



# An Introduction to Linked Data

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13/14 February 2009  
Austin, Texas

# Objectives

- Introduce the concept, principles, and key features of Linked Data
- Provide hands-on experience of creating Linked Data
- Provide a broad technical understanding of how to publish Linked Data
- Highlight some of the tools available for publishing and consuming Linked Data

# Schedule

- 09:00 Welcome and Introductions
- **09:15 Linked Data, What and Why?**
- **10:00 The Web of Data**
- 10:30 Coffee
- **11:00 Linked Data Hands-on**
- 12:30 Lunch
- **13:30 How to Publish Linked Data on the Web**
- 15:00 Coffee
- **15:30 Current Linked Data Applications**
- **16:00 Linked Data Toolbox**
- **16:30 Discussion**
- 17:00 Close

## Sponsors

- Organisation
- My time
- Coffee and lunch
- Tonight's beer



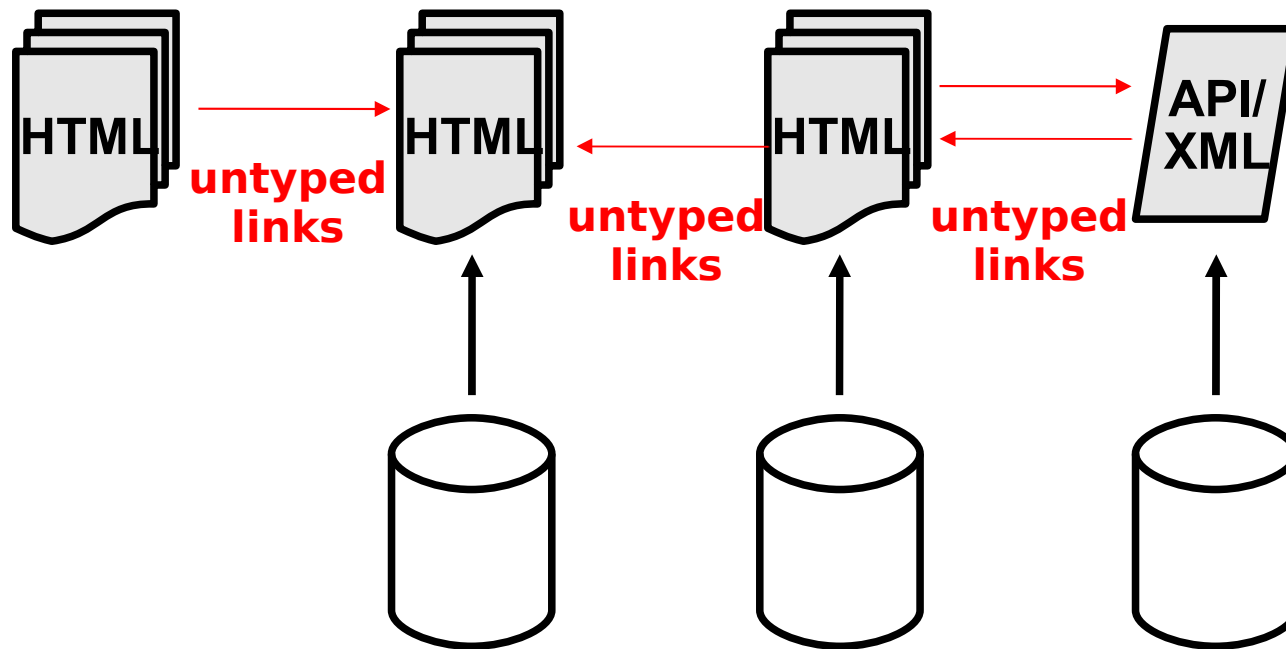
# Linked Data, What and Why?

# The Web of Documents

- Analogy
  - a global **filesystem**
- Designed for
  - **human** consumption
- Primary objects
  - **documents**
- Links between
  - **documents** (or sub-parts of)
- Degree of structure in objects
  - fairly **low**
- Semantics of content and links
  - **implicit**



# The Web of Linked Documents



# The Web of Documents: Issues

- Simplicity
  - Loosely structured data, untyped links, disconnected data
- Integration
  - Show me all the publications by publicly-funded PhD students
- Querying
  - Which papers have I written with people from European institutions outside the UK?

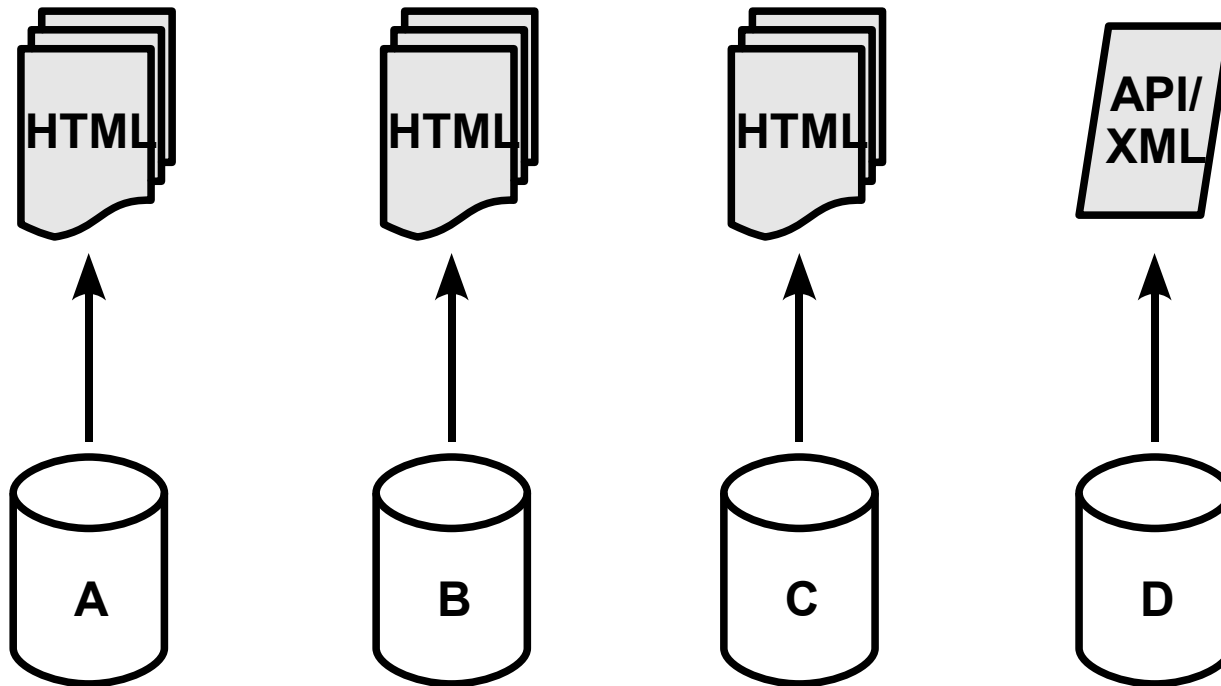




# Data Silos on the Web



# Data Silos on the Web



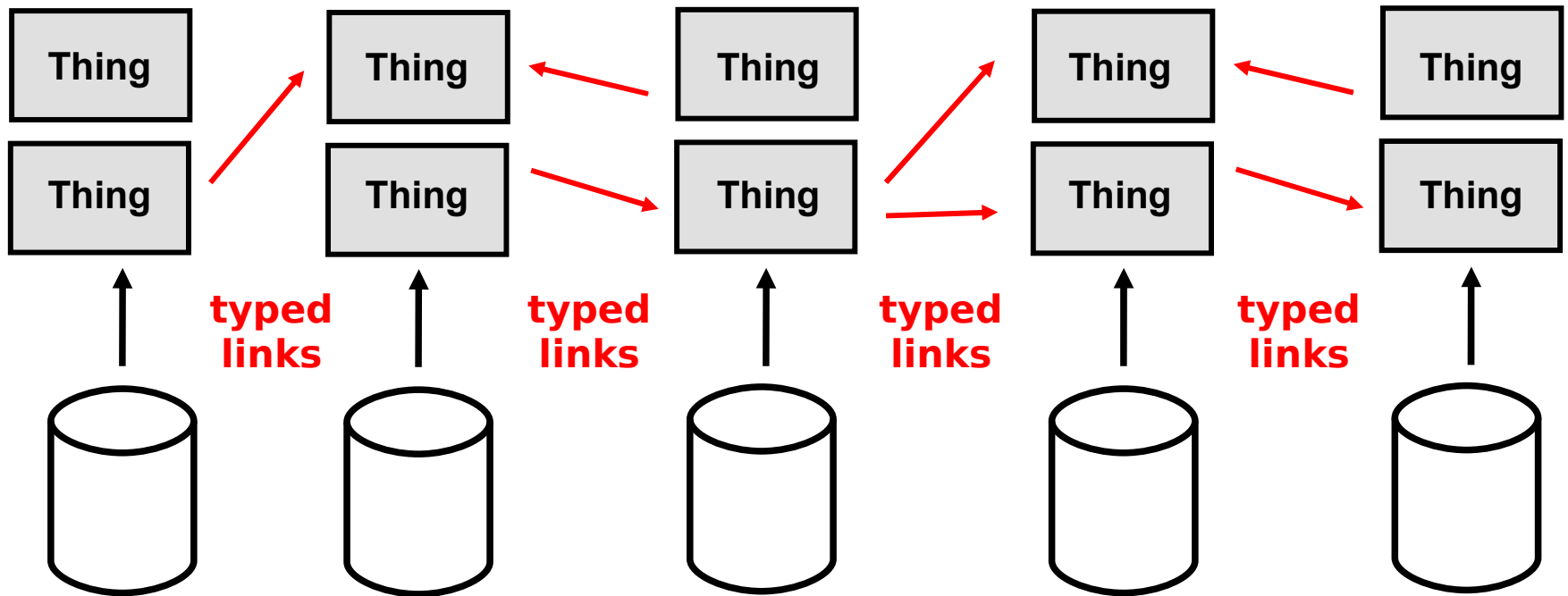
# The Web of Linked Data

- Analogy
  - a global **database**
- Designed for
  - **machines** first, **humans** later
- Primary objects
  - **things** (or **descriptions** of things)
- Links between
  - **things**
- Degree of structure in (descriptions of) things
  - **high**
- Semantics of content and links
  - **explicit**



# The Web of Linked Data

Don't just link the *documents*, link the *things*



## Linked Data is...

- ...a way of publishing data on the Web that:
  - encourages reuse
  - reduces redundancy
  - maximises its (real and potential) inter-connectedness
  - enables network effects to add value to data



# Linked Data Technology Stack

- URIs
- HTTP
- RDF
- (RDFS/OWL)

# URIs – Not Just for Web Pages

- “A Uniform Resource Identifier (URI) provides a simple and extensible means for identifying a resource.” -- RFC 3986
- Many different schemes: *http://*, *ftp://*, *tel:*, *urn:*, *mailto:*
- Some URIs for “real world” things:
  - <http://tomheath.com/id/me>
  - [http://dbpedia.org/resource/Talis\\_Group](http://dbpedia.org/resource/Talis_Group)
  - <http://sws.geonames.org/4671654/>



# HTTP

- Data access mechanism
- Using *http://* URIs to identify things allows people to look these things up



# RDF: Resource Description Framework

- Data format for describing things and their interrelations

# The RDF Data Model

- *Triples*

subject → predicate → object

*Tom → worksFor → Talis*

*Talis → basedIn → Birmingham*

<uri> → <uri> → <uri> or "literal"



## “Talis is Based Near Birmingham”

<[http://dbpedia.org/resource/Talis\\_Group](http://dbpedia.org/resource/Talis_Group)>

