Applied Databases

Lecture 18
XPath and XSLT

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University of Edinburgh - March 23rd, 2017

Outline

→ Lecture 19 (Monday March 27th): Recap / Exam preparation

→ Lecture 20 (Monday March 27th): Recap / Exam preparation

→ **no lectures after that!** [i.e., no lectures on April 3 & 6]

Outline

1. XPath
2. XSLT – eXtensible Stylesheet Language Transformations

Location Steps & Paths

→ A Location Path is a sequence of Location Steps

→ A Location Step is of the form

axis :: nodetest [Filter_1] [Filter_2] … [Filter_n]

Filters (aka predicates, (filter) expressions)
evaluate to **true/false**

nodetest: * or node-name (could be expanded →namespaces) or

→ text()
→ comment()
→ processing -instruction(In)
→ node()

12 Axes

Forward Axes:

→ self
→ child
→ descendant-or-self
→ descendant
→ following
→ following-sibling

In doc order

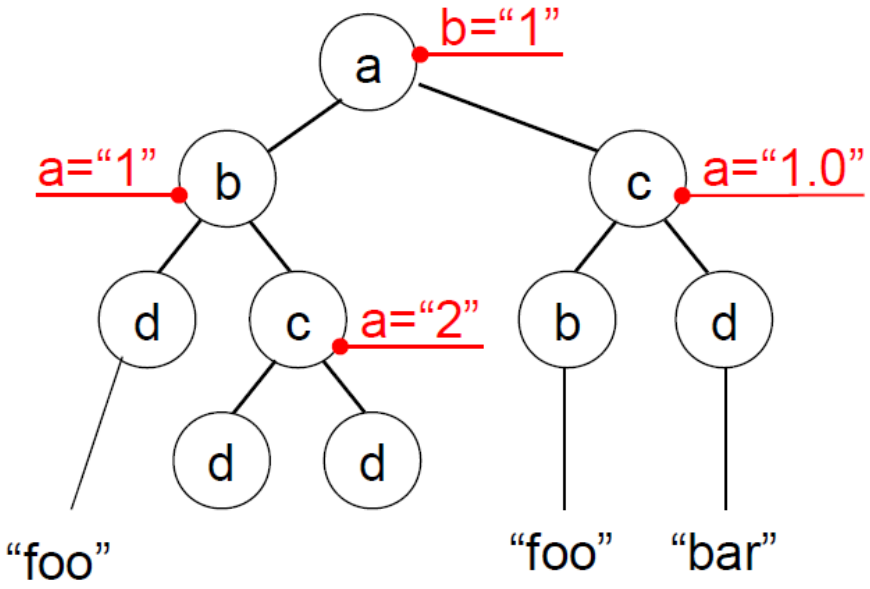
Backward Axes:

→ parent
→ ancestor
→ ancestor-or-self
→ preceding
→ preceding-sibling

→ attribute

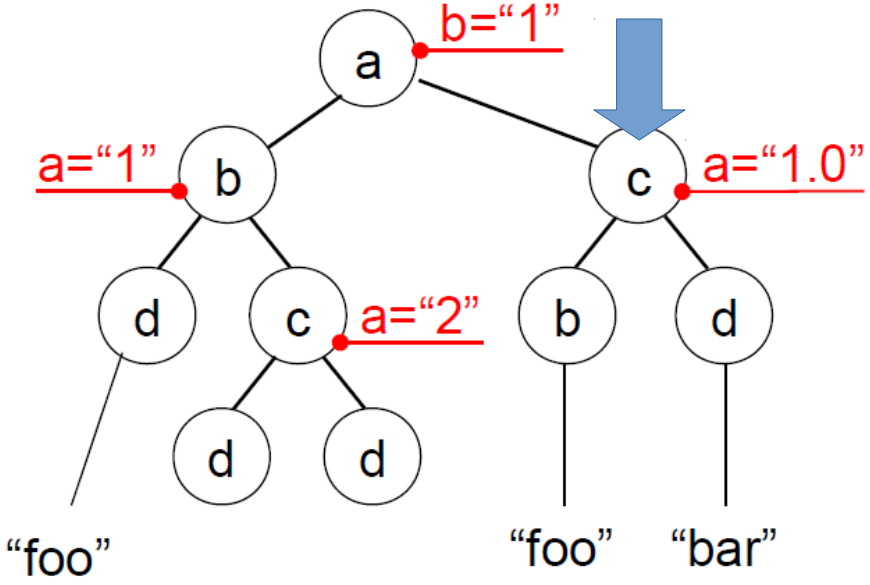
reverse doc order

1. XPath



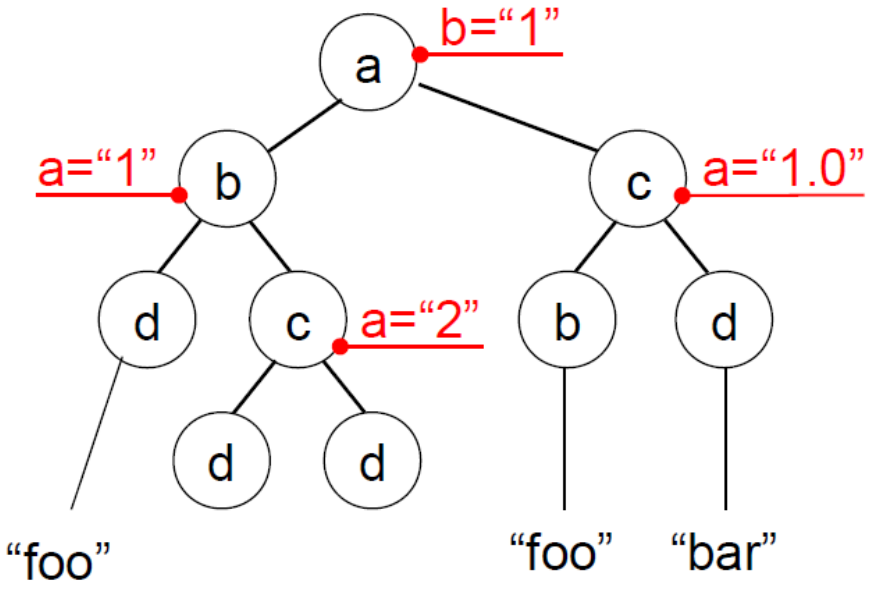
Query that selects c-nodes that have a b-child?

1. XPath



Query that selects c-nodes that have a b-child? `//c[b]`

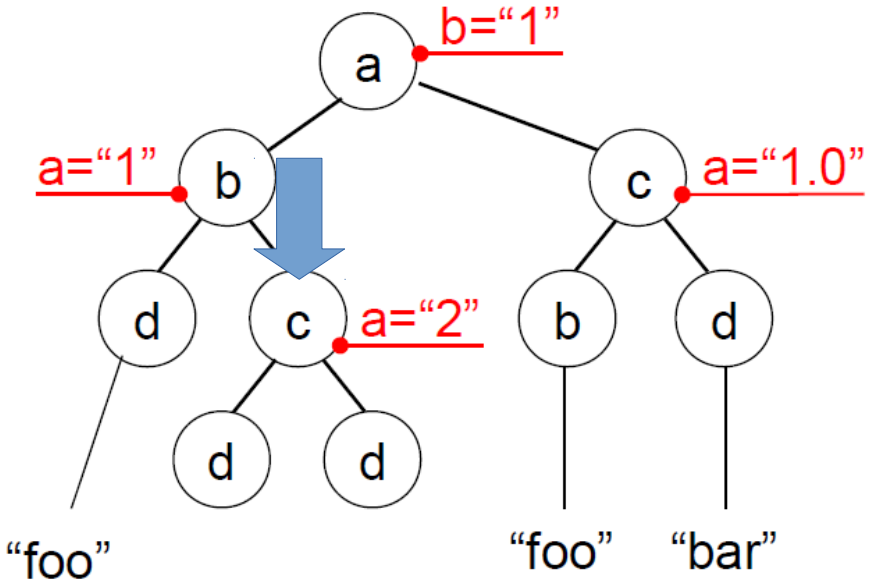
XPath



Query that selects c-nodes that have a b-child? `//c[b]`

c-nodes that have NO b-child?

