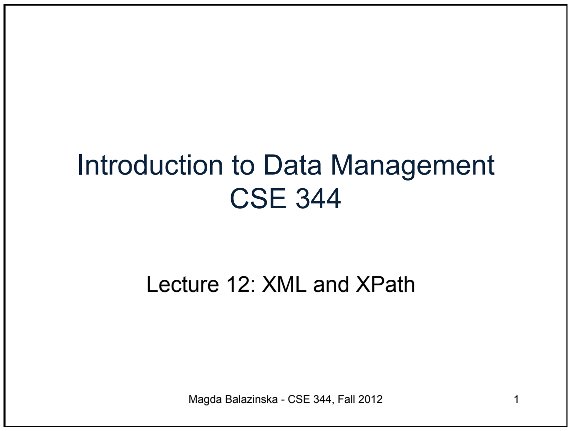
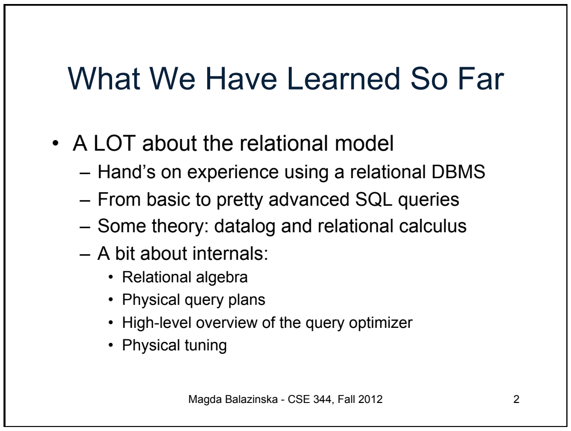


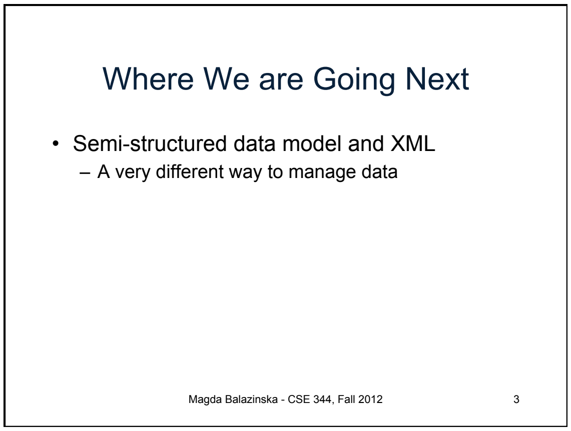
Introduction to Data Management CSE 344

Lecture 12: XML and XPath



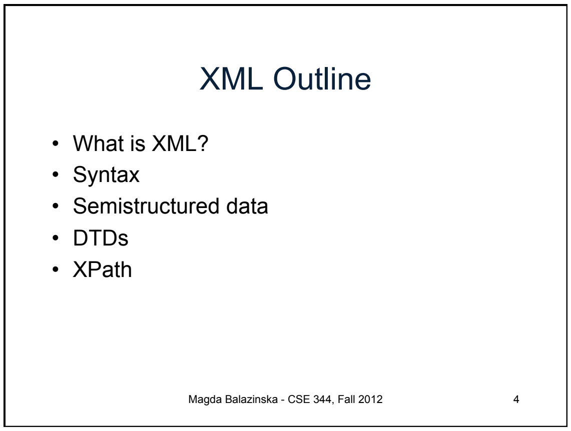
What We Have Learned So Far

- A LOT about the relational model
  - Hand's on experience using a relational DBMS
  - From basic to pretty advanced SQL queries
  - Some theory: datalog and relational calculus
  - A bit about internals:
    - Relational algebra
    - Physical query plans
    - High-level overview of the query optimizer
    - Physical tuning



