# Ontology Languages for the Semantic Web


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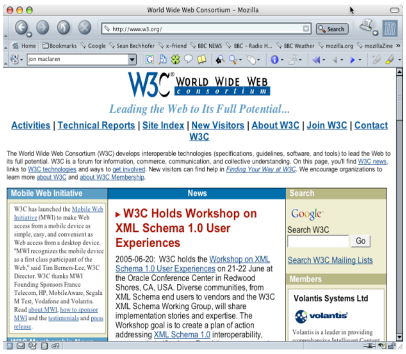
# The Semantic Web

- The Web made possible through established standards
  - TCP/IP for transporting bits down a wire
  - HTTP & HTML for transporting and rendering hyperlinked text
- Applications able to exploit this common infrastructure
  - Result is the WWW as we know it
- 1st generation web mostly handwritten HTML pages
- 2nd generation web often machine generated/active
  - But still intended for direct human processing/interaction
- In next generation web, resources should be more accessible to automated processes
  - Metadata annotations that describe content/function
  - Web of Data.

# What's the Problem?




- Consider a typical web page
- Markup consists of:
  - rendering information (e.g., font size and colour)
  - Hyper-links to related content
- Semantic content is accessible to humans but not (easily) to computers…
- Requires (at least) NL understanding





# A Semantic Web

- Make web resources more accessible to automated processes
- Extend existing rendering markup with semantic markup
  - Metadata annotations that describe content/function of web accessible resources
- Use Ontologies to provide vocabulary for annotations
  - New terms can be formed by combining existing ones
  - "Formal specification" is accessible to machines
- A prerequisite is a standard web ontology language
  - Need to agree common syntax before we can share semantics
  - Syntactic web based on standards such as HTTP and HTML

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# Technologies for the Semantic Web

- Metadata
  - Resources are marked-up with descriptions of their content. No good unless everyone **speaks the same language**;
- Terminologies
  - provide shared and common vocabularies of a domain, so search engines, agents, authors and users can communicate. No good unless everyone **means the same thing**;
- Ontologies
  - provide a shared and common understanding of a domain that can be communicated across people and applications, and will play a major role in supporting information exchange and discovery.



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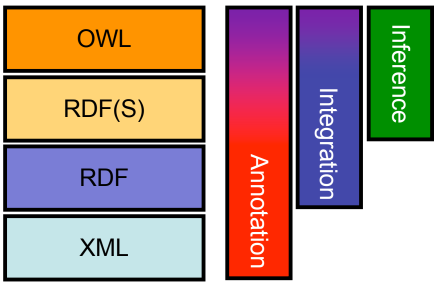
# Building a Semantic Web

- Annotation
  - Associating metadata with resources
- Integration
  - Integrating information sources
- Inference
  - Reasoning over the information we have.
  - Could be light-weight (taxonomy)
  - Could be heavy-weight (logic-style)
- Interoperation and Sharing are key goals

# Semantic Web Languages

- A number of languages have been defined that provide basic machinery used to represent the semantic information
  - XML
  - RDF
  - RDF(S)
  - OWL
  - …








# Object Oriented Models

- Many languages use an "object oriented model" with
- Objects/Instances/Individuals
  - Elements of the domain of discourse
- Types/Classes/Concepts
  - Sets of objects sharing certain characteristics
- Relations/Properties/Roles
  - Sets of pairs (tuples) of objects
- Such languages are/can be:
  - Well understood
  - Formally specified
  - (Relatively) easy to use
  - Amenable to machine processing

# Structure of an Ontology

Ontologies typically have two distinct components:

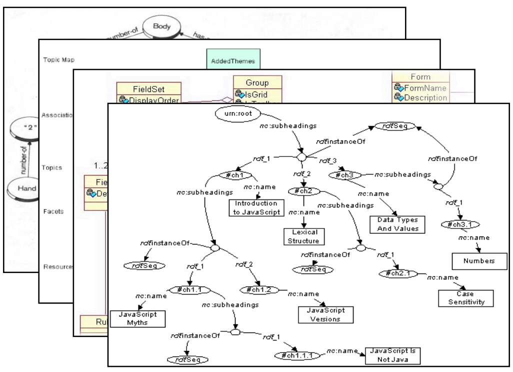
- Names for important concepts in the domain
  - Elephant is a concept whose members are a kind of animal
  - Herbivore is a concept whose members are exactly those animals who eat only plants or parts of plants
  - AdultElephant is a concept whose members are exactly those elephants whose age is greater than 20 years
- Background knowledge/constraints on the domain
  - AdultElephants weigh at least 2,000 kg
  - All Elephants are either AfricanElephants or IndianElephants
  - No individual can be both a Herbivore and a Carnivore





