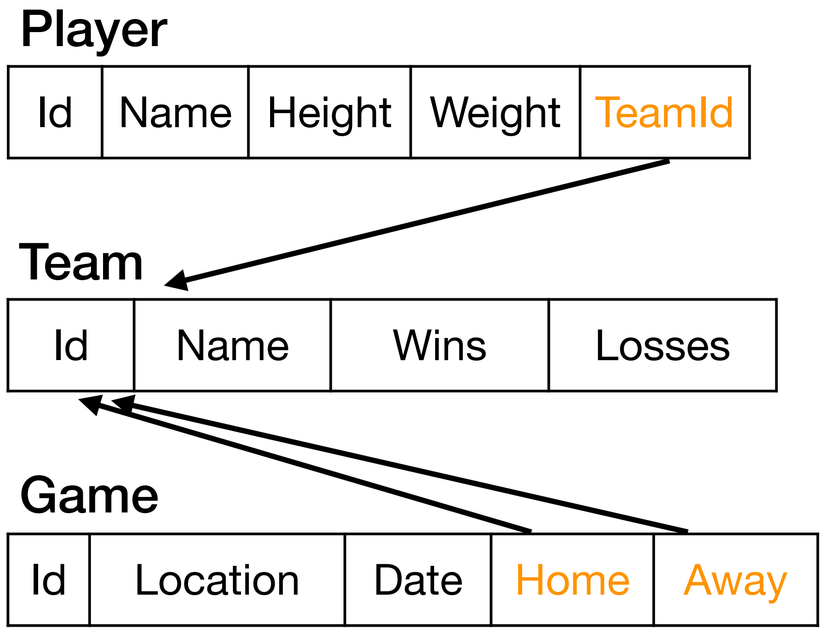
# Advanced Data Management (CSCI 680/490)

## Data Fusion

Dr. David Koop

# Football Game Data

- Have each game store the id of the home team and the id of the away team (one-to-one)
- Have each player store the id of the team he plays on (many-to-one)



# Concatenation

- Take two data frames with the same columns and add more rows
- `pd.concat([data-frame-1, data-frame-2, …])`
- Default is to add rows (`axis=0`), but can also add columns (`axis=1`)
- Can also concatenate Series into a data frame.
- `concat` preserves the index so this can be confusing if you have two default indices (0,1,2,3…)—they will appear twice
  - Use `ignore_index=True` to get a 0,1,2…

# Merges (aka Joins)

- Want to join the two tables based on the location and date
- Location and date are the **keys** for the join
- Merges are **ordered**: there is a left and a right side

**Game**

| Id | Location | Date | Home | Away |
|---|---|---|---|---|
| 0 | Boston | 9/2 | 1 | 15 |
| 1 | Boston | 9/9 | 1 | 7 |
| 2 | Cleveland | 9/16 | 12 | 1 |
| 3 | San Diego | 9/23 | 21 | 1 |

**Weather**

| wId | City | Date | Temp |
|---|---|---|---|
| 0 | Boston | 9/2 | 72 |
| 1 | Boston | 9/3 | 68 |
| ... | ... | ... | ... |
| 7 | Boston | 9/9 | 75 |
| ... | ... | ... | ... |
| 21 | Boston | 9/23 | 54 |
| ... | ... | ... | ... |
| 36 | Cleveland | 9/16 | 81 |

# Types of Joins

- Inner: intersection of keys (match on both sides)
- Outer: union of keys (if there is no match on other side, still include with NaN to indicate missing data)
- Left: always have rows from left table (no unmatched right data)
- Right: like left, but with no unmatched left data

# Data Merging in Pandas

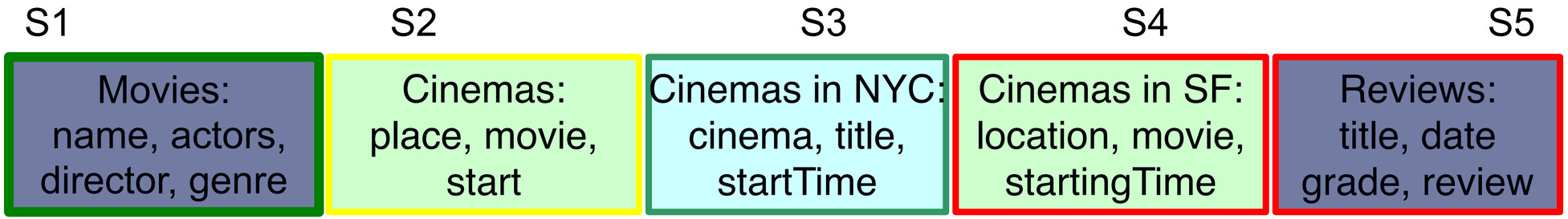
- `pd.merge(left, right, …)`
- Default merge: join on matching column names
- Better: specify the column name(s) to join on via `on` kwarg
  - If column names differ, use `left_on` and `right_on`
  - Multiple keys: use a list
- `how` kwarg specifies type of join `("inner", "outer", "left", "right")`
- Can add suffixes to column names when they appear in both tables, but are not being joined on
- Can also merge using the index by setting `left_index` or `right_index` to `True`

# Data Integration

```
select title, startTime
from Movie, Plays
where Movie.title=Plays.movie AND
            location="New York"  AND
            director="Ava DuVernay"
```

**Movie**: Title, director, year, genre
**Actors**: title, actor
**Plays**: movie, location, startTime
**Reviews**: title, rating, description

Sources S1 and S3 are relevant, sources S4 and S5 are irrelevant, and source S2 is relevant but possibly redundant.

