Semantic Web Languages and Standards (*Primer*)
Aidan Hogan — DERI Galway
WHAT IS THE SEMANTIC WEB?
The Semantic Web is Tim (et al.)’s Vision?
The Semantic Web is intelligent machines helping us make sense of the Web?
The Semantic Web is naming everything?
The Semantic Web is linking Web data

Image by Cyganiak & Jentzsch; http://lod-cloud.net
The Semantic Web is breaking down the data silos / walls?

Image from http://www.digitaltimes.ie
The Semantic Web is Web 3.0?

[Diagram showing the evolution of the web from Web 1.0 to Web 4.0, with Semantic Web, Web 3.0, Web 2.0, and Web 1.0 listed along with various technologies and features.


Image by Radar Networks; Nova Spivak; http://memebox.com/futureblogger/show/824]
The Semantic Web is a stack of technologies for interoperability?

Images by Hendler, Brickley Novack; [http://www.bnode.org/blog/tag/layer%20cake](http://www.bnode.org/blog/tag/layer%20cake)
The Semantic Web is a stack of technologies for interoperability?

Images by Hendler, Brickley Novack; [http://www.bnode.org/blog/tag/layer%20cake](http://www.bnode.org/blog/tag/layer%20cake)
The Semantic Web is a bunch of standards for interoperability?
The Semantic Web is something very very bad and it must die (apparently)?
The Semantic Web is a buzzword?
The Semantic Web is...
The Semantic Web is…

…cf. “What is the Web?”
...WHAT IS THE SEMANTIC WEB FOR?
Web = Flood of information

= 5.9 TB of data
(Jan. 2010 Dump)
Web = Flood of information

= 235 TB of data indexed
= 40 Wikipedias
(incl. Web archive)
Web = Flood of information

= 12 TB/day added
= 2 Wikipedias / day
(as of Mar. 2010)
Web = Flood of information

= 20 PB/day processed
= 3,389 Wikipedias/day
(Jan. 2010)
Web = Flood of information

= 160 TB/s transferred
= 27 Wikipedias/second
(2008; Cisco)
From signals ...
To binary ...

...10010110...
To characters (ASCII/Unicode) …

...Hello World...
To document markup (HTML) ...

<title>Hello World</title>

She'll know what to do with <title>

Ah yes, I display this at the top.
To data markup ...

<time="10:36"/>

She’ll know what <time> means

This is what my user asked for. Thanks!
To arbitrary information exchange ???

<aidan presents= "session1" />

This is the data I have.

What’s an “aidan”?
Arbitrary data/information exchange ...

We need ...

- Common data model for encoding data (triples)
- Common ways of serialising data (syntaxes)
- Well-defined languages for saying what terms mean (semantics)
- Common ways to query data (query languages)
- **Web standards!**

- **Make data machine-readable!**
Syntax to semantics / terms to entities

<aidan presents="session1"/>
...WHEN DID THE SEMANTIC WEB BEGIN?
Started with the Web?

1990
Pre-dating Web …

- Tim Berners Lee *ENQUIRE* (1980)
  - Pre-dates Web by 10 years / Closer to Semantic Web than Web
  - Link cards (each card reflected an “entity”)
  - Different types of relations
  - Never made it out of CERN … Disk containing software “re-used”

- Other works in Artificial Intelligence:
  - FOL / Logic Programming / Description Logics / Expert Systems
  - … Knowledge Representation
    - Frame languages / Semantic networks / Ontology
  - … Databases
    - Entity-Attribute-Value (EAV) model / Deductive databases / Conceptual + Logical Schema
  - … Information Retrieval, Natural Language Processing, …
Modern Semantic Web …

...SO WHERE IS THIS SEMANTIC WEB NOW?
Hidden within the Web?
Linked Open Data cloud
Open Government Data (US)

My Administration is committed to creating an unprecedented level of openness in Government. We will work together to ensure the public trust and establish a system of transparency, public participation, and collaboration. Openness will strengthen our democracy and promote efficiency and effectiveness in Government.