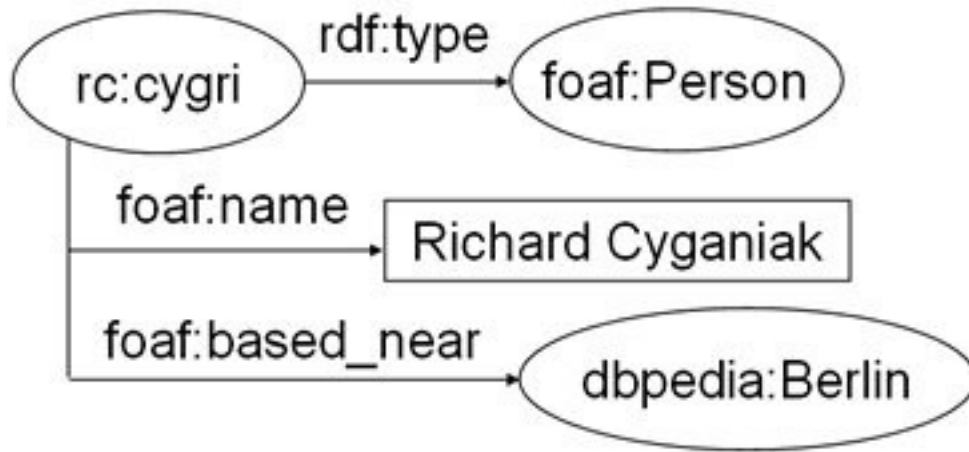
<[http://xmlns.com/foaf/0.1/based\\_near](http://xmlns.com/foaf/0.1/based_near)>

<<http://sws.geonames.org/3333125/>>

# Data Merging with RDF

- Mix schemas/vocabularies within one document
- Less painful data merging

# Data Merging with RDF



## Prefixes

rc: <<http://richard.cyganiak.de/foaf.rdf#>>

rdf: <<http://www.w3.org/1999/02/22-rdf-syntax-ns#>>

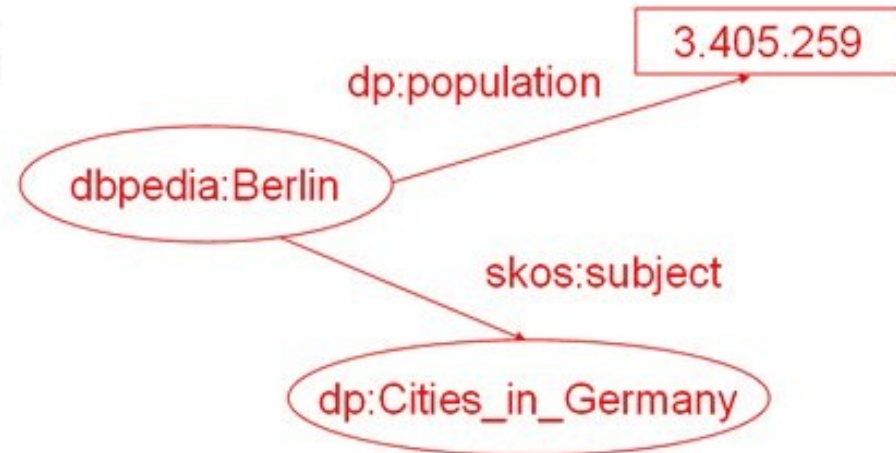
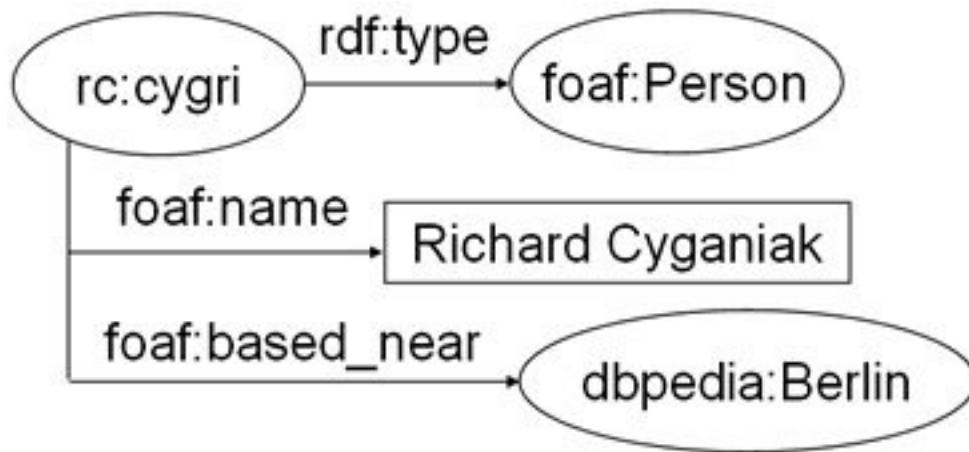
foaf: <<http://xmlns.com/foaf/0.1/>>

dbpedia: <<http://dbpedia.org/resource/>>

dp: <<http://dbpedia.org/property/>>

skos: <<http://www.w3.org/2004/02/skos/core#>>

# Data Merging with RDF



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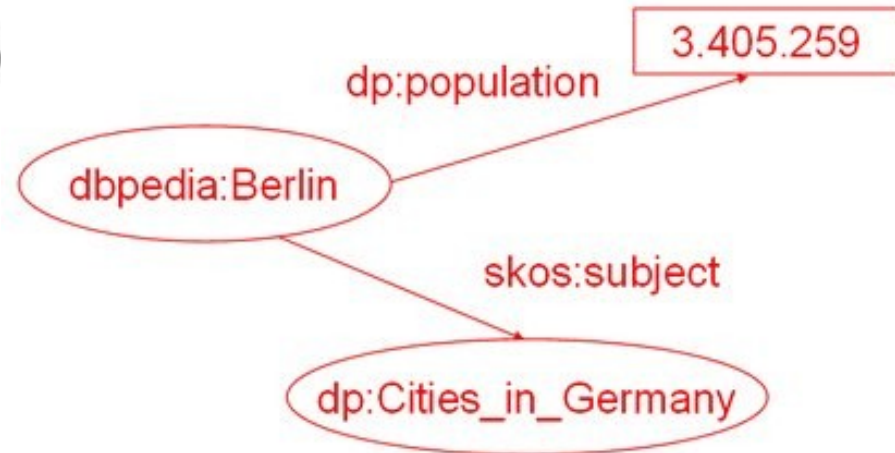
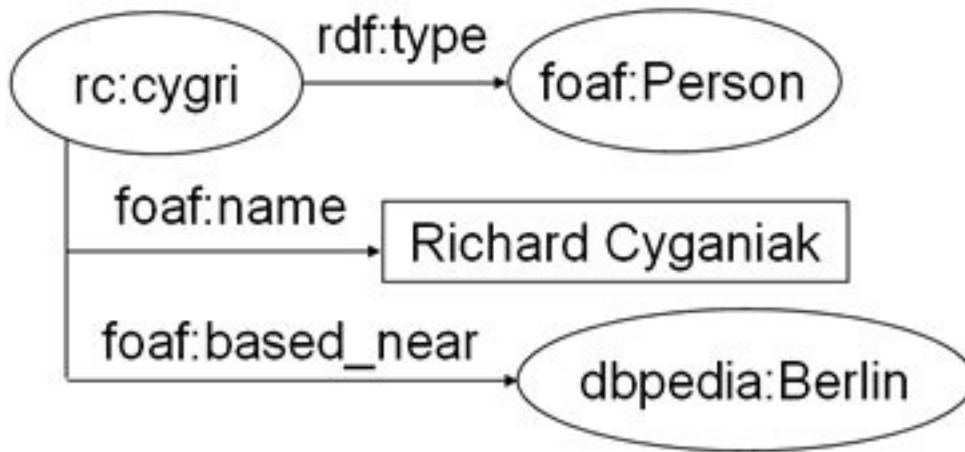
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# This is Linked Data



# Linked Data Principles

- Use URIs as names for things
  - anything, not just documents
  - you are not your homepage
  - information resources and non-information resources
- Use HTTP URIs
  - globally unique names, distributed ownership
  - allows people to look up those names
- Provide useful information in RDF
  - when someone looks up a URI
- Include RDF links to other URIs
  - to enable discovery of related information



# Why Publish Linked Data?

- Ease of discovery
- Ease of consumption
  - standards-based data sharing
- Reduced redundancy
- Added value
  - build ecosystems around your data/content



# The Web of Data

# The Linking Open Data Project



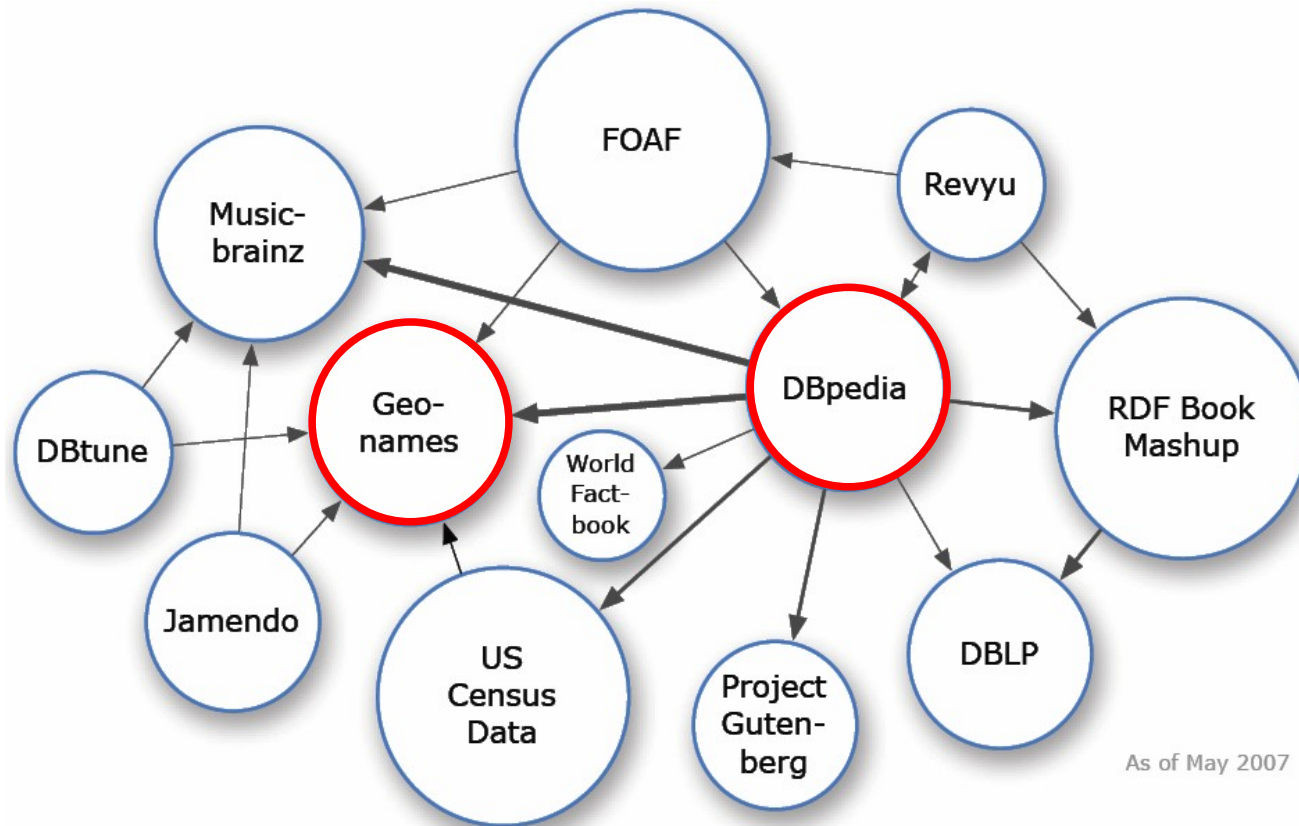
# The Linking Open Data Project

- Community project with W3C support
- Take existing open data sets
- Make them available on the Web in RDF
- Interlink them with other data sets
- Began early 2007

# Participants

- Massachusetts Institute of Technology (US)
- University of Southampton (UK)
- Freie Universität Berlin (DE)
- DERI (IE)
- KMi, Open University (UK)
- University of London (UK)
- Universität Hannover (DE)
- University of Pennsylvania (US)
- Universität Leipzig (DE)
- Universität Karlsruhe (DE)
- Joanneum (AT)
- University of Toronto (CA)
- BBC (UK)
- Talis (UK)
- Garlik (UK)
- OpenLink (UK)
- Thomson Reuters (US)
- Zitgist (US)
- Mondeca (FR)
- Cyc Foundation (US)

# The LOD "Cloud" - May 2007





Map center : N 52° 28' 48" W 1° 53' 40"