# Ontology Languages

- There are a wide variety of languages for "Explicit Specification"
  - Graphical Notations
    - Semantic Networks
    - Topic Maps
    - UML
    - RDF



# Ontology Languages

- There are a wide variety of languages for "Explicit Specification"
  - Graphical Notations
    - Semantic Networks
    - Topic Maps
    - UML
    - RDF
  - Logic Based
    - Description Logics
    - Rules
    - First Order Logic
    - Conceptual Graphs

**Every gardener likes the sun.**
(Ax) gardener(x) => likes(x,Sun)
**You can fool some of the people all of the time.**
(Ex)(At) (person(x) ^ time(t)) => can-fool(x,t)
**You can fool all of the people some of the time.**
(Ax)(Et) (person(x) ^ time(t) => can-fool(x,t)
**All purple mushrooms are poisonous.**
(Ax) (mushroom(x) ^ purple(x)) => poisonous(x)
**No purple mushroom is poisonous.**
~(Ex) purple(x) ^ mushroom(x) ^ poisonous(x)
(Ax) (mushroom(x) ^ purple(x)) => ~poisonous(x)
**There are exactly two purple mushrooms.**
(Ex)(Ey) mushroom(x) ^ purple(x) ^ mushroom(y) ^ purple(y) ^ ~(x=y) ^ (Az) (mushroom(z) ^ purple(z)) => ((x=z) v (y=z))
**Clinton is not tall.**
~tall(Clinton)



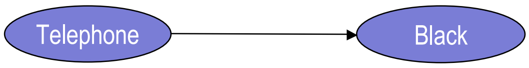


# Formal Languages

- The degree of formality of ontology languages varies widely
- Increased formality makes languages more amenable to machine processing (e.g. automated reasoning).
- The formal semantics provides an unambiguous interpretation of the descriptions.

# Why Semantics?

- What does an expression in an ontology mean?
- The semantics of a language can tell us precisely how to interpret a complex expression.
- Well defined semantics are vital if we are to support machine interpretability
  - They remove ambiguities in the interpretation of the descriptions.

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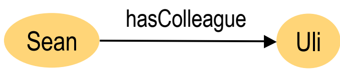
# RDF

- RDF stands for Resource Description Framework
- It is a W3C Recommendation
  - http://www.w3.org/RDF
- RDF is a graphical formalism ( + concrete syntax)
  - for representing metadata
  - for describing the semantics of information in a machine-accessible way
- Provides a simple data model based on triples.

# The RDF Data Model

- Statements are <subject, predicate, object> triples:
  - `<Sean,hasColleague,Uli>`
- Can be represented as a graph:



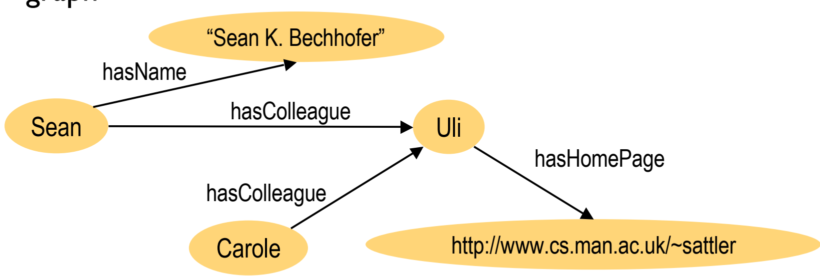

- Statements describe properties of resources
- A resource is any object that can be pointed to by a URI
- Properties themselves are also resources (URIs)





# Linking Statements

- The subject of one statement can be the object of another
- Such collections of statements form a directed, labeled graph




- Note that the object of a triple can also be a "literal" (a string)

# RDF Syntax

- RDF has an XML syntax that has a specific meaning:
- Every `Description` element describes a resource
- Every attribute or nested element inside a `Description` is a `property` of that `Resource`
- We can refer to resources by URIs

```
<Description about="some.uri/person/sean_bechhofer">
  <hasColleague resource="some.uri/person/uli_sattler"/>
  <hasName rdf:datatype="&xsd;string">Sean K. Bechhofer</hasName>
</Description>
<Description about="some.uri/person/uli_sattler">
  <o:hasHomePage>http://www.cs.mam.ac.uk/~sattler</o:hasHomePage>
</Description>
<Description about="some.uri/person/carole_goble">
  <o:hasColleague resource="some.uri/person/uli_sattler"/>
</Description>
```



# What does RDF give us?

- A mechanism for **annotating** data and resources.
- Single (simple) data model.
- Syntactic consistency between names (URIs).
- Low level **integration** of data.

