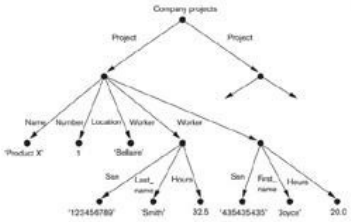


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# CZ2007 Introduction to Databases

## Semi-Structured Data

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Nanyang Technological University, Singapore

# Roadmap (Semi-Structured Data)

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- Semi-structured Data
- XML
- XML DTD
- JSON

# The More Data, The Merrier

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## Power of Data

- the more data the merrier (GB -> TB -> PB)
- data comes from everywhere in all shapes
- value of data often discovered later

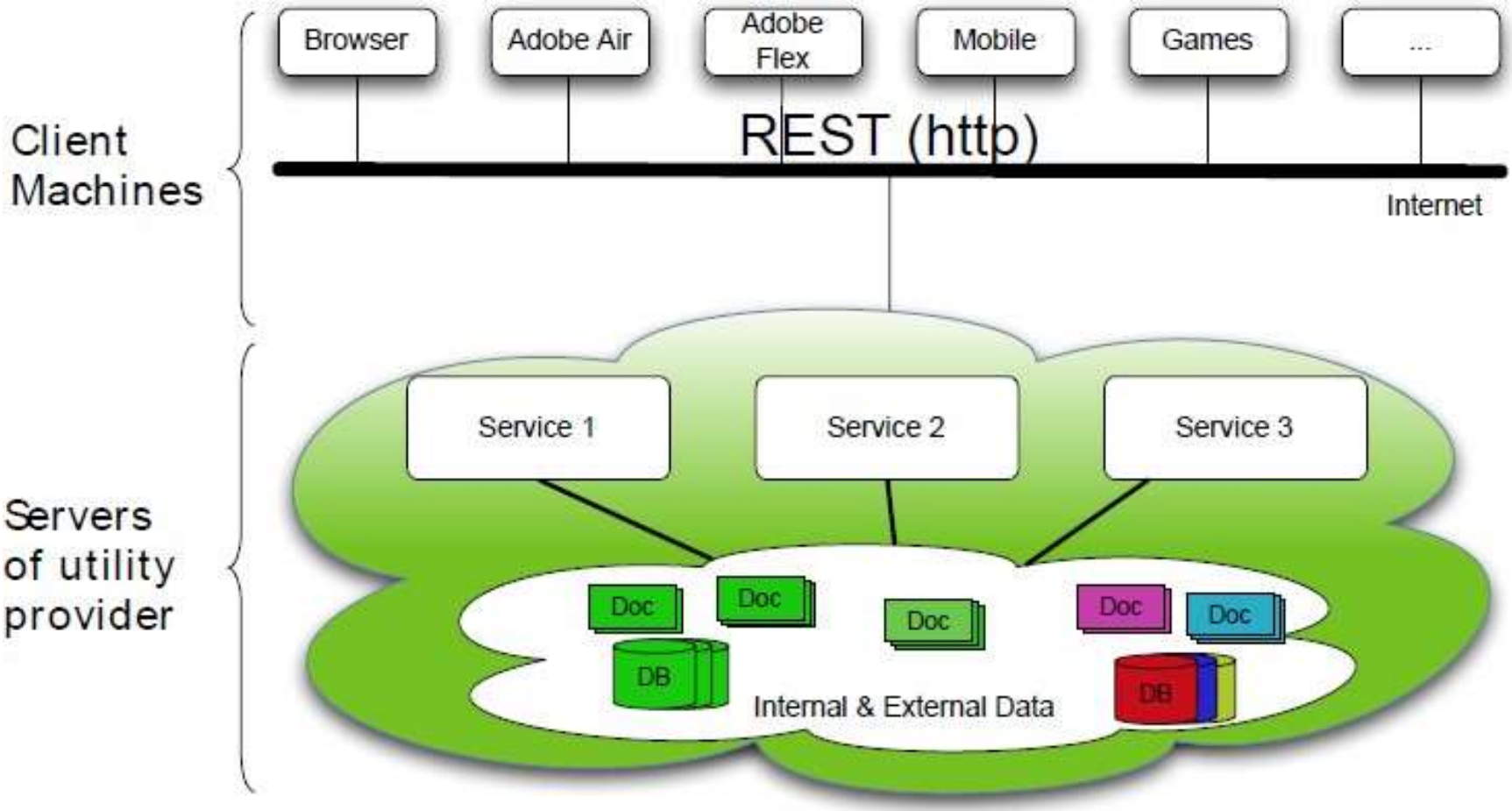
## Services turn data into $$$

- the more services the merrier (10 -> 1000 -> 1M -> 1B)
- need to adapt quickly

## Goal: Platforms for data and services

- any data, any service, anywhere and anytime

# Data Arrive in Many Shapes



# Structured vs. Unstructured Data

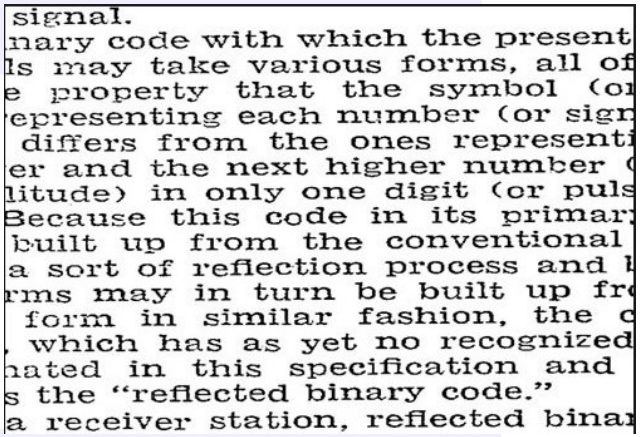
| Patient No. | Last name | First name | Sex | Date of birth | Ward No. |
|---|---|---|---|---|---|
| 454 | Smith | John | M | 14.08.58 | 6 |
| 223 | Jones | Peter | M | 07.12.65 | 8 |
| 597 | Brown | Brenda | F | 17.06.61 | 3 |
| 234 | Jenkins | Alan | M | 29.01.67 | 7 |
| 244 | Wells | Christopher | M | 25.02.55 | 6 |

