

I K N E X

Knowledge Representation & Reasoning

Fall 2023

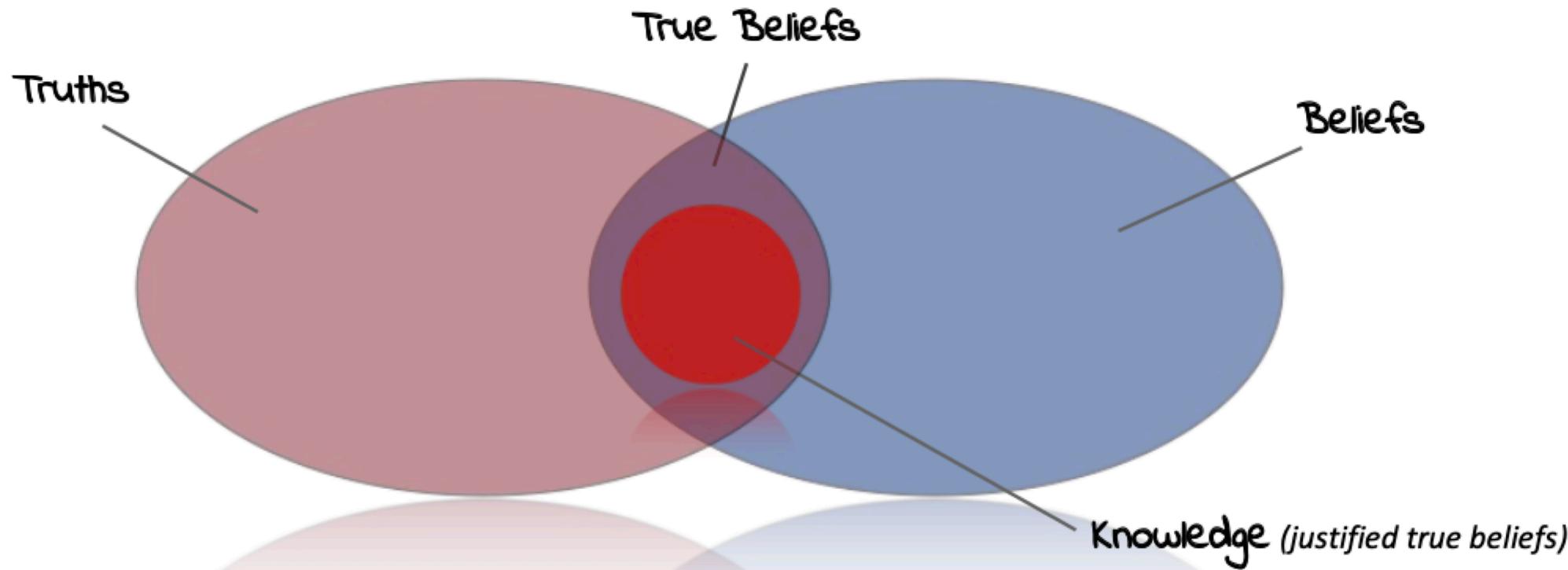
Dr. Amna Basharat | Ms. Amna Binte Kamran

Review

- What is the relationship between data, information and knowledge?
- What is knowledge?
- What is the DIKW pyramid?
- Getting from Data to Information requires _____?
- Getting from Information to Knowledge requires _____ ?
- Getting from Knowledge to Wisdom requires _____?
- What are the key elements necessary to speak a common language?
- What is an ontology?

What is Knowledge?

What is Knowledge?

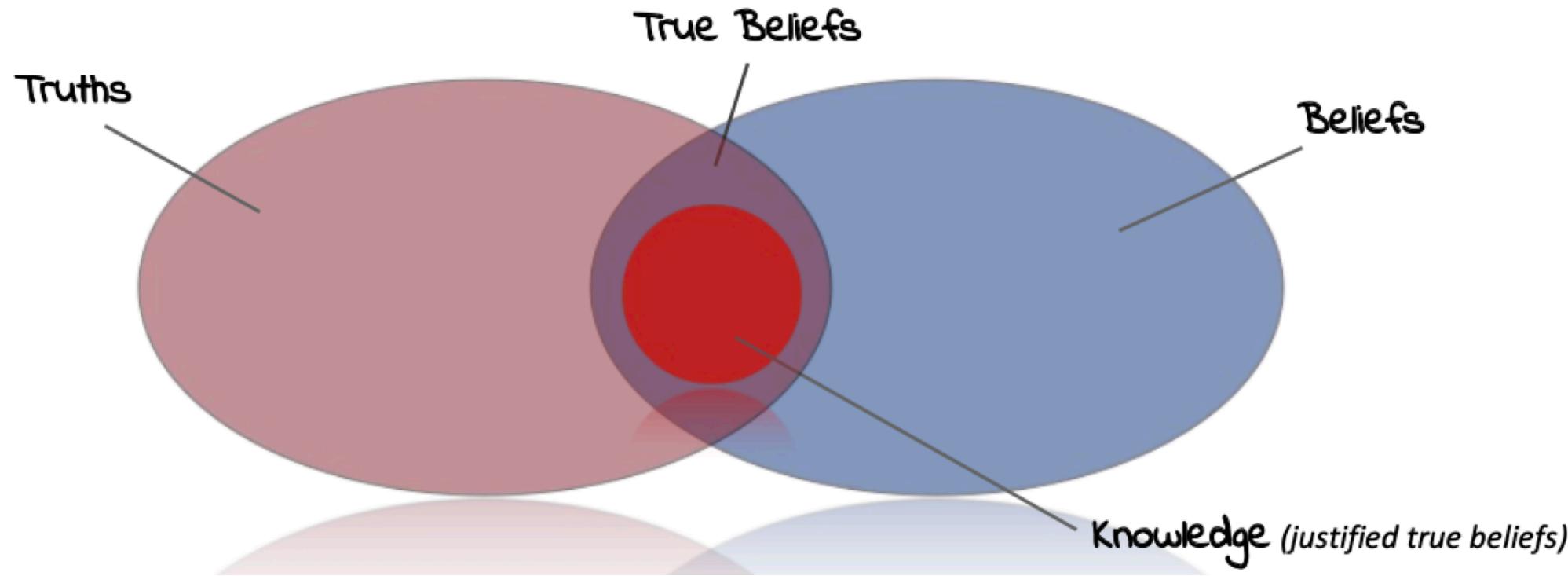


The Tripartite Analysis of Knowledge: S knows that p iff

- p is true;
- S believes that p ;
- S is justified in believing that p .

[*The Analysis of Knowledge*, Stanford Encyclopedia of Philosophy, 2001.](#)

What is Knowledge?



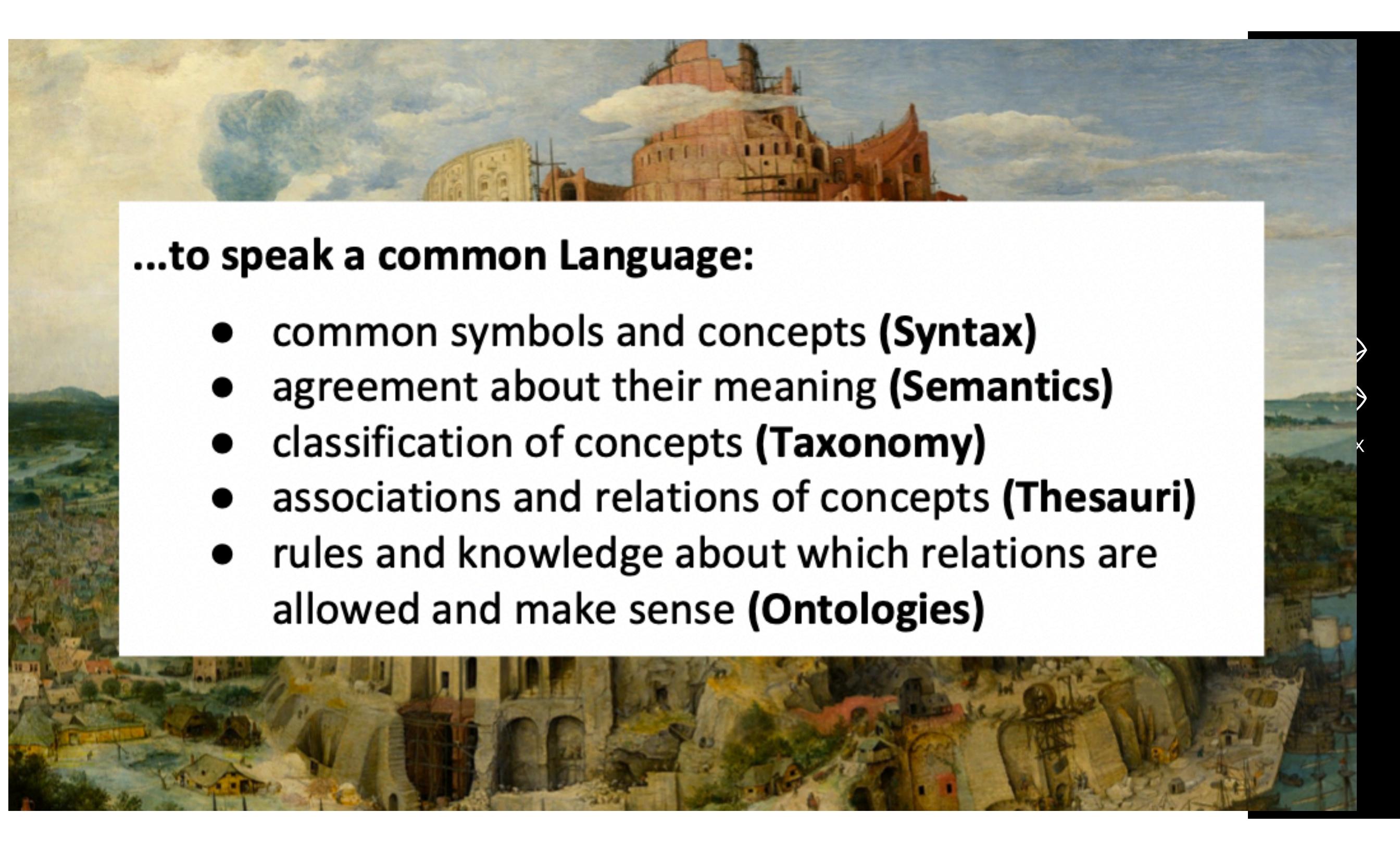
Traditional Definition: „*Knowledge is a justified subset of all true beliefs*“

To represent knowledge, we need a formal knowledge representation = **Ontologies**



