INFO-H-509 XML AND WEB TECHNOLOGIES

Lecture 2: XML and XPath

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LECTURE OUTLINE

Unicode

XML and Namespaces

XPath

JSON
UNICODE
UNICODE (1)

- HTML (and XML) files are represented as text files
- A text file is logically a sequence of characters
- But physically a sequence of bytes
- Several mappings from bytes to characters exist:
  - ASCII
  - EBCDIC
  - Unicode

Unicode aims to cover all characters in all past or present written languages. In its current version, Unicode consists of a repertoire of more than 107,000 characters covering 90 scripts.
UNICODE (2): CHARACTERS

Definition
A character is a symbol that appears in a text

Examples
- letters of the alphabet
- pictograms like ©
- accents

Unicode characters are abstract entities:
- LATIN CAPITAL LETTER A
- LATIN CAPITAL LETTER A WITH RING ABOVE
- HIRAGANA LETTER SA
- RUNIC LETTER THURISAZ THURS THORN
**Definition**

A *glyph* is a graphical presentation of a character.

For instance, the glyph Å represents several characters:

- LATIN CAPITAL LETTER A WITH RING ABOVE
- ANGSTROM SIGN

It can also be described by a *sequence* of characters:

- LATIN CAPITAL LETTER A COMBINING RING ABOVE

Some characters even result in several glyphs.
UNICODE (4): CODE POINTS

Definition
Every Unicode character is assigned a unique number between 0 and 1,114,112, called its code point.

For instance:
- the character HIRAGANA LETTER SA is assigned the code point 12,373
- Code points 0 through 127 coincide with ASCII

Only 107,000 code points in use today
UNICODE (5): CHARACTER ENCODINGS

Definition
A character encoding defines how to interpret a sequence of bytes as a sequence of code points.

In Unicode:
- bytes are first parsed into fixed-length code units
- one or more code units may be required to denote a code point

Example character encodings are UTF-8, UTF-16, UTF-32
UNICODE (6): UTF-8

- Each code unit is a single byte
- Code points is from 1 to 4 code units
- Code Units between 0 and 127 directly represent the corresponding code points (same as ASCII)

Consider the following sequence of 3 bytes

0100 0001 0100 0010 0100 0011
UNICODE (6): UTF-8

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Consider the following sequence of 3 bytes

<table>
<thead>
<tr>
<th>decimal</th>
<th>code unit 1</th>
<th>code unit 2</th>
<th>code unit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0100 0001</td>
<td>0100 0010</td>
<td>0100 0011</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>66</td>
<td>67</td>
</tr>
</tbody>
</table>
UNICODE (6): UTF-8

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Consider the following sequence of 3 bytes

<table>
<thead>
<tr>
<th></th>
<th>0100 0001</th>
<th>0100 0010</th>
<th>0100 0011</th>
</tr>
</thead>
<tbody>
<tr>
<td>decimal</td>
<td>65</td>
<td>66</td>
<td>67</td>
</tr>
<tr>
<td>glyphs</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>
UNICODE (6): UTF-8

- For a code unit > 127, the bit masks 110XXXXX, 1110XXXX, and 11110XXX are used to indicate that the code point comprises 2, 3, respectively 4 units.
- The remaining units must have bit mask 10XXXXXX

Consider the following sequence of 3 bytes

1110 0011 1000 0001 1001 0101

This is 12373 in decimal, the code point for HIRAGANA LETTER SA
For a code unit > 127, the bit masks 110XXXXX, 1110XXXX, and 11110XXX are used to indicate that the code point comprises 2, 3, respectively 4 units.

The remaining units must have bit mask 10XXXXXX

Consider the following sequence of 3 bytes

\[
\begin{array}{c}
1110 & 0011 \\
1000 & 0001 \\
1001 & 0101
\end{array}
\]

The first unit indicates that the code point comprises 3 units
For a code unit > 127, the bit masks 110XXXXX, 1110XXXX, and 11110XXX are used to indicate that the code point comprises 2, 3, respectively 4 units.