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# RDF(S): RDF Schema

- RDF gives a formalism for meta data annotation, and a way to write it down in XML, but it does not give any special meaning to vocabulary such as subClassOf or type
  - Interpretation is an arbitrary binary relation
- RDF Schema extends RDF with a schema vocabulary that allows you to define basic vocabulary terms and the relations between those terms
  - Class, Property
  - type, subClassOf
  - range, domain



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# RDF(S)

- These terms are the RDF Schema building blocks (constructors) used to create vocabularies:
  - `<Person,type,Class>`
  - `<hasColleague,type,Property>`
  - `<Professor,subClassOf,Person>`
  - `<Carole,type,Professor>`
  - `<hasColleague,range,Person>`
  - `<hasColleague,domain,Person>`
- Semantics gives "extra meaning" to particular RDF predicates and resources
  - specifies how terms should be interpreted

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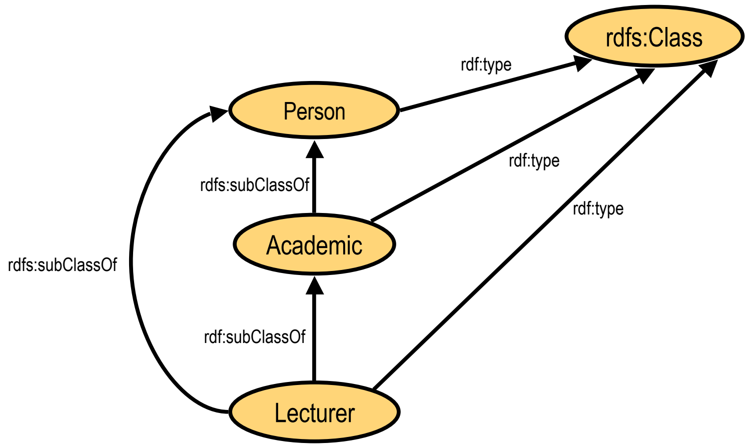
# RDF(S) Inference



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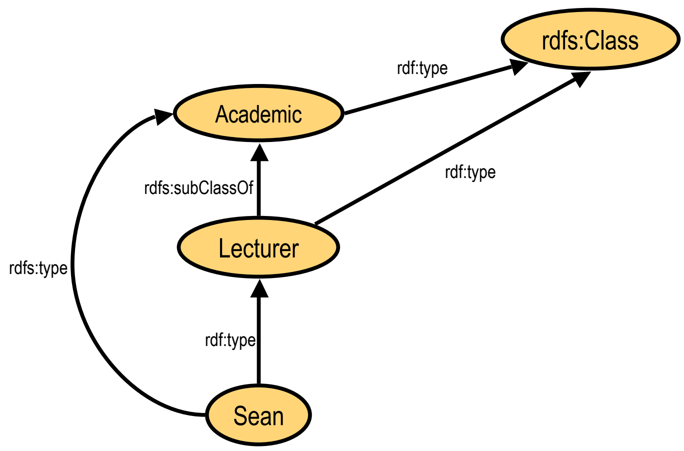
# RDF(S) Inference



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# RDF/RDF(S) "Liberality"

- No distinction between classes and instances (individuals)

```
<Species,type,Class>
<Lion,type,Species>
<Leo,type,Lion>
```

- No distinction between language constructors and ontology vocabulary, so constructors can be applied to themselves/each other

```
<type,range,Class>
<Property,type,Class>
<type,subPropertyOf,subClassOf>
```

- In order to cope with this, RDF(S) has a particular non-standard model theory.



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# What does RDF(S) give us?

- Ability to use simple schema/vocabularies when describing our resources.
- Consistent vocabulary use and sharing.
- Basic inference

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# Problems with RDF(S)

- RDF(S) is too weak to describe resources in sufficient detail
  - No localised range and domain constraints
    - Can't say that the range of hasChild is Person when applied to Persons and Elephant when applied to Elephants
  - No existence/cardinality constraints
    - Can't say that all *instances* of Person have a mother that is also a Person, or that Persons have exactly 2 parents
  - No transitive, inverse or symmetrical properties
    - Can't say that isPartOf is a transitive property, that hasPart is the inverse of isPartOf or that touches is symmetrical
- Difficult to provide reasoning support
  - No "native" reasoners for non-standard semantics
  - May be possible to reason via FO axiomatisation



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# OWL

- OWL: Web Ontology Language
- Extends existing Web standards
  - Such as XML, RDF, RDFS
- Is (hopefully) easy to understand and use
  - Based on familiar KR idioms
- Of "adequate" expressive power
- Formally specified
  - Possible to provide automated reasoning support

