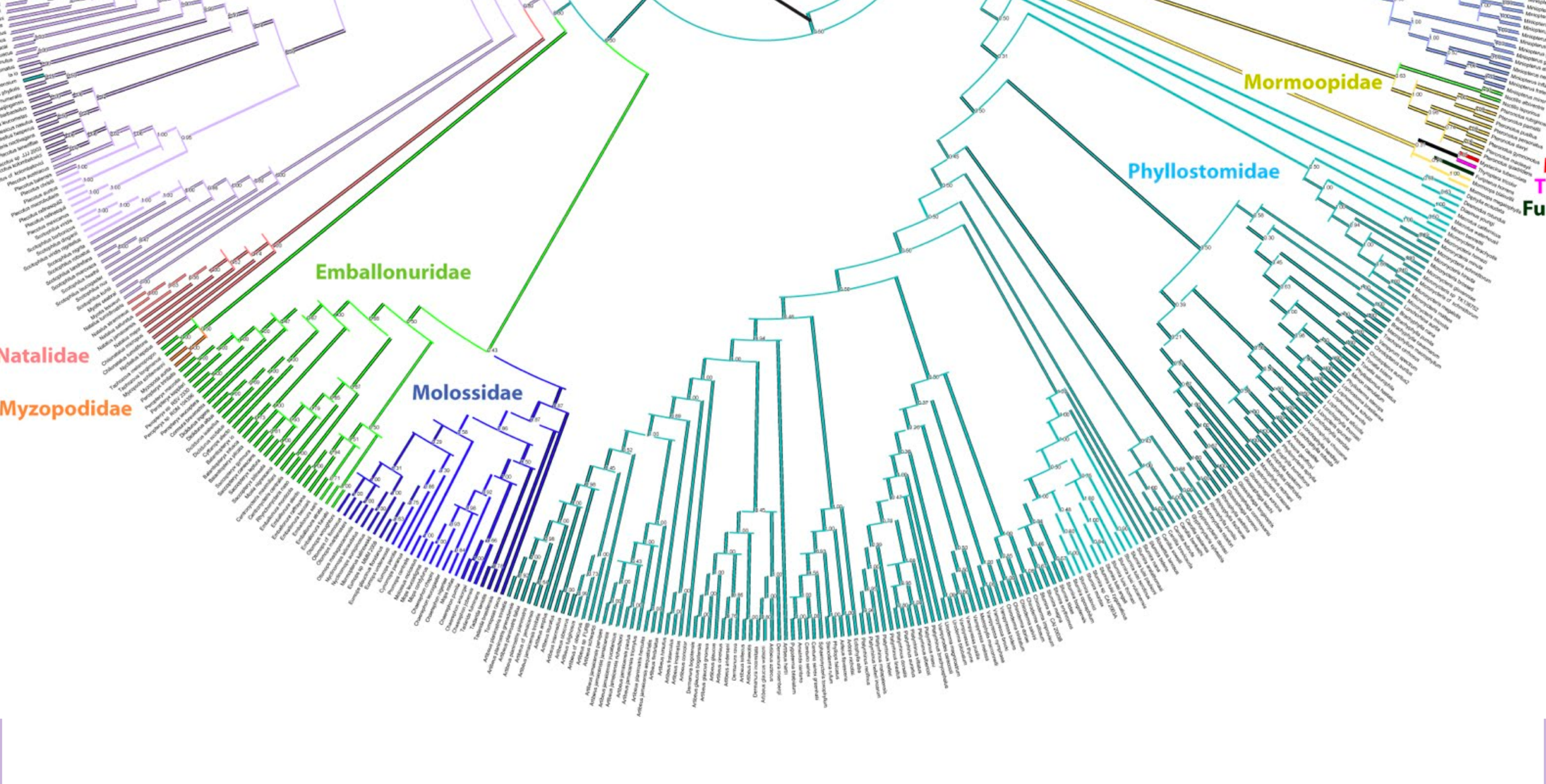

KNOWLEDGE REPRESENTATION

ECS170 Spring 2018

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Knowledge

Definition of KNOWLEDGE

1 **a** (1) : the fact or condition of knowing something with familiarity gained through experience or association (2) : acquaintance with or understanding of a science, art, or technique

b (1) : the fact or condition of being aware of something (2) : the range of one's information or understanding • answered to the best of my *knowledge*

c : the circumstance or condition of apprehending truth or fact through reasoning : COGNITION

d : the fact or condition of having information or of being learned • a person of unusual *knowledge*

2 **a** : the sum of what is known : the body of truth, information, and principles acquired by humankind