The remaining units must have bit mask 10XXXXXX

Consider the following sequence of 3 bytes

1110 0011 1000 0001 1001 0101

- The first unit indicates that the code point comprises 3 units
- We then interpret the non-bitmask bits of the 3 units as one binary number

0011 0000 0101 0101
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0011 0000 0101 0101

- This is 12373 in decimal, the code point for HIRAGANA LETTER SA
The big picture:

Other encodings:
- See book for details on **UTF-16** and **UTF-32**
- Another popular character encoding is **ISO-8859-1** (aka **Latin-1**) with only 256 code points. It coincides with ASCII on code points 0-127, but cannot represent general Unicode
UNICODE (8): USE IN HTML

<meta http-equiv="Content-Type" content="text/html; charset=ISO-8859-1"/>
XML AND NAMESPACES
WHAT IS XML?

XML: the eXtensible Markup Language

- In essence a data exchange format
- Each application domain is free to choose its own markup tags
- It can also be viewed as a framework for defining markup languages
- There is a common set of generic tools for processing XML documents
By means of Online demonstration
THE TEXTUAL REPRESENTATION OF XML: SOME KEY POINTS

- Always starts with the XML Declaration

```xml
<?xml version="1.1" encoding="UTF-8"?>
```

THE TEXTUAL REPRESENTATION OF XML: SOME KEY POINTS

- Always starts with the XML Declaration
  ```xml
  <?xml version="1.1" encoding="UTF-8"?>
  ```
- Consists mainly of Element start and end tags
  ```xml
  <bla ...> ... </bla>
  ```
  - Start and end tags must match and nest properly!
    - OK:  ```xml
      <x> <y> </y> </x>
    ```
    - Not OK:  ```xml
      </z> <x> <y> </x> </y>
    ```
  - Short hand for empty elements:  ```xml
    <bla/>
  ```
The textual representation of XML: some key points

- Always starts with the **XML Declaration**
  ```xml
  <?xml version="1.1" encoding="UTF-8"?>
  ```

- Consists mainly of Element start and end tags
  ```xml
  <bla ...> ... </bla>
  ```
  - Start and end tags **must match and nest properly**!
    - OK:  `<x> <y> </y> </x>`
    - Not OK:  `</z> <x> <y> </x> </y>`
  - Short hand for empty elements: `<bla/>`

- Attributes: **name="value"** in start tags
THE TEXTUAL REPRESENTATION OF XML: SOME KEY POINTS

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  ```

- Consists mainly of Element start and end tags
  
  ```xml
  <bla ...> ... </bla>
  ```

  - Start and end tags **must match and nest properly!**
    
    **OK:**  
    ```xml
    <x> <y> </y> </x>
    ```
    
    **Not OK:**  
    ```xml
    </z> <x> <y> </x> </y>
    ```

  - Short hand for empty elements: `<bla/>`

- Attributes: `name="value"` in start tags

- Always exactly one root element
Always starts with the XML Declaration

```xml
<?xml version="1.1" encoding="UTF-8"?>
```

Consists mainly of Element start and end tags

```xml
<bla ...> ... </bla>
```

- Start and end tags **must match and nest properly**!
  - OK:  
    ```xml
    <x> <y> </y> </x>
    ```
  - Not OK:
    ```xml
    </z> <x> <y> </x> </y>
    ```
- Short hand for empty elements: `<bla/>`

Attributes: `name="value"` in start tags

Always exactly one root element

Well-formedness can be checked by tools
• **Comment tags:** allow you to write some meta-information in the XML file. This is normally ignored by all XML processing applications.

```xml
<!– bla –>
```

• **Processing instructions:** allow you to specify specific instructions to specific processors. Each has a target and a value.