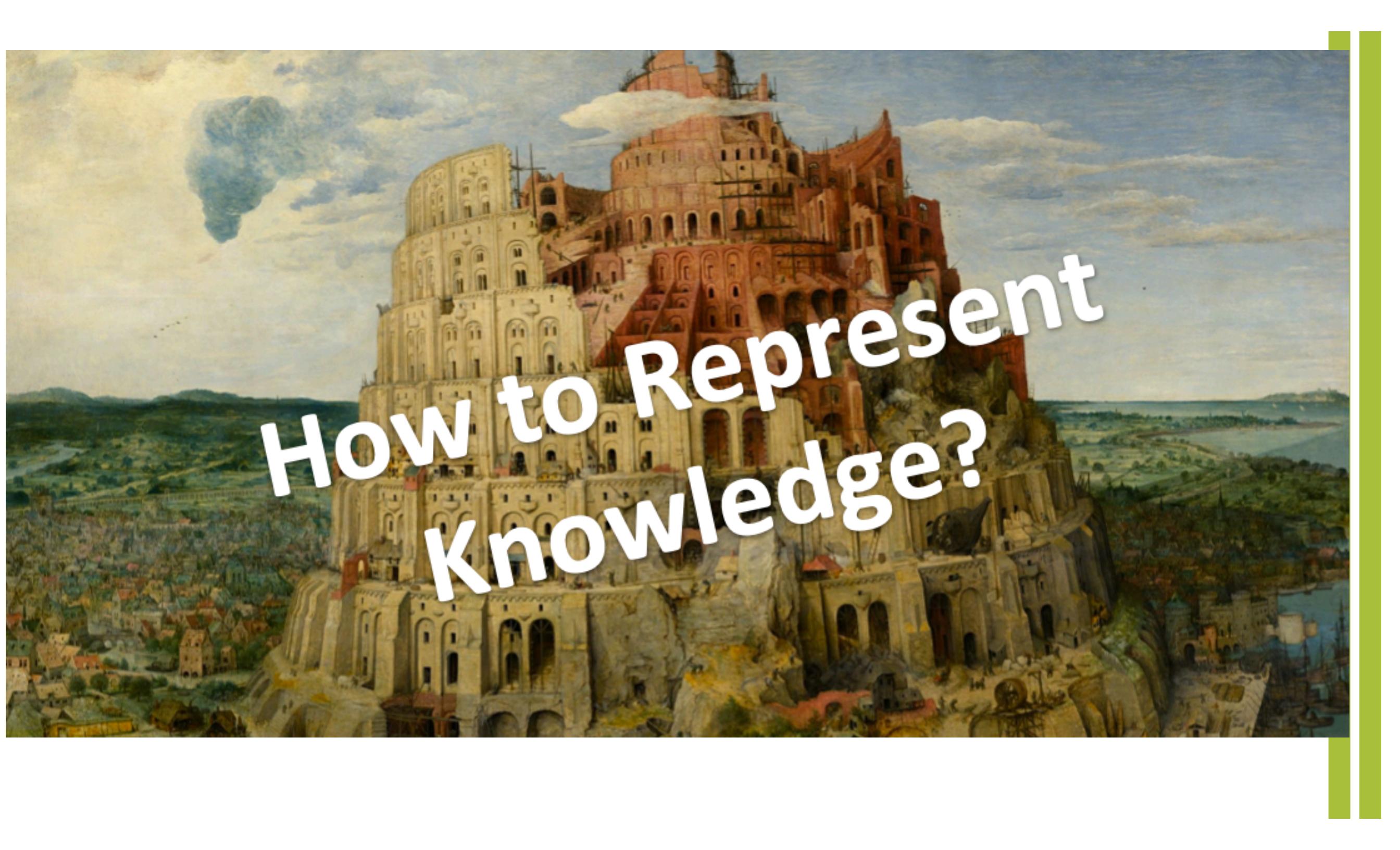
„People can't share knowledge if they don't speak a common language“

**What is the pre-requisite to sharing
knowledge and common understanding?**



...to speak a common Language:

- common symbols and concepts (**Syntax**)
- agreement about their meaning (**Semantics**)
- classification of concepts (**Taxonomy**)
- associations and relations of concepts (**Thesauri**)
- rules and knowledge about which relations are allowed and make sense (**Ontologies**)

A detailed oil painting by Pieter Bruegel the Elder depicting the Tower of Babel. The central focus is a massive, multi-tiered structure made of stone and brick, rising from a rocky cliff. The tower has multiple levels with arched windows and doors. In the background, a city with numerous smaller buildings stretches across a valley. The sky is filled with clouds, and a large, dark cloud of smoke or steam rises from the top of the tower. The overall style is characteristic of Northern Renaissance art, with its use of perspective and detailed architectural rendering.

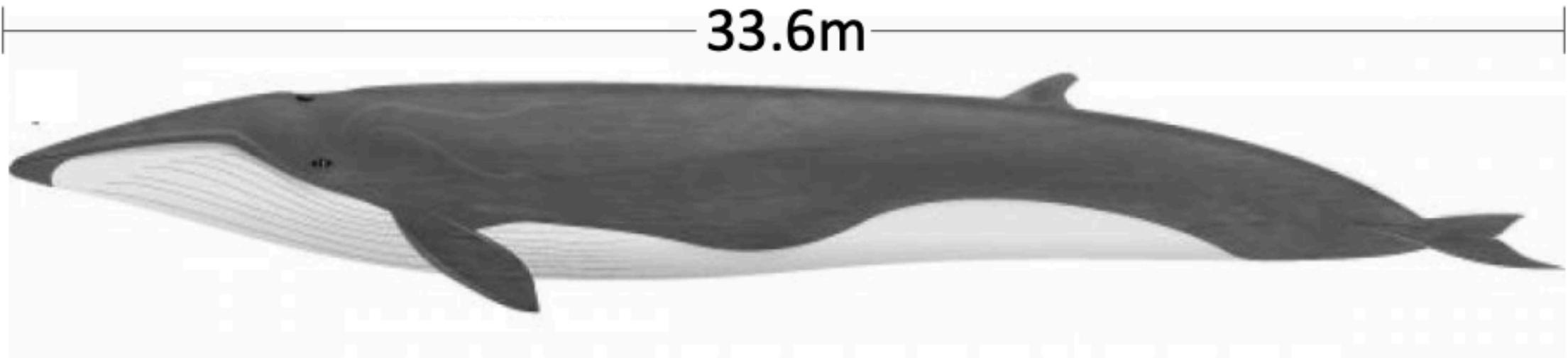
How to Represent
Knowledge?

33.6

- 33.6 is a number

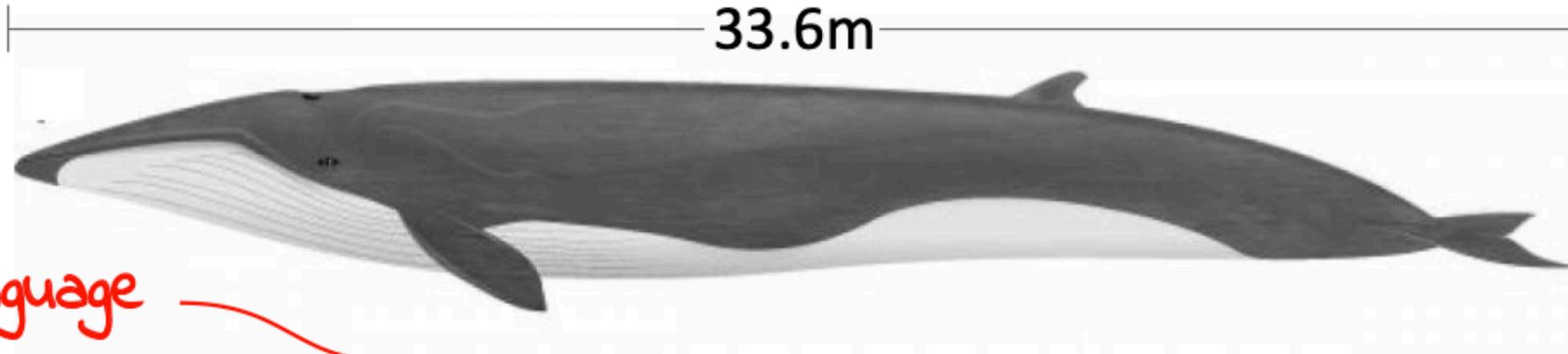
33.6 m

- 33.6 is a number
- 33.6 m is a length



- 33.6 is a number
- 33.6 m is a length
- 33.6 m is the length of a Blue Whale.

Data, Information & Knowledge



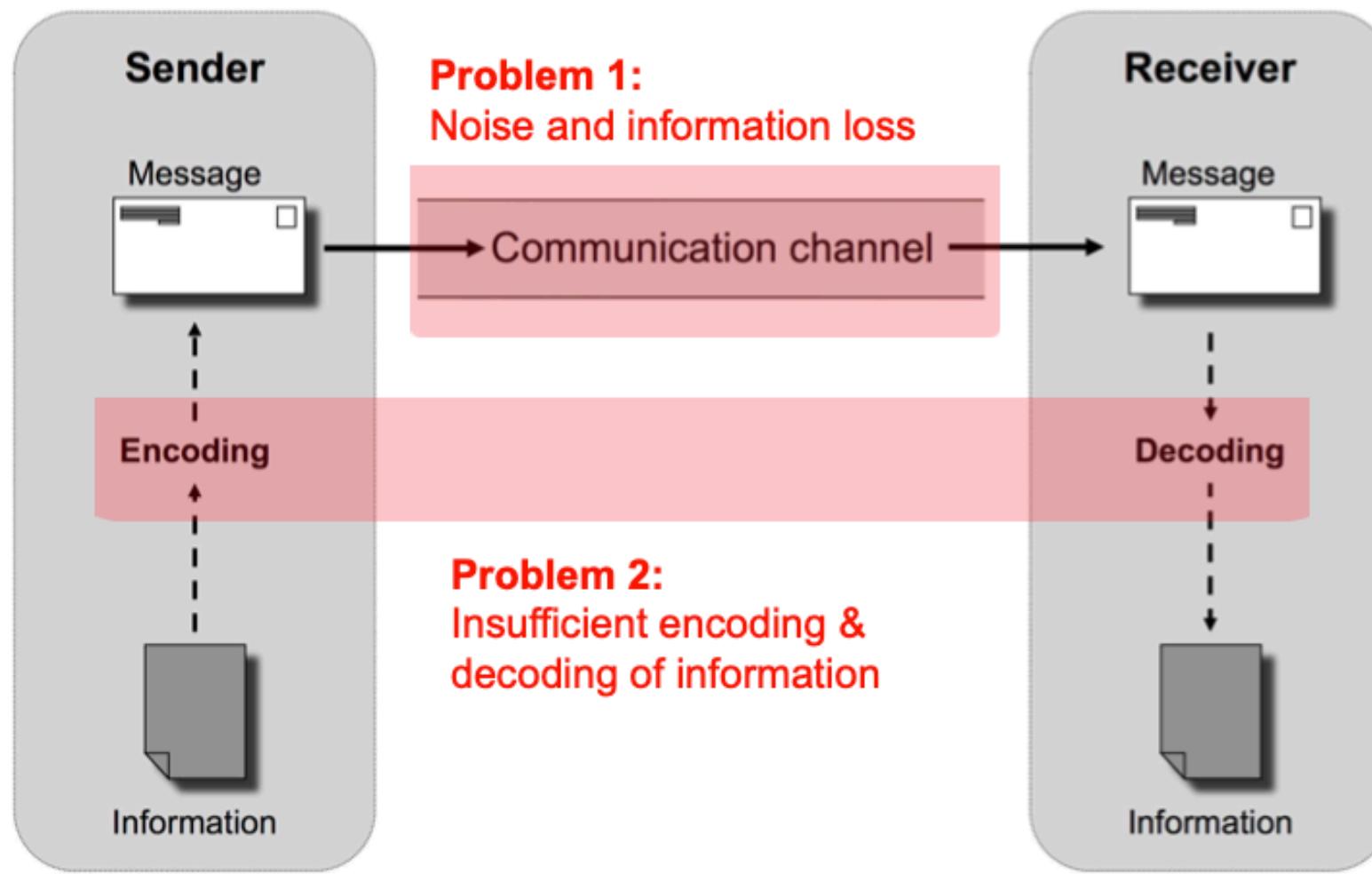
Language

- We want to express more:
 - The blue whale is a whale. A whale is a mammal. A mammal is an animal.
 - The whale lives in the oceans. An ocean is a body of water.
 - This is 'Moby', a specific blue whale. He lives in the Atlantic Ocean.
 - The longest ever measured blue whale had a length of 33.6 m
 - This means that - up to now and unless we may find a longer one - the largest blue whale measures 33.6 m, or no blue whale is longer than 33.6 m.
 - Moby is not longer than 33.6 m.
 - If you happen to find a longer whale, then either it is no blue whale or we have to change our previous assumptions.