- President Obama, 01/21/09

http://data.gov/
Open Government Data (UK)

http://data.gov.uk/
Semantics in HCLS/Biomedical Domain
GoodRelations for Products

GoodRelations
The Web Ontology for E-Commerce

Shopping results for One-Touch Gold BBQ (22.5-in.): Blue by Weber
- Weber 75001 Blue One-Touch 22.5" Blue Stainless Steel Charcoal Gold Grill, $159.70 - Build.com
- Weber One Touch 751001 22.5" One-Touch Gold Charcoal Grill with ... $129.00 - AJ Madison
- Weber One Touch 758001 22.5" One-Touch Gold Charcoal Grill with ... $149.00 - AJ Madison

Image from http://www.heppnetz.de/projects/goodrelations/primer/; Hepp
GoodRelations for Products

Shopping results for One-Touch Gold BBQ (22.5-in.): Blue by Weber

- Weber 75001 Blue One-Touch 22.5" Blue Stainless Steel Charcoal Gold Grill $159.70 - Build.com
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- Weber One Touch 758001 22.5" One-Touch Gold Charcoal Grill with ... $149.00 - AJ Madison

Image from http://www.heppnetz.de/projects/goodrelations/primer/; Hepp
FaceBook’s Open Graph Protocol

http://developers.facebook.com/tools/debug/

Object Properties

- fb:app_id: 115109575169727
- og:type: video.movie
- og:image:
- og:description: Directed by Michael Bay. With Sean Connery, Nicolas Cage, Ed Harris, John Spencer. A renegade ger aten San Francisco Bay with biological weapons. A chemical weapons specialist and the only man to l
- og:site_name: IMDb
- og:updated_time: 1337353695

http://developers.facebook.com/tools/debug/
FaceBook’s Open Graph Protocol
THE HUFFINGTON POST

http://developers.facebook.com/tools/debug/
schema.org

Thing > Organization > LocalBusiness > Store
A retail good store.

- LiquorStore
- MensClothingStore
- MobilePhoneStore
- MovieRentalStore
- MusicStore
- OfficeEquipmentStore
- OutletStore
- PawnShop
- PetStore
- ShoeStore
- SportingGoodsStore
- TireShop
- ToyStore
- WholesaleStore

http://schema.org
qwiki.com

http://qwiki.com/
Metaweb / Freebase

http://freebase.com/
Google’s Knowledge Graph

Aphex Twin - Wikipedia, the free encyclopedia
Richard David James (born 18 August 1971), best known under the pseudonym Aphex Twin, is a British electronic musician and composer. He founded the...

Polygon Window - Come To Daddy
13 Feb 2008 · 8 min · Lyuba

Polygon Window - Film
27 Jun 2007 · 3 min · ori2byl

Polygon Window - On
15 Jan 2008 · 4 min · TerryFuckwitt

Warp / Records / Aphex Twin
Off his multiple aliases and stater ores - AFX, Polygon Window, Caustic Window, The Diesel Man - none are active, even Aphex Twin, the primary conduit for his...

Aphex Twin -- duikad
The official Aphex Twin dükks microsite with MP3s and lots of strange things to look at.

The Aphex Twin Community v4
Your guide to Richard D. James aka Aphex Twin... Download Aphex Twin live shows and bootlegs on the Xtronic BitTorrent tracker. New RDJ Interview at...

Aphex Twin – Free listening, videos, concerts, stats, & pictures at...
More videos for Aphex Twin

Richard David James, best known under the pseudonym Aphex Twin, is a British electronic musician and composer. He founded the record label Rephlex Records in 1991 with Grant Wilson-Clayburn. Wikipedia

Born: August 18, 1971 (age 40), Limerick
Real name: Richard David James
Record labels: Rephlex Records, Mighty Force Records, Six Records, R&B Records, Warp Records
Music groups: The Tus, Universal Indicator, So Solid Crew

Song | Year | Album
--- | --- | ---
Windowlicker | 1999 | Cold Feet
Come to Daddy | 1997 | Come to Daddy EP
Milkman | 1995 | Richard D. James Album
Analogue Bubblebath | 2004 | Chill Out Classics
Digeridoo | 1992 | Analogue Bubblebath

Albums
- Digeridoo 2001
- Selected Ambient Works 88 1992
- Selected Ambient Works 93 1994
- Richard D. James Album 1995
- I Care Because You Do 1995

People also search for
- Squarepusher
- Chris Cunningham
- Bjork
- Brian Eno
- Venetian Snares

http://google.com/ncr/
Not there yet (but getting there…)
Not there yet (but getting there...)
Not there yet (but getting there...)