## Relational databases are highly structured

| Ward No. | Ward name | Type | No. of Beds |
|---|---|---|---|
| 3 | Carey | Medical | 8 |
| 6 | Bracken | Medical | 16 |
| 7 | Brent | Surgical | 12 |
| 8 | Meavy | Surgical | 10 |

- All data resides in tables
- Must define schema before entering data
- Every row confirms to the table schema
- Changing the schema is hard and may break many things

## Texts are highly unstructured


signal.
nary code with which the present
ls may take various forms, all of
e property that the symbol (or
epresenting each number (or sign
differs from the ones representi
er and the next higher number (
litude) in only one digit (or puls
Because this code in its primary
built up from the conventional
a sort of reflection process and l
rms may in turn be built up fr
form in similar fashion, the c
which has as yet no recognized
nated in this specification and
s the "reflected binary code."
a receiver station, reflected binar

- Data is free-form
- No schema and it's hard to define one
- Readers need to infer structures & meanings

## What's in between these two extremes?

# Semi-Structured Data

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## Observation: most data have "some" structure, e.g.

- Book: chapters, sections, titles, paragraphs, references, index, etc.
- Item for sale: name, picture, price, ratings, promotion, etc.
- Web page: HTML

## Ideas

- Ensure data is "well-formatted"
- If needed, ensure data is also "well-structured"
  - But make it easy to define and extend this structure
- Make data "self-describing"

# A Little Bit of History …

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*Database world*

- 1970 relational databases
- 1990 nested relational model and object oriented databases
- 1995 semi-structured databases

*Documents world*

- 1974 **SGML** (Structured Generalized Markup Language)
- 1990 **HTML** (Hypertext Markup Language)
- 1992 **URL** (Universal Resource Locator)

*Data + documents = information*

1996 **XML** (Extended Markup Language)

URI (Universal Resource Identifier)

# XML as Semi-Structured Data

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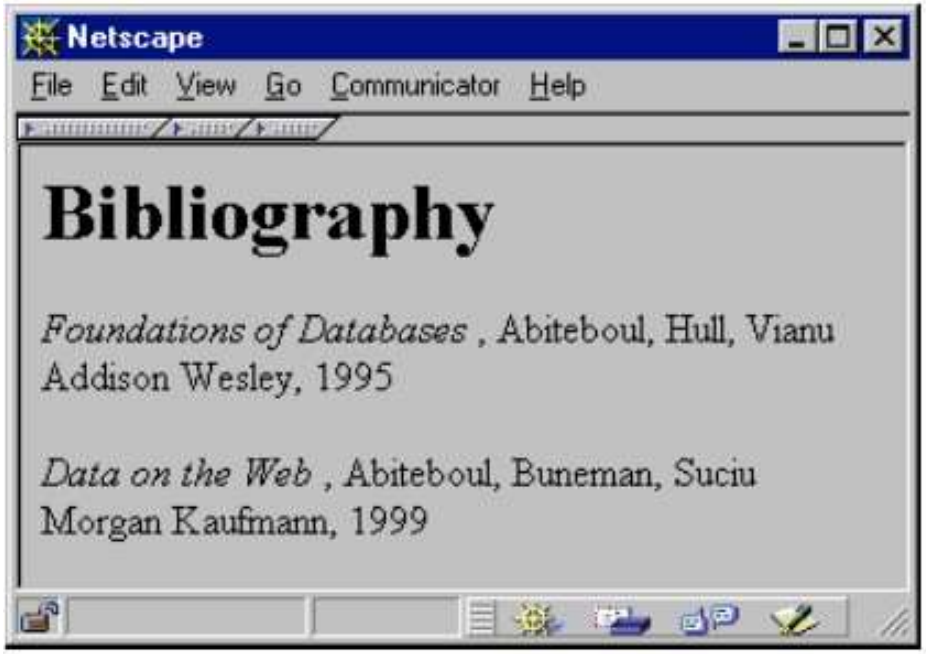
- XML - The E**X**tensible **M**arkup **L**anguage
- A flexible syntax for data: semi-structured data
- Used in:
  - Configuration files, e.g. Web.Config
  - Replacement for binary formats (MS Word)
  - Document markup: e.g. XHTML
  - Data: data exchange, semistructured data (sensor data, logs, blogs)
- Warning: not normal form! Not even 1NF
- XML is about half as popular as SQL