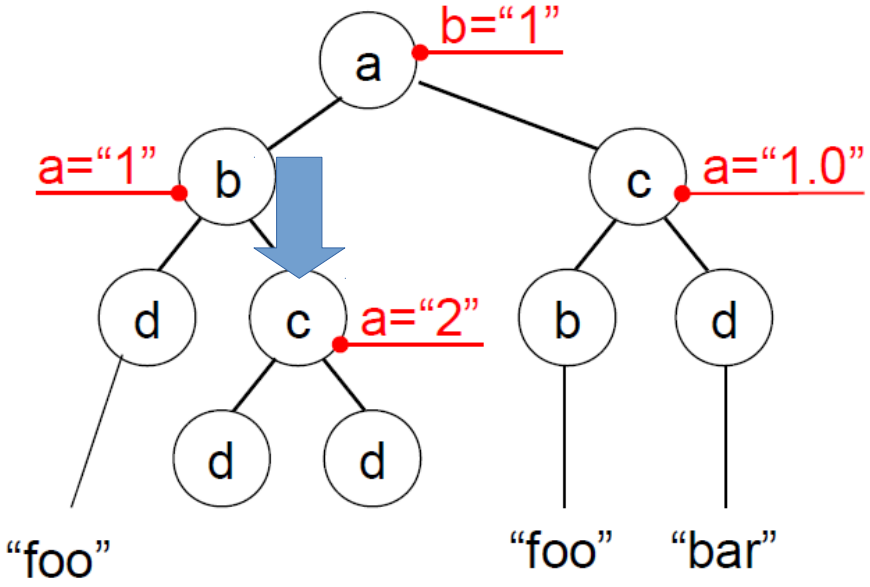
XPath



Query that selects c-nodes that have a b-child? `//c[b]`

c-nodes that have NO b-child? `//c[not(b)]`

XPath



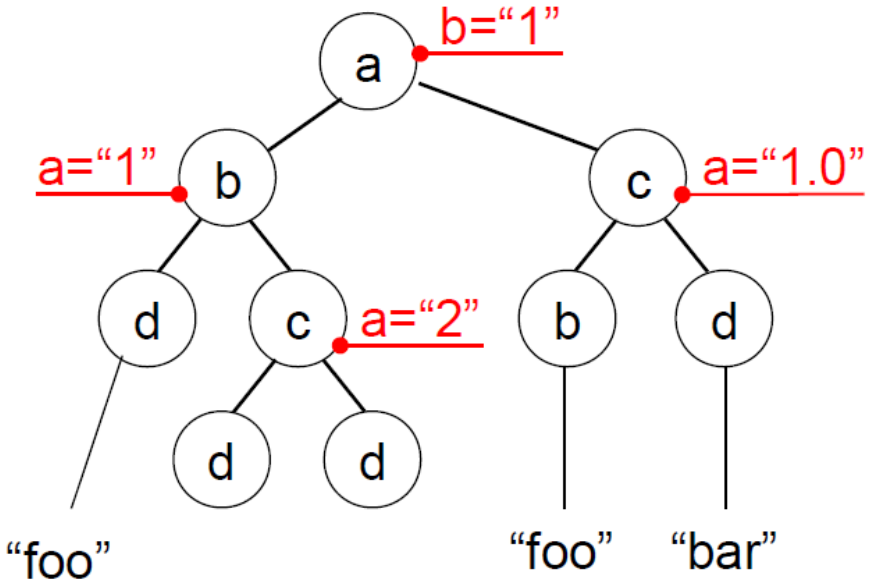
Query that selects c-nodes that have a b-child? `//c[b]`

c-nodes that do NOT have a b-child? `//c[not(b)]`

NEGATE

does there exist a b-node?

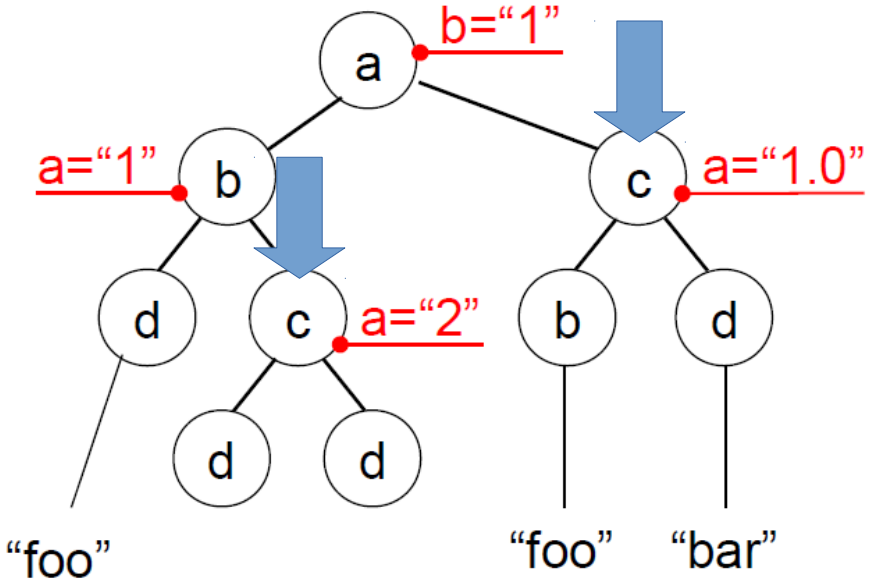
XPath



Query that selects c-nodes that have a b-child? `//c[b]`

c-nodes that have a child not labeled b?

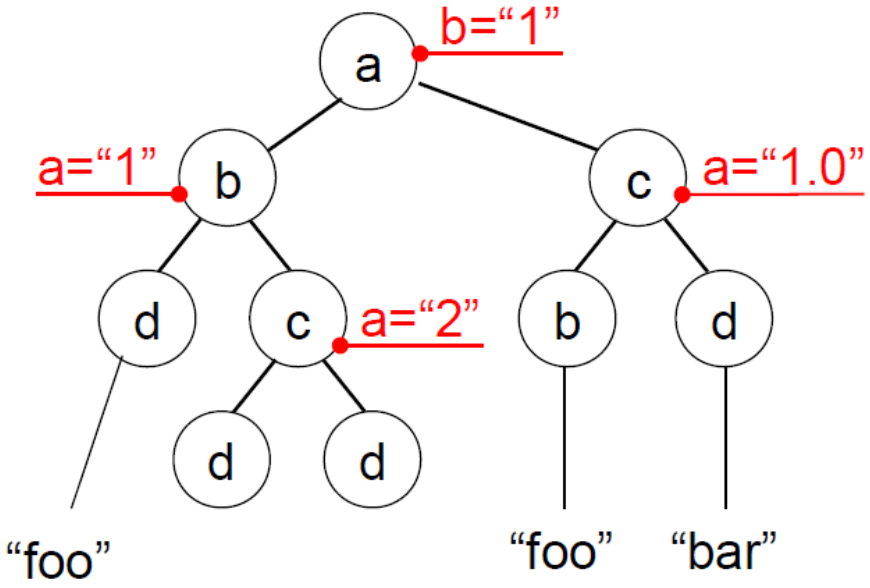
XPath



Query that selects c-nodes that have a b-child? `//c[b]`

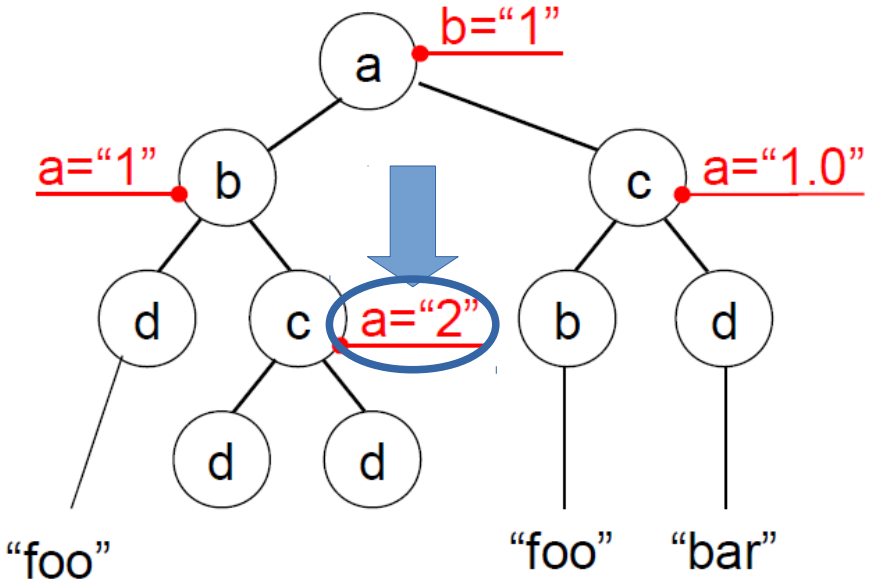
c-nodes that have a child not labeled b? `//c[*[not(self::b)]]`

