Introduction to Schematron

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Introduction to Schematron

Exhibit

Appendix

Introduction to Schematron

slide 1

Administrivia

- Who are you?
- Who are we?
- Timing

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Schematron is a ...

- Way to test XML documents
- Rules-based validation language
- Way to specify and test statements about your XML document
  - elements
  - attributes
  - content
- Cool report generator

All of the above!

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Reasons to use Schematron

- Business/operating rules other constraint languages can't enforce
- Different requirements at different stages of the document lifecycle
- Local or temporary requirements (not in the base schema)
- Unusual (but not illegal) variations to manage
- No DTD or schema (but some need for consistency)
- Need *ad hoc* querying and discovery

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What Schematron is used for

A few use cases

- QA / Validation
  - run reports for checking by human agents
    (Display all figure `titles` and `captions` for cross-checking)
  - validate things schemas can't express
    (If `owner-type` attribute is "consultant",
    value must be either "Mulberry" or "Menteith",
    otherwise value is unconstrained)
  - find patterns in documents
    (Show me all the `authors` who have no `bio`)
- Check element values against a controlled vocabulary
  (could be maintained externally)
- Validate output of a program against its input (or the reverse)

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Schematron is an XML vocabulary

- A Schematron "program" is a well-formed XML document
- Elements in the vocabulary are "commands" in the language
- The program is called a "schema" (sadly)

(schema, specification, rule set, program, pattern set,
assertion set, potato, potahto)

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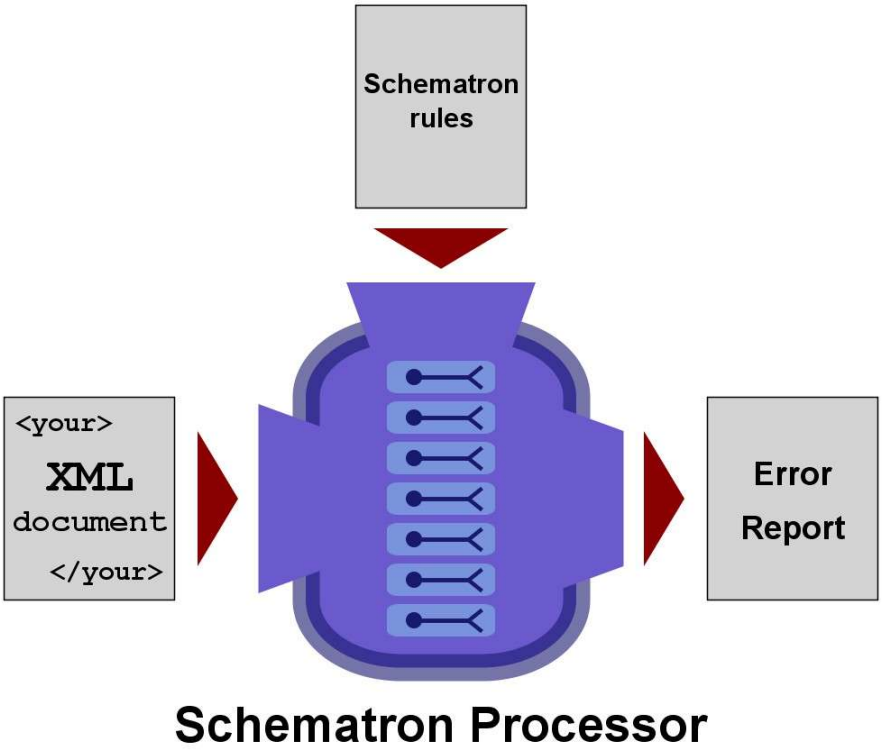
Schematron *specifies*, it does not *perform*

- A Schematron "schema" specifies tests to be made on your XML
- A set of *declarations* for a process
  ("test this; tell me that")
- A Schematron processor is necessary to make anything happen
  - reads and interprets your Schematron rules
  - applies the tests to your documents
  - reports back with any messages

Simple Schematron processing architecture

Easily scales up to accommodate more than one XML document, or more than one Schematron



