XPath
(and XQuery)

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Models of XML processing

- Text level processing
  - possible but inconvenient and error-prone
- Custom applications using standardised API (DOM, SAX, JAXB, etc.)
  - flexible and (relatively) efficient
  - requires some work
- XML-related standards with high-level view on documents
  - XPath, XQuery, XSLT
  - XML-oriented and (usually) more convenient than above
  - sometimes not flexible enough
- “Off the shelf” tools and solutions

XPath and XQuery
Querying XML documents

- Common properties
  - Expression languages designed to query XML documents
  - Convenient access to document nodes
  - Intuitive syntax analogous to filesystem paths
  - Comparison and arithmetic operators, functions, etc

XPath

- Used within other standards:
  - XSLT
  - XML Schema
  - XPointer
  - DOM

XQuery

- Standalone standard
- Extension of XPath
- Main applications:
  - XML data access and processing
  - XML databases

XPath – status

- XPath 1.0
  - W3C Recommendation, XI 1999
  - used within XSLT 1.0, XML Schema, XPointer
- XPath 2.0
  - Several W3C Recommendations, I 2007:
    - XML Path Language (XPath) 2.0
    - XQuery 1.0 and XPath 2.0 Data Model
    - XQuery 1.0 and XPath 2.0 Functions and Operators
    - XQuery 1.0 and XPath 2.0 Formal Semantics
  - Used within XSLT 2.0
  - Related to XQuery 1.0

Versions

- Subsequent generations of related standards.

When	**XPath**	**XSLT**	**XQuery**
1999	1.0	1.0	-
2007	2.0	2.0	1.0
WD	3.0	3.0	3.0

Paths – typical XPath application

- /company/department/person
- //person
- /company/department[name = 'accountancy']
- /company/department[@id = 'D07']/person[3]
- ./surname
- surname
- ../person[position = 'manager']/surname

But there is much more to learn here...