XPath



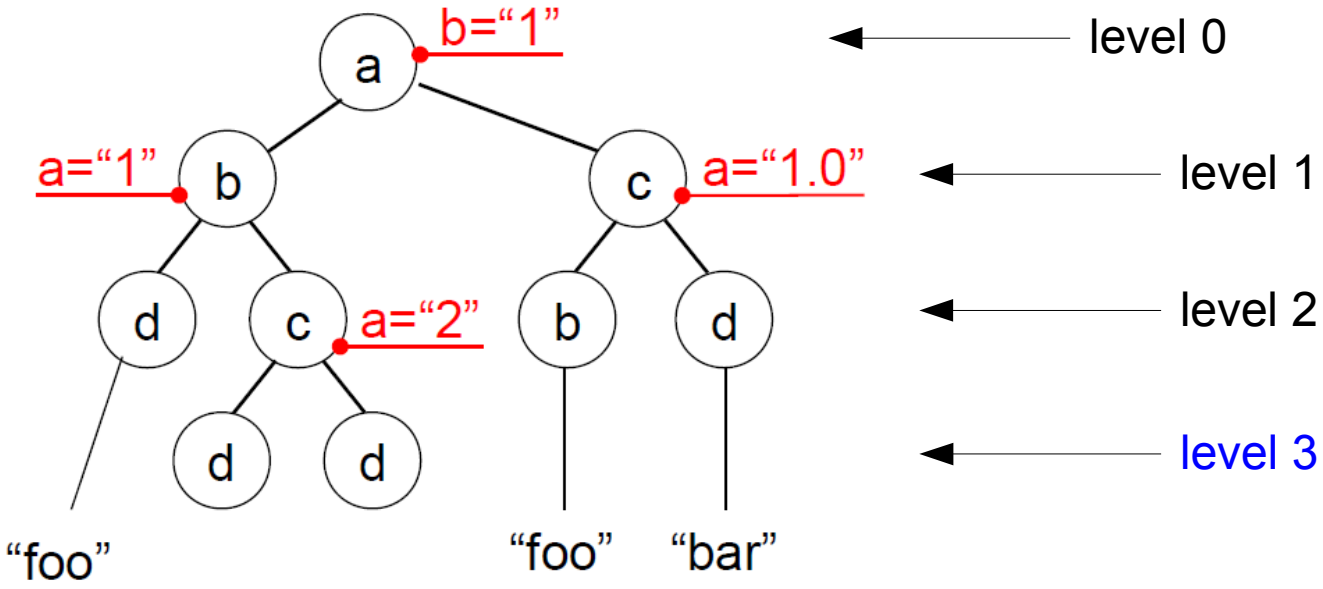
Query that selects a-attributes with maximal value?

XPath



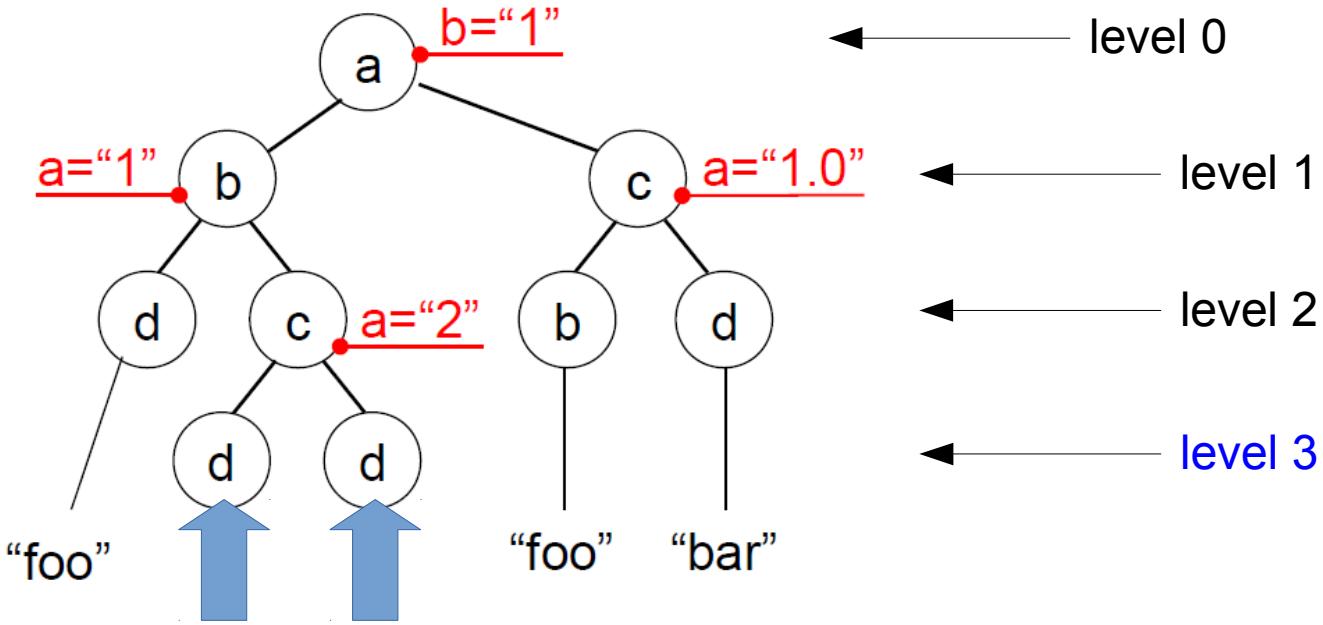
Query that selects a-attributes with maximal value? `//@a[not(. < //@a)]`

XPath



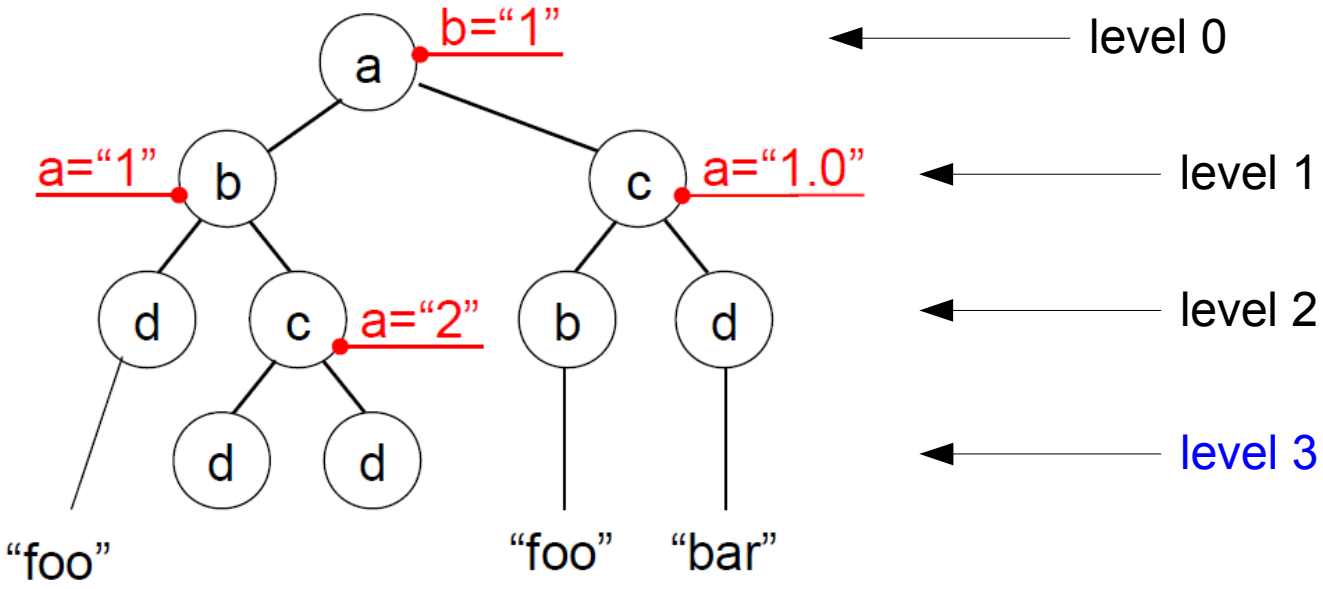
Query that selects element nodes at level 3 of the tree?