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Schematron validation in action

(a short demonstration on real data)

- We have XML data borrowed from PubMed Central
  - journal articles
  - multiple source files
- We have a Schematron rule set
- We can show the messages generated

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Basic Schematron building blocks

- *Assertions* —
  - are to be tested
  - describe conditions you'd like to be told about
- *Messages* — you get them back when tests succeed or fail
- *Rules* — tests are collected into rules, which apply to particular XML elements (context)
- *Patterns* — Rules are grouped into families called patterns
- *Phases* — Activate different families at different times

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How Schematron works

A rule (a collection of constraints)

- Declare its context (where it applies; usually an element)
- *In that context*, performs a series of tests

(Programmer-speak, simplified version: For every element in the document described as the context of a rule, the rule's tests will be made with that element as context)

```
 1 <?xml version="1.0" encoding="utf-8" ?>
 2 <schema xmlns="http://purl.oclc.org/dsdl/schematron" >
 3 <title>Check Sections 12/07</title>
 4 <pattern id="section-check">
 5   <rule context="section">
 6     <assert test="title">This section has no title</assert>
 7     <assert test="para">This section has no paragraphs</assert>
 8   </rule>
 9 </pattern>
10 </schema>
```

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Outline of a simple Schematron rule set

```
schema
  title
  pattern+
    rule+
      (assert or report)+
```

`schema`	The document element (contains all others)
`title`	A descriptive human readable title
`pattern`	Set of related rules
`rule`	One or more assertions that apply *in a given context*
`assert`, `report`	Tests: Declare conditions to be tested (in their attributes) and provide messages to be returned (in their content)

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A simple demonstration XML document

(know your document structure!)

```
<dog>
 <flea/>
 <flea/>
 <bone/>
</dog>
```

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A simple Schematron rule set

```
<schema xmlns="http://purl.oclc.org/dsdl/schematron">

 <title>Dog testing 1</title>

 <pattern id="obedience-school">
   <rule context="dog">
      <assert test="bone">Give that dog a bone!</assert>
      <report test="flea">Your dog has fleas!</report>
  </rule>
 </pattern>

</schema>
```

We thank Roger Costello for the “dogs and fleas” example (which we will elaborate)

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This Schematron translated into English

- There is a pattern with one rule
- The rule contains two tests
  (We can have as many as we need)
- The rule applies to `dog` elements (that's the *context*)
- The rule for dogs is that each dog:
  - Must have at least one bone
    (In the context of a `dog`,
    a `bone` element must be present or
    the assertion fails and you get a message.)
  - May have a flea, but if so we want to know
    (In the context of a `dog`,
    if any `flea` elements are present,
    a report will be given

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When does a rule fire?

- Context determines when to try the tests
- `context` attribute on `<rule>` sets the context

`<rule context="dog">...</rule>`	For any `dog` element, do these tests
`<rule context="section">...</rule>`	For any `section` element, do these tests
`<rule context="html:body">...</rule>`	For any `html:body` element, do these tests

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Assertions and reports are tests

Tests are expressed in two forms:

- `<assert>`: *a statement about an expectation*
  - "a section must have a title"
    tell me if you don't find one

```
<rule context="section"
   <assert test="title">Section has no title.</assert>
</rule>
```

- `<report>`: *a circumstance of interest*
  - "notes might turn up inside notes (but that's bizarre)"
    tell me if you see one

```
<rule context="note">
  <report test="ancestor::note">A note appears
  inside a note</report>
</rule>
```

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`assert` and `report`

- In the Schematron specification are called (confusingly) *assertions*
  But they work oppositely
  - `<assert>` means tell me if it is *not* true
  - `<report>` means tell me if it *is* true

Mnemonic:
`report` means "ho hum, show me where this is true";
`assert` means "it better be true, or else!"