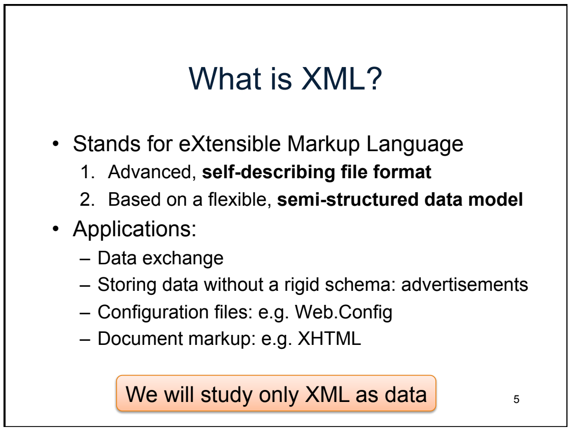
Where We are Going Next

- Semi-structured data model and XML
  - A very different way to manage data



XML Outline

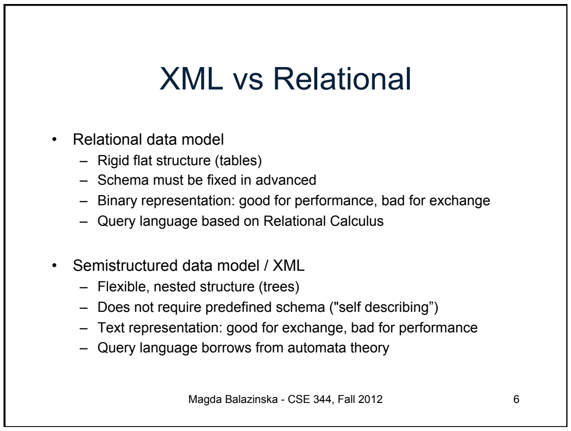
- What is XML?
- Syntax
- Semistructured data
- DTDs
- XPath



What is XML?

- Stands for eXtensible Markup Language
  1. Advanced, **self-describing file format**
  2. Based on a flexible, **semi-structured data model**
- Applications:
  - Data exchange
  - Storing data without a rigid schema: advertisements
  - Configuration files: e.g. Web.Config
  - Document markup: e.g. XHTML

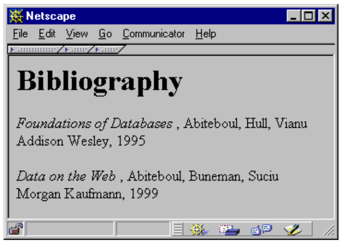
We will study only XML as data



XML vs Relational

- Relational data model
  - Rigid flat structure (tables)
  - Schema must be fixed in advanced
  - Binary representation: good for performance, bad for exchange
  - Query language based on Relational Calculus
- Semistructured data model / XML
  - Flexible, nested structure (trees)
  - Does not require predefined schema ("self describing")
  - Text representation: good for exchange, bad for performance
  - Query language borrows from automata theory

From HTML to XML



Bibliography

Foundations of Databases , Abiteboul, Hull, Vianu
Addison Wesley, 1995

Data on the Web , Abiteboul, Buneman, Suciu
Morgan Kaufmann, 1999

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>
       Abiteboul, Buneman, Suciu
       <br> Morgan Kaufmann, 1999
```

HTML describes the presentation

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>
```

XML describes the content

XML Terminology

- Tags: book, title, author, …
- Start tag: <book>, end tag: </book>
- Elements: <book>…</book>,<author>…</author>
- Elements are nested
- Empty element: <red></red> abbrv. <red/>
- An XML document: single *root element*

Well formed XML document
- Has matching tags
- A short header
- And a root element

Well-Formed XML

```
<? xml version=“1.0” encoding=“utf-8” standalone=“yes” ?>
<SomeTag>
   …
</SomeTag>
```

More XML: Attributes

```
<book price = “55” currency = “USD”>
   <title> Foundations of Databases </title>
   <author> Abiteboul </author>
   …
   <year> 1995 </year>
</book>
```

Attributes v.s. 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>
```

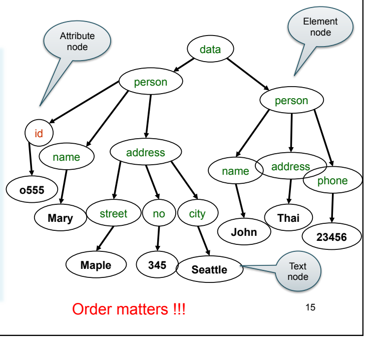
Attributes are alternative ways to represent data

Comparison

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

XML Semantics: a Tree !