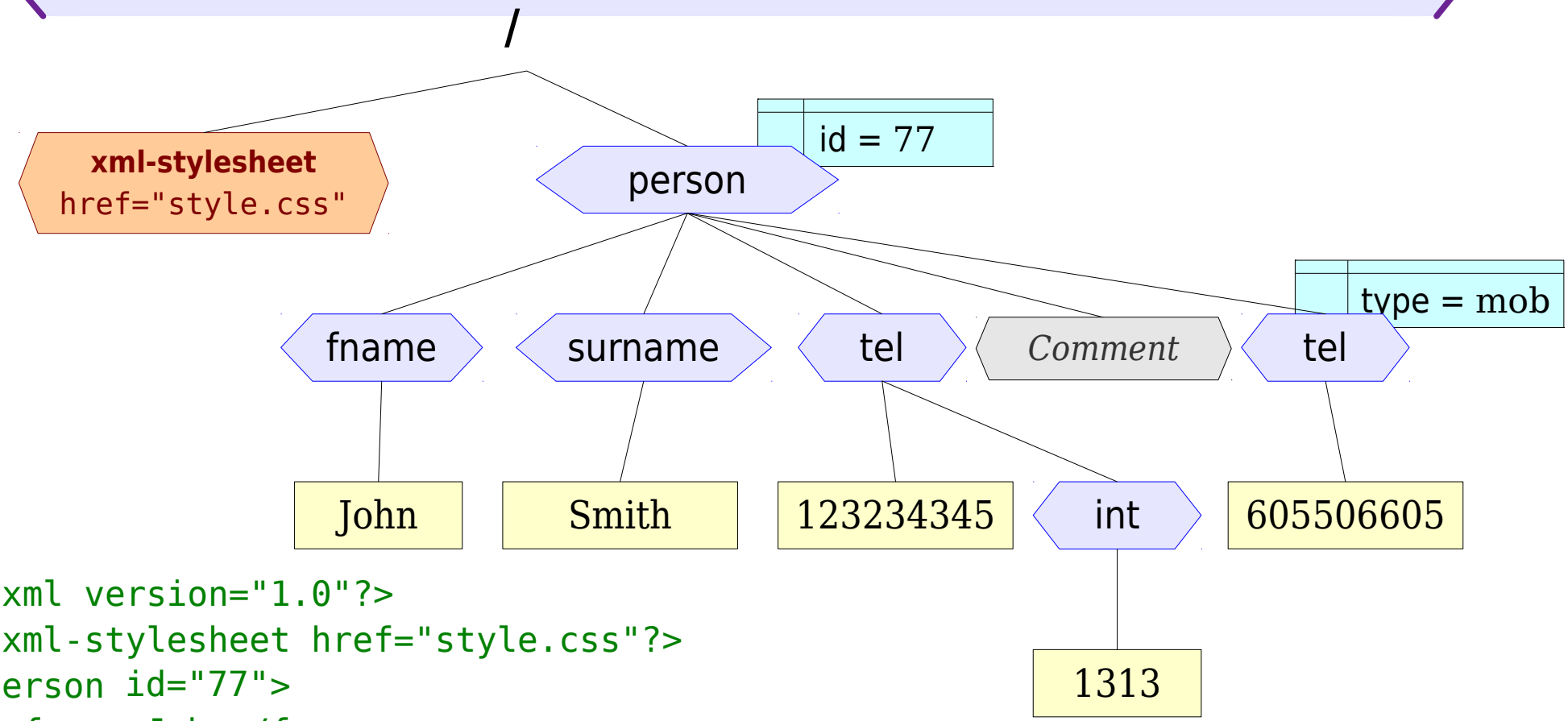
XPath (and XQuery) Data Model

- Theoretical base of XPath, XSLT, and XQuery
- XML document tree
- Structures and simple data types
- Basic operations (type conversions etc.)
- Model different in different versions of XPath
  - 1.0 – 4 value types, sets of nodes
  - 2.0 – XML Schema types, sequences of nodes and other values

XML document in XPath model

- Document as a tree
- Physical representation level fully expanded
  - CDATA, references to characters and entities
  - No adjacent text nodes
- Namespaces resolved and accessible
- XML Schema applied and accessible
  - XPath 2.0 “schema aware” processors only
- Attribute nodes as element “properties”
  - formally, attribute is not child of element
  - however, element is parent of its attributes
- Root of tree – document node
  - main element (aka *document element*) is not the root

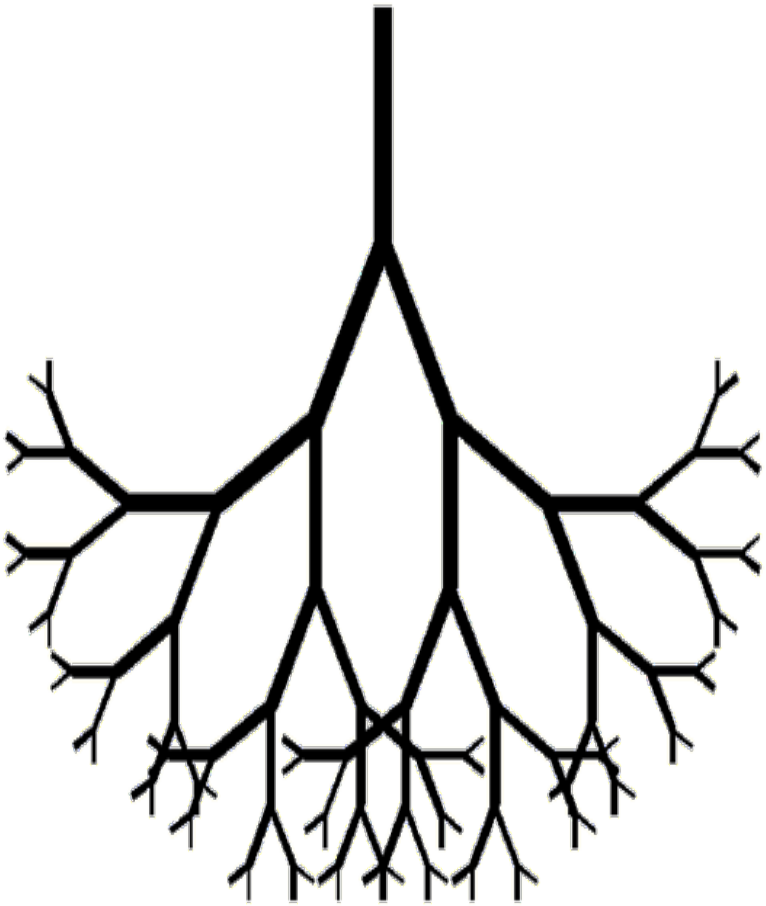
Document tree – example




```
<?xml version="1.0"?>
<?xml-stylesheet href="style.css"?>
<person id="77">
  <fname>John</fname>
  <surname>Smith</surname>
  <tel>123234345<int>1313</int></tel>
  <!-- Comment -->
  <tel type="mob">605506605</tel>
</person>
```