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Context and tests are stated in attributes

- A rules's `context` attribute **sets the context**
- The `test` attribute of an `assert` or `report` **expresses the test**

```
<rule context="dog">
  <assert test="bone">This dog has no bone.</assert>
</rule>

<rule context="note">
  <report test="ancestor::note">A note appears
   inside a note</report>
</rule>
```

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Just Enough XPath

XPath is the *query syntax* used for

- The `context` for `rules`*
  a *context* identifies a class of nodes (elements)
- the `tests` (for `assert` and `report`)*
- For example

```
<rule context="child::note">
   <report test="ancestor::note">A note appears inside a
    note</report>
</rule>
```

(In XPath, `child::note` is the same as plain `note`)

(*This could be done in another query language, but XPath is usual.)

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What is XPath?

- A language for addressing parts of an XML document
- A W3C Recommendation in 1999 (`http://www.w3.org/TR/xpath`)
- Named because it uses a path notation with slashes
  like UNIX directories and URLs

  ```
  invoice/customer/address/zipcode
  ```
- A lightweight query language
  ("Addressing" really means "querying")
  XPath expressions return data objects and values from XML documents
- Used by XQuery, XSLT, and XPointer (among others)
- Widely implemented in many languages
  (Perl, Python, Java, Javascript....)

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Faking it in XPath

- XPath to say *where* to test (*context*)
  - `<rule context="dog">...` applies to all elements named `dog`
  - `<rule context="chapter">...` applies to all the `chapter elements`
- XPath to say *what* to test
  - `test="bone"` is `true` if
    there is at least one `bone` element inside the given context
    (and `false` if no `bones`)
  - `test="flea"` is `true` if
    there is at least one `flea` element inside the context
    (and `false` if not)

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A (slightly) more complex example

The XML document:

```
<dog bark="11" bite="10">
  <bone/>
</dog>
```

(Test with `obedience-school/dogtest-2.sch`)

```
<schema xmlns="http://purl.oclc.org/dsdl/schematron">

 <title>Dog testing 2</title>

 <pattern id="obedience-school">
    <rule context="dog">
      <report test="@bark > @bite">
        This dog's bark is worse than his bite.
      </report>
    </rule>
 </pattern>

</schema>
```

- This time, the test compares the `bark` and `bite` *attributes*
- The > test compares two values, and is True if:
  - both are present
  - both are numbers
  - the first is greater than the second
- We get our message when the test is True (this is a `report`)

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Playing with dogs and bones

(a short demonstration)

Let's see how this works, with dogs and bones and fleas.

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Schematron context expressed in XPath

Value of `context` attribute on `<rule>` is an XPath expression

Rule with XPath Context	What the Context Means
`<rule context="figure">`	For any `figure` element
`<rule context="section/figure">`	For any `figure` whose parent is a `section`
`<rule context="section/figure/title">`	For any `title` whose parent is a `figure` whose parent is a `section`
`<rule context="/">`	For the document (the root node)
`<rule context="name [@title='Mr.']">`	For any `name` element with a `title` attribute with a value of "Mr."

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Schematron tests expressed in XPath

Value of `test` attribute on `assert` and `report` is an XPath expression

`<assert test="title">`	The context node has a `title` child (short form) (I.e., there must be a `title` child)
`<assert test="child::title">`	The context node has a `title` child (long form)
`<assert test="@float ='0'">`	The `float` attribute on the context node has a value of zero
`<rule test="count(*) > 20">`	There are more than 20 element children inside the context node ("*" means the all the element children)
`<assert test="string-length(.) > 25">`	The length of the context node is greater than 25 characters ("`.`" means "`self`")
`<report test="parent::section">`	The parent of the context node is a `section`
`<report test="parent::footnote and string-length(.) > 300">`	The parent of the context node is a `footnote` *and* the length of the node's content is longer than 300 characters

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Evaluating XPath expressions

```
<rule context="para">
  <assert test="string-length(.) &gt; 20">
    Paragraph seems awfully short.
  </assert>
</rule>
```

To evaluate an XPath test, we need to know at least two things:

1. The XPath expression itself

   ```
   string-length(.) &gt; 20
   ```

2. The *evaluation context*: a node in the document
   - Set in Schematron by the `context` attribute
   - Here, the *context* is a `para` element
   - Any `para` element in the document will match this context, so the test will be performed for each