# From HTML to XML



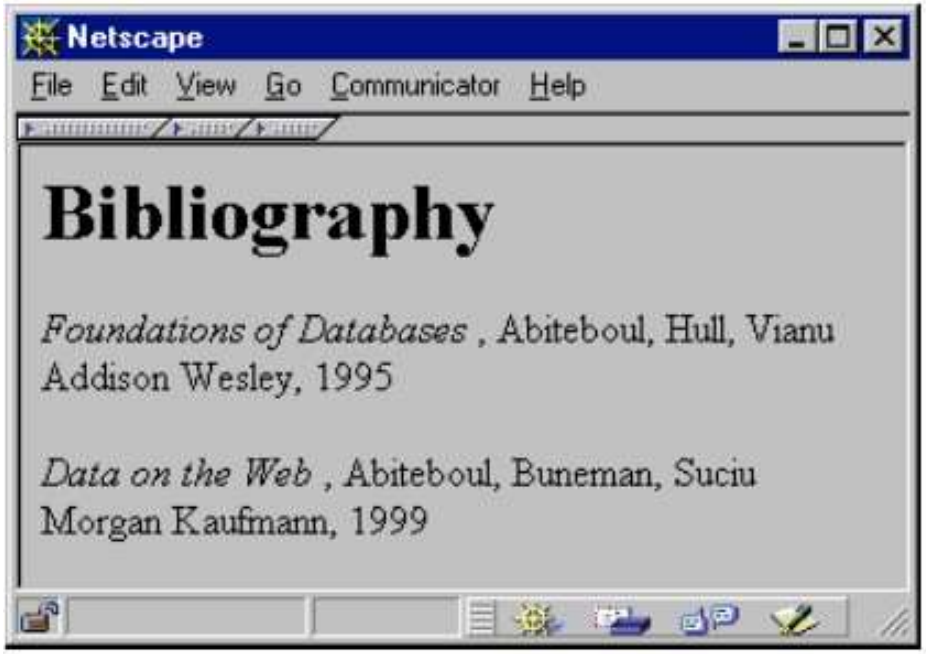

HTML
- The HyperText Markup Language

HTML describes the presentation

HTML

```
<h1> Bibliography </h1>
<p> <i> Foundations of Databases </i>
    Abiteboul, Hull, Vianu
    <br> Addison Wesley, 1995
<p> <i> Data on the Web </i>
    Abiteoul, Buneman, Suciu
    <br> Morgan Kaufmann, 1999
```

# From HTML to XML




HTML
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HTML describes the presentation

HTML

```
<h1> Bibliography </h1>
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    <br> Addison Wesley, 1995
<p> <i> Data on the Web </i>
    Abiteoul, Buneman, Suciu
    <br> Morgan Kaufmann, 1999
```
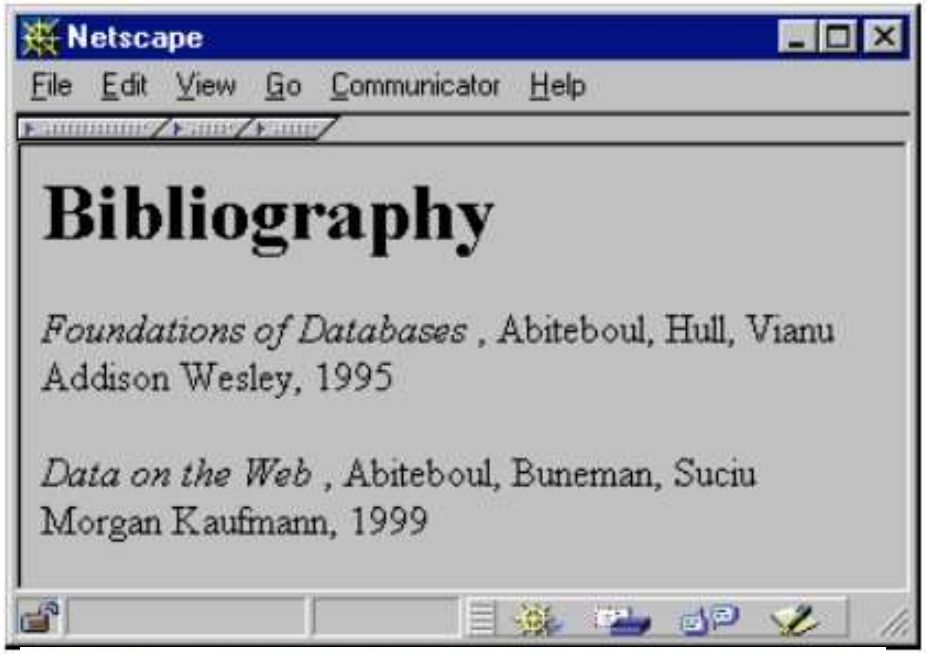

- It's mostly a "formatting" language
- It mixes presentation and content

# From HTML to XML



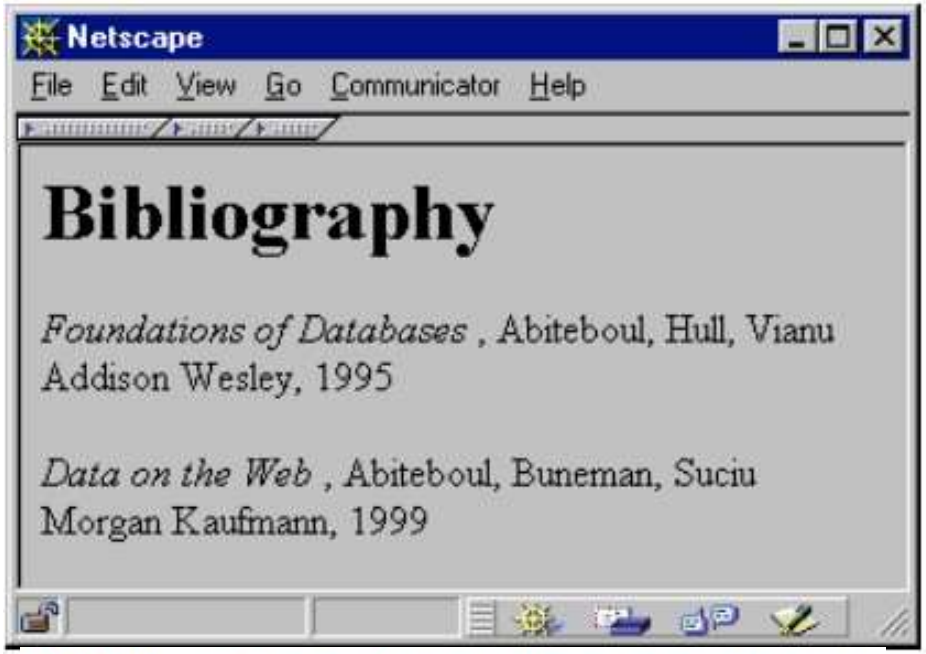

XML describes the content

XML
- The EXtensible Markup Language

## XML Syntax

```
<bibliography>
    <book>   <title> Foundations… </title>
             <author> Abiteboul </author>
             <author> Hull </author>
             <author> Vianu </author>
             <publisher> Addison Wesley </publisher>
             <year> 1995 </year>
    </book>
    …
</bibliography>
```

# From HTML to XML




XML
- The EXtensible Markup Language

XML describes the content

- Text-based
- Capture data (content), not presentation
- Data self-describes its structure
  - Names and nesting of tags have meanings!