XPath node kinds

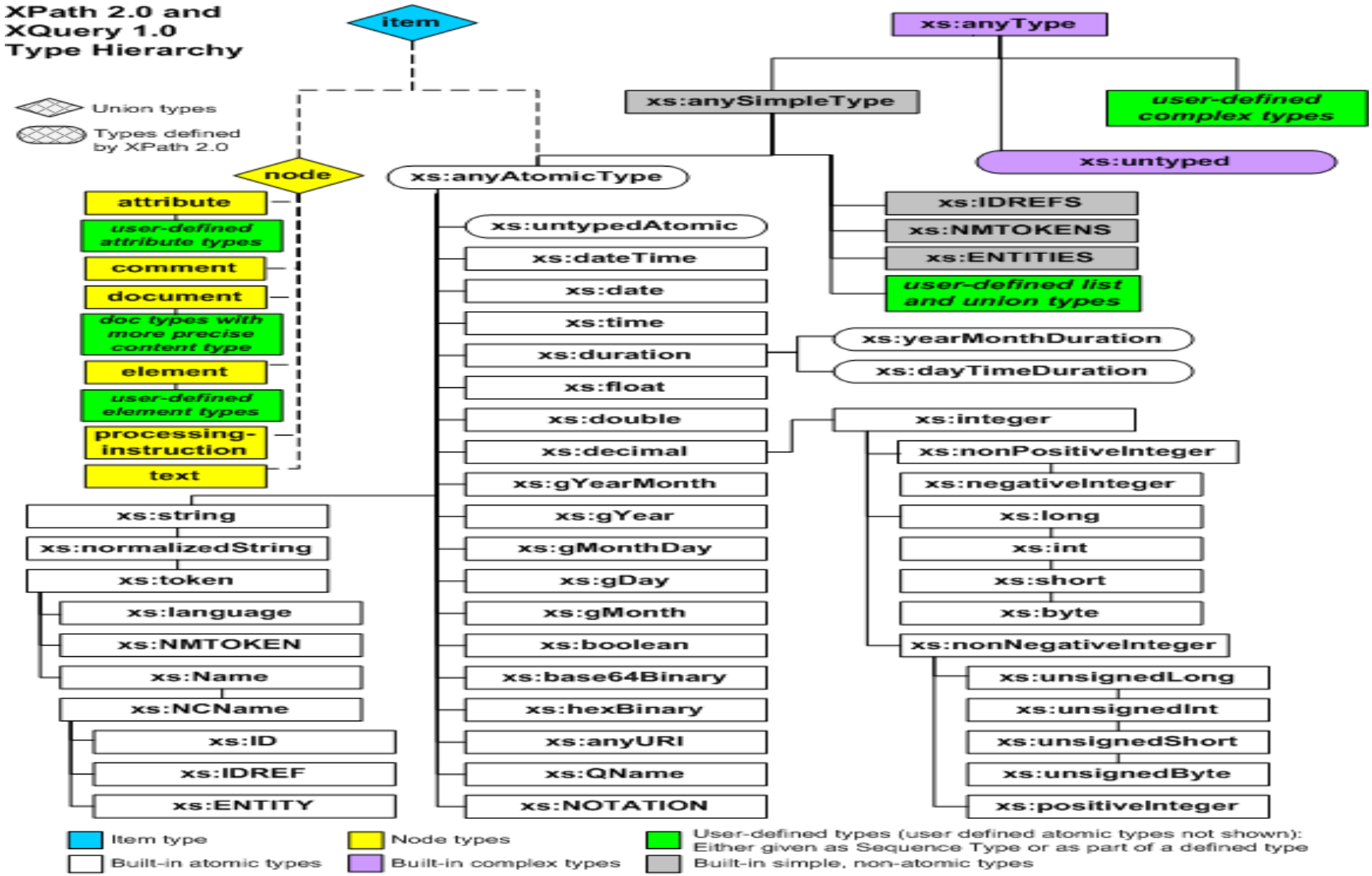
- Seven kinds of nodes:
  - document node (root)
  - element
  - attribute
  - text node
  - processing instruction
  - comment
  - namespace node
- Missing ones
  (e.g. when compared to DOM):
  - CDATA
  - entity
  - entity reference