`string-length(.) > 20` will be answered
`true` or `false` for every paragraph

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Organizing the Schematron schema

- `schema` is the document element
- Elements allowed at the top level inside `schema` include:
  - `title` - A title for the rule set. Optional, but a good idea.
  - `pattern` - A set of related rules: where the action is
  - `p` - A paragraph of human-readable documentation. (Never a bad idea!)
  - `ns` - Namespace declaration for your XML data so you can test it
  - `let` - A variable declaration (covered later)

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Other top-level elements

There are other top level elements inside `schema` that we won't cover today

- `include` - For calling in external Schematron modules (simple, not very common)
- `phase` - A collection of patterns to be run together (useful for some applications)
- `diagnostics` - Extended diagnostic information for rules to refer to (optional in Schematron; not all processors support this one)

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How Schematron performs its tests

- Any element in the document may be tested in each pattern
- In a pattern
  - the first rule with a `@context` matching the element is applied
  - subsequent rules in the same pattern that match the element are ignored
- In the rule, all assertions are tested with the matched element as context

```
<pattern>
  <rule context="p">
    <assert test="string-length(.) &gt; 20">
     paragraph is awfully short
    </assert>
  </rule>

  <rule context="title">
    <report test="string-length(.) &lt; 5">
      title is really short
    </report>
  </rule>
</pattern>
```

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Relations between patterns and rules

- `pattern` elements contain one or more `rule` elements
- `rule` elements group the tests for a single context
- Rules in a pattern are generally related in some way
  - functional
  - typically what messages do you want to see at the same time

If you need to look at the same context twice, you need another pattern

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Make your tests work together

- Remember, the first `rule` that matches in a `pattern` fires, no other matching `rule` does
- Don't just add rules without thinking
- Here, the second `rule` never fires:

```
<pattern>
   <rule context="sec">
     <assert test="title">Section does not have a
      title</assert>
   </rule>

   <rule context="sec[not(subsec)]">
     <assert test="p">Section without subsections has
     no  paragraphs</assert>
   <rule>
</pattern>
```

- Fix this as:

```
<pattern>
   <rule context="sec">
     <assert test="title">Section does not have a
       title</assert>
     <assert test="subsec|p">Section has neither
      paragraphs nor subsections</assert>
   <rule>
</pattern>
```

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Summarizing `assert`

Making sure things are as expected

- For validation, `assert` is bread and butter
  - You are looking for errors
  - You assert that something *is true*
  - If it is true, fine
  - If it is not, you get your message
- The message is the content of the `assert` element
- For reports or queries, you may use `report` more often
  `assert` is useful to know when things are *not* true

```
<rule context="dog">
  <assert test="bone">This dog has no bone.</assert>
</rule>
```

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A realistic example of `assert`

Context is `xref[@ref-type='fig-ref']`
(cross-reference of type `fig-ref`)

```
<assert test="@rid = //fig/@id">
    xref of type 'fig-ref' does not point to a
   figure in the document
</assert>
```

- Returns `true` if any `fig` element is found
  whose `@id` is the same as the `xref/@rid`
- The test is true if `@rid` equals the value of any
  `//fig/@id`
  (by existential quantification)

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A fancier realistic example

Context is `caption` (of a figure, table, etc.)

```
<assert
  test="*[1][self::p[(*|text()[normalize-space()])[1][self::b]]">
  Caption does not begin with bold inside p
</assert>
```

In other words: "The first element inside a `caption` must be a paragraph (`p`) which starts with bold (`b`)"

- Passes this:

```
<caption>
  <p><b>Two men and a balloon.</b>
   The Montgolfier brothers as depicted in 1785.</p>
</caption>
```

- Fails this:

```
<caption>
   <p>Two men and a balloon. <b>The Montgolfier brothers
   as depicted in 1785.</b></p>
</caption>
```

(This test could have been simpler if it didn't allow for comments, PIs, or whitespace-only text)

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Hints for writing assertions

- If your test is getting *really* complex
  - use more than one assertion
  - move some of the logic into the `context`
- If you have a context clash, you need more than one pattern

