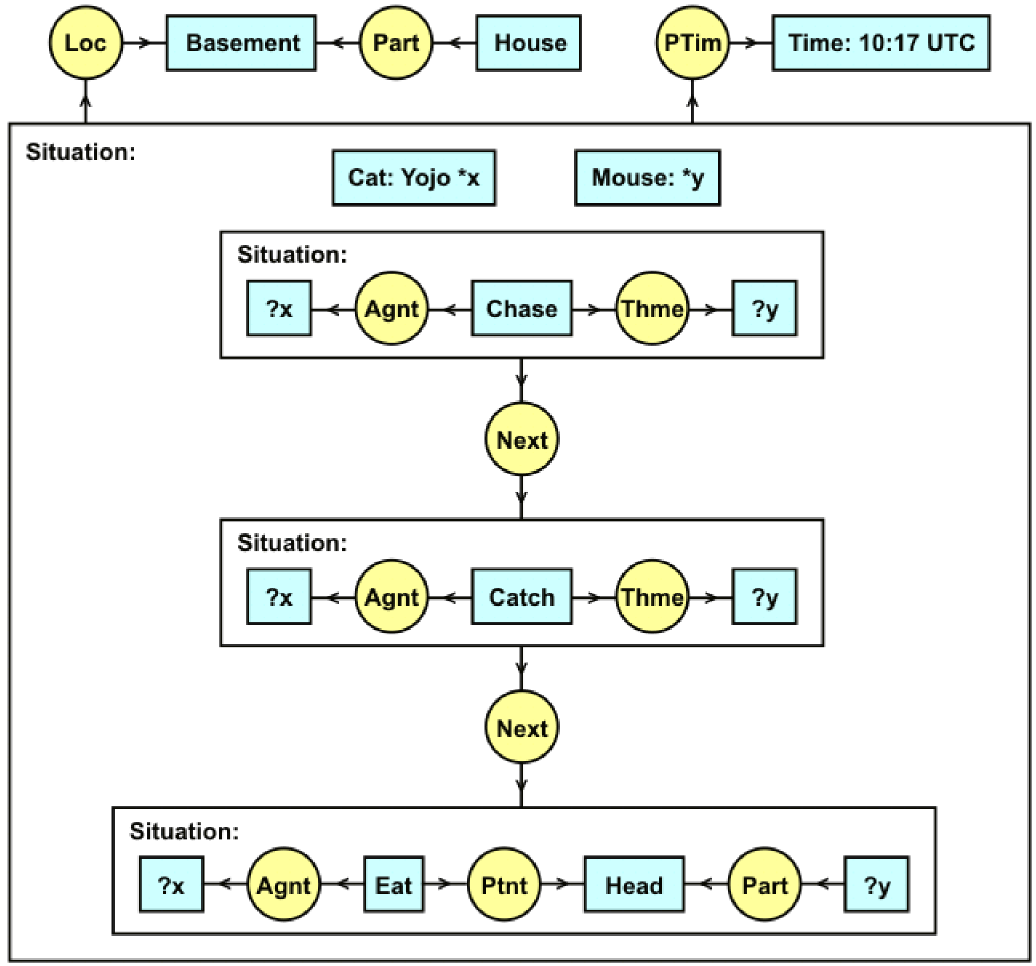
CG with Indexical Markers



The symbol # marks a concept with an unresolved indexical.

Each # marker must be replaced with a coreference label.

CG with Indexicals Resolved



Symbols *x and *y are defining labels; ?x and ?y are bound labels.

In the pure graph notation, coreference is shown by lines.

3. Catastrophe Theoretical Semantics

René Thom: a mathematician who invented catastrophe theory.

He was inspired by the way the discrete symbols of algebraic topology can be mapped to continuous differentiable manifolds.

He classified patterns, which he called *elementary catastrophes*, in the projections of continuous manifolds to a plane.

He showed that similar patterns could be found in diverse phenomena in physics, biology, and linguistics.

Thom used those patterns as a bridge between Tesnière's dependency graphs and the continuous manifolds.

Thom's methods were developed further by Wolfgang Wildgen, Jean Petitot, and their students and colleagues.

Iconicity

Fundamental principles of Peirce's semiotics:

- Iconicity: Structural similarities between representations and reality.
- Logic is the systematic study of the truth of representations.
- Existential graphs are more fundamental than other notations for logic because their structure is a more iconic representation of the subject.
- The EGs map directly to structures and operations on the subject matter.

René Thom independently discovered similar principles:

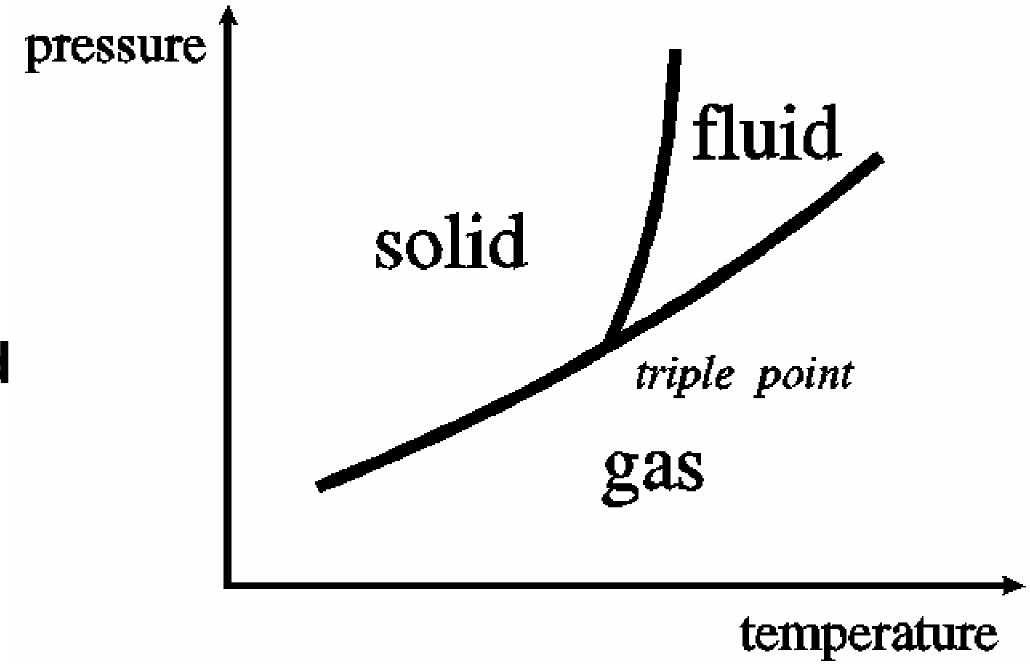
- Structural maps (homomorphisms) between language, Tesnière's graphs, and the subjects described by the language or by the graphs.
- He used catastrophe theory as a mathematical basis for mapping the structures of language, perception, and the world.

The diagrams in this section were copied or adapted, with permission, from the following book:

Wildgen, Wolfgang (1994) *Process, Image, and Meaning: A Realistic Model of the Meaning of Sentences and Narrative Texts*, Amsterdam: John Benjamins Publishing Co.

Boundaries in a Continuum

This diagram shows phase transitions of a substance with variations in temperature and pressure.



For water, the triple point occurs at a temperature of 0° Celsius and a pressure of 0.006 atmosphere.

At that point, all three phases of water – ice, liquid, and vapor – can coexist in equilibrium.

This is an example of the way discontinuities can create sharp boundaries that break a continuum into discrete regions.

René Thom showed how similar discontinuities, which he called catastrophes, can arise in dynamic systems.

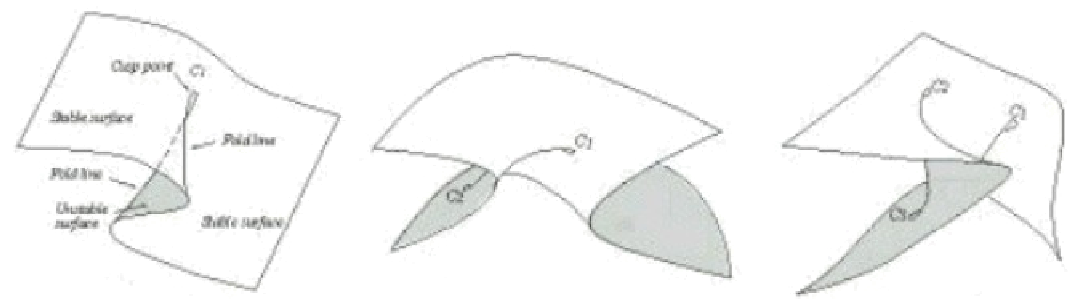
Elementary Catastrophes

Each elementary catastrophe is represented by a mathematical formula.

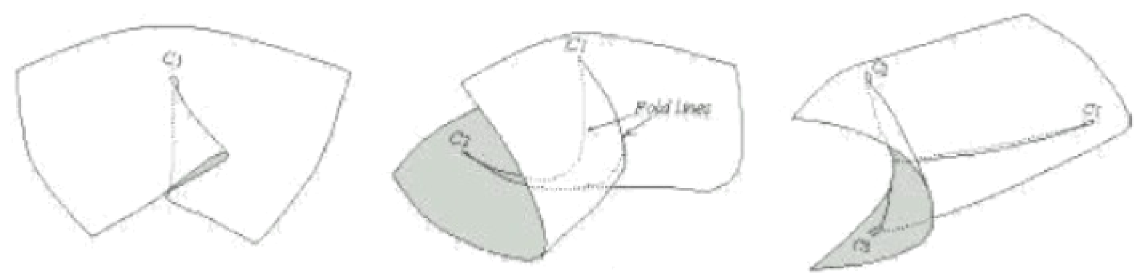
That formula defines a two-dimensional manifold embedded in a three-dimensional space.

The projection of that manifold to a “bifurcation” plane has one or more sharp discontinuities.

Those discontinuities map to the discrete patterns in language.