XPath



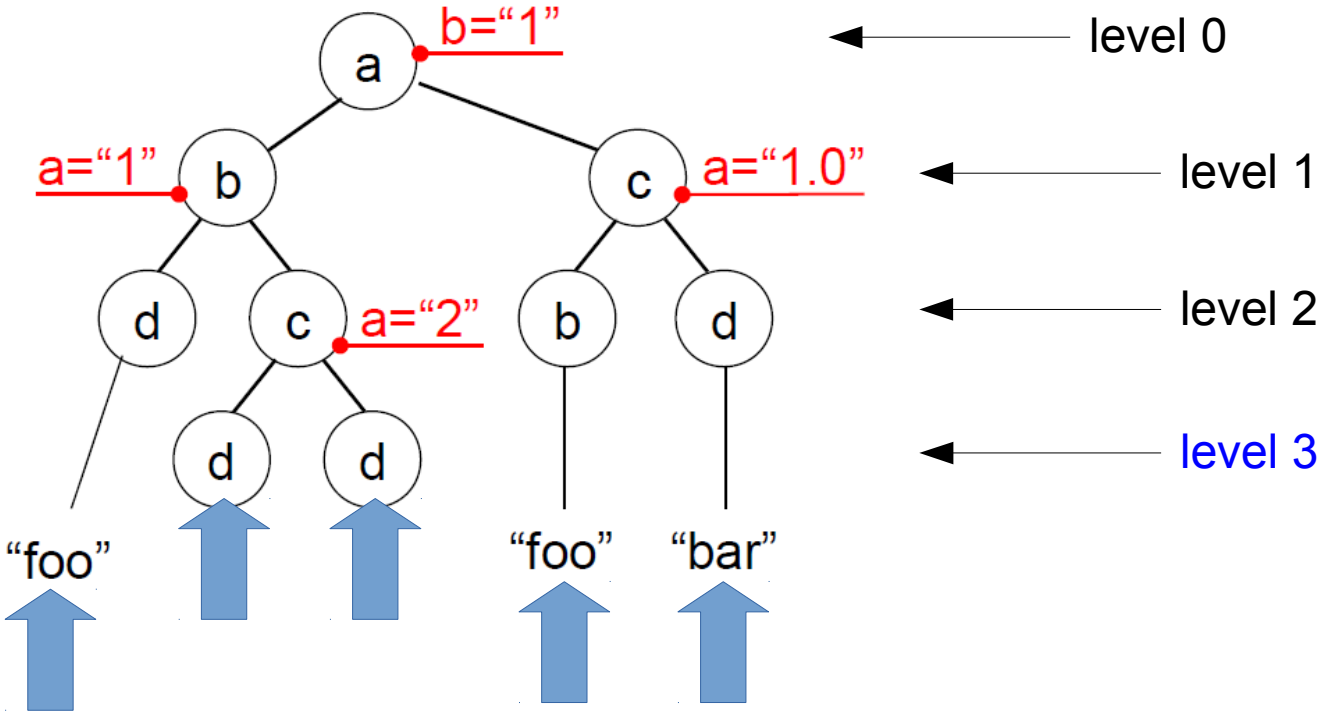
Query that selects element nodes at level 3 of the tree? /*/*/*/*

XPath



Query that selects element and text nodes at level 3 of the tree?

XPath



Query that selects element and text nodes at level 3 of the tree?

```
/*/*/*/child::node()
```

```
//node()[count(ancestor::*)=3]
```

XPATH Tester/Evaluator/Query

An XPATH Tester Tool which runs an XPATH statement against an XML fragment

XPATH Statment

```
//node()[count(ancestor::*)=3]
```

Run XPATH

XML

```
<a b="1"><b a="1"><d>foo</d><c a="2"><d/><d/></c></b><c
a="1.0"><b>foo</b><d>bar</d></c></a>
```

Result

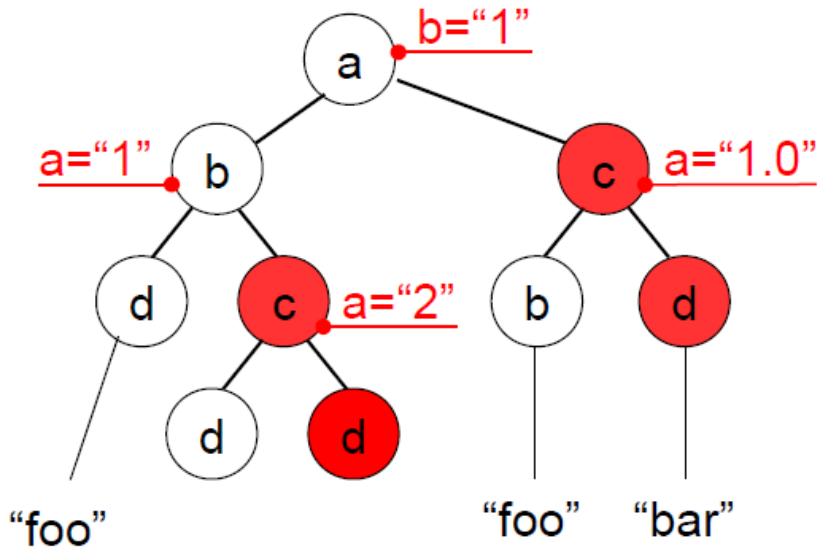
```
foo
----------------------
<d/>
----------------------
<d/>
----------------------
foo
----------------------
bar
```

http://xpath.online-toolz.com/tools/xpath-editor.php

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

→ `position()`
Returns context-position from the eval. context



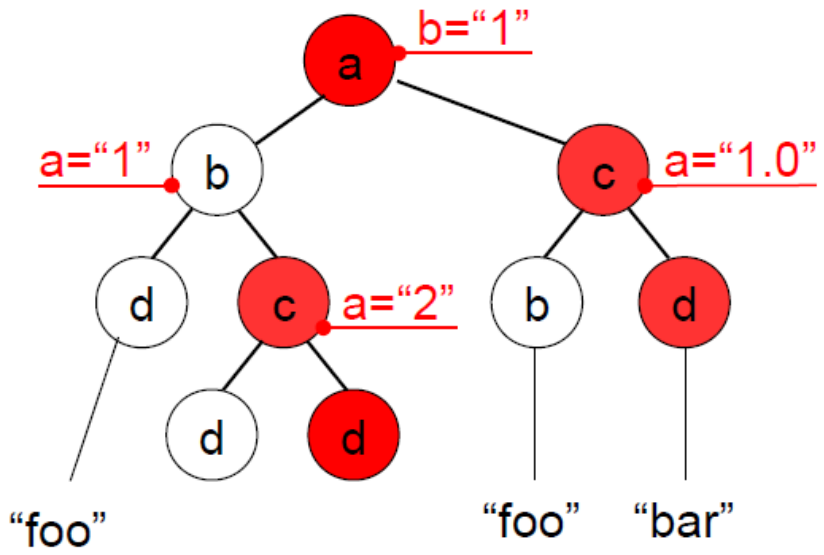

```
//*[position()=2]
```

Recall: `//a` abbreviates `//descendant-or-self::node()/child::a`

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

→ `position()`
Returns context-position from the eval. context




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

```
//*[position()=last()]
```