Diagram showing levels of technologies:
- URI / IRI
- Unicode
- Namespaces
- XML
- RDF Model & Syntax
- Ontology
- Rules / Query
- Logic
- Proof
- Trust
IT ALL BEGINS WITH RDF ...
A brief history of RDF

- Meta Content Framework (MCF) by Ramanathan V. Guha [1995]
  - Data-model consisting of Objects, Categories, and Properties
  - Directed, labelled graph
  - type / domain / range / superType / superPropertyType
  - XML syntax (based on XML names)

- Resource Description Framework (RDF) by W3C [1999]
  - Spec. edited by Ora Lassila and Ralph R. Swick
  - Data-model consisting of Resources, Class, and Properties
  - Directed, labelled graph
  - Later extended to RDFS, including type / domain / range / subClassOf / subPropertyOf
  - XML syntax (based on URIs)

- RDF Revised by W3C [2004]
What is RDF (not)?

RDF is not a syntax, and is not just fancy XML
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RDF is not a syntax, and is not just fancy XML
What is RDF?

A data-model based on triples!
What are triples?
### RDF Triples: statements in slots of three

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>PREDICATE</th>
<th>OBJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>aidan</td>
<td>presents</td>
<td>session1</td>
</tr>
<tr>
<td>aidan</td>
<td>attending</td>
<td>eswc2012</td>
</tr>
<tr>
<td>aidan</td>
<td>worksAt</td>
<td>deri</td>
</tr>
<tr>
<td>deri</td>
<td>location</td>
<td>galway</td>
</tr>
<tr>
<td>eswc2012</td>
<td>location</td>
<td>crete</td>
</tr>
</tbody>
</table>
Triples form a directed, labelled graph

- **aidan** presents **session1**
- **worksAt**
- **deri** livesIn **Galway**
- location
- **eswc2012**
  - location
  - Crete
Why triples? Simplest fixed-arity model ...

<table>
<thead>
<tr>
<th>PAIRS</th>
<th>FROM</th>
<th>TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>DERI</td>
<td>deri</td>
<td>location</td>
</tr>
<tr>
<td>location</td>
<td>galway</td>
<td></td>
</tr>
<tr>
<td>eswc2012</td>
<td>location</td>
<td></td>
</tr>
<tr>
<td>location</td>
<td>crete</td>
<td></td>
</tr>
<tr>
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<td>deri</td>
<td>galway</td>
</tr>
</tbody>
</table>
### Why triples? Simplest fixed-arity model ...

<table>
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<th>(PAIRS)</th>
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<th>TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>DERI</td>
<td>deri</td>
<td>galway</td>
</tr>
<tr>
<td>location</td>
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<td></td>
</tr>
<tr>
<td>eswc2012</td>
<td>location</td>
<td></td>
</tr>
<tr>
<td>concrete</td>
<td>galway</td>
<td></td>
</tr>
<tr>
<td>DERI</td>
<td>deri</td>
<td>galway</td>
</tr>
</tbody>
</table>
Naming in triples ... avoid ambiguity
Avoid ambiguities: use URIs (/IRIs)!

http://ex.org/#aidan ...
Abbreviating URIs

- Use “CURIEs” / namespaces

- PREFIX ex: <http://ex.org/>

- ex:aidan = <http://ex.org/#aidan>
RDF Triples: literals in object position

<table>
<thead>
<tr>
<th>SUBJECT</th>
<th>PREDICATE</th>
<th>OBJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>URI</td>
<td>BNode</td>
<td>URI</td>
</tr>
<tr>
<td>ex:aidan</td>
<td>ex:present</td>
<td>ex:session1</td>
</tr>
<tr>
<td>ex:aidan</td>
<td>ex:gender</td>
<td>&quot;Semantic Web Languages and Standards&quot;@en</td>
</tr>
<tr>
<td>ex:session1</td>
<td>ex:title</td>
<td>&quot;10:30:00+02:00&quot;</td>
</tr>
<tr>
<td>ex:session1</td>
<td>ex:startTime</td>
<td>^^xsd:time</td>
</tr>
</tbody>
</table>
Simple Literals

- Simple strings:
  - “male”, “Hello World”, “aju901odksad”
Language-tagged Literals

- Simple strings with specified language:
  - “Hello World”@en
  - “Bonjour tout le monde.”@fr
  - “Whilst I dreamt colourful dreams.”@en-GB

- (Defined by RFC 3066, ISO 639-2)
Datatype Literals

- Typed literals with mappings from strings to values
- String (lexical value) / URI (type) pair