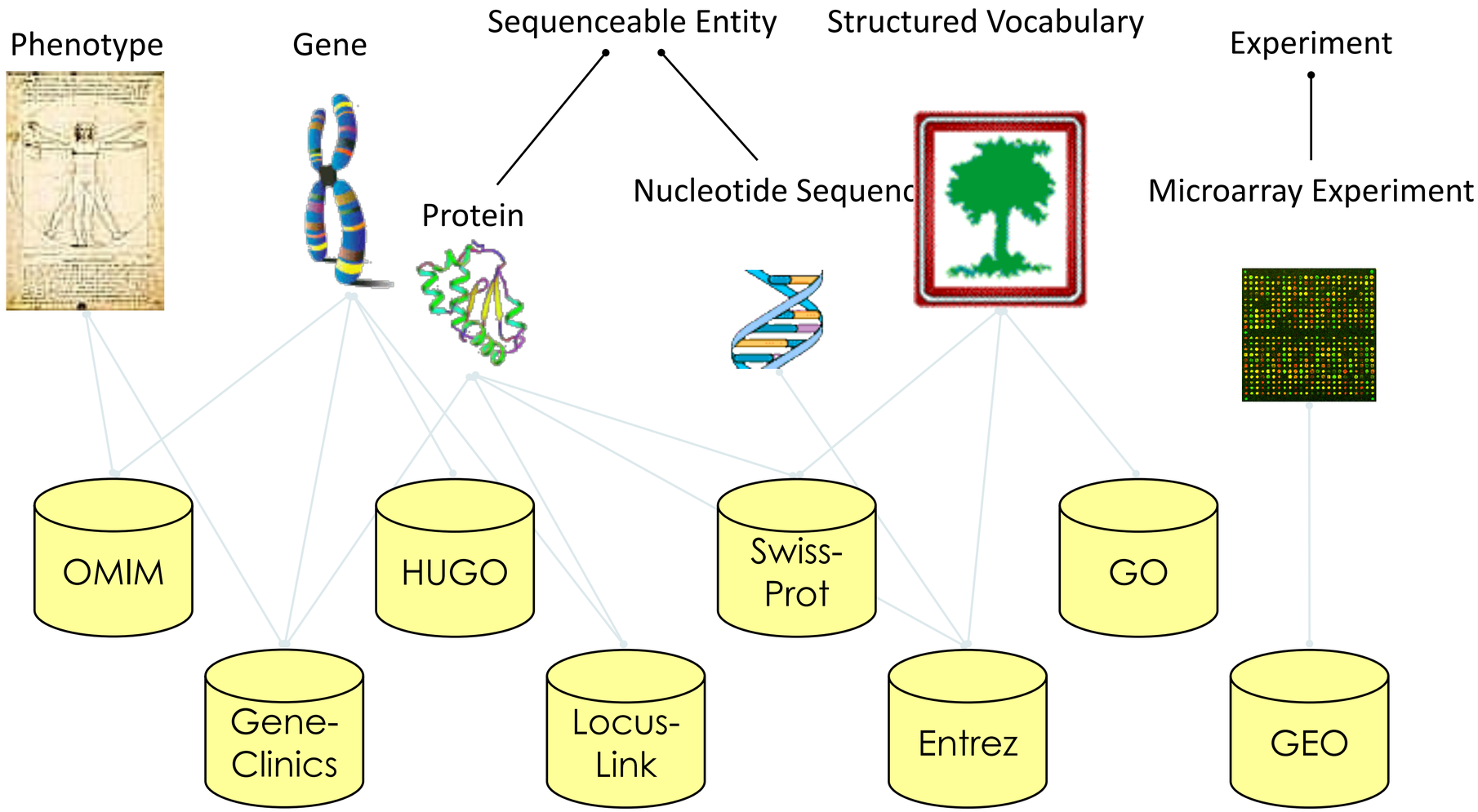



[AH Doan et al., 2012]

# Data Integration

- Lots of data sources, how do we answer questions where we need to access data from more than one?
- Schema matching
- Problem of heterogeneity
- AI-Complete problem: difficulty is the same as making computers as intelligent as people
- Two techniques:
  - Mediation
  - Data Warehouses

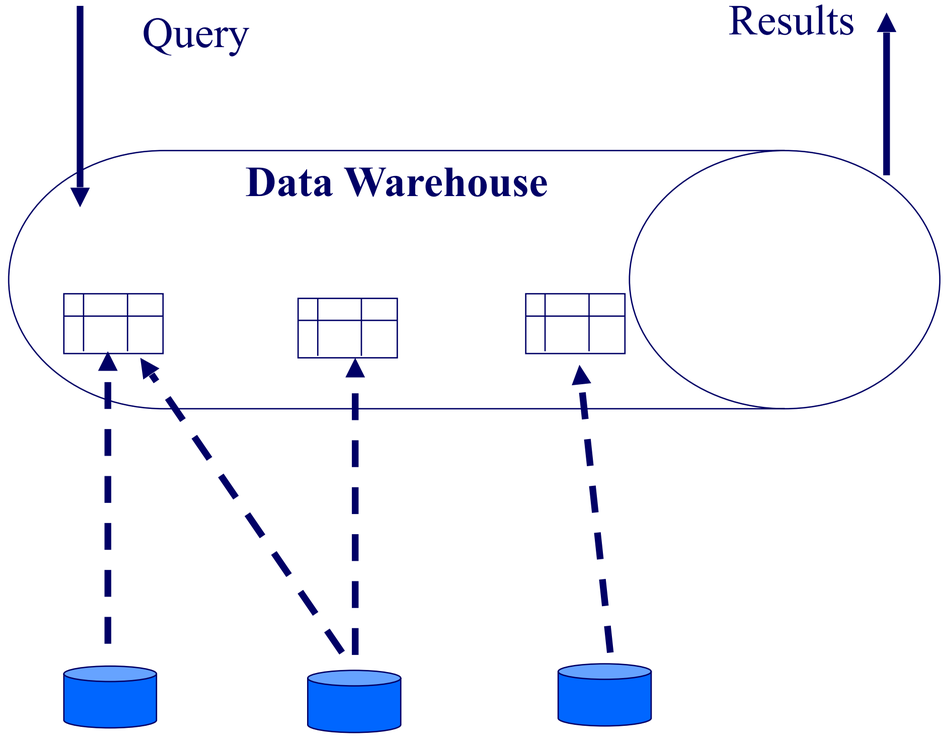
# Data Integration Application: Biomedical




[A. Doan et al., 2012]

