NAVIGATING DOCUMENTS AND TREES WITH XPATH

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KEEPING CURRENT SEMINAR

UNIVERSITY OF KENTUCKY

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OVERVIEW

- Background: XML and its document model
- XPath: History and basic syntax
- Examples (and demo)
- Where to go next?

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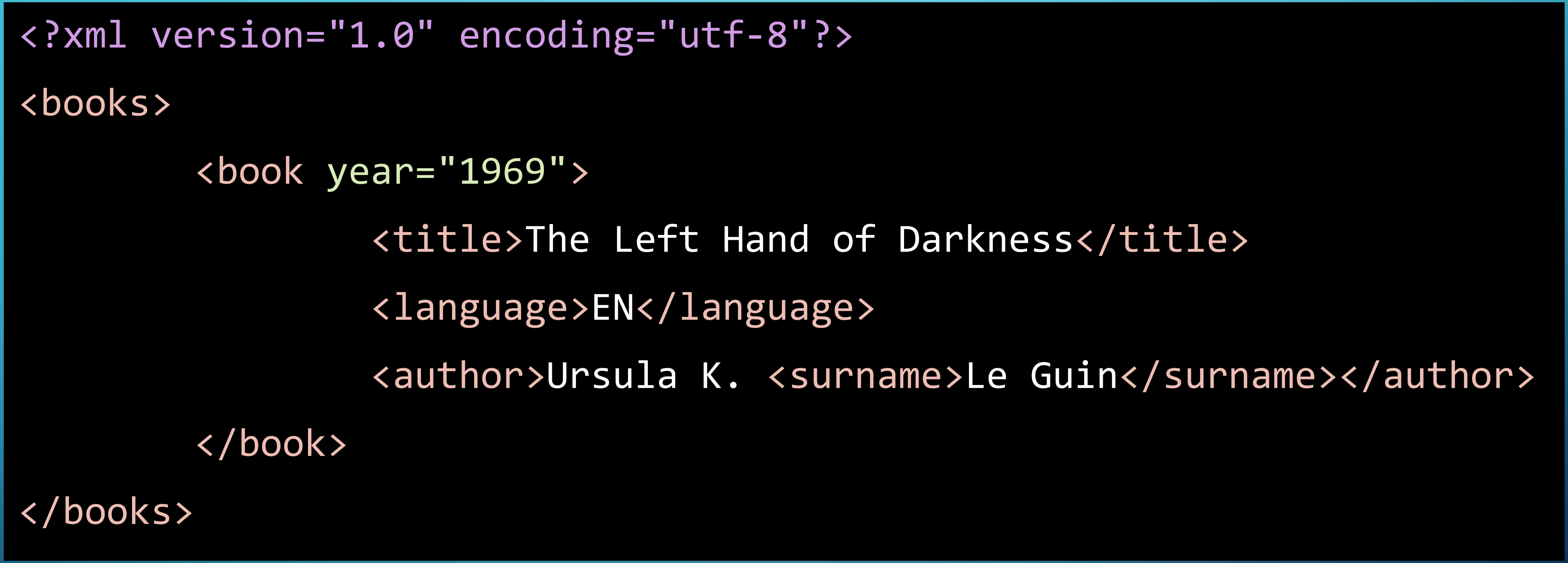
XML: THE EXTENSIBLE MARKUP LANGUAGE

- XML is a markup language:
    - For representing text with markup (“tags” or annotations”)
    - …or for representing arbitrary hierarchical data
    - With a human-readable syntax
        - XML syntax isn’t that important in this talk: XPath focuses on the data model
- Introduced by the World Wide Web Consortium (W3C)
    - First draft version in 1996, final in 1998
    - Based on SGML (so a sibling of HTML)
        - In fact, the XML document object model (DOM) is shared with HTML
    - Supplanted for some uses by Javascript Object Notation (JSON) these days