Language as Knowledge Representation

- (Natural) Language can be a way to represent knowledge
- What is Language?
 - Language is a system of conventional **spoken, manual, or written symbols** that combine to **convey meaning**, and by means of which human beings, as members of a social group and participants in its culture, **express** themselves.
 - One of the most important functions of language is **communication**.

Language of Communication



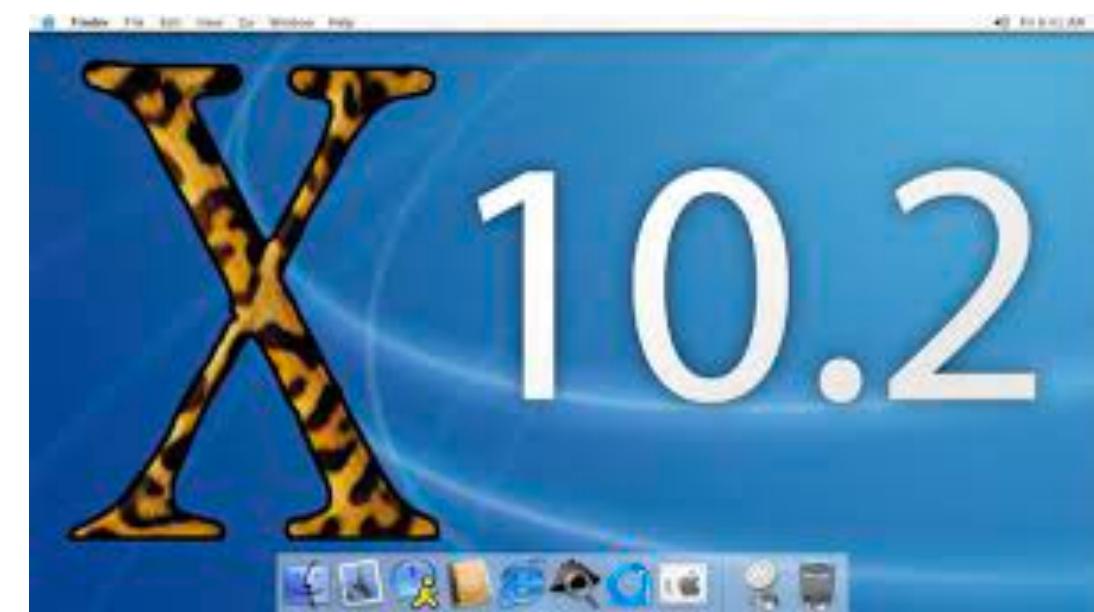
Ch. Meinel, H. Sack:
Digital Communication -
Communication Multimedia,
Security, Springer, 2014.

Communication of (Semantics) Meaning

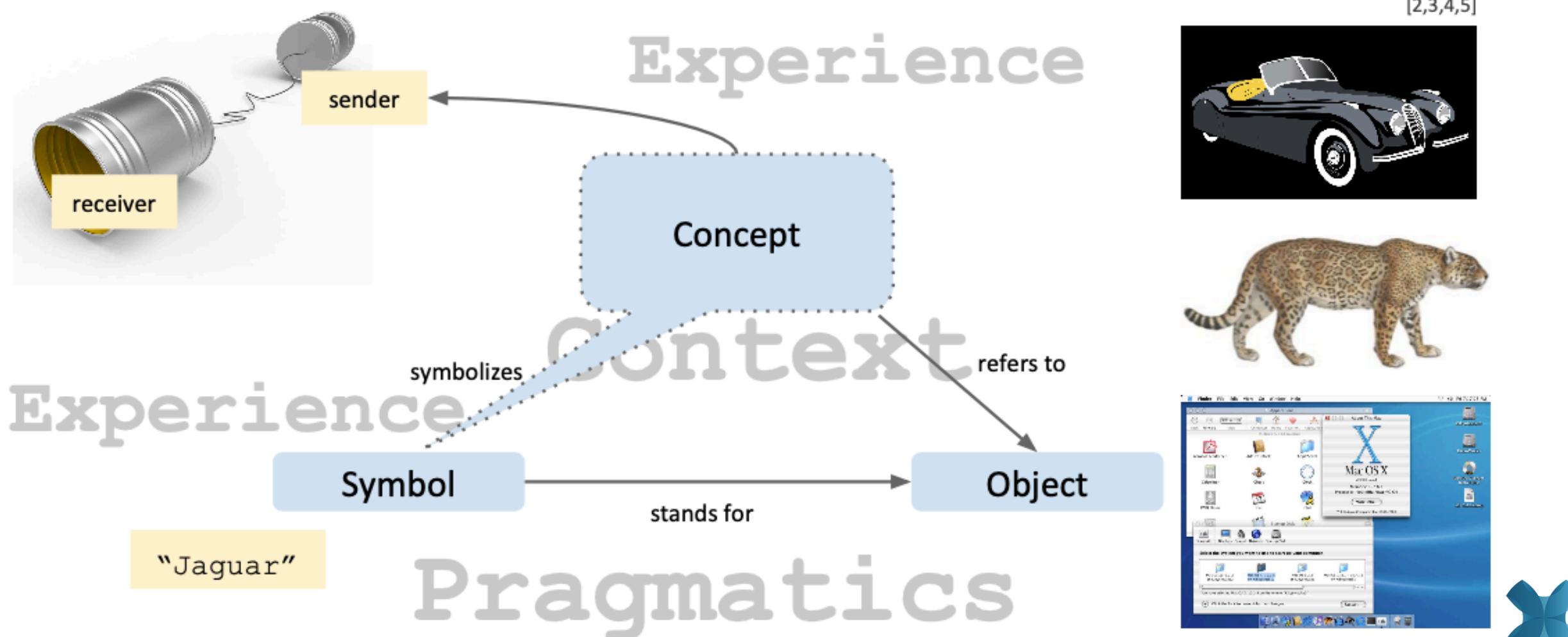
I am always dreaming about my Jaguar!

Or

I love my Jaguar

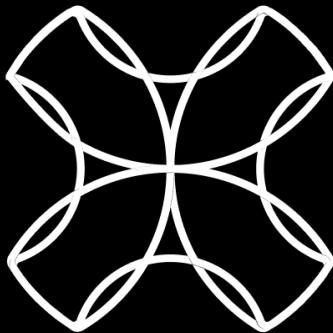


Communication of Meaning



Why (natural) Language is difficult?

- Paraphrasing
- Ambiguity

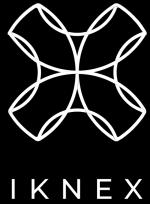


I K N E X

The Art of Understanding



Meaning and comprehension



- Understanding is the ability to grasp the meaning of information
- Information is conveyed in a message using a specific language
- Information is understood by the receiver of the message, if the receiver interprets the information correctly

Meaning and Comprehension

- **Correct interpretation depends on:**
 - Syntax
 - Semantics
 - Context
 - Pragmatics
 - Experience

Syntax

- = [greek] Arrangement, Ordering
- In grammatics syntax denotes the study of the principles and processes by which sentences are constructed in particular languages.
- In formal languages, syntax is just a set of rules, by which well formed expressions can be created from a fundamental set of symbols (alphabet).
- In computer science, syntax defines the normative structure of data.

Semantics

- =[greek] pertains to the character, the study of meaning
- Is part of the linguistics focused on the Sense and Meaning of language or symbols of language.
- Is the study of interpretation of signs or symbols as used by agents or communities within particular circumstances and context.
- Semantics ask, how sense and meaning of complex concepts can be derived from simple concepts based on the rules of syntax.
- The Semantics of a message depends on context and pragmatics.

Context

- [lat.] **contextus** = interweaved
- Denoted the surrounding of a symbol (concept) in an expression resp. its relationship with surrounding expressions (concepts) and further related elements,
- Contexts denotes all elements of any sort of communication that define the interpretation of the communicated content.
- We distinguish
 - **General contexts:** place, time, interrelation of action in a message
 - **Personal or social contexts:** relation between sender and receiver of a message

Pragmatics

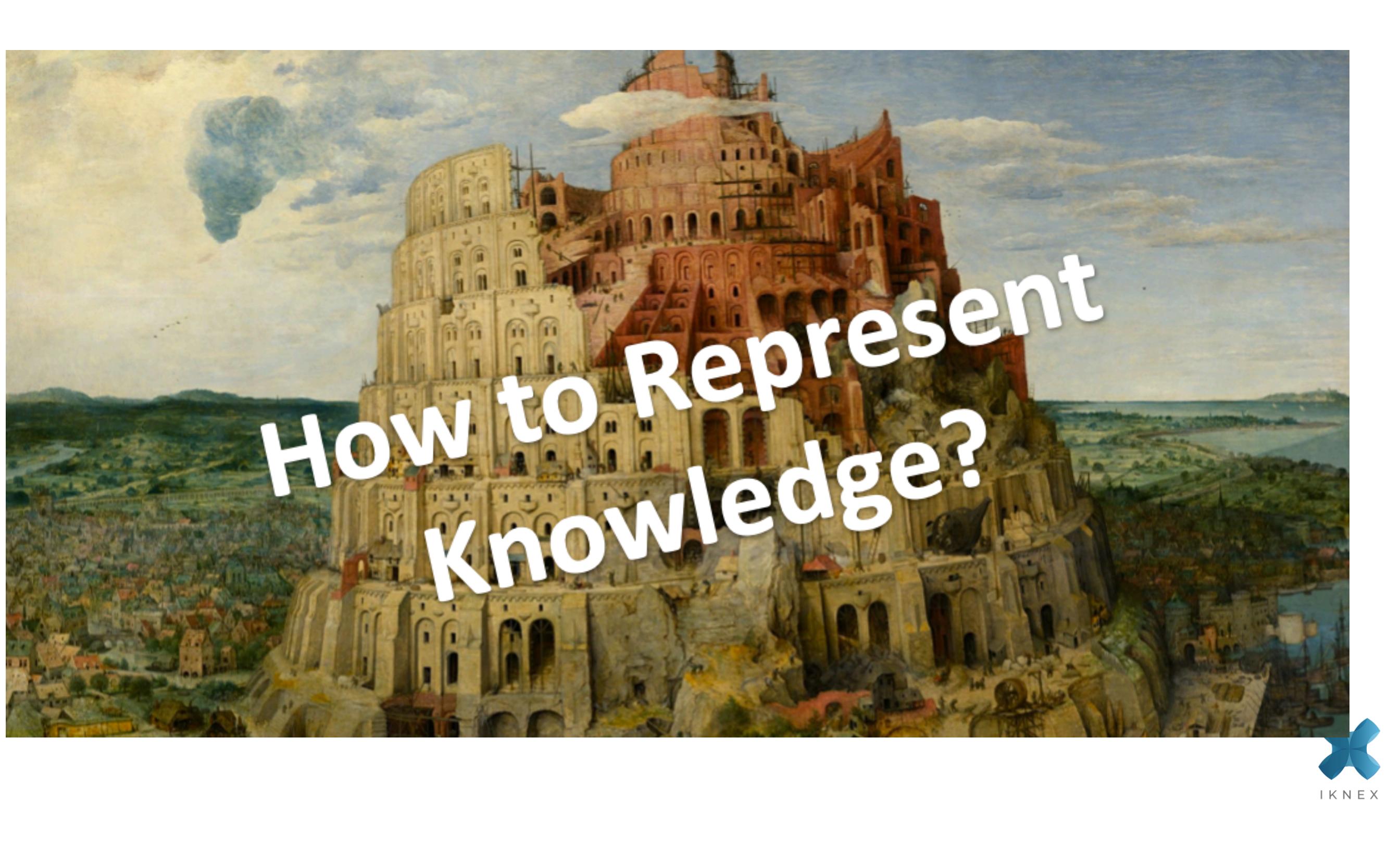
- [greek] = action
- Reflects the intention by which the language is used to communicate a message.
- In linguistics pragmatics denotes the study of applying language in different situations.
- It also denotes the intended purpose of the speaker.
- Pragmatics studies the ways in which context contributes to meaning.