Sequences

- Values in XPath 2.0 – sequences
- Sequence consists of zero or more items
  - nodes
  - atomic values
- Sequences properties
  - Items order and number of occurrence meaningful
  - Singleton sequence equivalent to its item
    3.14 = (3.14)
  - Nested sequences implicitly flattened to canonical representation:
    (3.14, (1, 2, 3), 'Ala') = (3.14, 1, 2, 3, 'Ala')

Type system



http://www.w3.org/TR/xpath-datamodel/#types-hierarchy

Data model in XPath 1.0

- Four types:
  - `boolean`
  - `string`
  - `number`
  - `node set`
- No collections of simple values
- Sets (and not sequences) of nodes

Effective Boolean Value

- Treating any value as boolean
- Motivation: convenience in condition writing, e.g. `if (customer[@passport]) then`
- Conversion rules
  - empty sequence → false
  - sequence starting with a node → true
  - single boolean value → that value
  - single empty string → false
  - single non-empty string → true
  - single number equal to 0 or NaN → false
  - other single number → true
  - other value → error

Atomization

- Treating any sequence as a sequence of atomic values
  - often with an intention to get a singleton sequence
- Motivation: comparison, arithmetic, type casting

Conversion rules (for each item)

- atomic value → that value
- node of declared atomic type → node value
- node of list type → sequence of list elements
- node of unknown simple type or one of xs:untypedAtomic, xs:anySimpleType → text content as single item
- node with mixed content → text content as single item
- node with element content → error

Literals and variables

Literals

- strings:
  - `'12.5'`
  - `"He said, ""I don't like it."""`
- numbers:
  - `12`
  - `12.5`
  - `1.13e-8`

Variables

- `$x` – reference to variable x
- Variables introduced with:
  - XPath 2.0 constructs (`for`, `some`, `every`)
  - XQuery (FLWOR, `some`, `every`, function parameters)
  - XSLT 1.0 and 2.0 (`variable`, `param`)

Type casting

Type constructors

- `xs:date("2010-08-25")`
- `xs:float("NaN")`
- `adresy:kod-pocztowy("48-200")`
  (schema aware processing)
- `string(//obiekt[4])` (valid in XPath 1.0 too)

Cast operator

- `"2010-08-25" cast as xs:date`

Functions

- Function invocation:
  - `concat('Mrs ', name, ' ', surname)`
  - `count(//person)`
  - `my:factorial(12)`
- 150 built-in functions in XPath 2.0, 27 in XPath 1.0
- Abilities to define custom functions
  - XQuery
  - XSLT 2.0
  - execution environment
  - EXSLT – de-facto standard of additional XPath functions and extension mechanism for XSLT 1.0