STRUCTURE OF AN XML DOCUMENT

- An XML document is a tree consisting of nodes. Nodes may be:
  - **Text** nodes (sequences of characters with no tags)
    - Always leaves of the tree (cannot have children)
  - **Element** nodes (<tag>content</tag>)
    - Have a list of key-value **attributes** (which are nodes, but *not* “children” of the element!)
    - The “content” is a sequence of child nodes (elements or text)
  - A single unique **document** (or **root**) node, the root of the tree
    - With a single element child
  - A few other things (comments, processing instructions, CData, …)

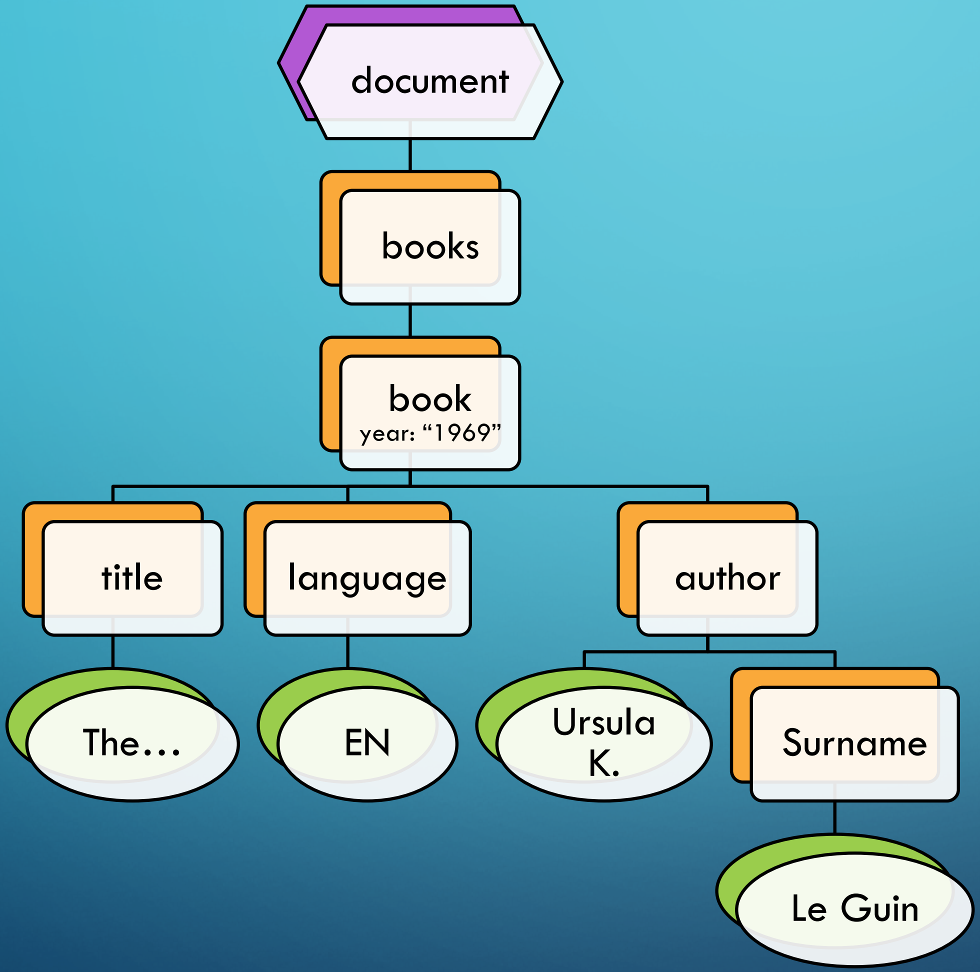
EXAMPLE XML DOCUMENT (XML SYNTAX)