## GeoNames Wikipedia

- features
- ☒ city, village, ...
  - ☒ mountain, hill, rock, ...
  - ☒ stream, lake, ...
  - ☒ country, state, region, ...
  - ☒ parks, area, ...
  - ☒ road, railroad
  - ☒ spot, building, farm
  - ☒ forest, heath, ...
  - ☒ undersea



Name	country	feature	km to center
1  City and Borough of Birmingham	United Kingdom	third-order administrative division	0.26 km
2  Comfort Inn Birmingham	United Kingdom	hotel	0.49 km
3  New Street Station	United Kingdom	railroad station	0.51 km
4  Snow Hill Station	United Kingdom	railroad station	0.51 km
5  Holiday Inn Birmingham City Centre	United Kingdom	hotel	0.58 km
6  Malmaison Birmingham	United Kingdom	hotel	0.7 km
7  Moor Street Station	United Kingdom	railroad station	0.84 km
8  Nitenite Birmingham Ltd	United Kingdom	hotel	0.87 km
9  The International Convention Centre	United Kingdom	community center	1.09 km
10  Brasshouse	United Kingdom	school	1.41 km
11  Worcester and Birmingham Canal	United Kingdom	canal	1.54 km





- navigation
- Main page
  - Contents
  - Featured content
  - Current events
  - Random article
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- interaction
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  - Community portal
  - Recent changes
  - Contact Wikipedia
  - Donate to Wikipedia
  - Help

- toolbox
- What links here
  - Related changes
  - Upload file
  - Special pages
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  - Permanent link
  - Cite this page
- languages
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  - العربية
  - Avañe'ẽ
  - Aymar aru
  - Bosanski
  - Български
  - Català
  - Чӕвашна
  - Česky
  - Cymraeg
  - Dansk
  - Deutsch
  - Eesti
  - Ελληνικά
  - Español
  - Esperanto

## Birmingham

From Wikipedia, the free encyclopedia

Coordinates: 52°29′1″N 1°54′23″W﻿ / ﻿

*This article is about the city in England. For the U.S. city named after it, see [Birmingham, Alabama](#). For other uses, see [Birmingham \(disambiguation\)](#).*

**Birmingham** (pronunciation (help·info), /ˈbɜːrmɪŋəm/ *BIRR-ming-əm*) is a city and metropolitan borough in the West Midlands county of England. Birmingham is the most populous of England's core cities, and is the second most populated British city after London, with a population of 1,010,200 (2005 estimate). Often considered to be the *second city of the United Kingdom*<sup>[2]</sup>, the City of Birmingham forms part of the larger West Midlands conurbation, which has a population of 2,284,093 (2001 census)<sup>[3]</sup> and includes several neighbouring towns and cities, such as Solihull, Wolverhampton and the towns of the Black Country.

The city's reputation was forged as a powerhouse of the Industrial Revolution in England, a fact which led to Birmingham being known as "the workshop of the world" or the "city of a thousand trades".<sup>[4]</sup> Although Birmingham's industrial importance has declined, it has developed into a national commercial centre, being named as the third best place in the United Kingdom to locate a business, and the 21st best in Europe by Cushman & Wakefield in 2007.<sup>[5]</sup> It is also the fourth most visited city by foreign visitors in the UK.<sup>[6]</sup> In 1998, Birmingham hosted the G8 summit at the International Convention Centre, on the site of Bingley Hall, the world's first purpose-built exhibition hall, and remains a popular location for conventions today along with the National Exhibition Centre in nearby Solihull.<sup>[7]</sup> In 2007, Birmingham was ranked as the 55th most livable city in the world, according to the Mercer Index of worldwide standards of living.<sup>[8]</sup>

People from Birmingham are known as 'Brummies', a term derived from the city's nickname of *Brum*. This comes in turn from the city's dialect name, *Brummagem*,<sup>[9]</sup> which is derived from one of the city's earlier names, 'Bromwicham'. There is a distinctive Brummie dialect and accent, both of which differ from the adjacent Black Country.

### Contents [hide]

- History
- Geography
  - 2.1 Geology
  - 2.2 Climate
  - 2.3 Nearby places
- Demographics
- Places of interest
- Economy
- Politics
- Transport
- Education
- Sport
- Food & drink
- Culture and arts
  - 11.1 Arts
  - 11.2 Festivals and shows
  - 11.3 Media
  - 11.4 Leisure
  - 11.5 Architecture
- Environment
- Crime and policing
- Second City
- Notable residents
- Science and invention

### Birmingham

— City and Metropolitan borough —

City of Birmingham



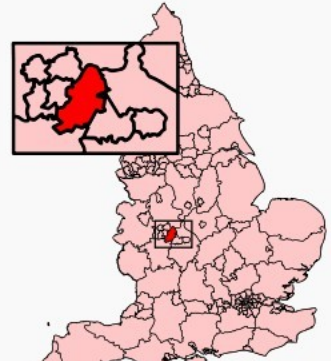
Birmingham's skyline viewed from Bartley Green



Coat of Arms of the City Council

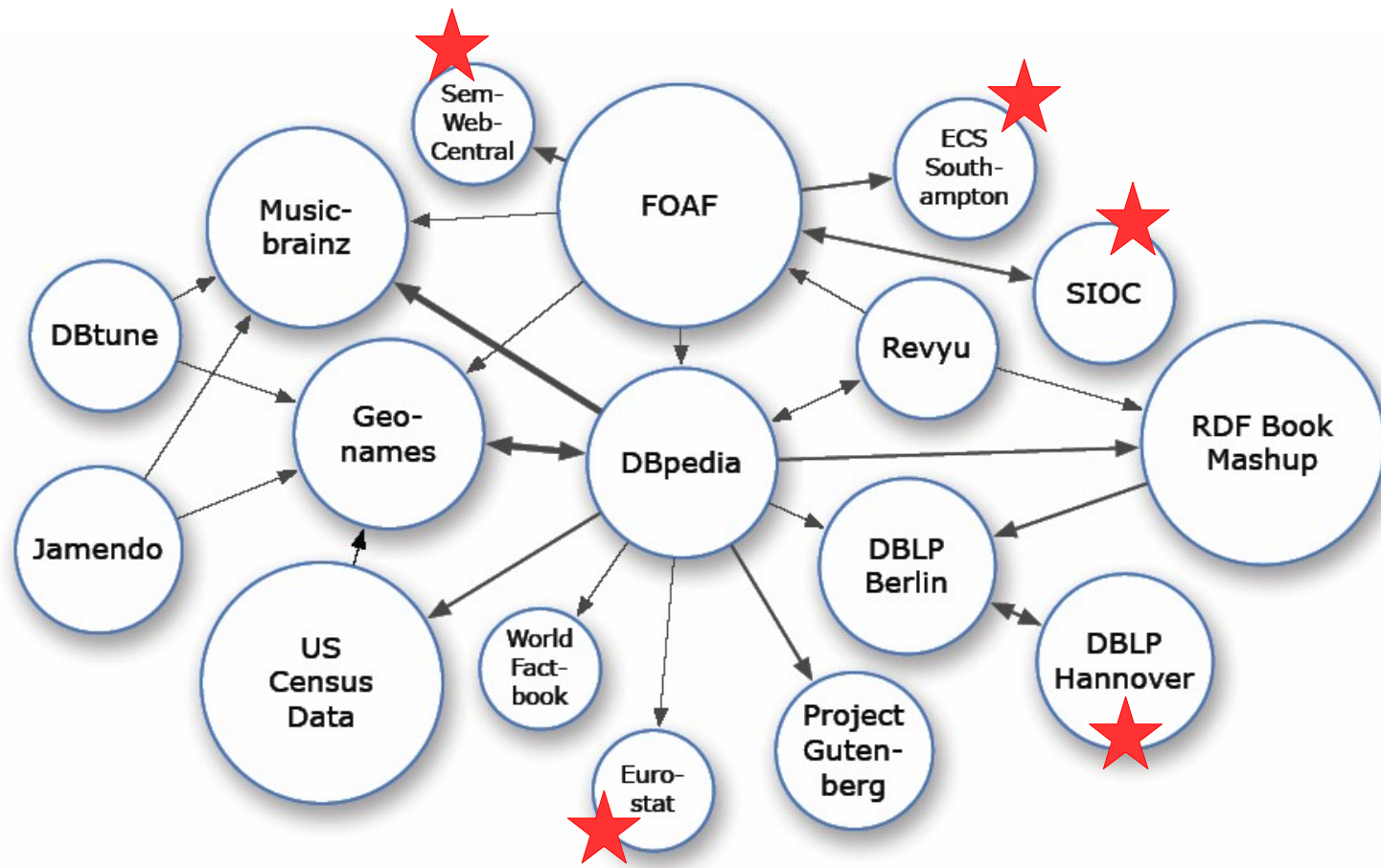
Nickname(s): "Brum", "Brummagem", "Second City", "Workshop of the World", "City of a Thousand Trades", "Canal City"

