Querying XML Documents

XPath

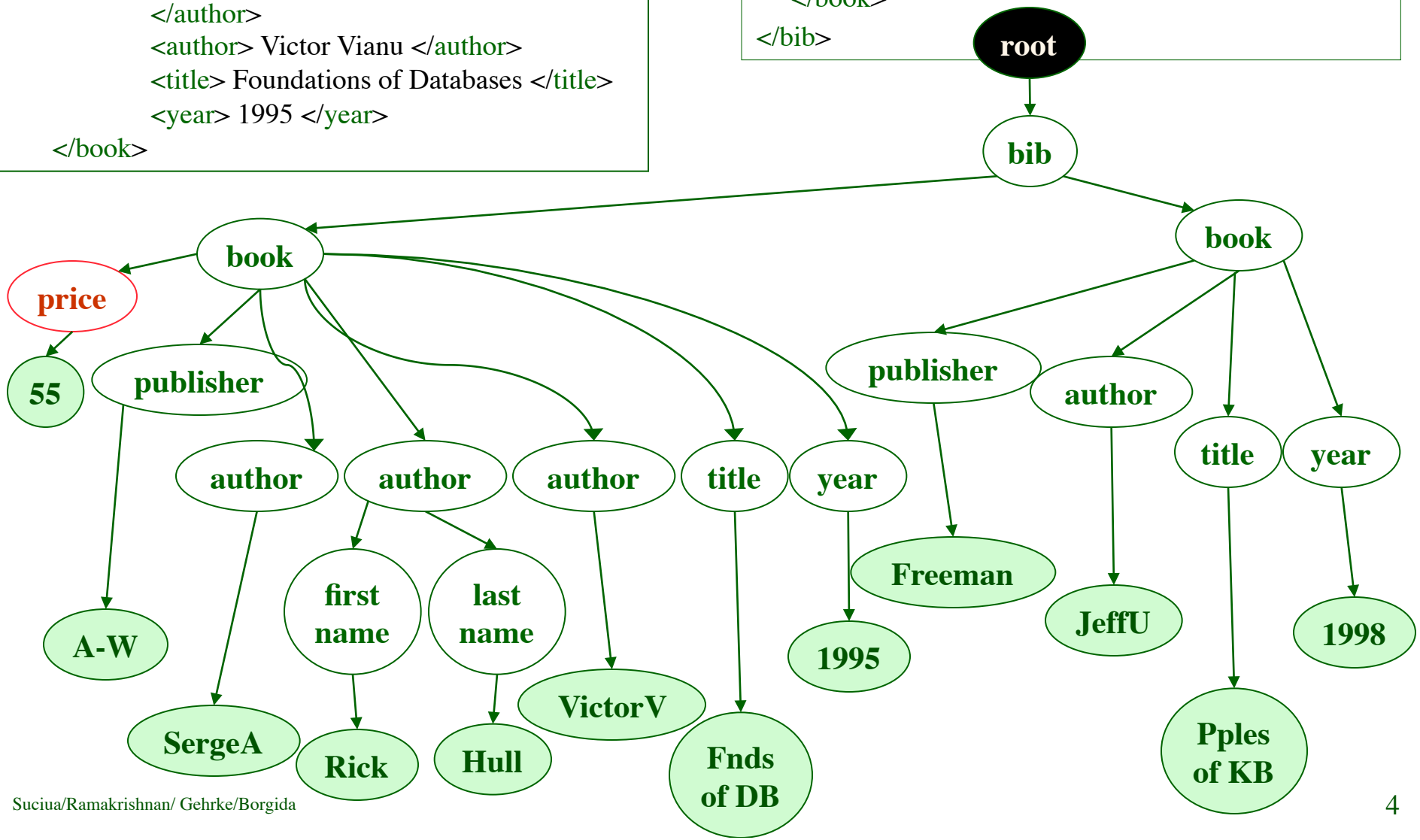
- http://www.w3.org/xpath
- Building block for other W3C standards:
  - XSL Transformations (XSLT)
  - XML Query
- Was originally part of XSL