```
<data>
   <person id=“o555” >
      <name> Mary </name>
      <address>
         <street>Maple</street>
         <no> 345 </no>
         <city> Seattle </city>
      </address>
   </person>
   <person>
      <name> John </name>
      <address>Thailand
      </address>
      <phone>23456</phone>
   </person>
</data>
```



Order matters !!!

XML Data

- XML is self-describing
- Schema elements become part of the data
  - Relational schema: person(name,phone)
  - In XML <person>, <name>, <phone> are part of the data, and are repeated many times
- Consequence: XML is much more flexible
- XML = semistructured data

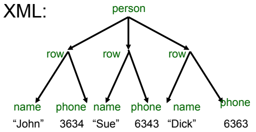
Mapping Relational Data to XML Data

The canonical mapping:

Person

Name	Phone
John	3634
Sue	6343
Dick	6363

XML:



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

Mapping Relational Data to XML Data

Application specific mapping

Person

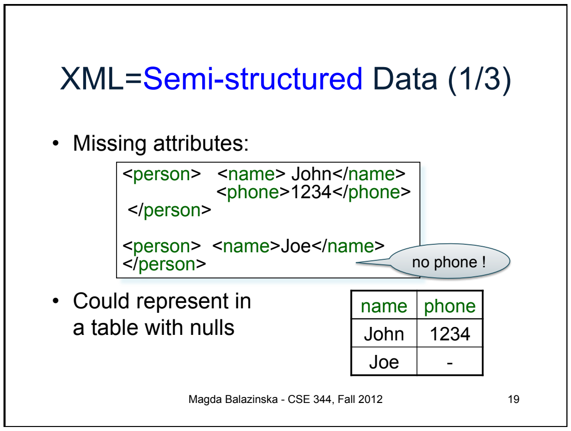
Name	Phone
John	3634
Sue	6343

Orders

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

XML

```
<people>
  <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>
</people>
```



XML=Semi-structured Data (1/3)

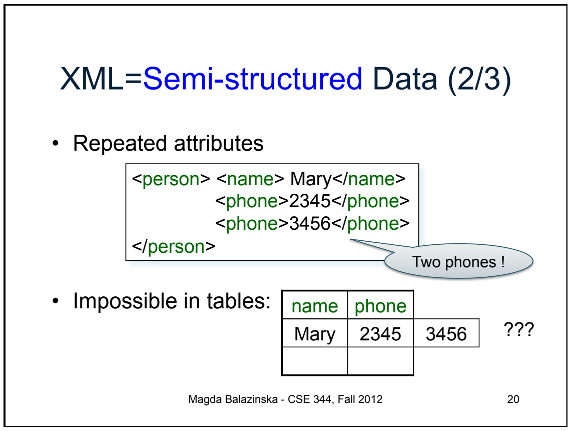
- Missing attributes:

```
<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=Semi-structured Data (2/3)

- Repeated attributes

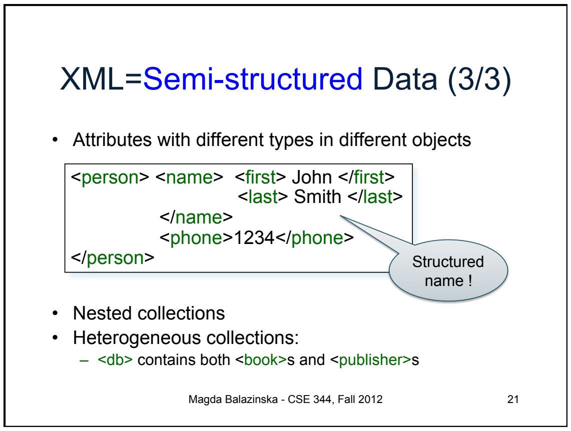
```
<person> <name> Mary</name>
         <phone>2345</phone>
         <phone>3456</phone>
</person>
```

Two phones !

- Impossible in tables:

name	phone	
Mary	2345	3456

???