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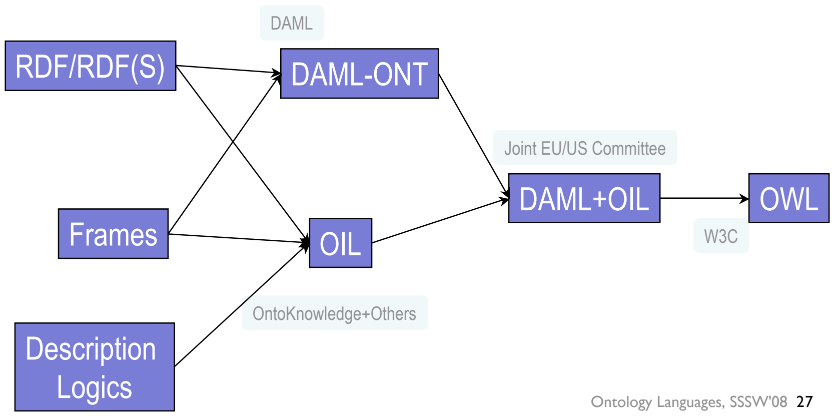
# The OWL Family Tree



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# Aside: Description Logics

- A family of logic based Knowledge Representation formalisms
  - Descendants of semantic networks and KL-ONE
  - Describe domain in terms of concepts (classes), roles (relationships) and individuals
- Distinguished by:
  - Formal semantics (typically model theoretic)
    - Decidable fragments of FOL
    - Closely related to Propositional Modal & Dynamic Logics
  - Provision of inference services
    - Sound and complete decision procedures for key problems
    - Implemented systems (highly optimised)

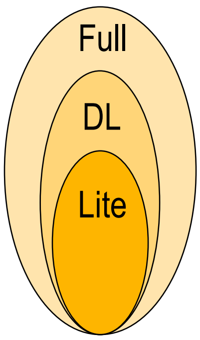
# DL Semantics

- Model theoretic semantics. An interpretation consists of
  - A domain of discourse (a collection of objects)
  - Functions mapping
    - classes to sets of objects
    - properties to sets of pairs of objects
  - Rules describe how to interpret the constructors and tell us when an interpretation is a model.
- In a DL, a class description is thus a characterisation of the individuals that are members of that class.



# OWL Layering

- There are three "species" of OWL
  - OWL Full
  - OWL DL
  - OWL Lite
- Syntactic Layering
- Semantic Layering
  - OWL DL semantics = OWL Full semantics (within DL fragment)
  - OWL Lite semantics = OWL DL semantics (within Lite fragment)



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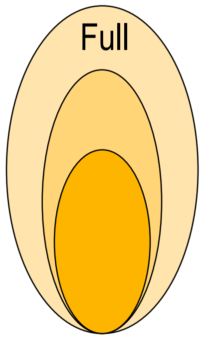
# OWL Full

- No restriction on use of OWL vocabulary (as long as legal RDF)
  - Classes as instances (and much more)
- RDF style model theory
  - Semantics should correspond with OWL DL for suitably restricted KBs



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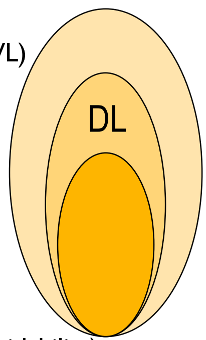
# OWL DL

- Use of OWL vocabulary restricted
  - Can't be used to do "nasty things" (i.e., modify OWL)
  - No classes as instances
  - Defined by abstract syntax + mapping to RDF
- Standard DL/FOL model theory (definitive)
  - Corresponds to *SHOIN*($D_n$) Description Logic
  - Direct correspondence with (first order) logic
- Benefits from DL research
  - Well defined semantics
  - Formal properties well understood (complexity, decidability)
  - Known reasoning algorithms
  - Implemented (optimised) systems



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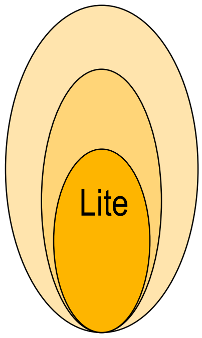
# OWL Lite

- Like DL, but fewer constructs
  - No explicit negation or union
  - Restricted cardinality (zero or one)
  - No nominals (oneOf)
- Semantics as per DL
  - Reasoning via standard DL engines (+datatypes)
- In practice, not really used.
  - Possible alternative: “tractable fragments”



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# OWL Syntaxes

- Abstract Syntax
  - Used in the definition of the language and the DL/Lite semantics
- OWL in RDF (the “official” concrete syntax)
  - RDF/XML presentation
- XML Presentation Syntax
  - XML Schema definition
- Other, Human readable syntaxes
  - Manchester OWL Syntax
  - Syndey OWL Syntax
  - Rabbit

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# OWL (DL) Semantics

- OWL has a number of operators for constructing class expressions.
- These have an associated semantics which is given in terms of a domain:
  - $\Delta$
- And an interpretation function
  - *I:concepts* $\rightarrow \wp(\Delta)$
  - *I:properties* $\rightarrow \wp(\Delta \times \Delta)$
  - *I:individuals* $\rightarrow \Delta$
- *I* is then extended to concept expressions.



