XML

Semistructured data
XML, DTD, (XMLSchema)
XPath, XQuery

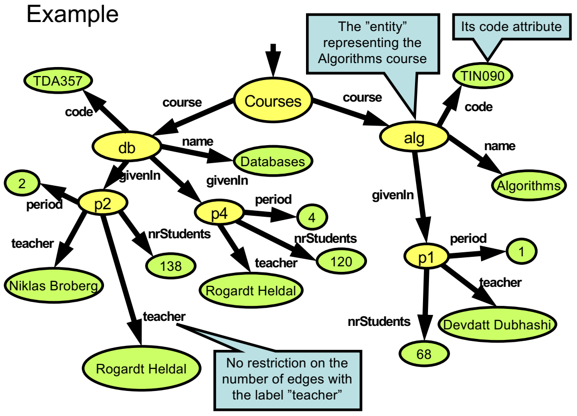
Semi-structured data (SSD)

- More flexible data model than the relational model.
  - Think of an object structure, but with the type of each object its own business.
  - Labels to indicate meanings of substructures.
- Semi-structured: it is structured, but not everything is structured the same way!

SSD Graphs

- Nodes = ”objects”, ”entities”
- Edges with labels represent attributes or relationships.
- Leaf nodes hold atomic values.
- Flexibility: no restriction on
  - Number of edges out from a node.
  - Number of edges with the same label
  - Label names

Example



The ”entity” representing the Algorithms course

Its code attribute

No restriction on the number of edges with the label ”teacher”

Schemas for SSD

- Inherently, semi-structured data does not have schemas.
  - The type of an object is its own business.
  - The schema is given by the data.
- We can of course restrict graphs in any way we like, to form a kind of ”schema”.
  - Example: All ”course” nodes must have a ”code” attribute.

SSD Examples

- XML
  - 90’s
  - Case Sensitive
  - <open_tag>…</close_tag> or <tag />
  - <!-- *comments* -->
- JSON
  - 2000
  - Collection of key/value pairs (hash table, associative array)
  - Begins with **{** and ends with **}**
  - Each keyis followed by **:** (colon) and the key/value pairs are separated by **,** (comma)

XML

- XML = eXtensible Markup Language
- Derives from document markup languages.
  - Compare with HTML: HTML uses ”tags” for formatting a document, XML uses ”tags” to describe semantics.
- Key idea: create tag sets for a domain, and translate data into properly tagged XML documents.

Example

```
<?xml version="1.0”  standalone=”yes” encoding="utf-8" ?>
<!-- This is a comment in XML -->
<Employees>
    <Employee>
        <Name>Alice</Name>
        <NID>34233456-D</NID>
        <Age>35</Age>
        <Salary Currency="EUR">1200</Salary>
    </Employee>
    <Employee>
        <Name>Bob</Name>
        <NID>31245659-D</NID>
        <Age>29</Age>
        <Salary Currency="SEK">18000</Salary>
    </Employee>
</Employees>
```

Standalone means: ”no schema provided”

Child nodes are represented by child elements inside the parent element.

Leaf nodes with values can be represented as either attributes…

… or as element data

XML namespaces

- XML is used to describe a multitude of different domains. Many of these will work together, but have name clashes.
- XML defines *namespaces* that can disambiguate these circumstances.

Use xmlns to bind namespaces to variables in this document.

```
<?xml version="1.0"?>
<cat:catalog xmlns:cat="http://www.shop.com/catalog/xml"
    xmlns:prov="http://www.proveedores.com/xml">
    <cat:produt id=”14”>
        <cat:name>WD AV-GP WD20EURX</cat:name>
        <cat:description>AV-GP WD20EURX 2 TB</cat:description>
        <prov:name>HDD Shop, Inc.</prov:name>
    </cat:product>
</cat:catalog>
```

Quiz!