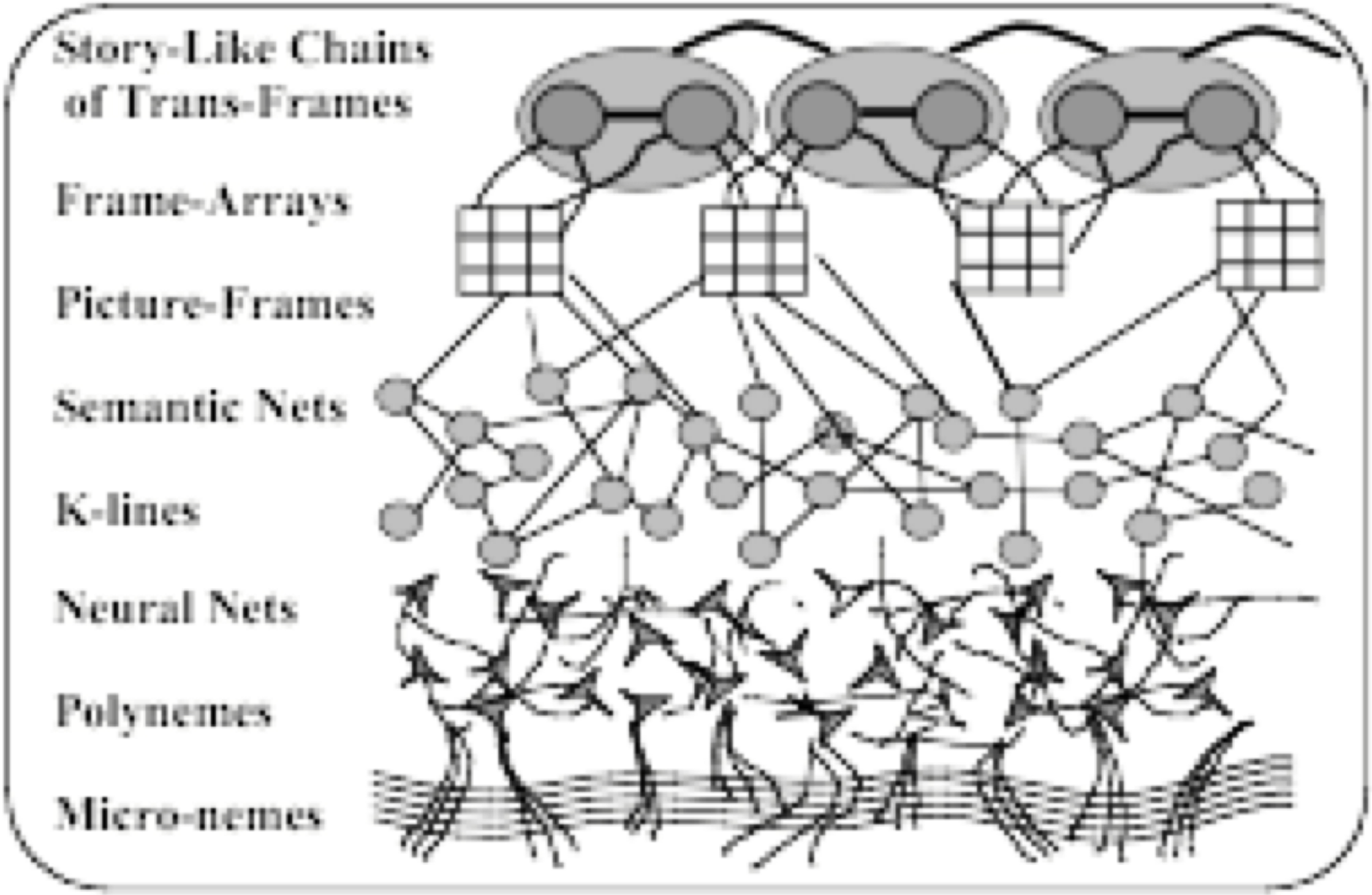
b *archaic* : a branch of learning

3 *archaic* : SEXUAL INTERCOURSE

4 *obsolete* : COGNIZANCE

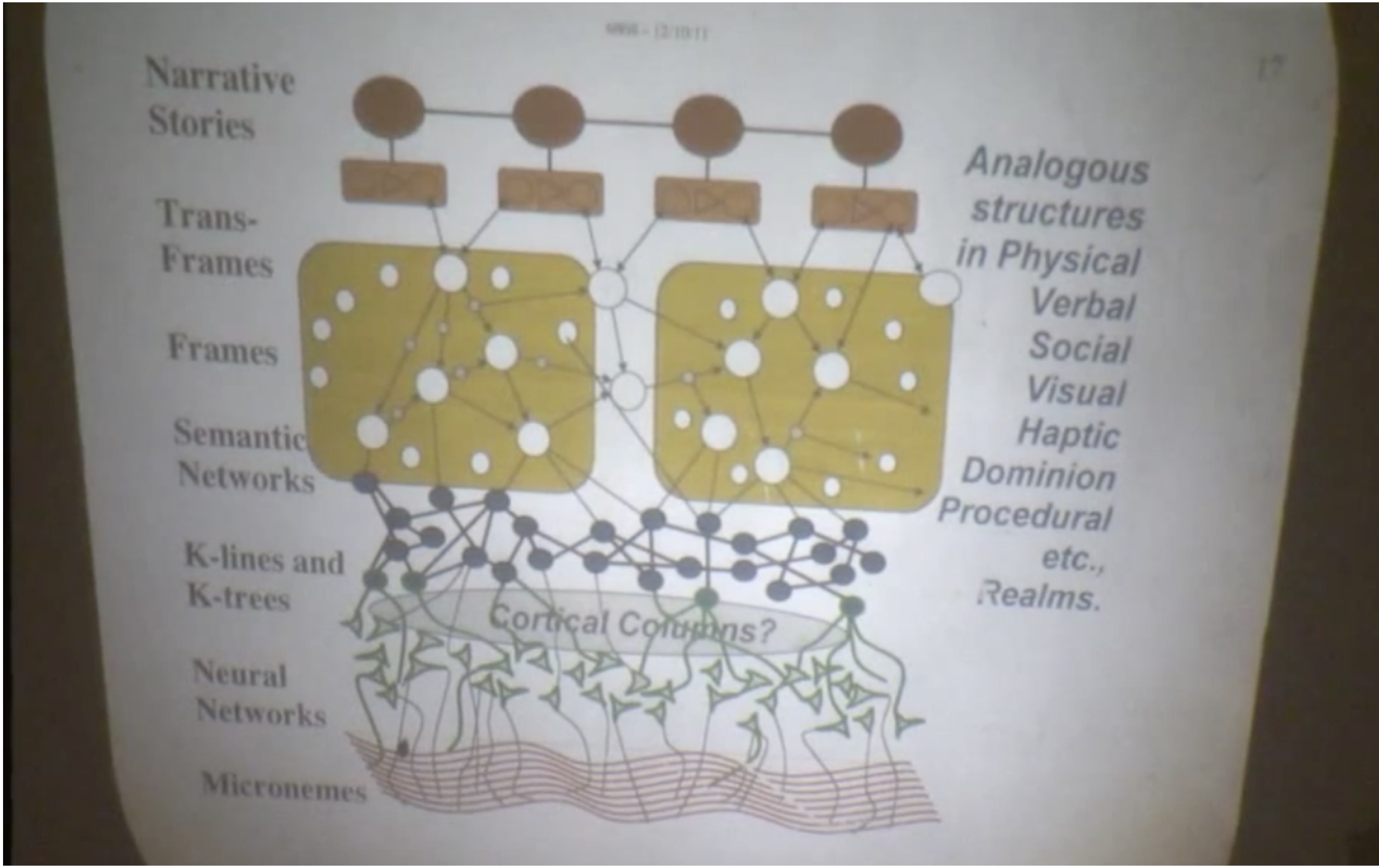
https://www.merriam-webster.com/dictionary/knowledge

Minsky's Layered Knowledge



https://web.media.mit.edu/~minsky/eb9.html

Minsky's Layered Knowledge



https://www.youtube.com/watch?v=oG6FyY2r9G0&t=474s

Knowledge Representation Hypothesis

Any mechanically embodied intelligent process will be comprised of structural ingredients that

- we as external observers naturally take to represent a propositional account of the knowledge that the overall process exhibits, and
- independent of such external semantic attribution, play a formal but causal and essential role in engendering the behavior that manifests that knowledge.

Reflection and Semantics in a Procedural Language, Brian Smith, 1982

Knowledge Representation Hypothesis

"Any process capable of reasoning intelligently about the world must consist in part of a field of structures, of a roughly linguistic sort, which in some fashion represent whatever knowledge and beliefs the process may be said to possess."

Readings in Knowledge Representation, Ronald J. Brachman & Hector J. Levesque, 1985

Knowledge Representation Hypothesis

```
# is not KR
function translate1(color):
        if color is "red" return "rouge"
        if color is "blue" return "bleu"


# is KR
function translate2(color):
        dictionary = [ "red" -> "rouge", "blue" -> "bleu" ]
        return dictionary[color]
```

Add reference link.

KR != Data Structures

"... the choices being made are about representation, not data structures. Part of what makes a language representational is that it carries meaning, i.e., there is a correspondence between its constructs and things in the external world. That correspondence in turn carries with it constraint."

"While every representation must be *implemented* in the machine by some data structure, the representational property is in the correspondence to something in the world and in the constraint that correspondence imposes."

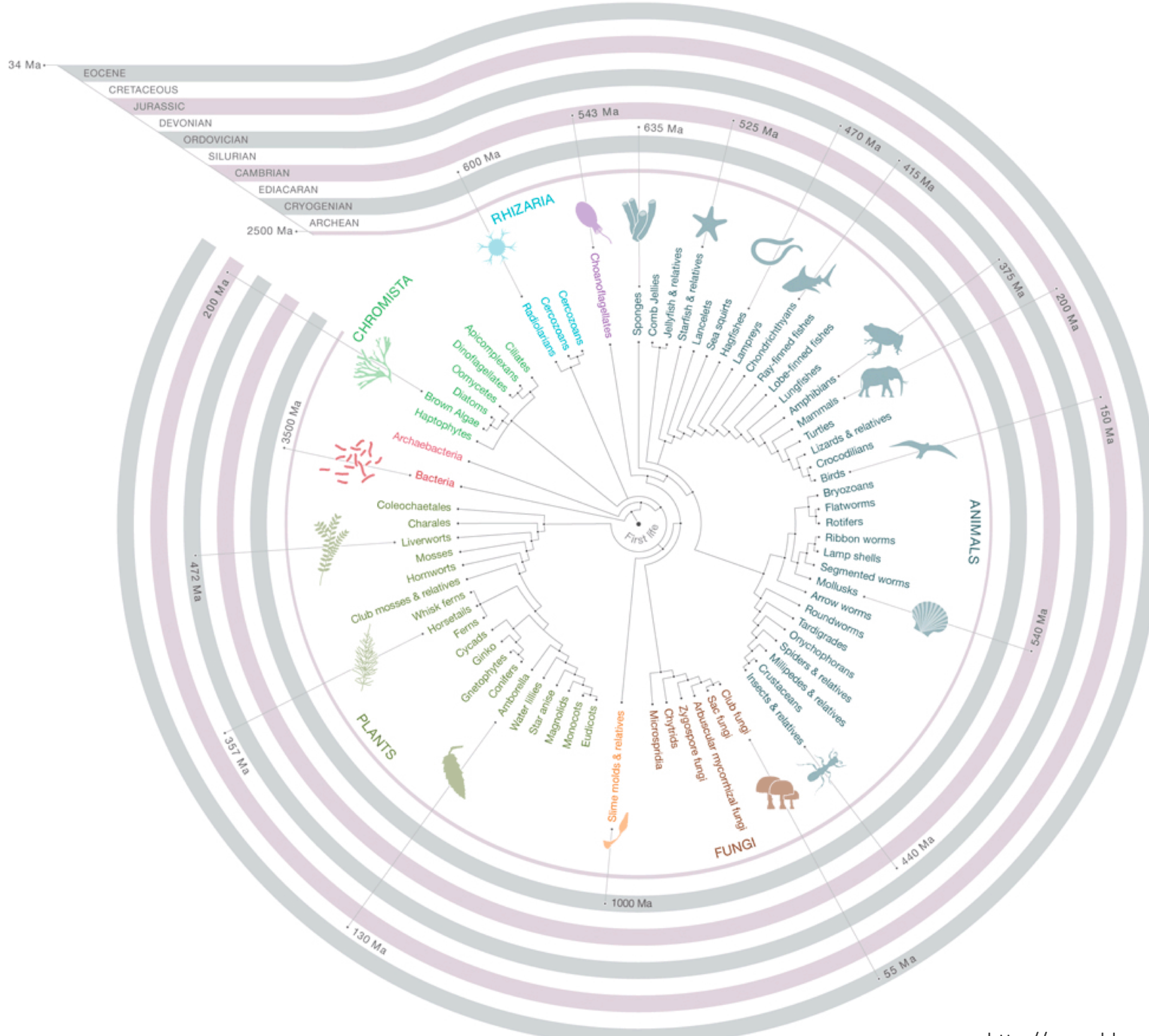
https://groups.csail.mit.edu/medg/ftp/psz/k-rep.html