```xml
<?target value?>
```
Special characters can be referenced by character references

- These take the form `&#XXXX;`

  `<bla> Copyright © 2005 </bla>`

- `&lt;` and `&gt;` and `&amp;` denote `<` and `>` and `&` respectively

**CDATA** sections allow text that doesn't need to be escaped by `&lt` and `&gt`

  `<![CDATA[ <this is not a tag> ]]>`
Do you know the following terms?

- node, edge
- root, leaf
- child, parent
- sibling (ordered trees), ancestor, descendant
Conceptually, an XML document is an ordered tree with different types of nodes:

- **document structure** = tree structure
- **document data** = leaf of tree
- Also comment nodes, processing instructions, … (not shown)
An XML parser is an algorithm that given the textual XML document, constructs its tree representation.
There are multiple data models for XML:

- XQuery and XPath data model (used here)
- The post-validation infoset
- DOM, JDOM
- ...

We use the XPath data model unless specified otherwise!
<xml version="1.0" encoding="UTF-8"/>
<collection>
<description>Recipes suggested by Jane Dow</description>

<recipe id="r117">
  <title>Rhubarb Cobbler</title>
  <date>Wed, 14 Jun 95</date>

  <ingredient name="diced rhubarb" amount="2.5" unit="cup"/>
  <ingredient name="sugar" amount="2" unit="tablespoon"/>
  <ingredient name="fairly ripe banana" amount="2"/>
  <ingredient name="cinnamon" amount="0.25" unit="teaspoon"/>
  <ingredient name="nutmeg" amount="1" unit="dash"/>

  <preparation>
    <step>Combine all and use as cobbler, pie, or crisp.</step>
  </preparation>

  <comment>Rhubarb Cobbler made it with ...</comment>

  <nutrition calories="170" fat="28%"
    carbohydrates="58%" protein="14%"/>
  <related ref="42">Garden Quiche</related>
</recipe>
</collection>
APPLICATIONS OF XML

Rough Classification:

- Data-oriented languages (e.g. configuration files, CML)
- Document-oriented languages (e.g. XHTML)
- Protocols and programming languages (e.g. SOAP, WSDL, XSLT)
- Hybrids
EXAMPLE: XHTML

XHTML is the XML version of HTML

- XHTML must be a well-formed XML document (e.g. tags must match and nest properly)
- Ordinary HTML is typically “invalid” and hence renders differently on different browsers.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<html xmlns="http://www.w3.org/1999/xhtml">
  <head><title>Hello world!</title></head>
  <body>
    <h1>This is a heading</h1>
    This is some text.
  </body>
</html>
```
<?xml version="1.0" encoding="UTF-8"?>
<molecule id="METHANOL">
  <atomArray>
    <stringArray builtin="id">a1 a2 a3 a4 a5 a6</stringArray>
    <stringArray builtin="elementType">C O H H H H</stringArray>
    <floatArray builtin="x3" units="pm">
      -0.748 0.558 ...
    </floatArray>
    <floatArray builtin="y3" units="pm">
      -0.015 0.420 ...
    </floatArray>
    <floatArray builtin="z3" units="pm">
      0.024 -0.278 ...
    </floatArray>
  </atomArray>
</molecule>
<?xml version="1.0" encoding="UTF-8"?>
<MultiPartyCollaboration name="DropShip">
  <BusinessPartnerRole name="Customer">
    <Performs initiatingRole='//binaryCollaboration[@name="Firm Order"]/InitiatingRole[@name="buyer"]'/>
  </BusinessPartnerRole>
  <BusinessPartnerRole name="Retailer">
    <Performs respondingRole='//binaryCollaboration[@name="Firm Order"]/RespondingRole[@name="seller"]'/>
    <Performs initiatingRole='//binaryCollaboration[@name="..."]/InitiatingRole[@name="buyer"]'/>
  </BusinessPartnerRole>
  <BusinessPartnerRole name="DropShip Vendor">
    ...
  </BusinessPartnerRole>
</MultiPartyCollaboration>
<?xml version="1.0" encoding="UTF-8"?>
<h3 class="s05" id="One.2.p0.2">Having a Humble Opinion of Self</h3>
<p class="First" id="One.2.p0.3">EVERY man naturally desires knowledge</p>
<note place="foot" id="One.2.p0.4">
  <p class="Footnote" id="One.2.p0.5"><added id="One.2.p0.6">Aristotle</added></p>
</note>

but what good is knowledge without fear of God? Indeed a humble rustic who serves God is better than a proud intellectual who neglects his soul to study the course of the stars.
<added id="One.2.p0.8"><note place="foot" id="One.2.p0.9">
  <p class="Footnote" id="One.2.p0.10">Augustine, Confessions V. 4.</p>
</note></added>
</p>
Consider an XML language for widgets. The `<info>` element contains information in XHTML markup.

```xml
<widget type="gadget">
  <head size="medium"/>
  <big>
    <subwidget ref="gizmo"/>
  </big>
  <info>
    <head>
      <title>Description of gadget</title>
    </head>
    <body>
      <h1>Gadget</h1>
      A gadget contains a big gizmo
    </body>
  </info>
</widget>
```
XML NAMESPACES (1): MOTIVATION

Consider an XML language for widgets. The `<info>` element contains information in XHTML markup.