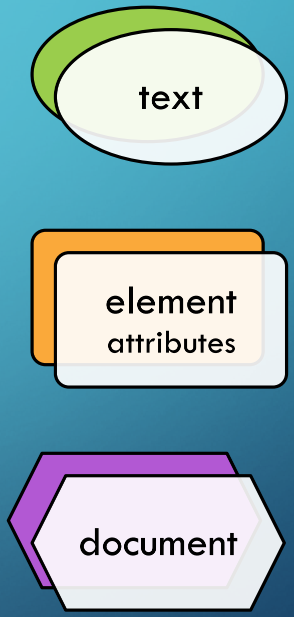


```
<?xml version="1.0" encoding="utf-8"?>
<books>
        <book year="1969">
                <title>The Left Hand of Darkness</title>
                <language>EN</language>
                <author>Ursula K. <surname>Le Guin</surname></author>
        </book>
</books>
```

Elements are in orange (running from <tag> to </tag>), attributes in yellow, and text in white.
Purple can be thought of as representing the document node itself.

EXAMPLE XML DOCUMENT (AS A TREE)





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XPATH BACKGROUND

XPath is a language for querying XML (and HTML) documents according to their hierarchical structure

- Introduced by W3C in 1999 (XPath 1.0)
  - Most recent version is 3.1, March 2017
  - We'll focus on 1.0: Most browsers don't even support 2.0 out of the box
- Declarative query language
  - Like basic SQL, it is *not* Turing-complete
- Most queries return a **nodeset** – an unordered list of nodes in the XML tree
  - XPath also has strings, numbers, and booleans