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# OWL Class Constructors

| Constructor | Example | Interpretation |
|---|---|---|
| Classes | Class: Human | $I(Human)$ |
| and | (Human and Male) | $I(Human) \cap I(Male)$ |
| or | (Doctor or Lawyer) | $I(Doctor) \cup I(Lawyer)$ |
| not | not(Male) | $\Delta \setminus I(Male)$ |
| {} | {john mary} | $\{I(john), I(mary)\}$ |

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# OWL Class Constructors

| Constructor | Example | Interpretation |
|---|---|---|
| some | hasChild some Lawyer | $\{x \mid \exists y.\langle x,y\rangle \in I(hasChild) \wedge y \in I(Lawyer)\}$ |
| only | hasChild only Doctor | $\{x \mid \forall y.\langle x,y\rangle \in I(hasChild) \Rightarrow y \in I(Doctor)\}$ |
| min | hasChild min 2 | $\{x \mid \#\langle x,y\rangle \in I(hasChild) \geq 2\}$ |
| max | hasChild max 2 | $\{x \mid \#\langle x,y\rangle \in I(hasChild) \leq 2\}$ |



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# OWL Axioms

- Axioms allow us to add further statements about arbitrary concept expressions and properties
  - Subclasses, Disjointness, Equivalence, characteristics of properties etc.
- An interpretation *I* satisfies an axiom if the interpretation of the axiom is true.
  - Axioms constrain the allowed models
  - They provide the additional "assumptions" about the way in which the domain should be interpreted.
- *I* satisfies or is a model of an ontology (or knowledge base) if the interpretation satisfies all the axioms in the knowledge base.

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# OWL Axioms

| Axiom | Example | Interpretation |
|---|---|---|
| SubClassOf | Class: Human<br>SubClassOf: Animal | $I(Human) \subseteq I(Animal)$ |
| EquivalentTo | Class: Man<br>EquivalentTo: (Human and Male) | $I(Man) = I(Human) \cap I(Male)$ |
| Disjoint | Disjoint: Animal, Plant | $I(Animal) \cap I(Plant) = \emptyset$ |



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# OWL Individual Axioms

| Axiom | Example | Interpretation |
|---|---|---|
| Individual | Individual: Sean<br>Types: Human | $I(Sean) \in I(Human)$ |
| Individual | Individual: Sean<br>Facts: worksWith Ian | $\langle I(Sean), I(Ian)\rangle \in I(worksWith)$ |
| DifferentIndividuals | Individual: Sean<br>DifferentFrom: Ian | $I(Sean) \neq I(Ian)$ |
| SameIndividuals | Individual: GeorgeWBush<br>SameAs: PresidentBush | $I(GeorgeWBush) = I(PresidentBush)$ |

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# OWL Property Axioms

| Axiom | Example | Interpretation |
|---|---|---|
| SubPropertyOf | ObjectProperty: hasMother SubpropertyOf: hasParent | $I(hasMother) \subseteq I(hasParent)$ |
| Domain | ObjectProperty: owns Domain: Person | $\forall x.\langle x,y \rangle \in I(owns) \Rightarrow x \in I(Person)$ |
| Range | ObjectProperty: employs Range: Person | $\forall x.\langle x,y \rangle \in I(employs) \Rightarrow y \in I(Person)$ |
| Transitive | ObjectProperty: hasPart Characteristics: Transitive | $\forall x,y,z.\ (\langle x,y \rangle \in I(hasPart) \wedge \langle y,z \rangle \in I(hasPart)) \Rightarrow \langle x,z \rangle \in I(hasPart)$ |



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# Consequences

- An ontology (collection of axioms) places constraints on the models that are allowed.
- Consequences may be derived as a result of those constraints.
- *C* subsumes *D* w.r.t. an ontology *O* iff for *every* model *I* of *O*, $I(D) \subseteq I(C)$
- *C* is equivalent to *D* w.r.t. an ontology *O* iff for *every* model *I* of *O*, $I(C) = I(D)$
- *C* is satisfiable w.r.t. *O* iff there exists *some* model *I* of *O* s.t. $I(C) \neq \emptyset$
- An ontology *O* is consistent iff there exists *some* model *I* of *O*.