Roles KR Plays: Surrogate

- Program-internal representations or surrogates of external things that exist externally.
- With incomplete representations:
  - What is it a surrogate for?
  - What is left unconnected?
  - How close is it to the real thing?
- Imperfect surrogates lead to incorrect inferences or conclusions.

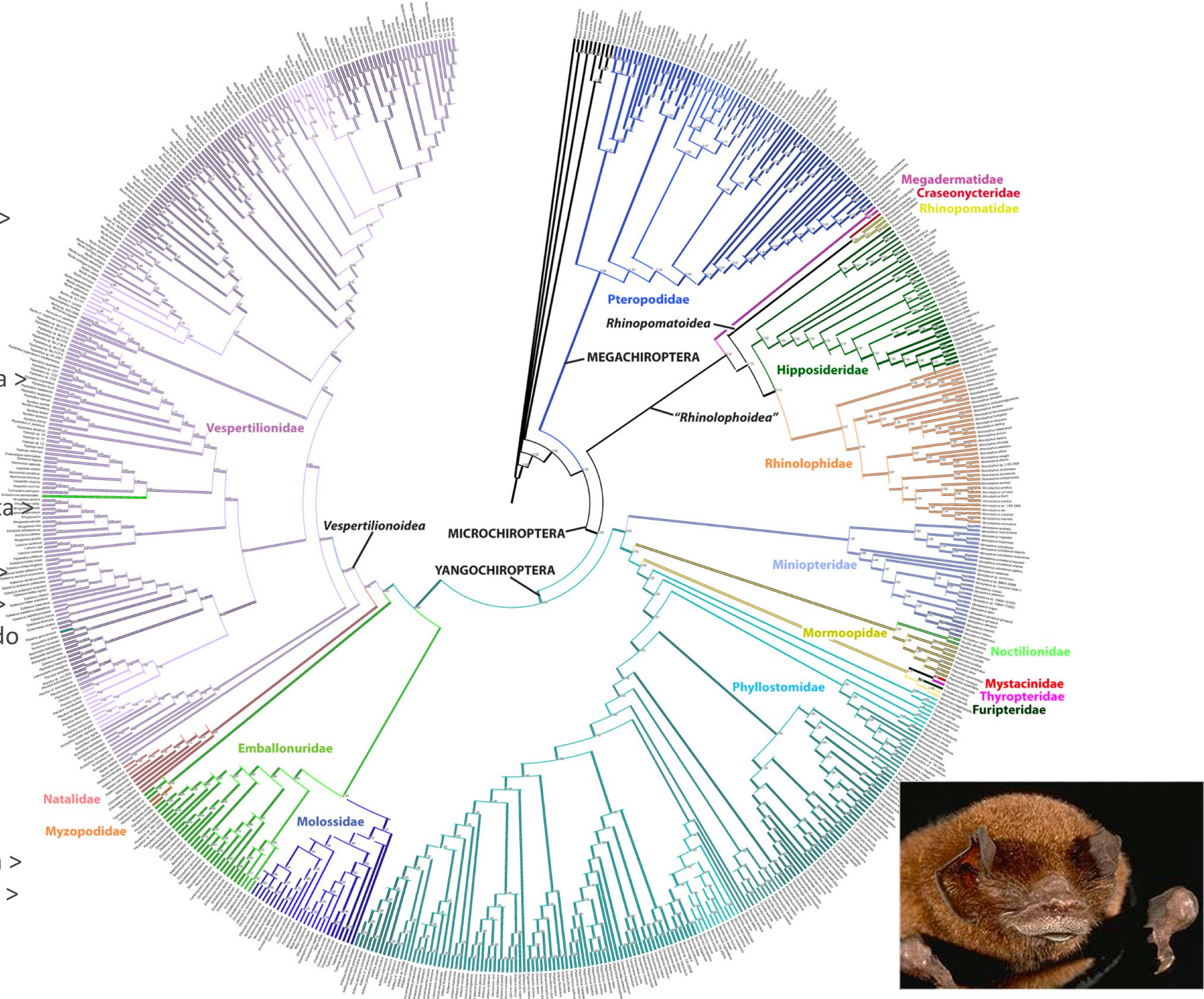
Roles KR Plays: Ontological Commitments

- Ontology: the philosophical study of the nature of being and its categories and their relations.
  - Parmenides, ~490 BC
- The complexity of the natural world is overwhelming.
  - What do we focus on to make KR tractable?
- Early choices and accumulation in layers.



http://www.bbc.co.uk/nature/life

life >
cellular organisms >
Eukaryota >
Opisthokonta >
Holozoa >
Metazoa >
Eumetazoa >
Bilateria >
Deuterostomia >
Chordata >
Craniata >
Vertebrata >
Gnathostomata >
Teleostomi >
Euteleostomi >
Sarcopterygii >
Dipnotetrapodomorpha >
Tetrapoda >
Amniota >
Mammalia >
Theria >
Eutheria >
Boreoeutheria >
Laurasiatheria >
Chiroptera



https://tree.opentreeoflife.org/opentree/argus/opentree9.1@ott93302

Roles KR Plays: Partial Theory of Reasoning

- "Motivated by some insight indicating how people reason intelligently, or by some belief about what it means to reason intelligently at all."
- Fragmentary in two senses:
  - Contains only part of the insight that motivated it.
  - Only part of the complicated whole of intelligent reasoning.
- Each KR is a theory of intelligent reasoning
  - How it allows for inference.
  - The types of inference is supports?
  - Recommended ways to use the KR.
    - They are complex and can be used incorrectly.
- What can we infer from what we know?
- Prolog?