- Many from XML Schema (namespace often given xsd: or xs: prefix)
  - "true"^^xsd:boolean • "false"^^xsd:boolean
  - "1.0"^^xsd:decimal • "1"^^xsd:int • "1"^^xsd:byte
  - "2012-05-21"^^xsd:date • "2012-05-21T10:30:00Z"^^xsd:dateTime
  - "---15"^^xsd:gDay "--05-15"^^xsd:gMonthDay "2010"^^xsd:gYear
  - "Hello World"^^xsd:string  (...and more besides)

- Other datatypes defined elsewhere (rdf:XMLLiteral, owl:real)
- Can define custom datatypes (e.g., dbt:usDollars)

- "literal"^^xsd:string ≡ "literal"
- Can’t mix datatypes and language tags ("Hello World"^^xsd:string@en)
RDF Literals: summary

Plain Literals

Simple Literals
“string”

Lang-tag Literals
“string”@en

Datatype Literals
“string”^^xsd:string
### RDF Triples: blank-nodes

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<tbody>
<tr>
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<td>BNode</td>
<td>URI</td>
</tr>
<tr>
<td>ex:aidan</td>
<td>ex:present</td>
<td>ex:session1</td>
</tr>
<tr>
<td>ex:aidan</td>
<td>ex:gender</td>
<td>“male”</td>
</tr>
<tr>
<td>ex:session1</td>
<td>ex:venue</td>
<td>_:somewhere</td>
</tr>
<tr>
<td>_:somewhere</td>
<td>ex:location</td>
<td>ex:kalamaki</td>
</tr>
</tbody>
</table>
Blank Nodes

- Often denoted with the prefix "_:", and a label suffix
  - _:bnode4 • _:genid2 • _:venue

- Can only be referenced in a local document!
- Values of labels are inconsequential
  - Can consistently re-label blank nodes; makes no difference

- Used:
  - to avoid creating a URI for something
  - for syntax shortcuts
  - if a value is unknown or not concretely identifiable
  - once-off resource (e.g., for time-of-access)
  - only allow local reference
  - etc.
Blank Nodes are existential (in theory)

- Denote the existence of something
  - `ex:JohnFKennedy ex:assassin _:unknown`.

- Blank nodes can introduce redundancy (non-lean RDF)

```
ex:aidan ex:coauthoredPaper _:bnodel

_ex:coauthoredPaper

_:bnodel2

"On Blank Nodes"@en
```
Summary of RDF Triples

- **Slots of three:** Subject, Predicate, Object
- **Used to make statements about the world**
- **Subject:** URIs or Blank Nodes
- **Predicate:** URIs only
- **Object:** URIs, Blank Nodes, Literals (plain [w/lang] or typed)

- An RDF graph is a set of triples

![RDF Graph Diagram]

(1) `ex:aidan` `ex:coauthoredPaper` `:_:bnodel`
(2) `:_:bnodel` `ex:title` "On Blank Nodes"@en
(3) `ex:aidan` `ex:coauthoredPaper` `:_:bnodel2`
Triples are everywhere!
Triples are everywhere!

{{Infobox Town AT |
  name = Innsbruck |
  image_csa = InnsbruckWappen.png |
  image_map = Karte-tirol-I.png |
  state = [[Tyrol]] |
  regbzk = [[Statutory city]] |
  population_as_of = 2006 |
  pop_dens = 1,119 |
  area = 104.91 |
  elevation = 574 |
  lat_deg = 47 |
  lat_min = 16 |
  lat_hem = N |
  lon_deg = 11 |
  lon_min = 23 |
  lon_hem = E |
  postal_code = 6010-6080 |
  area_code = 0512 |
  licence = I |
  mayor = Hilde Zach |
  website = [http://innsbruck.at] |
}}

Country Austria
State Tyrol
Administrative region Statutory city
Area 104.91 km²
Population density 1,119/km²
Elevation 574 m
Coordinates 47°16′ N 11°23′ E
Postal code 6010-6080
Area code 0512
Licence plate code I
Mayor Hilde Zach
Website www.innsbruck.at
Triples are everywhere!

Aphex Twin - Wikipedia, the free encyclopedia
Richard David James (born 18 August 1971), best known under the pseudonym Aphex Twin, is a British electronic musician and composer. He founded the ... Richard D. James discography - Classics (Aphex Twin album)

Polygon Window - Come to Daddy
www.youtube.com/watch?v=5Az_JU0-cKO
13 Feb 2008 - 6 min - Ljuba

Polygon Window - Flim
www.youtube.com/watch?v=RhHkUg-QCw
27 Jun 2007 - 3 min - on2byl

Polygon Window - 
www.youtube.com/watch?v=B-US1WUIzA
15 Jan 2008 - 4 min - TerryFuckwitt

More videos for aphex twin »

Warp / Records / Aphex Twin
warp.net/records/aphex-twin
Of his multiple alias and alter egos - AFX, Polygon Window, Cheetah Chrome, The Goo Goo Dolls, Dice Man - none are active, even Aphex Twin, the primary conduit for his ...