Motto: Forward

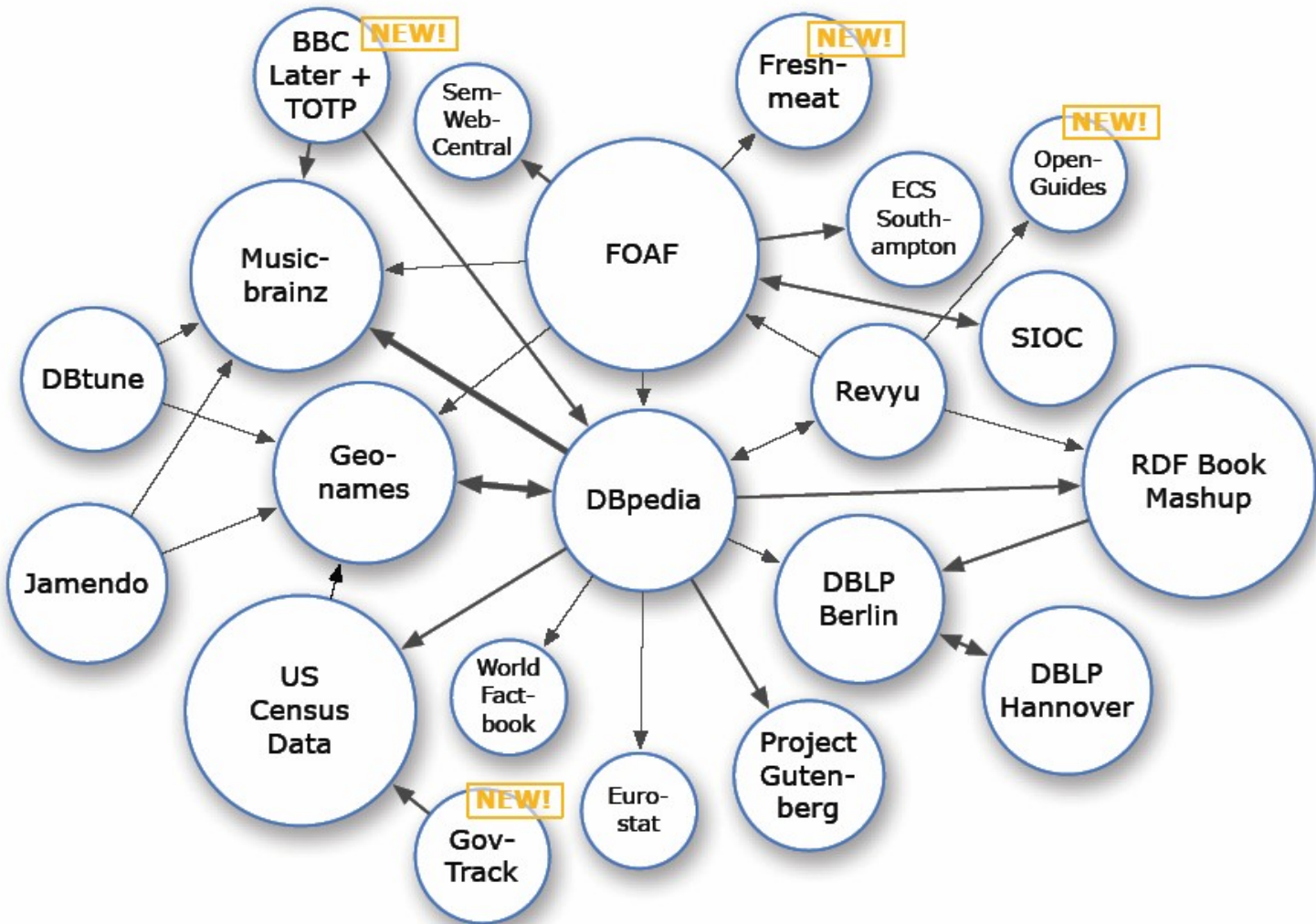




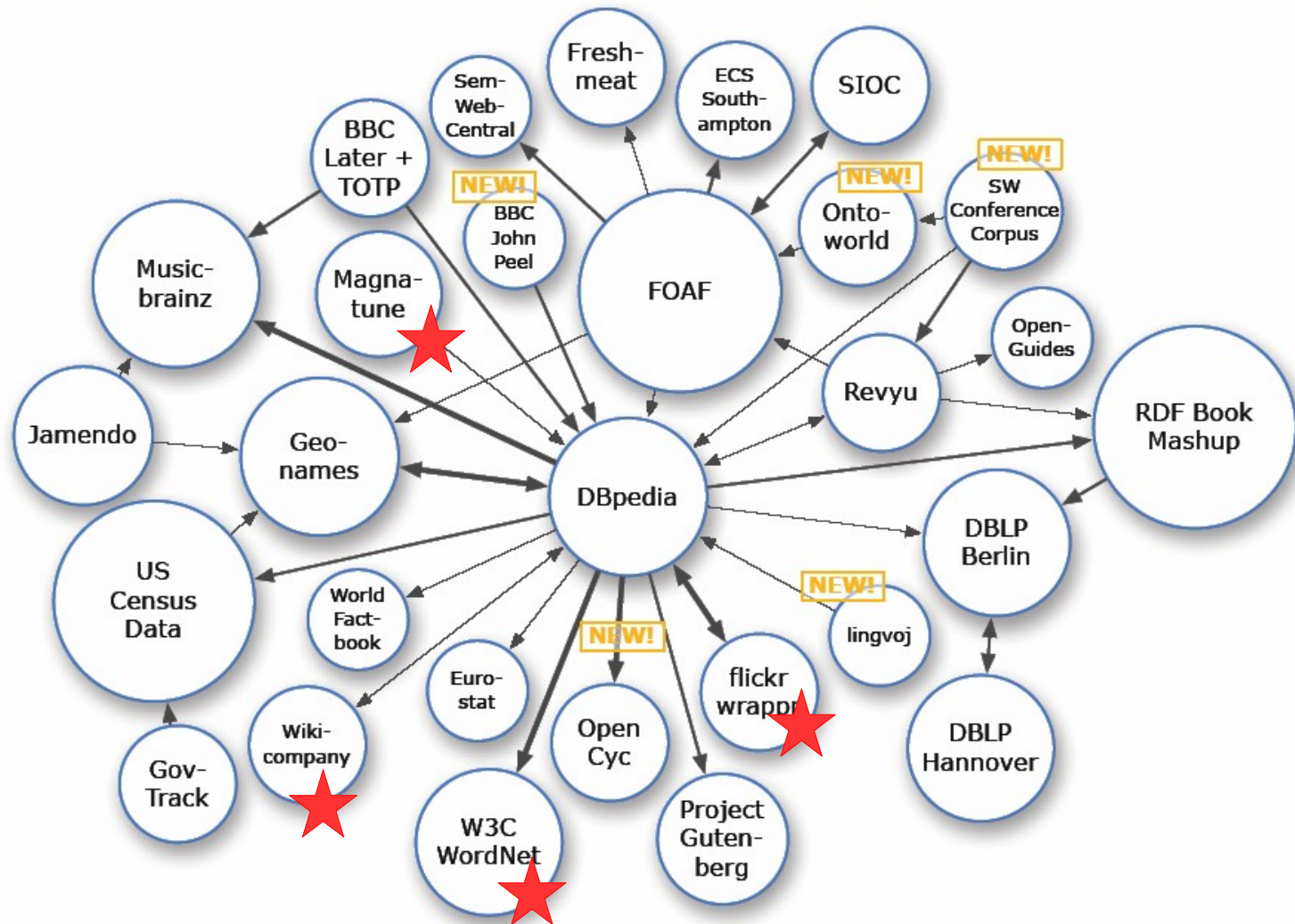
# The LOD "Cloud" - July 2007



# The LOD "Cloud" - August 2007

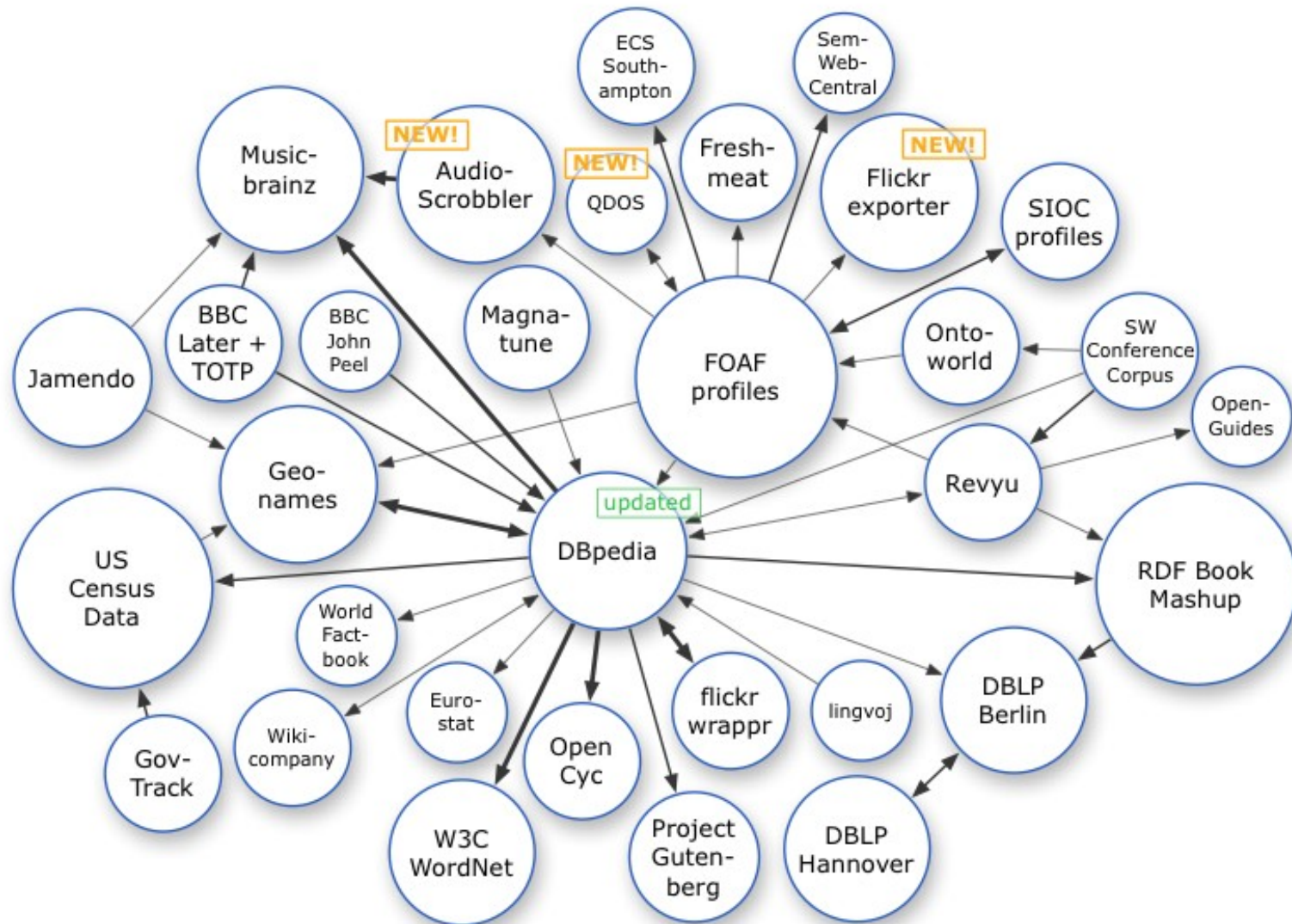


# The LOD "Cloud" - November 2007

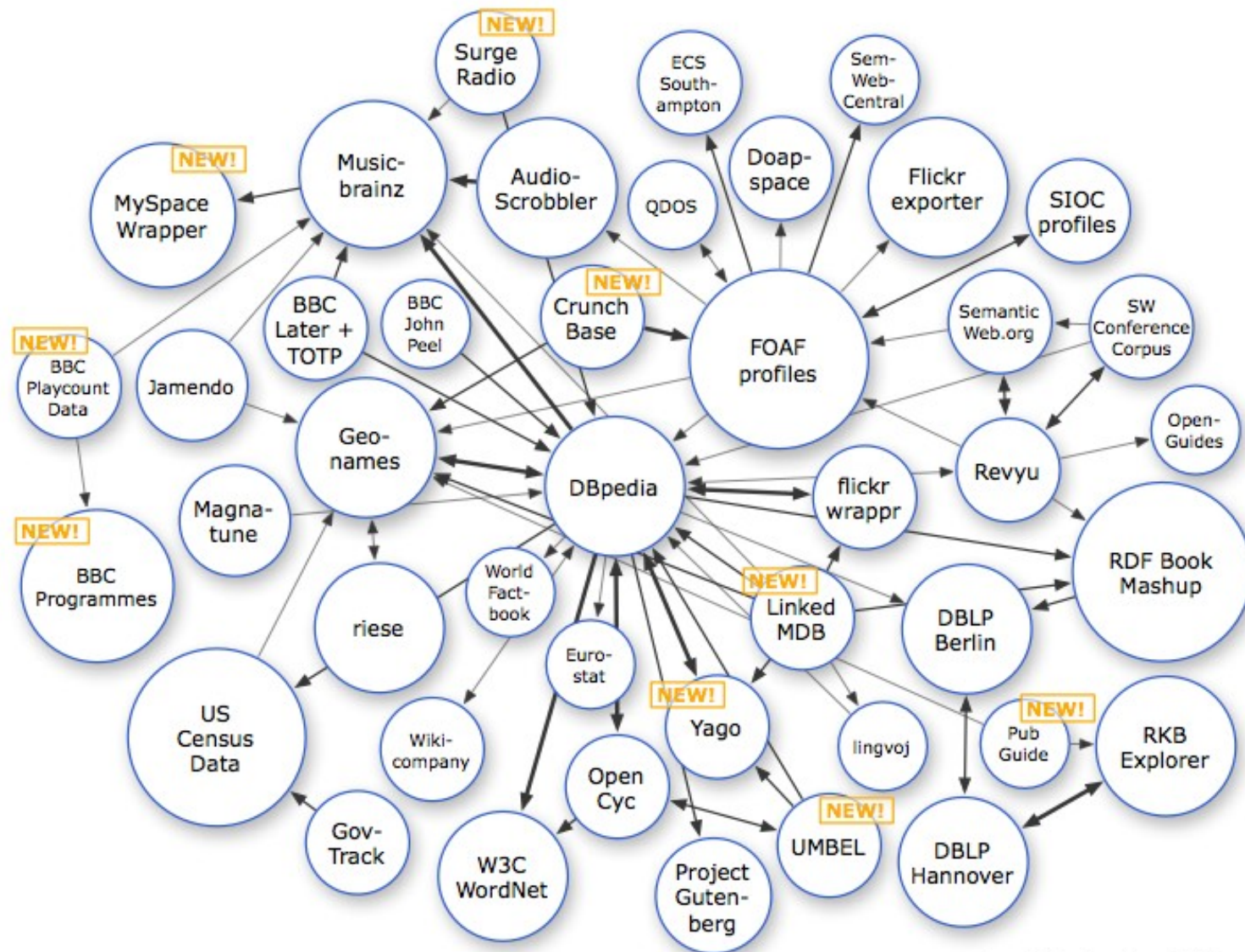




# The LOD "Cloud" – Feb 2008



# The LOD "Cloud" – Sept 2008



# **Linked Data Hands-On: Pimp Your FOAF**

# FOAF: Friend of a Friend

- An RDF vocabulary for describing people:
  - identities
  - interests
  - affiliations
  - social networks
  - etc

# Pimp Your FOAF

- Hands-on Exercise
- Create a basic FOAF file
- Enhance it with Linked Data
- Prizes for the best pimping
  - number of links, accuracy, diversity...