Roles KR Plays: Medium for Efficient Computation

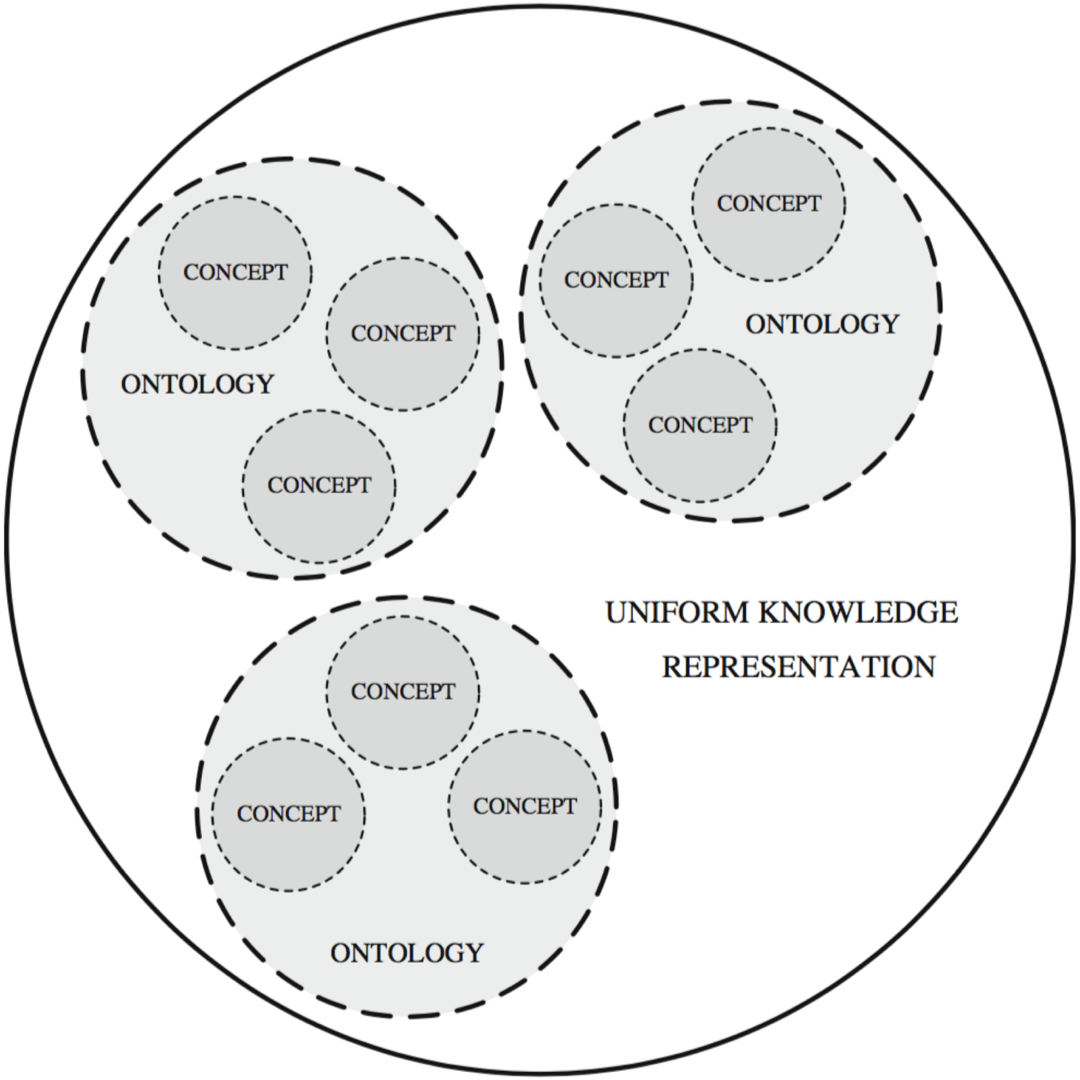
- Fragmented theory and ontologies reduce the complexity of the natural world.
  - Stereotypes, abstractions, commonalities.
- KR systems guaranteed results and efficiency.
- Efficient both to represent and to retrieve.
- Relational Databases

Roles KR Plays: Medium of Human Expression

- Allows us to express things about the world in a way that can be communicated to a computer.
- How well does it function a medium for communication between human and machines?
- Not "can we represent?" but "how easy is it to represent?".

Examples

Uniform Knowledge Representation



COKR p. 2

CONCEPTS

What is a concept?

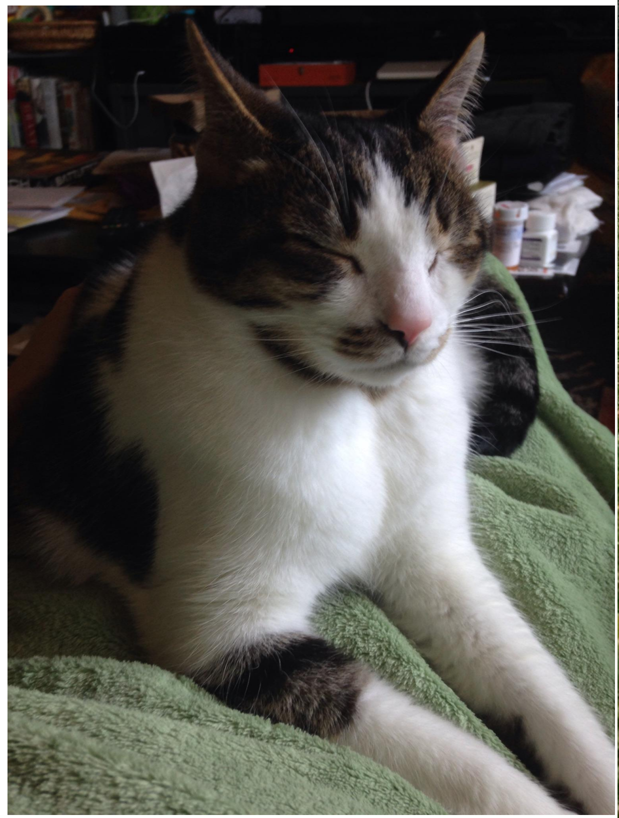
- Entity of consciousness
- Stand-in descriptive label
- Abstract
- Universal
  - Well, locally-universal within cultures, regions, groups, etc.

Concepts and Objects

- Concepts are abstractions.
- Concepts apply to objects when objects match the qualities of the concept.

Concept Example: Cats

- Generalized cat:
  - Fuzzy
  - Has 4 legs
  - Purrs
  - Ears
  - Whiskers
  - Pounces
  - Sleeps a lot
  - Meows
  - …



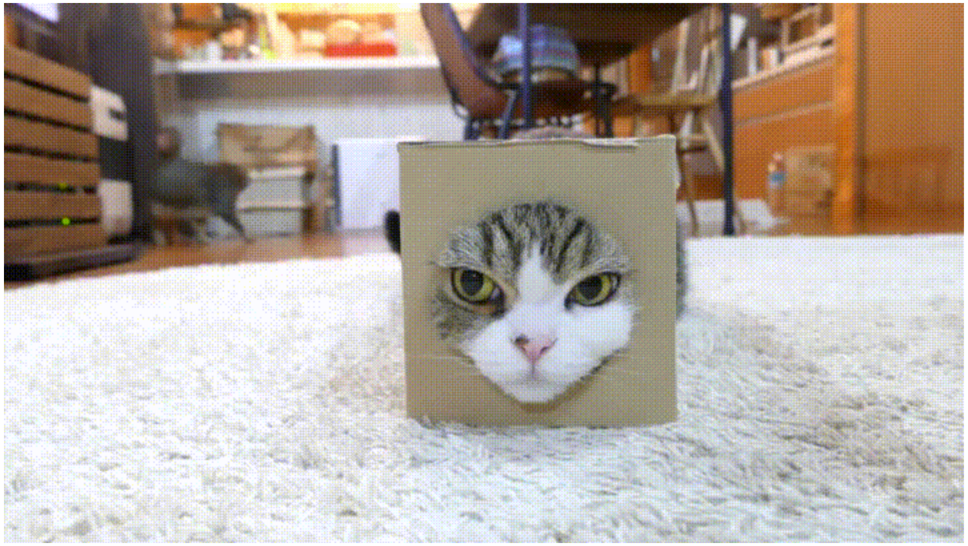
- How does "cute" generalize?

Using Concepts

Using partial abstraction matches for:
- Association between objects.
- Matching to a concept.