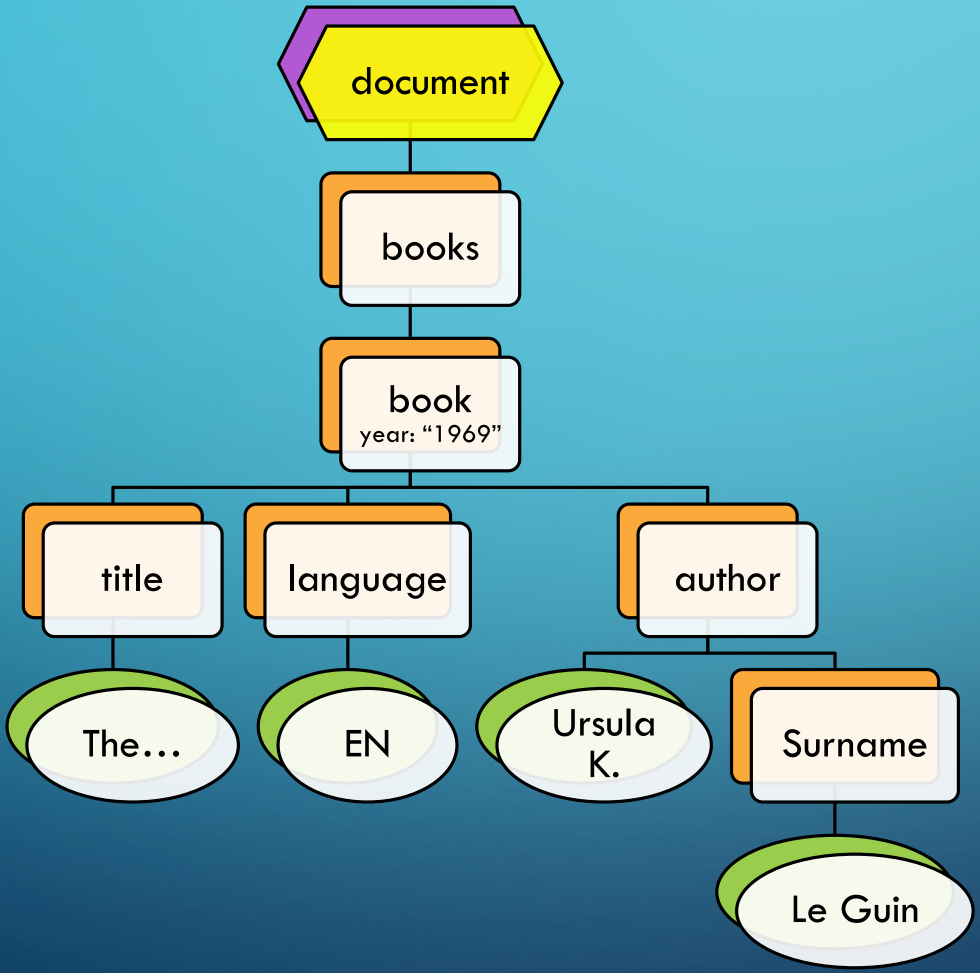
XPATH QUERIES

- Queries are evaluated in a **context**: a node of the tree
    - And, for our purposes, they return a node set.
- The most basic kind of XPath expression is a **location path**
    - A sequence of steps indicating how to navigate from the context node to a set of other nodes.
    - Each step has an **axis** (which direction to go; default “child”),
    - …a **node test** (which nodes along that axis to select), and
    - …zero or more **predicates** (additional filters to restrict the results)
    - Each step is evaluated in the context(s) of the nodes selected by the previous step

LOCATION STEPS

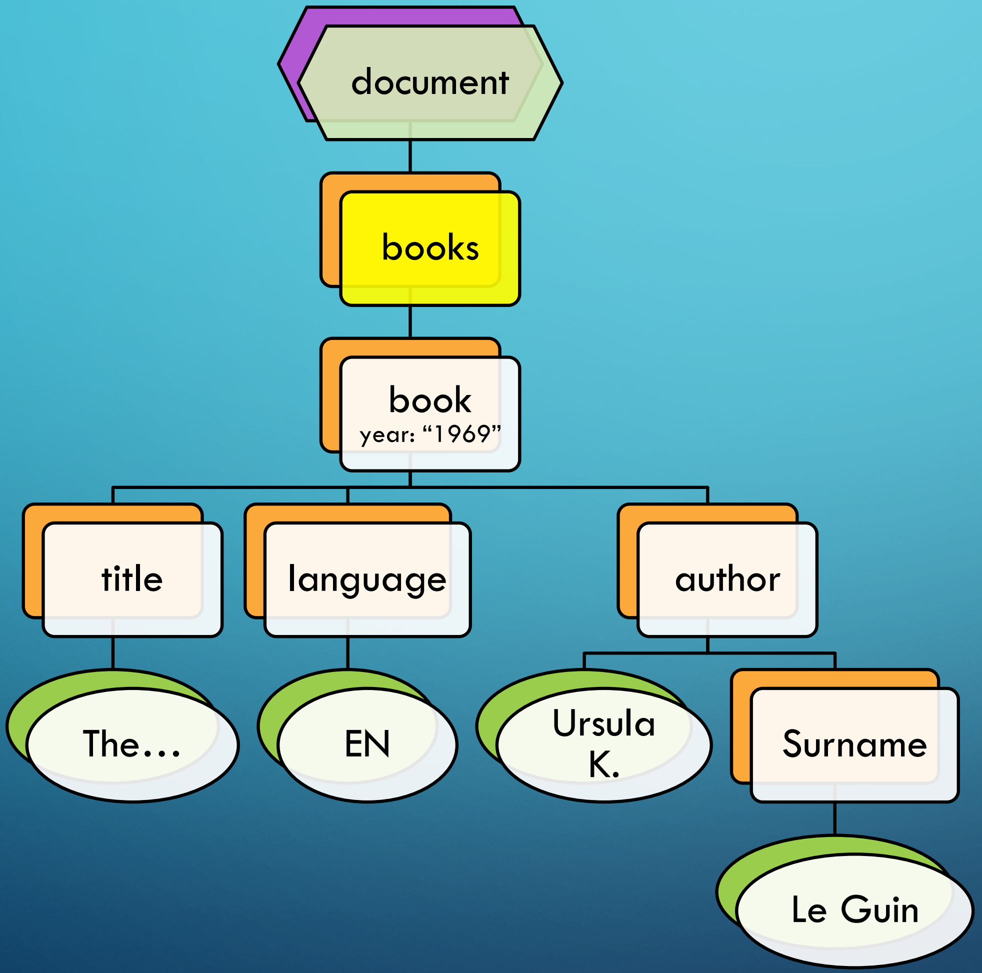
- Location steps are separated by slashes
  - A location path beginning with a slash is “absolute” (context = document)
  - `/books/descendant::surname/text()`
    - First step: axis is **child** (the default: select children of the context node), node test is **books** (only select nodes with that name), and no predicates
    - Second step: axis is **descendant**, node test is **author**
    - Third step: axis is **child**, node test is **text()** (select nodes of that type)
  - “.” is shorthand for “self::node()”, and “..” for “parent::node()”
  - Double slash is shorthand for /descendant-or-self::node()/
  - So /books//surname/text() is similar to the first query, but not exactly the same
    - In particular, it has four steps, not three: This will matter later.