Aphex Twin -- duktsg
www.duktsg.net/
The Official Aphex Twin duktsg microsite with Mp3s and lots of strangeness to look at.

The Aphex Twin Community v4
www.aphextwinnu.com/
Your guide to Richard D. James aka Aphex Twin. ... Download Aphex Twin live shows and bootlegs on the Xltronic BitTorrent tracker - New ROJ Interview at ...

Aphex Twin – Free listening, videos, concerts, stats, & pictures at ...
www.last.fm/music/Aphex+Twin
Watch videos & listen to Aphex Twin live, built with 6 years, plus 100

Aphex Twin

Richard David James, best known under the pseudonym Aphex Twin, is a British electronic musician and composer. He founded the record label Rephlex Records in 1991 with Grant Wilson-Claridge. He was born on August 18, 1971 in Limerick, Ireland. His real name is Richard David James. His record labels include Rephlex Records, Mighty Force Records, Sire Records, R&S Records, Warp Records, and others. His music groups include The Tuss, Universal Indicator, So Solid Crew, and others. His songs include Windowwicker, Come to Daddy, Milkman, and others. His albums include Cold Feet, Come to Daddy EP, Richard D. James Album, Chill Out Classics, and others. His people also search for Squarepants, Chris Cunningham, Björk, Brian Eno, and others.
What is RDF?

A data-model based on triples! (+ a little more)
Features of RDF: typing / classes

```
(rdf:type) ex:aidan
(rdf:type) ex:matthew
(rdf:type) ex:denny
(rdf:type) ex:Tutor
(rdf:type) ex:dan
(rdf:type) ex:elena
```

ex:aidan
ex:barry
ex:matthew
ex:dan
ex:denny
ex:elena
Features of RDF: containers (aka. lists)

ex:summerSchool  ex:lstDaySchedule _:dayOne
  _:dayOne      rdf:first           “Enrico’s Keynote”
  _:dayOne      rdf:rest              _:dayOneB
  _:dayOneB     rdf:first            “Session 1”
  _:dayOneB     rdf:rest              _:dayOneC
  _:dayOneC     rdf:first            “Session 2”
  _:dayOneC     rdf:rest              _:dayOneD
  _:dayOneD     rdf:first            “Hands On 1”
  _:dayOneD     rdf:rest              rdf:nil

Ordered! Closed!
Other features of RDF (not covered)

- RDF containers
- RDF reification
- RDF $n$-ary predicates

*Hint: if you’re using these features, you’re probably doing it wrong*

*(unless you specifically know what you’re doing)*
Writing RDF triples down?

How do we write RDF triples down for exchange?
The bit between angle brackets is a URI
RDF syntaxes

- N-Triples
  - Simple syntax for line-delimited triples
- Turtle
  - Superset of N-Triples, with lots of nice shortcuts
- Notation3 (N3)
  - Superset of Turtle and RDF (goes beyond RDF!)
- RDF/XML
  - RDF syntax based on XML
- RDFa
  - Syntax for embedding RDF directly into XHTML documents
N-Triples

- Full URIs in ‘<>’ angle brackets
- Terms delimited by space or tab
- Triples ended by ‘.’, delimited by new line
- Blank nodes with ‘_:’ prefix
- Literals enclosed with quotes
- Optional datatype with ‘^^’
- Optional lang-tag with ‘@’

```
```
Turtle (Terse RDF Triple Language)

```turtle
@base <http://ex.org/#> .
@prefix ns: <http://ns.com/> .

<aidan> ns:worksAt <DERI> ; ns:author _:bnode1 , _:bnode2 .
_:bnode2 ns:title "On Blank Nodes"@en ; ns:pages 16 .
```

- Re-usable URI prefixes
- '@' for common subject
- ',' for common subject & predicate
- Rel. URIs resolved against base
- Expands to "16"^^xsd:integer (Similar shortcuts for decimals, floating points and booleans)
Turtle (Blank node abbreviation)

@base <http://ex.org/#> .
@prefix ns: <http://ns.com/> .

<aidan> ns:worksAt <DERI> ; ns:author [],
Turtle (RDF collection / list abbreviation)

@base <http://ex.org/#> .