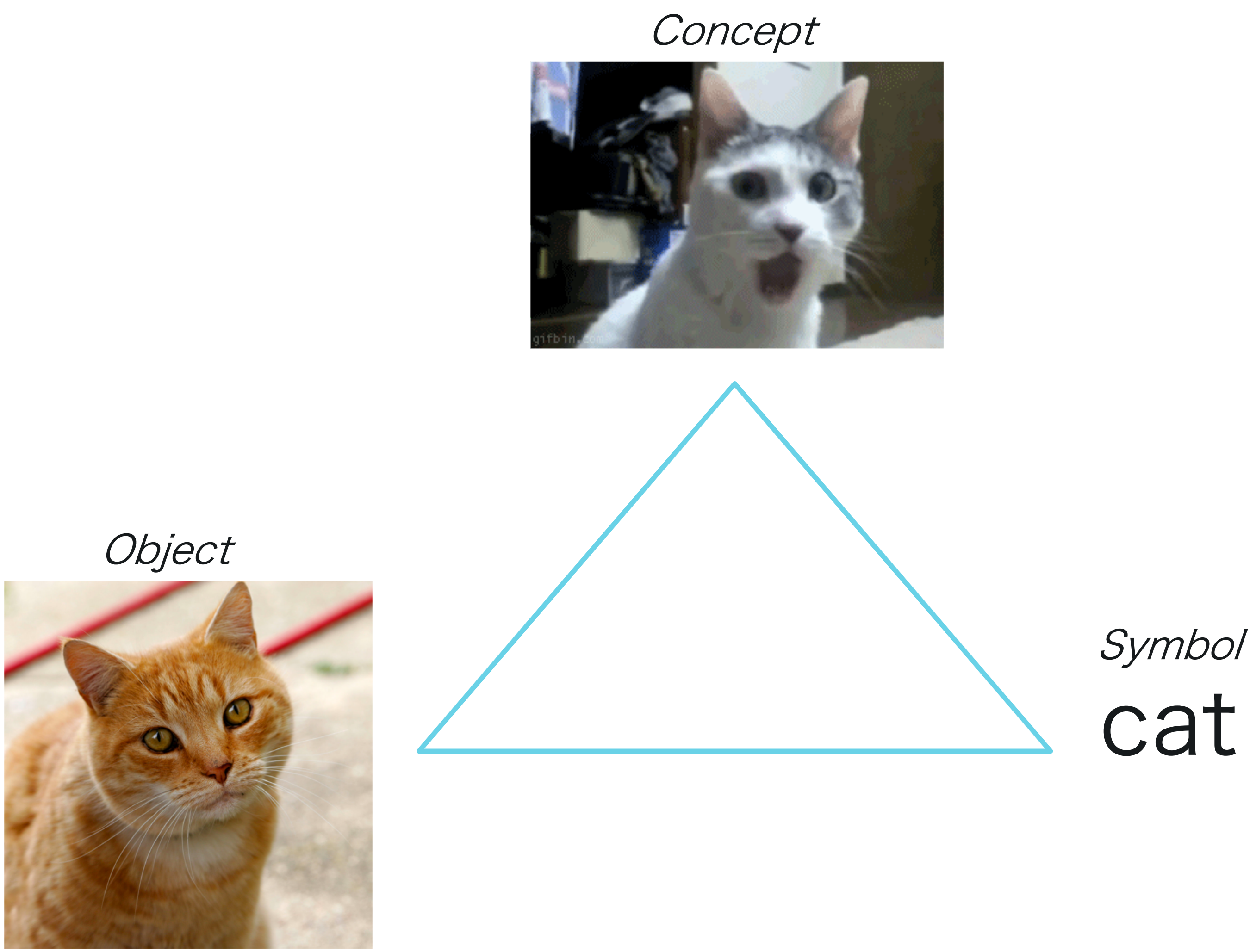
- Useful tool for reasoning about objects.

https://giphy.com/gifs/transparent-baby-shake-nNxT5qXR02FOM



https://imgur.com/gallery/GzCLG

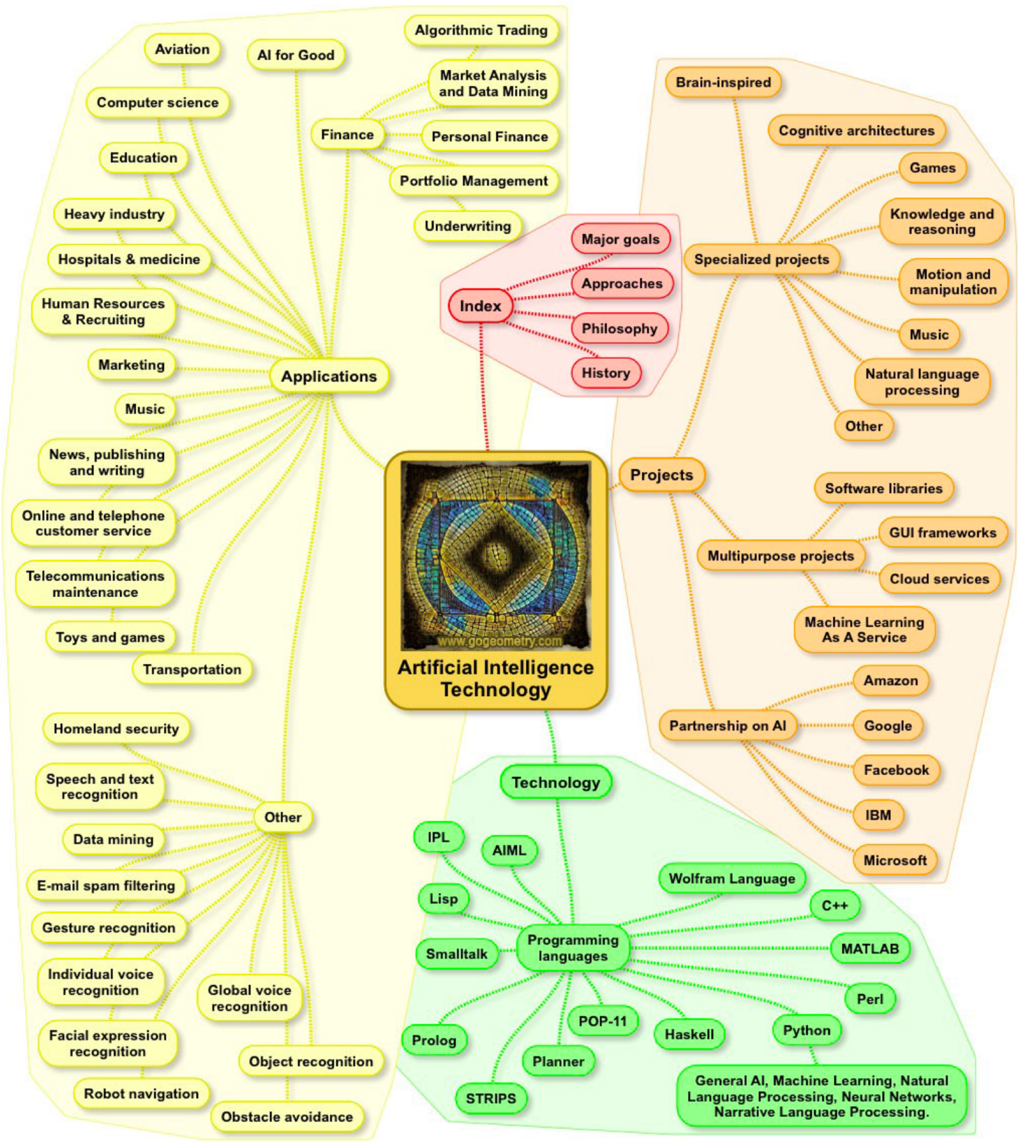
Meaning Triangle (Semiotics)



Concepts in KR

- Atomic elements in KR
  - Akin to species in the taxonomy of life.