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    </body>
  </info>
</widget>
```

- When combining languages, **element names may become ambiguous**
- A general solution?
XML NAMESPACES (2): THE IDEA

- Assign a URI to every (sub-)language
  
e.g. http://www.w3.org/1999/xhtml for XML 1.0

- Qualify element names with URIs:
  
  {http://www.w3.org/1999/xhtml}head
Namespace declarations bind URIs to prefixes

```xml
<... xmlns:foo="http://www.w3.org/TR/xhtml1">
    ...
    <foo:head>...</foo:head>
    ...
</...>
```

- Lexical scope
- Default namespace (no prefix) declared with xmlns="...
- Attribute names can also be prefixed
Namespace declarations bind URIs to prefixes

```
<widget type="gadget" xmlns="http://www.widget.inc">
  <head size="medium"/>
  <big><subwidget ref="gizmo"/></big>
  <info xmlns:xhtml="http://www.w3.org/TR/xhtml1">
    <xhtml:head>
      <xhtml:title>Description of gadget</xhtml:title>
    </xhtml:head>
    <xhtml:body>
      <xhtml:h1>Gadget</xhtml:h1>
      A gadget contains a big gizmo
    </xhtml:body>
  </info>
</widget>
```

Namespace map: for each element, maps prefixes to URIs
XPATH
XPath is:

- A flexible notation for navigating in trees
- Widely used as a basic component in many XML-related standards:
  - XML Schema: uniqueness and scope
  - XSLT & XQuery: pattern matching, selection and value computation
  - XLink & XPointer: document relationships

XPath has multiple versions:

- version 1.0 (limited to location paths)
- version 2.0 (focus of this lecture)
- version 3.0 (small changes w.r.t 2.0, standardized in 2014)
- version 3.1 (towards support for JSON, standardized in 2017)
The basic building block of XPath expressions is the location path, which consists of a sequence of location steps separated by ./.

Example location path:

descendant::C / child::E[attribute::id]/ child::F
Definition

The basic building block of XPath expressions is the location path, which consists of a sequence of location steps separated by /.

Example location path:

\texttt{descendant::C / child::E\{attribute::id\} / child::F}
Basic Syntax

**Definition**

A location step consists of

- an axis
- a nodetest
- (optionally) some predicates

with the following general syntax

\[
axis :: nodetest \[ exp1 \] \[ exp2 \] \ldots
\]

**Examples:**

- child::rcp:ingredient
- child::rcp:recipe[attribute::id='117']
- attribute::amount
EVALUATING A LOCATION PATH

- Semantically, each step maps a context node into a sequence.
- This is easily extended to map sequences of nodes to sequences of nodes:
  - each node in the input sequence serves as a context node.
  - and is replaced with the result of applying the step.
- The path then applies each step in return.
EVALUATING A LOCATION PATH

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Example:

Start with context node.
- Semantically, each step maps a context node into a sequence.
- This is easily extended to map sequences of nodes to sequences of nodes:
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Example:

descendant::C
EVALUATING A LOCATION PATH

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Example:

descendant::C/child::E
EVALUATING A LOCATION PATH

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Example:

descendant::C/child::E/child::F
EVALUATING A LOCATION PATH

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- This is easily extended to map sequences of nodes to sequences of nodes
  - each node in the input sequence serves as a context node
  - and is replaced with the result of applying the step
- The path then applies each step in return

Example:

descendant::C/child::E/child::F
EVALUATING A SINGLE LOCATION STEP (1)

Definition

- The input to a location step consists of (1) the tree representation of an XML document and (2) a context
- The output of a location step is a sequence of nodes

```
A
   /
  /  \
B   B
 /    /
C   C
 / 
E   F
 /  /
F   F
    /
    n1
    /
    /
    n2
```

```
descendant::E
(n1, n2, n3, n4)
```
EVALUATING A SINGLE LOCATION STEP (2)

**Definition**

The **context** of an XPath expression consists of 6 components:

- a **context node** (a node in the XML tree)
- a context **position** and **size** (two natural numbers)
- a set of **variable bindings**
- a **function library** (depends on the implementation)
- a set of **namespace declarations** (mapping prefixes to namespace URIs)

- The application determines the initial context
- If the path starts with ‘/’ then
  - the initial context node is the root
  - the initial position and size are 1
To evaluate \textit{axis} :: \textit{nodetest} [ \textit{exp1} ] [ \textit{exp2} ]:

1. Evaluate\textit{ axis}
2. Filter by \textit{node test}
3. Filter by \textit{predicates}

\textit{input tree + context}
\hline
\textit{sequence of nodes}
\hline
\textit{sequence of nodes}
\hline
\textit{sequence of nodes}
**The order of nodes in the resulting sequence**

**Definition**

- The **document order** of an XML tree is the order in which node \( m \) occurs before node \( n \) if the open tag of \( m \) occurs before the open tag of \( n \) in the corresponding text representation.

- The result of a location step and path is always sorted in **document order**, with duplicate nodes removed.