/BOOKS/DESCENDANT::SURNAME/TEXT()



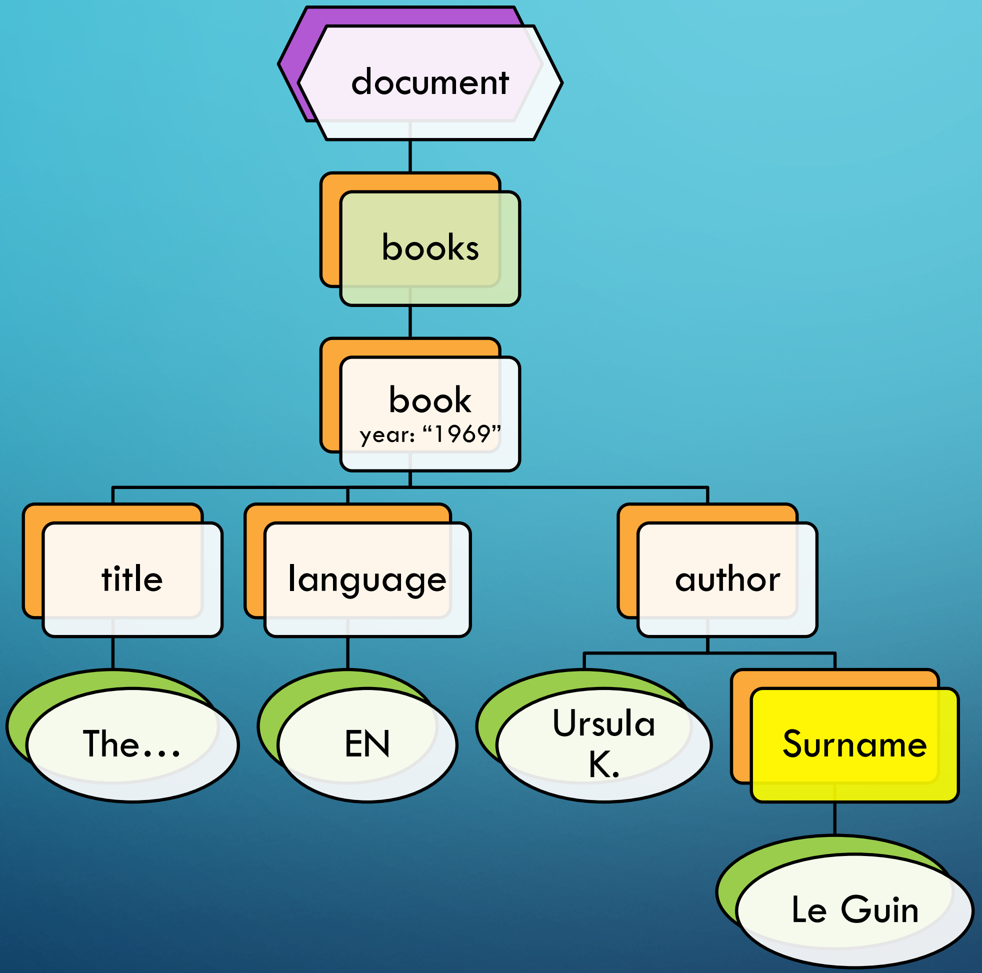
The leading slash means this is an absolute path, so the initial context node is the document