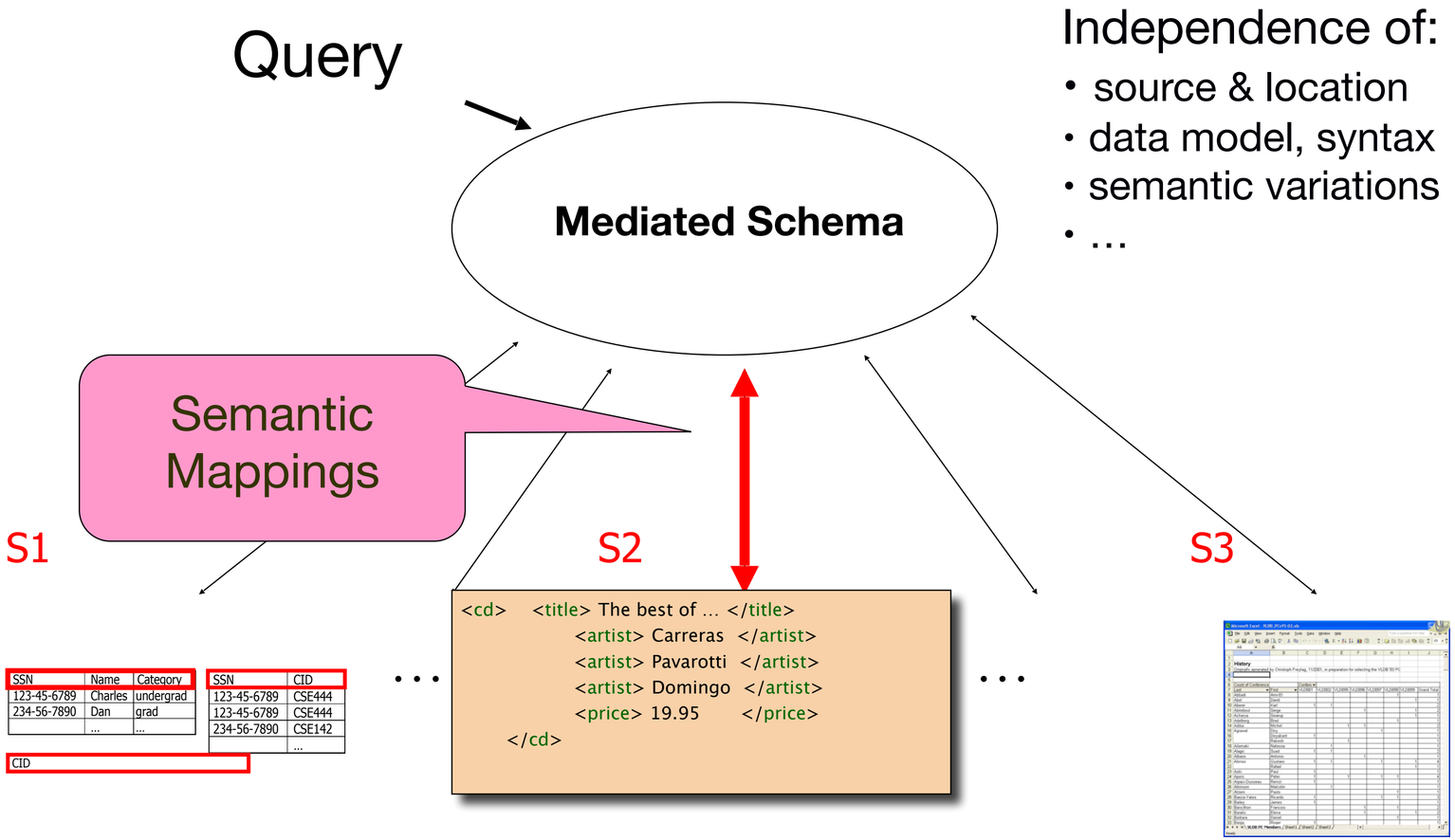
# Data Warehouses: Offline Replication

- Determine physical schema
- Define a database with this schema
- Define procedural mappings in an “ETL tool” to import the data and clean it.
- Periodically copy all of the data from the data sources
  - Note that the sources and the warehouse are basically independent at this point