# Pimp Your FOAF: Instructions

## 1. Create yourself a FOAF file

- <http://www.ldodds.com/foaf/foaf-a-matic>
- name your file *yourname.rdf*

## 2. Upload it

- <ftp://playground.linkeddata.org>
- user: \*\*\*\*\*, pass: \*\*\*\*\*
- validate it: <http://www.w3.org/RDF/Validator/>

## 3. Explore the cloud

- <http://linkeddata.org/images-and-posters>

## 4. Create as much Linked Data in your FOAF as you can

- Look for predicates:
  - <http://xmlns.com/foaf/spec/>
  - <http://schemaweb.info/>

## 5. Browse it using e.g. *Marbles*

- <http://beckr.org/marbles>



# Pimp Your FOAF: Prizes!

# How to Publish Linked Data on the Web

## Scenario

- Online whisky shop: *Wiskii.com*
- New business venture, founded by *Jeff*
- For the whisky connoisseur
- Detailed background information from experts
- Contributions from customers
- Custom web app, relational backend
- Simultaneous publication in HTML and RDF

# 5 Steps to Publishing Linked Data

1. Understand the Principles
2. Understand your Data
3. Choose URIs for Things in your Data
4. Setup Your Infrastructure
5. Link to other Data Sets

# 1. Understand the Principles

# Linked Data Principles: Redux

- Use URIs as names for things
  - anything, not just documents
  - you are not your homepage
  - information resources and non-information resources
- Use HTTP URIs
  - globally unique names, distributed ownership
  - allows people to look up those names
- Provide useful information in RDF
  - when someone looks up a URI
- Include RDF links to other URIs
  - to enable discovery of related information



## **2. Understand your Data**





## 2. Understand Your Data

- What are the key things present in your data?
  - People?
  - Places?
  - Books?
  - Films?
  - Musicians?
  - Concepts?
  - Photos?
  - Comments?
  - Reviews?
  - ...

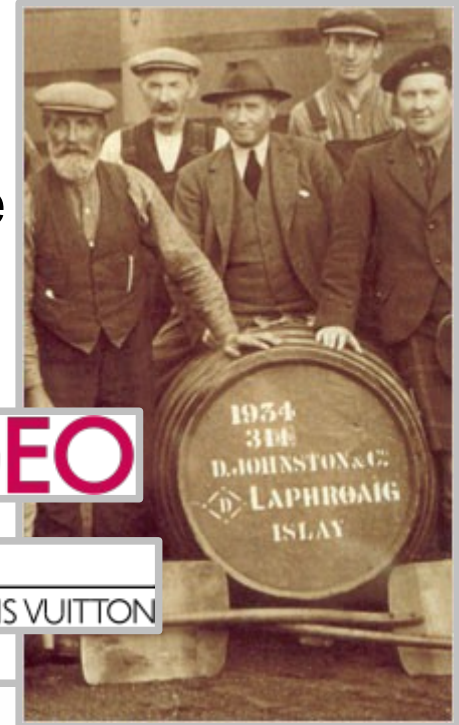
## 2. Understand Your Data

- Things in the *Wiskii.com* database
  - Distilleries
  - Regions and Locations
  - Founders
  - Owners
  - Brands
  - Products
  - Photos
  - Reviews
  - Comments
  - Prices/Offers

**DIAGEO**

LVMH

MOËT HENNESSY • LOUIS VUITTON



## 2. Understand Your Data

- What vocabularies can be used to describe these?
  - Principles
    - Reuse, don't reinvent
    - Mix liberally
  - Potential Ontologies/Vocabularies
    - Geo
    - GoodRelations
    - FOAF
    - Review
    - SIOC
    - Whisky



### **3. Choose URIs for Things in Your Data**

## 3. Choosing URIs: Principles

- Use HTTP URIs
- Keep out of other peoples' namespaces
  1. <http://www.imdb.com/title/tt0441773/>
  2. <http://www.imdb.com/title/tt0441773/thing>
  3. <http://myfilms.com/tt0441773>
  4. <http://myfilms.com/tt0441773/html>
- Abstract away from implementation details
  1. <http://dbpedia.org/resource/Berlin>
  2. <http://www4.wiwiss.fu-berlin.de:2020/demos/dbpedia/cgi-bin/resources.php?id=Berlin>
- Hash or Slash
  1. <http://mydomain.com/foaf.rdf#me>
  2. <http://mydomain.com/id/me>

## 3. Choosing URIs: Common Patterns

- [http://dbpedia.org/resource/New\\_York\\_City](http://dbpedia.org/resource/New_York_City) ← Thing
- [http://dbpedia.org/data/New\\_York\\_City](http://dbpedia.org/data/New_York_City) ← RDF data
- [http://dbpedia.org/page/New\\_York\\_City](http://dbpedia.org/page/New_York_City) ← HTML page
  
- <http://revyu.com/people/tom> ← Thing
- <http://revyu.com/people/tom/about/rdf> ← RDF data
- <http://revyu.com/people/tom/about/html> ← HTML page
  
- <http://kmi.open.ac.uk/people/tom/> ← Thing
- <http://kmi.open.ac.uk/people/tom/rdf> ← RDF data
- <http://kmi.open.ac.uk/people/tom/html> ← HTML page
  
- <http://mydomain.com/thing> ← Thing
- <http://mydomain.com/thing.rdf> ← RDF data
- <http://mydomain.com/thing.html> ← HTML page



### 3. Choosing URIs: Wiskii.com

- <http://wiskii.com/regions/speyside>
- <http://wiskii.com/distilleries/talisker>
- <http://wiskii.com/brands/talisker>
- <http://wiskii.com/products/talisker-20-yo>
- <http://wiskii.com/products/glenmorangie-lasanta>
- <http://wiskii.com/people/william-matheson>
- <http://wiskii.com/photos/58>
- <http://wiskii.com/reviews/271>

## 3. Choosing URIs: Wiskii.com

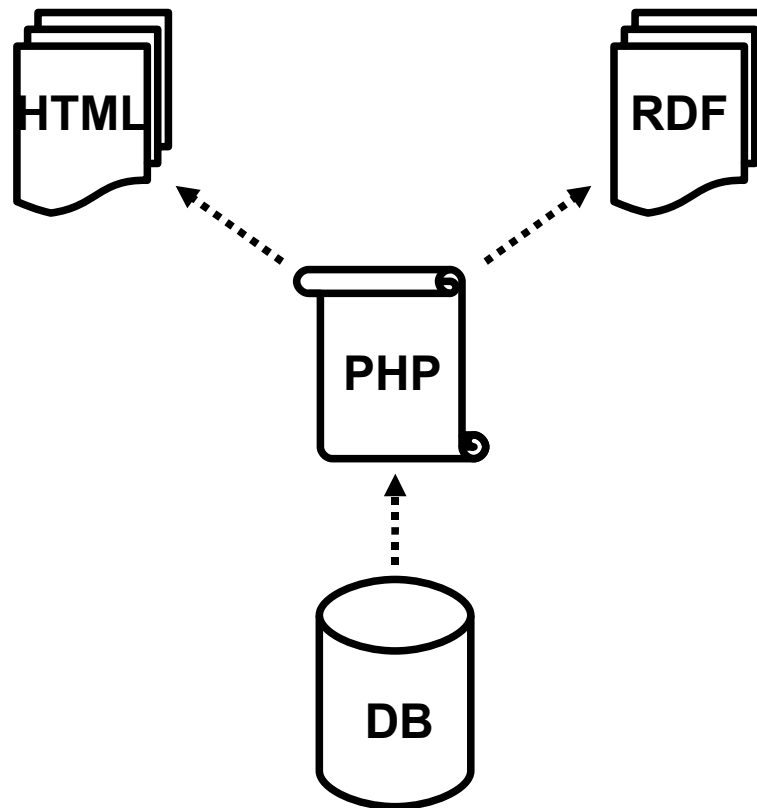
- <http://wiskii.com/distilleries/talisker>
- <http://wiskii.com/distilleries/talisker/rdf>
- <http://wiskii.com/distilleries/talisker/html>
- <http://wiskii.com/brands/talisker>
- <http://wiskii.com/brands/talisker/rdf>
- <http://wiskii.com/brands/talisker/html>
- <http://wiskii.com/people/william-matheson>
- <http://wiskii.com/people/william-matheson/rdf>
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- <http://wiskii.com/photos/58>