## XML Syntax

```
<bibliography>
    <book>   <title> Foundations… </title>
             <author> Abiteboul </author>
             <author> Hull </author>
             <author> Vianu </author>
             <publisher> Addison Wesley </publisher>
             <year> 1995 </year>
    </book>
    …
</bibliography>
```

# HTML vs. XML

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## Difficulties with HTML ?

- Fixed set of tags
- Elements have document structuring semantics
- For presentation to human readers
- Applications cannot consume and process HTML easily

These difficulties are not in XML

# XML Terminology

- Tag names: book, title, …
- Start tags: <book>, <title>, …
- End tags: </book>, </title>, …
- An element is enclosed by a pair of start and end tags: <book>…</book>
- Elements can be nested: <book>…<title>…</title>…</book>
- Empty elements: <is_textbook></is_textbook>

- Can be abbreviated: <is_textbook/>

- Elements can also have attributes: <book ISBN="…" price="80.00">

```
<bibliography>
  <book ISBN="ISBN-10" price="80.00">
    <title>Foundations of Databases</title>
    <author>Abiteboul</author>
    <author>Hull</author>
    <author>Vianu</author>
    <publisher>Addison Wesley</publisher>
    <year>1995</year>
  </book>…
</bibliography>
```

Ordering generally matters, except for attributes

# Well-formed XML documents

A well-formed XML document

- Follows XML lexical conventions

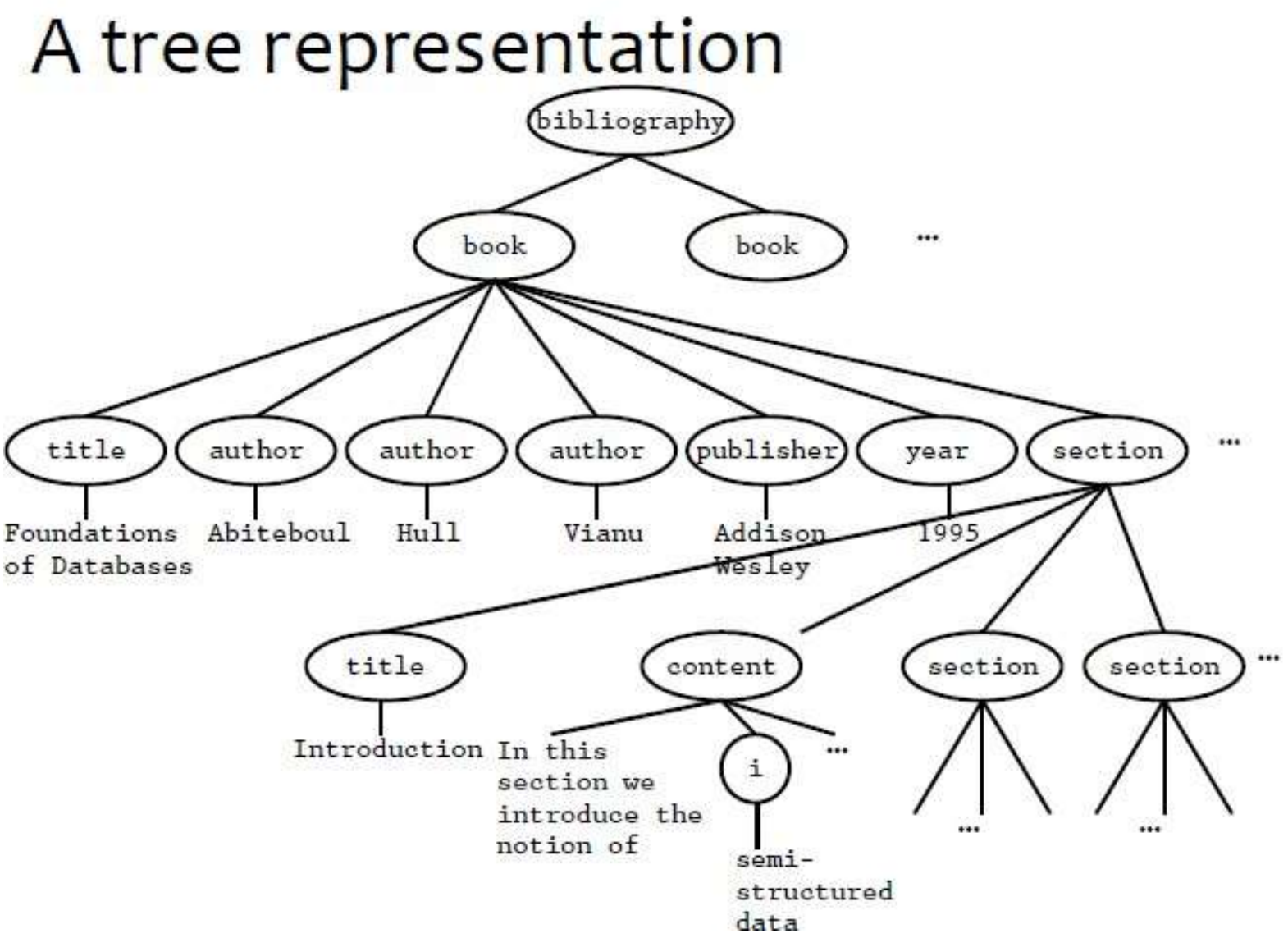
- Wrong: <section>We show that x < 0…</section>
- Right: <section>We show that x < 0…</section>
- Other special entities: > becomes > and & becomes &