```
  A
  /\    \\
 /   \   /\    \
B    B  C  D
 |   /\  |
C   C  E  D
  |   /\  |
  F   F  E  F
   |     |
 n1  n2  n3  n4
     /\     /
    F   F  E  F
         |     |
          F
```

\[
\text{descendant::E} \rightarrow (n_1, n_2, n_3, n_4)
\]
Remember:

- An axis is evaluated relative to the context node
- And evaluates to a sequence of nodes

XPath supports 12 different axes

- child
- descendant
- parent
- ancestor
- following-sibling
- preceding-sibling
- attribute
- following
- preceding
- self
- descendant-or-self
- ancestor-or-self
Selects the unique parent node of the context node.
 Returns the empty sequence if the context node is the root.
EVALUATING THE AXIS (2): THE CHILD AXIS

- Selects all children **excluding attributes**
The transitive closure of the child axis. Selects all descendants excluding attributes.

The descendant-or-self axis returns the concatenation of the self and descendant sequences.
The transitive closure of the parent axis. All ancestors of the context node, from parent to the root element node.

The **ancestor-or-self** axis returns the concatenation of the **self** and **ancestor** sequences.
• Returns the right-hand siblings of the context node excluding attributes. It returns the empty sequence if the context node is an attribute.
EVALUATING THE AXIS (6): THE PRECEDING-SIBLING AXIS

- Returns the left-hand siblings of the context node, excluding attributes. It returns the empty sequence if the context node is an attribute.
EVALUATING THE AXIS (7): THE FOLLOWING AXIS

- Returns all nodes appearing strictly later in document order, but excluding descendants and attribute nodes.
• Returns all nodes appearing strictly earlier in document order, but excluding ancestors and attribute nodes.
To evaluate \textit{axis :: nodetest} \[ \text{exp1} \] \[ \text{exp2} \]:

1. Evaluate axis
2. Filter by node test
3. Filter by predicates

\textit{sequence of nodes}
The node test in a location path takes as input the sequence computed by the location step, and further selects from this sequence all nodes that satisfy the test.

In particular

- `text()` selects all text nodes in the sequence
- `comment()` selects all comment nodes
- `processing-instruction()` selects all processing instruction nodes
- `node()` selects all nodes
- `*` selects all element nodes, except when it is used after an `attribute` axis, in which case it selects all attribute nodes
- `name` selects all nodes with the given name (must be a Qualified Name, or QName for short). Text nodes do not have a name!
- `*:localname` selects the nodes with the given name in any namespace
- `prefix:*` selects nodes as *, but only those in the given namespace.
What does location step child::hi select in the following document when evaluated from the root?

```xml
<bla>
  <hi/> hi
</bla>
```
To evaluate $\text{axis :: nodetest [ exp1 ][ exp2 ]}$:

1. Evaluate axis
2. Filter by node test
3. Filter by predicates
The **predicates** in a location path take as input the sequence computed by the node test. For each node in that sequence, the predicate is evaluated (using the current node as context node). The result is coerced into a boolean:

- a number yields **true** if it equals the context position
- a string yields **true** if it is nonempty
- a sequence yields **true** if it is nonempty

All nodes that returned **true** are kept, the rest is discarded.

A predicate can be any XPath expression (see later), it need not be a location step

**Examples**

- /descendant::recipe[descendant::ingredient]
- /descendant::ingredient[attribute::name='sugar']
- /descendant::recipe[descendant::ingredient[attribute::name='sugar']]
- /descendant::recipe[4]
- /descendant::recipe[position()=4][position()=1]
Each XPath axis has a direction

- A forward direction means that the input sequence is filtered in document order:
  - child, descendant, following-sibling, following, self, descendant-or-self

- A backward direction means that the input sequence is filtered in reverse document order:
  - parent, ancestor, preceding-sibling, preceding

- Attribute nodes are considered to be unordered. Therefore, the order in which the nodes in the sequence resulting from the attribute axis are filtered is implementation-dependent, but stable.

Example:

- `child::node()[position()=2]` returns the second child
- `ancestor::node()[position()=2]` returns the grand-parent (the parent has position 1, the grand-parent position 2, and so on ...)
XPath has an abbreviated syntax

- Child is the default axis, so /child::rcp:recipe is equivalent to /rcp:recipe
- The attribute axis may be replaced by the @ character
- The fragment descendant-or-self::node() may be replaced by //
- The fragment self::node() may be replaced by .
- The fragment parent::node() may be replaced by ..

What is the unabbreviated syntax for the following expression?

