Advanced Databases

Querying XML - XPath

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Michaelmas Term

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Course Outline

- Enhanced Entity-Relationship (EER) Model
- Semistructured Databases - XML
- **XML Data Manipulation - XPath,** XQuery
- Transactions and Concurrency Control
- Distributed Transactions
- Distributed Concurrency Control

Semi-structured data

- Main language for semi-structured data:
  - XML (eXtended Markup Language)
  - a language for *structuring* and *exchanging* web data

- Similarities with HTML:
  - HyperText Markup Language
  - a language for *displaying* web pages

- Both XML and HTML are “tag” languages

XML terminology

- XML data have a (directed) tree structure
- tags: book, title, author, …
- start tag: <book>, end tag: </book>
- elements:
  - <book>…</book>
  - <author>…</author>
- elements are nested
- empty element:
  - <author></author> or: <author/>
- an XML document: single *root element*

Querying XML data

How would you query a directed tree?

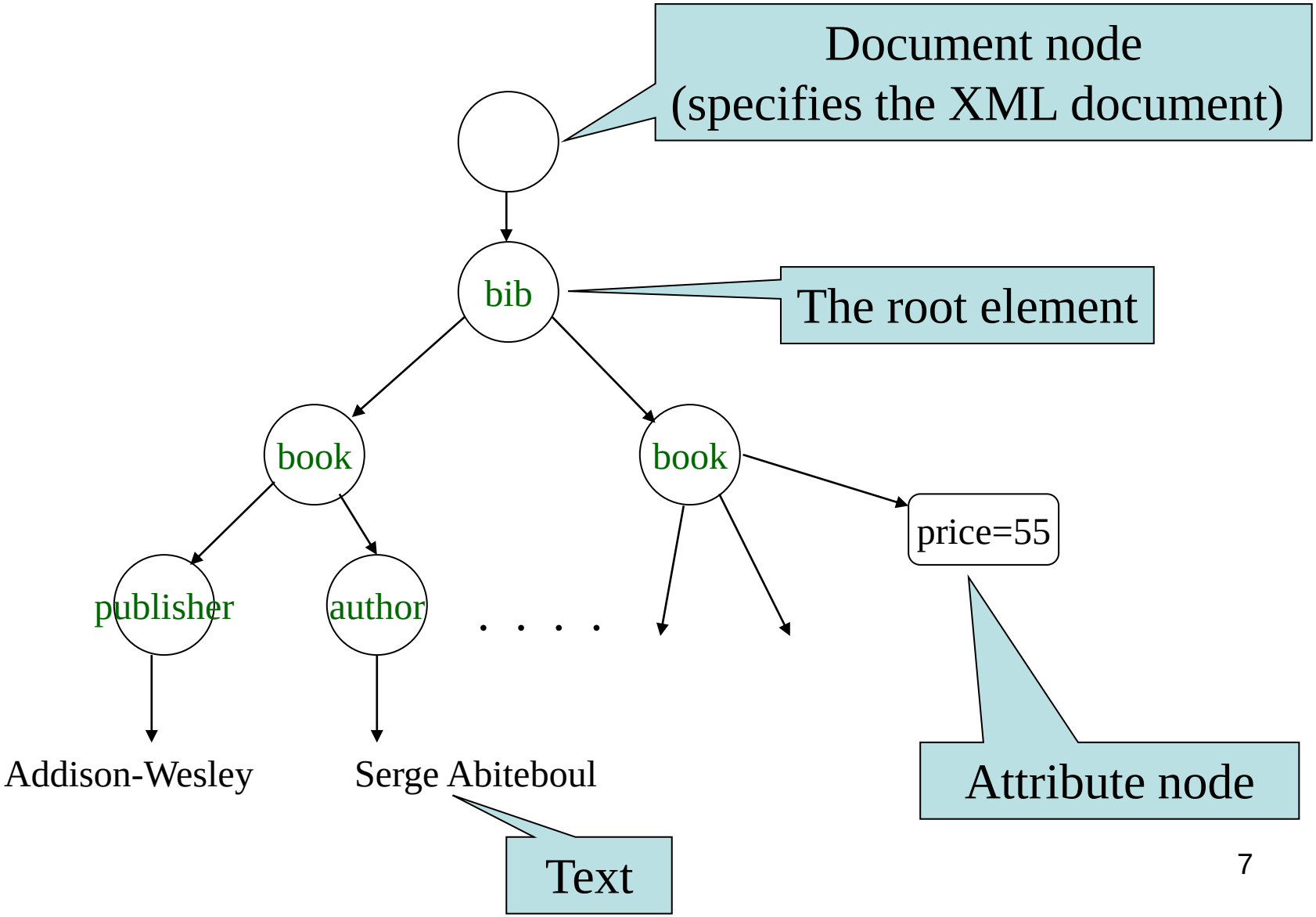
- A common approach: define a template describing traversals from the root
  - simple navigation through the tree
- XPath: the basis of this template
  - navigates through the tree to select data
- XQuery: the complete XML query language
  - "the SQL of XML"
  - selects / combines data (using XPath) and constructs output

Path Expressions

XPath:

- a declarative (non-procedural) query language for XML
- simple syntax for addressing parts of an XML document
- treats an XML document as a logical ordered tree with nodes:
  - root, elements, attributes, text
- a location path is composed by a series of steps, joined with ‘ ***/*** ’
  - like in a directory path

Data model for XPath



Sample Data for Queries

```
<bib>
    <book>
            <publisher>  Addison-Wesley  </publisher>
            <author>   Serge Abiteboul   </author>
            <author>  <firstName> Rick  </firstName>
                      <lastName> Hull   </lastName>
            </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>
```

XPath: Simple Expressions

Navigation path: Output is the end of the path !

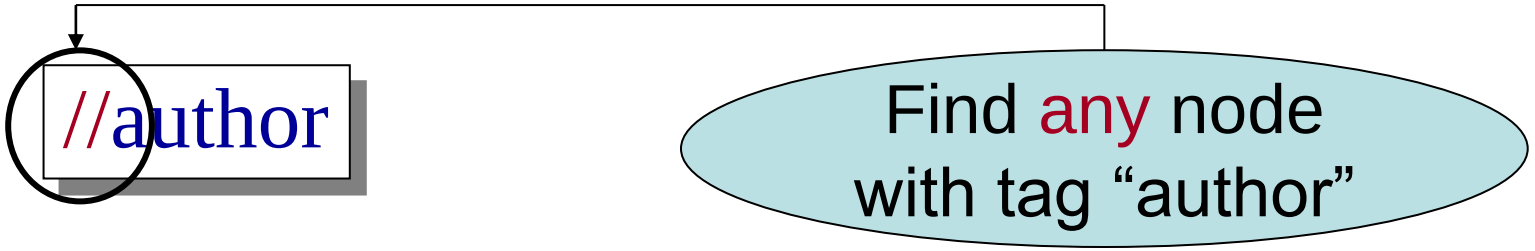
/bib/book/year

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

/bib/paper/year

Result: empty (there were no papers)

Restricted Kleene Closure



Result:

```
<author>  Serge Abiteboul  </author>
<author>   <firstName>  Rick  </firstName>
           <lastName>  Hull  </lastName>
</author>
<author>  Victor Vianu  </author>
<author>  Jeffrey D. Ullman  </author>
```

4 nodes of the tree

/bib/book//firstName

Result:

```
<firstName> Rick </firstName>
```

Kleene Closure in Logic

In mathematical logic (background):