- Contains a single root element

- Has properly matched tags and properly nested elements

- Right: <section>…<subsection>…</subsection>…</section>
- Wrong: <section>…<subsection>…</section>…</subsection>

# Tree Representation of XML Documents



# More XML Example: Attributes

```
<book price = "55" currency = "USD">
  <title> Foundations of Databases </title>
  <author> Abiteboul </author>
   ...
  <year> 1995 </year>
</book>
```

# Attributes vs. Elements

```
<book price = "55" currency = "USD">
  <title> Foundations of DBs </title>
  <author> Abiteboul </author>
  ...
  <year> 1995 </year>
</book>
```

```
<book>
  <title> Foundations of DBs </title>
  <author> Abiteboul </author>
  ...
  <year> 1995 </year>
  <price> 55 </price>
  <currency> USD </currency>
</book>
```

attributes are alternative ways to represent data

# Attributes vs. Elements

| Elements | Attributes |
|---|---|
| Ordered | Unordered |
| May be repeated | Must be unique |
| May be nested | Must be atomic |

Attribute names must be unique! (No Multisets)

<**person** name = "Wilde" name = "Wutz"/> is illegal!

# Documents to XML

Documents are a quite natural way to represent “objects”

- A great deal of text and semi-structured info

... <comment> "The odds of finding the pinger are very slim," </comment> said <name>Rob McCallum</name>, an <occupation> ocean search specialist </occupation>. "Even when you know roughly where the target is, it can be very tricky to find the pinger. They have a very limited range." ...


```
<news>
  <name>Rob McCallum</name>
  <occupation>ocean search specialist</occupation>
  <comment> The odds of finding the pinger are very slim </comment>
</news>
```

# Benefits of XML over Relational Data

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- Portability: Just like HTML, you can ship XML data across platforms
- Relational data requires heavy-weight API's

- Flexibility: You can represent any information (structured, semi-structured, documents, …)
- Relational data is best suited for structured data

- Extensibility: Since data describes itself, you can change the schema easily
- Relational schema is rigid and difficult to change

# XML vs. Relational Data

- Relational data
  - *Killer application*: Banking
  - Invented as a mathematically clean *abstract data model*
  - *Philosophy*: schema first, then data
- XML
  - First *killer application*: publishing industry
  - Invented as a *syntax for data*, only later an abstract data model
  - *Philosophy*: data and schemas should not be correlated, data can exist with or without schema, or with multiple schemas

# XML vs. Relational Data

- Relational data
  - Never had a *standard syntax* for data
  - Strict rules for data *normalization*, flat tables
  - *Order* is irrelevant, textual data supported but not primary goal
- XML
  - *Standard syntax* existed before the data model
  - No data *normalization*, flexibility is a must, nesting is good
  - *Order may* be very important, textual data support a primary goal

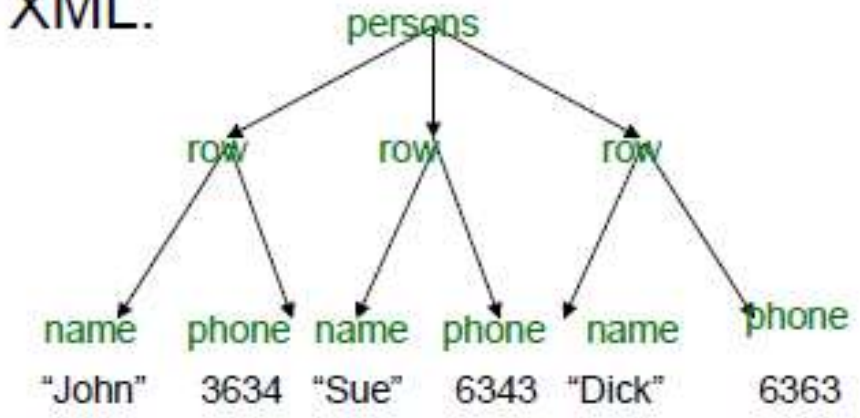
# Mapping Relational Data to XML

**XML view** of relational data

Persons

| Name | Phone |
|---|---|
| John | 3634 |
| Sue | 6343 |
| Dick | 6363 |

XML:




```
<persons>
    <row> <name>John</name>
          <phone> 3634</phone></row>
    <row> <name>Sue</name>
          <phone> 6343</phone>
    <row> <name>Dick</name>
          <phone> 6363</phone></row>
</persons>
```

# Mapping Relational Data to XML

XML view of relational data

Persons

| Name | Phone |
|---|---|
| John | 3634 |
| Sue | 6343 |

Orders

| PersonName | Date | Product |
|---|---|---|
| John | 2002 | Gizmo |
| John | 2004 | Gadget |
| Sue | 2002 | Gadget |

XML

```
<persons>
 <person>
   <name> John </name>
   <phone> 3634 </phone>
   <order>  <date> 2002 </date>
            <product> Gizmo </product>
    </order>
    <order> <date> 2004 </date>
            <product> Gadget </product>
    </order>
 </person>
 <person>
   <name> Sue </name>
   <phone> 6343 </phone>
   <order>  <date> 2004 </date>
            <product> Gadget </product>
    </order>
 </person>
</persons>
```

# XML is Semi-Structured

- Missing attributes:

```
<person>   <name> John</name>
           <phone>1234</phone>
 </person>

<person>  <name>Joe</name>
</person>
```

no phone !

- Could represent in a table with nulls

| name | phone |
|---|---|
| John | 1234 |
| Joe | - |

# XML is Semi-Structured

- Repeated attributes

```
<person> <name> Mary</name>
         <phone>2345</phone>
         <phone>3456</phone>
</person>
```

Two phones !