For example

```
<rule context="citation">
  <report test="article-title and not(source)">
    citation has an article-title, but no source
  </report>
</rule>
```

can be rewritten as

```
<rule context="citation[article-title]">
  <assert test="source">
    citation with an article-title has no source
  </assert>
</rule>
```

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Summarizing `report`

Finding things of interest

- Schematron `reports` are not just for "errors"
- With `report` you can
  - locate elements of interest
  - describe the features of a document
  - find conditions in the document
    - things you expect, but want to know about
    - things you don't expect, but expect enough to ask about
- If the test is true, you get your message
- The message is the content of the `<report>` element

```
<rule context="dog">
   <report test="flea">
     This dog has fleas!
   </report>
</rule>
```

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Some examples of `report`

```
<rule context="sec">
   <report test="count(//sec[title=current()/title]) > 1">
     Section has the same title as another section
   </report>
</rule>
```

```
<rule context="back">
   <report test="5 > count(.//citation)">
     Fewer than five citation elements appear in the
     back matter
   </report>
</rule>
```

```
<rule context="lpage[../fpage]">
   <report test=". &lt; ../fpage">
     Last page given is lower than first page
   </report>
</rule>
```

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When being right is enough

- Sometimes the fact that a rule matches is useful in itself
- For example, maybe you want to find all your titles so you can look at them:

```
<rule context="title">
   <report test="true()">title found</report>
</rule>
```

- (We also sometimes write `test="."` — how does this work?)
- This is especially useful when running Schematron in interactive batch mode over a set of documents
- Development technique: locate elements like this when you need to inspect them to write your actual validation rules

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Schematron for Real

(a short demonstration)

Watch it go!

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Making better error messages (Advanced)

- `value-of` puts values into messages
- `name` puts elements names into messages

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`value-of` puts values into messages

- Provide generated text in your messages
- Empty element `value-of` is replaced with its value in your message
- Value is determined by `@select`
- Value of `@select` is an XPath expression that depends on the context of the message

For example:

```
<assert test="@ref-type='fig' or
   @ref-type='sec' or @ref-type='fn'>
   Unknown 'ref-type' value ('<value-of select="@ref-type"/>');
   Value must be 'fig', 'sec', or 'fn'
</assert>

<report test="string-length(.) > 20">
   The element is too long (only 20 characters are allowed);
   <value-of select="string-length(.)"/> characters present)
</report>
```

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`name` puts elements names into messages

- `<name/>` is short for `<value-of select="name()"/>`
- Let's you put the name of *the matched element* into your message
- For example, to tell sections from appendices when the context is either:

```
<rule context="sec | app">
   <assert test="title"><name/> must have a title</assert>
   <report test="count(title) > 1">
      <name/> has too many titles:
      <value-of select="count(title)"/> are present
   </report>
 </rule>
```

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Wrapup: Taking advantage of Schematron

(if time permits)

- Download a Schematron processor or
  use an editor/environment that runs Schematron
- Write out your assertions in your native language
- Turn your assertions into XPath statements
  (yes, this is the hard part)
- Write the message you would like to get back

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Remember what Schematron can do

- Validate/report on document structure
  - presence/absence of elements
  - location of elements
- Validate/report on document content
  - there must be some content
  - there must be some particular content
  - content must follow some rule
- Validate/report on attributes
  - presence/absence of attributes
  - content of attributes
- Check co-occurrence constraints
  - if X is true, then Y should be true
  - A, B, C, and W must all be present (somewhere)

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Schematron gives you the world's best error messages

You write them!

- You specify where to test your documents
- You specify the test
- The test can be positive or negative
  - you want to know *if*
  - you want to know *unless*
- *You write the message you want to come back*
- Message can be
  - as specific or general as you need
  - in the language of your users
  - in the jargon of your audience

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Schematron allows "soft validation"

- Schematron allows a stretchy definition of an "error"
- Can find actual *and potential* problem areas
  - even if they are valid
  - even if they won't stop the system from working correctly
  - even if the rules are blurry
    - maybe we *can* fix it, maybe not
    - maybe we *should* or shouldn't
    - maybe we'll need to consider it (or get authority)

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Why Schematron?