- let $V_0 = V$ be a set of strings,
  including the *empty* string ε
- define recursively:

$$V_{i+1} = \{uw \mid u \in V_i \text{ and } w \in V\}$$

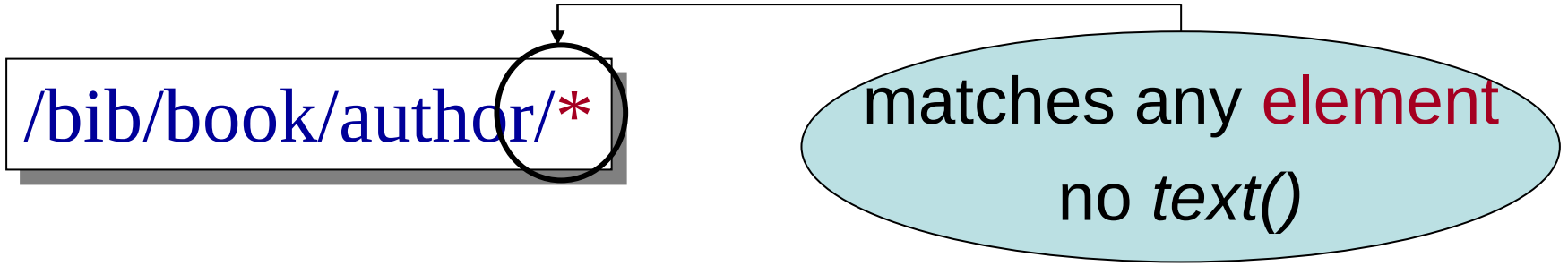
- The Kleene closure (or Kleene star) on V *is:*

$$V^* = \bigcup_{i \geq 0} V_i = V_0 \cup V_1 \cup V_2 \cup V_3 \ldots$$

i.e. the set of all possible strings obtained
by concatenations of strings in V

// in XPath: "restricted" (i.e. finite) Kleene closure
of elements with their subelements

XPath: Wildcards



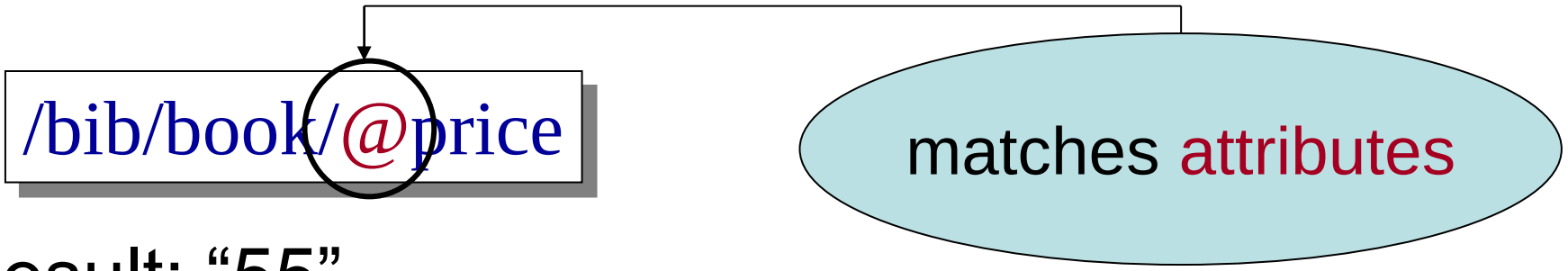
Result: <firstName> Rick </firstName>
<lastName> Hull </lastName>

Note: the same as //author/*

//book/*

Result: <publisher> Addison-Wesley </publisher>
<author> Serge Abiteboul </author>
. . .

XPath: Attribute nodes



Result: “55”

@price means that price has to be an attribute

@* matches any attribute

XPath: Predicates

In Xpath, we can add a predicate after a tag:

- a boolean condition in square brackets

⇒ follow only the subset of paths whose tags satisfy the predicate (i.e. make it "true")

```
//book[@price = "55"]
```

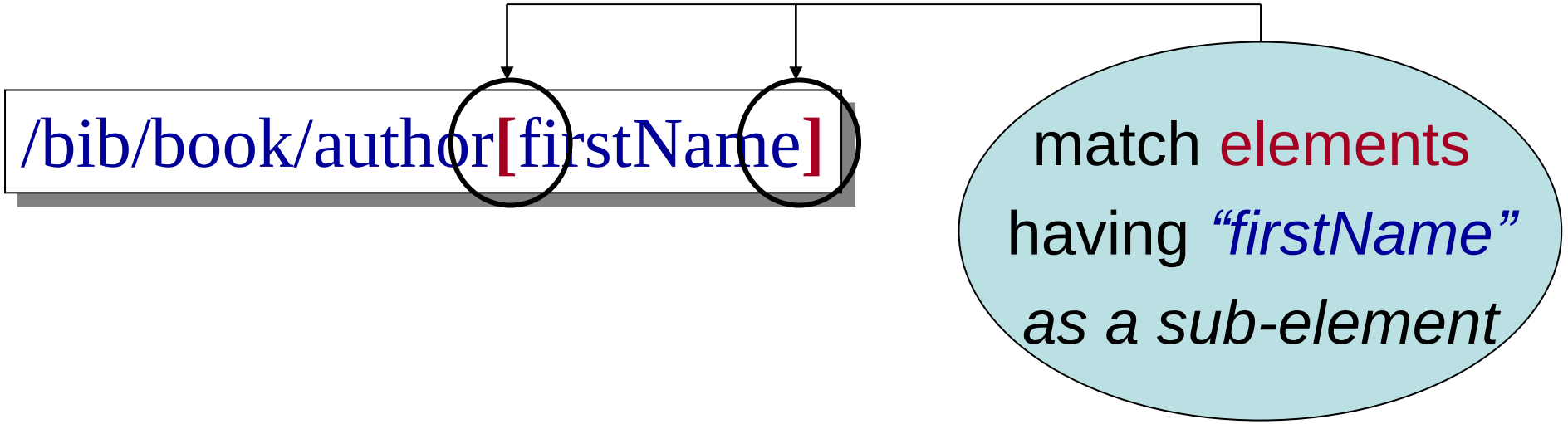
Result:

```
<book price="55">
    <publisher>  Freeman  </publisher>
    <author>  Jeffrey D. Ullman  </author>
    <title>  Principles of Database and Knowledge Base Systems  </title>
    <year>  1998  </year>
</book>
```

XPath: Predicates

In Xpath predicates:

- comparisons have an implicit "there exists" sense



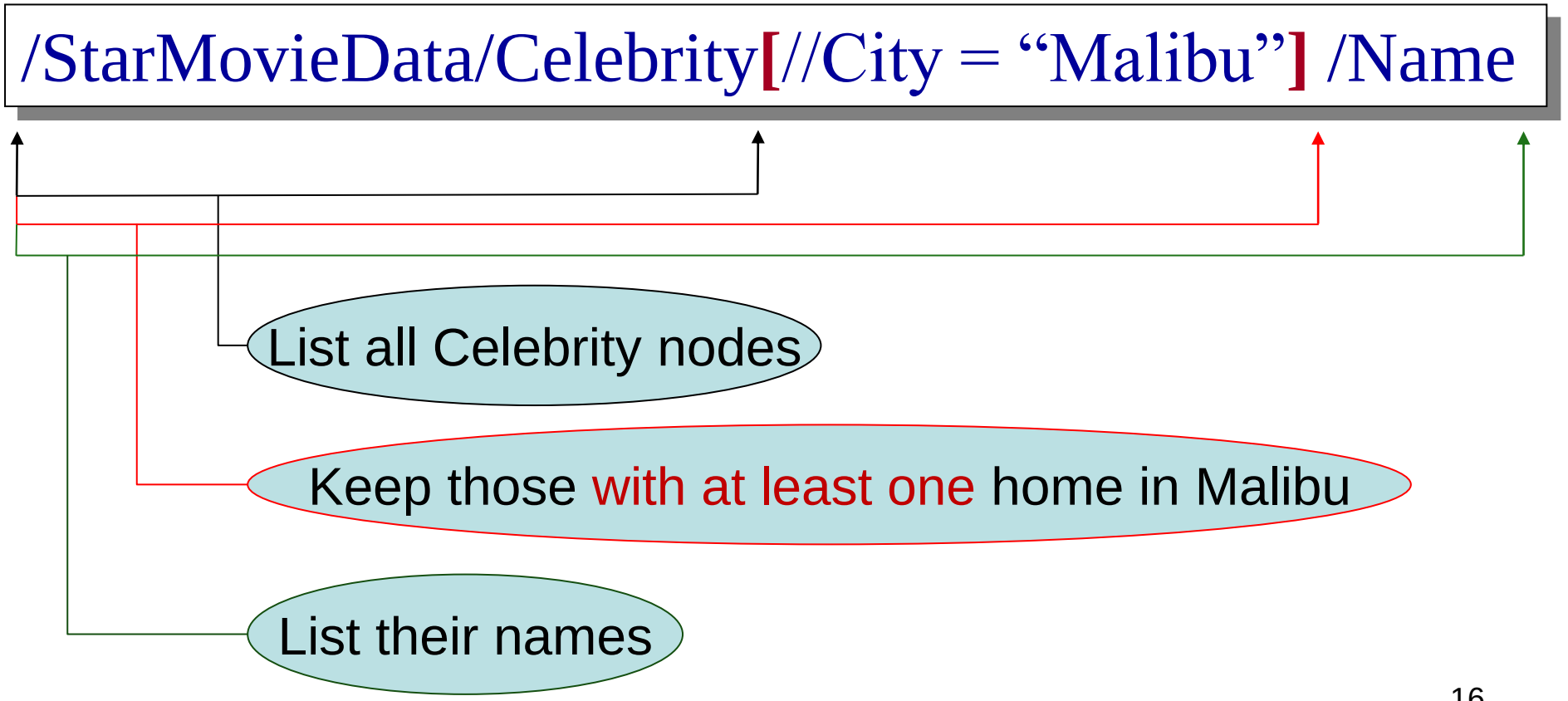
Result:

```
<author>
        <firstName> Rick </firstName>
        <lastName> Hull </lastName>
</author>
```

XPath: Predicates

In Xpath predicates:

- comparisons have an implicit "there exists" sense



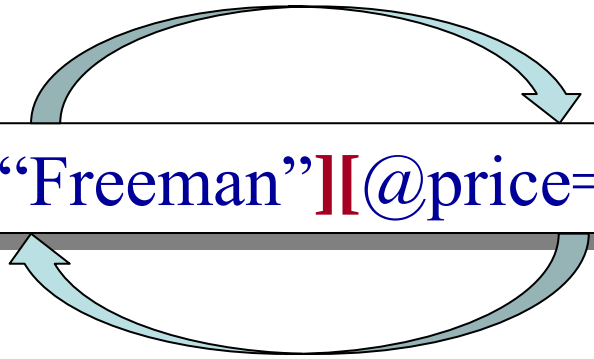
More than one predicates

Find all *books*, which have *price 55* and
a *firstName* (at some depth) or a *publisher "Freeman"*

```
/bib//book[@price="55"][//firstName | publisher = "Freeman"]
```

The same as:

```
/bib//book[//firstName | publisher = "Freeman"][@price="55"]
```



Result:

```
<book price="55">
    <publisher>  Freeman  </publisher>
    <author>  Jeffrey D. Ullman  </author>
    <title>  Principles of Database and Knowledge Base Systems
    </title>
    <year>  1998  </year>
</book>
```

More than one predicates

- Can we always swap predicates in a query?
- A priority rule:
  - first satisfy the first predicate
  - among those nodes that satisfy the first predicate, select the nodes that satisfy the second one, etc.
- In the previous example:
  - two independent predicates $\Rightarrow$ we can swap them

```
/bib//book[@price="55"][//firstName | publisher = "Freeman"]
```

- Not always the case !

XPath: Axes

The general form of an Xpath query:

/step-1/step-2/step-3/…/step-*n*

- Each of these steps consists of:
  - a basis and (optionally) a list of predicates
- A basis consists of:
  - an axis (the direction in which the navigation proceeds from the current node)
  - a node test (the type of node we navigate to)
- So far we only navigated:
  - from a node to its children or to an attribute

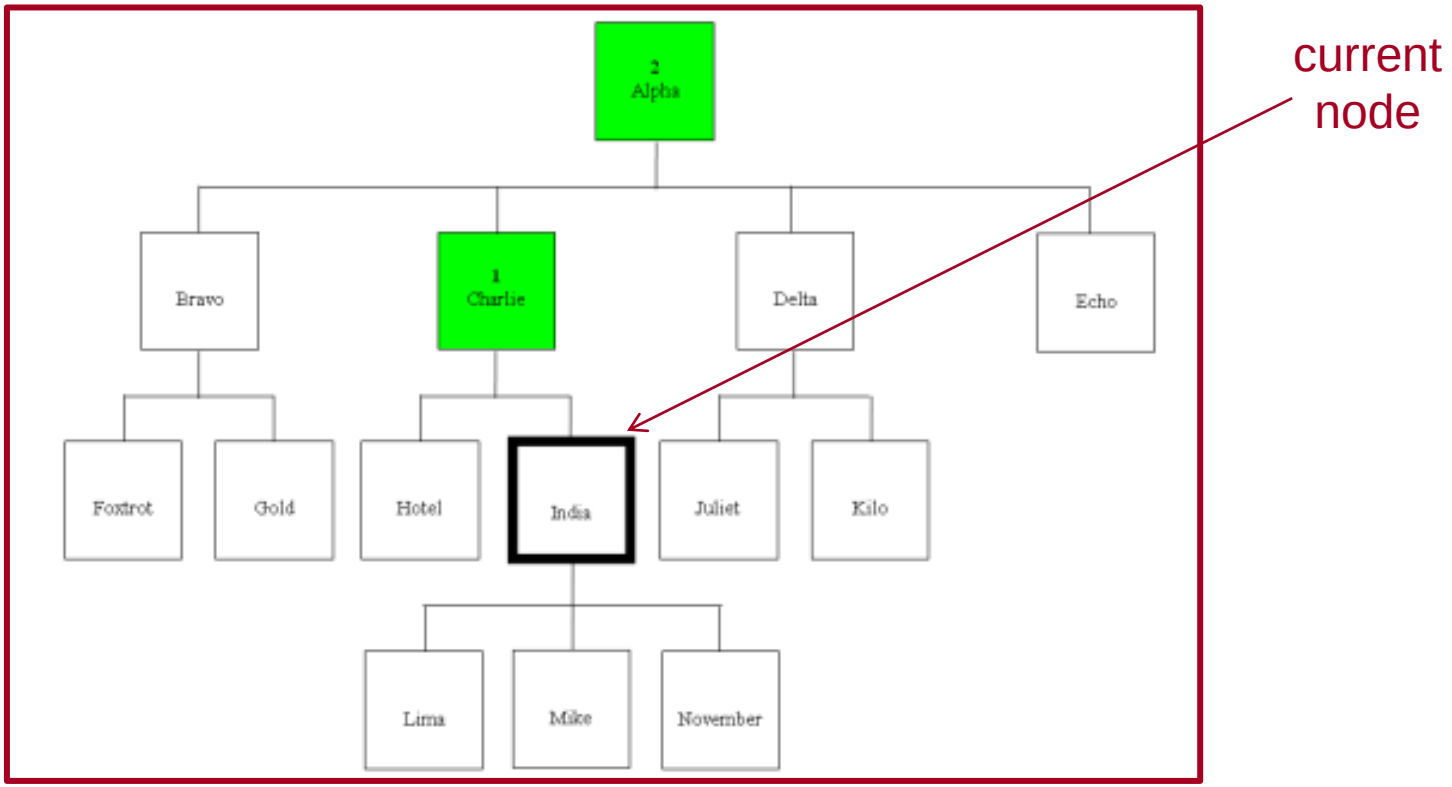
XPath: Axes

- An axis in XPath is a “local navigation mode”:
- Xpath provides several axes, among them:
  - child (the default axis)
  - parent
  - attribute
  - self
  - descendant
  - descendant-or-self
  - ancestor
  - ancestor-or-self
  - following-sibling
  - preceding-sibling
  - following
  - preceding

nodes after / before the current node in the (serial) XML document order, which are not descendants / not ancestors of the current node