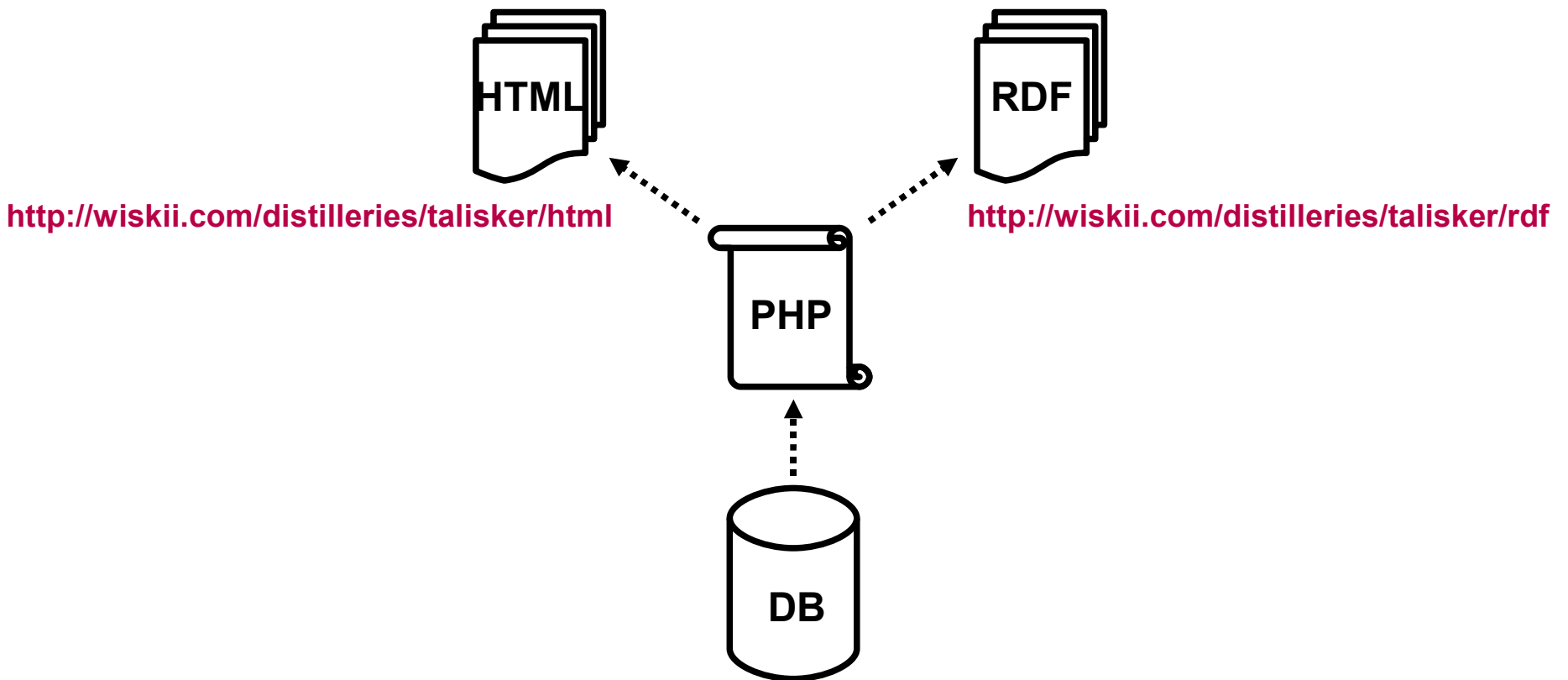


## **4. Setup Your Infrastructure**

## 4. Setup Your Infrastructure

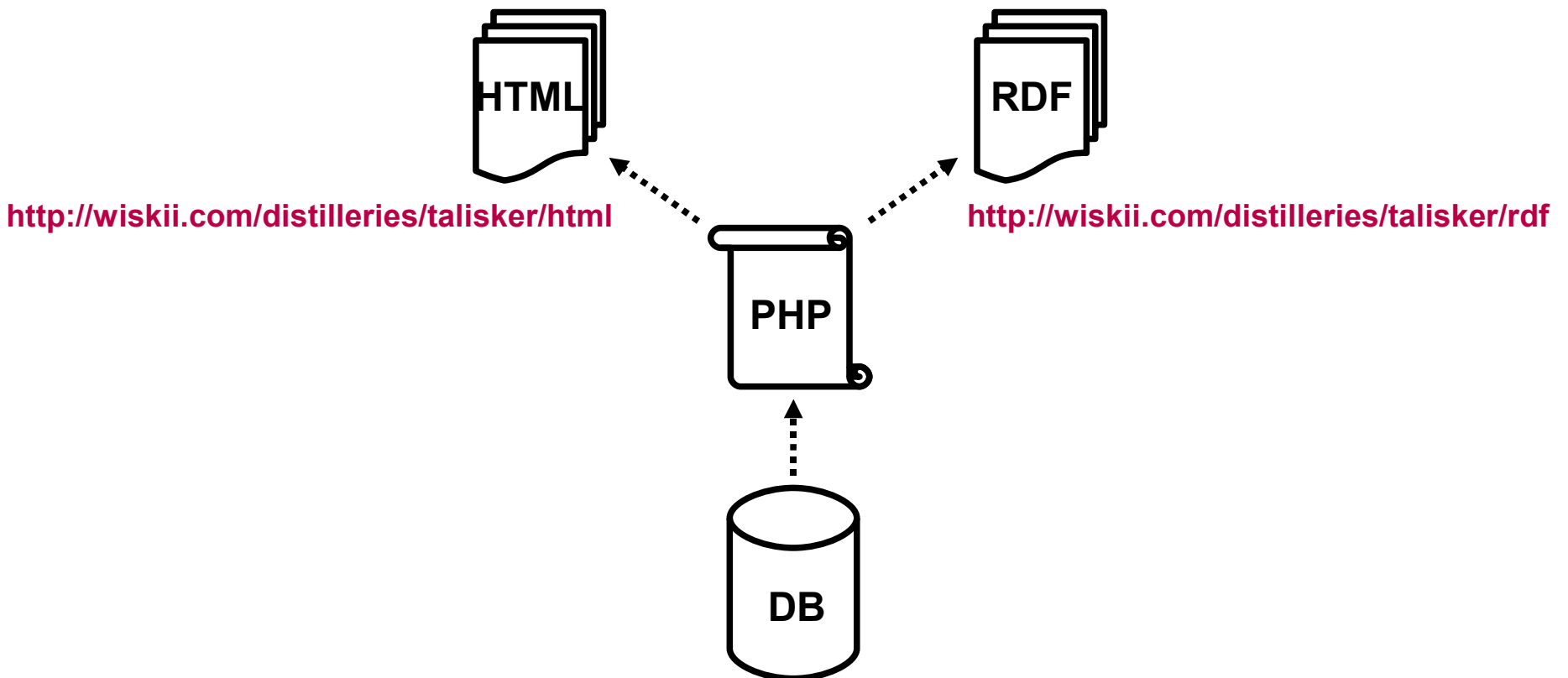


## 4. Setup Your Infrastructure

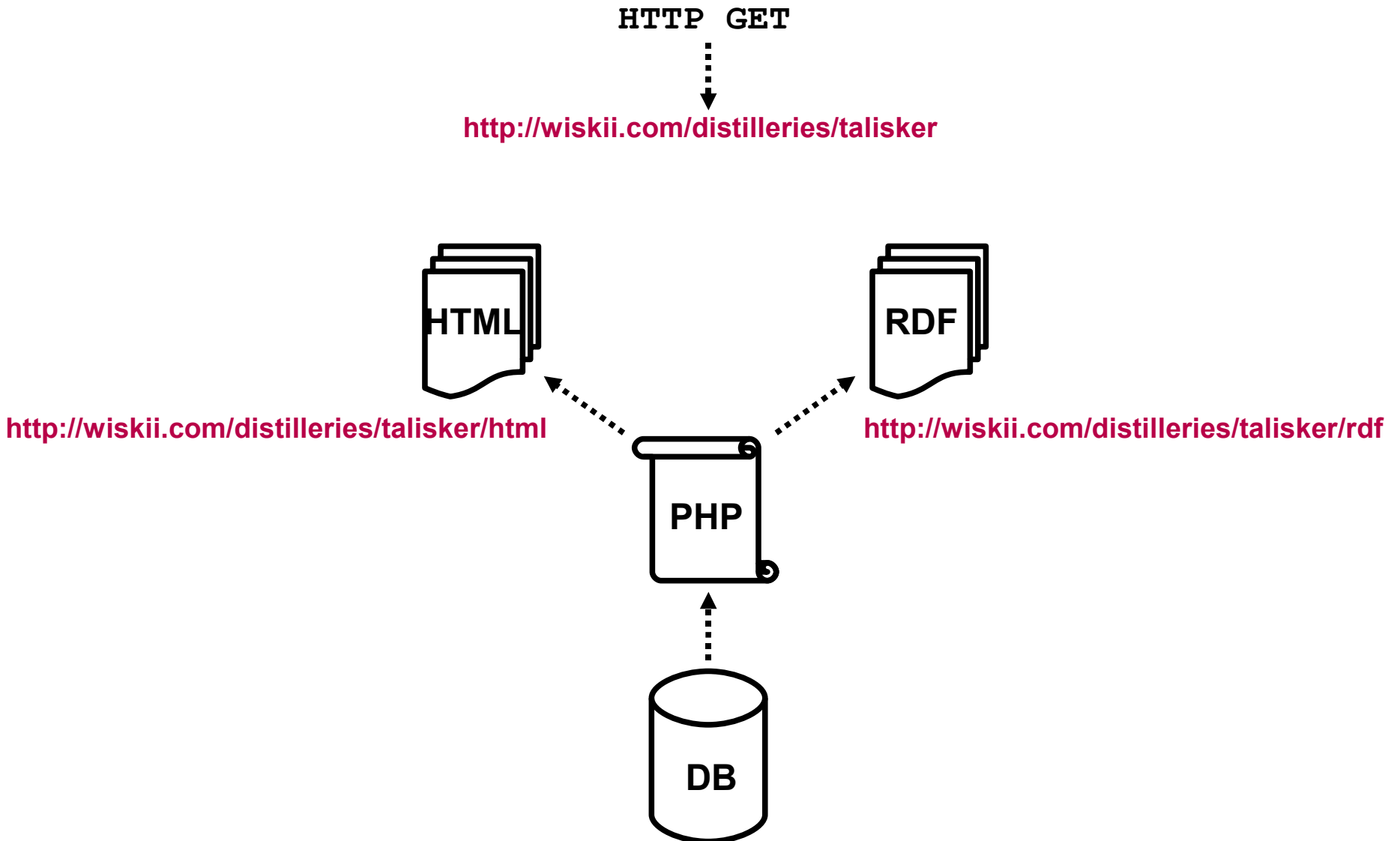


## 4. Setup Your Infrastructure

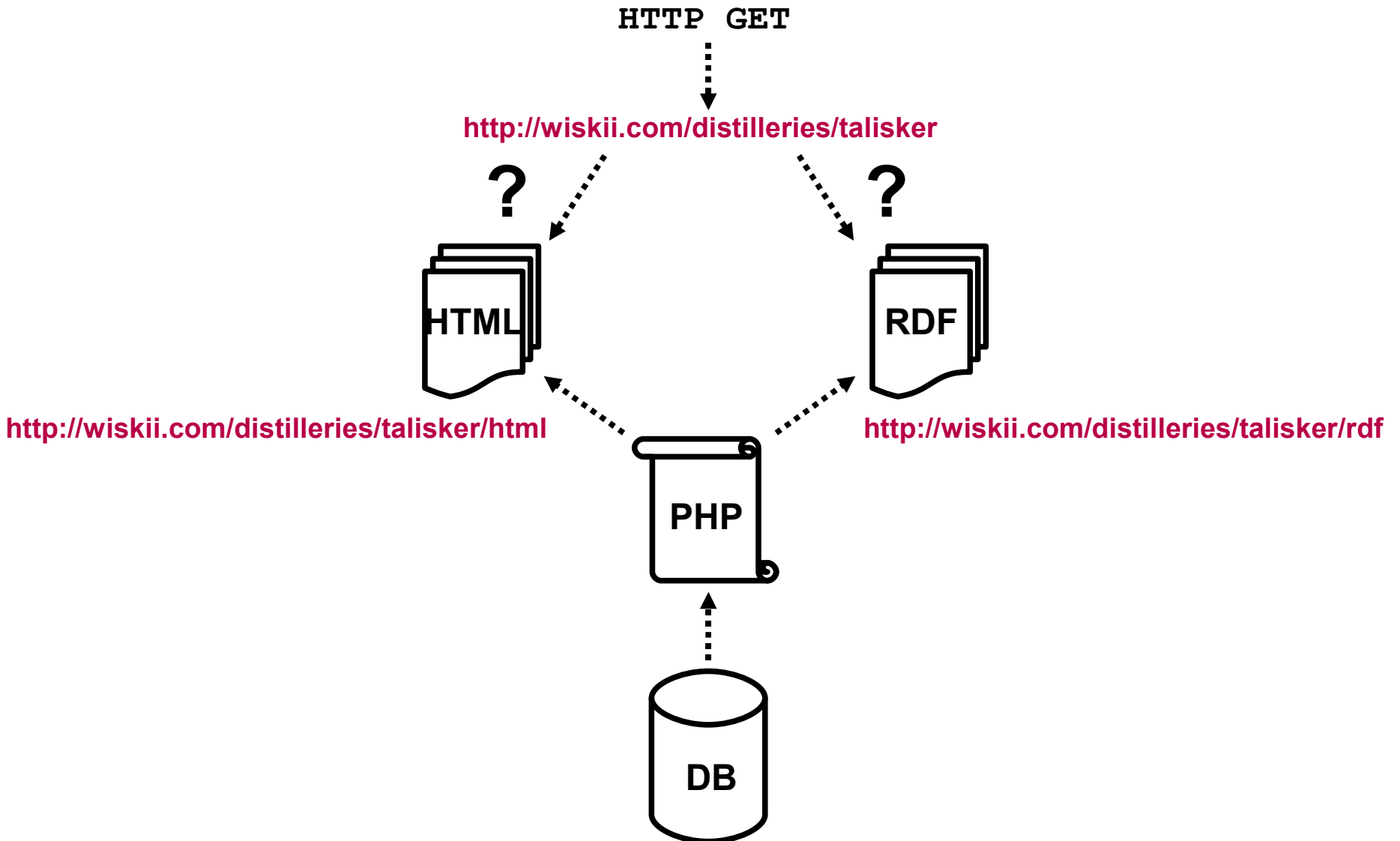
<http://wiskii.com/distilleries/talisker>