- Impossible in tables:

| name | phone | |
|---|---|---|
| Mary | 2345 | 3456 |
| | | |

???

# XML is Semi-Structured

## XML is Semi-structured Data

- Attributes with different types in different objects

```
<person> <name>  <first> John </first>
                 <last> Smith </last>
         </name>
         <phone>1234</phone>
</person>
```

Structured name !

- Nested collections (no 1NF)

# Questions?

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- Semi-structured Data ✓
- XML ✓
- **XML DTD**
- JSON

# XML Format Descriptions

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- Easy to start with, use your own tags
  - Contrast to relational DB, OO languages
- Only restriction: XML needs to be well-formed
- At some point, this is too much freedom
  - Use same syntax for different documents
  - Facilitate the writing of applications that process data
  - Exchange data with other parties
- Need to restrict the amount of freedom
  - Document Description Methods

# Overview of XML Schema Languages

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- Several standard Schema Languages
  - **DTDs**, XML Schema, RelaxNG, Schematron

- Schema languages have been designed after, and in an orthogonal fashion, to XML itself

- Schemas and data are decoupled in XML
  - Data can exist with or without schemas
  - Or with multiple schemas
  - Schema evolutions rarely impose evolving the data
  - Schemas can be designed before the data, or extracted from the data

- Makes XML the right choice for manipulating semi-structured data, or rapidly evolving data, or highly customizable data

# Document Type Definition (DTD)

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Goals:

- Define what tags and attributes are allowed
- Define how they are nested
- Define how they are ordered

Superseded by XML Schema

- Very complex: DTDs still used widely

# Element Type Declaration

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- Element Types are composed of:
  - Subelements (identified by Name)
  - Attribute lists (identified by Name)
  - Selection of Subelemente (choice)
  - PCDATA **text that WILL be parsed by a parser**
- Quantifier for Subelements and Choice
  - "+" for at least 1
  - "*" for 0 or more
  - "?" for 0 or 1
  - Default: exactly 1
- EMPTY and ANY are special predefined Types

- "|": Declaring either/or Content

<!ELEMENT note
(to,from,header,(message|body))>

<!ELEMENT element-name category>
or
<!ELEMENT element-name (element-content)>

Example:
<!ELEMENT br EMPTY>

XML example:
<br />

# Element Type Declaration

- Structure: <!ELEMENT *name content*>
- **Example**

```
<!ELEMENT book (title, (author+ | editor), publisher?)>
<!ELEMENT title (#PCDATA)>
<!ELEMENT author EMPTY>
<!ELEMENT publisher ANY>
```

- Valid document according to this DTD

```
<book >
    <title>Die wilde Wutz</title>
    <author/>  <author></author>
 <publisher><anything>...</anything></publisher>
</book>
```

# Declaring Attributes

- An attribute declaration has the following syntax:
- <!ATTLIST element-name attribute-name attribute-type attribute-value>

  DTD example:

  <!ATTLIST payment type CDATA "check">

  XML example:

  <payment type="check" />

# attribute-type

The **attribute-type** can be one of the following:

| Type | Description |
|---|---|
| CDATA | The value is character data |
| (*en1*\|*en2*\|..) | The value must be one from an enumerated list |
| ID | The value is a unique id |
| IDREF | The value is the id of another element |
| IDREFS | The value is a list of other ids |
| NMTOKEN | The value is a valid XML name |
| NMTOKENS | The value is a list of valid XML names |
| ENTITY | The value is an entity |
| ENTITIES | The value is a list of entities |
| NOTATION | The value is a name of a notation |
| xml: | The value is a predefined xml value |

# attribute-value

The **attribute-value** can be one of the following:

| Value | Explanation |
|---|---|
| *value* | The default value of the attribute |
| #REQUIRED | The attribute is required |
| #IMPLIED | The attribute is optional |
| #FIXED *value* | The attribute value is fixed |

Default Attribute Value

DTD:

```
<!ELEMENT square EMPTY>
<!ATTLIST square width CDATA "0">
```

Valid XML:

```
<square width="100" />
```

In the example above, the "square" element is defined to be an empty element with a "width" attribute of type CDATA. If no width is specified, it has a default value of 0.

# Attribute type--#REQUIRED

- Syntax: <!ATTLIST element-name attribute-name attribute-type #REQUIRED>
- Example
- DTD:
  <!ATTLIST person number CDATA #REQUIRED>

  Valid XML:
  <person number="5677" />

  Invalid XML:
  <person />
- Use the #REQUIRED keyword if you don't have an option for a default value, but still want to force the attribute to be present.

# Attribute type-- #IMPLIED

- Syntax: <!ATTLIST element-name attribute-name attribute-type #IMPLIED>
- Example
- DTD:
  <!ATTLIST contact fax CDATA #IMPLIED>

  Valid XML:
  <contact fax="555-667788" />

  Valid XML:
  <contact />
- Use the #IMPLIED keyword if you don't want to force the author to include an attribute, and you don't have an option for a default value.

# Attribute type (#fixed)

- Syntax
- <!ATTLIST element-name attribute-name attribute-type #FIXED "value">
- Example
- DTD:
  <!ATTLIST sender company CDATA #FIXED "Microsoft">

  Valid XML:
  <sender company="Microsoft" />

  Invalid XML:
  <sender company="W3Schools" />
- Use the #FIXED keyword when you want an attribute to have a fixed value without allowing the author to change it. If an author includes another value, the XML parser will return an error.