Cusp | Swallowtail | Butterfly

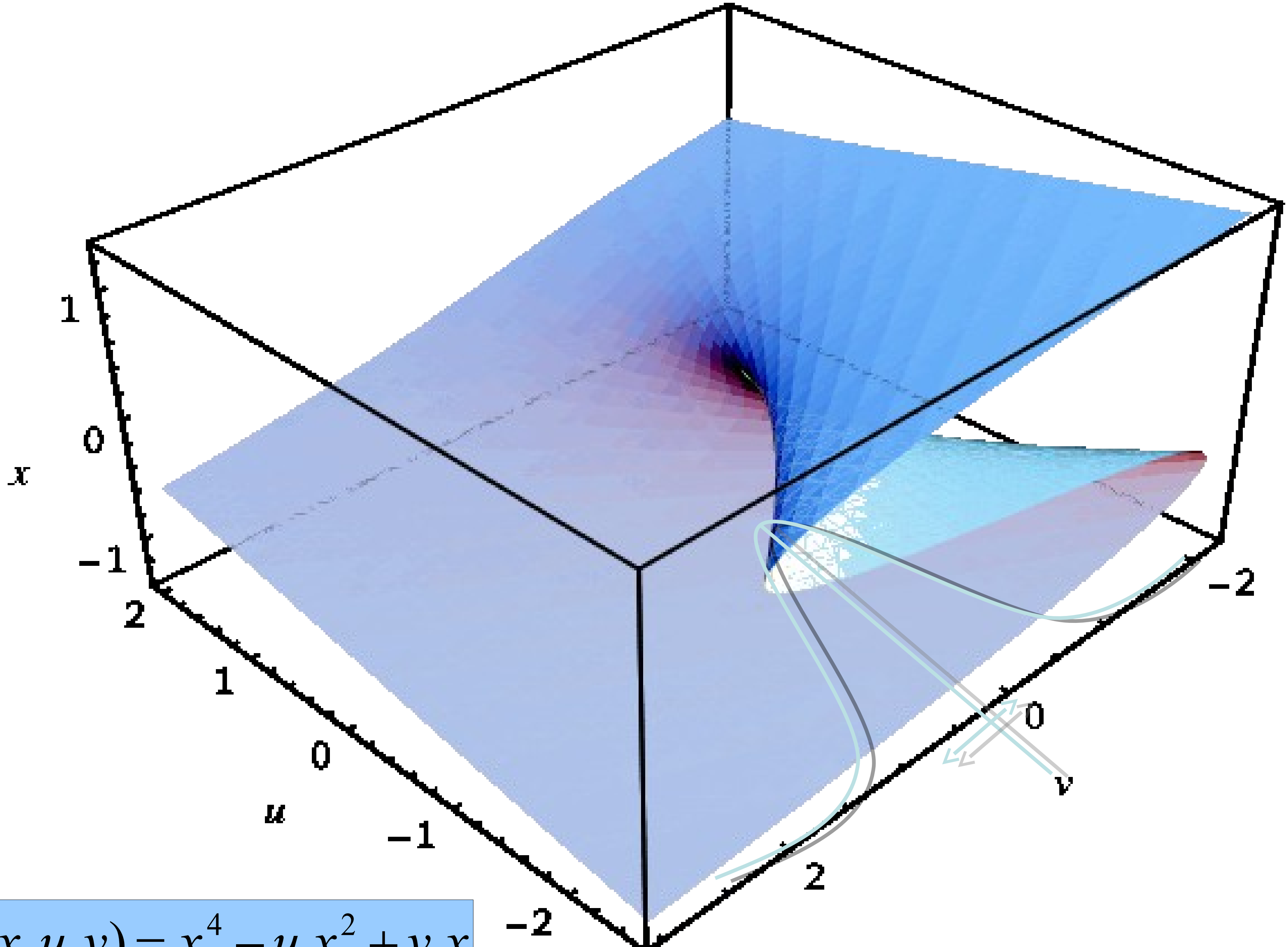


Cusp crimp | Swallowtail crimp | Butterfly crimp

This diagram shows the manifolds for six common catastrophes: Cusp, Swallowtail, Butterfly, Cusp crimp, Swallowtail crimp, and Butterfly crimp.

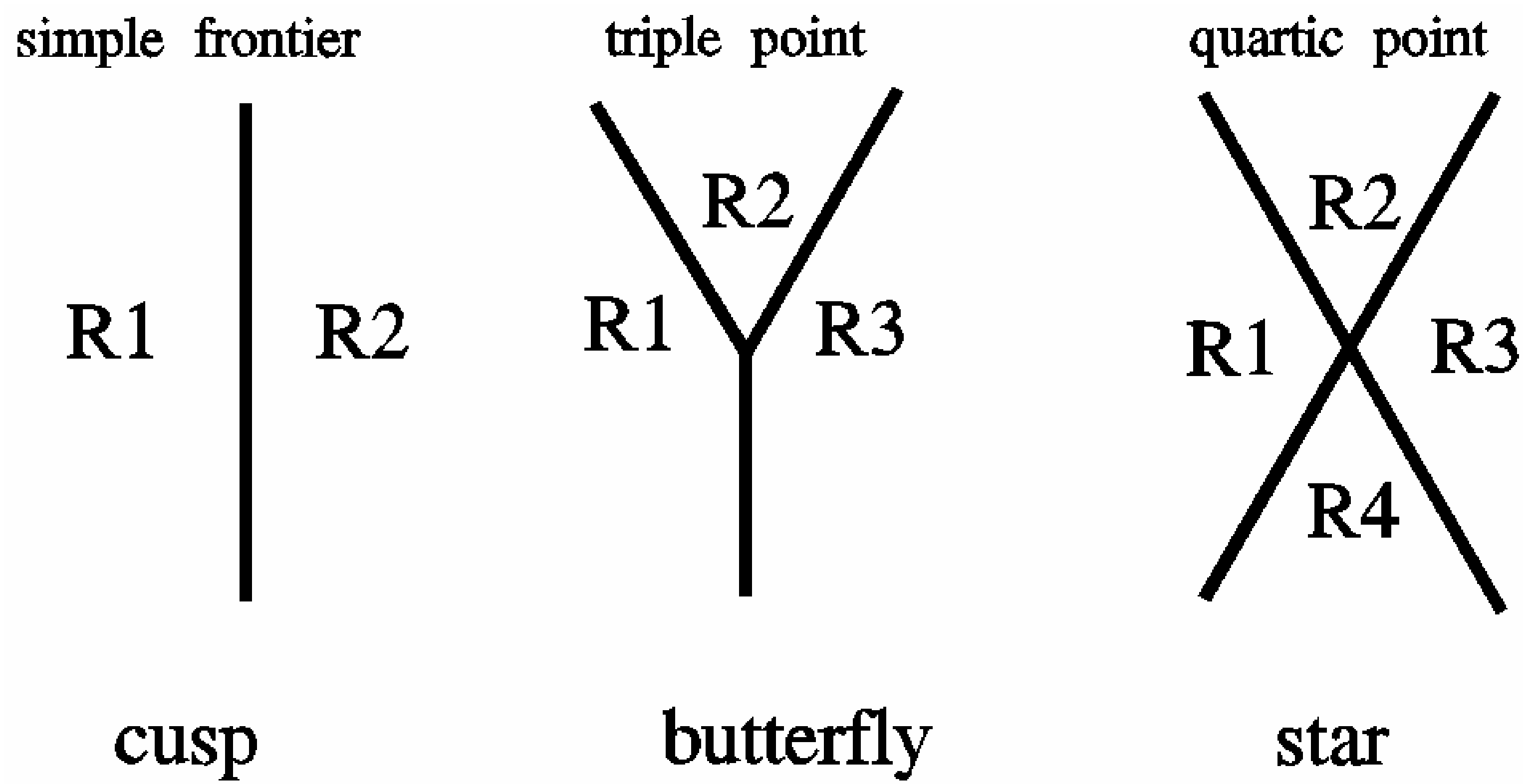
René Thom showed how these catastrophes could be mapped to and from linguistic schemata represented by Tesnière’s dependency graphs.