- Handy: Really useful, fast-to-write constraint language
- Lightweight: Lets you test as much or as little as you like
- Flexible: Tests constraints other constraint languages can, and some they cannot

"Schematron is a feather duster that reaches areas other schema languages cannot." — Rick Jelliffe

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Colophon

- Slides and handouts created from a single XML source
- Slides projected in HTML (created from XML using XSLT)
- Handouts distributed in PDF
  - source XML transformed to Open Office XML with XSLT
  - pagination and tables hand-adjusted
  - Open Office made PDF
- Slideshow tools available at `http://www.mulberrytech.com/slideshow`

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Reference Slides (Homework)

Advanced concepts for answering questions and at-home reference

- Namespaces in Schematron
- Naming and reusing XPath expressions (variables)
- Schematron using XPath 2.0
- Abstract Rules (declaring and reusing Schematron rules)

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Namespaces in Schematron (Reference)

- Document element of the Schematron schema is `schema`
- <schema> *requires* a namespace declaration

```
<schema xmlns="http://purl.oclc.org/dsdl/schematron">
 ...
</schema>
```

- ISO (DSDL) Schematron is designated by `http://purl.oclc.org/dsdl/schematron`
- Other versions have other namespace bindings (The `URI` for Version 1.6 is `http://www.ascc.net/xml/schematron`)

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Using a prefix on Schematron instructions

- In this class, the ISO namespace has been bound to the default (prefixless) namespace

```
<schema xmlns="http://purl.oclc.org/dsdl/schematron">
```

- If you prefer, a name prefix may be used ("`sch`" is traditional)

```
<sch:schema xmlns:sch="http://purl.oclc.org/dsdl/schematron">
 ...
</sch:schema>
```

  - Works exactly the same way
  - All Schematron elements use the prefix (`<sch:rule>`, `<sch:assert>`, `<sch:report>`, etc.)
  - This is most helpful when mixing Schematron with other vocabularies(such as other schema languages, or XSLT)

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Namespaces in your XML documents

- When you have namespaces in your XML documents
  - for element and attribute names
  - that you need to use in `@context` and `@test` expressions
- Use the `ns` element to enable Schematron to see these namespaces (this declares the namespace to the processor)
- Each `<ns>` specifies a prefix/URI pair
- For example

```
<ns prefix="xlink" uri="http://www.w3.org/1999/xlink"/>
```

  - allows recognition of elements and attributes in the XLink namespace using the `xlink` prefix
  - lets you write code like this to test for an `xlink:href` attribute

```
<assert test="@xlink:href">Make this into a live link</assert>
```

(By convention, `<ns>` elements are placed just after the `<title>` inside the schema.)

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Using Variables (Advanced)

- Let you use the same XPath expressions
  - more than once
  - and give them a name
- Can make your Schematron logic
  - easier to read and understand
  - more efficient to process
  - more general and reusable (as opposed to element-or-attribute-name-specific) with abstract patterns
- Are used in XPath expressions

For example, once *$attribute* has been established:

```
<report test="not($attribute)">
   Expected attribute is missing
</report>
```

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`let`: Declaring variables

- `<let>` declares a variable
  - gives it a name using `@name` (required)
    - a good name describes the variable
    - variable names follow the rules of XML names
  - gives it a value using `@value` (required)
    - the value is an XPath expression
- Once defined, a variable reference looks like `$name`
  - *name* is the variable name
  - the `$` says that it is a variable

```
<let name="figures" value="//fig"/>

<rule context="xref[@ref-type='fig-ref']">
   <assert test="@rid = $figures/@id">
     xref of type 'fig-ref' does not point to a figure
   </assert>
</rule>
```

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Scope of variable bindings

- A variable created with `let` has *scope*
- Scope means the context where it can be used
- Scope is set by where the `let` declaration appears
- If `let` is inside a `rule`
  - variable is calculated with that `context`
  - scope is only inside the `rule`
- Any other `let` location creates a global variable (context = document root)