Concept Maps

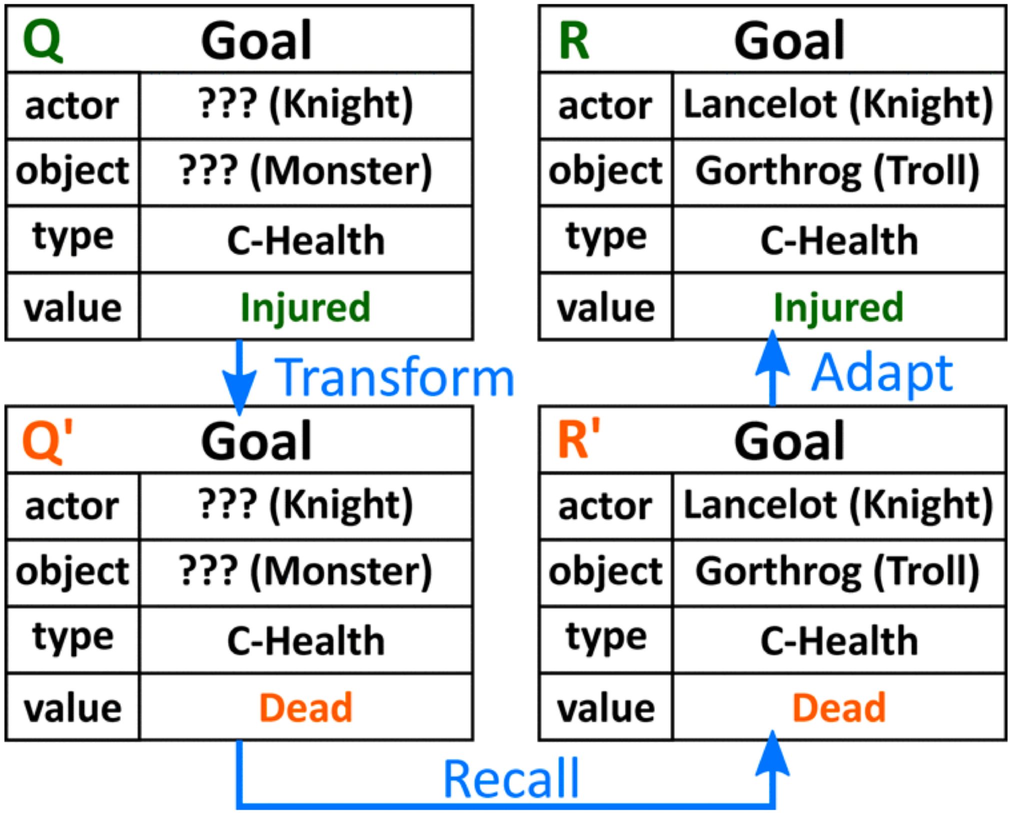


Formal Logic

```
player_at(0,X,Y):- start(X,Y).
player_at(T,X,Y):-
    player_at(T-1,SX,SY),
    passable(SX,SY,X,Y),
    0 {player_at(0..T-1,X,Y)} 0.
victory_at(T):- player_at(T,X,Y), finish(X,Y).
victory:- victory_at(T).
```

https://adamsmith.as/papers/tciaig-asp4pcg.pdf

Frames



Skald: Minstrel Reconstructed
https://ieeexplore.ieee.org/abstract/document/6672047/

Object Oriented Programming

```
! The program defines the main class "Geometry". ;

Class Geometry;
Begin

  Class Point(X,Y); Real X,Y;
  Begin
    Procedure Print; Begin  ...  End;
    Procedure Shift(Dx, Dy); Real Dx, Dy; Begin  ...  End;
    Print;                  ! Life of point;
  End of Point;

  Class Rectangle(RecName, Width, Height);
      Text RecName; Real Width, Height;
  Begin
    Real Area, Perimeter;
    Procedure Update; Begin  ...  End;
    Procedure Show; Begin  ...  End;
    Update; Show;           ! Life of rectangle;
  End of Rectangle;

  Class Circle(Radius, Center); Real Radius; Ref(Point) Center;
  Begin
    Procedure Shift(Dx, Dy); Real Dx, Dy; Begin  ...  End;
    OutText("Circle created at "); ! Life of circle;
    Center.Print;
  End of Circle;

 Class Line(M,N); Ref(Point) M,N; ! Line defined by two
points;
  Begin
    Real Slope;
    Slope :=  ...  ;       ! Life of line;
  End of Line;

  !Variables declared in geometry: ;
  Ref(Point) Origin, A, B;
  Ref(Line) X,Y;

  !Life of geometry: ;
  Origin :- New Point(0,0); ! Creating the origin;
  A :- New Point(1,0); B :- New Point(0,1);
  X :- New Line(Origin, A); ! Creating the axes;
  Y :- New Line(Origin, B);
  OutText("*** Geometry initialized ***"); OutImage;
End of Geometry;
```

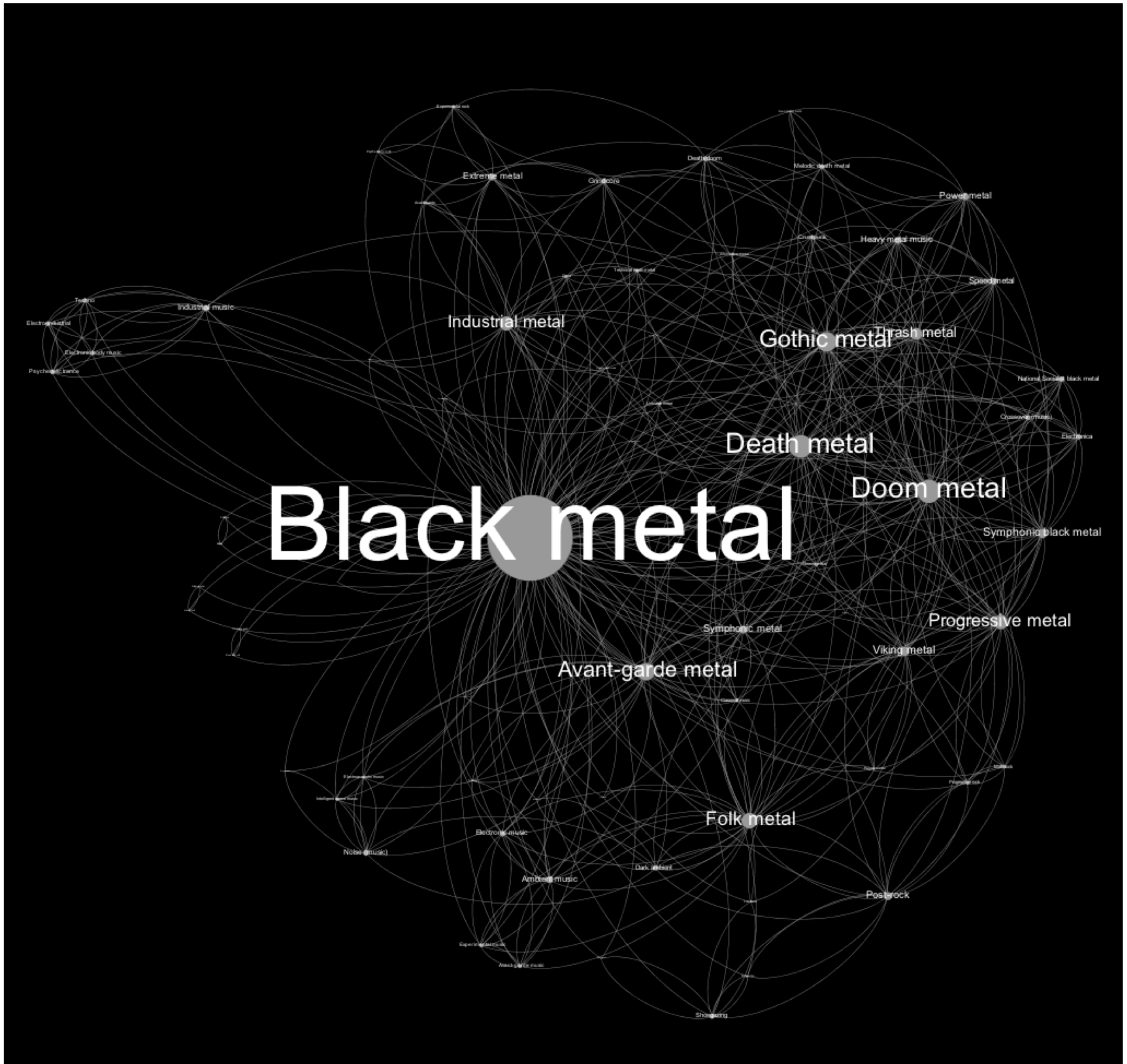
INTRODUCTION TO OOP IN SIMULA
http://staff.um.edu.mt/jskl1/talk.html#Classes