Experience

- **Experience** considers all information that you have learned and put in context with the world you are living in.
- Experience in this sense also often is referred to as **common sense knowledge** or **world knowledge**.

Successful Communication

- **For successful communication,**
 - Information has to be correctly transmitted (**Syntax**)
 - The meaning (**Semantics**) of the transmitted information must be interpreted correctly (= **understanding**)
- **Understanding** depends on
 - The **context** of both sender and receiver and
 - The **pragmatics** of the sender
- **Context** of sender and receiver depend on
 - The **experience** (knowledge of the world) of both sender and receiver.



How to Represent Knowledge?

Formal Knowledge Representation

- **Formal Knowledge Representation**
 - is a field of **artificial intelligence (AI)**,
 - which (unambiguously) captures the **semantics (meaning)** of **concepts, properties, relationships, and entities**
 - of specific **knowledge domains**, i.e., fields of interest or areas of concern,
 - as **structured data**.
- **Machines (computers)** must be able to **understand** formal knowledge representations.
- To “**understand**” a knowledge representation, the machine must be able to **interpret it correctly**.

Towards Universal Knowledge Representation

Climate Change is
the Everest of all
problems...

A wide-angle photograph of a rugged mountain range under a clear blue sky. The mountains are covered in patches of white snow and rocky terrain. In the foreground, there are dark, billowing clouds. The text is overlaid on the upper portion of the image.

Climate Change is
the Everest of all
problems...

Knowledge & Understanding



Text: "Everest"

*Entity Mapping
Entity Disambiguation*

Everest, Kansas

a small village

Everest, Gasfield

a gas field near Scotland

George Everest

a Surveyor General of India

Jack Everest

an Irish football player

...

Mount Everest

a mountain

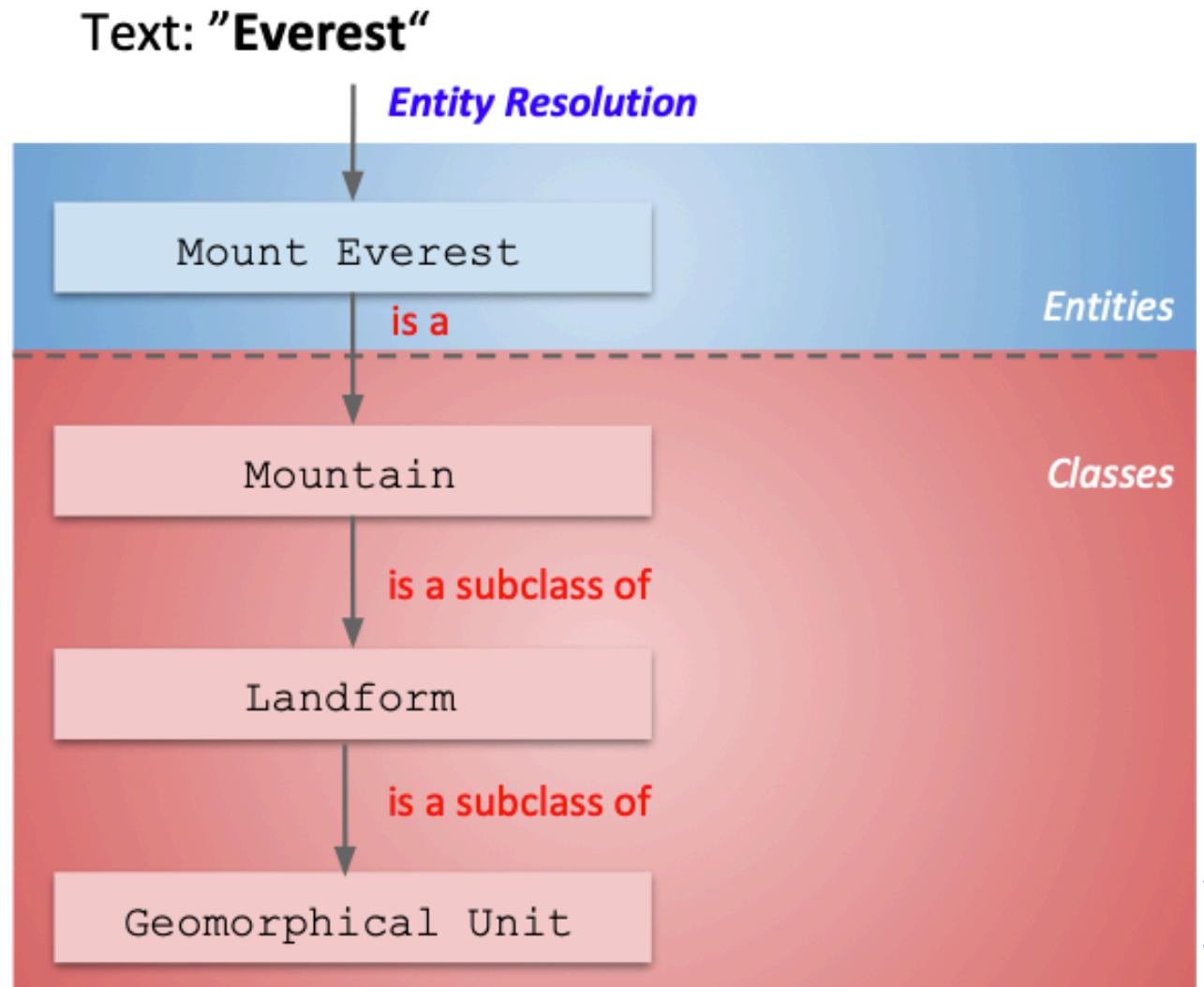
Disambiguation

- solution of linguistic ambiguities

Knowledge & Understanding



- The **Meaning (Semantics)** of entities and classes must be defined explicitly.



Knowledge & Understanding



MountEverest \in Mountain

Mountain \subseteq Landform

Landform \subseteq GeomorphicalUnit

GeomorphicalUnit \subseteq NaturalGeographicObject

GeorgeEverest \in Person

Person \cap Mountain = \emptyset

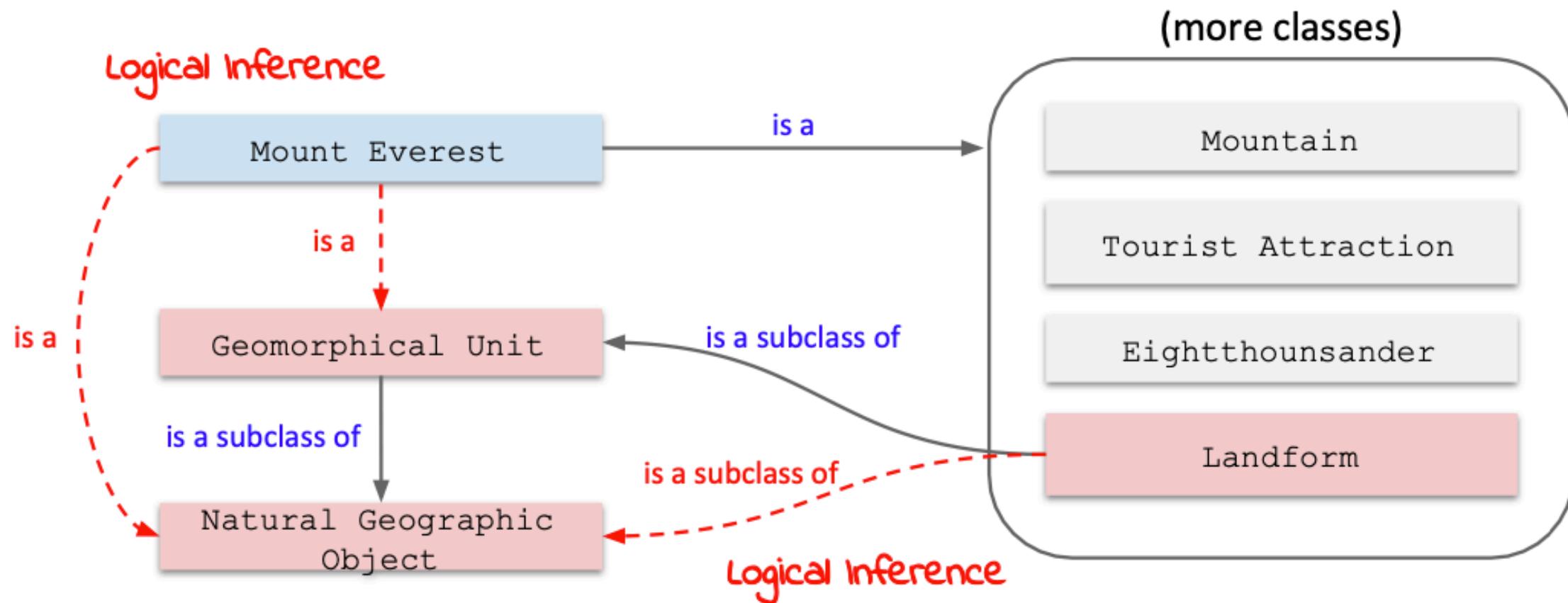
Logical Inference

MountEverest \notin Person

GeorgeEverest \notin Mountain

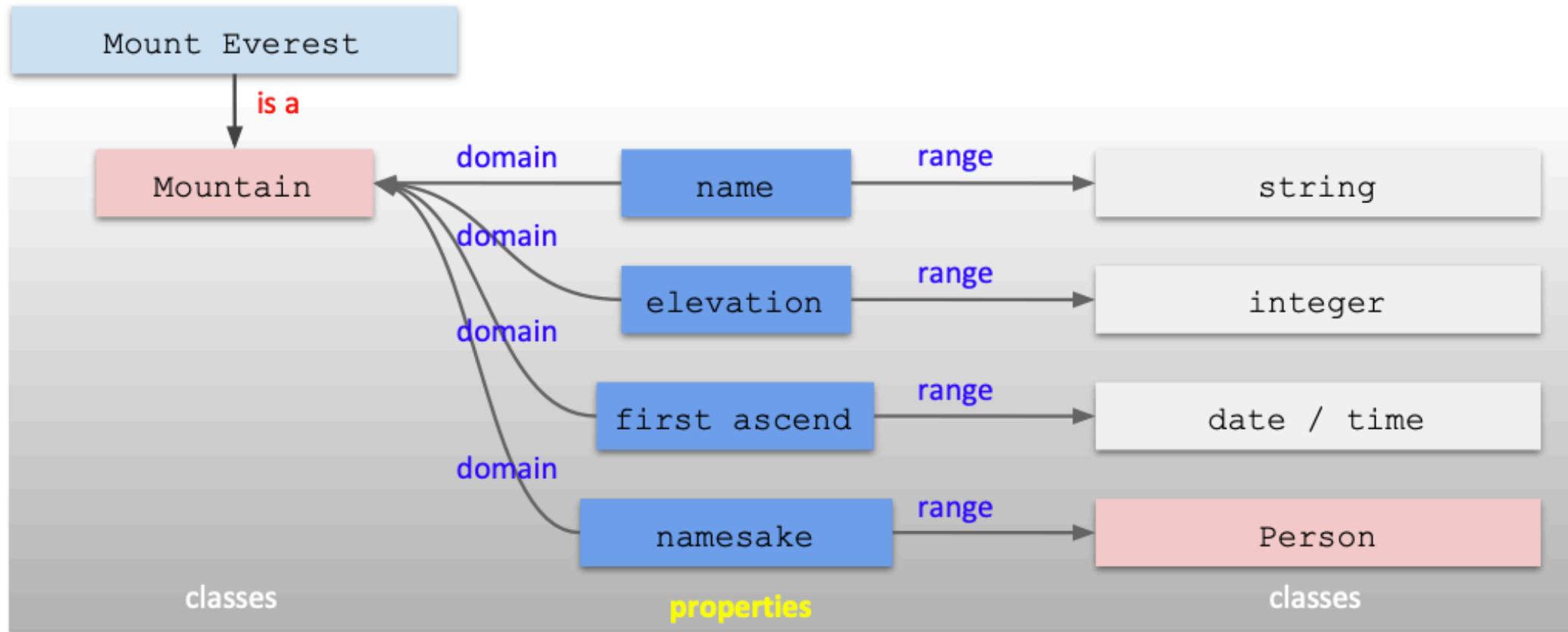
Knowledge and Understanding

- The Meaning (Semantics) of information is expressed with the help of knowledge representations (**Ontologies**)