Recall: `//a` abbreviates `//descendant-or-self::node()/child::a`

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

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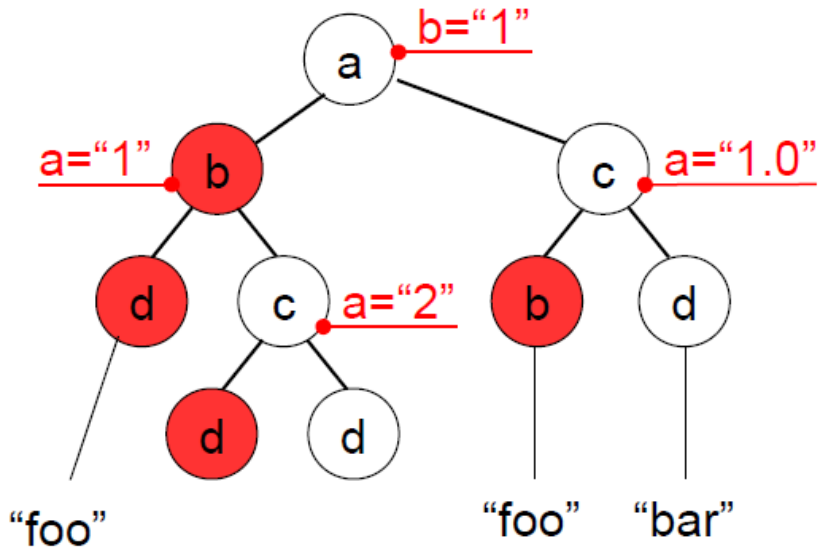



```
//*[position()=2]
```

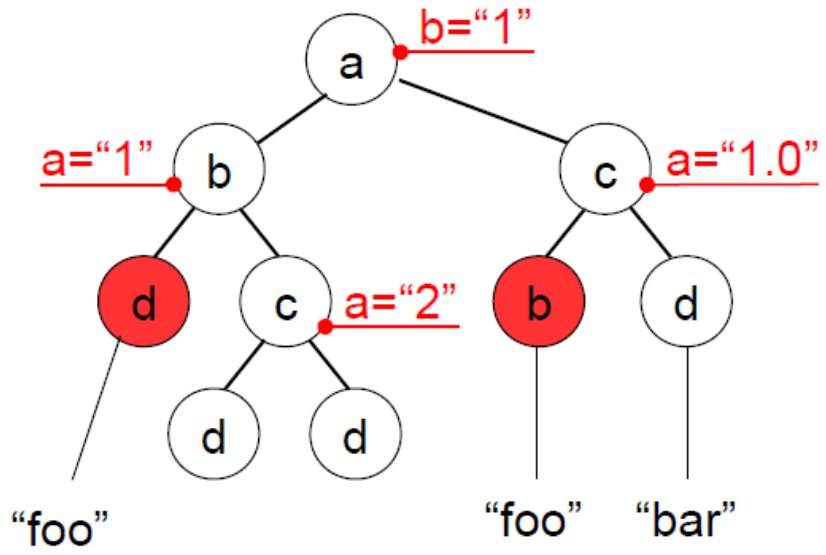
```
//*[position()=last()-1]
```

Recall: `//a` abbreviates `//descendant-or-self::node()/child::a`

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

→ `position()`
Returns context-position from the eval. context



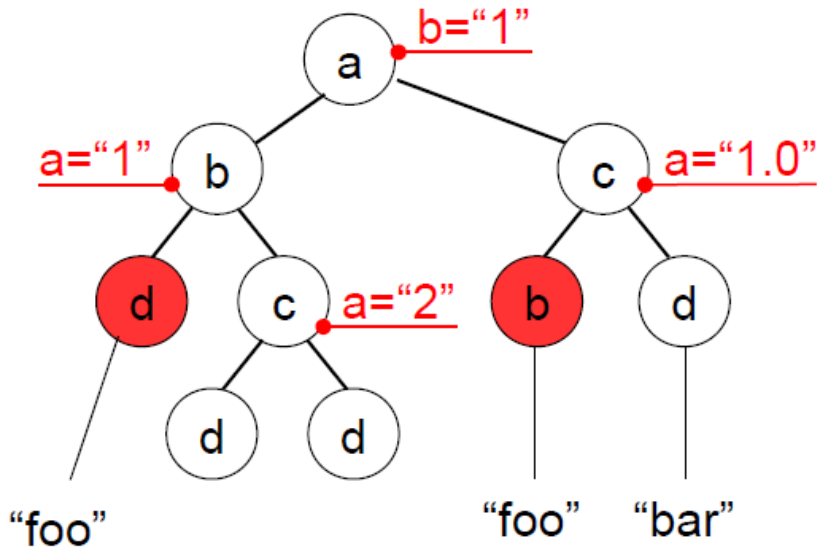

```
//*[position()=2]
```

```
//*[position()=last()-1
    and ./text()="foo"]
```

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

→ `position()`
Returns context-position from the eval. context




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

```
//*[position()=last()-1
    and ./text()="foo"]
```

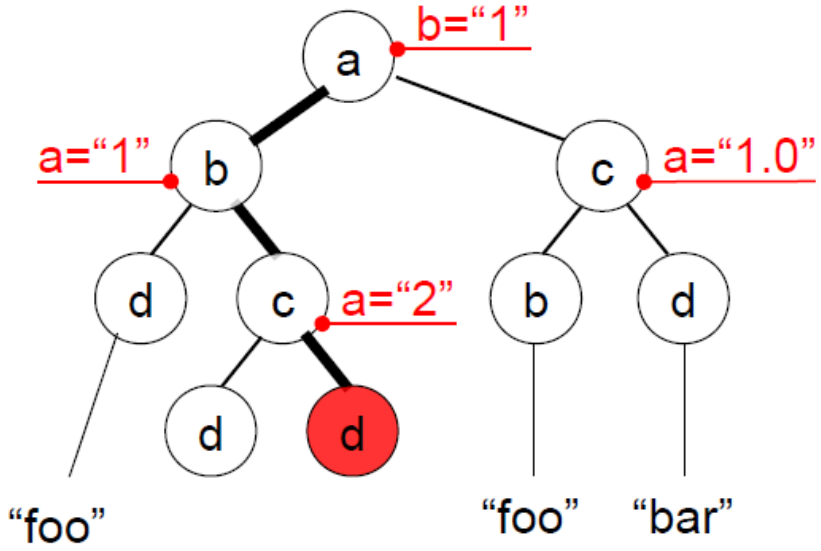
Useful:
`child::*[self::chapter or self::appendix][position()=last()]`
selects the last chapter or appendix child of the context node

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

→ `position()`
Returns context-position from the eval. context

Melvil Dewey




```
*/*[position()=1]/*[position()=2]/*[position()=2]
```

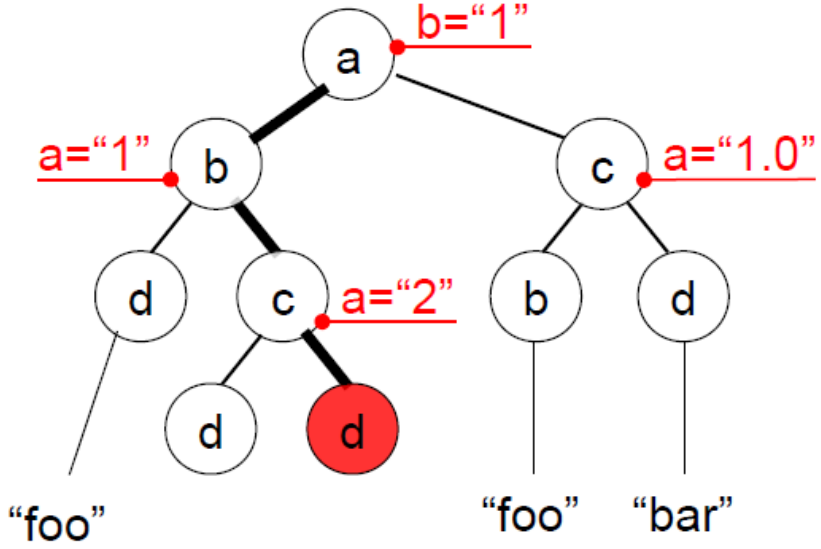
→ allows absolute location of any node (a la Dewey)