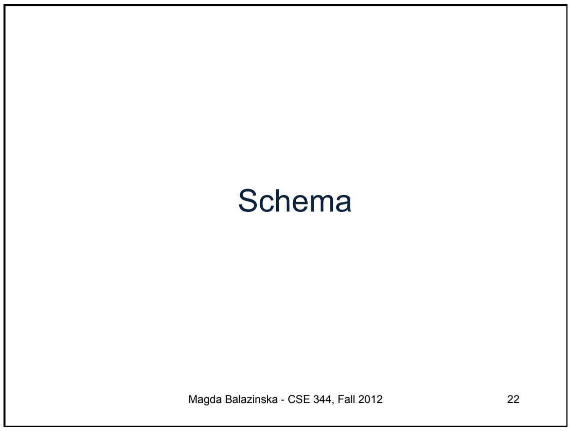
XML=Semi-structured Data (3/3)

- Attributes with different types in different objects

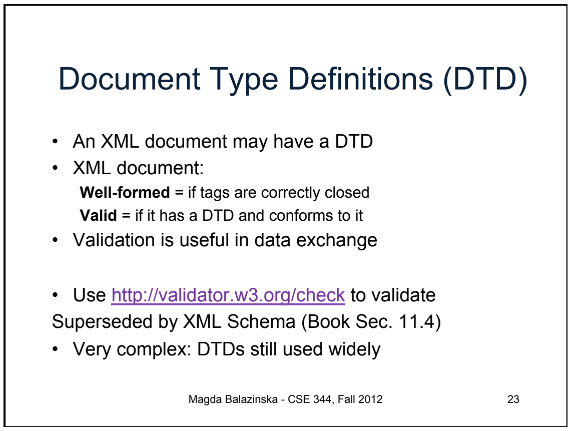
```
<person> <name>  <first> John </first>
                 <last> Smith </last>
         </name>
         <phone>1234</phone>
</person>
```

Structured name !

- Nested collections
- Heterogeneous collections:
  - <db> contains both <book>s and <publisher>s



Schema



Document Type Definitions (DTD)

- An XML document may have a DTD
- XML document:

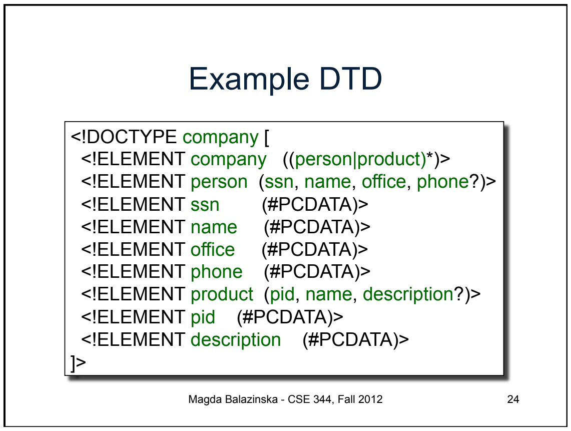
  Well-formed = if tags are correctly closed

  Valid = if it has a DTD and conforms to it
- Validation is useful in data exchange

- Use http://validator.w3.org/check to validate

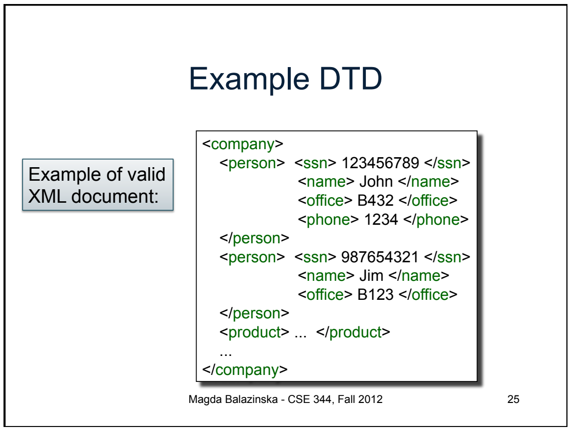
Superseded by XML Schema (Book Sec. 11.4)