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# Reasoning

- A reasoner makes use of the information asserted in the ontology.
- Based on the semantics described, a reasoner can help us to discover inferences that are a consequence of the knowledge that we've presented that we weren't aware of beforehand.
- Is this new knowledge?
  - What's actually in the ontology?



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# Reasoning

- Subsumption reasoning
  - Allows us to infer when one class is a subclass of another
  - B is a subclass of A if it is necessarily the case that (in all models), all instances of B *must* be instances of A.
  - This can be either due to an explicit assertion, or through some inference process based on an intensional definition.
  - Can then build concept hierarchies representing the taxonomy.
  - This is classification of classes.
- Satisfiability reasoning
  - Tells us when a concept is unsatisfiable
    - i.e. when there is no model in which the interpretation of the class is non-empty.
  - Allows us to check whether our model is consistent.

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# Instance Reasoning

- Instance Retrieval
  - What are the instances of a particular class C?
  - Need not be a named class
- Instantiation
  - What are the classes that x is an instance of?



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# Why Reasoning?

- Reasoning can be used as a design support tool
  - Check logical consistency of classes
  - Compute implicit class hierarchy
- May be less important in small local ontologies
  - Can still be useful tool for design and maintenance
  - Much more important with larger ontologies/multiple authors
- Valuable tool for integrating and sharing ontologies
  - Use definitions/axioms to establish inter-ontology relationships
  - Check for consistency and (unexpected) implied relationships
  - Already shown to be useful technique for DB schema integration

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# Example

Class: pet_owner
EquivalentTo:
  person
  and has_pet some animal

- A pet_owner is a person that has some pet that is an animal
- This is a equivalent class, thus any person who has a pet that is an animal will be a pet_owner.
- If we know someone is a pet_owner, then we know that there must be some animal that is their pet: we may not know the name of this particular animal though.



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# Example

Class: giraffe
SubClassOf:
  animal,
  eats only leaf

- A giraffe is an animal that only eats leaves.
- This is a partial definition, thus every giraffe must have these characteristics, however there may be animals that eat only leaves that are **not** giraffes.

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# Necessary and Sufficient Conditions

- Classes can be described in terms of necessary and sufficient conditions.
  - This differs from some frame-based languages where we only have necessary conditions.
- Necessary conditions
  - Must hold if an object is to be an instance of the class
- Sufficient conditions
  - Those properties an object must have in order to be recognised as a member of the class.
  - Allows us to perform automated classification.

If it looks like a duck and walks like a duck, then it's a duck!



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# Example

Class: animal_lover
EquivalentTo:
  person
  and has_pet min 3

- An animal_lover is a person that has at least 3 pets.
- All of these pets must be distinct individuals.
- Any person with 5 pets will be inferred to be an instance of this class.

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# Example

```
Class: newspaper
SubClassOf:
   publication
   broadsheet or tabloid

Class: broadsheet
SubClassOf: newspaper
DisjointWith tabloid

Class: tabloid
SubClassOf: newspaper
```

- A newspaper is either a broadsheet or a tabloid.
- By default there is no mutual exclusion.
- If we know something is a newspaper we can infer that it must be either a broadsheet or a tabloid, but we may not know for sure which one it actually is (cf Open World).



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# Example

```
Individual: Mick
Types: male
Facts:
   reads Daily_Mirror
   drives Q123_ABC

DifferentFrom:
   Dewey, Fido, …, Walt
```

- Mick is an individual and an instance of the class male.
- He is related to individuals Daily_Mirror and Q123_ABC via the properties reads and drives.

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## Common Misconceptions

- Disjointness of primitives
- Interpreting domain and range
- And and Or
- Quantification
- Closed and Open Worlds



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## Disjointness

- By default, primitive classes are not disjoint.
- Unless we explicitly say so, the description (Animal and Vegetable) is not inconsistent.
- Similarly with individuals -- the so-called Unique Name Assumption (often present in DL languages) does not hold, and individuals are not considered to be distinct unless **explicitly** asserted to be so.

## Domain and Range

- OWL allows us to specify the domain and range of properties.
- Note that this is not interpreted as a constraint.
- Rather, the domain and range assertions allow us to make inferences about individuals.
- Consider the following:
  - ObjectProperty: employs
    Domain: Company
    Range: Person
    Individual: IBM
    Facts: employs Jim
- If we haven't said anything else about IBM or Jim, this is **not** an error. However, we can now **infer** that IBM is a Company and Jim is a Person.