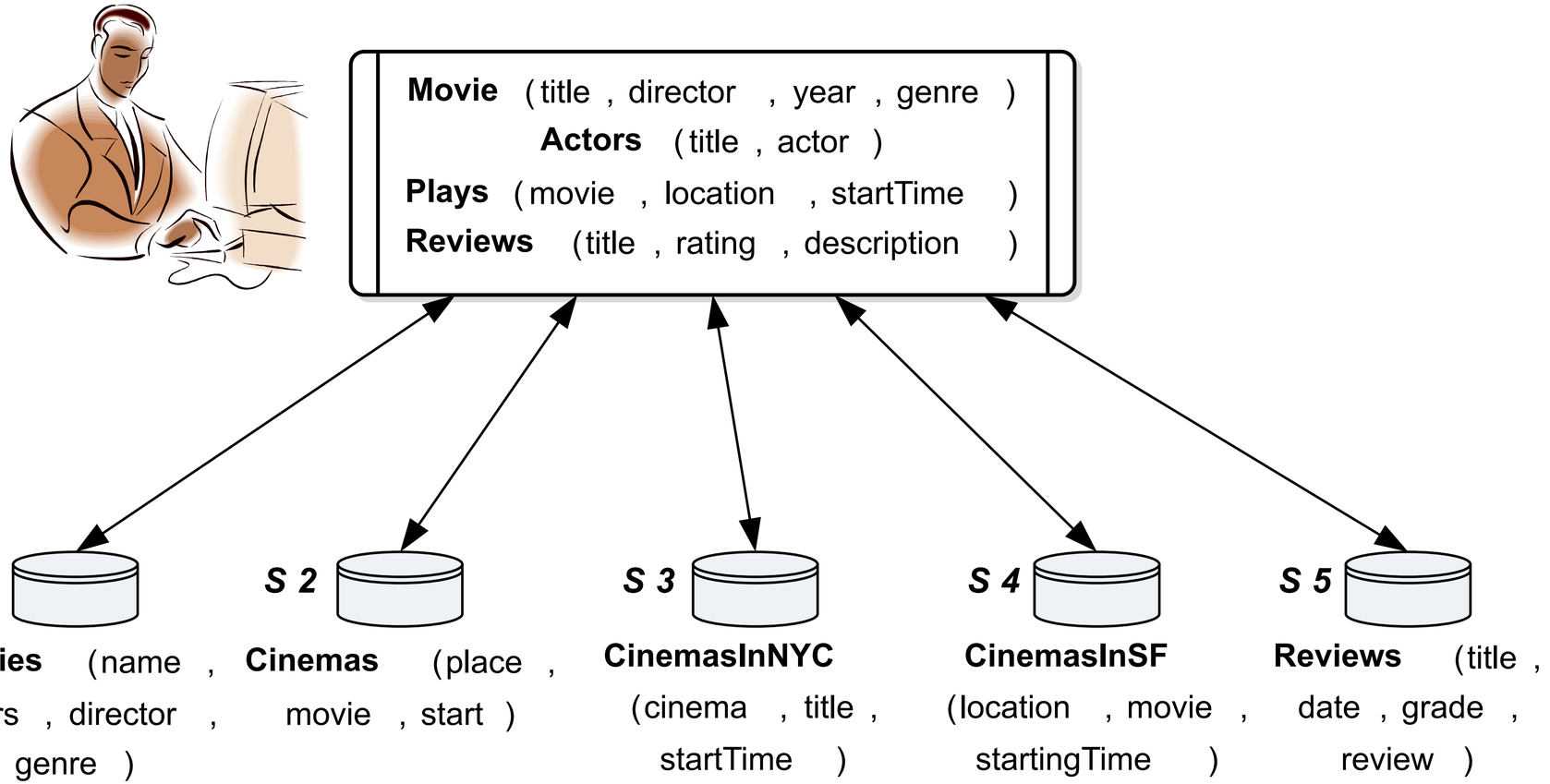

[A. Doan et al., 2012]

# Virtual Data Warehouses




[A. Doan et al., 2012]

# Integrated Schema Example




[A. Doan et al., 2012]

# Why is Data Integration Hard?

- Systems-level reasons:
  - Managing different platforms
  - SQL across multiple systems is not so simple
  - Distributed query processing
- Logical reasons:
  - Schema (and data) heterogeneity
- ‘Social’ reasons:
  - Locating and capturing relevant data in the enterprise.
  - Convincing people to share (data fiefdoms)
    - Security, privacy and performance implications

[A. Doan et al., 2012]

# Reading Quiz

# Assignment 3

- Due Friday
- Same dataset as A1 and A2…
- …but dealing with the full raw data now
- Want to clean and transform using Trifacta and pandas
  - Medium
  - Date cleanup
  - Tags expansion
  - [CSCI 680] Artist Data

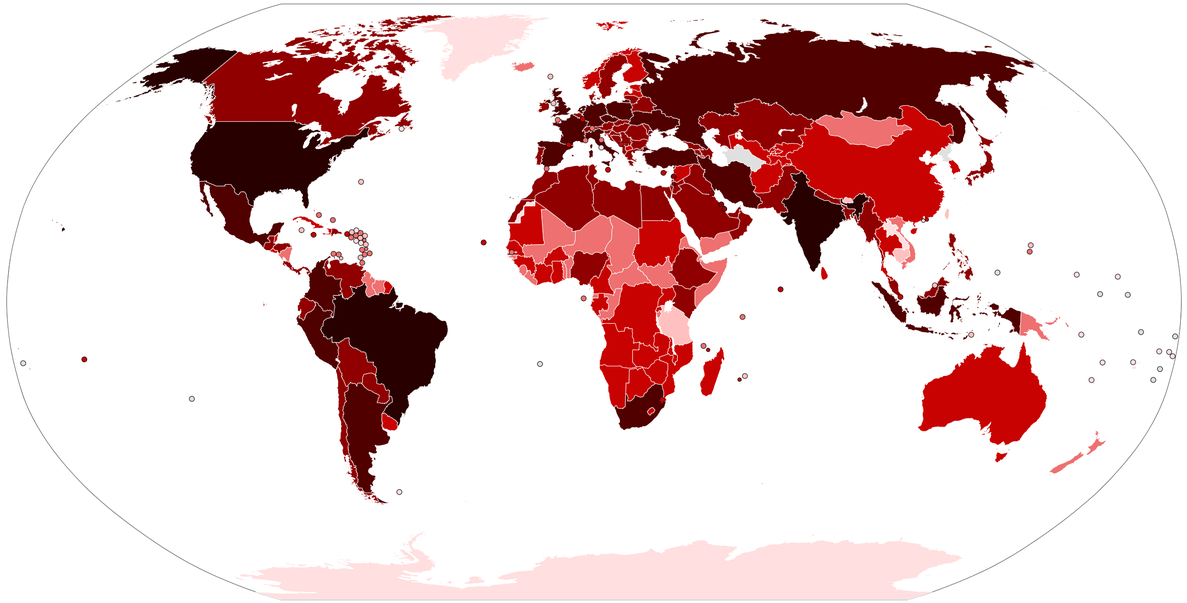
# Record Linkage Motivation

- Often data from different sources need to be integrated and linked
  - To allow data analyses that are impossible on individual databases
  - To improve data quality
  - To enrich data with additional information
- **Lack of unique entity identifiers** means that linking is often based on personal information
- When databases are linked across organisations, maintaining privacy and confidentiality is vital
- The linking of databases is challenged by **data quality**, **database size**, and **privacy concerns**

[P. Christen , 2019]

# Motivating Example

- Preventing the outbreak of epidemics requires monitoring of occurrences of unusual patterns of symptoms, ideally in real time
- Data from many different sources will need to be collected (including travel and immigration records; doctors, emergency and hospital admissions; drug purchases; social network and location data; and possibly even animal health data)