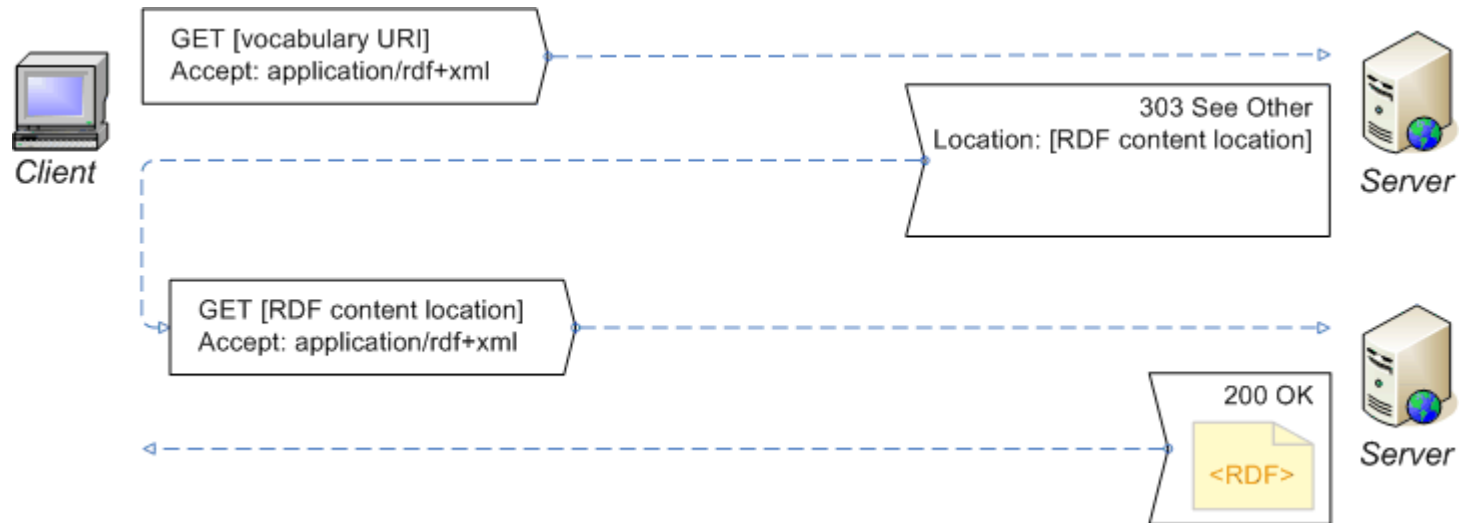
## 4. Setup Your Infrastructure



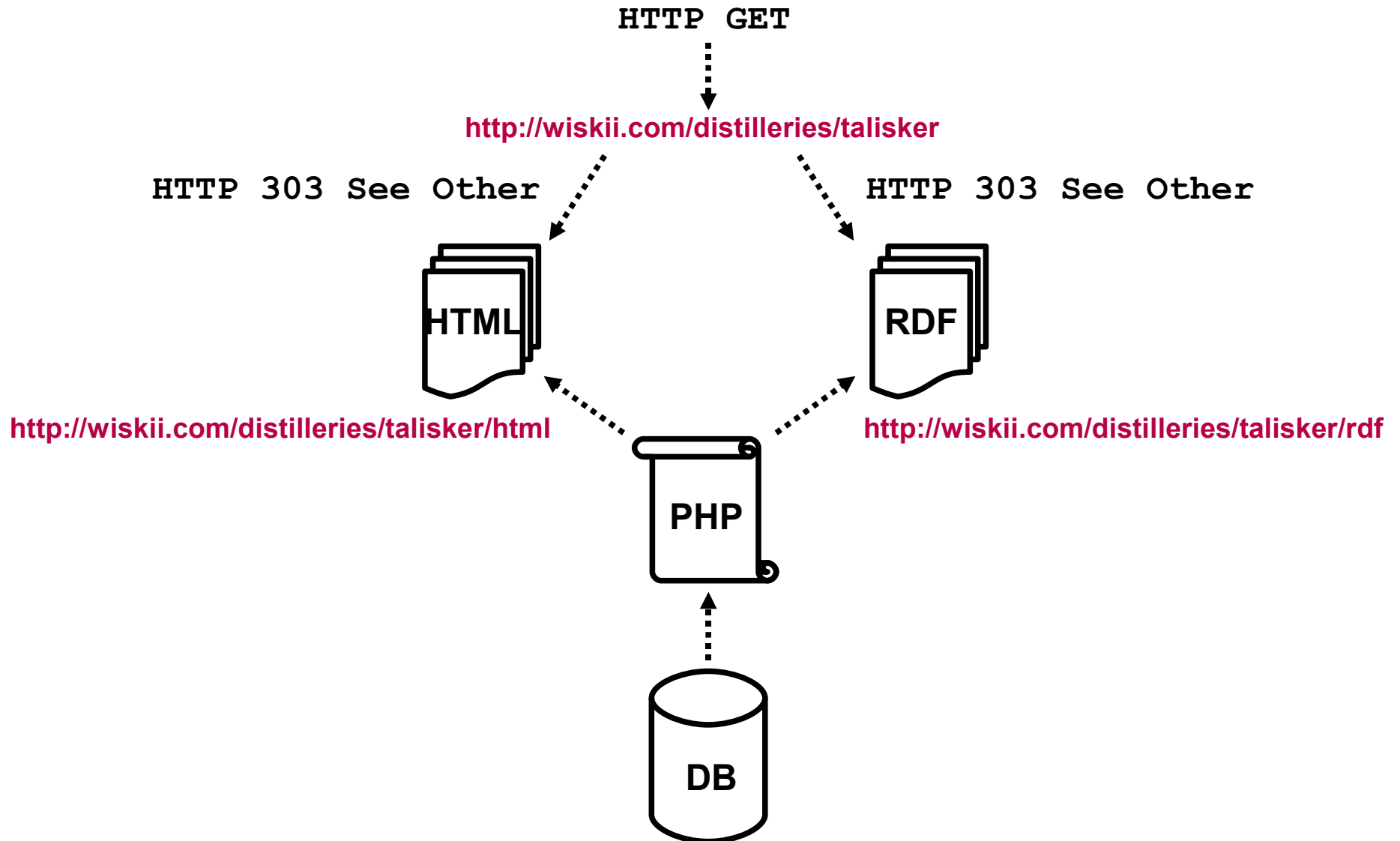
## 4. Setup Your Infrastructure



# Content Negotiation



## 4. Setup Your Infrastructure





## 4. Setup Your Infrastructure

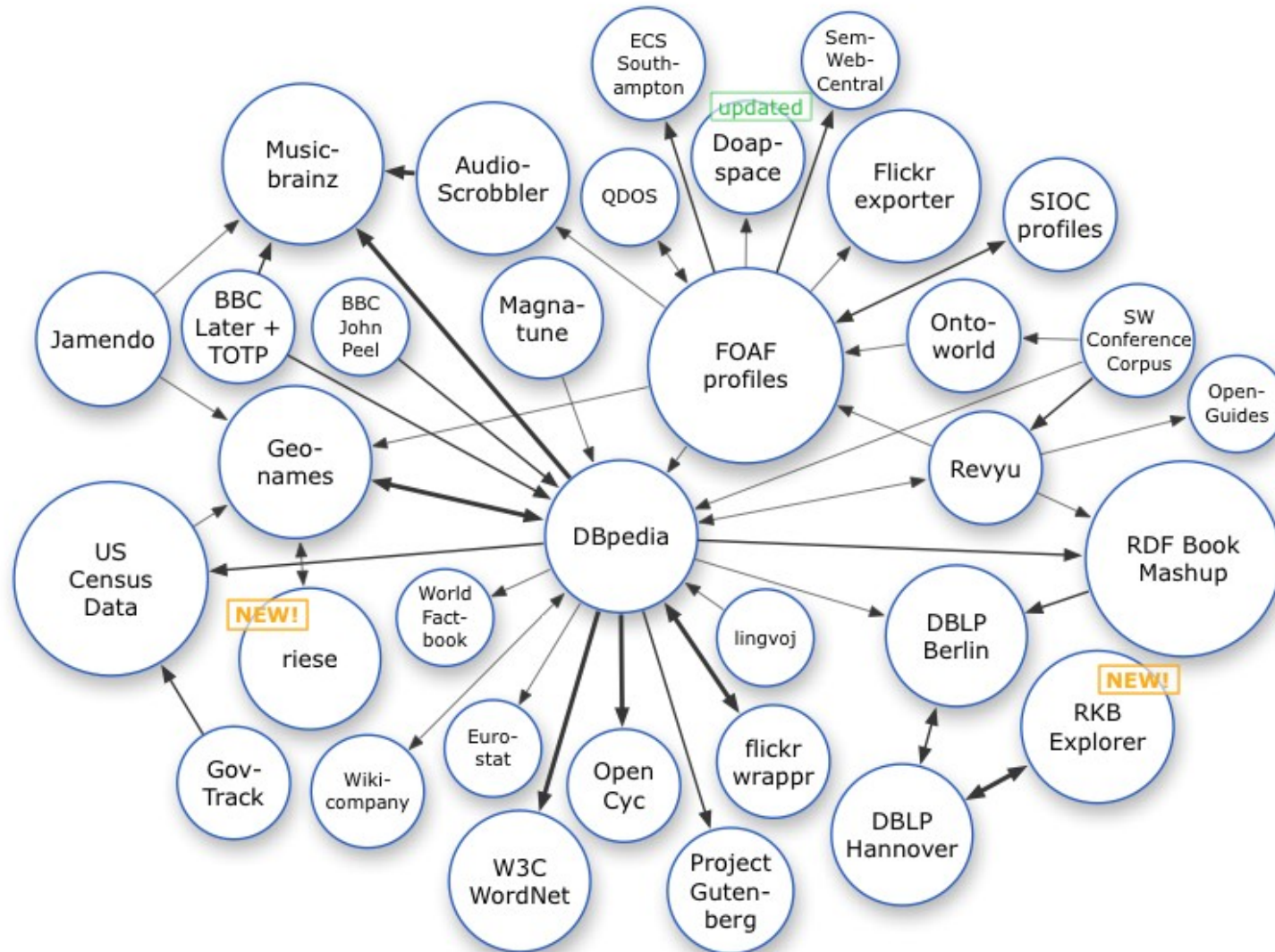
- Testing your content negotiation
  - Install the LiveHTTPHeader and Modify Headers extensions for Firefox
  - Try LiveHTTPHeader against my URI
    - <http://tomheath.com/id/me>
    - do the same with URIs from other data sets
  - Modify your headers to ask for application/rdf+xml
  - What do you get back?
  - Do the same with cURL
    - <http://dowhatimean.net/2007/02/debugging-semantic-web-sites-with-curl>

## 4. Setup Your Infrastructure

- Rolling your own is not the only option
- See Linking Open Data area of the ESW Wiki
  - <http://esw.w3.org/topic/TaskForces/CommunityProjects/LinkingOpenData/PublishingTools>

## **5. Link to Other Data Sets**

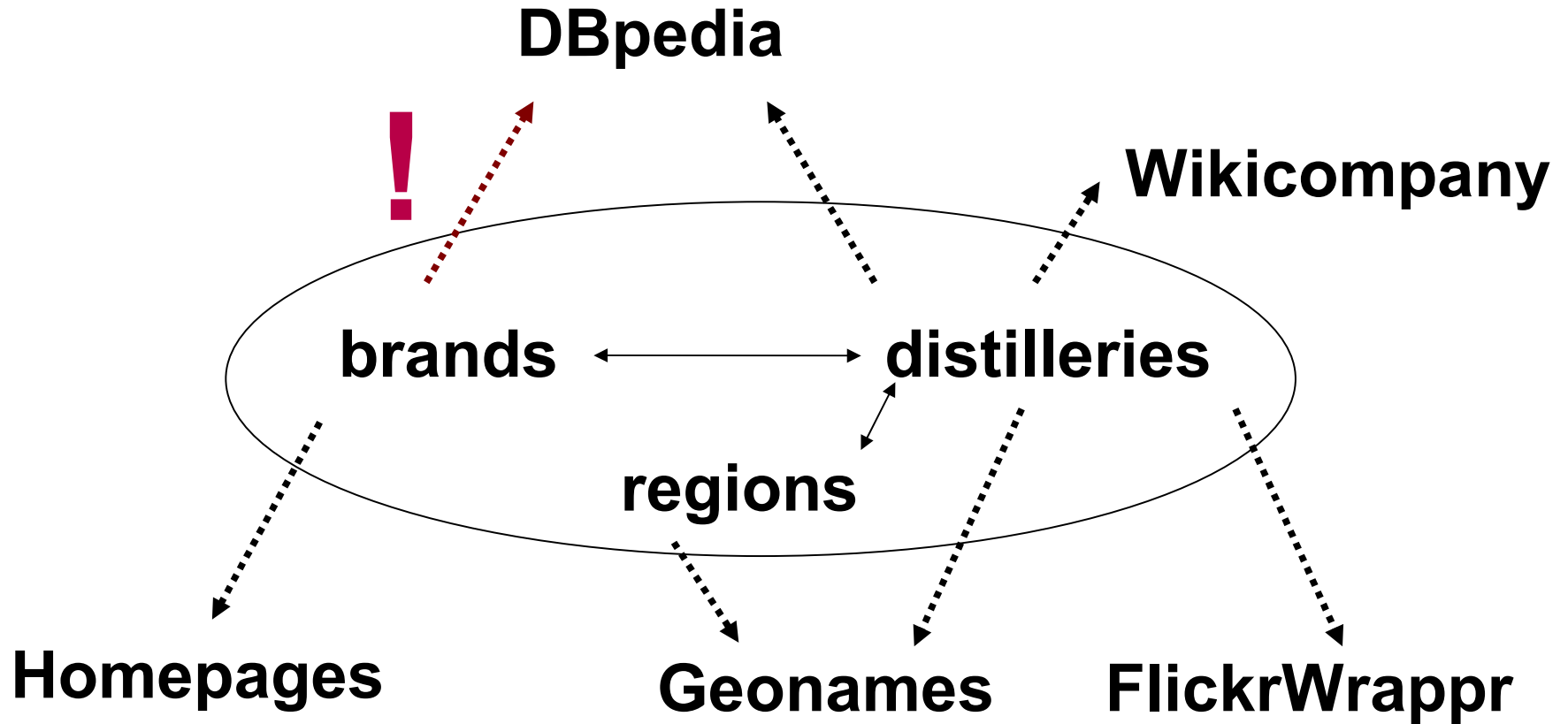
# Other Available Data Sets



## 5. Link to other Data Sets

- Popular Predicates for Linking
  - owl:sameAs
  - foaf:homepage
  - foaf:topic
  - foaf:based\_near
  - foaf:maker/foaf:made
  - foaf:depiction
  - foaf:page
  - foaf:primaryTopic
  - rdfs:seeAlso