Single Cusp Catastrophe



$$F(x,u,v) = x^4 - u.x^2 + v.x$$

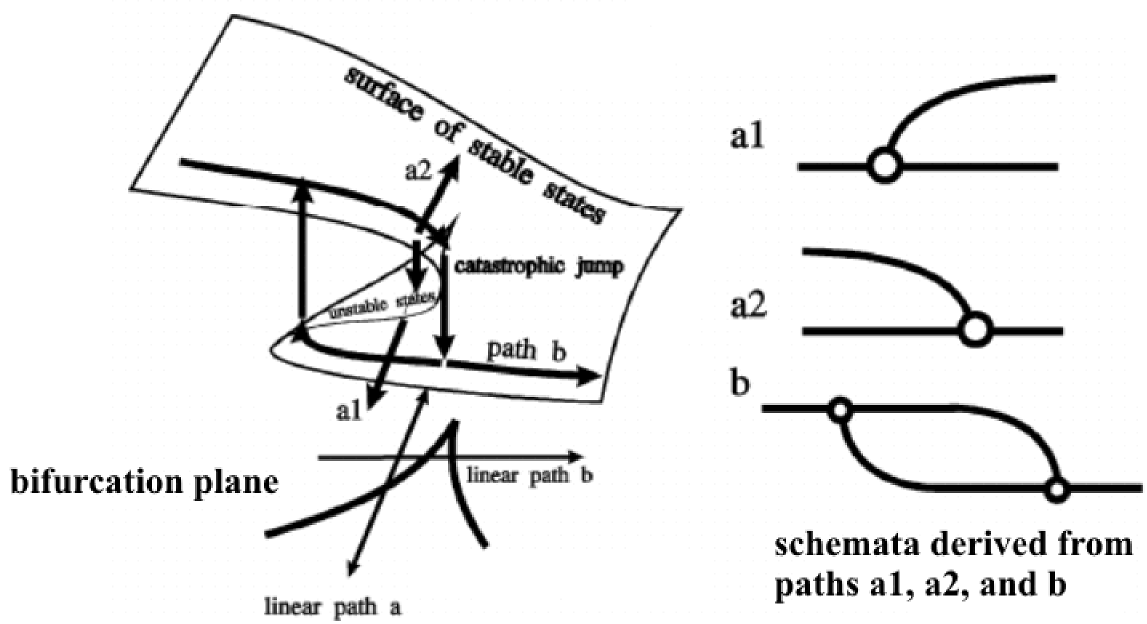
Projecting Catastrophes to a Plane



When the manifolds are projected to a plane, the folds map to discontinuous boundaries in the plane.

When the path of a narrative crosses a boundary, the participants experience a discontinuous change.

Projecting the Cusp to a Plane

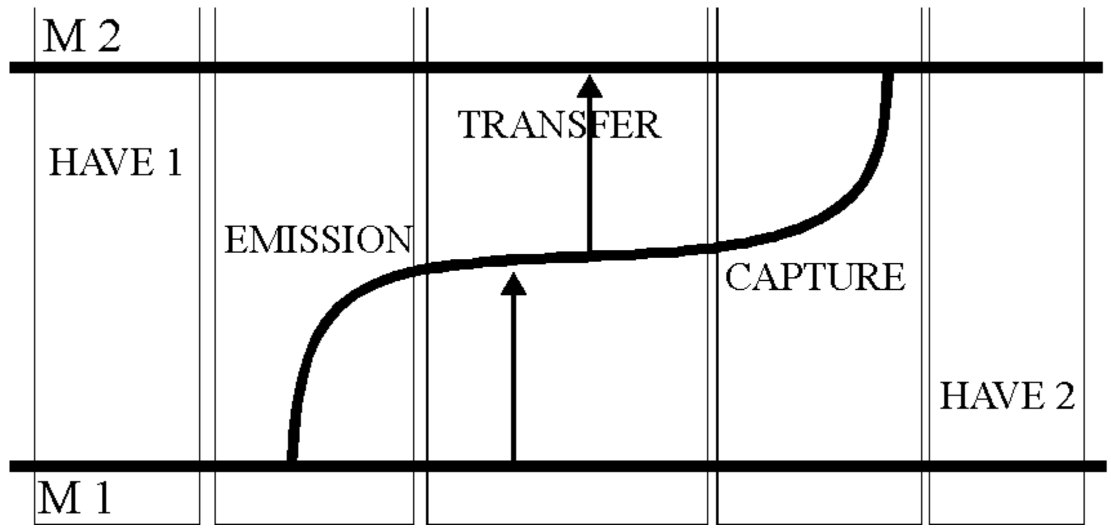


Paths along the back of the surface are smooth.