Knowledge and Understanding

- The Meaning (Semantics) is expressed with the help of knowledge representations (**Ontologies**)

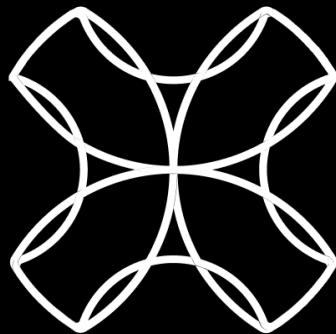


Knowledge Representation vs Data Structures

- What's the difference to traditional data structures?
 - Mathematical Logic provides a framework to formally express the semantics of knowledge representations.
 - Semantics of knowledge representations can be defined explicitly.
 - Mathematical Logic enables logical inferences and reasoning for knowledge representations.

The Semantic Web - A Web of Data

- The Semantic Web is an **Extension of the current Web**.
- The meaning of information (Semantics) is made explicit by **formal (structured) and standardized knowledge representations (Ontologies)**.
- Thereby it will be possible,
 - to **process** the meaning of information automatically,
 - to **relate and integrate** heterogeneous data,
 - to **deduce** implicit (not evident) information from existing (evident) information in an automated way.
- The Semantic Web is kind of a **global database** that contains a **universal network of semantic propositions**.



I K N E X

Knowledge Engineering & Linked Data

Spring 2023
Dr. Amna Basharat

What is the Semantic Web?

What has it got to do with Knowledge Graphs?

Key Terms

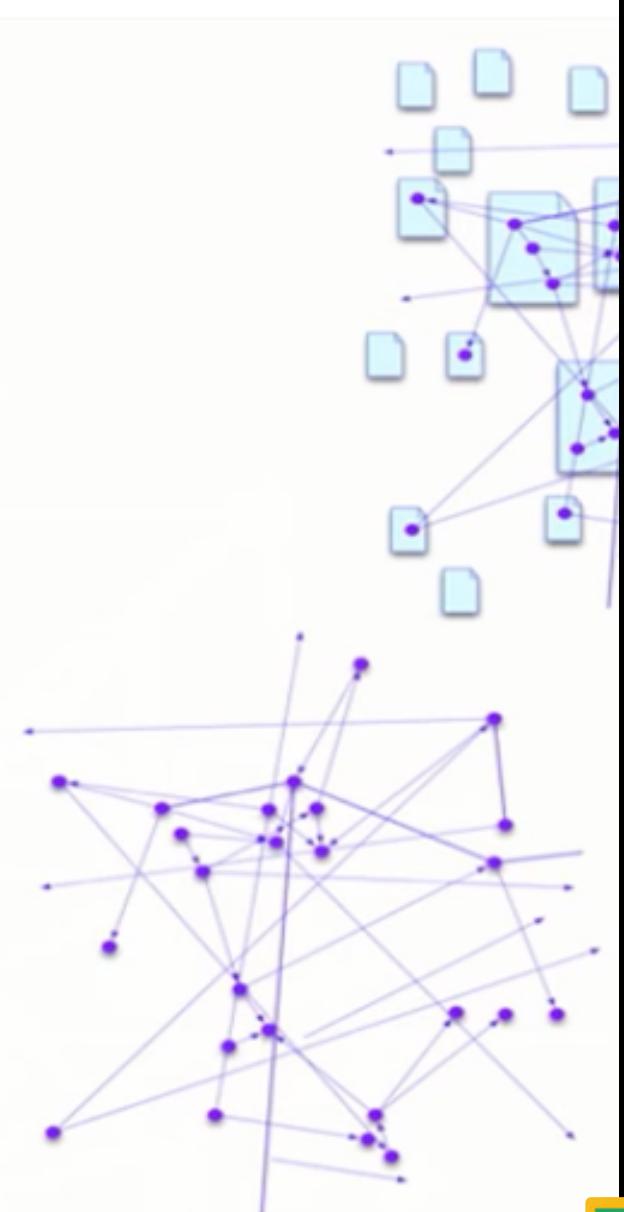
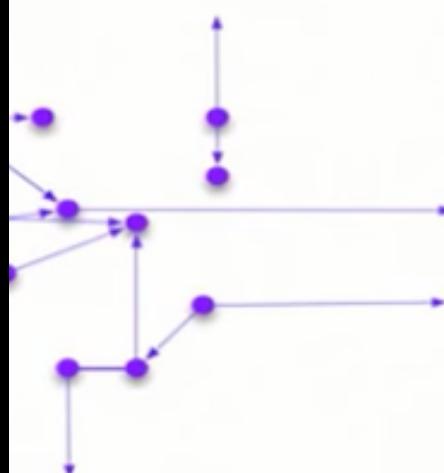
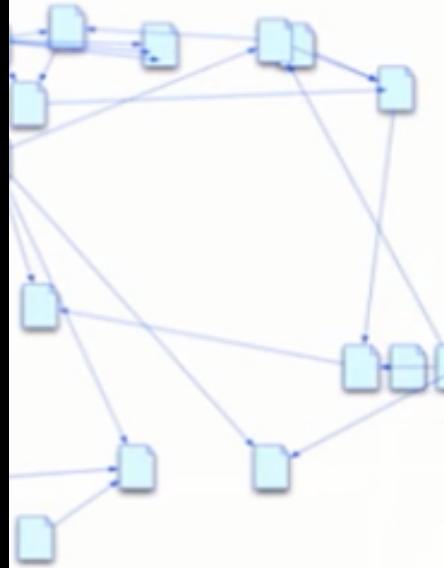
Key Terms

- Knowledge
- Syntax vs. Semantics
- Linked Data
- Ontology
- Web 1.0/Web 2.0/Web 3.0
- Web of Data
- Semantic Web



Understanding Web 1.0/Web 2.0/Web 3.0

Understanding the Web of Data



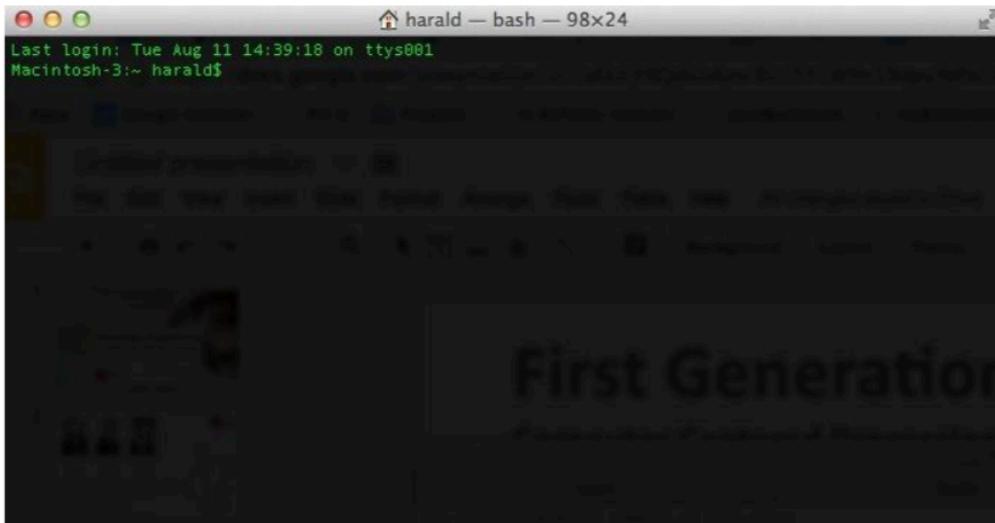
<https://www.youtube.com/watch?v=V6BR9DrmUQA>



First Generation: The Internet

Computer Centered Processing

- How does the user get the information?



1. Open Terminal
2. Connect to remote system
3. Retrieve file system data from remote system
4. Download file from remote to local system
5. Read file on local system

Problems

- Information access requires expert knowledge and is expensive
- Information retrieval is even more expensive

Second Generation: The Web

Document Centered Processing

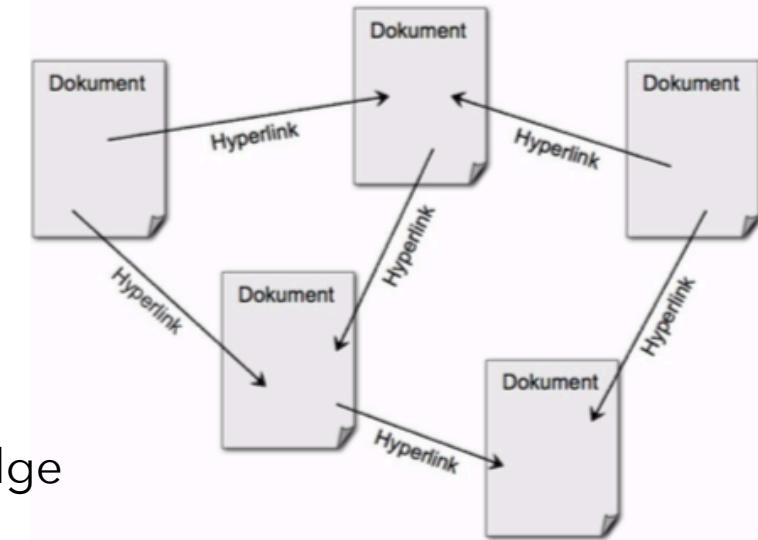
- How does the user get the information?