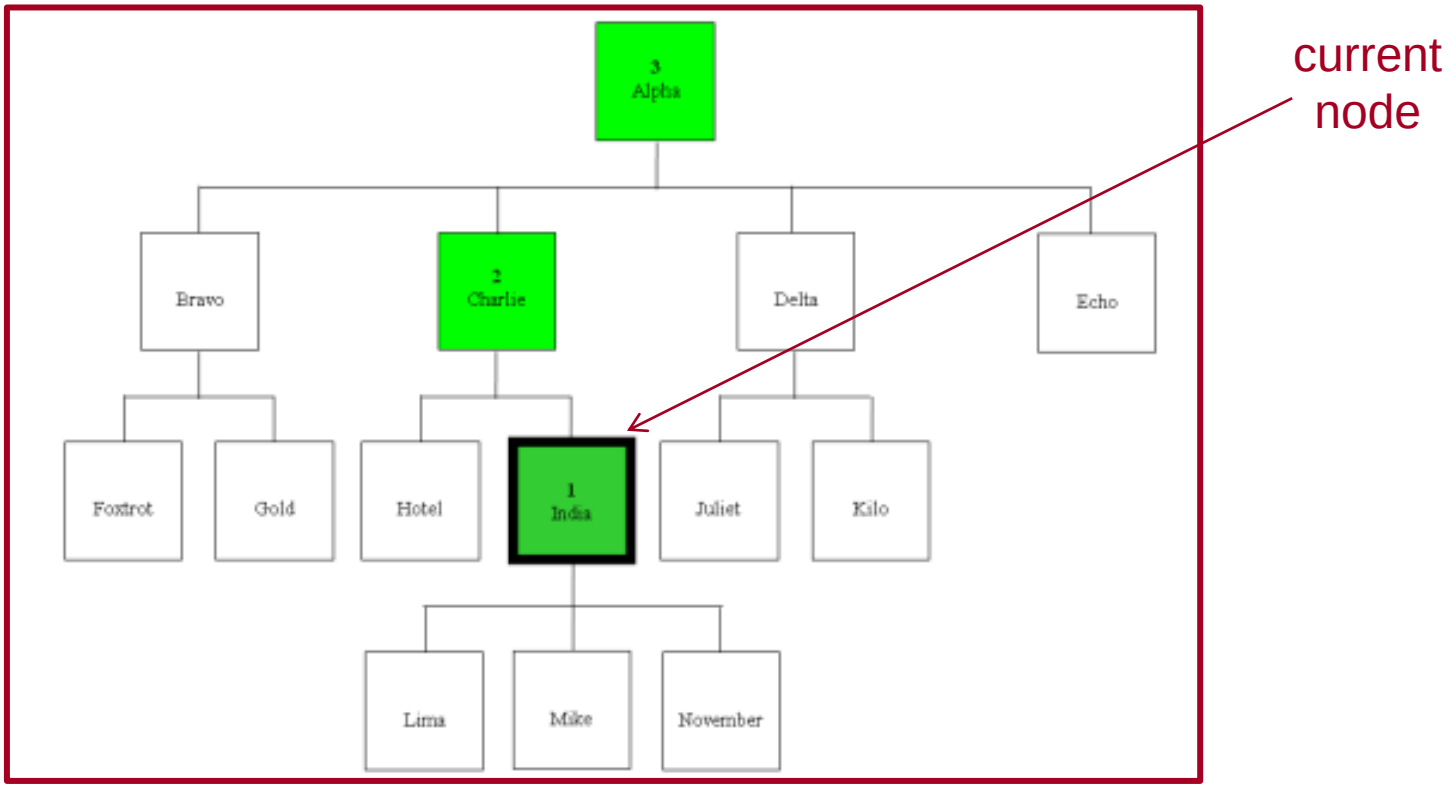
XPath: Axes (examples)

- Ancestor axis:
  - parent and parent's parent, etc.



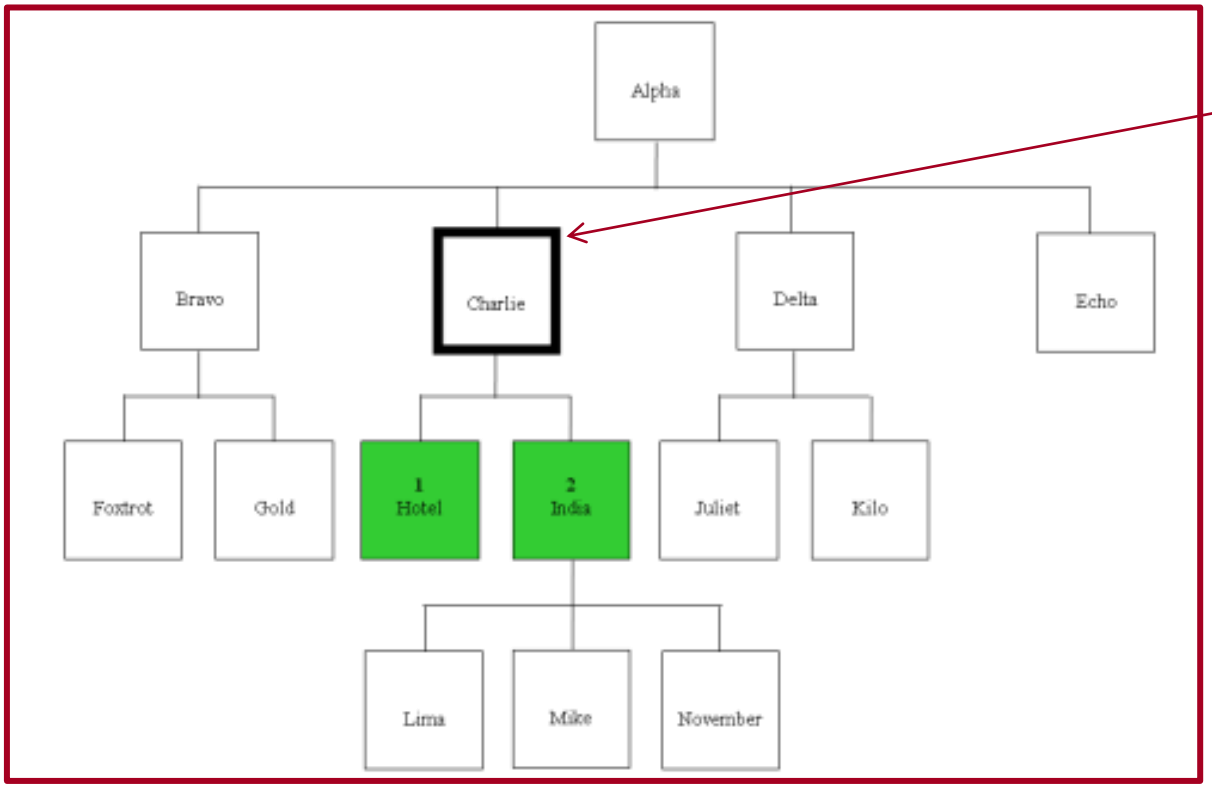
XPath: Axes (examples)

- Ancestor-or-self axis:
  - current node and parent and parent's parent, etc.