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

→ `position()`
Returns context-position from the eval. context

Melvil Dewey




```
*/*[position()=1]/*[position()=2]/*[position()=2]
```

Abbreviation: `*/*[1]/*[2]/*[2]`

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

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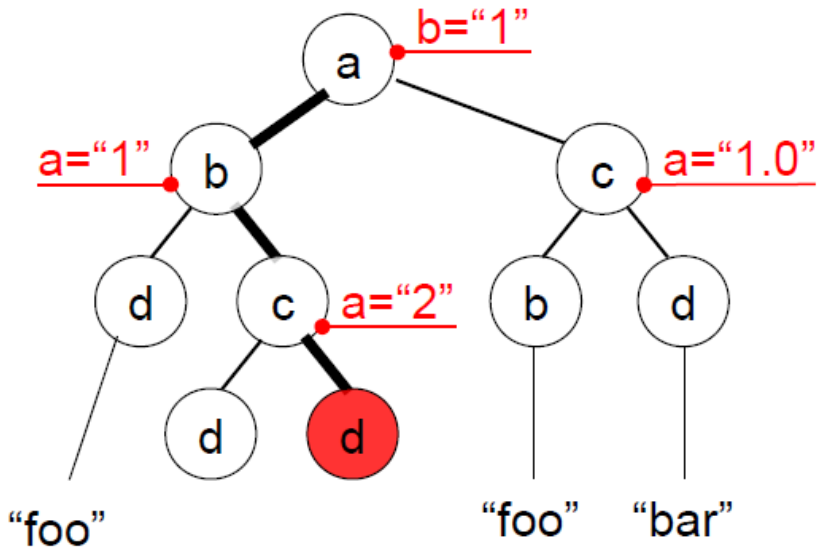


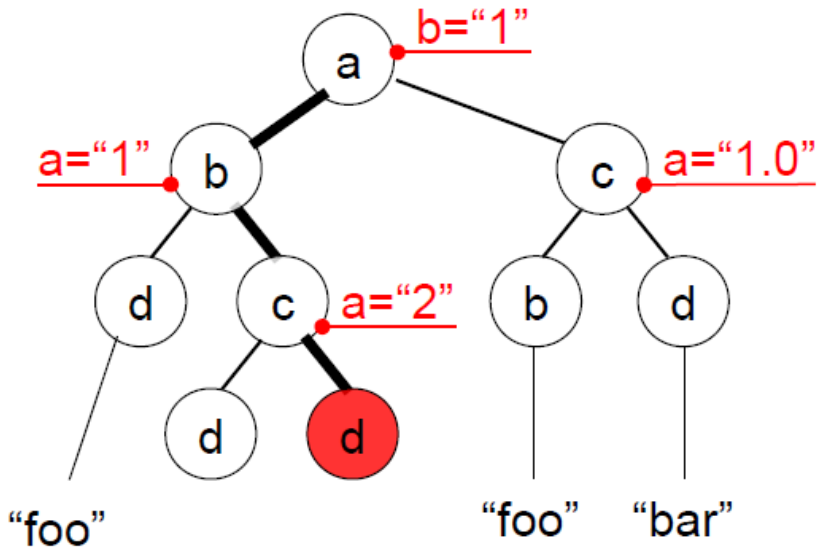

```
*/*[position()=1]/*[position()=2]/*[position()=2]
```

Abbreviation: `*/*[1]/*[2]/*[2]` ➔**What is result for** `//*[./*[2]/*[2]]`

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

→ `position()`
Returns context-position from the eval. context



What is the result for
`//d[position() = last()]`

```
*/*[position()=1]/*[position()=2]/*[position()=2]
```

Abbreviation: `*/*[1]/*[2]/*[2]` ➔**What is result for** `//*[./*[2]/*[2]]`

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

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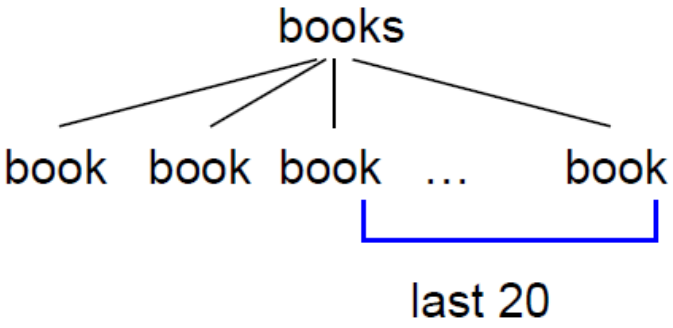
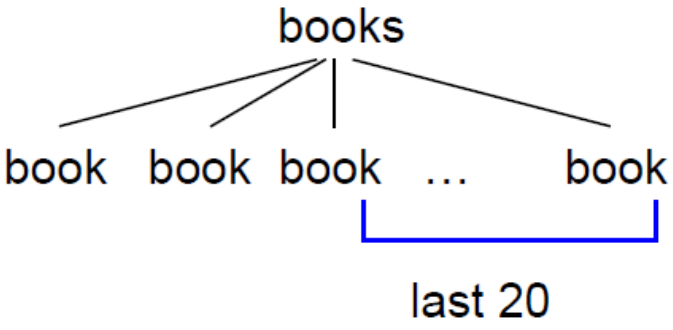


How do you select the
last 20 book-children of books?

Useful Functions (on Node Sets)

→ `last()`
returns contex-size from the evaluation context

→ `position()`
Returns context-position from the eval. context



How do you select the
last 20 book-children of books?

```
/books/book[position()>last()-20]
```

XPath Evaluation

→ can be done polynomial time

→ based on “context-value tables”

→ careful recording of unique values (no duplicates)

2. XSLT

2. XSLT

→ Extensible Stylesheet Language Transformations

→ W3C Standard

→ developed early on (XSL in 1998)

→ Version 2.0 (W3C recommendation 2007)

→ Version 3.0 (streaming)
W3C candidate recommendation (15. November 2015)

All major browsers (Chrome, Firefox, IE, Safari, etc)
support XSLT

→ if an XML document has an XSL stylesheet associated with it,
the browser will transform it on-the-fly

XML, typical usage scenario

Document structure

Def. of price, gst, …

DTD, XML Schema

Presentation
Format info

XML Stylesheet

```
<Product>
  <product_id> d101 </product_id>
  <name> Sony discman </name>
  <currency> AUD </currency>
  <price> 169.00 </price>
  <gst> 10% </gst>
</Product>
…
```

X M L

XML Stylesheet

XML Stylesheet

One data source

→ **many**

(dynamic gen.) **views**

XML

→ General data format

→ Includes no formatting information

Usage Idea

→ Store data *once*, in most general format
(free tech writers from bothering with layout issues)

→ Reuse fragments of the data (same contents; looks different depending on the context)

E.g. different output formats (size, device)
style tailored to reader's preference
style tailored to adhere w. corporate/web site identity

eXtensible Stylesheet Language

"stylesheet" = recipe how to *display* your XML data

e.g. "display titles of books in bold, large font"
"display authors of books in italic, medium size"
etc.

→ Choose an output format (e.g. XHTML, HTML, text, PDF, etc.)