But paths a1, a2, and b cross discontinuities when the manifold is projected to the bifurcation plane.

The schemata on the right, which can be mapped to linguistic patterns in dependency graphs, are derived from the paths.

Transfer Schema

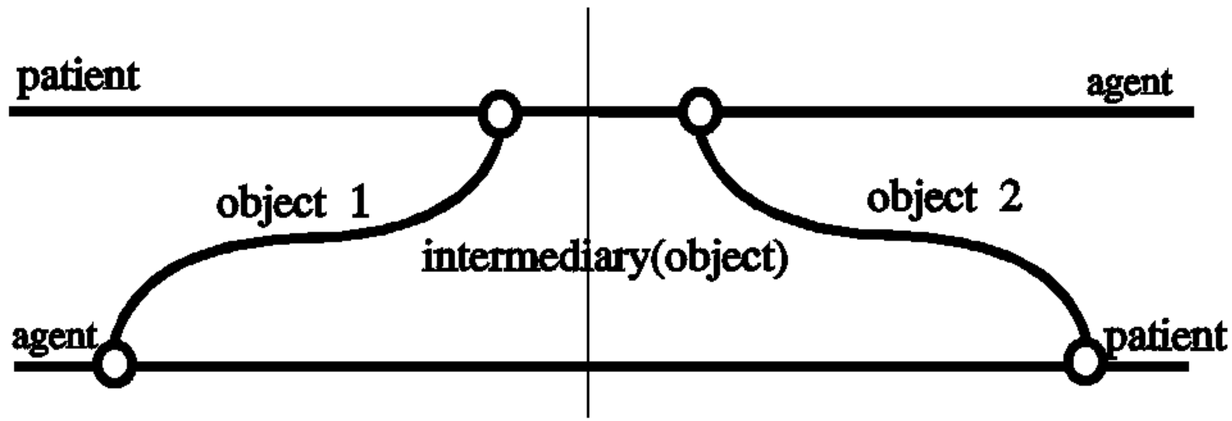


One or more schemata, which can be mapped to linguistic patterns, can be derived from each catastrophe.

The transfer schema has three participants or *actants*: a giver, a gift, and a recipient.

The verb *give* and each of its actants map to nodes in Tesnière's graphs or to concept nodes in conceptual graphs.

Schema With Four Actants



Two schemata for *giving* are combined to form the schema for *buying* or *selling*.

The verbs *buy* and *sell* have four actants:

- ***X1 buys X2 from X3 for an amount X4.***
- ***X3 sells X2 to X1 for an amount X4.***

Pattern for the Verb *Betray*

The verb *betray* has a complex pattern with several steps:

- **Agent X promises agent Y some benefit Z.**
- **Y expects the benefit Z.**
- **X does not fulfill the conditions of the promise.**
- **Y does not receive the benefit Z.**

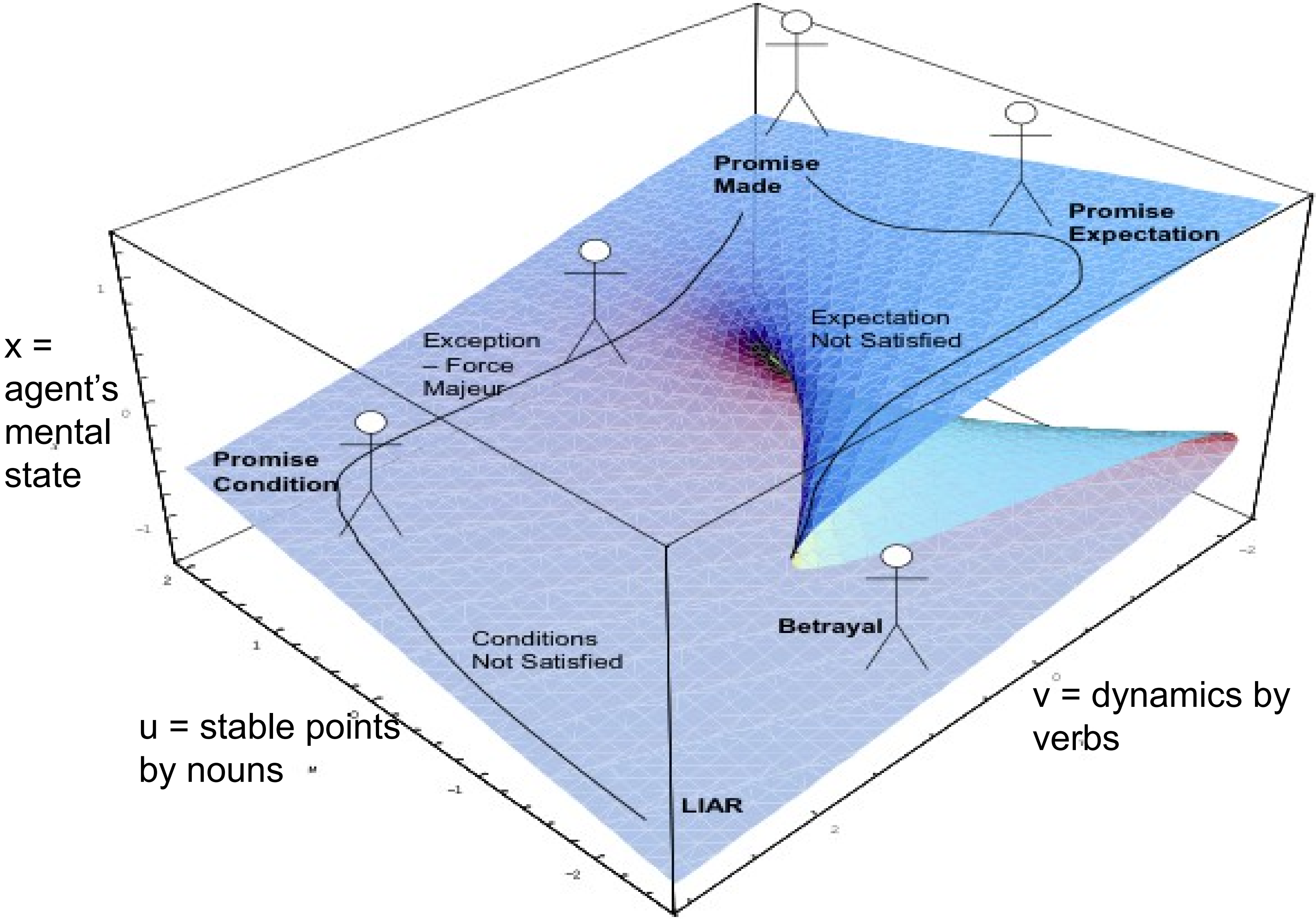
The critical step is a cusp catastrophe:

- **Y has an expectation of getting Z.**
- **But Y's expectations are not fulfilled.**

The next slide shows the paths taken by two agents X and Y:

- **Agent X, who makes the promise, moves along a smooth path on the left side of the manifold.**
- **But agent Y, who expects the benefit Z, experiences a sharp discontinuity when the expectation is not satisfied.**

Betrayal: Paths of Two Agents



Related Patterns

Other contrasts can also be represented by a cusp catastrophe:

- **Rage — fear**
- **Prohibition — violation**
- **Question — answer**
- **Deception — transparency**
- **Villainy — friendship**
- **Mandate — choice**
- **Submission — confrontation**
- **Struggle — victory**
- **Pursuit — rescue**
- **Challenge — success**
- **Treason — loyalty**
- **Punishment — reward**

Fundamental Principles

Philosophers have debated the issues for millennia:

- **Heraclitus: Everything is in flux (*panta rhei*).**
- **Plato: Unchangeable mathematical forms are the ultimate reality.**
- **Aristotle: The forms are abstractions from physical objects.**
- **Whitehead: The forms are patterns for recognizing "permanences amidst the flux."**

René Thom: Catastrophes determine boundaries in the flux:

- **Dynamic systems are far from equilibrium.**
- **Physical objects are islands of temporary stability.**
- **The brain recognizes and deals with the flux and the objects.**
- **Nouns map to stable regions; verbs map to transitions.**
- **Sentences are discrete approximations to the continuous flux.**

Thom developed the first mathematical theory that relates the dynamic physical phenomena to cognition and to language.

But much more research is necessary at every level.

4. Cognitive Neurodynamics

Applications and extensions of René Thom's methods to a wide range of cognitive phenomena.

Petitot showed that there are many variations of mathematical methods that are compatible with Thom's principles. *

At VivoMind Research, we use conceptual graphs as the basic semantic representation for language.

Those graphs can be mapped to continuous mathematics in a variety of ways.

They support some novel computational methods for analyzing language and reasoning about the results.

*** See Petitot, Jean (2011)** ***Cognitive Morphodynamics: Dynamical Morphological Models of Constituency in Perception and Syntax*****, Bern: Peter Lang.**

Biological Morphodynamics

Epigenetic landscape by the biologist C. H. Waddington (1957).

An egg (the ball) develops along paths through the landscape:

- **The egg begins as a symmetric cell; the landscape is its environment.**
- **As a cell divides, its genes and environment determine the options.**
- **The final form (*morphos*) results from dynamic choices along the paths.**

Waddington had a strong influence on René Thom's ideas.

Cognitive Neurodynamics

Most of the research has been theoretical, and very little of it has been implemented in computational systems.

VivoMind implemented global methods that were strongly influenced by the theories of Thom, Wildgen, and Petitot.

But the global methods use the results from a detailed prior analysis based on conceptual graphs:

- **A parser and semantic interpreter that generates CGs.**
- **The VivoMind Analogy Engine (VAE).**
- **Cognitive signatures, which VAE uses to find analogies.**
- **Mathematical computations on the cognitive signatures that are similar to, but not identical to those by Thom et al.**
- **Applications to analyzing documents and processing the results.**

For earlier examples, see http://jfsowa.com/talks/cogmem.pdt . But more recent R & D has gone far beyond them.

Finding Analogies

The basis for human reasoning and language understanding.