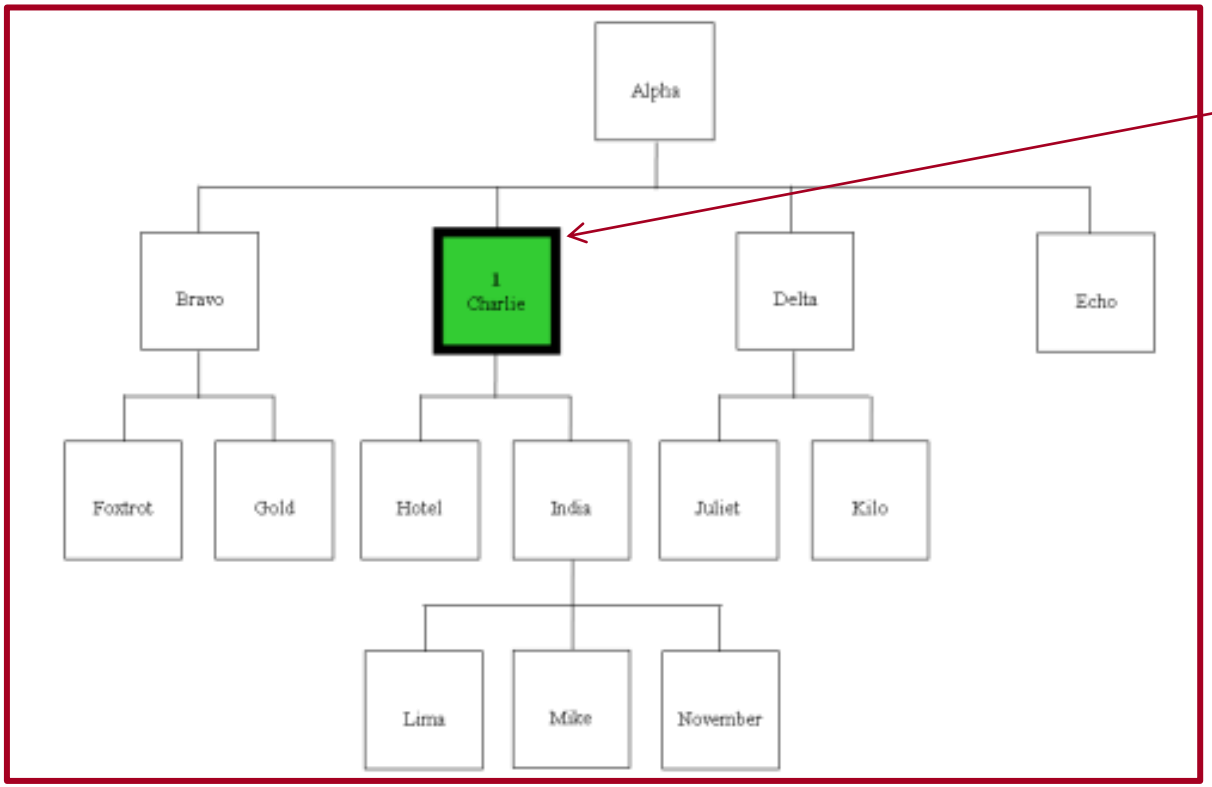
XPath: Axes (examples)

- Child axis:
  - children of the current node



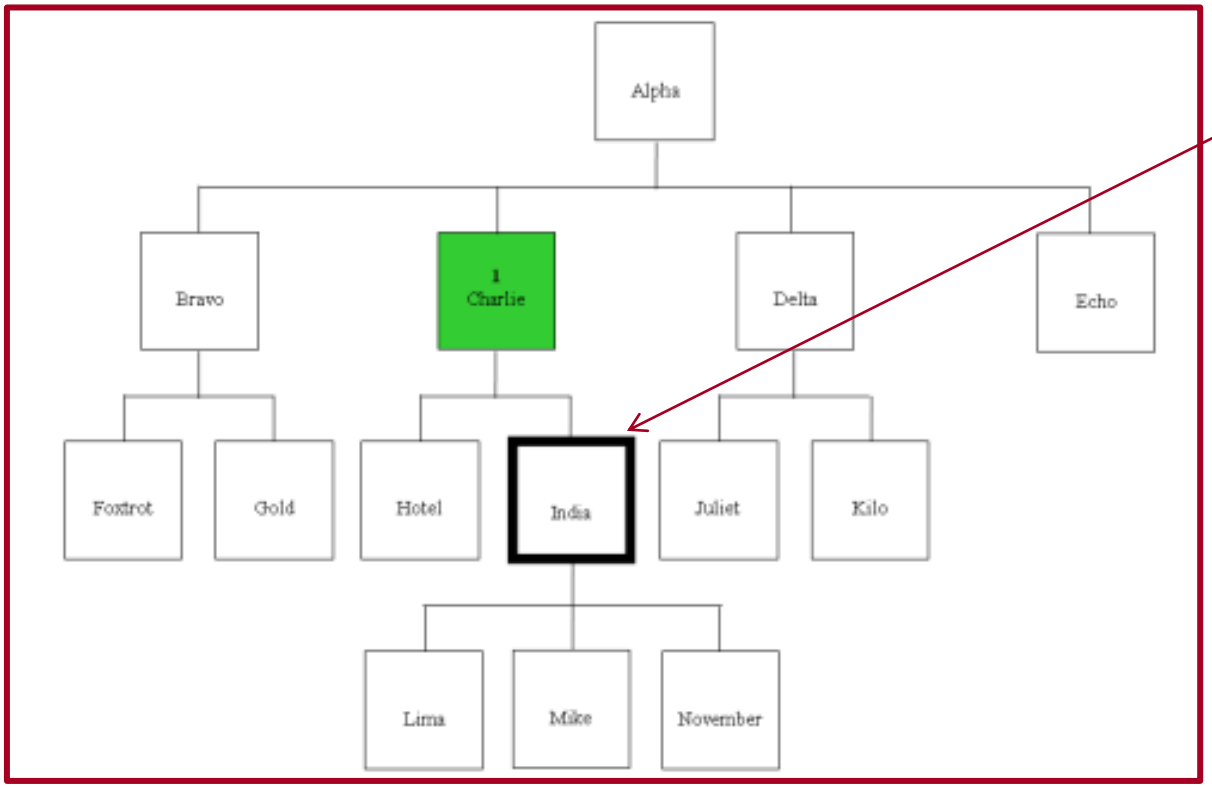
XPath: Axes (examples)