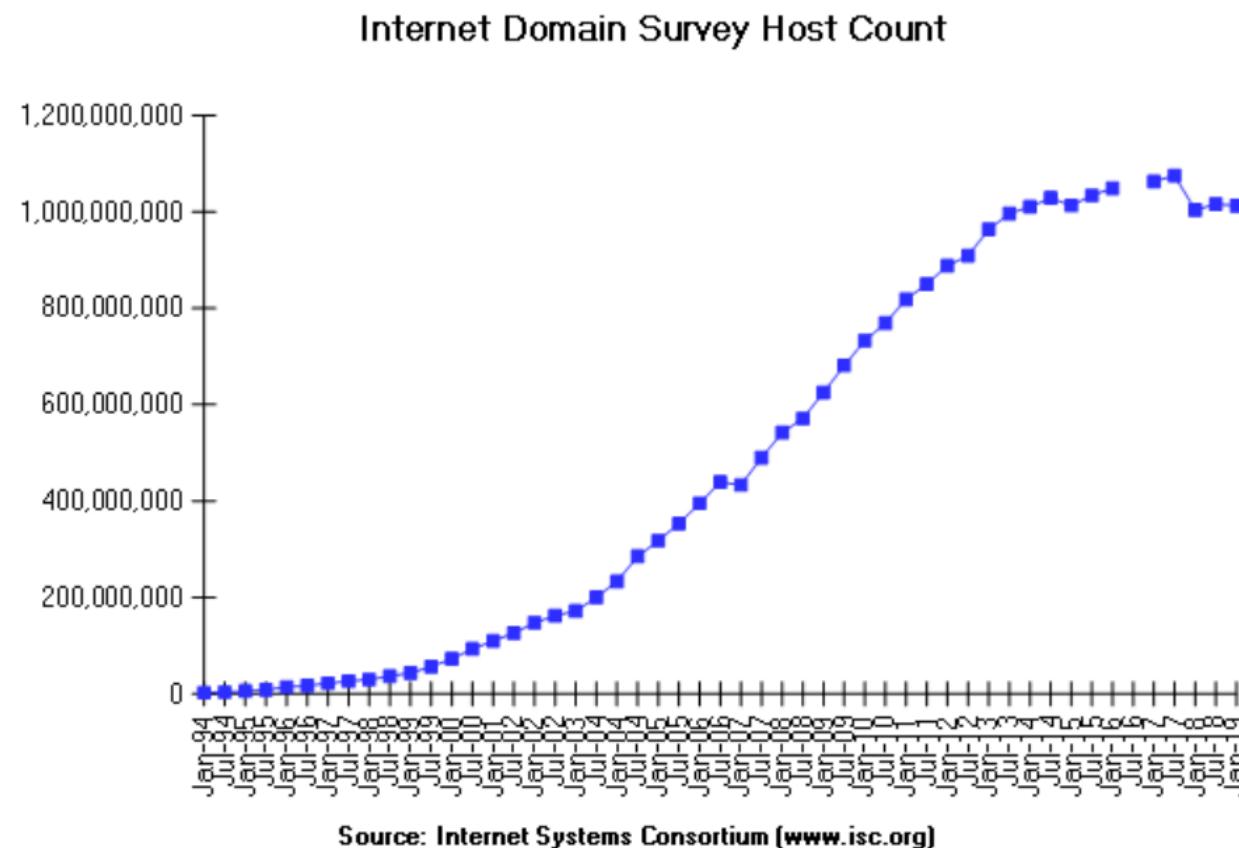
Advantages

- Information access does not require expert knowledge
- Information retrieval via search engine

1. Open browser
2. Load Document
3. Click on the next hyperlink
4.



No Limits of Growth

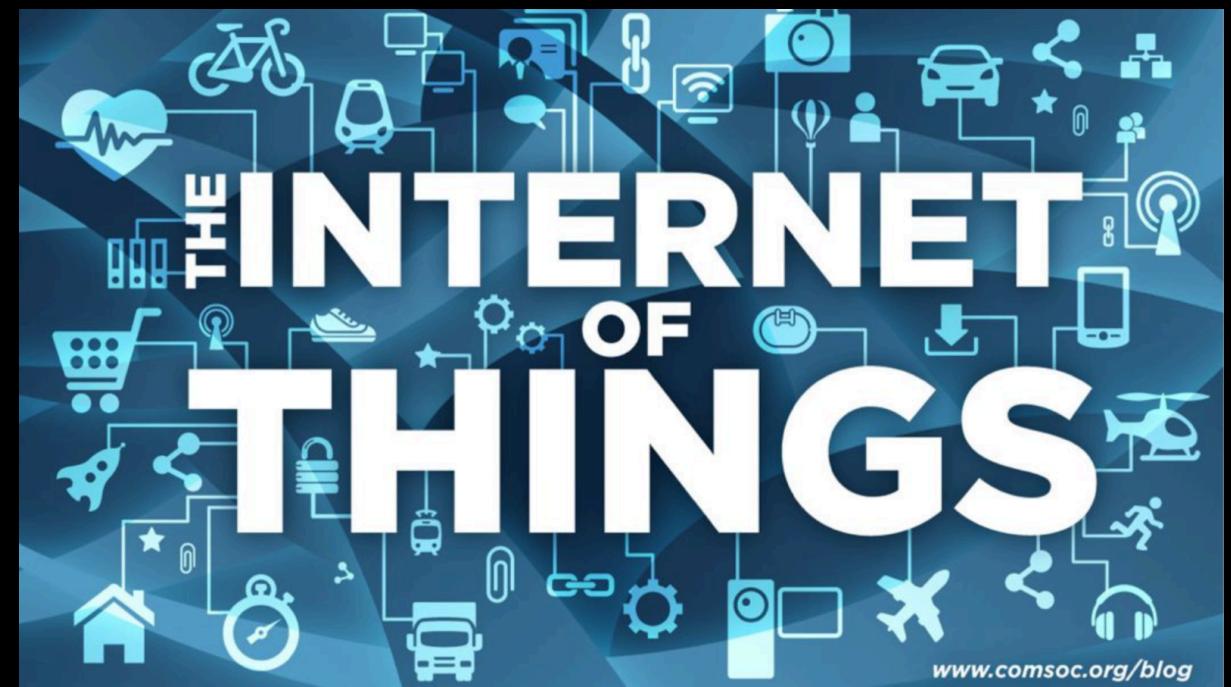


**“The Web is
Big! Really
Big. You just
won’t believe
how vastly,
hugely, mind-
bogglingly big
it is.”**

- -According to Douglas Adams



The Next Revolution!



The need for Semantics
AKA ‘Meaning’

Understanding the Limitations

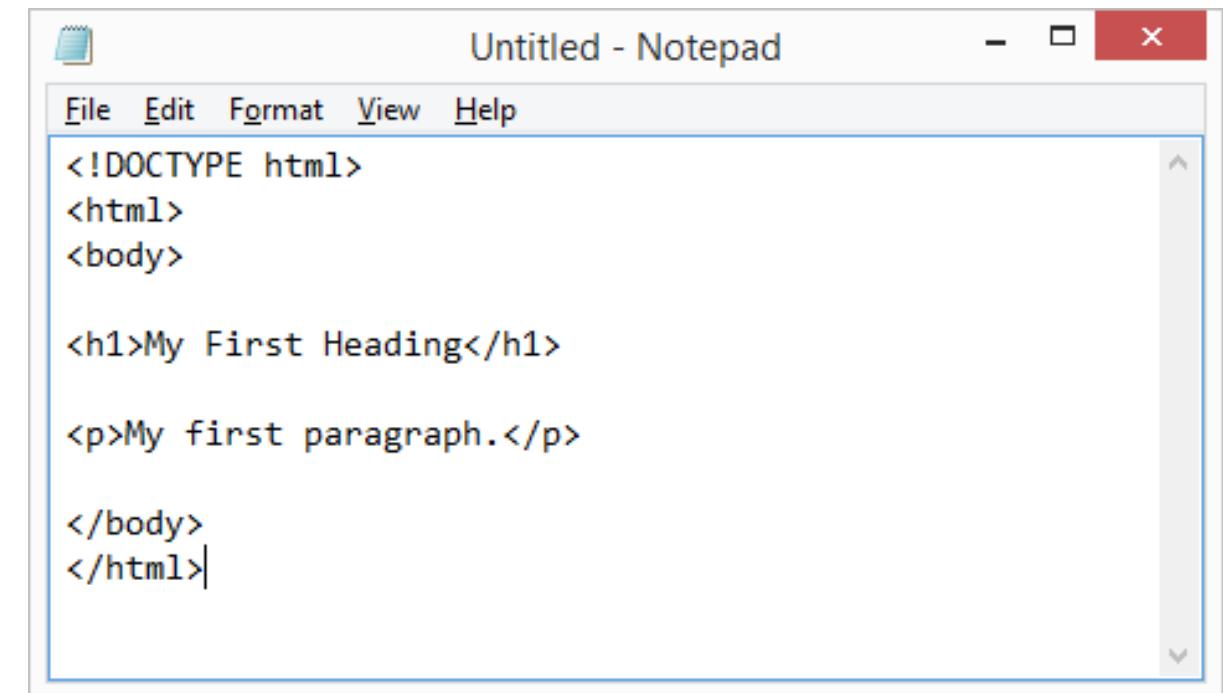
Humans vs. Machines

- Humans have contextual knowledge, world knowledge and experience to solve the problems



The (Document) Web is for Humans

- The Web is based on the markup language HTML
- HTML describes
 - how information is presented
 - how information is linked
 - but NOT, what the information means



A screenshot of a Windows Notepad window titled "Untitled - Notepad". The window contains the following HTML code:

```
<!DOCTYPE html>
<html>
<body>

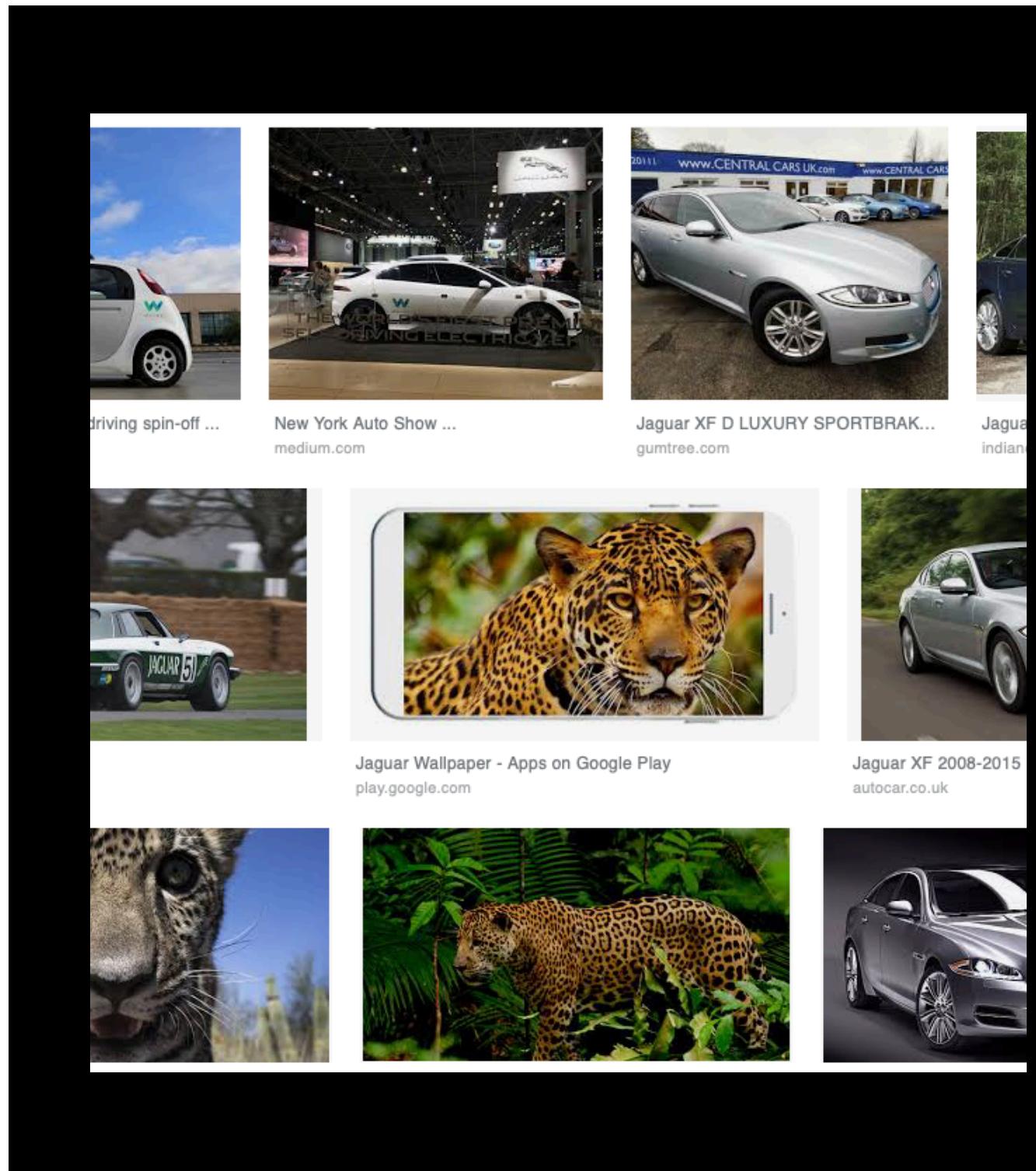
<h1>My First Heading</h1>

<p>My first paragraph.</p>

</body>
</html>
```