<summerSchool> <1stDaySchedule>   
( "Enrico’s Keynote" "Session 1" "Session 2" "Hands-on 1" ) .

Enclose list elements in parentheses, and you’re done!
Turtle (my favourite abbreviation)

```turtle
@base <http://ex.org/#> .

<aidan> a <Tutor> .
```

‘a’ instead of rdf:type
(No need to declare rdf: prefix)
Notation3 (N3) ... a quick note

- A superset of RDF
  - Contains non-RDF features like rules, scoping graphs, etc.
- Intersection of N3 and RDF ≈ Turtle
RDF/XML overview

- RDF syntax based on XML
- RDF/XML and RDF often conflated:
  - RDF is a data-model based on triples
  - RDF/XML is a syntax to serialise triples

- A very prominent syntax (dates back to 1999); used widely
- Unfortunately, not a very nice syntax:
  - Difficult to see triple structure
  - Shortcuts are confusing
  - Relative name schemes are confusing
  - Not all RDF can be written as RDF/XML (due to limitations of XML names for writing down predicates)
  - Not canonical: XML tools are useless
  - Just plain difficult to read/write-parse/learn, etc.
RDF/XML (…will not go into detail)

```xml
<rdf:Description rdf:about="http://.../TR/rdf-syntax-grammar">
  <ex:editor>
    <rdf:Description>
      <ex:homePage rdf:resource="http://purl.org/net/dajobe/" />
      <ex:fullName>Dave Beckett</ex:fullName>
    </rdf:Description>
  </ex:editor>
  <dc:title>RDF/XML Syntax Specification (Revised)</dc:title>
</rdf:Description>
```

Image from http://www.w3.org/TR/REC-rdf-syntax/; Beckett
RDFa overview

- RDFa allows for embedding RDF into XHTML
- Mix human readable and machine readable
  - No need for separate docs!
  - Less server costs simpler hosting

- Becoming more and more prominent (rec. since 2008)
RDFa (…will not go into detail)

```xml
<div typeof="foaf:Person" xmlns:foaf="http://xmlns.com/foaf/0.1/">
  <p property="foaf:name">Alice Birpemswick</p>
  <p>Email: <a rel="foaf:mbox" href="mailto:alice@example.com">alice@example.com</a></p>
  <p>Phone: <a rel="foaf:phone" href="tel:+1-617-555-7332">+1 617.555.7332</a></p>
</div>
```

Image from [http://www.w3.org/TR/xhtml-rdfa-primer/](http://www.w3.org/TR/xhtml-rdfa-primer/); Adida & Birbeck
THAT’S RDF …

… NEXT UP…
RDFS and OWL!

**RDF Schema**

**Web Ontology Language**

- W3C Recommendations, 2004
  - OWL 2 since 2009

- Standardised schema/ontology languages
  - Can be serialised in RDF
  - OWL (partly) extends RDFS
Features walkthrough...

...modelling family relationships in RDFS and OWL...
A Family-Relations OWL Ontology

- ex:Vito
- ex:Carmela
- ex:Sonny
- ex:Connie
- ex:Fredo
- ex:Michael
- ex:Vincent
- ex:Mary

The Godfather
RDFS

1. rdfs:subPropertyOf
2. rdfs:subClassOf
3. rdfs:domain
4. rdfs:range
ex:Vito :husbandOf ex:Carmela .
:husbandOf rdfs:subPropertyOf :spouse .
⇒ ex:Vito :spouse ex:Carmela .

ex:Carmela :wifeOf ex:Vito .
⇒ ex:Carmela :spouse ex:Vito .
ex:Mary rdf:type :Woman .

:Woman rdfs:subClassOf :Person .

⇒ ex:Mary rdf:type :Person .
ex:Carmela :motherOf ex:Fredo .
:motherOf rdfs:domain :Woman .
⇒ ex:Carmela rdf:type :Woman .
rdfs:range

ex:Carmela :hasSon ex:Fredo .
:hasSon rdfs:range :Man .
⇒ ex:Fredo rdf:type :Man .
Recap RDFS

- What would be the **rdfs:domain** of the property :fatherOf?
- What would be the **rdfs:range** of the property :wifeOf?
RDFS