- Self axis:
  - the current node



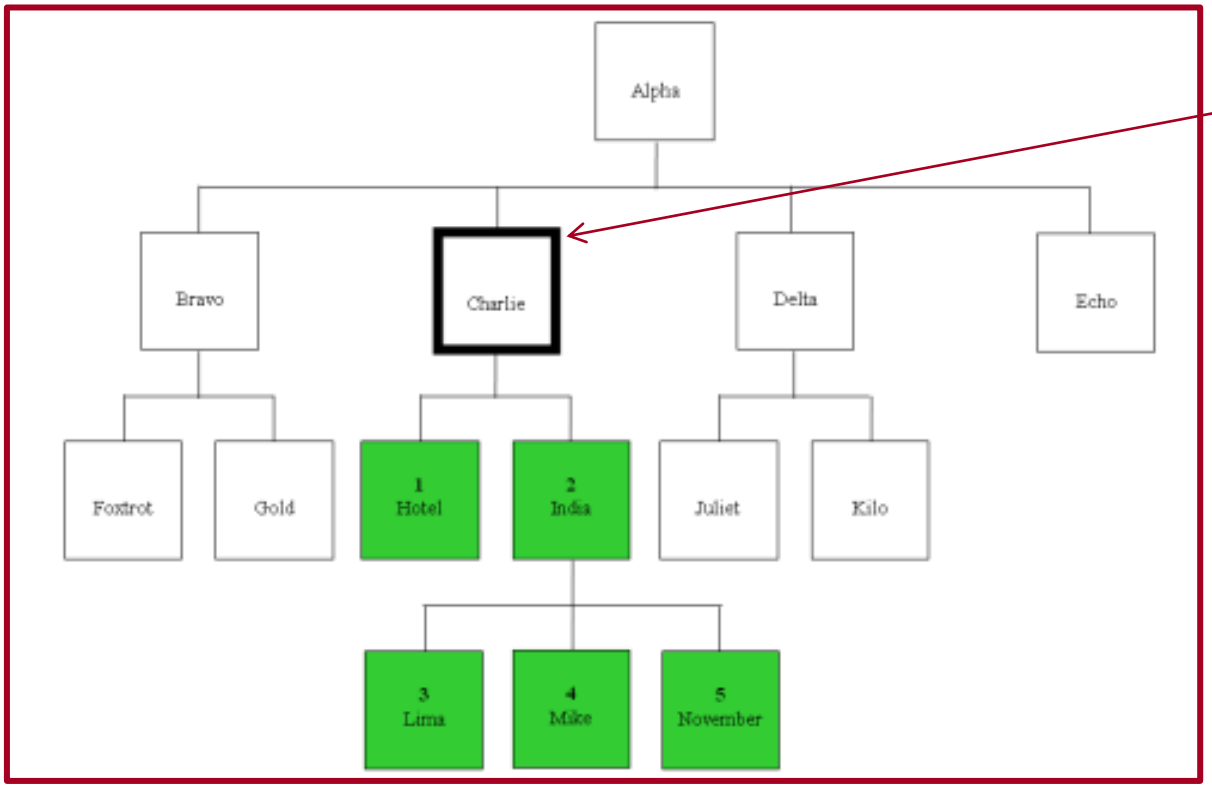
XPath: Axes (examples)

- Parent axis:
  - the parent of the current node



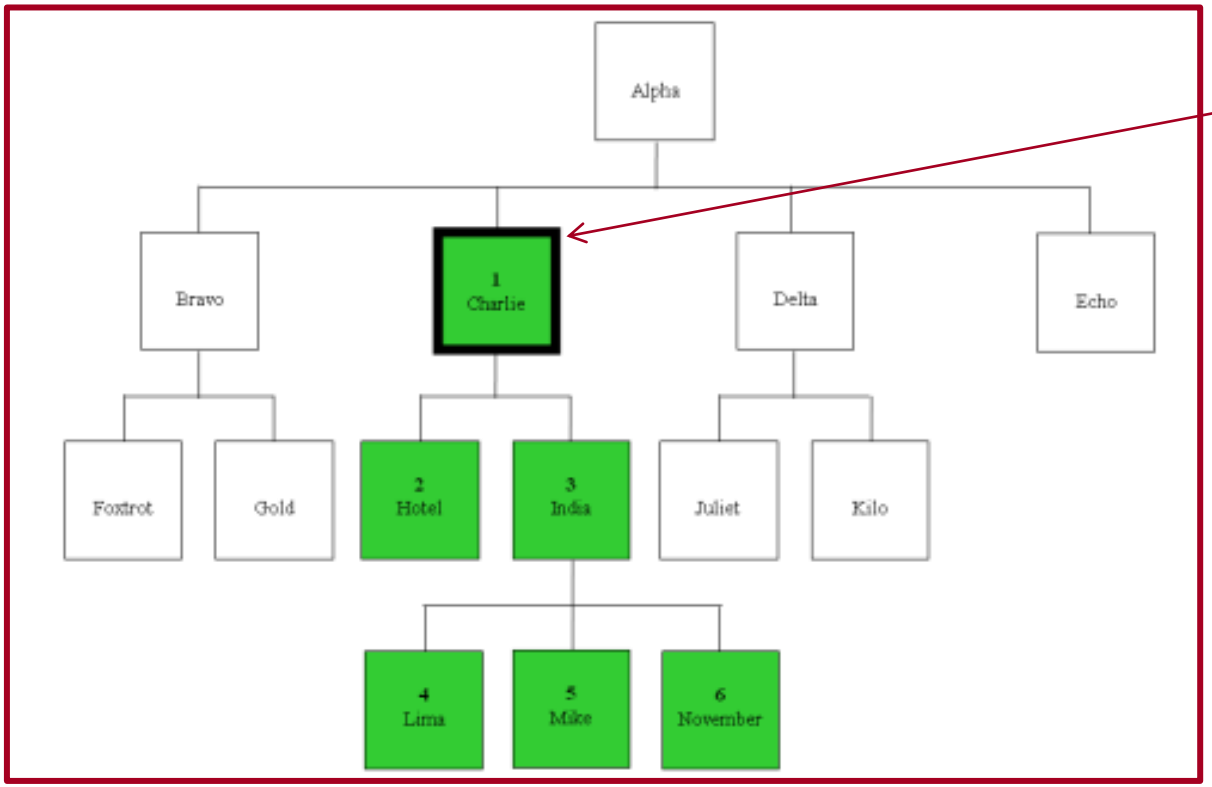
XPath: Axes (examples)

- Descendant axis:
  - children and their children, etc.



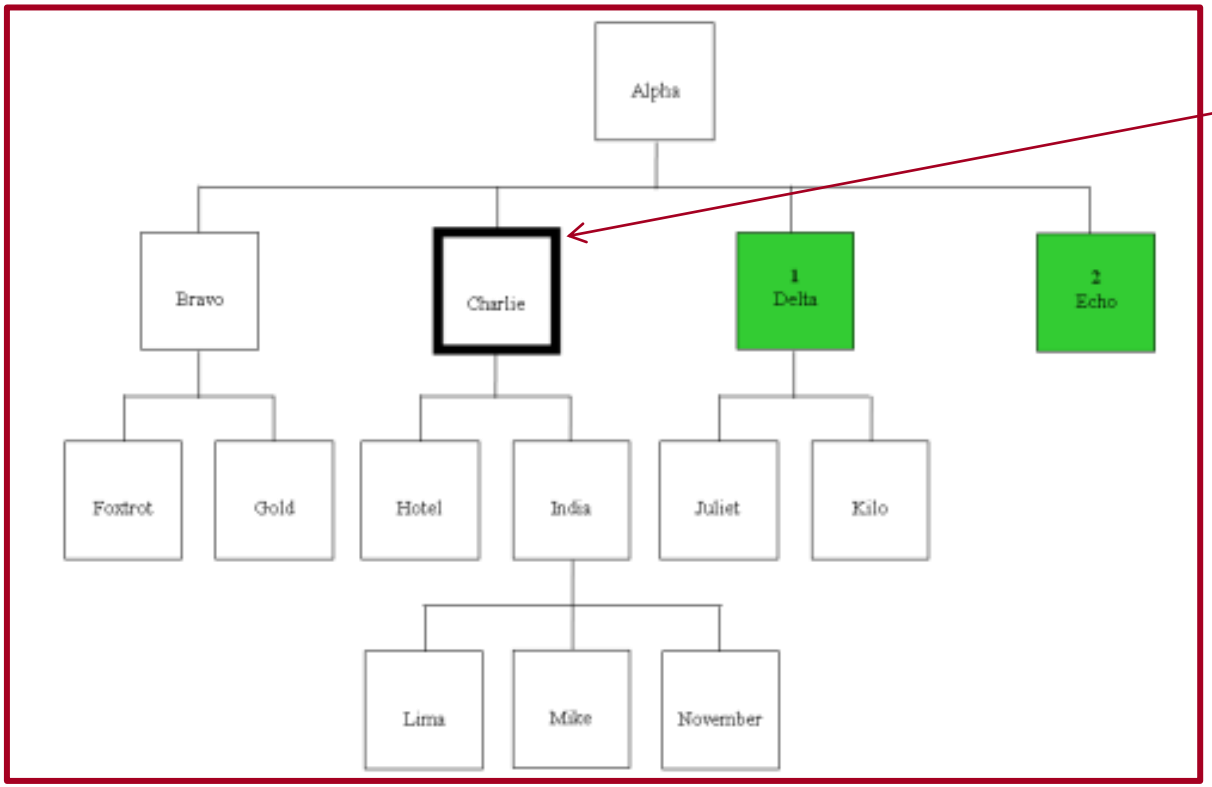
XPath: Axes (examples)