Example doc for XPath 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>
```

```
<bib>
    <book price="55 >
        <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>
        <publisher> Freeman </publisher>
        <author> Jeffrey D. Ullman </author>
        <title> Principles of  Knowledge Bases</title>
        <year> 1998 </year>
  </book>
</bib>
```



XPath: Simple Expressions

/bib/book/year

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

/bib/paper/year

Result: empty *(there were no papers)*

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: Wildcard

```
//author/*
```

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

* *Matches any element*

```
/*/*/author/
```

"authors at 3rd level"

Xpath: Local Info About Nodes

/bib/book/author/text()

Result: "Serge Abiteboul"
"Victor Vianu"
"Jeffrey D. Ullman"

Rick Hull doesn't appear because he has firstname, lastname

Functions in XPath:

- text() = matches a text value
  text() returns a string for each text element that is a direct child of the context element.

- name() = returns the name of the current tag
  /bib/book/*/name()! ~~> "author"

Xpath: Attribute Nodes

/bib/book/@price

Result: “55”

@price means that there is a price attribute with a value present

Xpath: Qualifiers

/bib/book/author[firstname]

[firstname] means '***has*** firstname ***element***'

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

Xpath: Combining Qualifiers

/bib/book/author[firstname][address[//zip][city]]/lastname

Result: <lastname> … </lastname>

"**lastname *of* author**
(*which has* firstname *and* address (*which has* zip *below and* city))"

Xpath: Qualifiers with conditions on values

/bib/book[@price < “60”]

/bib/book[author/@age < “25”]

/bib/book[author/text()]

XPath: more tree traversal

- current node: .
- parent node: ..
- siblings?

/bib//first-name/.. ~~> <author> ..rick</author>

author[3] ~~> 3rd author element as a child

General *axes*:

- self::path-step
- parent::path-step
- descendant::path-step
- descendant-or-self::path-step
- preceding-sibling::path-step
- preceding::path-step

- child::path-step
- ancestor::path-step
- ancestor-or-self::path-step
- following-sibling::path-step
- following::path-step

- (previous XPaths we saw were in "abbreviated form")

/bib//last-name/preceding::* ~~> <first-name>hull</fitst-name>

(/bib//last-name/ <~~> /*child*::bib/*descendant-or-self*::last-name/)

Xpath: Summary

bib	matches a (all) 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/..	matches the parent of 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…

XQuery

- XQuery is the language for querying XML data.
- XQuery for XML is like SQL for databases.
- XQuery is built on XPath expressions.
- XQuery is supported by all major databases.
- XQuery is a W3C Recommendation.

- "The mission of the XML Query project is to provide flexible query facilities to extract data from real and virtual documents on the World Wide Web, therefore finally providing the needed interaction between the Web world and the database world. Ultimately, collections of XML files will be accessed like databases." – W3C

XQuery

- http://www.w3.org/TR/xquery/

- Try out queries at

  http://www.w3.org/TR/xquery-use-cases/

- You can download your own XQuery interpreter from http://basex.org (also available on iLab mahines)

FLWOR ("Flower") Expressions

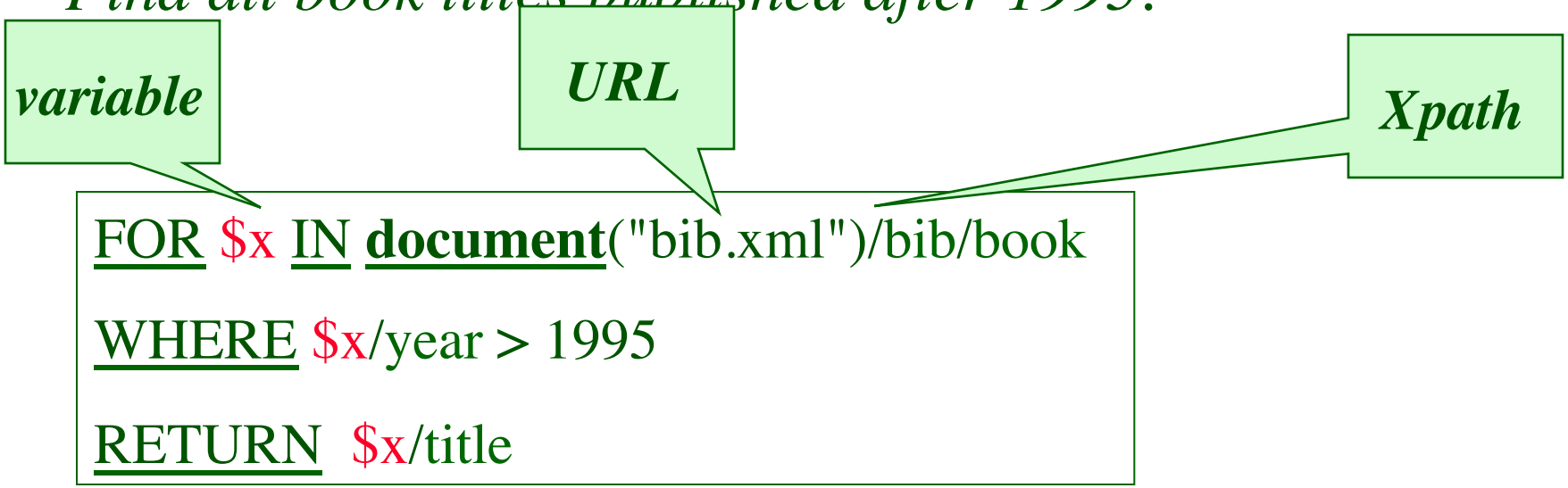
FOR ... LET... FOR... LET...
WHERE...
ORDER BY
RETURN...

Comparing with SQL Expressions

SELECT…
FROM…
WHERE...
ORDER BY…

XQuery

Find all book titles published after 1995:



Result:

<title> abc </title>
<title> def </title>
<title> ghi </title>

XQuery: make better use of Xpath

Find all book titles published after 1995:

```
FOR $b IN document("bib.xml")/bib/book[year > 1995]
RETURN  $b/title
```

or even shorter

```
document("bib.xml")/bib/book[year > 1995]/title
```

Result:

<title> abc </title>
<title> def </title>
<title> ghi </title>

XQuery: constructing answers

"For all books published after 1995 return title and authors"

```
FOR $b IN document("bib.xml")/bib/book[year > 1995]
RETURN <result>
            <the-title>{ $b/title/text() } </the-title>
            <authors>
                  { $b/author }
            </authors>
       </result>
```

Beware of forgetting the { and }; they mean "evaluate *nested* expression"

If you left { } out, you'll get

```
<authors> $b/author </author>
```

XQuery: nested queries

"For each author of a book by AW, list all books she published:"

```
FOR $a IN document("bib.xml")
                    /bib/book[publisher="AW"]/author
RETURN <result>
            { $a,
              FOR $t IN /bib/book[author=$a]/title
              RETURN $t
            }
          </result>
```

XQuery

Result:

```
<result>
        <author>Jones</author>
        <title> abc </title>
        <title> def </title>
  </result>
  <result>
        <author> Smith </author>
        <title> ghi </title>
  </result>
```

XQuery: LET expressions

- FOR $x IN *expr* -- binds $x *in turn to each value* in the list expr

- LET $x **:=** *expr* -- binds $x *once* to the entire sequence expr
  - Useful for common subexpressions and for aggregations

XQuery