ONTOLOGIES

Definitions of Ontology

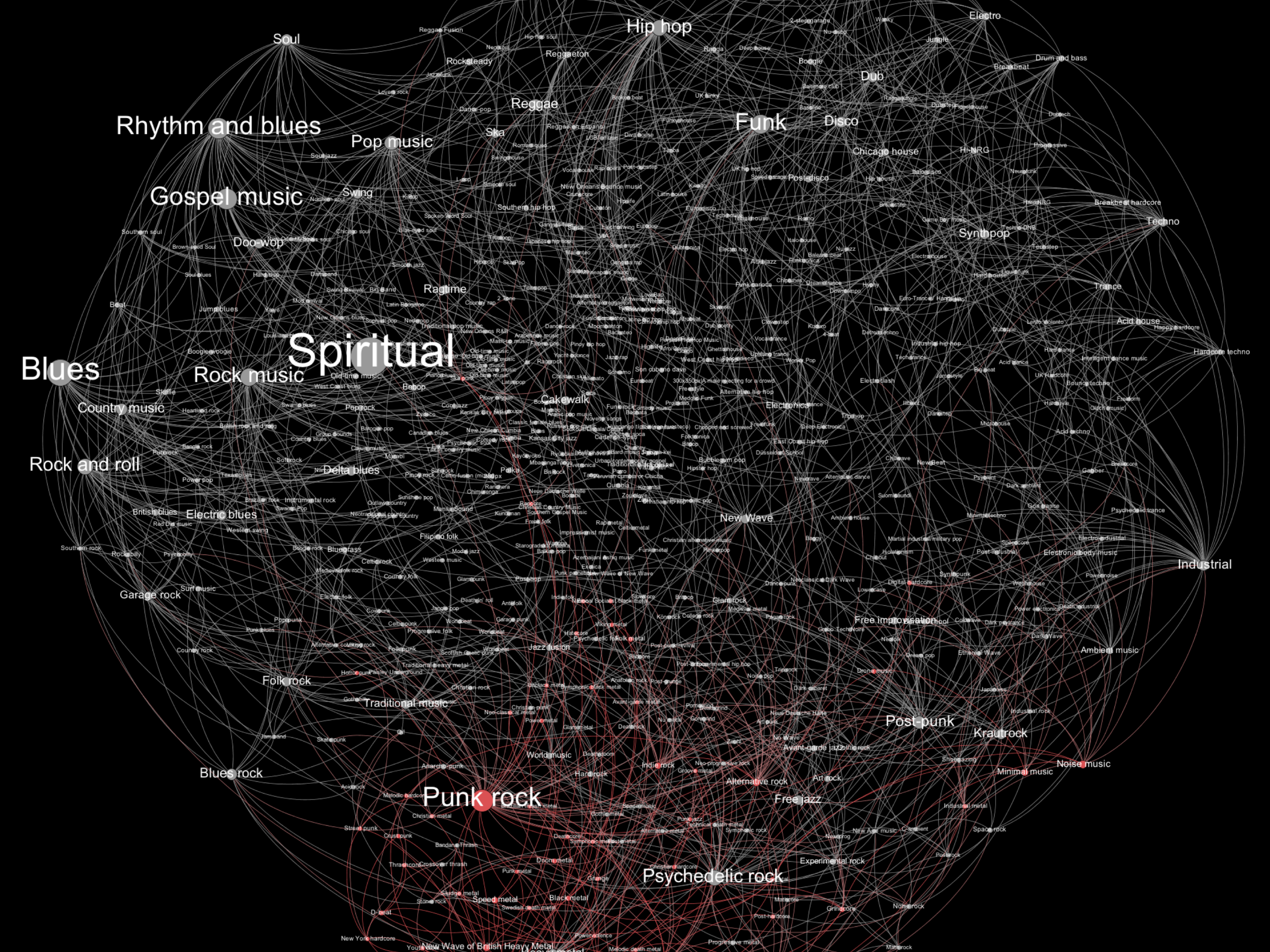
- Study of being or existence and the organization of reality
- An ontology is a formal and explicit specification of a shared conceptualization.

Aspects of Ontologies



http://www.geirmund.com/black-metal-family-tree/black-metal-family-tree.html

- Conceptualizations
- Explicit
- Formal
- Shared



Soul
Hip hop
Electro
Rhythm and blues
Reggae
Funk
Disco
Pop music
Ska
Dub
Gospel music
Swing
Chicago house
Doo-wop
Synthpop
Techno
Ragtime
Trance
Acid house
Spiritual
Blues
Rock music
Cakewalk
Electronica
Country music
Rock and roll
Delta blues
Electric blues
New Wave
Industrial
Garage rock
Free improvisation
Jazz fusion
Ambient music
Folk rock
Traditional music
Post-punk
Krautrock
World music
Blues rock
Noise music
Minimal music
Alternative rock
Punk rock
Free jazz
Psychedelic rock
Speed metal
Black metal
New Wave of British Heavy Metal

Hierarchical Organization of Ontologies

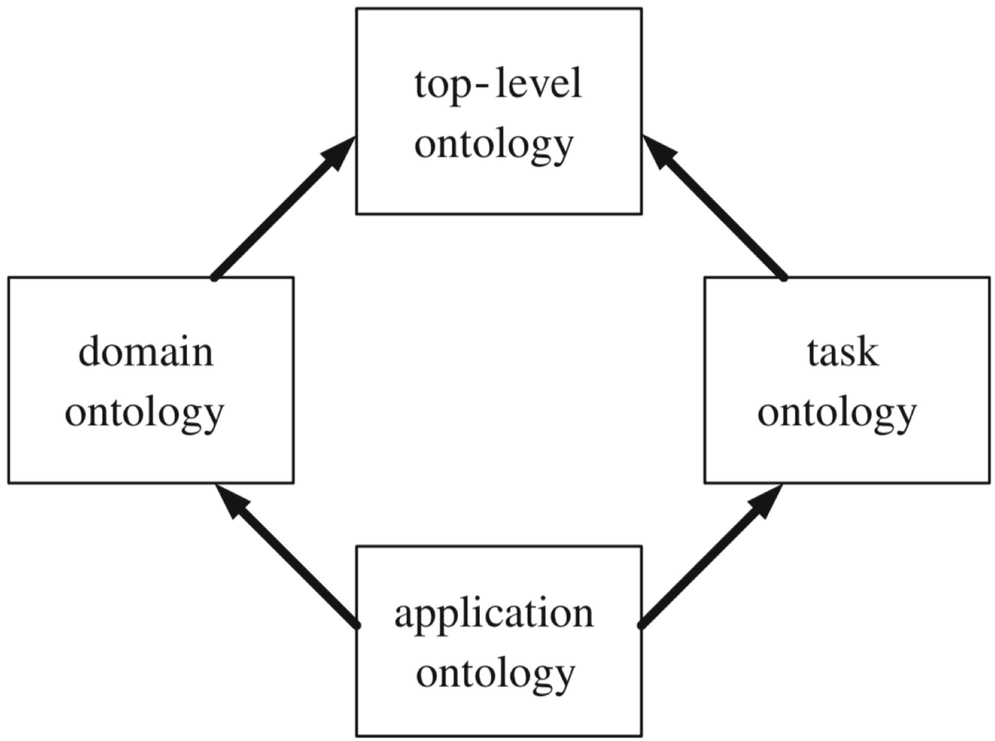


Fig. 3.2 Types of ontologies in an ontology-driven information system (Guarino 1998)