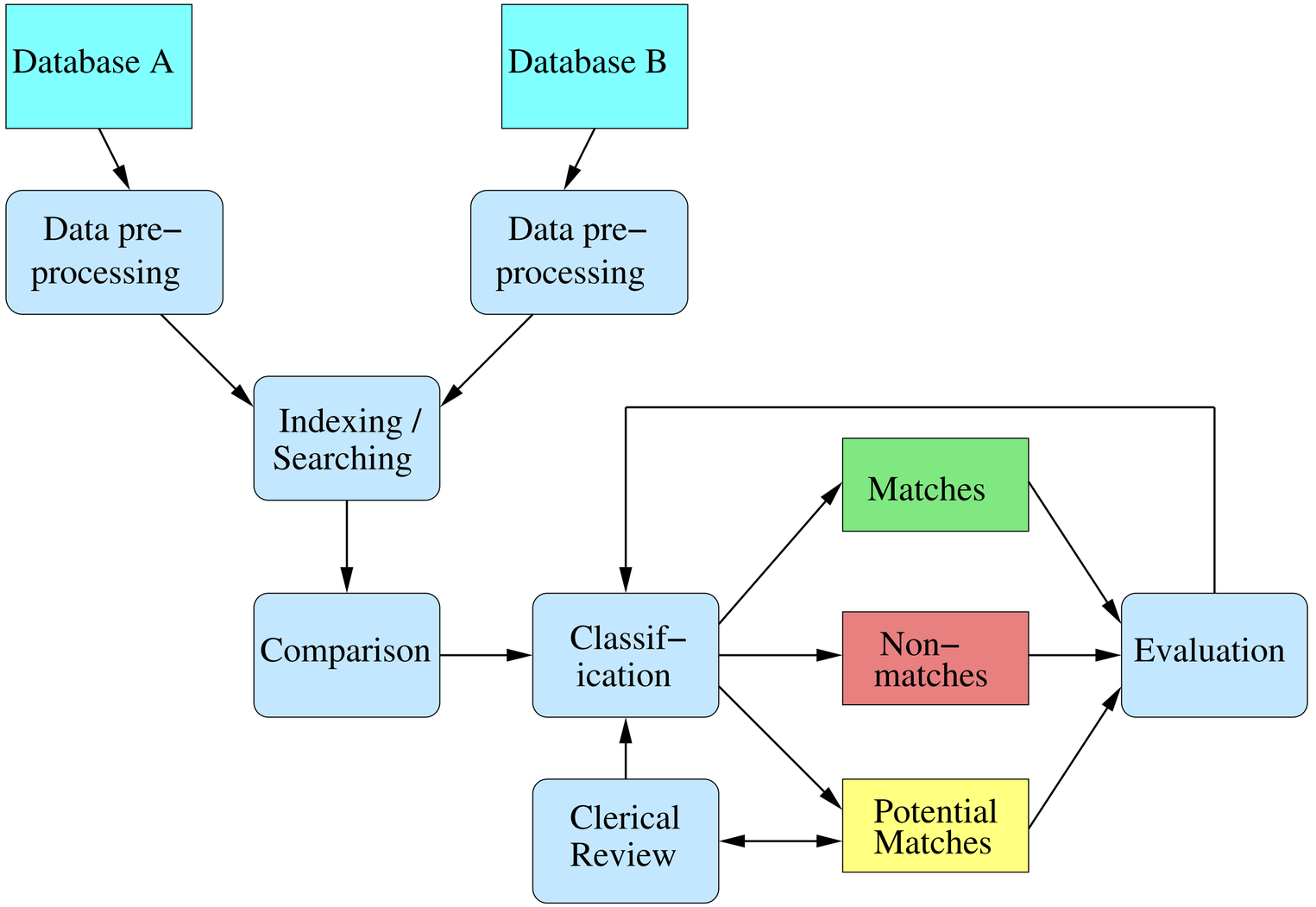


[P. Christen , 2019], image: [Pharexia, Wikipedia]

# Record Linkage

P. Christen

# Record Linkage Process




[P. Christen , 2019]