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Example of scope

```
<rule context="sec">
   <let name="section-bibrefs" select=".//xref[@ref-type='bibl']"/>

   <assert test="count($section-bibrefs) >= 5">
     section contains fewer than 5 bibliographic references
   </assert>

   <report test="$section-bibrefs[not(@rid = //ref/@id)]">
     section contains one or more broken bibliographic references
   </report>
</rule>
```

The variable `$section-bibls` is scoped to the rule matching `sec`

- variable is recalculated for each `sec` that matches the rule (with the `sec` as context node)
- variables can be used anywhere inside this rule, but not outside

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Tips when using variables

Schematron `let` may appear

- At the top level (reuse inside any rule)
- Inside a `pattern` (reuse inside any rule)
- Inside a `rule` (for use only in its assertions)

A variable may be useful any time

- You use the same XPath expression several times
- You collect many nodes, especially repeatedly

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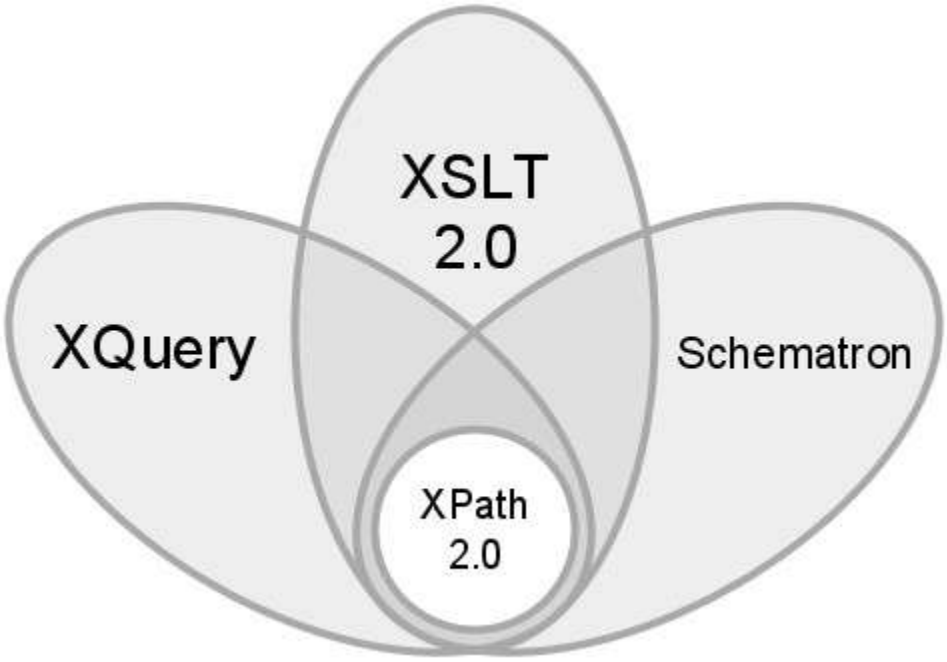
XPath 2.0 in Schematron

XQuery, XSLT, and Schematron can all use XPath 2.0



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From XPath 1.0 to XPath 2.0

XPath 2.0 is considerably more complex than XPath 1.0

- Closer to "complete" query language
- More functions, operators, functionality
- Real datatypes (XSD)
- Regular expressions on strings

and much much more!

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Schematron using XPath 2.0

The Exhibit below shows some more complex Schematron, using the power that XPath 2.0 can provide.