What’s wrong with this XML document?

```
        <Employee>
                <Name>Alice</Name>
                <NID>31245659-D</NID>
                 <PreviousCompany Name=”Co” >
                <Salary Currency="SEK">18000<Salary>
        </Employee>
```

No end tags provided for the PreviousCompany elements!
We probably meant e.g. <PreviousCompany .../>

What about the Age?

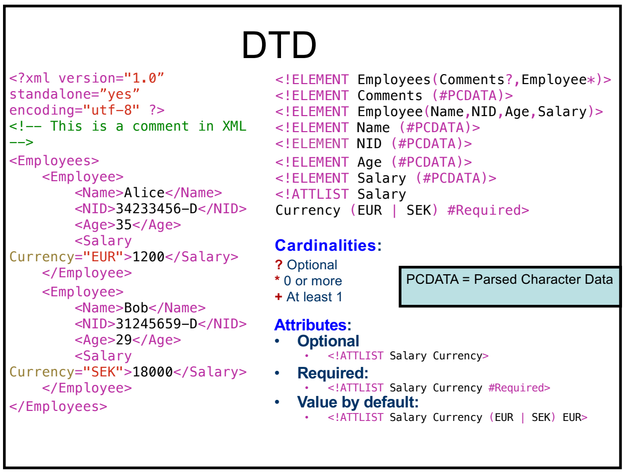
Well-formed and valid XML

- Well-Formed:
  - One *root* element
  - Each element must be closed
  - Case sensitive
  - Hierarchy and consistency
  - Attributes between quotes
- Valid:
  - Weel-Formed
  - Follows:
    - DTD
    - XML Schema

```
<Employees>
    <Employee>
        <Name>Alberto</name> <NID>34233456-D  35</Age>
        <Salary Moneda="Euro"> 1200 </Employee> </Salary>
</Employees>
<Employees>
    ....
</Employees>
```

DTDs

- DTD = Document Type Definition
- A DTD is a schema that specifies what elements may occur in a document, where they may occur, what attributes they may have, etc.
- Essentially a context-free grammar for describing XML tags and their nesting.



DTD

```
<?xml version="1.0”
standalone=”yes”
encoding="utf-8" ?>
<!-- This is a comment in XML
-->
<Employees>
    <Employee>
        <Name>Alice</Name>
        <NID>34233456-D</NID>
        <Age>35</Age>
        <Salary
Currency="EUR">1200</Salary>
    </Employee>
    <Employee>
        <Name>Bob</Name>
        <NID>31245659-D</NID>
        <Age>29</Age>
        <Salary
Currency="SEK">18000</Salary>
    </Employee>
</Employees>
```

```
<!ELEMENT Employees(Comments?,Employee*)>
<!ELEMENT Comments (#PCDATA)>
<!ELEMENT Employee(Name,NID,Age,Salary)>
<!ELEMENT Name (#PCDATA)>
<!ELEMENT NID (#PCDATA)>
<!ELEMENT Age (#PCDATA)>
<!ELEMENT Salary (#PCDATA)>
<!ATTLIST Salary
Currency (EUR | SEK) #Required>
```

Cardinalities:

? Optional

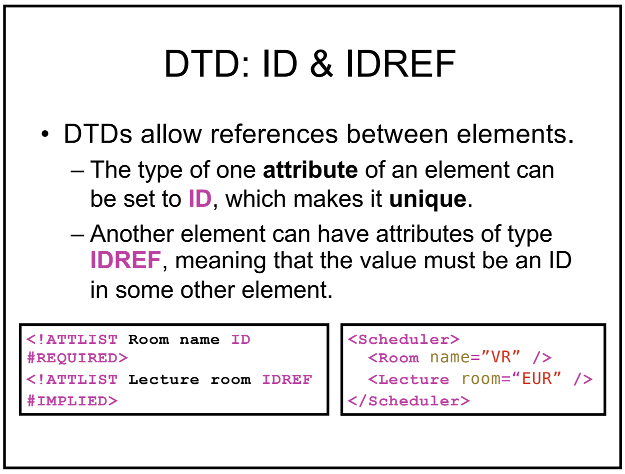
* 0 or more

+ At least 1

PCDATA = Parsed Character Data

Attributes:

- **Optional**
  - `<!ATTLIST Salary Currency>`
- **Required:**
  - `<!ATTLIST Salary Currency #Required>`
- **Value by default:**
  - `<!ATTLIST Salary Currency (EUR | SEK) EUR>`

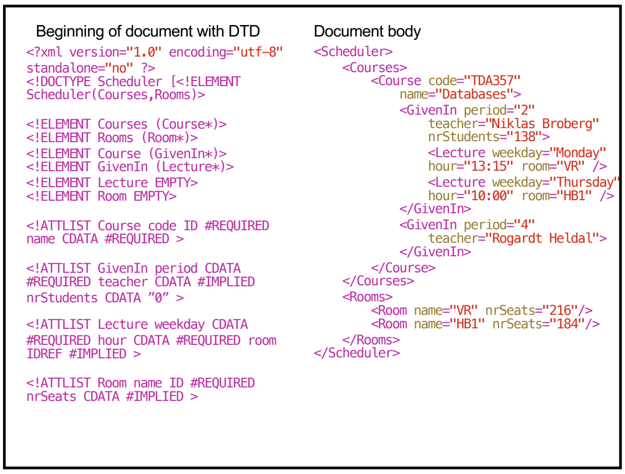


DTD: ID & IDREF

- DTDs allow references between elements.
  - The type of one **attribute** of an element can be set to **ID**, which makes it **unique**.
  - Another element can have attributes of type **IDREF**, meaning that the value must be an ID in some other element.

```
<!ATTLIST Room name ID
#REQUIRED>
<!ATTLIST Lecture room IDREF
#IMPLIED>
```

```
<Scheduler>
  <Room name=”VR” />
  <Lecture room=“EUR” />
</Scheduler>
```

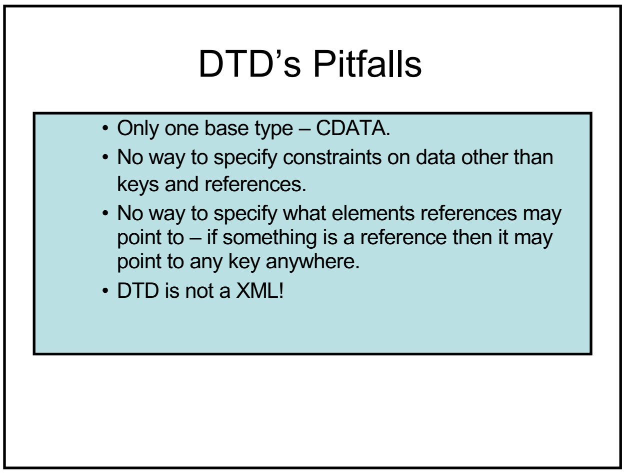


Beginning of document with DTD

```
<?xml version="1.0" encoding="utf-8"
standalone="no" ?>
<!DOCTYPE Scheduler [<!ELEMENT
Scheduler(Courses,Rooms)>

<!ELEMENT Courses (Course*)>
<!ELEMENT Rooms (Room*)>
<!ELEMENT Course (GivenIn*)>
<!ELEMENT GivenIn (Lecture*)>
<!ELEMENT Lecture EMPTY>
<!ELEMENT Room EMPTY>

<!ATTLIST Course code ID #REQUIRED
name CDATA #REQUIRED >

<!ATTLIST GivenIn period CDATA
#REQUIRED teacher CDATA #IMPLIED
nrStudents CDATA ”0” >

<!ATTLIST Lecture weekday CDATA
#REQUIRED hour CDATA #REQUIRED room
IDREF #IMPLIED >

<!ATTLIST Room name ID #REQUIRED
nrSeats CDATA #IMPLIED >
```