```
<big_publishers>
      FOR $p IN document("bib.xml")//publisher
      LET $b := document("bib.xml")/book[publisher = $p]
      WHERE count($b) > 100
      RETURN  $p
</big_publishers>
```

count = a (aggregate) function that returns the number of elms

XQuery

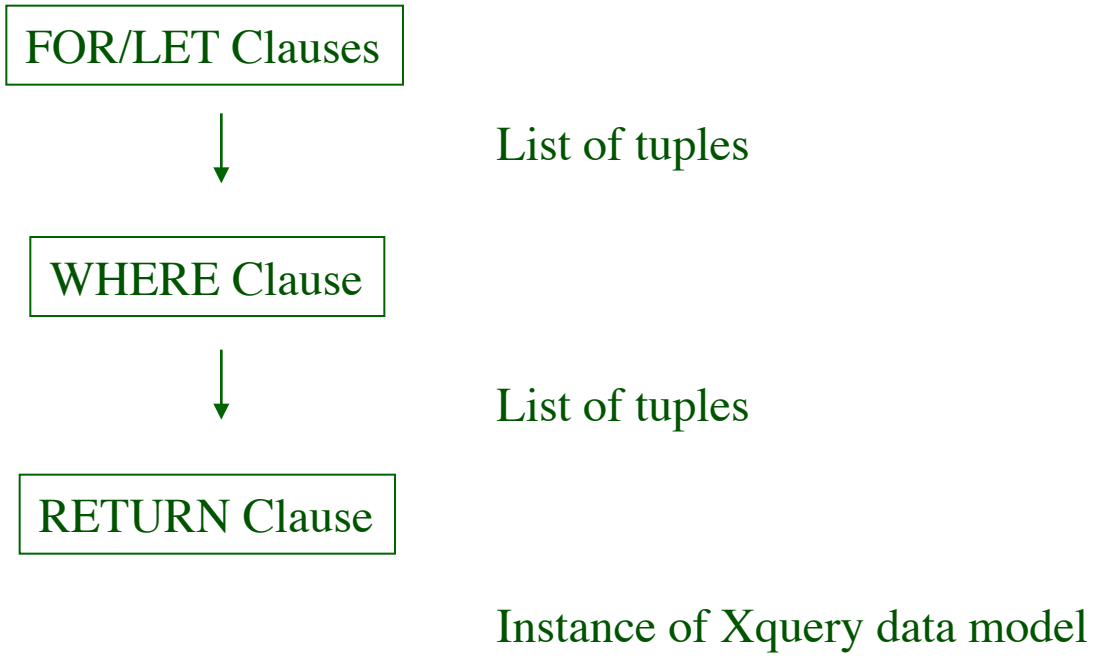
"Find books whose price is larger than average":

```
LET $a := avg( document("bib.xml")/bib/book/@price )
FOR $b in document("bib.xml")/bib/book
WHERE $b/@price > $a
RETURN  $b
```

XQuery

Summary:

- FOR-LET-WHERE-RETURN = FLWR



FOR vs. LET

FOR

- Binds *node variables* → iteration

LET

- Binds *collection variables* → one value

```
FOR $x IN document("bib.xml")/bib/book
RETURN <result> { $x } </result>
```

Returns:

```
<result> <book>...</book></result>
<result> <book>...</book></result>
<result> <book>...</book></result>
...
```

```
LET $x :=  document("bib.xml")/bib/book
RETURN <result> { $x } </result>
```

Returns:

```
<result> <book>...</book>
         <book>...</book>
         <book>...</book>
         ...
</result>
```

Collections in XQuery

- Ordered and unordered collections
  - /bib/book/author ~~> an ordered collection
  - distinct_values(/bib/book/author) ~~> an unordered collection
- LET $b := /bib/book ~~> $b is a collection
- $b/author ~~> a collection (*authors of all books*)

RETURN <result> { $b/author } </result>

Returns:

```
<result> <author>...</author>
         <author>...</author>
         <author>...</author>
         ...
</result>
```

distinct_values($arg)

- The $arg sequence can contain atomic values or nodes, or a combination of the two. The nodes in the sequence have their typed values extracted. This means that only the *contents* of the nodes are compared, not any other properties of the nodes (for example, their names).

e.g. LET $in-xml := <in-xml> <a>3 5 3 </in-xml>

Then distinct-values($in-xml/*) = (3, 5)

Sequences in Xquery

- 1,2,3 = (1,2,3) = (1, (2,3),())
- () can be used as sort of a null; () + 2 = ()
- but boolean logic is 2-valued: () *and true()* yields *false()*
- although there are automatic coercions for tests

  if x then ... else

  x a sequence ~~> check for non-null

  x a number ~~> check for non-zero

  (**yuck**!)

If-Then-Else

```
FOR $h IN //catalogoue
RETURN <catalogue>
            { $h/title,
              IF $h/@type = "Journal"
                    THEN $h/editor
              ELSE $h/author
            }
       </catalogue>
```

Existential Quantifiers

"Books which have some paragraph containing both the words **sailing** *and* **windsurfing***"*