The Information Retrieval Dilemma

- **Syntactic vs. Semantic Search**
- Ambiguity of natural language (polysemy)
- Different words/expression for the same concept (synonyms/metaphors)



Implicit Knowledge

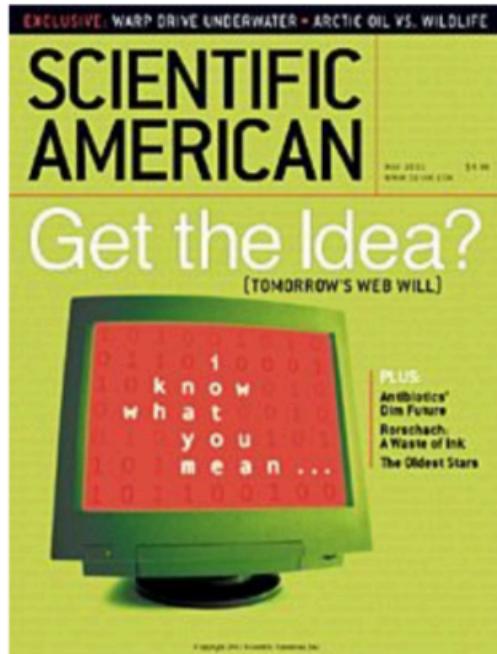
- Information does not have to be specified explicitly, but may be derived via logical deductions from the available information



Meaning and comprehension

- Understanding is the ability to grasp the meaning of information
- Information is conveyed in a message using a specific language
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The Semantic Web - A Web of Data



„The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation“

Tim Berners-Lee, James Hendler, Ora Lassila: [The Semantic Web](#), Scientific American, 284(5), pp. 34-43(2001)

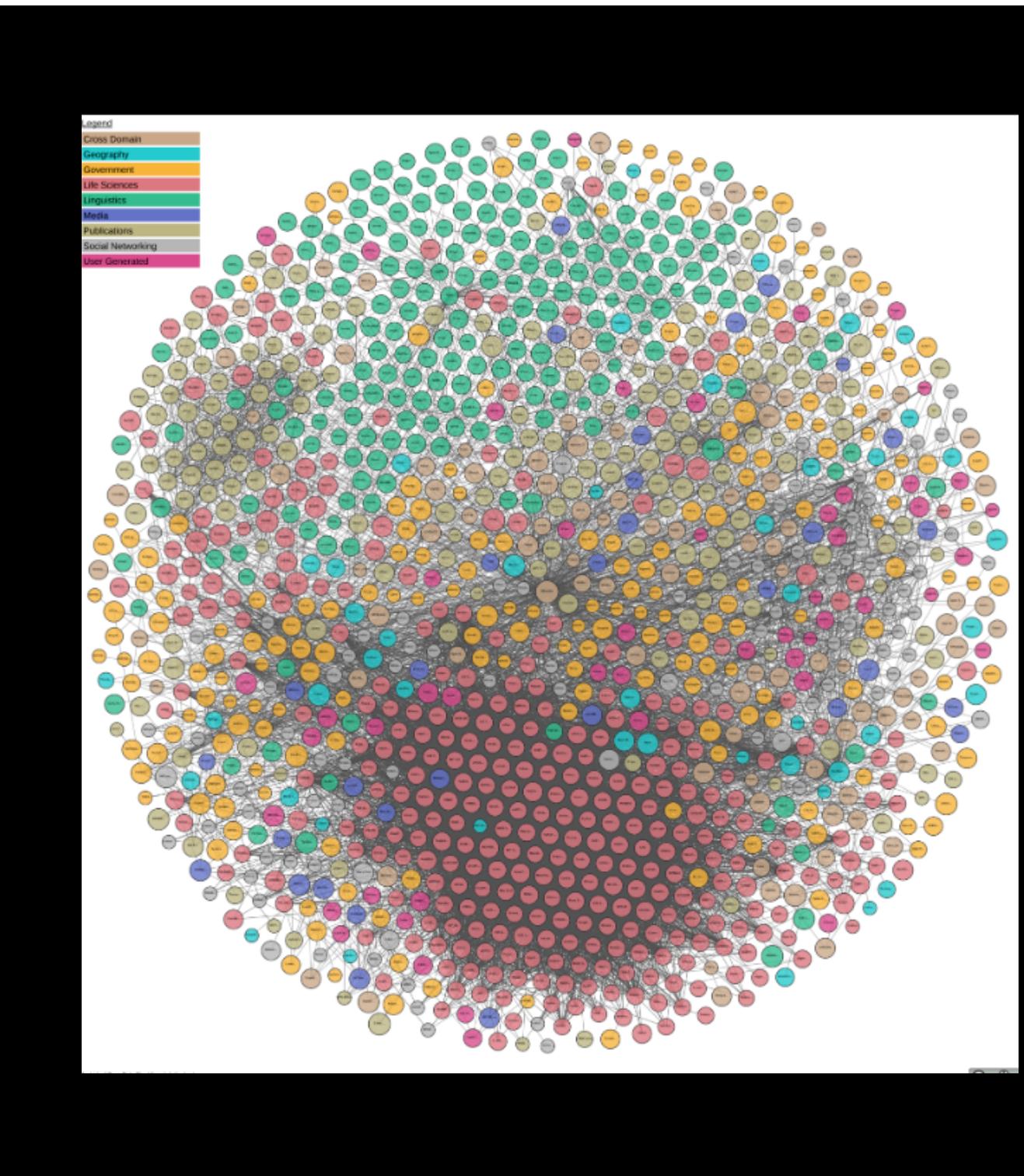
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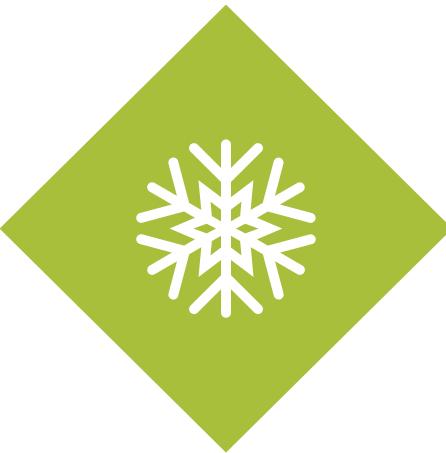
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- **Thus it will be possible,**
 - To process the meaning of information automatically
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- **The Semantic Web is kind of a global database that contains a universal network of semantic propositions.**

The Take Away

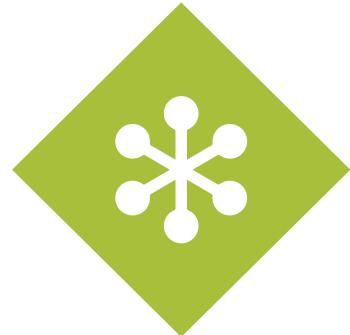
Simple Take Away

- If we use standard languages and semantic markup for our data on the web
 - we allow for easier discovery and reuse of data, even automatically by machines/agents
 - we can build "smarter applications"
- Semantic Web technologies are not ONLY for the open Web





Review Questions



Review

- What is the difference between the Internet and the Web?
- Distinguish Web 1.0 vs 2.0 vs. 3.0
- Distinguish semantic vs syntactic search
- What 5 things correct meaning and interpretation of knowledge depends upon?
- What is the limitation of the traditional web?



Review - II

- What is the semantic web?
- Give another name for semantic web.
- How is meaning expressed on the semantic web?
- Give three inherent benefits of the semantic web.
- What are the key elements in first three layers of the semantic web stack?