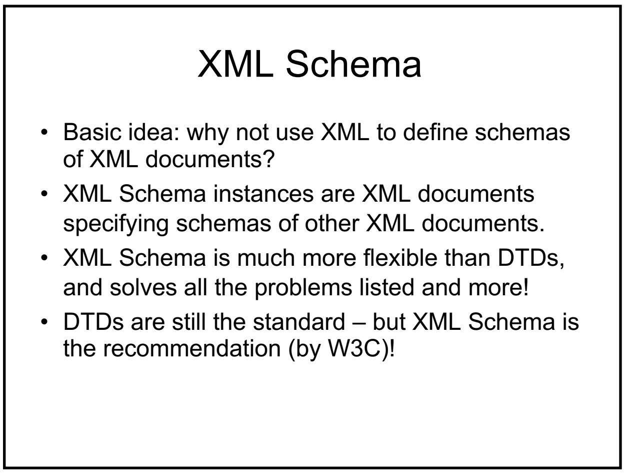
Document body

```
<Scheduler>
    <Courses>
        <Course code="TDA357"
            name="Databases">
            <GivenIn period="2"
                teacher="Niklas Broberg"
                nrStudents="138">
                <Lecture weekday="Monday"
                hour="13:15" room="VR" />
                <Lecture weekday="Thursday"
                hour="10:00" room="HB1" />
            </GivenIn>
            <GivenIn period="4"
                teacher="Rogardt Heldal">
            </GivenIn>
        </Course>
    </Courses>
    <Rooms>
        <Room name="VR" nrSeats="216"/>
        <Room name="HB1" nrSeats="184"/>
    </Rooms>
</Scheduler>
```



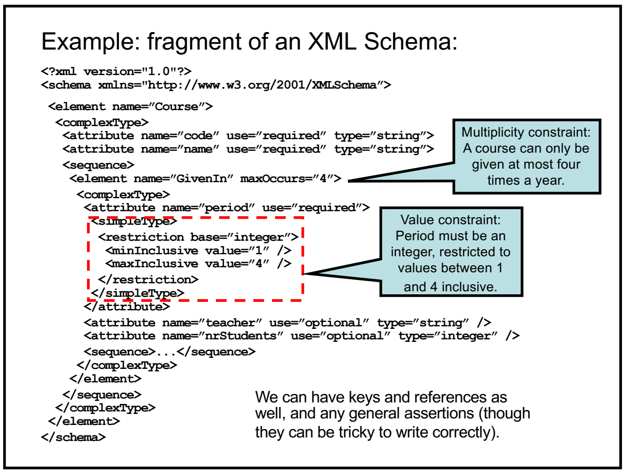
DTD’s Pitfalls

- Only one base type – CDATA.
- No way to specify constraints on data other than keys and references.
- No way to specify what elements references may point to – if something is a reference then it may point to any key anywhere.
- DTD is not a XML!



XML Schema

- Basic idea: why not use XML to define schemas of XML documents?
- XML Schema instances are XML documents specifying schemas of other XML documents.
- XML Schema is much more flexible than DTDs, and solves all the problems listed and more!
- DTDs are still the standard – but XML Schema is the recommendation (by W3C)!



Example: fragment of an XML Schema:

```
<?xml version="1.0"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema”>

 <element name=”Course”>
  <complexType>
   <attribute name=”code” use=”required” type=”string”>
   <attribute name=”name” use=”required” type=”string”>
   <sequence>
    <element name=”GivenIn” maxOccurs=”4”>
     <complexType>
      <attribute name=”period” use=”required”>
       <simpleType>
        <restriction base=”integer”>
         <minInclusive value=”1” />
         <maxInclusive value=”4” />
        </restriction>
       </simpleType>
      </attribute>
      <attribute name=”teacher” use=”optional” type=”string” />
      <attribute name=”nrStudents” use=”optional” type=”integer” />
      <sequence>...</sequence>
     </complexType>
    </element>
   </sequence>
  </complexType>
 </element>
</schema>
```

Multiplicity constraint: A course can only be given at most four times a year.

Value constraint: Period must be an integer, restricted to values between 1 and 4 inclusive.

We can have keys and references as well, and any general assertions (though they can be tricky to write correctly).