Exhibit 1

Schematron using XPath 2.0

(Note new namespace `URI` and `@queryBinding`)

```
<schema xmlns="http://purl.oclc.org/dsdl/schematron"
 queryBinding="xslt2" >

<title>Sample Schematron using XPath 2.0</title>

<ns prefix="xlink" uri="http://www.w3.org/1999/xlink"/>
<ns prefix="xs" uri="http://www.w3.org/2001/XMLSchema"/>

<!-- Uses XPath 2.0 and XML Schema datatypes to do
 some fancy checking -->

<pattern id="uri-testing">
   <rule context="*[@xlink:href]">
     <assert test="normalize-space(@xlink:href)">
      @xlink:href is given with no value
     </assert>
     <assert test="@xlink:href castable as xs:anyURI">
      Broken URI in @xlink:href
     </assert>
   </rule>
</pattern>

<pattern id="preformat-testing">
   <rule context="preformat">
     <assert
      test="every $line in tokenize(.,'&#xA;')
      satisfies string-length($line) le 72">
      preformat is wider than 72 characters
     </assert>
   </rule>
</pattern>

</schema>
```

("
" is a linefeed character)

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Abstract rules and patterns (Advanced)

- For reusing Schematron logic (not just XPath logic)
- Write a rule or an entire pattern as an *abstract* rule or pattern
- `@abstract="true"` identifies it as an abstract pattern
- context and tests will be *parameterized*
  (not all explicit element or attribute names)
- an `@id` identifies the pattern
- Invoking patterns
  - use an `@is-a` to point to the named `pattern` (it's `@id`)
  - are therefore an instance of the abstract pattern
  - set up the parameters for the abstract pattern and then invoke it

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An abstract pattern

(invoking patterns in bold)

```
<pattern id="non-ws-attribute" abstract="true">
 <rule context="$my-element[$my-attribute]">
 <assert test="normalize-space($my-attribute)">
 <name/> has no <value-of select="name($my-attribute)"/>
given</assert>
 </rule>

 <rule context="$my-element">
 <report test="not($my-attribute)">
 <name/> is missing an expected attribute</report>
 </rule>
</pattern>

<pattern id="xref-rid" is-a="non-ws-attribute">
 <param name="my-element" value="xref"/>
 <param name="my-attribute" value="@rid"/>
</pattern>

<pattern id="ext-link-href" is-a="non-ws-attribute">
 <param name="my-element" value="ext-link"/>
 <param name="my-attribute" value="@xlink:href"/>
</pattern>
```

Appendix 1

Resources

Schematron Resources

- The source for all things Schematron — **http://www.schematron.com/resources.html**
- The ISO Schematron Specification — **http://www.schematron.com/spec.html**
- Tools — **http://www.eccnet.com/schematron/index.php/Tools-url**
- Eric van der Vlist has written an O'Reilly Shortcut on Schematron **http://www.oreilly.com/catalog/9780596527716/cover.html**
- Tutorials (some of these are very good but not ISO Schematron)
  - Roger Costello (both) — **http://www.xfront.com/schematron/**
  - Uche Ogbuji (non-ISO) — **http://www.ibm.com/developerworks/edu/x-dw-xschematron-i.html**
  - Zvon — (beginner non-ISO) **http://www.zvon.org/xxl/SchematronTutorial/General/contents.html**
  - Dave Pawson — (advanced ISO) **http://www.dpawson.co.uk/schematron/index.html**

XPath Resources

- XPath 1.0 Recommendation **http://www.w3.org/TR/xpath**
- XPath 2.0 Recommendation **http://www.w3.org/TR/xpath20/**
- XPath tutorials (find one that works for you)
  - (XPath 1.0) **http://www.zvon.org/xxl/XPathTutorial/General/examples.html**
  - (XPath2.0) **http://www.w3schools.com/xpath/**
  - (XPath 1.0) **http://www.ibm.com/developerworks/edu/x-dw-xxpath-i.html**
  - (XPath 1.0) **http://www.tizag.com/xmlTutorial/xpathtutorial.php**
- XPath Books
  - *XSLT 2.0 and XPath 2.0: Programmer's Reference*, by Michael Kay (4th Edition, Wiley, 2008; 0-470-19274-0)
  - *XPath Essentials*, by Andrew Watt (John Wiley & Sons, 2002; ISBN: 0471205486)
  - *XPath: Navigating XML with XPath 1.0 and 2.0*, by Steven Holzner (SAMS Kick Start, 2004; 0-672-32411-3)
  - *XPath and XPointer*, by John E. Simpson (O'Reilly 2002; ISBN: 0-596-00291-2)