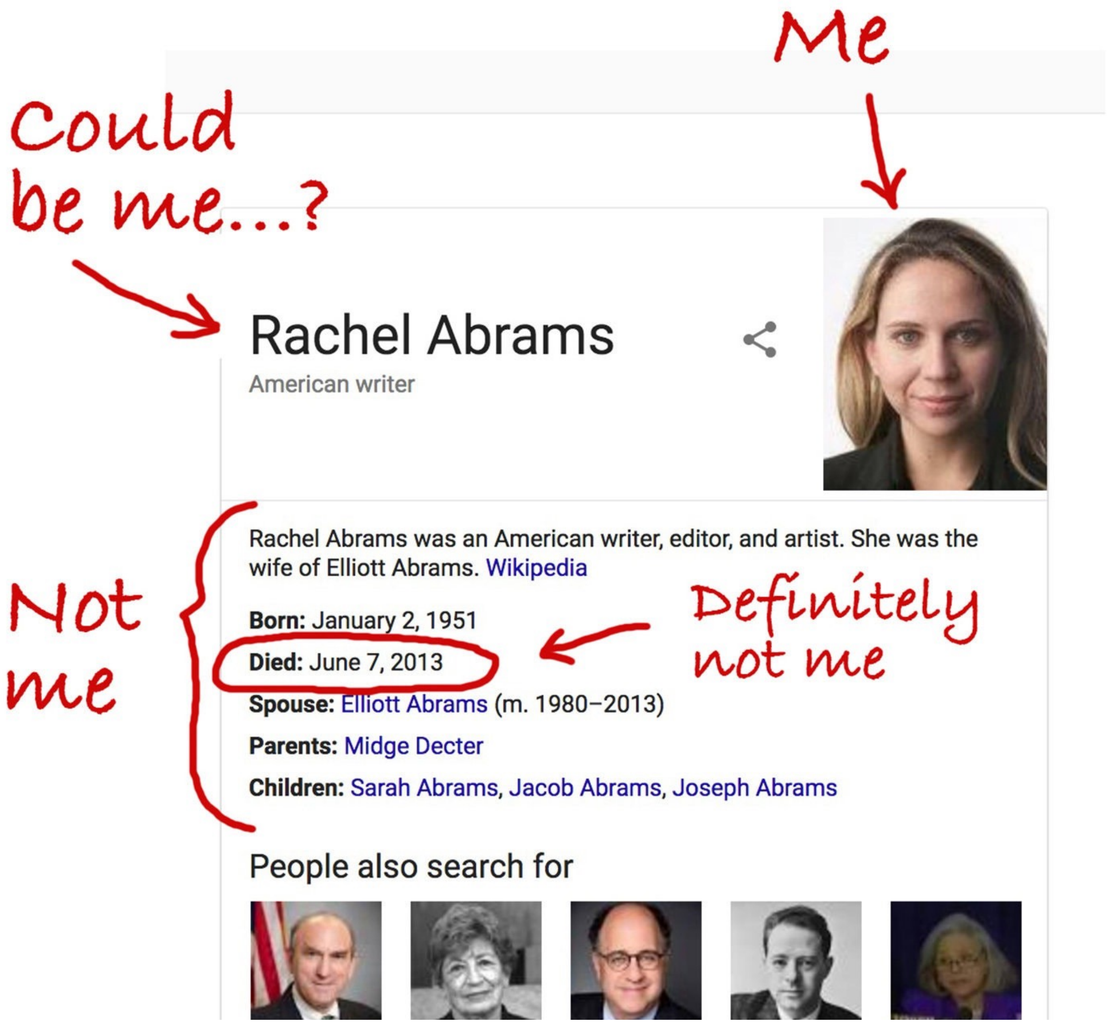
# Record Linkage Techniques

- Deterministic matching
  - Rule-based matching (complex to build and maintain)
- Probabilistic record linkage [Fellegi and Sunter, 1969]
  - Use available attributes for linking (often personal information, like names, addresses, dates of birth, etc.)
  - Calculate match weights for attributes
- “Computer science” approaches
  - Based on machine learning, data mining, database, or information retrieval techniques
  - Supervised classification: Requires training data (true matches)
  - Unsupervised: Clustering, collective, and graph based

[P. Christen , 2019]

# Data Matching & Data Fusion

- Google Thinks I'm Dead (I know otherwise.) [R. Abrams, NYTimes, 2017]
- Not only Google, but also Alexa:
  - "Alexa replies that Rachel Abrams is a sprinter from the Northern Mariana Islands (which is true of someone else)."
  - "He asks if Rachel Abrams is deceased, and Alexa responds yes, citing information in the Knowledge Graph panel."



# Data Integration and Data Fusion

- Data Integration: focus on integrating data from different sources
- When sources are orthogonal, no problems
- What happens when two sources provide the same type of information and they **conflict**?
- Data Fusion: create a single object while resolving conflicting values

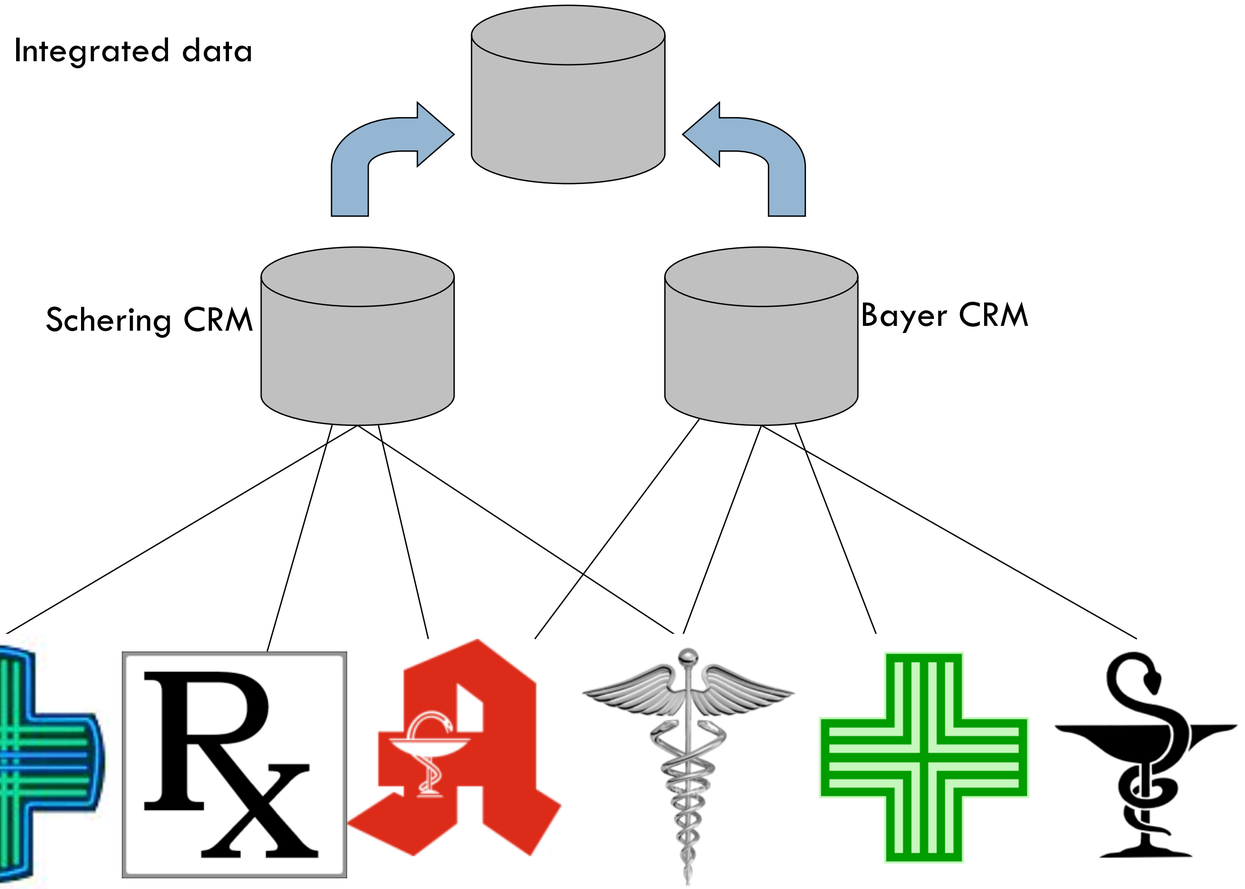
# Data Fusion—
# Resolving Data Conflicts in Integration