XML query languages

XPath
XQuery

XPath

- XPath is a language for describing paths in XML documents.
- Path descriptors are similar to path descriptors in a (UNIX) file system.

Symbol	Meaning
/	Root
.	Current Element
..	Parent Element
//*	All elements anywhere
elem1/elem2	Path
[test]	Condition (to filter)
@Att	Attribute

Examples:

```
<?xml version="1.0”  standalone=”yes” encoding="utf-8" ?>
<!-- This is a comment in XML -->
<Employees>
    <Employee>
        <Name>Alice</Name>
        <NID>34233456-D</NID>
        <Age>35</Age>
        <Salary Currency="EUR">1200</Salary>
    </Employee>
    <Employee>
        <Name>Bob</Name>
        <NID>31245659-D</NID>
        <Age>29</Age>
        <Salary Currency="SEK">18000</Salary>
    </Employee>
</Employees>
```

Employees with salary>1000:

/Employees/Employee[Salary>"1000"]

Salaries in EUR :

//Salary[@Currency=”EUR”]/text()

NID of employees whose age>35 and their salary>1400 EUR

/Employees/Employee[Age=”35”][Salary[@Currency=”EUR”]>”1400”]/NID

Axes

- The various directions we can follow in a graph are called *axes* (sing. axis).
- General syntax for following an axis is

  ***axis*::**

  – Example: **/Courses/child::Course**
- Only giving a label is shorthand for **child::label**, while @ is short for **attribute::**

More axes

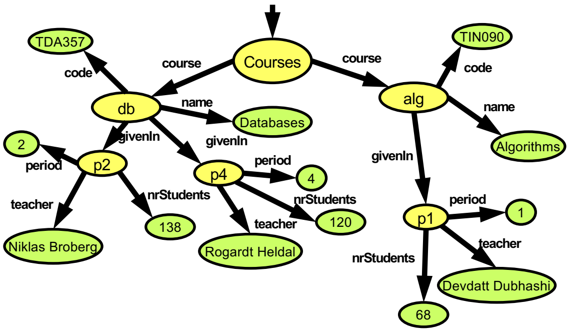
- Some other useful axes are:
  – parent:: = parent of the current node.
    - Shorthand is ..
  – descendant-or-self:: = the current node(s) and all descendants (i.e. children, their children, …) down through the tree.
    - Shorthand is //
  – ancestor::, ancestor-or-self = up through the tree
  – following-sibling:: = any elements on the same level that come *after* this one.
  – …

Quiz!

Write an XPath expression that gives the courses that are given in period 2, but with only the GivenIn element for period 2 as a child!

It can’t be done!
XPath is not a full query language, it only allows us to specify paths to elements or groups of elements. We can restrict in the path using [ ] notation, but we cannot restrict further down in the tree than what the path points to.

Example: **/Courses/Course[GivenIn/@period = 2]**



XQuery

- XQuery is a full-fledged querying language for XML documents.
  - – Cf. SQL queries for relational data.
- XQuery is built on top of XPath, and uses XPath to point out element sets.
- XQuery is a W3 recommendation.

XQuery “Hello World”

If our XQuery file contains:

```
<Greeting>Hello World</Greeting>
```

or:

```
let $s := "Hello World"
return <Greeting>{$s}</Greeting>
```

then the XQuery processor will produce the following XML document:

```
<?xml version="1.0" encoding="UTF-8"?>
<Greeting>Hello World</Greeting>
```

Function doc("file.xml")

```
bash$ cat example.xq
doc("courses.xml")
bash$ xquery example.xq
<?xml version="1.0" encoding="UTF-8"?>
<Courses>
  <Course name="Databases" code="TDA357">
    <GivenIn period="2" teacher="Niklas Broberg"/>
    <GivenIn period="4" teacher="Rogardt Heldal"/>
  </Course>
  <Course name="Algorithms" code="TIN090">
    <GivenIn period="1" teacher="Devdatt Dubhashi"/>
  </Course>
</Courses>
```

Quiz!