- Very complex: DTDs still used widely



Example DTD

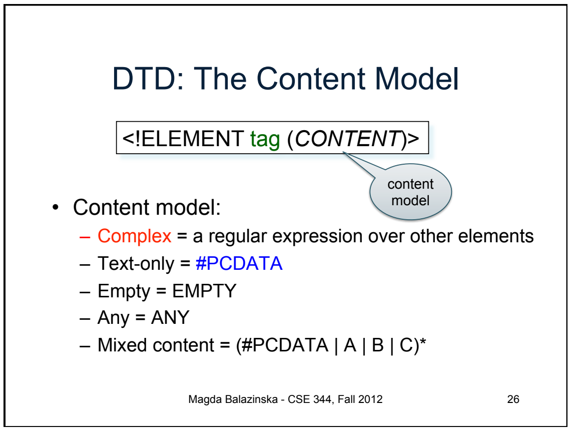
```
<!DOCTYPE company [
  <!ELEMENT company    ((person|product)*)>
  <!ELEMENT person  (ssn, name, office, phone?)>
  <!ELEMENT ssn        (#PCDATA)>
  <!ELEMENT name       (#PCDATA)>
  <!ELEMENT office     (#PCDATA)>
  <!ELEMENT phone      (#PCDATA)>
  <!ELEMENT product  (pid, name, description?)>
  <!ELEMENT pid     (#PCDATA)>
  <!ELEMENT description     (#PCDATA)>
]>
```



Example DTD

Example of valid XML document:

```
<company>
   <person>  <ssn> 123456789 </ssn>
             <name> John </name>
             <office> B432 </office>
             <phone> 1234 </phone>
   </person>
   <person>  <ssn> 987654321 </ssn>
             <name> Jim </name>
             <office> B123 </office>
   </person>
   <product> ...  </product>
   ...
</company>
```

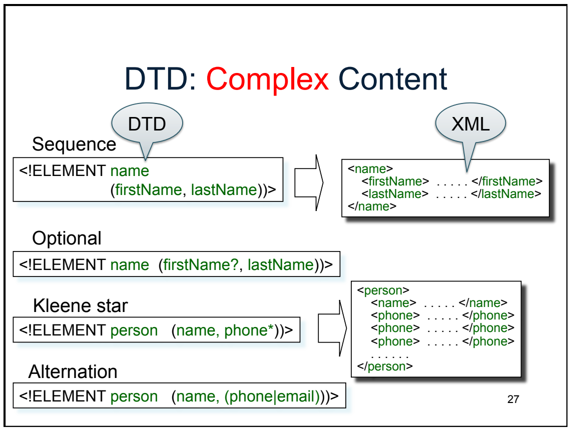


DTD: The Content Model

<!ELEMENT tag (*CONTENT*)>

content model

- Content model:
  - Complex = a regular expression over other elements
  - Text-only = #PCDATA
  - Empty = EMPTY
  - Any = ANY
  - Mixed content = (#PCDATA | A | B | C)*



DTD: Complex Content

Sequence

```
<!ELEMENT name
        (firstName, lastName))>
```

```
<name>
   <firstName>  . . . . . </firstName>
   <lastName>  . . . . . </lastName>
</name>
```

Optional

```
<!ELEMENT name  (firstName?, lastName))>
```

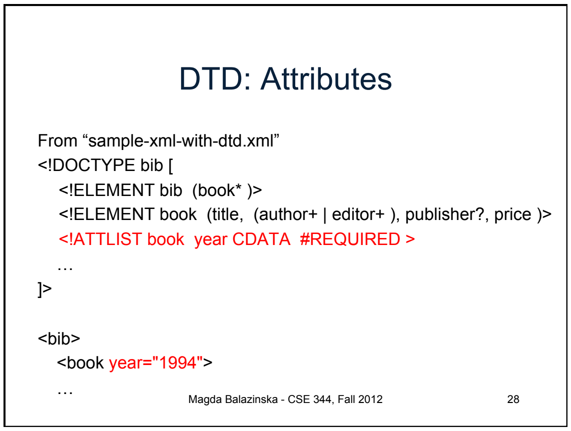
Kleene star

```
<!ELEMENT person   (name, phone*))>
```

```
<person>
   <name>  . . . . . </name>
   <phone>  . . . . . </phone>
   <phone>  . . . . . </phone>
   <phone>  . . . . . </phone>
   . . . . . .
</person>
```