Chosen built-in XPath functions

- Text:

  `concat(s1, s2, ...)` `substring(s, pos, len)`

  `starts-with(s1, s2)` `contains(s1, s2)`

  `string-length(s)` `translate(s, t1, t2)`

- Numbers:

  `floor(x)` `ceiling(x)` `round(x)`

- Nodes:

  `name(n?)` `local-name(n?)` `namespace-uri(n?)`

- Sequences (*some only in XPath 2.0*):

  `count(S)` `sum(S)` *`min(S)`* *`max(S)`* *`avg(S)`*
  `empty(S)` *`reverse(S)`* *`distinct-values(S)`*

- Context:

  `current()` `position()` `last()`

Operators

- Arithmetic
  - `+ - * div idiv mod`
  - `+ -` also on date/time and duration
- Logical values
  - `and or`
    - true(), false(), and not() are functions
- Node sets / sequences
  - `union | intersect except`
  - not nodes found – type error
  - result without repeats, document order preserved
- Nodes
  - `is << >>`

Comparison operators

- Atomic comparison (XPath 2.0 only)
  - `eq  ne  lt  le  gt  ge`
  - applied to singletons
- General comparison (XPath 1.0 and 2.0)
  - `=  !=  <  <=  >  >=`
  - applied to sequences
  - XPath 2.0 semantics:
    There exists a pair of items, one from each argument sequence, for which the corresponding atomic comparison holds. (Argument sequences atomized on entry.)

Typical usage

```
books/price > 100
```

"At least one of the books has price greater than 100"

General comparison – nonobvious behaviour

- Equality operator does not check the real equality
  - `(1,2) != (1,2)` → true
  - `(1,2) = (2,3)` → true
- "Equality" is not transitive
  - `(1,2) = (2,3)` → true
  - `(2,3) = (3,4)` → true
  - `(1,2) = (3,4)` → false
- Inequality is not just equality negation
  - `(1,2) = (1,2)` → true
  - `(1,2) != (1,2)` → true
  - `() = ()` → false
  - `() != ()` → false

Conditional expression (XPath 2.0)

- `if (`*`CONDITION`*`)`
  `then` *`RESULT1`* `else` *`RESULT2`*
- Using Effective Boolean Value of *CONDITION*
- One branch computed

Example

```
if(details/price)
then
  if(details/price >= 1000)
  then 'Insured mail'
  else 'Ordinary mail'
else 'No data'
```

Iteration through sequence (XPath 2.0)

- `for $VAR in SEQUENCE`
  `return RESULT`
  - *VAR* assigned subsequent values from *SEQUENCE*
  - *RESULT* computer in context where *VAR* is assigned current value
  - overall result – (flattened) sequence of subsequent partial results

Example

```
for $i in (1 to 10)
  return $i * $i

for $o in //obiekt
  return concat('Nazwa obiektu:', $o/@nazwa)
```

Sequence quantifiers (XPath 2.0)

- `some $VAR in SEQUENCE`
  `satisfies CONDITION`
- `every $VAR in SEQUENCE`
  `satisfies CONDITION`
  - Using Effective Boolean Value of *CONDITION*
  - Lazy evaluation allowed
  - Evaluation order not specified