Write an XQuery expression that puts extra <Result></Result> tags around the result, e.g.

```
<Result>
  <Courses>
    <Course name="Databases" code="TDA357">
      <GivenIn period="2" teacher="Niklas Broberg"/>
      <GivenIn period="4" teacher="Rogardt Heldal"/>
    </Course>
    <Course name="Algorithms" code="TIN090">
      <GivenIn period="1" teacher="Devdatt Dubhashi"/>
    </Course>
  </Courses>
</Result>
```

Putting tags around the result

Curly braces are necessary to evaluate the expression between the tags.

```
<Result>{doc("courses.xml")}</Result>
```

Alternatively, we can use a **let** clause to assign a value to a variable. Again, curly braces are needed to get the value of variable $d.

```
let $d := doc("courses.xml")
return <Result>{$d}</Result>
```

FLWOR

- Basic structure of an XQuery expression is:
  - FOR-LET-WHERE-ORDER BY-RETURN.
  - Called FLWOR expressions (pronounce as *flower*).
- A FLWOR expression can have any number of FOR (iterate) and LET (assign) clauses, possibly mixed, followed by possibly a WHERE clause and possibly an ORDER BY clause.
- Only required part is RETURN.

Quiz!

What does the following XQuery expression compute?

```
let $courses := doc("courses.xml")
for $gc in $courses//GivenIn
where $gc/@period = 2
return <Result>{$gc}</Result>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<Result>
  <GivenIn period="2" teacher="Niklas Broberg"/>
</Result>
```

Quiz!

What does the following XQuery expression compute?

```
let $courses := doc("courses.xml")
let $gc := $courses//GivenIn[@period = 2]
return <Result>{$gc}</Result>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<Result>
  <GivenIn period="2" teacher="Niklas Broberg"/>
</Result>
```

Quiz!

What does the following XQuery expression compute?

```
let $courses := doc("courses.xml")
for $c in $courses/Courses/Course
let $code := $c/@code
let $given := $c/GivenIn
where $c/GivenIn/@period = 2
return <Result code="{$code}">{$given}</Result>
```

```
<? xml version="1.0" encoding="UTF-8"?>
<Result code="TDA357">
  <GivenIn period="2" teacher="Niklas Broberg"/>
  <GivenIn period="4" teacher="Rogardt Heldal"/>
</Result>
```

Quiz!

Write an XQuery expression that gives the courses that are given in period 2, but with only the `GivenIn` element for period 2 as a child!

```
let $courses := doc("courses.xml")
for $c in $courses/Courses/Course
let $code := $c/@code, $name := $c/@name
let $given := $c/GivenIn[@period = 2]
where not(empty($given))
return <Course code="{$code}"
               name="{$name}">{$given}</Course>
```

A sequence of elements

The previous examples have all returned a single element. But an XQuery expression can also evaluate to a sequence of elements, e.g.

```
let $courses := doc("courses.xml")
for $gc in $courses/Courses/Course/GivenIn
return $gc
```

```
<GivenIn period="2" teacher="Niklas Broberg"/>
<GivenIn period="4" teacher="Rogardt Heldal"/>
<GivenIn period="1" teacher="Devdatt Dubhashi"/>
```

Putting tags around a sequence

```
let $courses := doc("courses.xml")
let $seq := (
    for $gc in $courses/Courses/Course/GivenIn
    return $gc )
return <Result>{$seq}</Result>
```

```
<Result>
  {
    let $courses := doc("courses.xml")
    for $gc in $courses/Courses/Course/GivenIn
    return $gc
  }
</Result>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<Result>
  <GivenIn period="2" teacher="Niklas Broberg"/>
  <GivenIn period="4" teacher="Rogardt Heldal"/>
  <GivenIn period="1" teacher="Devdatt Dubhashi"/>
</Result>
```

Quiz!