Alternation

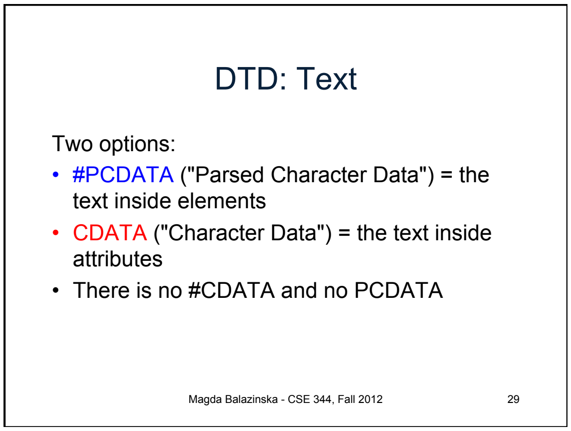
```
<!ELEMENT person   (name, (phone|email)))>
```



DTD: Attributes

From “sample-xml-with-dtd.xml”

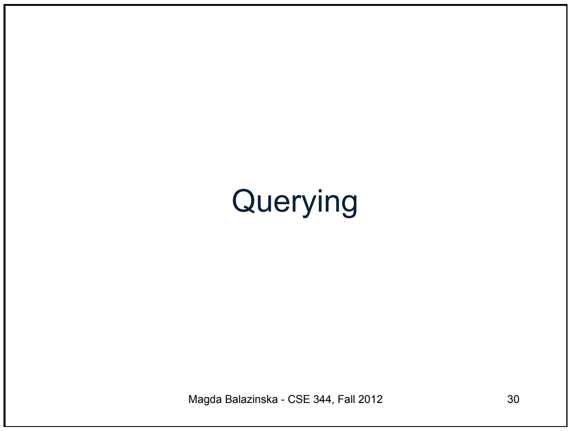
```
<!DOCTYPE bib [
   <!ELEMENT bib  (book* )>
   <!ELEMENT book  (title,  (author+ | editor+ ), publisher?, price )>
   <!ATTLIST book  year CDATA  #REQUIRED >
   …
]>

<bib>
   <book year="1994">
   …
```



DTD: Text

Two options:

- #PCDATA ("Parsed Character Data") = the text inside elements
- CDATA ("Character Data") = the text inside attributes
- There is no #CDATA and no PCDATA



Querying

Querying XML Data

- XPath = simple navigation → today
- XQuery = the SQL of XML → Friday
- XSLT = recursive traversal
  - will not discuss in class

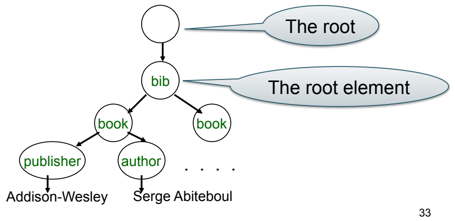
Sample Data for Queries

```
<bib>
    <book>  <publisher> Addison-Wesley </publisher>
            <author> Serge Abiteboul </author>
            <author> <first-name> Rick </first-name>
                     <last-name> Hull </last-name>
            </author>
            <author> Victor Vianu </author>
            <title> Foundations of Databases </title>
            <year> 1995 </year>
    </book>
    <book price="55">
           <publisher> Freeman </publisher>
            <author> Jeffrey D. Ullman </author>
            <title> Principles of Database and Knowledge Base Systems </title>
            <year> 1998 </year>
    </book>
</bib>
```

Data Model for XPath

XPath returns a sequence of items. An item is either:

- A value of primitive type, or
- A node (doc, element, or attribute)



XPath: Simple Expressions

/bib/book/year

Result: <year> 1995 </year>
<year> 1998 </year>

/bib/paper/year

Result: empty (there were no papers)