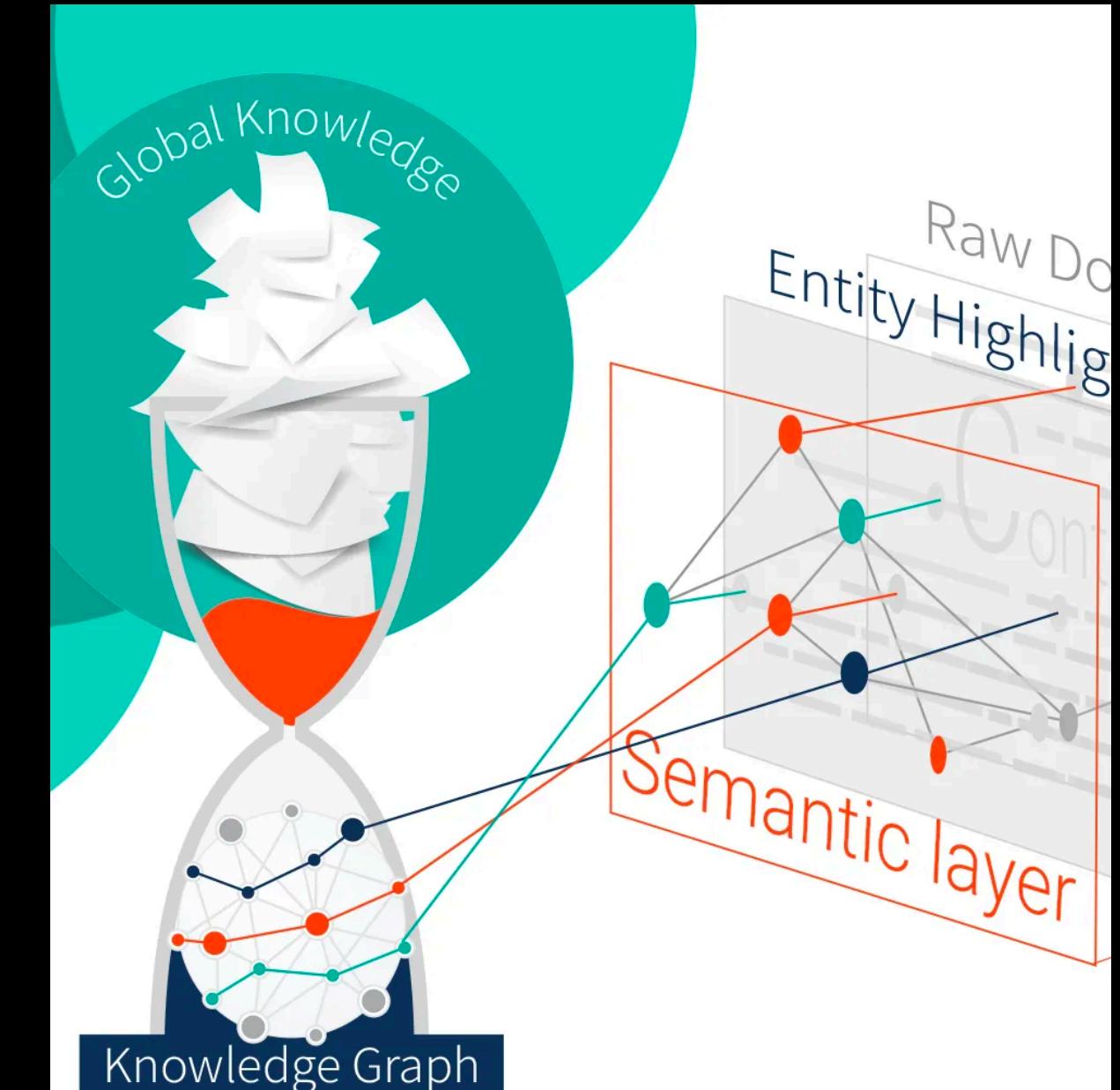


Review - III

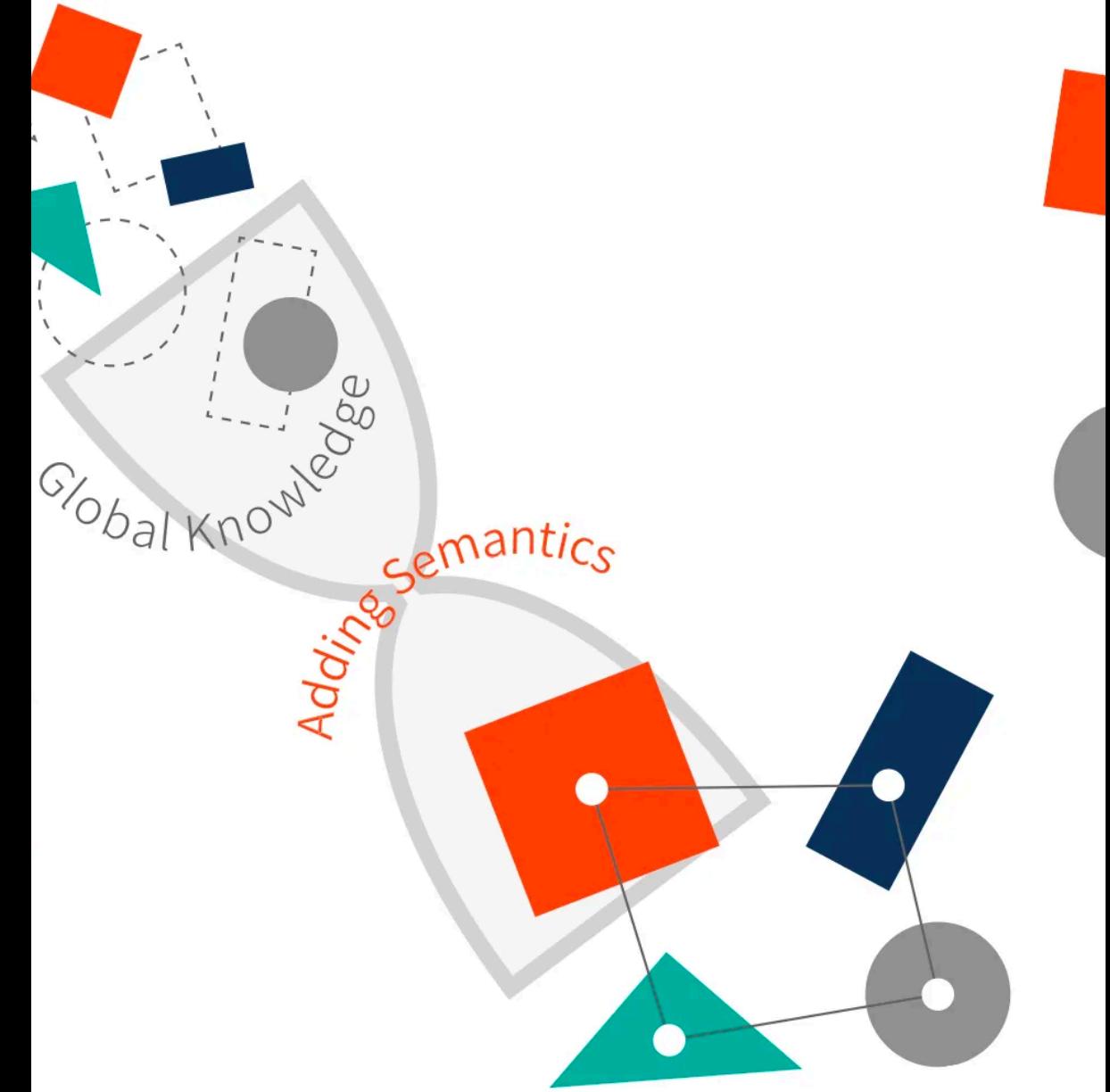
- What is the linked data cloud?
- What is considered the nucleus of linked data cloud?
- What is dbpedia?

What is the Semantic Web?

What has it got to do with Knowledge Graphs?



- What is Semantic Metadata?
- What is the difference between explicit & implicit knowledge?
- What are 3 main benefits of semantic web?



THE SEMANTIC WEB^C

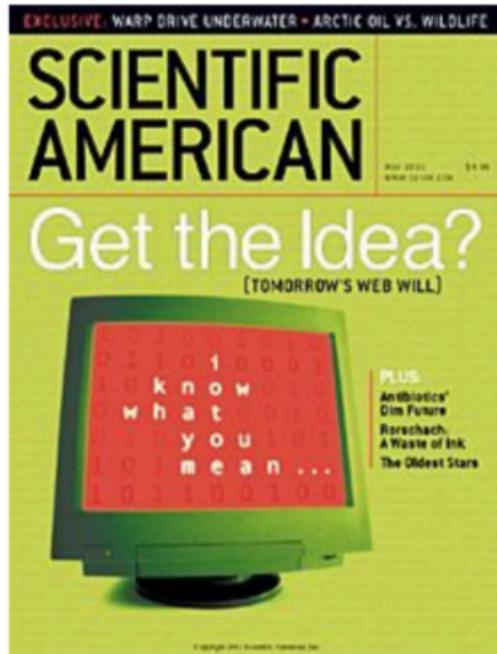
A new form of Web content
that is meaningful to computers
will unleash a revolution of new possibilities

by

TIM BERNERS-LEE,
JAMES HENDLER and
ORA LASSILA

PHOTOILLUSTRATIONS BY MIGUEL SALMERON

The Semantic Web - A Web of Data



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From WWW to Web of Data

- Precondition:
 - Content can be **read and interpreted correctly (= "understood") by machines**



Natural Language Processing

- Technologies of **traditional Information Retrieval**
- Statistical models & machine learning

Semantic Web Technologies

- Natural language web content is **explicitly annotated with semantic metadata**
- Semantic metadata encode the **meaning** of the content and can be **read and interpreted correctly by machines**

Knowledge Representation with XML

Knowledge Representation - A simple Example

- How do I represent the following fact:
 - “Pluto has been discovered in 1930” in XML?

```
<discovered>
  <discovery>Pluto</discovery>
  <year>1930</year>
</discovered>
```

```
<planet name = "Pluto">
  <yearDiscovered>1930</yearDiscovered>
</planet>
```

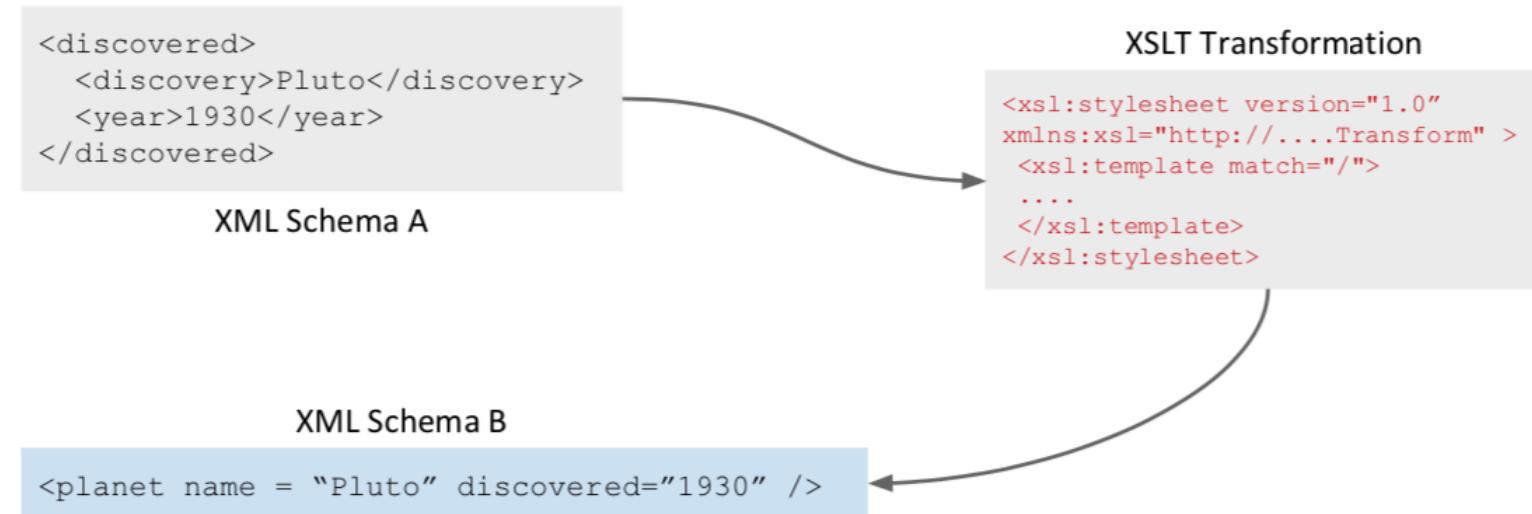
```
<planet name = "Pluto" discovered="1930" />
```



- is there a unique (intuitive) way to model knowledge (in XML)?
 -

Knowledge Representation - with XML

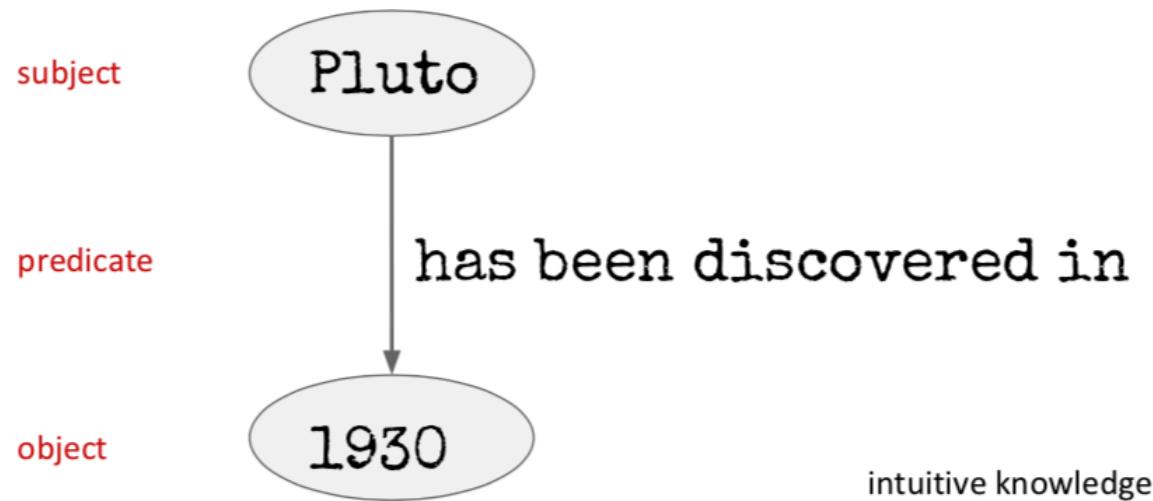
- In XML successful communication of information requires translation among different XML serializations



Knowledge Representation

- A simple example

- How do I represent the following fact:
“Pluto has been discovered in 1930” in an intuitive way?
-



intuitive knowledge representation with a **directed graph**

Resource Description Framework

Basic concepts of RDF

Formats for serializing RDF data

Advanced features of RDF

What is Linked Data?

Resource Description Framework

- Resource
 - can be everything
 - must be uniquely identified and referencable via URI
- Description
 - = description of resources
 - ia representing properties and relationships among resources as graphs
- Framework
 - = combination of web based protocols (URI, HTTP, XML, Turtle, JSON, ...)
 - based on formal model (semantics)
- Knowledge in RDF is expressed as a list of statements
- All RDF statements follow the same simple schema (= RDF Triple)

Resource Description Framework