Use of Ontologies

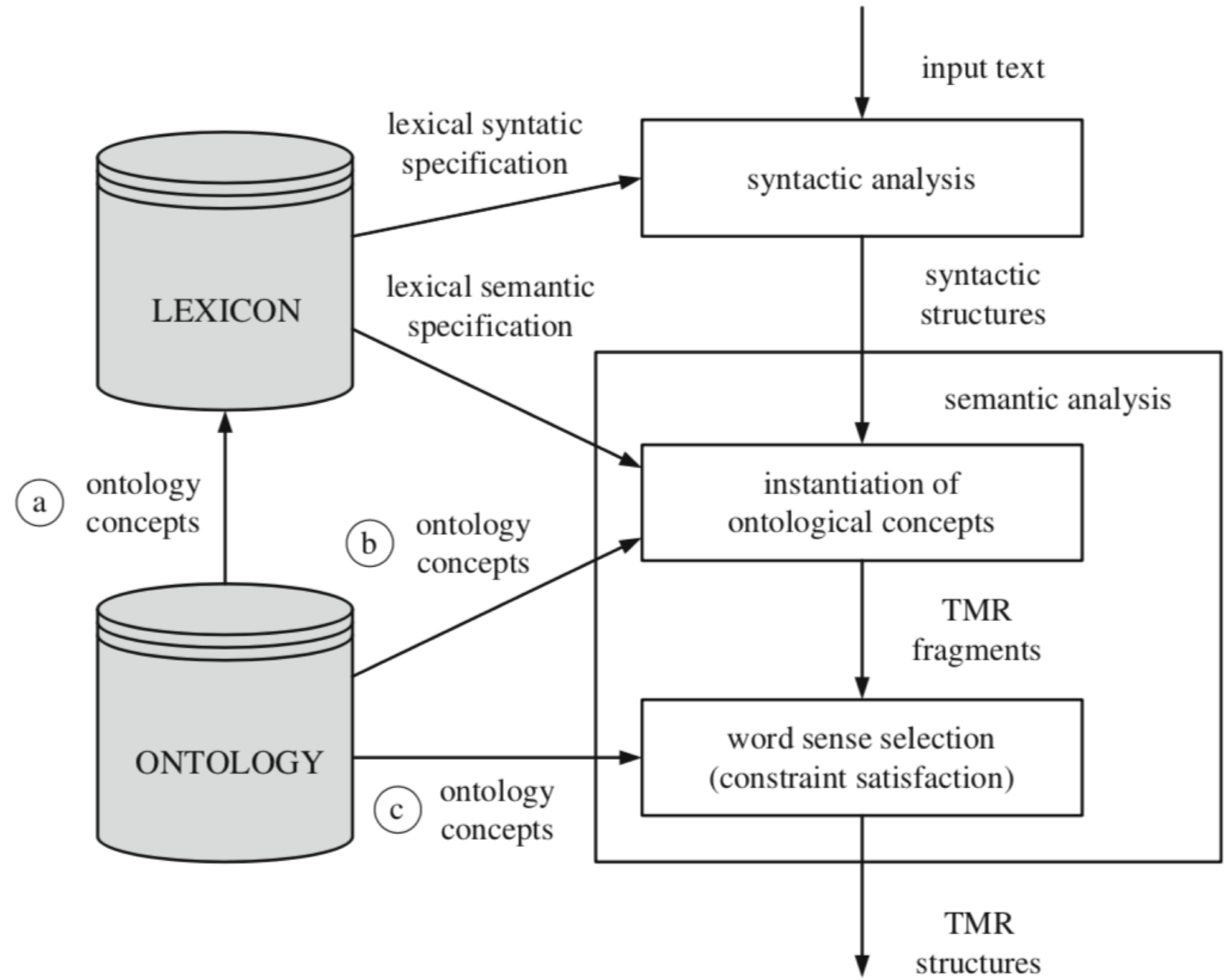


Fig. 3.6 The role of ontology in the architecture of the Mikrokosmos text analyzer (Beale et al. 1995)

Use of Ontologies

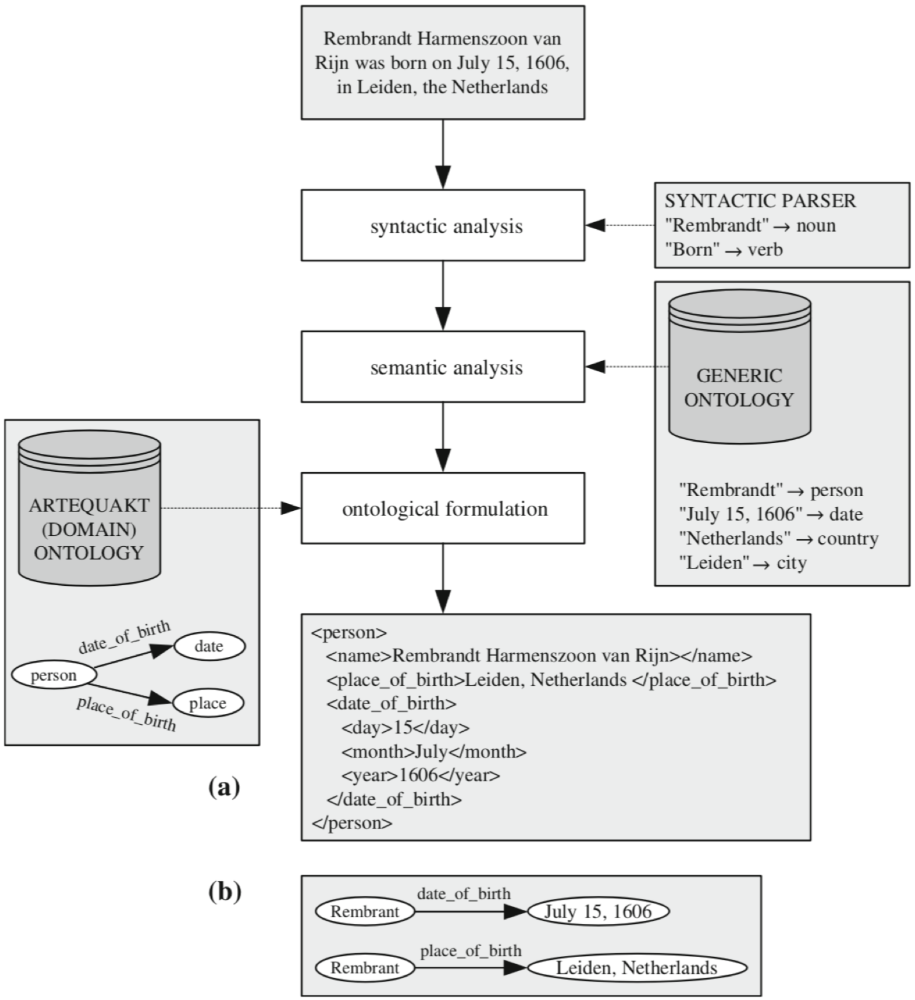


Fig. 3.10 An example of knowledge extraction from a Web page using Artequakt (Alani et al. 2003)

KNOWLEDGE REPRESENTATION

Definition

- "using formal symbols to represent a collection of propositions believed by some putative agent"
  - (Brachman and Levesque 2004)
- Choosing types of knowledge to use is an **ontological commitment**.
- Operationalization of KR:
  - Knowledge base: formally represented
  - Knowledge engine: derives conclusions from a knowledge base.

Key Areas of KR

- Knowledge Acquisition
  - Elicitation: from human experts
  - Discovery: extracted form data
- Knowledge Modeling
  - Ontologies and concepts in a knowledge base
- Reasoning
  - Use of knowledge model to solve problems or infer new information.
  - Logical inference is the common mode.

Web Ontology Language OWL

```xml
▼<owl:ObjectProperty rdf:about="http://www.co-ode.org/ontologies/pizza/pizza.owl#hasBase">
   <rdfs:subPropertyOf rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#hasIngredient"/>
   <owl:inverseOf rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#isBaseOf"/>
   <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
   <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#InverseFunctionalProperty"/>
   <rdfs:domain rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#Pizza"/>
   <rdfs:range rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#PizzaBase"/>
 </owl:ObjectProperty>

▼<owl:Class rdf:about="http://www.co-ode.org/ontologies/pizza/pizza.owl#Cajun">
   <rdfs:subClassOf rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#NamedPizza"/>
  ▼<rdfs:subClassOf>
    ▼<owl:Restriction>
       <owl:onProperty rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#hasTopping"/>
       <owl:someValuesFrom rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#MozzarellaTopping"/>
     </owl:Restriction>
   </rdfs:subClassOf>
  ▼<rdfs:subClassOf>
    ▼<owl:Restriction>
       <owl:onProperty rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#hasTopping"/>
       <owl:someValuesFrom rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#OnionTopping"/>
     </owl:Restriction>
   </rdfs:subClassOf>
  ▼<rdfs:subClassOf>
    ▼<owl:Restriction>
       <owl:onProperty rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#hasTopping"/>
       <owl:someValuesFrom rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#PeperonataTopping"/>
     </owl:Restriction>
   </rdfs:subClassOf>
  ▼<rdfs:subClassOf>
    ▼<owl:Restriction>
       <owl:onProperty rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#hasTopping"/>
       <owl:someValuesFrom rdf:resource="http://www.co-ode.org/ontologies/pizza/pizza.owl#PrawnsTopping"/>
     </owl:Restriction>
   </rdfs:subClassOf>
  ▼<rdfs:subClassOf>
```

https://protege.stanford.edu/ontologies/pizza/pizza.owl