## And/Or and Quantification

- The logical connectives And and Or often cause confusion
  - Tea or Coffee?
  - Milk and Sugar?
- Quantification can also be contrary to our intuition.
  - Universal quantification over an empty set is true.
  - Sean is a member of hasChild only Martian
  - Existential quantification may imply the existence of an individual that we don't know the name of.

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# Closed and Open Worlds

- The standard semantics of OWL makes an Open World Assumption (OWA).
  - We cannot assume that all information is known about all the individuals in a domain.
  - Facilitates reasoning about the intensional definitions of classes.
  - Sometimes strange side effects
- Closed World Assumption (CWA)
  - Named individuals are the only individuals in the domain
- Negation as failure.
  - If we can't deduce that x is an A, then we know it must be a (not A).
  - Facilitate reasoning about a particular state of affairs.



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# OWL isn't everything

- OWL is not intended to be the answer to all our problems.
- For some applications, less formal vocabularies may be more appropriate
- For some applications, more expressiveness may be needed.

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# Lightweight Vocabularies

- For many applications, lightweight representations are more appropriate.
- Thesauri, classification schemes, taxonomies and other controlled vocabularies
  - Many of these already exist and are in use in cultural heritage, library sciences, medicine etc.
  - Often have some taxonomic structure, but with a less precise semantics.



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# Concept Schemes

- A concept scheme is a set of concepts, potentially including statements about relationships between those concepts
  - Broader Terms
  - Narrower Terms
  - Related Terms
  - Synonyms, usage information etc.
- Concept schemes aren't formal ontologies in the way that OWL ontologies are formal ontologies.

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# SKOS: Simple Knowledge Organisation System

- SKOS aims to provide an RDF vocabulary for the representation of such schemes.
- W3C Semantic Web Deployment Group currently working towards a Recommendation for SKOS
- Focus on Retrieval Scenarios
  A. Single controlled vocabulary used to index and then retrieve objects
  B. Different controlled vocabularies used to index and retrieve objects
     - Mappings then required between the vocabularies
  – Initial use cases/requirements focus on these tasks
     - Not worrying about activities like Natural Language translation



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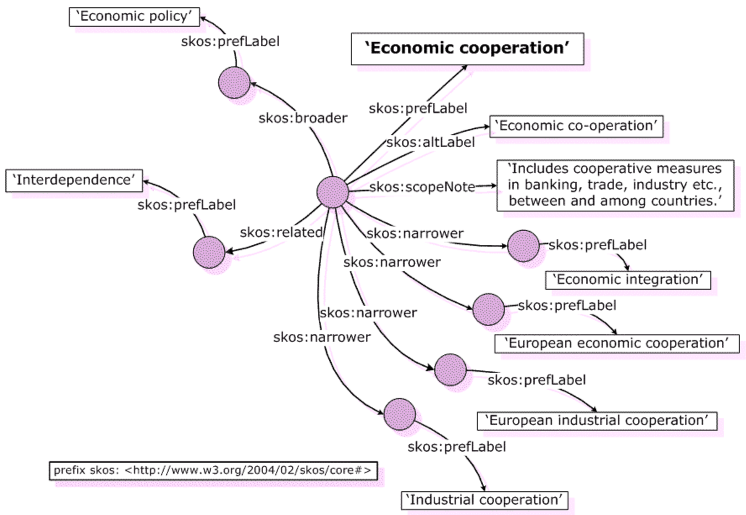
# SKOS Example



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# SKOS

- Semantic Web Deployment Working Group
  http://www.w3.org/2006/07/SWD/
- SKOS Reference:
  http://www.w3.org/TR/skos-reference/
- SKOS Primer
  http://www.w3.org/TR/skos-primer/
- Last Call Planned 1st July



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# Rules: RIF

- W3C Group Rules Interchange Format WG
  http://www.w3.org/2005/rules/
- Identification of Use Cases and Requirements
- Drafts identifying Basic Logic Dialect (BLD)
  - Horn rules plus equality
  - FOL Semantics
- Extensions defined using Framework for Logic Dialects (FLD)
- Somewhat slow moving process
  - Large and disparate group, e.g. production rules, business rules, FOL.