/bib → What's the difference ? → /

XPath: Restricted Kleene Closure

//author

```
Result:<author> Serge Abiteboul </author>
       <author> <first-name> Rick </first-name>
                <last-name> Hull </last-name>
       </author>
       <author> Victor Vianu </author>
       <author> Jeffrey D. Ullman </author>
```

/bib//first-name

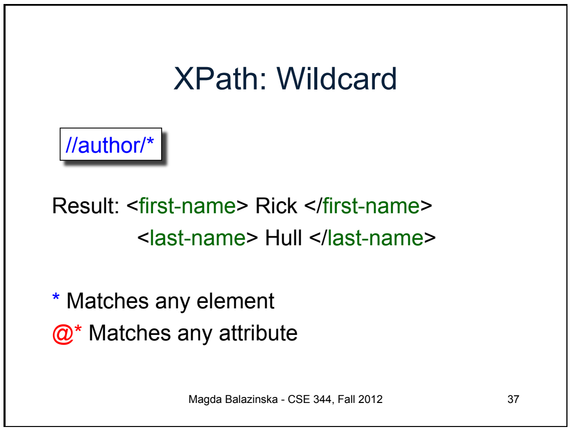
Result: <first-name> Rick </first-name>

XPath: Attribute Nodes

/bib/book/@price

Result: “55”

@price means that price has to be an attribute



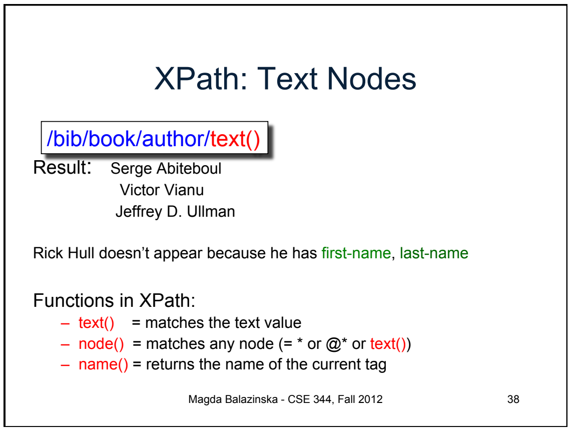
XPath: Wildcard

```
//author/*
```

Result: <first-name> Rick </first-name>
<last-name> Hull </last-name>

* Matches any element

@* Matches any attribute



XPath: Text Nodes

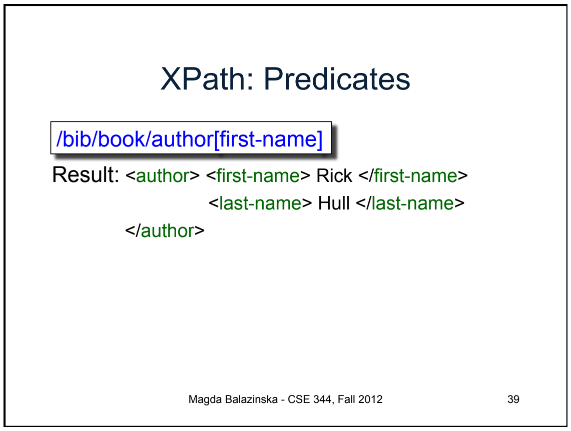
```
/bib/book/author/text()
```

Result: Serge Abiteboul
Victor Vianu
Jeffrey D. Ullman

Rick Hull doesn't appear because he has first-name, last-name

Functions in XPath:

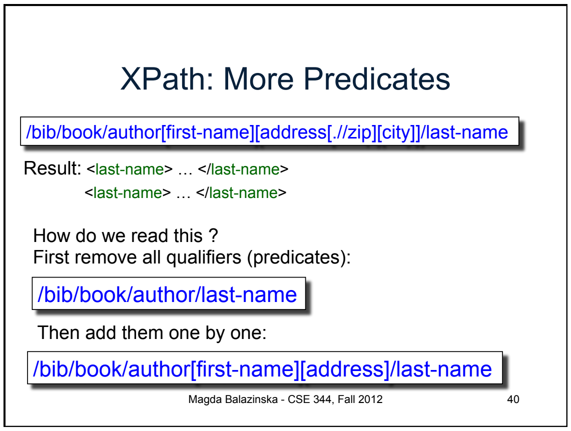
- text() = matches the text value
- node() = matches any node (= * or @* or text())
- name() = returns the name of the current tag