Example

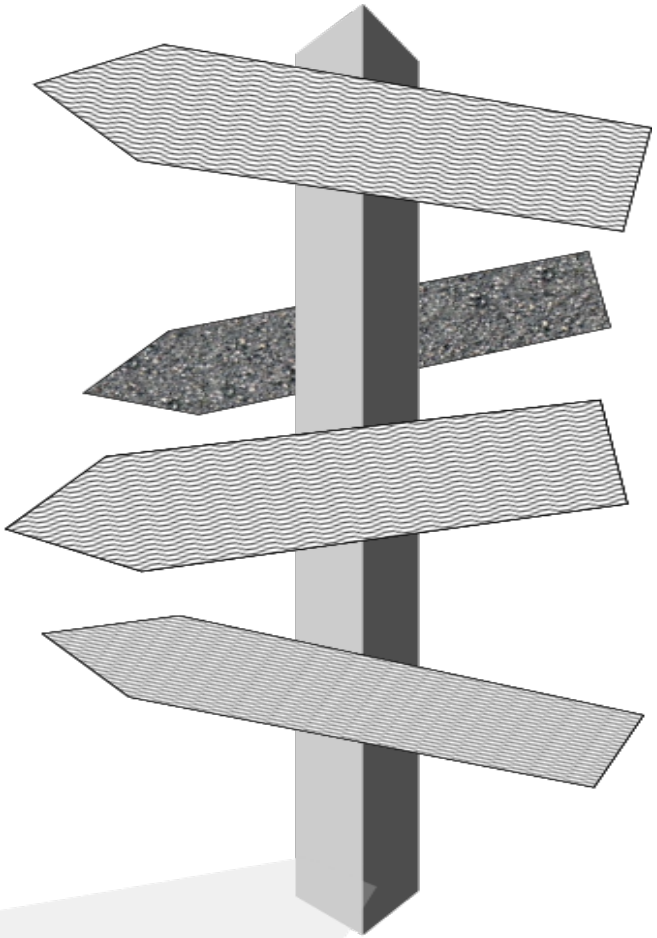
```
some $i in (1 to 10)  satisfies $i > 7
every $p in //person  satisfies $p/surname
```

Paths – more formally

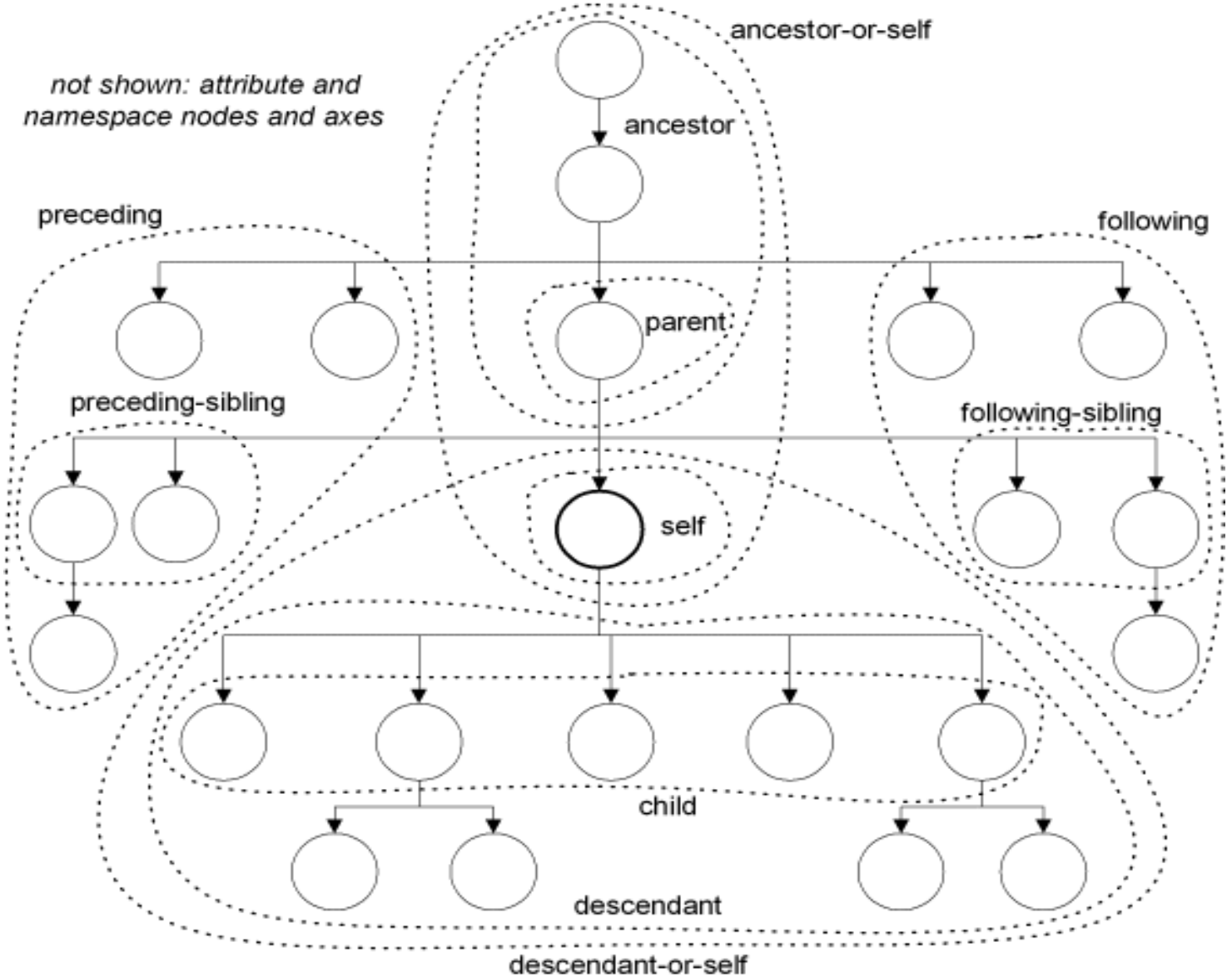
- Absolute path: /step/step ...
- Relative path: step/step ...
- Step – full syntax:
  axis::node-set [predicate1] [predicate2] ...
  - **axis** – direction in document tree
  - **node-test** – selecting nodes by kind, name, or type
  - **predicate**s – (0 or more) additional logical conditions for filtering