Logic is a disciplined special case of analogical reasoning:

- **Essential for precise reasoning in mathematics and science.**
- **Important for precision in any field.**
- **But even in science and engineering, analogy is necessary for knowledge discovery and innovation.**

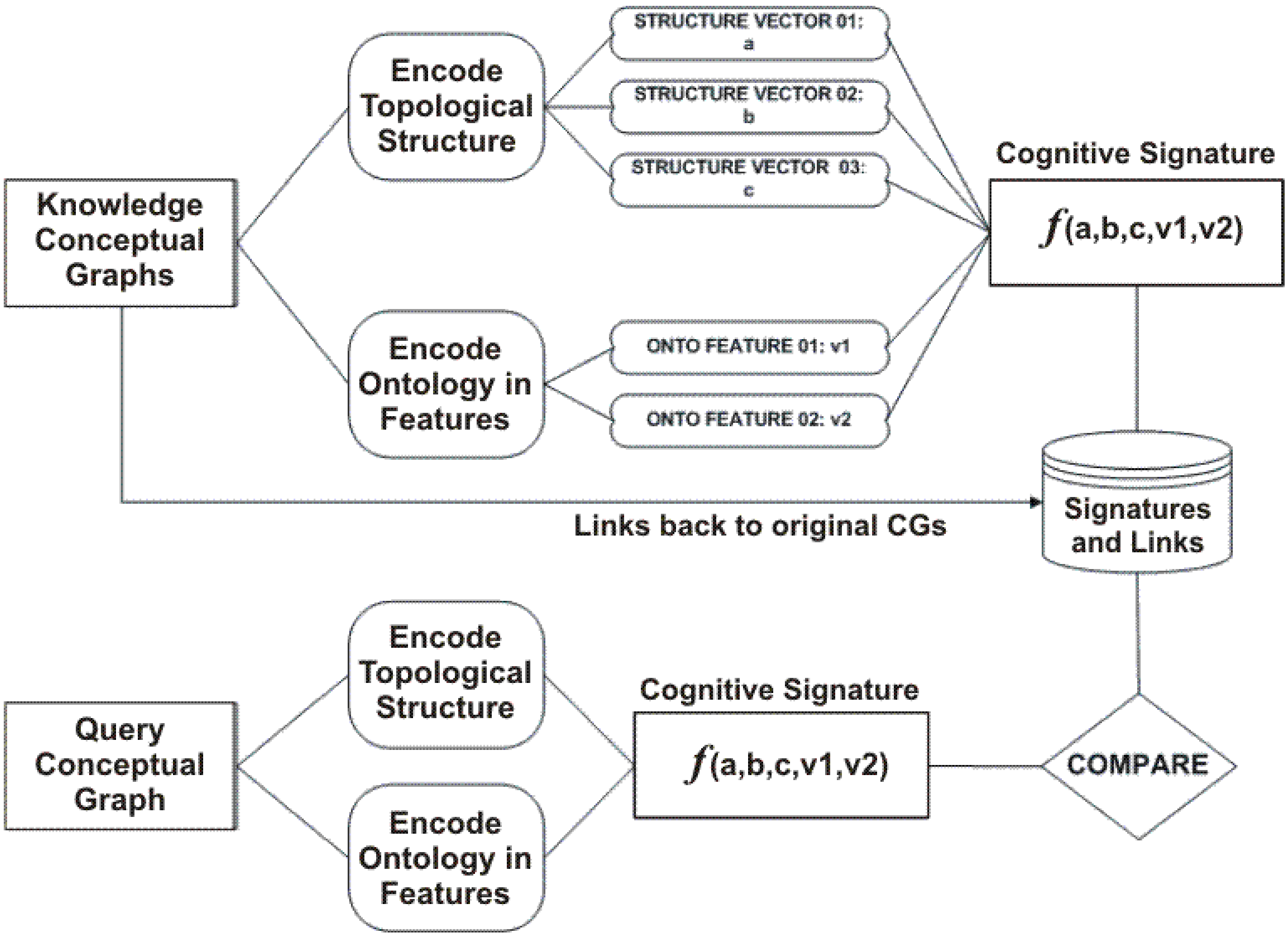
Conceptual graphs support logical and analogical methods:

- **They are defined by the ISO/IEC standard 24707 for Common Logic.**
- **But they also support approximate methods for finding analogies.**
- **They provide a bridge between informal language and formal logic.**

Structure mapping can find graph analogies in polynomial time.

But continuous mathematics derived from the CGs can be used to find analogies in logarithmic time.

Cognitive Memory™



Basis for the VivoMind Analogy Engine (VAE)

Using Cognitive Signatures™

A cognitive signature™ is a numeric encoding of a conceptual graph that represents its structure and its ontology.

A lossless encoding is an isomorphism that preserves all the information: the original CG can be derived from its signature.

More compact, but lossy encodings are also useful:

- Finding similar graphs in logarithmic time.
- Putting greater or lesser emphasis on the ontology (labels on the nodes) or on the topological structure (connections between nodes).
- Minimizing the effect of local details when comparing global patterns.

Cognitive signatures are a good intermediate representation for mapping natural language texts to continuous manifolds.

But an open-ended variety of different mappings is possible.

For a survey of VivoMind technology, see slides 111 to 156 of the tutorial, http://www.jfsowa.com/talks/goal.pdf

Detailed Operations in LH

Information extraction from documents requires a detailed analysis of the kind performed by the left hemisphere.

The next slide shows a table of data generated as part of a contract with the US Department of Energy.

Analysis performed on each document:

- **Map each sentence to a conceptual graph, as illustrated in Slide 26.**
- **Find coreference links between concept nodes, as in Slide 27.**
- **Encode CGs in cognitive signatures; store them in Cognitive Memory.**

Get data from Cognitive Memory and put it in the table:

- **Map a request stated in English to a query graph:**

  For each document and each chemical compound, list the chemical formula of the compound, its Curie temperature, and the document title.