X. L. Dong and F. Naumann

# Data Fusion Summary

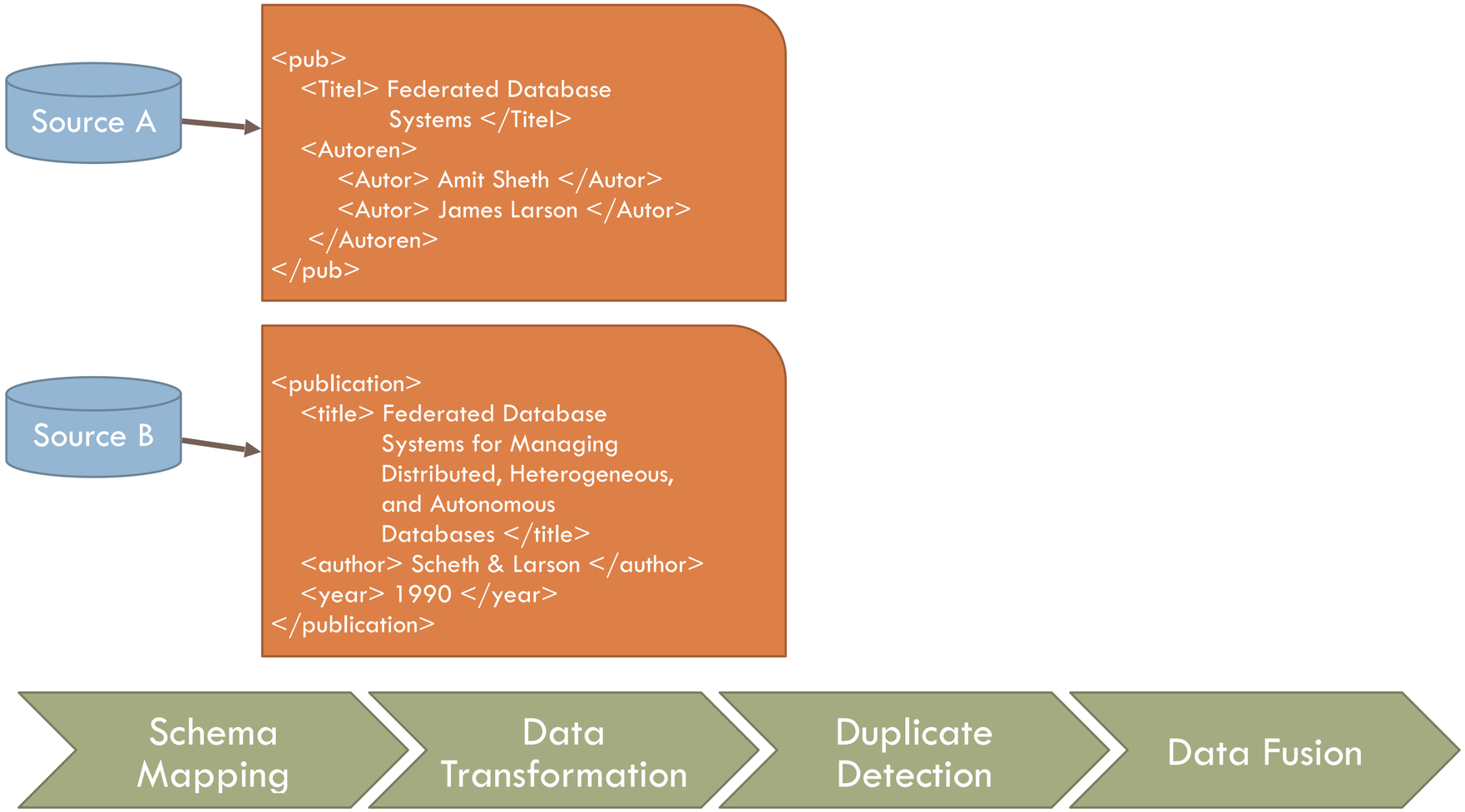
- Conflict resolution strategies
- "Truth-discovery" techniques
  - Accuracy
  - Freshness
  - Dependence
- Fusion Issues
  - Accuracy
  - Efficiency
  - Usability
  - How fusion fits with the rest of data integration?