```
FOR $b IN //book
WHERE SOME $p IN $b//para SATISFIES
        contains($p, "sailing")
        AND contains($p, "windsurfing")
RETURN  $b/title
```

Universal Quantifiers

***"Books in which all paragraphs contain the word* sailing"**

```
FOR $b IN //book
WHERE EVERY $p IN $b//para SATISFIES
        contains($p, "sailing")
RETURN  $b/title
```

Comparisons

- If one operand is a single value and the other is a sequence, the result of the comparison is true if there exists some member of the sequence for which the comparison with the single operand is true.
- If both operands are sequences, the comparison is true if there exists some member of the first sequence and some member of the second sequence for which the comparison is true.

Value Comparisons (=, !=, <, <=, >, and >=)

- If both operands are simple values of the same type, the result is straightforward.
- If one operand is a node and the other is a simple value, the content of the node is extracted by an implicit invocation of the "data" function before the comparison is performed. ("data" of a node [basically] returns its typed value - the concatenated contents of all its descendant text nodes, in document order, as untypedAtomic.)
- If both operands are nodes, the string-values of the nodes are compared. (The string-value of a node is the concatenated contents of all its descendant text nodes, in document order, as string.)

Node Identity Comparison (== and !=)

- Defined only for nodes or sequences of nodes
- If both operands of == are nodes, the comparison is true only if both operands are the same node (not just nodes with the same name and value)
- If either or both operands is a node sequence, the rules stated previously apply.

Flattening

- "Flatten" the authors, i.e. return a list of (author, title) pairs

```
FOR $b IN document("bib.xml")/bib/book,
    $x IN $b/title,
    $y IN $b/author
RETURN <answer>
           <title> {data($x)} </title>
           <author> {data($y)} </author>
       </answer>
```

Result:

```
<answer>
   <title> abc </title>
   <author> efg </author>
</answer>
<answer>
   <title> abc </title>
   <author> hkj </author>
</answer>
```

Re-grouping

- "For each author, return all titles of her/his books"

```
FOR $b IN document("bib.xml")/bib,
        $x IN $b/book/author
RETURN
  <answer>
     <author> {data($x)} </author>
     { FOR $y IN $b/book[author=$x]/title
       RETURN $y }
  </answer>
```

Result:

```
<answer>
    <author> efg </author>
     <title> abc </title>
     <title> klm </title>
     . . . .
</answer>
```

What about duplicate authors ?

- Same, but eliminate duplicate authors:

```
FOR $b IN document("bib.xml")/bib
LET $a := distinct-values($b/book/author/text() )
FOR $x IN $a
RETURN
  <answer>
    <author> { $x }</author>
    { FOR $y IN $b/book[author=$x]/title
      RETURN $y }
  </answer>
```

distinct-values eliminates duplicates (but must be applied to a collection of *text* values, not of *elements)*

Re-grouping

- Same thing:

```
FOR $b IN document("bib.xml")/bib,
        $x IN distinct-values($b/book/author/text())
RETURN
  <answer>
    <author> { $x } </author>
    { FOR $y IN $b/book[author=$x]/title
      RETURN $y }
  </answer>
```

Another Example

"Find book titles by the coauthors of 'Database Theory' "

```
FOR $x IN bib/book[title/text() = "Database Theory"]/author
      $y IN bib/book[author/text() = $x/text()]/title

RETURN <answer> { $y/text() } </answer>
```

The answer will contain duplicates !

Result:

<answer> abc </ answer >
< answer > def </ answer >
< answer > abc </ answer >
< answer > ghk </ answer >

Distinct-values

Same as before, but eliminate duplicates:

```
LET $x := bib/book[title/text() = "Database Theory"]/author/text()
FOR $y IN distinct-values(bib/book[author/text() = $x]/title/text())

RETURN <answer> { $y } </answer>
```

Result:

<answer> abc </ answer >
< answer > def </ answer >
< answer > ghk </ answer >

distinct-values = a function that eliminates duplicates

Need to apply to a collection of *text* values, not of *elements – note how query has changed*

SQL and XQuery Side-by-side

'Find all product names, prices'

Product(pid, name, maker, price)

```
<db>
  <Product>
    <row>
      <pid 1234 /> <name 'bulb/> <maker …
    </row>
```