- **Use VAE to find CGs that match the query graph.**
- **Move the data from the CGs to the rows of the table.**

Information Extracted from Published Documents

COMPOUND	CURIE TEMP.	SOURCE
Mn3[Cr(CN)6]2 ·16H2O	89 K	A solid-state hybrid density functional theory study
Sr3Ir2O7 in Sr3Ir2O7 single-cr	~ 280 K	Canted antiferromagnetic ground state in Sr3Ir2O7
PrPt2B2C	6 K	Coexistence of superconductivity and magnetic ord
La0:3Nd0:7Pt2:1-	2.8 K	Coexistence of superconductivity and magnetic ord
NdPt2:1B2:4C1:2	3 K	Coexistence of superconductivity and magnetic ord
NdPt1:5Au0:6B2C	3 K	Coexistence of superconductivity and magnetic ord
SmNiC2	= 17.7 K	Commensurate charge-density wave with frustrate
Co0.2Zn0.8Fe2O4. in CdxCo1-	~ 780 K	Does Ti+4 ratio improve the physical properties of C
Zn0.88Co0.12O in ZnO	~ 540 K	Effect of Co doping on the structural; optical and m
La in Sr2-xLaxFeMoO6	425 K	Effect of La doping on the properties of Sr2-xLaxFeM
Fe in Sr2-xLaxFeMoO6	~ 1040 K	Effect of La doping on the properties of Sr2-xLaxFeM
FeSe	~ 305 K	Electronic and magnetic properties of FeSe thin film
Ni-Mn-Ga	= 376 K	Electronic and structural properties of ferromagnet
LaFexSi1 - x13 in La1-zPrz(Fe(	~ 190 K	Enhancement of magnetocaloric effects in La1-zPrz
LaFe0.88Si0.1213 in La1-zPrz(	= 195 K	Enhancement of magnetocaloric effects in La1-zPrz
Co2MnGa in Co2MnGa	600 K	Ferromagnetic resonance in Co2MnGa films with va
HoCrO4 in HoCrO4	17.6 K	Ferromagnetism vs. antiferromagnetism of the dim
Mn3(HCOO)6 in Mn3(HCOO)(	8.0 K	Guest-induced chirality in the ferrimagnetic nanopo
NaZn13- in La0.5Pr0.5(Fe0.88	range from 195 K to 185 K	Large isothermal magnetic entropy change after hy
La2/3Ba1/3MnO3 in La2-3Ba1	range from 300 K to 250 K	Magnetic and neutron diffraction study of La2-3Ba1
CuMnSb in Co1-xCuxMnSb	range from 476 K to 300 K	Magnetic properties of half-metallic semi Heusler C
Nd2 in Nd2-yDyyFe17-xSix	range from 61.46 °C to 236 °	Magnetic properties of iron-rich Nd2-yDyyFe17-xSix
Tb2Fe17 in Nd2-yDyyFe17-xSi	~ 80 °C	Magnetic properties of iron-rich Nd2-yDyyFe17-xSix

Society of Interacting Agents

The society of mind by Minsky (1986, 2006):

- **There can be no single, unified theory of all neural computation.**
- **The brain contains many areas specialized for different purposes.**
- **Learning creates more specializations for every human need.**
- **The result is a society of interacting heterogeneous modules.**
- **Knowledge consists of a network of K-lines that connect related aspects in areas of the brain with different specializations.**
- **Emotions are the driving forces that motivate all operations.**

VivoMind software is based on a society of heterogeneous, dynamically interacting agents.

All interactions are carried out by message passing.

Messages can be represented in conceptual graphs, natural languages, or any computable notation.

Global Operations in RH

For many applications, left hemisphere operations are sufficient.

But global operations typical of the right hemisphere are needed to detect plots, goals, intentions, sentiment, and emotions.

VivoMind strategy:

- Support a society of heterogeneous interacting agents.
- Take advantage of multiple CPUs by letting the agents run in parallel.
- LH and RH styles of processing can cooperate and compete.
- Sometimes, LH results are used for RH interpretations.
- At other times, RH methods can interrupt the LH processes and redirect them to more appropriate or more promising options.

This mixed strategy is psychologically more realistic than a fixed, predefined algorithm.

It is also more flexible: new reasoning methods can be supported by adding new kinds of agents to the society.

Language Understanding

Meaning is based on each person's needs, desires, and ways of living and communicating with other people in the world.

Language evolved as an integral part of social activity:

- **Perception and action map mental models to and from the world.**
- **Verbs express actions and states in those models.**
- **Nouns represent participants in the actions and states.**
- **Prepositions link to structural and dynamic circumstances.**
- **Adjectives and adverbs qualify the nouns and verbs.**
- **Syntactic structures map to structures in the mental models, which map to structures among the people, things, and events in the world.**

LH methods process the fine details.

RH methods see, feel, and interpret the big picture.

Full understanding must integrate both kinds of methods.

Suggested Readings

René Thom's semiotics and its sources,
http://www.hum.au.dk/semiotics/docs2/pdf/bundgaard_peer/rene_thoms_semiotics.pdf

Wolfgang Wildgen's publications,
http://www.fb10.uni-bremen.de/lehrpersonal/wildgen.aspx

Jean Petitot's publications,
http://jean.petitot.pagesperso-orange.fr/JPbibli.html

The goal of language understanding,
http://www.jfsowa.com/talks/goal.pdf

Role of Logic and Ontology in Language and Reasoning,
http://www.jfsowa.com/pubs/rolelog.pdf

Conceptual Graphs for Representing Conceptual Structures,
http://www.jfsowa.com/pubs/cg4cs.pdf

Peirce's tutorial on existential graphs,
http://www.jfsowa.com/pubs/egtut.pdf

ISO/IEC standard 24707 for Common Logic,
http://standards.iso.org/ittf/PubliclyAvailableStandards/c039175_ISO_IEC_24707_2007(E).zip

For other references, see the combined bibliography for this web site:
http://www.jfsowa.com/bib.htm