# Attribute Lists

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- Structure: <!ATTLIST *ElementName definition*>
- <!ATTLIST book
  isbn ID #REQUIRED
  price CDATA #IMPLIED
  curr CDATA #FIXED "EUR"
  index IDREFS "" >
- Valid and Not-valid Books

```
<book isbn="abc" curr="EUR"/>  !! no price
<book isbn="abc" price="30"/>  !! Curr, index default
<book index="DE" isbn="abc" curr="EUR"/>
<book/>   !! Missing isbn Attribute
<book isbn="abc" curr="USD"/>  !! wrong currency
```

# Entity

| Entity References | Character |
|---|---|
| &lt; | < |
| &gt; | > |
| &amp; | & |
| &quot; | " |
| &apos; | ' |

- Syntax: <!ENTITY entity-name "entity-value">
- DTD Example:
  <!ENTITY writer "Donald Duck.">
  <!ENTITY copyright "Copyright W3Schools.">
- XML example:
  <author>&writer;&copyright;</author>

**Note:** An entity has three parts: an ampersand (&), an entity name, and a semicolon (;).

# Entity

- An External Entity Declaration
- Syntax  <!ENTITY entity-name SYSTEM "URI/URL">
- Example
- DTD Example:

  <!ENTITY writer SYSTEM
  "https://www.w3schools.com/entities.dtd">
  <!ENTITY copyright SYSTEM
  "https://www.w3schools.com/entities.dtd">

- XML example:

  <author>&writer;&copyright;</author>

# DTD Example

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```
<!ELEMENT book (title, (author+ | editor), publisher?)>
<!ATTLIST book
   year CDATA #REQUIRED
   isbn  ID       #REQUIRED
   price  CDATA  #IMPLIED
   curr  CDATA  #FIXED "EUR"
   index  IDREFS  "" >
<!ELEMENT author (firstname, lastname)>
<!ELEMENT firstname (#PCDATA)>
<!ELEMENT lastname (#PCDATA)>
<!ELEMENT title (#PCDATA)>
```

# SUMMARY

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- Semi-structured Data ✓
- XML ✓
- XML DTD ✓
- **JSON**

# Difficulties with XML

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- "Tree, and not a graph."
  - Difficulty in modeling N:M relationships
  - The notion of reference (e.g. XLink, XPointer) not well integrated in the XML stack
- "Duplication of concepts"
  - Many ways to do the same thing
  - Justification for a "simpler" data model like RDF
- "Concepts that *seem* logically unnecessary"
  - PIs, comments, documents, etc
- Additional complexity factors
  - xsi:nil, QName in content, etc
- "Boring"
  - so is the (enterprise) world where XML lives

# Other Semi-Structured Data

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- JSON
- CSV
- Avro
- Protocol Buffers
- RDF
- Property Graphs
- …

# Why do we still talk about XML ?

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- It is a standard (not owned by anybody)
- Very well documented
- Many tools available
- Mother of all semi-structured data
- has the most features
- XML is here to stay
- It actually works!

# JSON

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## JSON

- JavaScript Object Notation
  - lightweight text-based open standard designed for human-readable data interchange.
- Interfaces in C, C++, Java, Python, Perl, etc.
- The filename extension is .json.

## Semistructured data model

- Flexible, nested structure (trees)
- Does not require predefined schema ("self describing”)
- Text representation: good for exchange, bad for performance
- Most common use: Language API

# JSON - Syntax

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```
{  "book": [
     {"id": "01",
       "language": "Java",
       "author": "H. Javeson",
        "year": 2015
     },
     {"id": "07",
       "language": "C++",
       "edition": "second"
       "author": "E. Sepp",
       "price": 22.25
     }
   ]
}
```

# JSON - Terminology

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## Curly braces

- Hold objects
- Each object is a list of name/value pairs separated
- by , (comma)
- Each pair is a name is followed by ':' (colon) followed by the value

## Square brackets

- Hold arrays and values are separated by , (comma).

## What is the data made up of?

- Objects, lists, and atomic values (integers, floats, strings, booleans).

# JSON – Data Structure

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## Collection

- Collections of name-value pairs:
  - {“name1”: value1, “name2”: value2, …}
- The “name” is also called a “key”
- Ordered lists of values: [obj1, obj2, obj3, …]

# XML vs. JSON

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## XML

```
<empinfo>
   <employees>
      <employee>
         <name>James Kirk</name>
         <age>40></age>
      </employee>
      <employee>
         <name>Jean-Luc Picard</name>
         <age>45</age>
      </employee>
      <employee>
         <name>Wesley Crusher</name>
         <age>27</age>
      </employee>
   </employees>
</empinfo>
```

## JSON

```
{  "empinfo" :
      {
            "employees" :  [
            {
                  "name" : "James Kirk",
                  "age" : 40,
            },
            {
                  "name" : "Jean-Luc Picard",
                  "age" : 45,
            },
            {
                  "name" : "Wesley Crusher",
                  "age" : 27,
            }
                              ]
      }
}
```