```
SELECT x.name,
       x.price
FROM Product x
```

```
FOR $x in document("db.xml")/db/Product/row
RETURN <answer>
          { $x/name,  $x/price }
       </answer>
```

SQL

XQuery

Xquery's Answer

```
<answer>
      <name>  abc  </name>
      <price>  7 </price>
</answer>
<answer>
      <name>  def  </name>
      <price>  23 </price>
</answer>
  . . . .
```

Notice: this is NOT a well-formed document ! (WHY ???)

Producing a Well-Formed Answer

```
<myQuery>
  {  FOR $x in document("db.xml")/db/Product/row
     RETURN <row>
                  { $x/name,  $x/price }
            </row>
   }
</myQuery>
```

Xquery's Answer

```
<myQuery>
  <row>
        <name>  abc  </name>
        <price>  7 </price>
  </row>
  <row>
        <name>  def  </name>
        <price>  23 </price>
  </row>
    . . . .
</myQuery>
```

Now it is well-formed !

SQL and XQuery Side-by-side

"Find all product names, prices sorted by price"

Product(pid, name, maker, price)

```
SELECT x.name, x.price
FROM Product x
ORDER BY price
```

SQL

```
FOR $x in $db/Product/row
ORDER BY  $x /price/text()

RETURN <a>

{ $x/name, $x/price }</a>
```

XQuery

Answer:

```
<answer>
      <name>  abc  </name>
      <price>  7 </price>
</answer>
<answer>
      <name>  def  </name>
      <price>  23 </price>
</answer>
  . . . .
```

Notice: this is NOT a well-formed document ! (WHY ???)

Producing well formed doc

```
<result>
  {  FOR $x in document("db.xml")/db/Product/row
     ORDER BY $x/price/text()
     RETURN <a>
                    { $x/name,  $x/price }
                </a>
   }
</result>
```

```
<result>
  <a>
       <name>  abc  </name>
       <price>  7 </price>
  </a>
  <a>
       <name>  def  </name>
       <price>  23 </price>
  </a>
    ....
</result>
```

SQL and XQuery Side-by-side

"Find all products made in Seattle"

Product(pid, name, maker, price)
Company(cid, name, city, revenues)

```
SELECT x.name
FROM Product x, Company y
WHERE x.maker=y.cid
      and y.city="Seattle"
```

SQL

```
FOR $x in $db/Product/row,
      $y in $db/Company/row
WHERE
   $x/maker=$y/cid
   and  $y/city = "Seattle"
RETURN { $x/name }
```

XQuery

Compact XQuery

```
FOR $y in /db/Company/row[city="Seattle"],
      $x in /db/Product/row[maker=$y/cid]
RETURN  $x/name
```

```
<product>
        <row> <pid> 123 </pid>
                <name> abc </name>
                <maker> efg </maker>
         </row>
         <row> …. </row>
         …
</product>
<product>
    . . .
</product>
. . . .
```

SQL and XQuery Side-by-side

For each company with revenues < 1M count the products over $100

```
SELECT c.name, count(*)
FROM Product p, Company c
WHERE p.price > 100 and p.maker=c.cid and c.revenue < 1000000
GROUP BY c.cid, c.name
```

```
FOR $r in document("db.xml")/db,
      $c in $r/Company/row[revenue<1000000]
RETURN
   <proudCompany>
      <companyName> { $c/name  } </companyName>
      <numberOfExpensiveProducts>
          { count($r/Product/row[maker=$c/cid][price>100]) }
      </numberOfExpensiveProducts>
   </proudCompany>
```

SQL and XQuery Side-by-side

Find companies with at least 30 products, and their average price

```
SELECT y.name, avg(x.price)
FROM Product x, Company y
WHERE x.maker=y.cid
GROUP BY y.cid, y.name
HAVING count(*) > 30
```

An element

A collection
= the group for y

```
FOR $r in document("db.xml")/db,
    $y in $r/Company/row
LET $p := $r/Product/row[maker=$y/cid]
WHERE count($p) > 30
RETURN
  <theCompany>
    <companyName> { $y/name  }
    </companyName>
    <avgPrice> avg($p/price) </avgPrice>
  </theCompany>
```