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# OWL 2

- A number of domains require expressivity that is not in the current OWL specification
  - Driven by User Requirements and technical advances
  - OWLEd series of workshops
- Much of this functionality can be added in a principled way that preserves the desirable properties of OWL (DL).
- The proposed extended language is now known as OWL 2

  http://www.w3.org/2007/OWL



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# OWL 2

- Syntactic Sugar
  - DisjointUnion
  - Negated Property assertions
- Richer Datatypes
- Complex Role Axioms
  - Role inclusion
- Metamodelling and Annotations
  - Punning
- Tractable Fragments
  - Language fragments with desirable computational complexity

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# OWL 2: Role Axioms

- Many applications (for example medicine) have requirements to specify interactions between roles:
  - A fracture located in part of the Femur is a fracture of the Femur.
- We cannot express such general patterns in OWL.
- Algorithms have been developed to support sound and complete reasoning in a DL extended with complex role inclusions



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# OWL 2: Metamodelling

- OWL DL has strict rules about separation of namespaces.
- A URI cannot be typed as both a class and individual in the same ontology.
- OWL 2 allows punning, where a URI can be used in multiple roles.
  - However, the use of the URI as an individual has no bearing on the use of the URI as a class.
  - Requires explicit context telling us the role that a URI is playing

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# OWL 2: Fragments

- EL++
  - Medical Ontologies
  - SNOMED/GALEN
- DL Lite
  - Tailored for handling large numbers of facts
  - Efficient Querying
- DLP
  - Subset of OWL DL and Horn Logic
  - OWL semantics
- Horn-SHIQ
  - Similar to DLP
- RDF Schema
  - RDFS ontologies that are valid OWL 2



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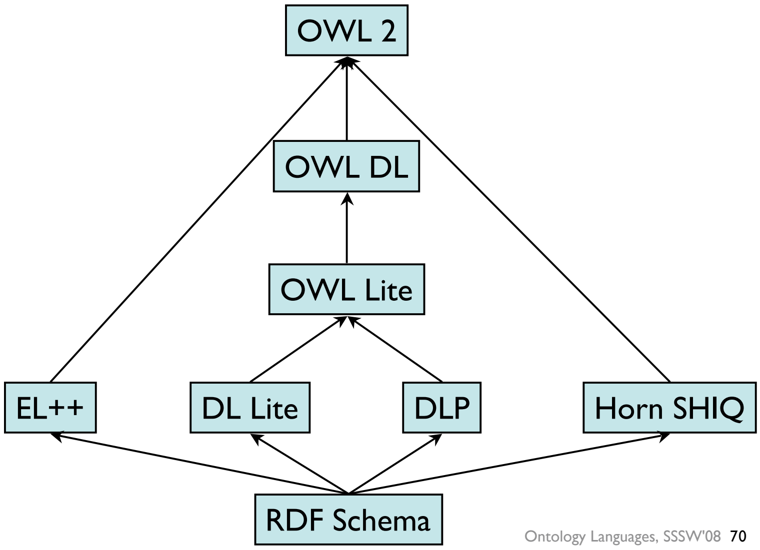
# OWL 2: Fragments



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# Query and Retrieval

- In standard DLs, reasoning is split into:
  - T-Box: reasoning about classes
  - A-Box: reasoning about instances
- T-Box reasoning is well understood, at least for languages like SHIQ (~OWL Lite)
  - e.g. subsumption & satisfiability testing
- Full A-Box reasoning is much more challenging
  - E.g. instance retrieval & instantiation



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# Query Languages

- SPARQL Query Language for RDF.
  - http://www.w3.org/TR/rdf-sparql-query/
- SPARQL Protocol
  - http://www.w3.org/TR/rdf-sparql-protocol/
- W3C Recommendations as of 15th January

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# Tools

- Editors
  - Protégé OWL, SWOOP, ICOM, TopQuadrant Composer, OntoTrack, NeOn…
  - Tend to present the user with "frame-like" interfaces, but allow richer expressions
  - Offer the possibility of using reasoners.
- Reasoners
  - DL style reasoners based on tableaux algorithms
    - Racer, FaCT++, Pellet
  - Based on rules or F-logic
    - F-OWL, E-Wallet…..
- APIs and Frameworks
  - Jena, WonderWeb OWL-API, Protégé OWL API, OWLIM



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# Take Home

- Representation languages are needed to allow us to describe our annotations and semantic information
- RDF, RDF Schema, OWL, SKOS etc. all provide mechanisms for this, with greater or lesser degrees of formality
- Formal Semantics seen as important when unambiguous interpretations of expressions are required
  - Facilitates use of reasoning
- Tools, both research and commercial, now available to support these languages

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# Acknowledgements

- "If I have seen further, it is by standing on the shoulders of giants"
- Many thanks to all the people who I "borrowed" material from, in particular
  - Ian Horrocks, Frank van Harmelen, Alan Rector, Nick Drummond, Matthew Horridge, Uli Sattler, Bijan Parsia
- and thanks to all those that *they* borrowed material from!
  - Too many to mention…



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# Thank you!