1. rdfs:subPropertyOf
2. rdfs:subClassOf
3. rdfs:domain
4. rdfs:range

OWL

1. Property Axioms
   a. owl:equivalentProperty
   b. owl:inverseOf
   c. owl:SymmetricProperty
   d. owl:TransitiveProperty
   e. owl:propertyChainAxiom
\[ ex:Vito \text{ :parentOf} ex:Michael . \]
\[ ex:Michael \text{ :hasChild} ex:Mary . \]
\[ \text{:parentOf } \text{owl:equivalentProperty :hasChild} . \]
\[ \Rightarrow ex:Vito \text{ :hasChild} ex:Vincent . \]
\[ \Rightarrow ex:Michael \text{ :parentOf} ex:Mary . \]
owl:inverseOf

\[ \text{ex:Carmela} : \text{parentOf} \quad \text{ex:Sonny} . \]
\[ \text{ex:Vincent} : \text{childOf} \quad \text{ex:Sonny} . \]
\[ \text{:parentOf} \quad \text{owl:inverseOf} \quad \text{:childOf} . \]
\[ \Rightarrow \text{ex:Sonny} : \text{parentOf} \quad \text{ex:Vincent} . \]
\[ \Rightarrow \text{ex:Sonny} : \text{childOf} \quad \text{ex:Carmela} . \]
ex:Connie :sibling ex:Fredo .
:sibling rdf:type owl:SymmetricProperty .
owl:TransitiveProperty

ex:Carmela :ancestorOf ex:Michael .
ex:Michael :ancestorOf ex:Mary .
:ancestorOf rdf:type owl:TransitiveProperty .
⇒ ex:Carmela :ancestorOf ex:Mary .
\[ \text{ex:Sonny} :\text{brotherOf} \text{ex:Michael} . \]
\[ \text{ex:Michael} :\text{fatherOf} \text{ex:Mary} . \]
\[ :\text{uncleOf} \ \text{owl:propertyChainAxiom} ( :\text{brotherOf} :\text{fatherOf} ) . \]
\[ \Rightarrow \text{ex:Sonny} :\text{uncleOf} \text{ex:Mary} . \]
Recap OWL property axioms

- What would be the **owl:inverseOf** of the property :fatherOf?
- Name an **owl:SymmetricProperty** to do with family relations?
- Name an **owl:TransitiveProperty** to do with family relations?
- Give a **owl:propertyChainAxiom** for hasNiece?
RDFS

1. rdfs:subPropertyOf
2. rdfs:subClassOf
3. rdfs:domain
4. rdfs:range

OWL

1. Property Axioms
2. Equality
   a. owl:sameAs
   b. owl:FunctionalProperty
   c. owl:InverseFunctionalProperty
ex:Vito_old owl:sameAs ex:Vito_young.
\[
\text{ex:Fredo} :\text{hasFather} \ \text{ex:Vito\_old} . \\
\text{ex:Fredo} :\text{hasFather} \ \text{ex:Vito\_young} . \\
:\text{hasFather} \ \text{rdf:type} \ \text{owl:FunctionalProperty} . \\
\Rightarrow \text{ex:Vito\_old} \ \text{owl:sameAs} \ \text{ex:Vito\_young} .
\]
\[ \text{owl:InverseFunctionalProperty} \]

\[
\begin{align*}
\text{ex:Vito}_\text{old} & : \text{fatherOf} \text{ ex:Connie} . \\
\text{ex:Vito}_\text{young} & : \text{fatherOf} \text{ ex:Connie} . \\
\text{:fatherOf} & \text{ rdf:type} \\
\text{owl:InverseFunctionalProperty} . \\
\Rightarrow \text{ex:Vito}_\text{old} & \text{ owl:sameAs ex:Vito}_\text{young} .
\end{align*}
\]
Recap OWL equality axioms

- Name an `owl:FunctionalProperty` to do with family relations?
- Name a similar `owl:InverseFunctionalProperty`?
RDFS

1. rdfs:subPropertyOf
2. rdfs:subClassOf
3. rdfs:domain
4. rdfs:range

OWL

1. Property Axioms
2. Equality
3. Class Axioms
   a. owl:unionOf
   b. owl:intersectionOf
   c. owl:oneOf
   d. owl:allValuesFrom
   e. owl:someValuesFrom
\texttt{ex:Vincent \texttt{rdf:type} :Man} .