- Descendant-or-self axis:
  - current node and children and their children, etc.



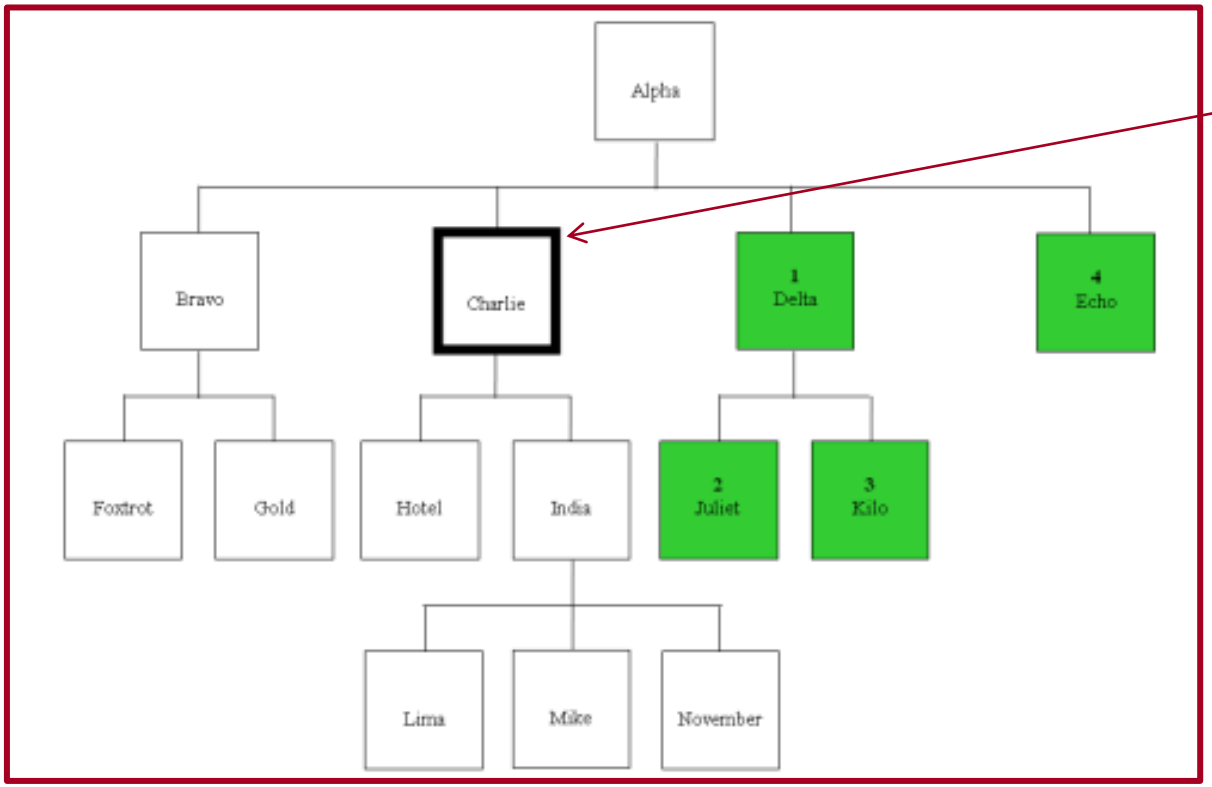
XPath: Axes (examples)

- Following-sibling axis:
  - following siblings (in the XML document order)



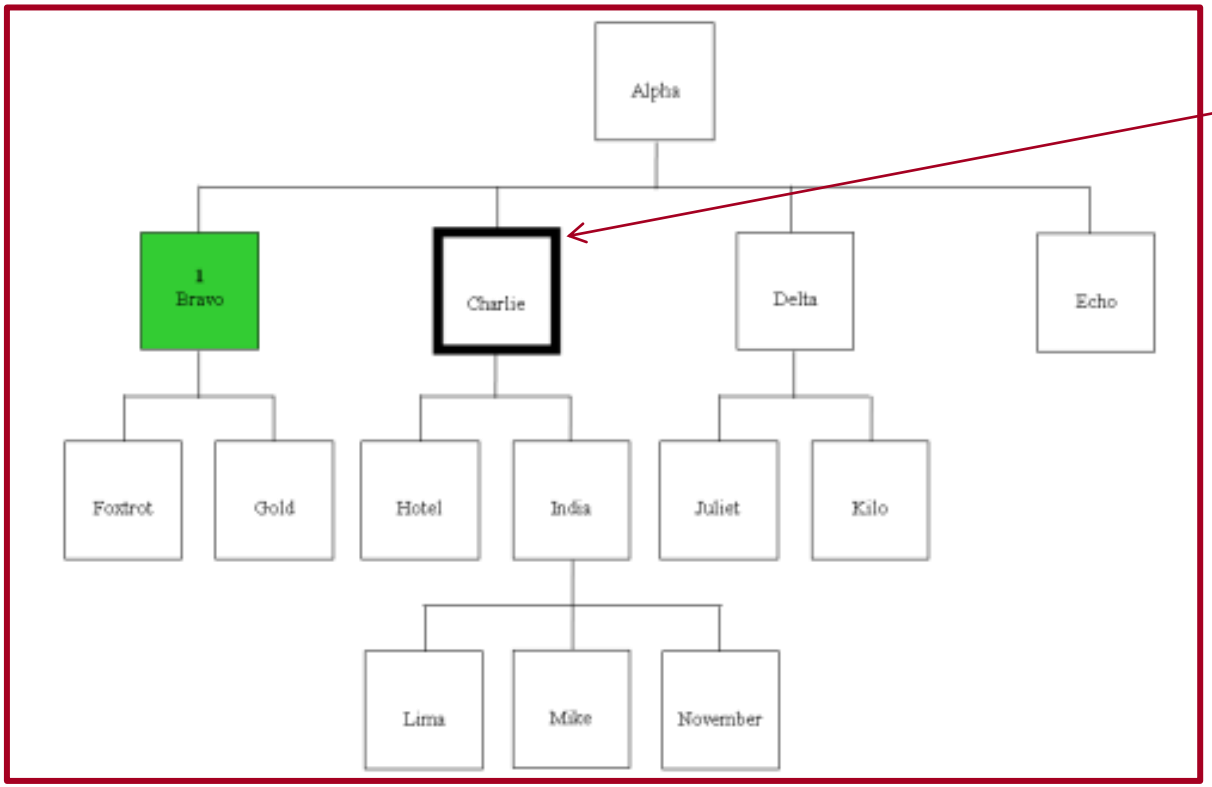
XPath: Axes (examples)

- Following axis:
  - following siblings and their children and their children, etc.