What will the result of the following XQuery expression be?

```
let $courses := doc("courses.xml")
for $c in $courses/Courses/Course
for $gc in $courses/Courses/Course/GivenIn
return <Info name="{$c/@name}" teacher="{$gc/@teacher}" />
```

```
<Courses>
 <Course name=”Databases” code=”TDA357”>
  <GivenIn period=”3” teacher=”Niklas Broberg” />
  <GivenIn period=”2” teacher=”Graham Kemp” />
 </Course>
 <Course name=”Algorithms” code=”TIN090”>
  <GivenIn period=”1” teacher=”Devdatt Dubhashi” />
 </Course>
</Courses>
```

Answer: Cartesian product

Two **for** clauses will iterate over all combinations of values for the loop variables, e.g.

```
let $courses := doc("courses.xml")
for $c in $courses/Courses/Course
for $gc in $courses/Courses/Course/GivenIn
return <Info name="{$c/@name}" teacher="{$gc/@teacher}" />
```

```
<Info name="Databases" teacher="Niklas Broberg"/>
<Info name="Databases" teacher="Rogardt Heldal"/>
<Info name="Databases" teacher="Devdatt Dubhashi"/>
<Info name="Algorithms" teacher="Niklas Broberg"/>
<Info name="Algorithms" teacher="Rogardt Heldal"/>
<Info name="Algorithms" teacher="Devdatt Dubhashi"/>
```

Aggregations

XQuery provides the usual aggregation functions: count, sum, avg, min, max.

```
<Result>
  {
    count(doc("scheduler.xml")//Room)
  }
</Result>
```

```
<Result>
  {
    sum(doc("scheduler.xml")//Room/@nrSeats)
  }
</Result>
```

Joins in XQuery

We can join two or more documents in XQuery by calling the function doc() two or more times.

```
let $a = doc("a.xml")
let $b = doc("b.xml")
...
   (... compare values in $a with values in $b ...)
```

Quiz: what does this XQuery expression compute?

```
<Result>
  {
    for $d in ( doc("scheduler.xml"), doc("courses.xml") )
    return $d
  }
</Result>
```

Sorting in XQuery

```
<Result>
  {
    let $courses := doc("courses.xml")
    for $gc in $courses/Courses/Course/GivenIn
    order by $gc/@period
    return $gc
  }
</Result>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<Result>
  <GivenIn period="1" teacher="Devdatt Dubhashi"/>
  <GivenIn period="2" teacher="Niklas Broberg"/>
  <GivenIn period="4" teacher="Rogardt Heldal"/>
</Result>
```

Quantification in XQuery

An XQuery expression might evaluate to a single item or a sequence of items.

```
every variable in expression satisfies condition

 some variable in expression satisfies condition
```

Most tests in XQuery, such as the "=" comparison operator, are existentially quantified anyway, so "some" is rarely needed.

Comparing items in XQuery

- The comparison operators eq, ne, lt, gt, le and ge can be used to compare single items.
- If either operand is a sequence of items, the comparison will fail.

Updating XML

- We have corresponding languages for XML and relational databases:
  - SQL DDL ⇔ DTDs or XML Schema.
  - SQL queries ⇔ XQuery
  - SQL modifications ⇔ ??
- XQuery Update is a semi-official extension of XQuery, recommended by W3C.
  - As of June 2009

XQuery Update

- XQuery Update
  - Extends XQuery to support insertions, deletions and updates.
  - Example:

```
for $1 in /Scheduler/Courses/Course
            [@code = ″TDA357″]/GivenIn
            [@period = 2]/Lectures
where $1/@hour = ″08:00″
return
    replace $1/@hour with ″10:00″
```

Summary XML

- XML is used to describe data organized as *documents*.
  - Semi-structured data model.
  - Elements, tags, attributes, children.
  - Namespaces.
- XML can be valid with respect to a schema.
  - DTD: ELEMENT, ATTLIST, CDATA, ID, IDREF
  - XML Schema: Use XML for the schema domain to describe your schema.
- XML can be queried for information:
  - XPath: Paths, axes, selection
  - XQuery: FLWOR.

Next lecture

Database Systems:

”NoSQL”