# Tree View of JSON Data

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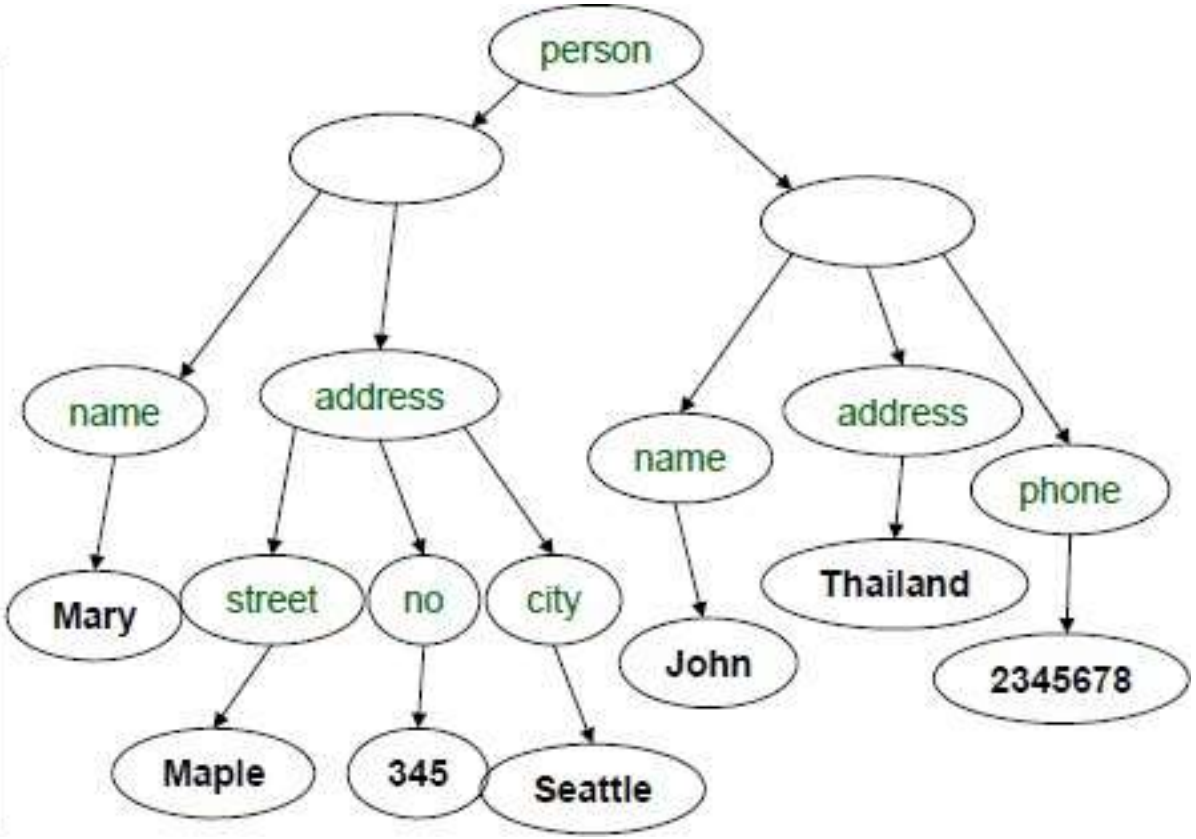
```
{"person":
  [ {"name": "Mary",
     "address":
       {"street": "Maple",
        "no": 345,
        "city": "Seattle"}},
    {"name": "John",
     "address": "Thailand",
     "phone": 2345678}
  ]
}
```

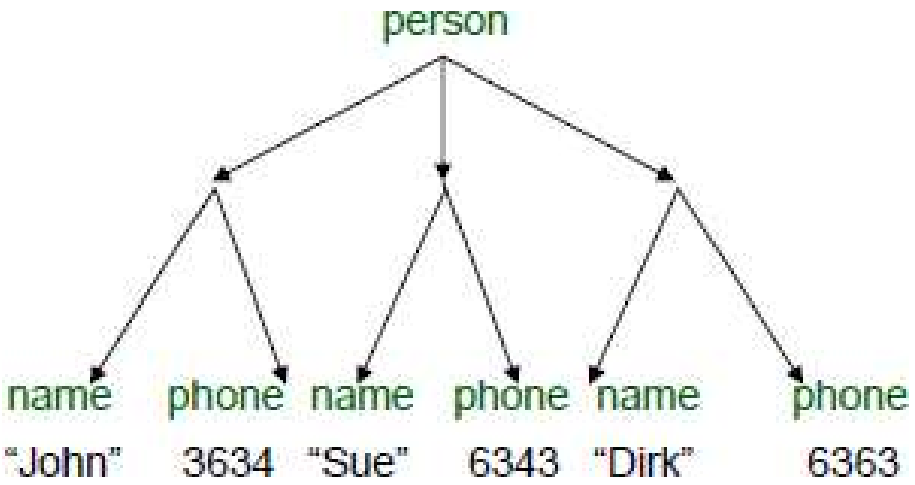



Self-describing

# Mapping Relational Data to JSON

Person

| name | phone |
|---|---|
| John | 3634 |
| Sue | 6343 |
| Dirk | 6363 |




```
{"person":
    [{"name": "John", "phone": 3634},
     {"name": "Sue",  "phone": 6343},
     {"name": "Dirk",  "phone": 6383}
    ]
}
```

# Mapping Relational Data to JSON

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Person

| name | phone |
|---|---|
| John | 3634 |
| Sue | 6343 |

Orders

| personName | date | product |
|---|---|---|
| John | 2002 | Gizmo |
| John | 2004 | Gadget |
| Sue | 2002 | Gadget |

```
{"Person":
    [{"name": "John",
      "phone": 3646,
      "Orders": [{"date": 2002,
                  "product": "Gizmo"},
                 {"date": 2004,
                  "product": "Gadget"}
                ]
    },
    {"name": "Sue",
     "phone": 6343,
     "Orders": [{"date": 2002,
                   "product": "Gadget"}
                ]
     }
    ]
}
```

# Handling NULL and Repeated Values

| name | phone |
|---|---|
| John | 1234 |
| Joe | - |

```
{"person":
   [{"name": "John", "phone": 1234},
    {"name": "Joe"}]
}
```

no phone !

```
{"person":
   [{"name": "John", "phone": 1234},
    {"name": "Mary", "phone": [1234, 5678]}]
}
```

Two phones !

# Handling Heterogeneous Objects

```
{"person":
   [{"name": "Sue", "phone": 3456},
    {"name": {"first": "John", "last": "Smith"}, "phone": 2345}
   ]
}
```

Structured name !

- Nested collections
- Heterogeneous collections

# Summary

## Data Exchange Format

- Well suited for exchanging data between applications
- XML, JSON

## Data Models

- Some systems use them as data models
- SQL Server – supports XML-valued relations
- CouchBase, Mongodb – JSON as data model

## Query Languages

- Xpath, Xquery
- CouchBase – N1QL
- JSONiq

Will NOT discuss in this lecture!