Axis

- self
- child
- descendant
- parent
- ancestor
- following-sibling
- preceding-sibling
- following
- preceding
- attribute
- namespace
- descendant-or-self
- ancestor-or-self



Axis



src: www.GeorgeHernandez.com

Node test

- By kind of node:
  - `node()`
  - `text()`
  - `comment()`
  - `processing-instruction()`
- By name (examples):
  - `person`
  - `pre:person`
  - `pre:*`
  - `*:person` (XPath 2.0 only)
  - `*`
  - kind of node here: element or attribute, depending on axis

Node test in XPath 2.0

- In XPath 2.0 more tests, basing on kinds of nodes, and schema-provided types of nodes (“schema aware” only). Examples:
  - `document-node()`
  - `processing-instruction(xml-stylesheet)`
  - `element()`
  - `element(person)`
  - `element(*, personType)`
  - `element(person, personType)`
  - `attribute()`
  - `attribute(id)`
  - `attribute(*, xs:integer)`
  - `attribute(id, xs:integer)`

Predicates

- Evaluated for each node selected so far (node becomes the context node)
- Every predicate filters result sequence
- Depending on result type:
  - number – compared to item position (counted from 1)
  - not number – Effective Boolean Value used
- Filter expressions – predicates outside paths (XSLT 2.0)

Examples

```
/child::staff/child::person[child::name = 'Patryk']

child::person[child::name = 'Patryk']/child::surname

//person[attribute::passport][3]

(1 to 10)[. mod 2 = 0]
```

Abbreviated Syntax

- `child` axis may be omitted
- `@` before name indicates attribute axis
- `.` equals self::node()
- `..` equals parent::node()
- `//` translated to `/descendant-or-self::node()/` (textually, inside an expression)

Example

```
.//object[@id = 'E4']
```

expands to

```
self::node()/descendant-or-self::node()/
                              child::object[attribute::id = 'E4']
```

Evaluation order

- From left to right
- Step by step
  - `//department/person[1]`
  - `(//department/person)[1]`
- Predicate by predicate
  - `//person[@manages and position() = 5]`
  - `//person[@manages][position() = 5]`