# Data Conflicts



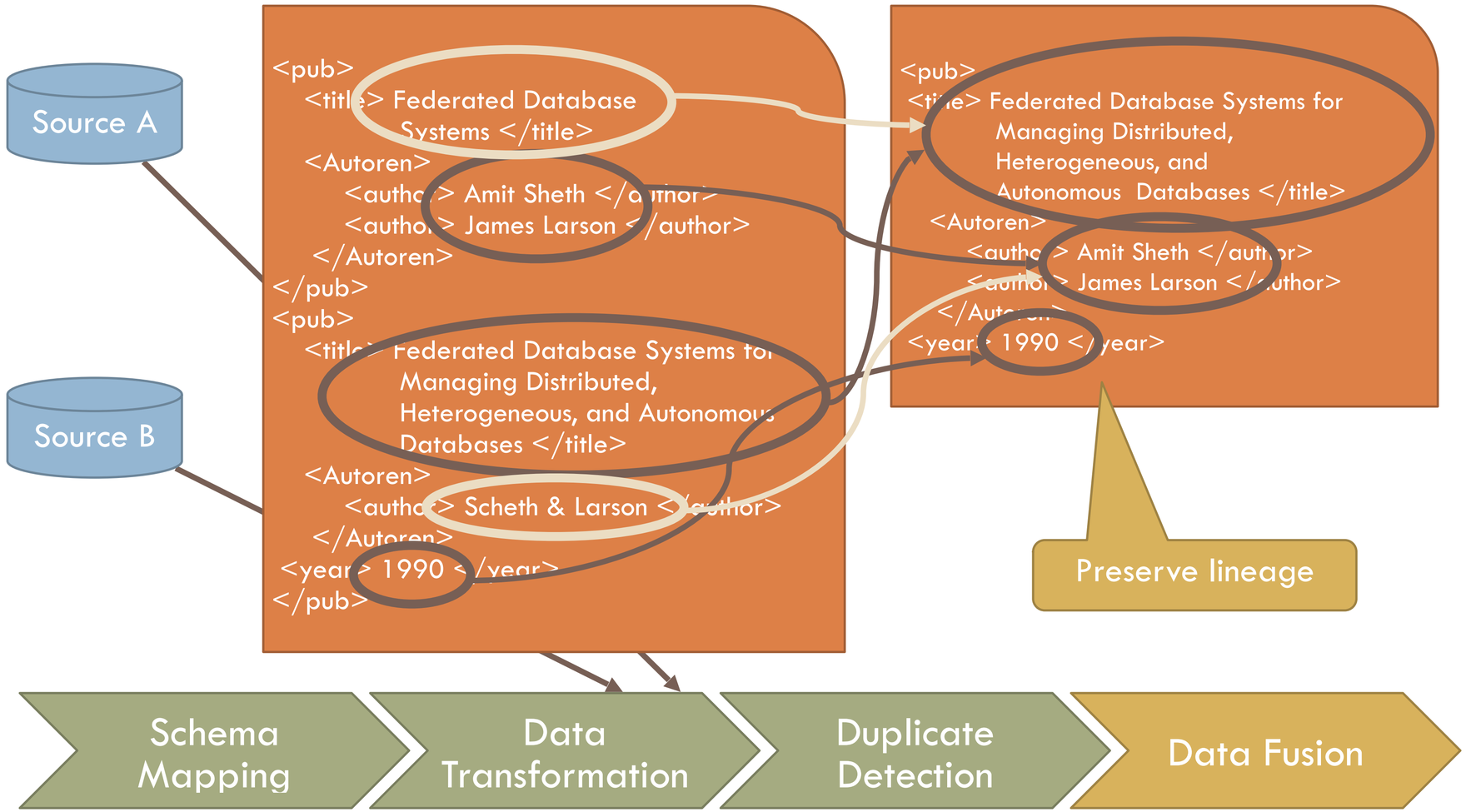

[L. Dong and F. Naumann, 2009]

# Information Integration




[L. Dong and F. Naumann, 2009]

# Information Integration

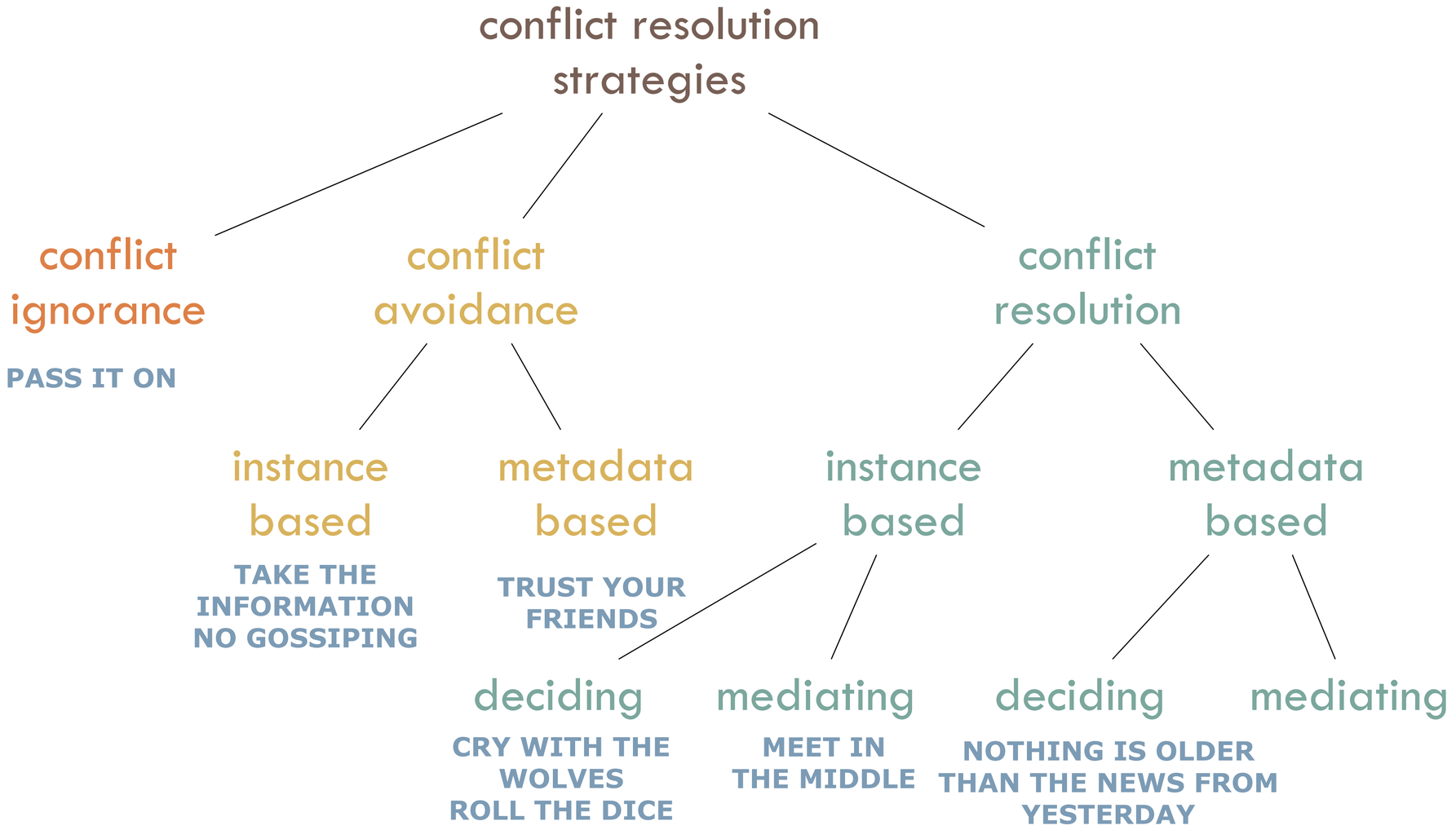



[L. Dong and F. Naumann, 2009]

# Data Fusion

- Problem: Given a duplicate, create a single object representation while resolving conflicting data values.
- Difficulties:
  - Null values: Subsumption and complementation
  - Contradictions in data values
  - Uncertainty & truth: Discover the true value and model uncertainty in this process
  - Metadata: Preferences, recency,  correctness
  - Lineage: Keep original values and their origin
  - Implementation in DBMS: SQL, extended SQL, UDFs, etc.

# Conflict Resolution Strategies




[L. Dong and F. Naumann, 2009]

# Integrating Conflicting Data: The Role of Source Dependence

X. L. Dong, L. Berti-Equille, and D. Srivastava