```
//rcp:nutrition[@calories=349]/..//rcp:title/text()
```
XPath has an abbreviated syntax

- Child is the default axis, so `/child::rcp:recipe` is equivalent to `/rcp:recipe`
- The `attribute` axis may be replaced by the `@` character
- The fragment `descendant-or-self::node()` may be replaced by `//`
- The fragment `self::node()` may be replaced by `.`
- The fragment `parent::node()` may be replaced by `..`

What is the unabbreviated syntax for the following expression?

`//rcp:nutrition[@calories=349]/..//rcp:title/text()`
A general XPath expression evaluates to a sequence of items, where each item is either an node or an atomic value

Atomic values may be:
- numbers
- booleans
- Unicode strings
- or one of the other datatypes defined in XML Schema (see later)

And we already know that each node has an identity
Examples:

- 42
- 3.1415
- 6.022E13
- 'XPath is a lot of fun'
- "XPath is a lot of fun"
- 'The cat said "Meow!"
- "The cat said ""Meow!""
- "XPath is just so much fun"
General Expressions: Arithmetic Expressions

Examples:
- $42 + 34$
- $42 - 34$
- $3.1415 \times 5$
- $3.1415 \text{ div } 5$
- $42 \text{ idiv } 34$
- $42 \text{ mod } 3$

Operators are generalized to sequences

- If any argument is empty, the result is empty
- If all argument are singleton sequences of numbers, the operation is performed
- Otherwise, a runtime error occurs
Examples:

- $foo
- $bar:foo

Variables are set in the context

- Can be set by the application before running the XPath expression (input variables)
- But variables can also be bound by the XPath for-expression (see later)

Careful!

- $foo-17 refers to the variable “foo-17”
- To subtract 17 from the value of variable “foo”, we write ($foo)-17, $foo-17, or $foo+-17
Operators are generalized to sequences

- The ',' operator concatenates sequences
- Integer ranges are constructed with 'to'
- Sequences containing only nodes can be combined using the set operators union, intersect, except. The result is always sorted in document order, and duplicate-free.
- Sequences are always flattened

The following expressions all give the same result:

- (1, (2,3,4), ((5)), (), (((6,7)), 8,9))
- 1 to 9
- 1,2,3,4,5,6,7,8,9
GENERAL EXPRESSIONS: FUNCTIONS

- XPath has an extensive function library
- Default namespace for functions: http://www.w3.org/2006/xpath-functions
- 106 functions are required
- More functions with the namespace: http://www.w3.org/2001/XMLSchema
- See book for pages 78-81 for useful standard functions

Example
- calling a function with 4 arguments: \textbf{fn:avg}(1,2,3,4)
- calling a function with 1 argument: \textbf{fn:avg}((1,2,3,4))
Location Paths are expressions

- They may start from arbitrary sequences that contain only nodes
  - evaluate the path for each node in the sequence
  - using the current node as context node
  - context position and size are taken from the sequence
  - the results are combined in document order

Example:

- `(fn:doc("veggie.xml"), fn:doc("bbq.xml"))/rcp:title`

(For multiple documents, the document order between nodes in different documents is implementation-dependent, but stable).
• Predicates are generalized to arbitrary sequences
• The expression ‘.’ is the context item

Example (what is the result?):
• \((10 \text{ to } 40)[. \mod 5 = 0 \text{ and position()} > 20]\)
GENERAL EXPRESSIONS: VALUE COMPARISON

- Operators \texttt{eq}, \texttt{ne}, \texttt{lt}, \texttt{le}, \texttt{gt}, \texttt{ge}
- Used on atomic values
- when applied to an arbitrary values:
  - atomize
  - if either argument is empty, the result is empty
  - if either has length $> 1$, raise runtime error (error in book)
  - if incomparable (e.g. string comparison with float), raise runtime error
  - otherwise, compare the two atomic values

Examples:
- \texttt{8 eq 4+4}
- \texttt{(/rcp:ingredient)[1]/@name eq "beef cube steak"}
**Definition**

*Atomization* is the process of transforming an *arbitrary* sequence into a sequence of atomic values.

- Each node is replaced by its atomized value
- For element nodes, the atomized value is the concatenation of the content of all descendant text nodes (in document order)
- For other nodes, the atomized value is the obvious string
GENERAL EXPRESSIONS: GENERALIZED COMPARISON

- Operators =, !=, <, <=, >, >=
- Used on arbitrary values:
  - atomize
  - if either argument is empty, the result is empty
  - if there exists two atomic values, one from each atomized argument, whose comparison holds, the result is true
  - otherwise, the result is false
- So, this is an existential semantics!

Examples:
- 8 = 4+4
- (1,2) = (2,4)
- //rcp:ingredient/@name = "salt"
• Operators **is**, «, »,

• Used to compare nodes on *identity* and *document order*

• When applied to **arbitrary values**:
  - if either argument is empty, the result is empty
  - if both are singleton nodes, the nodes are compared
  - otherwise, a runtime error is raised

**Examples:**

• `((//rcp:recipe)[2] is //rcp:recipe[rcp:title eq "Ricotta Pie"]`

• `/rcp:collection « (//rcp:recipe)[4]`

• `((//rcp:recipe)[4] » (//rcp:recipe)[3]`
What is the result of the following comparisons?

- (((//rcp:ingredient)[40]/@name, //(rcp:ingredient)[40]/@amount) eq ((//rcp:ingredient)[53]/@name, //(rcp:ingredient)[53]/@amount))

- (((//rcp:ingredient)[40]/@name, //(rcp:ingredient)[40]/@amount) = ((//rcp:ingredient)[53]/@name, //(rcp:ingredient)[53]/@amount))

- (((//rcp:ingredient)[40]/@name, //(rcp:ingredient)[40]/@amount) is ((//rcp:ingredient)[53]/@name, //(rcp:ingredient)[53]/@amount))
XPath violates most algebraic laws of equality

- Reflexivity:
  
  \( () = () \) yields \text{false} 

- Transitivity:

  \( (1,2) = (2,3) \) and \( (2,3) = (3,4) \), but not \( (1,2) = (3,4) \)

- Anti-symmetry:

  \( (1,4) \leq (2,3) \) and \( (2,3) \leq (1,4) \) but not \( (1,2) = (3,4) \)

- Negation:

  both \( (1) \neq () \) and \( (1) = () \) yield \text{false}
Operators **and**, **or**, **not**,  
Arguments are interpreted as **false** if  
- the boolean false  
- the empty sequence  
- the empty string  
- the number zero  
Constants using functions **true()** and **false()**

Example:  
- \((//rcp:recipe)\) and \(//ingredient[4]/@quantity\)
GENERAL EXPRESSIONS: FOR EXPRESSIONS

General form for $var in expr_1 return expr_2

- evaluates $expr_1$ to a sequence
- for each item in that sequence evaluate $expr_2$ with $var$ bound to the current item
- concatenates the resulting sequences

Examples:
- for $r$ in //rcp:recipe return fn:count($r//rcp:ingredient[fn:not(rcp:ingredient)])
- for $i$ in (1 to 5)
  for $j$ in (1 to $i$)
    return $j
Example:

```
fn:avg(
  for $r in //rcp:ingredient return
    if ( $r/@unit = "cup" )
      then xs:double($r/@amount) * 237
    else if ( $r/@unit = "teaspoon" )
      then xs:double($r/@amount) * 5
    else if ( $r/@unit = "tablespoon" )
      then xs:double($r/@amount) * 15
    else ()
  )
```
Example:
- some $r$ in //rcp:ingredient satisfies $r/@name$ eq "sugar"
- every $r$ in //rcp:recipe satisfies $r/@name$ neq "cake"
Many implementations only support XPath 1.0

- Smaller function library
- Implicit casts of values
- Some expressions change semantics:
  
  "4" < "4.0"

  is false in XPath 1.0 but true in XPath 2.0
New features in XPath 3.0 include:

- String concatenation operator `||`
- Simple mapping operator `!`. \( E_1 \! E_2 \) is similar to \( E_1/E_2 \) except that:
  - \( E_1 \) can return an arbitrary sequence, not necessarily a sequence of nodes
  - \( E_1 \) is evaluated to a sequence. For every item in that sequence \( E_2 \) is evaluated with the current item as context item.
  - Results are concatenated, but there is no duplicate elimination, nor sorting after the concatenation.

- Higher-order functions: functions are valid items; anonymous functions can be defined and called dynamically.
- Let binding.

Examples:

- `'ab' || 'def' = 'abdef'`
- `let $x := doc('a.xml')/*/,$y := $x//,*
  return $y[@value gt $x/@min]`
XPath 3.1 extends the XPath Data Model

- **Value** in xpath 3.1 is a sequence of 0 or more items, where every item is an atomic value, a node, a map, an array, or a function.
- **Maps** are dictionaries from keys to values.
  - Keys must be atomic values.
  - Duplicate keys are not allowed.
- **Arrays** are ordered collections of items (like sequences), but an array can include as element a sequence (which a sequence cannot).
- New expressions to create and manipulate maps and arrays.
- This allows to also load json.

Create a map with 3 entries:

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Maps can be nested:

- map { "book" : map { "author" : ["J. Doe", "X. Brown"], "title" : "The X"} }
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**Maps lookup**
- $x("book")$
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- New expressions to create and manipulate maps and arrays.
- This allows to also load **json**.

### Array creation

- Array with three members: `[1, 2, "book"]`
- Array with two members, both sequences: `[(), (27, 17, 0)]`
- Array with two members, the second being a sequence: `[1, $x//recipe]`
- Curly array constructor creates flat arrays: `array {1, $x//recipe}`
JSON
JSON = JavaScript Object Notation

- A syntactical fragment of JavaScript (aka EcmaScript) for describing data
- Libraries for reading & writing JSON exist for virtually every programming language
- Widely used with JavaScript & AJAX

Example:

```json
{
  "company": {
    "name": "WIND solutions",
    "symbol": "WIND"
  },
  "reportData": [
    {
      "year": 2011,
      "profit": 2000000
    },
    {
      "year": 2010,
      "deficit": 1000
    }
  ],
  "author": "John Doe"
}
```
JSON can represent four primitive types (strings, numbers, booleans, and null) and two structured types (objects and arrays).

- A **value** is a string, number, boolean, null, object, or array.

**Number primitive type**

- A **number** is any integer or fractional number like in most programming languages.

**Example:**

<table>
<thead>
<tr>
<th>10</th>
<th>-12.34</th>
<th>10e5</th>
<th>+3.141516</th>
</tr>
</thead>
</table>
• JSON can represent four primitive types (strings, numbers, booleans, and null) and two structured types (objects and arrays).

• A value is a string, number, boolean, null, object, or array.

String primitive type

• A string is a sequence of zero or more unicode characters.

• String literals are delimited by double quotes. The C-style escape characters (\”, \n, \t, …) apply.

Example:

"This is a string literal\nThis continues on a new line"
JSON can represent four primitive types (strings, numbers, booleans, and null) and two structured types (objects and arrays).

- A **value** is a string, number, boolean, null, object, or array.

### Boolean primitive types
- A **boolean** is either the literal true or false
JSON IN A NUTSHELL

- JSON can represent four primitive types (strings, numbers, booleans, and null) and two structured types (objects and arrays).
- A **value** is a string, number, boolean, null, object, or array.

Object structured type

- An **object** is an unordered collection of zero or more **name**/value pairs, where a **name** is a string and a **value** is a string, number, boolean, null, object, or array.
- Objects are delimited by curly braces; within the same object, each name must be unique.

Example:

```json
{
  "company": {
    "name": "WIND solutions",
    "symbol": "WIND"
  },
  "reportData": [
    {
      "year": 2011,
      "profit": 2000000
    },
    {
      "year": 2010,
      "deficit": 1000
    }
  ],
  "author": "John Doe"
}
```
JSON IN A NUTSHELL

- JSON can represent four primitive types (strings, numbers, booleans, and null) and two structured types (objects and arrays).
- A value is a string, number, boolean, null, object, or array.

Array structured type
- An array is an ordered sequence of zero or more values.
- Arrays are delimited by square brackets.

Example:

```json
[
  {
    "year": 2011,
    "profit": 2000000
  },
  {
    "year": 2010,
    "deficit": 1000
  }
]
```