XQuery – **the** query language for XML

- Status
  - XQuery 1.0 – W3C Recommendation, I 2007
    - XQuery 3.0 – working draft, partially implemented e.g. in eXists DB
  - Data model, functions and ops – shared with XPath 2.0
  - Formally syntax defined separately
    - In practice: extension of XPath
- Main features
  - Picking up data from XML documents
  - Constructing new result nodes
  - Sorting, grouping
  - Custom functions definition
  - Various output methods (XML, HTML, XHTML, text)
    - shared with XSLT

XQuery – query structure

- (Unexpectledly) XQuery is not an XML application
  - There exists an XML syntax for XQuery
- Typical file extensions: .xquery, .xq, .xqm (for modules)
- Text format, header and body
  - header optional in normal queries
  - units declared as *modules* do not have body

Minimalistic example

```
2 + 2
```

XQuery headers

- Header part consists of declarations:
  - version declaration
  - import
  - flags and options
  - namespace declaration
  - global variable or query parameter
  - function

Example

```
xquery version "1.0" encoding "utf-8";
declare namespace foo = "http://example.org";
declare variable $id as xs:string external;
declare variable $doc := doc("example.xml");

$doc//foo:object[@id = $id]
```

FLWOR expression

- **F**or, **L**et, **W**here, **O**rder by, **R**eturn
- Replaces `for` from XPath
- Explicit influence of SQL SELECT

Example

```
for $obj in doc("example.xml")/list/object
let $prev := $obj/preceding-sibling::element()
let $prev-name := $prev[1]/@name
where $obj/@name
order by $obj/@name
return
    <div class="result">
      Object named xs:string($obj/@name)
      has count($prev) predecessors.
      The nearest predecessor name is
      xs:string($prev-name).
    </div>
```

Node constructors – direct

- XML document fragment within query

```
for $el in doc("example.xml")//* return

   <p style="color: blue">I have found an element.
     <?pi bla Bla ?>
     <!-- Comments and PIs also taken to result --!>
   </p>
```

- Expressions nested within constructors – braces

```
<result> {
for $el in doc("example.xml")//* return
   <elem depth="{count($el/ancestor::node())}">
      {name($el)}
    </elem>
} </result>
```

Node constructors – computed

- Syntax

```
for $el in doc("example.xml")//* return
   element p {
      attribute style {"color: blue"},
      text { "I have found an element."},
      processing-instruction pi { "bla Bla" }
      comment { "Comments and PIs also taken to result" }
   }
```

- Application example – dynamically computed name

```
<result> {
  for $el in doc("example.xml")//* return
    element {concat("elem-", name($el))} {
      attribute depth {count($el/ancestor::node())},
      text {name($el)}
}    }
</result>
```

Custom function definitions

- Simple example:

```
declare function local:factorial($n) {
   $n * local:factorial($n - 1)
};
```

- Example using type declarations:

```
declare function local:factorial($n as xs:integer)
    as xs:integer {
  $n * local:factorial($n - 1)
};
```

Type constraints

- Type declarations possible (but not obligatory) for:
  - variables
  - function arguments and result
  - also in XSLT 2.0 (variables and parameters)
- Dynamic typing used in practical applications
  - `13 + if(makeMeFail) then 'not a valid number' else 1`
    may fail or not depending on input data
  - `some $x in (1+1, xs:date('long long time ago'))`
    `satisfies $x=2` fails nondeterministically
- Static typing discussed, but rarely deployed
  (“academic” solutions, for XQuery rather than XSLT)

Type declarations

- Capabilities:
  - type name
    - built-in – always available
    - user-defined – schema aware processors only
  - kind of node | `node()` | `item()`
  - occurrence modifier (`?`, `*`, `+`, exactly one occurrence by default).
- Examples:
  - `xs:double`
  - `element()`
  - `node()*`
  - `xs:integer?`
  - `item()+`

New features of XQuery 3.0

- On the next lecture...