XPath: Predicates

```
/bib/book/author[first-name]
```

Result: <author> <first-name> Rick </first-name>
<last-name> Hull </last-name>
</author>



XPath: More Predicates

```
/bib/book/author[first-name][address[.//zip][city]]/last-name
```

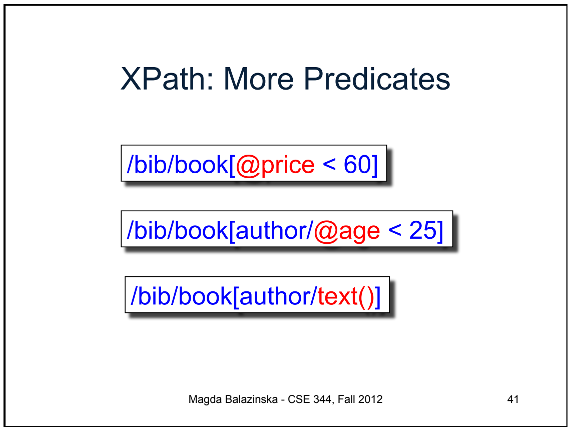
Result: <last-name> … </last-name>
<last-name> … </last-name>

How do we read this ?
First remove all qualifiers (predicates):

```
/bib/book/author/last-name
```

Then add them one by one:

```
/bib/book/author[first-name][address]/last-name
```

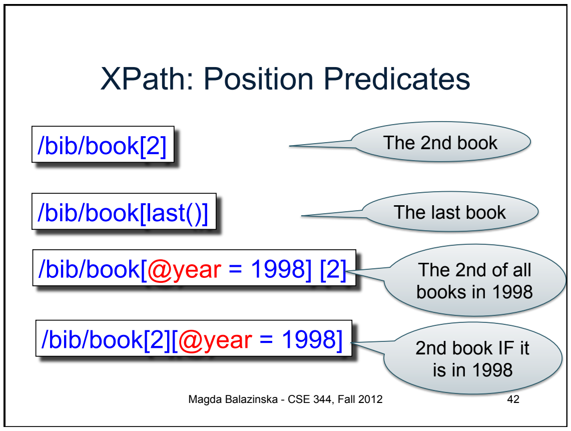


XPath: More Predicates

```
/bib/book[@price < 60]
```

```
/bib/book[author/@age < 25]
```

```
/bib/book[author/text()]
```



XPath: Position Predicates

```
/bib/book[2]
```

The 2nd book

```
/bib/book[last()]
```

The last book

```
/bib/book[@year = 1998] [2]
```

The 2nd of all books in 1998

```
/bib/book[2][@year = 1998]
```

2nd book IF it is in 1998

XPath: More Axes

. means *current node* /bib/book[.//review]

/bib/book[./review] Same as /bib/book[review]

/bib/author/. /first-name Same as /bib/author/first-name

XPath: More Axes

.. means *parent node*

/bib/author/.. /author/zip Same as /bib/author/zip

/bib/book[.//review/../comments]

Same as

/bib/book[.//*[comments][review]]

Hint: don't use ..

A Few Extra Examples

Run these examples on the sample xml posted on course website
Follow hw4 instructions

Each line is a separate example:

```
doc("sample-xml.xml")//book/price
doc("sample-xml.xml")//book[editor]/price
doc("sample-xml.xml")//book[price/text() > 100]/title
```

XPath: Summary

bib	matches a bib element
*	matches any element
/	matches the root element
/bib	matches a bib element under root
bib/paper	matches a paper in bib
bib//paper	matches a paper in bib, at any depth
//paper	matches a paper at any depth
paper|book	matches a paper or a book
@price	matches a price attribute
bib/book/@price	matches price attribute in book, in bib
bib/book[@price<"55"]/author/last-name	matches…
bib/book[@price<"55" or @price>"99"]/author/last-name	matches…