\texttt{:Person \texttt{owl:equivalentClass} [ \texttt{owl:unionOf} (:Woman :Man) ]} \\
\Rightarrow \texttt{ex:Vincent \texttt{rdf:type} :Person} .
\[
\text{ex:Carmela} \text{ rdf:type } \text{:Mother} . \\
\text{:Mother rdfs:subClassOf [ owl:intersectionOf (\text{:Woman :Parent}) ]} \\
\Rightarrow \text{ex:Carmela rdf:type :Woman , :Parent} .
\]
owl:intersectionOf (ii)

```

:Mother owl:equivalentClass [ owl:intersectionOf (:Woman :Parent) ]
⇒ ex:Carmela rdf:type :Mother.
```
\[ \text{:DonCorleone} \quad \text{owl:equivalentClass} \quad \{ \text{ex:Vito} \quad \text{ex:Michael} \quad \text{ex:Vincent} \} \quad \Rightarrow \quad \text{ex:Vito} \quad \text{rdf:type} \quad \text{:DonCorleone} . \\
\Rightarrow \quad \text{ex:Michael} \quad \text{rdf:type} \quad \text{:DonCorleone} . \\
\Rightarrow \quad \text{ex:Vincent} \quad \text{rdf:type} \quad \text{:DonCorleone} . \]
ex:Michael rdf:type ex:DonCorleone .
\[ \forall \text{:hasParent} . \]

\[ \text{ex:Mary rdf:type :Person} ; \text{hasParent ex:Michael} . \]

\[ \text{:Person rdfs:subClassOf} \]

\[ [ \text{owl:allValuesFrom :Person ; owl:onProperty :hasParent} ] \]

\[ \Rightarrow \text{ex:Michael rdf:type :Person} . \]

:Parent owl:equivalentClass

[ owl:someValuesFrom :Person ; owl:onProperty :hasChild ]

⇒ ex:Mary rdf:type :Parent .
owl:someValuesFrom (ii)

\[ \exists \text{:Parent} \subseteq \exists \text{:_hasChild} \cdot \exists \text{:Person} ; \text{owl:onProperty} :\text{hasChild} \]

\[ \Rightarrow \text{ex:Mary :hasChild :_someone} ; \_:_\text{someone rdf:type :Person} . \]
Recap OWL class axioms

- A class :Parent might be the `owl:unionOf` what classes?

- A class :OnlySon might be the `owl:intersectionOf` what classes?

- What OWL feature allows to define enumerations?

- An example of `owl:allValuesFrom` for family relations?

- An example of `owl:someValuesFrom` for the class :Uncle?
RDFS
1. rdfs:subPropertyOf
2. rdfs:subClassOf
3. rdfs:domain
4. rdfs:range

OWL
1. Property Axioms
2. Equality
3. Class Axioms
...some OWL features not covered:

1. owl:hasKey
2. owl:hasValue
3. owl:cardinality(s)
4. owl:different
5. owl:AssymetricProperty
6. owl:IrreflexiveProperty
7. owl:propertyDisjointWith
8. …
But what does it all mean?
RDFS History

- Dan Brickley & R. V. Guha [2000]
- Pat Hayes [2004]
RDF(S) Semantics

- Built directly on top of RDF (Semantics)
- Given a mathematical model-theoretic semantics

http://ex.org/#aidan ... ...
RDF(S) Semantics: existential blank nodes

Called “simple entailment”
RDFS Semantics: RDFS rules / reasoning

Body/Antecedent/Condition  Head/Consequent

IF ⇒ THEN

?c₁ rdfs:subClassOf ?c₂ .
?x rdf:type ?c₁ .
⇒ ?x rdf:type ?c₂ .

ex:Tutor rdfs:subClassOf ex:Person .
ex:aidan rdf:type ex:Tutor .
⇒ ex:aidan rdf:type ex:Person .
# OWL History

- **Description Logics** [1980’s to now]
- **DAML (Hendler, McGuinness)** [2000]
- **OIL (Fensel, van Harmelen, McGuinness, Patel-, Frank van Harmelen)** [2001]
- **DAML+OIL** [2002]
- **OWL (W3C Rec.)** [2004]
- **OWL 2 (W3C Rec.)** [2008]
OWL Semantics

Much more complex language = Much more complex semantics

Direct Semantics

Considers Axioms:

\[
\text{Parent} \sqsubseteq \exists \text{hasChild}\cdot\text{Person}
\]

Restricted so that triples correspond to axioms

Decidable for OWL 2 DL (but super-exponential)

RDF-Based Semantics

Considers Triples:

\[
:\text{Parent} \text{rdfs:subClassOf} [\text{owl:someValuesFrom :Person ; owl:onProperty :hasChild}]
\]

Unrestricted

Undecidable
THAT’S RDFS/OWL … … NEXT UP…