## 5. Link to other Data Sets



## 5. Link to other Data Sets

- Linking Algorithms
  - String Matching
    - e.g. Lexical Distance between labels
  - Common Key Matching
    - e.g. ISBN, Musicbrainz IDs
  - Property-based Matching
    - Do these two things have the same label, type and coordinates
- Aim for reciprocal links

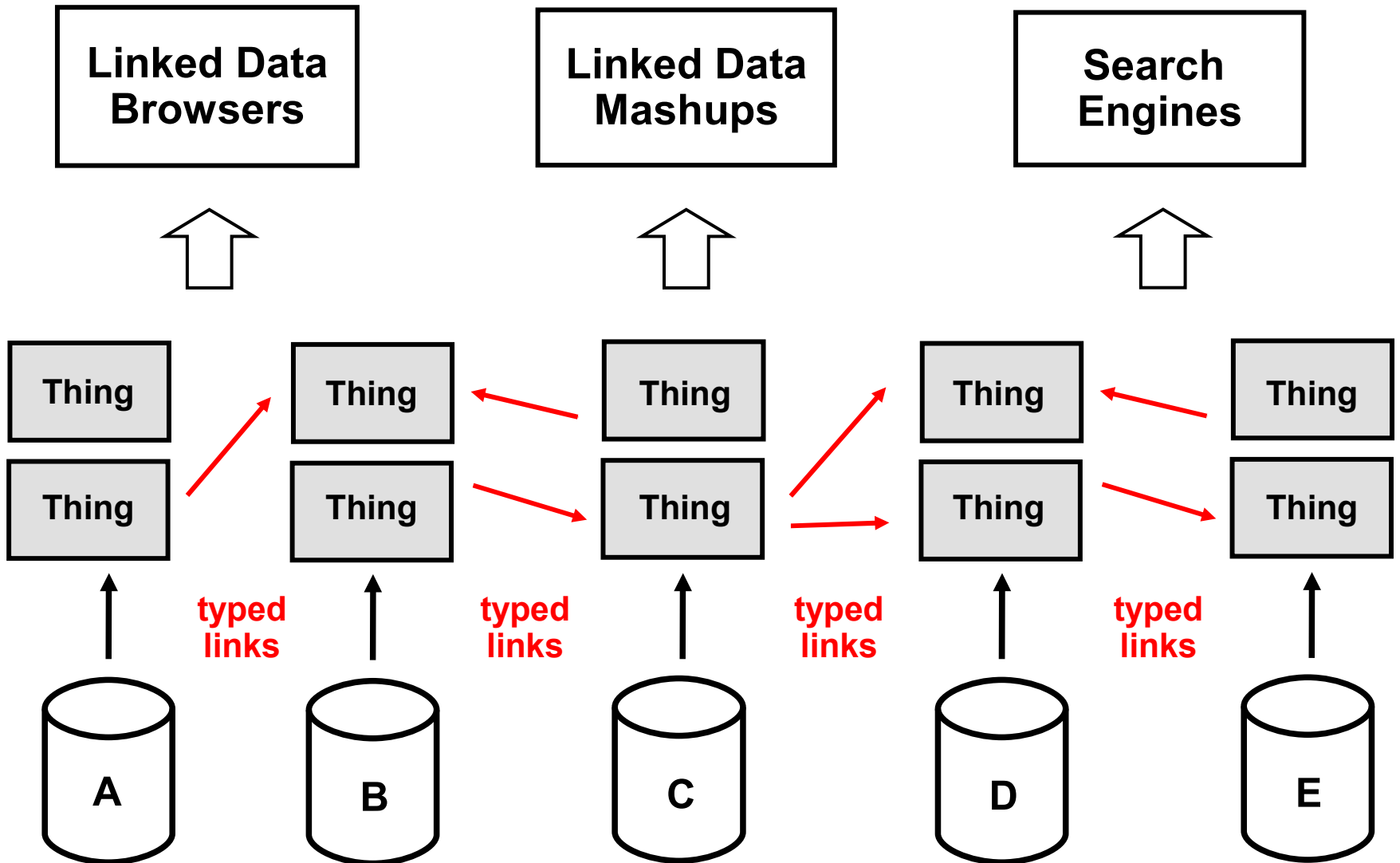


# Summary

1. Understand the Principles
2. Understand your Data
3. Choose URIs for Things in your Data
4. Setup Your Infrastructure
5. Link to other Data Sets



# Linked Data Applications



# Current Linked Data Applications

- - Browsing with Marbles and DBpedia Mobile
- - Searching with Falcons
- - Mashups, e.g. Revyu, BBC Music, Pipes



# Marbles

- <http://beckr.org/marbles>
- plug in a URI of your choice
- browse the Web of Data/Things
- notice the effect of link density

# DBpedia Mobile





## The Prestige

### Links

Homepage: <http://theprestige.movies.go.com/>  
See Also: <http://imdb.com/title/tt0482571/>

### Tags

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### Reviews (1)

★★★★★ by martinp on 23 Jan 2007

This is a drama about intense rivalry between stage magicians in the late 19th Century. The evocation of the period, although first rate, is not the main attraction, however. The Prestige has an incredibly clever plot including the most ingenious murder I've ever come across. It also has a deeply moving and sad love story hidden in it, which gradually emerges over the course of the film.

The film requires a strong suspension of disbelief on some key points: there is a science-fiction premise which is introduced using the real historical character of Nikola Tesla (I'd rather they had used a fictional scientist). There are a couple more implausibilities required to hold it together (something odd that goes on that none of the characters pick up on and a dead-end that by a huge coincidence turns out not to be a dead-end: I can't be more specific without spoiling the plot).

However, rather than feeling cheated by these aspects of the film, I'm hugely impressed. The writers have taken an implausible (okay, impossible) premise but created an intricate, involving and visual story that would be impossible without that premise. Scenes join up with each other in many subtle ways, echoing the same writers' earlier film Memento. Even when you've seen the twist coming, the final scene which lays it all out are has a lot of impact and I suspect the final shot will haunt my dreams.

I expected the film to be about nice costumes or impressive magical trickery, but it is actually about deep emotions felt by the main characters as they deal with the situations life has dealt them, and it rather than serving up those emotions on a plate, it requires you to think and piece together what you've seen. That's got to be a good thing, in fact the best of what film a be.

What do you think of **The Prestige**? [Write Your Own Review...](#)

### The Prestige



directed by [Christopher Nolan](#)

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### Artists

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At present information about music played on BBC radio does not include every programme or network.

29 JANUARY - 5 FEBRUARY

1  **Coldplay**  
amount played this week   
amount played last week 

2  **Lily Allen**  
amount played this week   
amount played last week 

3  **Franz Ferdinand**  
amount played this week   
amount played last week 

4  **The Killers**  
amount played this week   
amount played last week 

5  **U2**  
amount played this week   
amount played last week 

6  **Kings of Leon**  
amount played this week   
amount played last week 

#### On This Day

05 FEBRUARY

##### Born on this day



##### **Bobby Brown (1969)**

Bobby Brown is a Grammy Award-winning American R&B singer-songwriter and dancer. After...

Also [Sara Evans \(1971\)](#)



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**Birmingham** is a *Borough, City*

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**Birmingham City F.C.** is a *Club, Company*

- abstract: ...-cn:伯明翰足球俱乐部)-(zh-hk:伯明翰足球會;zh-cn:伯明翰足球俱乐部)- (**Birmingham** City Football Club)是一家英格蘭-(zh-hk:球會;zh-cn:俱樂部)-... - [From dbpedia.org »](#)
- has subject: Category:English\_football\_clubs - [From dbpedia.org »](#)
- hasPhotoCollection: **Birmingham** City F C - [From dbpedia.org »](#)

[http://dbpedia.org/resource/Birmingham\\_City\\_F.C.](http://dbpedia.org/resource/Birmingham_City_F.C.) - Described in 205 documents

**Birmingham** is a *Ontology, Subject, City, Geographical region*

- ☆ imports: <http://semantic-mediawiki.org/swikt/1.0> - [From semanticweb.org »](#)
- ☆ date of creation: 2008-05-29T13:42:38+02:00 - [From semanticweb.org »](#)
- ☆ page: **Birmingham** - [From semanticweb.org »](#)

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**Birmingham%2C\_Alabama** is a *City*

- abstract: **Birmingham** to także nazwa miasta w Anglii. **Birmingham** - mi... - [From dbpedia.org »](#)
- has subject: Category:United\_States\_communities\_with\_African\_American\_majority\_populations - [From dbpedia.org »](#)
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- hasPhotoCollection: **Birmingham** Barons - [From dbpedia.org »](#)

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# Semantic Web Pipes

- Like Yahoo Pipes, but for RDF
- <http://pipes.deri.org/>

# Outlook for Linked Data Applications

- Requirements
  - slicker interfaces
  - better backend infrastructure
  - highly focused functionality

# Linked Data Toolbox

# Linked Data Storage/Publishing Layers

- D2R Server
  - Relational Database to RDF Middleware
  - SPARQL access to RDB
  - <http://www4.wiwiss.fu-berlin.de/bizer/d2r-server/>
  - Example
  - LinkedMDB <http://linkedmdb.org/>

# Linked Data Storage/Publishing Layers

- Virtuoso
  - Many things, including RDF triplestore
  - SPARQL access to data
  - Open source edition
  - <http://virtuoso.openlinksw.com/>



# Linked Data Storage/Publishing Layers

- Talis Platform
  - SaaS, Cloud-based storage for RDF data and binary objects
  - SPARQL access
  - REST APIs to additional services
    - Faceting, Augmentation
  - Linked Data compatible out of the box
  - <http://www.talis.com/platform>

# Linked Data Storage/Publishing Layers

- Paget Framework
  - publishing framework for Linked Data
  - serves up RDF according to Linked Data principles
  - reduces configuration overhead
  - can serve up data from static files or the Talis Platform
  - <http://code.google.com/p/paget>

# Consuming Linked Data

- RDF Frameworks
  - ARC (PHP) <http://arc.semsol.org/>
  - RAP (PHP) <http://www4.wiwiss.fu-berlin.de/bizer/rdfapi/>
  - Jena (Java) <http://jena.sourceforge.net/>
  - Summary
    - <http://www.semanticscripting.org/SFSW2005/SFSW-Toolkits.pdf>
- Discovering more data
  - Sindice <http://sindice.com/>
  - SQUIN <http://squid.sourceforge.net/>





# Discussion



## More Information

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  - <http://tomheath.com/>
  - <http://www.talis.com/>
- Slides
  - ...
- Tutorial
  - <http://linkeddata.org/docs/how-to-publish>

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