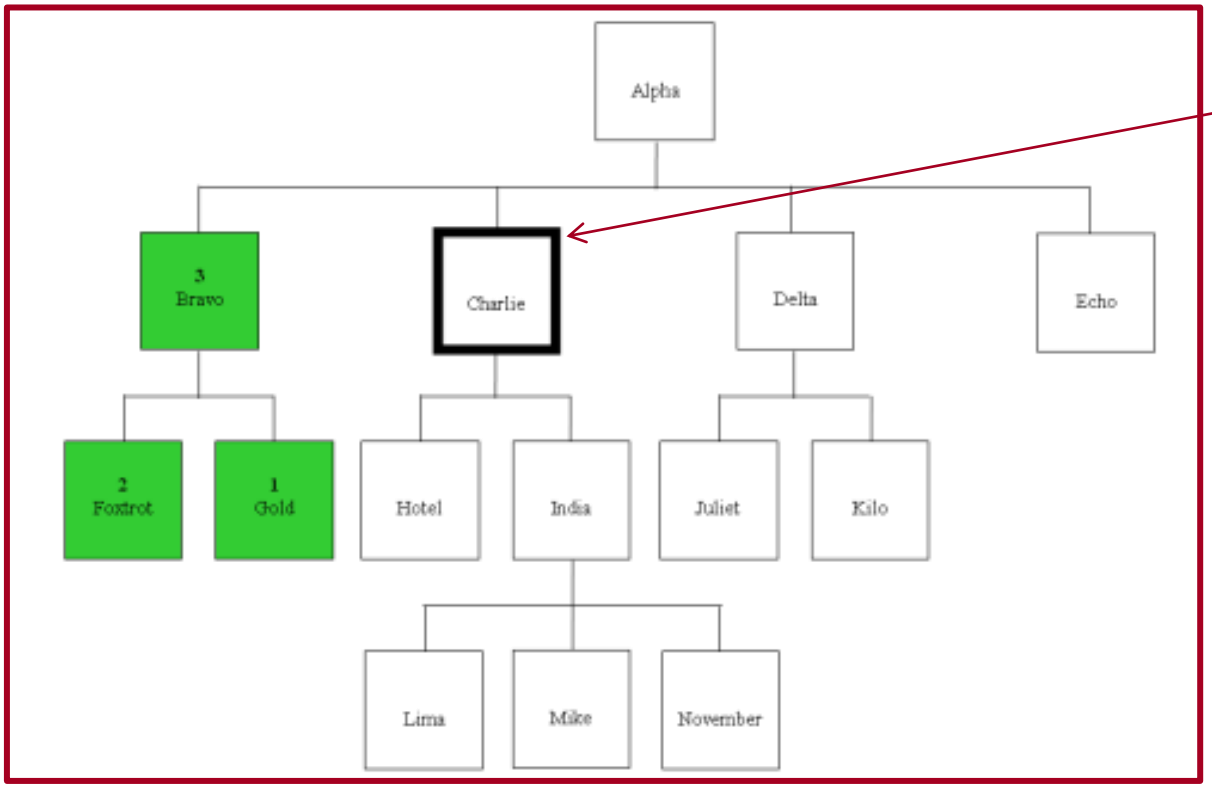
XPath: Axes (examples)

- Preceding-sibling axis:
  - preceding siblings (in the XML document order)



XPath: Axes (examples)

- Preceding axis:
  - preceding siblings and their children and their children, etc.



XPath: Axes (syntax)

- prefix a tag (or attribute name) by an axis name and a double-colon:

```
/bib/book/@price
```

is equivalent to:

```
/child::bib/child::book/attribute::price
```

```
//book/*
```

is equivalent to:

```
/descendant-or-self::book/child::*
```

Functions in XPath

Basic functions in XPath:

- text() = matches the text value
- name() = returns the name of the current tag

/bib/book/author/text()

Result:
Serge Abiteboul
Victor Vianu
Jeffrey D. Ullman

output is text, not nodes !

Note: "Rick Hull" doesn't appear,
because he has firstName, lastName
i.e. no *text()* within his "author" element

Functions in XPath

Basic functions in XPath:

- text() = matches the text value
- name() = returns the name of the current tag

```
/bib//*[name() = "book"]
```

Result:

```
<book>
        <publisher> Addison-Wesley </publisher> . . .
</book>
<book price="55">
        <publisher> Freeman </publisher> . . .
</book>
```

Note: the same as `/bib//book`

Positional Predicates

- Order of elements matters in XML !
- We can select a subelement of an element using the predicate format:

```
[position() = i ]
```

where i is the position of the desired subelement within the element (starting from 1)

```
//author[position() = 2]
```

Result:

```
<author>   <firstName> Rick  </firstName>
           <lastName> Hull   </lastName>
</author>
```

i.e. “the second author” of an element

Positional Predicates

- An alternative way of selecting a subelement that has a particular order:

```
ElemTag[ i ]
```

where i is the position of the desired subelement among the ElemTags

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

i.e. “the second author of a book”

Result:

```
<author>  <firstName>  Rick  </firstName>
          <lastName>  Hull  </lastName>
</author>
```

XPath: More Predicates

/bib/ book/ author [firstName] [address [//zip] [city]] / lastName

Nested predicates:

- "Find all authors who have:
  - a sub-element firstName and
  - a sub-element address, which has:
    - a zip code (as a descendant at some depth)
    - and a city (as a child)
- and return the lastName of these authors (if they have one)"

Result: <lastName> . . . </lastName>

<lastName> . . . </lastName>

XPath: More Predicates

/bib/book[@price < “60”]

/bib/book[author/@age < “25”]

/bib/book[author/text()=“John”]

/bib/book[year > “1996”]/year

XPath: More Predicates

Test: "find the *first book that has price 55*"

```
/descendant-or-self::book[@price = "55"]
                         [position()=1]
```

or equivalently:

```
//book[@price = "55"][position()=1]
```

Test: "find the *first book, if it has price 55*"

```
/descendant-or-self::book[position()=1]
                         [@price = "55"]
```

or equivalently:

```
//book[position()=1][@price = "55"]
```

Positional Predicates vs. Axes

- An important note on the positional predicates:
  - we always count positions on the specified axis
- For a reverse axis (e.g. ancestor, preceding, etc.):
  - we count in the reverse XML document order !

Example:

```
…/ansestor::*[position()=1]/…
```

is the same as:

```
…/parent::*/…
```

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/lastName

matches…

XPath and XQuery

- XQuery (for XML, i.e. semi-structured data):
  - is based on XPath
  - is similar to SQL (for structured data)

XQuery basic form:
FLWR (“Flower”) Expressions

FOR ...
LET...
WHERE...
RETURN...

SQL basic form:

SELECT ...
FROM...
WHERE...

Summary of the Lecture

- XML has a (directed) tree structure
  (semi-structured data)
- Querying XML with XPath
  - navigates through the tree to select data
- XPath:
  - output is at the end of a path
  - restricted Kleene closure: //
  - functions: text(), name()
  - wildcard: *
  - attributes: @
  - predicates: [. . .]
  - axes
  - nested predicates: [. . . [. . .]]