→ Transform the XML:
- add formatting information
- rearrange data
- sorting
- delete certain parts, copy others

etc

Example Transformations

→ XML to HTML – for browser display
→ XML to LaTeX – for TeX layout
→ XML to SVG – graphs, charts, trees
→ XML to tab-delimited – for DB/stat packages
→ XML to plain text, e.g., PDF – for printing

e.g. print bills for a telecom company
→ data comes in XML
→ want to produce bills in PDF

Example Transformations

→ XML to HTML – for browser display
→ XML to LaTeX – for TeX layout
→ XML to SVG – graphs, charts, trees
→ XML to tab-delimited – for DB/stat packages
→ XML to plain text, e.g., PDF – for printing

e.g. print bills for a telecom company
→ data comes in XML
→ want to produce bills in PDF

XSLT vs. custom SAX/DOM traversal (as your XML→CSV from Assignment 1)

→ smaller code

→ better readability & maintainability

→ let XSLT compiler attempt to *stream* the transformation

Example Transformations

→ smaller code

→ better readability & maintainability

→ let XSLT compiler attempt to ***stream*** the transformation

→ “best effort” approach
→ very hard to detect statically
(interesting research question)
→ XSLT 3.0

Some academic transformation languages even have

→ static type checking
→ compiler can verify if all outputs are, e.g., correct XHTML

XSLT program: list of **template** (rules) – written in XML syntax
Template: pattern → action

Template

```
<xsl:template match="para">
  <p><xsl:apply-templates/></p>
</xsl:template>
```

(relative) XPath expression
→ current node labeled "para"?

output p-node (in XML)

recursively descent & apply templates

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="para">
  <p><xsl:apply-templates/></p>
</xsl:template>

</xsl:stylesheet>
```

para.xslt

XSLT program
→ changes “para” nodes to “p”-nodes
→ deletes all other element nodes

```
$ cat t1.xml
<x><t/><para><para/></para></x>

$ xsltproc para.xslt t1.xml
<?xml version="1.0"?>
<p><p/></p>
```

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="para">
  <p><xsl:apply-templates/></p>
</xsl:template>

</xsl:stylesheet>
```

para.xslt

XSLT program
→ changes “para” nodes to “p”-nodes
→ deletes all other element nodes
→ **keeps all text-nodes!**

```
$ cat t2.xml
<a z="TT">this<b>is a <d a="1278"/><e/></b>
<para u="18">hello world<c/></para></a>

$ xsltproc para.xslt t2.xml
<?xml version="1.0"?>
thisis a <p>hello world</p>
```

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node()">
  <xsl:copy><xsl:apply-templates/></xsl:copy>
</xsl:template>

</xsl:stylesheet>
```

trans.xslt

```
$ cat t2.xml
<a z="TT">this<b>is a <d a="1278"/><e/></b>
<para u="18">hello world<c/></para></a>

$ xsltproc trans.xslt t2.xml
<?xml version="1.0"?>
<a>this<b>is a <d/><e/></b><para>hello world<c/></para></a>
```

→ all nodes are matched and taken over
→ **except** *attributes nodes* (they are deleted)

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node() | @*">
  <xsl:copy><xsl:apply-templates select="node() | @*"/></xsl:copy>
</xsl:template>

</xsl:stylesheet>
```

identity.xslt

```
$ cat t2.xml
<a z="TT">this<b>is a <d a="1278"/><e/></b>
<para u="18">hello world<c/></para></a>

$ xsltproc identity.xslt t2.xml
<?xml version="1.0"?>
<a z="TT">this<b>is a <d a="1278"/><e/></b>
<para u="18">hello world<c/></para></a>
```

→ all nodes are matched and taken over

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node() | @*">
  <xsl:copy><xsl:apply-templates select="node() | @*"/></xsl:copy>
</xsl:template>

</xsl:stylesheet>
```

identity.xslt

```
$ cat t2.xml
<a z="TT">this<b>is a <d a="1278"/><e/></b>
<para u="18">hello world<c/></para></a>

$ xsltproc identity.xslt t2.xml
<?xml version="1.0"?>
<a z="TT">this<b>is a <d a="1278"/><e/></b>
<para u="18">hello world<c/></para></a>
```

→ all nodes are matched and taken over
→ compare the (size of the) above XSLT program to a SAX program for the same task!

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node() | @*">
  <xsl:copy><xsl:apply-templates select="node() | @*"/></xsl:copy>
</xsl:template>

</xsl:stylesheet>
```

identity.xslt

→ all nodes are matched and taken over
→ compare the (size of the) above XSLT program to SAX program for the same task!

→ would be interesting to rewrite the ebay XML→ CSV converter in XSLT

XPATH Tester/Evaluator/Query

An XPATH Tester Tool which runs an XPATH statement against an XML fragment

XPATH Statment

```
//node() | //@*
```

Run XPATH

XML

```
<a b="1"><b a="1"><d>foo</d><c a="2"><d/><d/></c></b><c
a="1.0"><b>foo</b><d>bar</d></c></a>
```

Result

```
<a b="1"><b a="1"><d>foo</d><c a="2"><d/><d/></c></b><c
a="1.0"><b>foo</b><d>bar</d></c></a>
----------------------
b="1"
----------------------
<b a="1"><d>foo</d><c a="2"><d/><d/></c></b>
----------------------
a="1"
----------------------
<d>foo</d>
----------------------
foo
----------------------
<c a="2"><d/><d/></c>
----------------------
a="2"
----------------------
<d/>
----------------------
<d/>
----------------------
<c a="1.0"><b>foo</b><d>bar</d></c>
----------------------
a="1.0"
----------------------
<b>foo</b>
----------------------
foo
----------------------
<d>bar</d>
----------------------
bar
```

http://xpath.online-toolz.com/tools/xpath-editor.php

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node() | @*">
  <xsl:copy><xsl:apply-templates select="."/></xsl:copy>
</xsl:template>

</xsl:stylesheet>
```

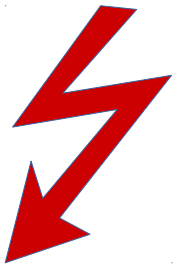
What will this program do?

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node() | @*">
  <xsl:copy><xsl:apply-templates select="."/></xsl:copy>
</xsl:template>

</xsl:stylesheet>
```

```
$ xsltproc identity.xslt t2.xml
runtime error: file loop.xslt line 6 element copy
xsltApplyXSLTTemplate: A potential infinite template recursion was
detected.
You can adjust xsltMaxDepth (--maxdepth) in order to raise the
maximum number of nested template calls and variables/params
(currently set to 3000).
Templates:
#0 name node() | @*
#1 name node() | @*
#2 name node() | @*
```

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node() | @*">
  <xsl:copy><xsl:apply-templates select="."/></xsl:copy>
</xsl:template>

</xsl:stylesheet>
```

→ XSLT is Turing-complete
→ easy to write non-terminating programs



```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node() | @*">
  <xsl:copy><xsl:apply-templates select="."/></xsl:copy>
</xsl:template>

<xsl:template match="b">
  <fff><xsl:apply-templates select="."/></fff>
</xsl:template>

</xsl:stylesheet>
```

→ both templates are applicable to b-nodes

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="node() | @*">
  <xsl:copy><xsl:apply-templates select="."/></xsl:copy>
</xsl:template>

<xsl:template match="b">
  <fff><xsl:apply-templates select="."/></fff>
</xsl:template>

</xsl:stylesheet>
```

→ both templates are applicable to b-nodes
→ **more specific** template is used ("b" before "node()")

Conflict Resolution and Modes in XSLT

- Note that for each node visited by the XSLT processor (cf. default template ②), **more than one template might yield a match**.
- XSLT assigns a **priority** to each template. The more specific the template pattern, the higher the priority:

`<xsl:template match="`*e*`">` *cons* `</xsl:template>`

Pattern *e*	**Priority**
*	−0.5
ns:*	−0.25
element/attribute name	0
any other XPath expression	0.5

- **Example**:
  Priority of `author` is 0, priority of `/strip/prolog/author` is 0.5.
- Alternatively, make priority explicit:
  `<xsl:template priority="`*p*`" ...>`.

any real number

Delete all nested <list>s

```
<xsl:template match="list/list"
   priority="2">
   <!-- deleted nested list -->
</xsl:template>

<xsl:template match="list"
   priority="1">
   <list><xsl:apply-templates/></list>
</xsl:template>
```

```
<d>
<list>text1
<list>
blah
</list>
</list>
<list>
next
</list>
</d>
```

```
<?xml version="1.0"?>
<list>text1
</list>
<list>
next
</list>
```

Delete all nested <list>s

```
<xsl:template match="list/list"
                >
   <!-- deleted nested list -->
</xsl:template>

<xsl:template match="list"
                >
   <list><xsl:apply-templates/></list>
</xsl:template>
```

```
<d>
<list>text1
<list>
blah
</list>
</list>
<list>
next
</list>
</d>
```

```
<?xml version="1.0"?>
<list>text1
</list>
<list>
next
</list>
```

→ if no priorities are given, what is the output?

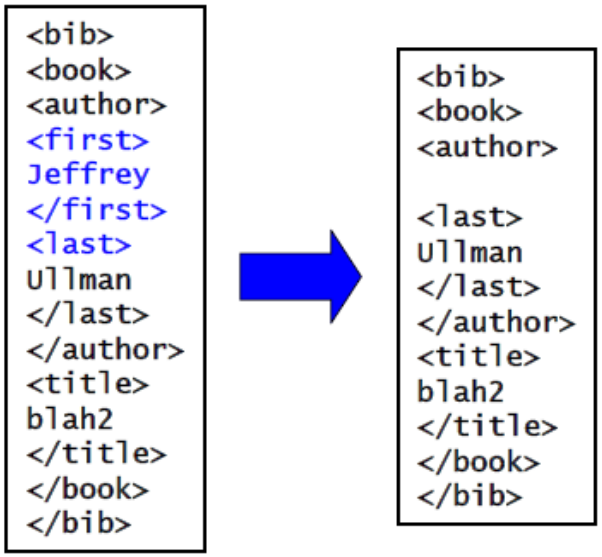
Question

How do you remove book//author/first elements,
but keep everything else in the XML?

Question

How do you remove book//author/first elements,
but keep everything else in the XML?

```
<?xml version="1.0"?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform" version="1.0">

<xsl:template match="book//author/first" priority="5">
</xsl:template>

<xsl:template match="@*|node()">
  <xsl:copy>
    <xsl:apply-templates select="@*|node()"/>
  </xsl:copy>
</xsl:template>

</xsl:stylesheet>
```



Context

Quite often, an XSLT stylesheet wants to be **context-aware**.

- Since the XSLT priority mechanism is *not* dynamic, this can cause problems.

Example: Transform the following XML document (sectioned text with cross references) into XHTML:

self-ref.xml

```
1  <section id="intro">
2     <title>Introduction</title>
3     <para> This section is self-referential: <xref to="intro"/>. </para>
4  </section>
```

We want to generate XHTML code that looks somewhat like this:

self-ref.html

```
1  <h1>Introduction</h1>
2  <p> This section is self-referential: <em>Introduction</em>. </p>
```

The section title needs to be processed twice, once to produce the heading and once to produce the cross reference.

The "obvious" XSLT stylesheet produces erroneous output:

buggy-self-ref.xsl

```
1  <?xml version="1.0"?>
2  <xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
3                  version="1.0">
4
5  <xsl:template match="title">
6    <h1><xsl:apply-templates/></h1>
7  </xsl:template>
8
9  <xsl:template match="para">
10   <p><xsl:apply-templates/></p>
11 </xsl:template>
12
13 <xsl:template match="xref">
14    <xsl:apply-templates select="id(@to)/title"/>
15 </xsl:template>
16
17 </xsl:stylesheet>
```

buggy-output.html

```
1  <h1>Introduction</h1>
2  <p> This section is self-referential: <h1>Introduction</h1>. </p>
```

XSLT modes

- We need to make the processing of the `title` element aware of the context (or **mode**) it is used in: inside an `xref` or not.
- This is a job for **XSLT modes**.
  - In `<xsl:apply-templates>` switch to a certain `mode` *m* depending on the context:

    ```
    <xsl:apply-templates mode="m" .../>
    ```

  - After mode switching, only `<xsl:template>` instructions with a `mode` attribute of value *m* will match:

    ```
    <xsl:template mode="m" .../>
    ```

  - As soon as `<xsl:apply-templates mode="m" .../>` has finished matching nodes, the previous mode (if any) is restored.

self-ref.xsl

```
1  <xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
2                  version="1.0">
3
4  <xsl:template match="title">
5    <h1><xsl:apply-templates/></h1>
6  </xsl:template>
7
8  <xsl:template match="title" mode="ref">
9    <em><xsl:apply-templates/></em>
10 </xsl:template>
11    .
12    .
13    .
14 <xsl:template match="xref">
15    <xsl:apply-templates select="id(@to)/title" mode="ref"/>
16 </xsl:template>
17
18 </xsl:stylesheet>
```

output.html

```
1  <h1>Introduction</h1>
2  <p> This section is self-referential: <em>Introduction</em>. </p>
```

More on XSLT

XSLT Instruction	Effect
`xsl:choose`, `xsl:when`	switch statement (ala C)
`xsl:call-template`	explicitly invoke a (named) template
`xsl:for-each`	replicate result construction for a sequence of nodes
`xsl:import`	import instructions from another stylesheet
`xsl:output`	influence XSLT processor's output behaviour
`xsl:variable`	set/read variables

- For a complete XSLT reference, refer to W3C `http://www.w3.org/TR/xslt`
- Apache's Cocoon is an XSLT-enabled web server (see `http://xml.apache.org/cocoon/`).

Syntax

```
<xsl:output
method="xml|html|text|name"
version="string"
encoding="string"
omit-xml-declaration="yes|no"
standalone="yes|no"
doctype-public="string"
doctype-system="string"
cdata-section-elements="namelist"
indent="yes|no"
media-type="string"/>
```

This example declares a global variable para-font-size, which it references in an attribute value template.

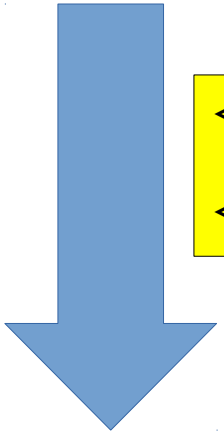
```
<xsl:variable name="para-font-size">12pt</xsl:variable>
.
.

<xsl:template match="para">
    <fo:block font-size="{$para-font-size}">
        <xsl:apply-templates/>
    </fo:block>
</xsl:template>
```

<xsl:number>

- *Used to generate auto-numbering*
-

```
<xsl:number
  level="single|multiple|any"
  count="pattern" -- which nodes count?
  from="pattern"  -- starting point
  value="number-expr" -- force value
  format="s"      -- (not covering)
  lang="lg"       -- lang to use
  letter-value="alphabetic|traditional"
  grouping-separator="char" -- 1,000
  grouping-size="number"    -- 3 in EN
/>
```

```
<colors>
  <color>red</color>
  <color>green</color>
  <color>blue</color>
  <color>yellow</color>
</colors>
```



```
<xsl:template match="color">
  <xsl:number/>. <xsl:apply-templates/>
</xsl:template>
```

1. red
2. green
3. blue
4. yellow

```
<colors>
  <color>red</color>
  <color>green</color>
  <color>blue
     <color>robin's egg</color>
     <color>navy</color>
     <color>cerulean</color>
  </color>
  <color>yellow</color>
</colors>
```

```
<xsl:template match="color">
    <xsl:number level="multiple" format="1. "/>
    <xsl:apply-templates/>
  </xsl:template>
```

```
1. red
2. green
3. blue
   3.1. robin's egg
   3.2. navy
   3.3. cerulean
4. yellow
```

```
<?xml version="1.0"?>
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">

<xsl:template match="@*|node()">
  <xsl:copy>
  <xsl:number level="multiple" count="*"/>
    <xsl:apply-templates select="@*|node()"/>
  </xsl:copy>
</xsl:template>

</xsl:stylesheet>
```

```
<c>
<c>
<AA>
<a1/>
<a2/>
<a3><u/></a3>
</AA>
</c>
<b>
<BB>
<b1/>
<b2/>
<b3/>
</BB>
</b>
</c>
```

```
<?xml version="1.0"?>
<c>1
<c>1.1
<AA>1.1.1
<a1>1.1.1.1</a1>
<a2>1.1.1.2</a2>
<a3>1.1.1.3<u>1.1.1.3.1</u></a3>
</AA>
</c>
<b>1.2
<BB>1.2.1
<b1>1.2.1.1</b1>
<b2>1.2.1.2</b2>
<b3>1.2.1.3</b3>
</BB>
</b>
</c>
```

That's all folks!

This ends the main lectures of "Applied Databases".

→ Lectures 19 & 20 (next week): Recap / Exam preparation

→ no lectures after that! [i.e., no lectures on April 3 & 6]

Thank you for your attention!

END
Lecture 18