/BOOKS/DESCENDANT::SURNAME/TEXT()



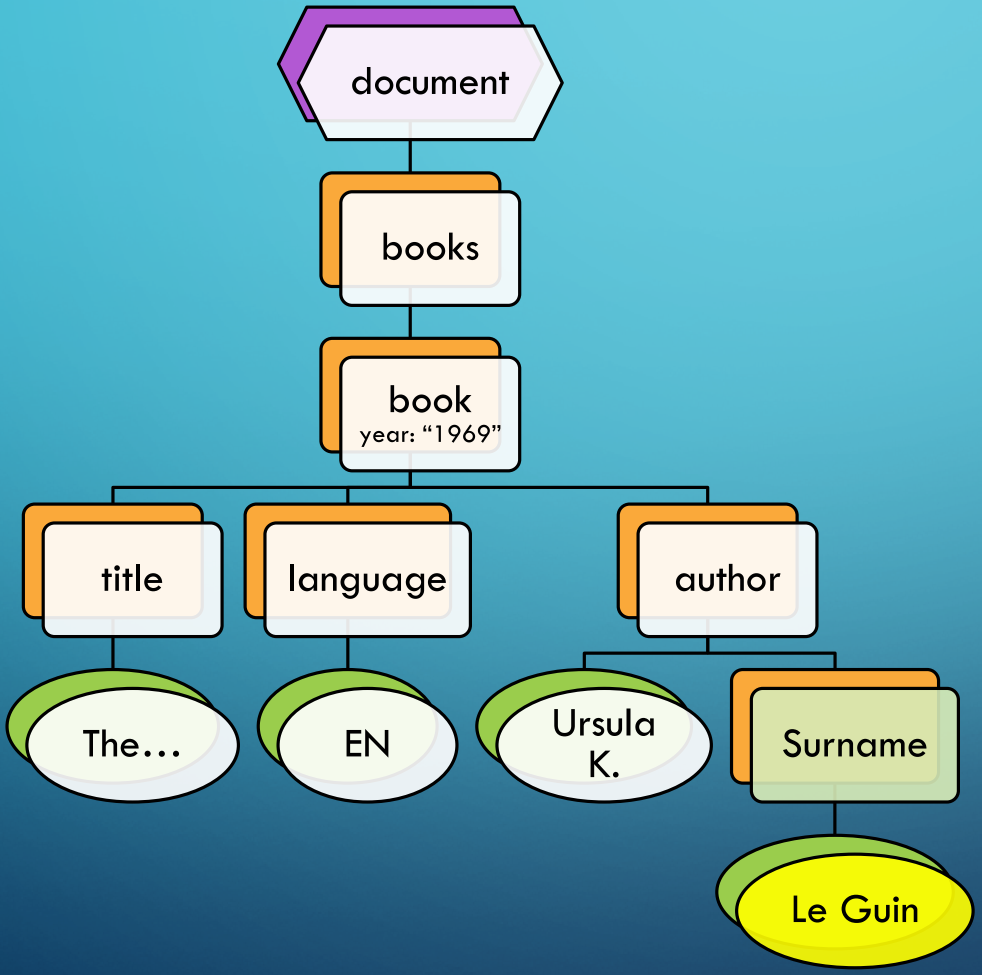
Select children of the context node(s) named “books”

/BOOKS/DESCENDANT::SURNAME/TEXT()



Select descendants of the context node(s) named “surname”

/BOOKS/DESCENDANT::SURNAME/TEXT()



Select descendants of the context node(s) that are text nodes.

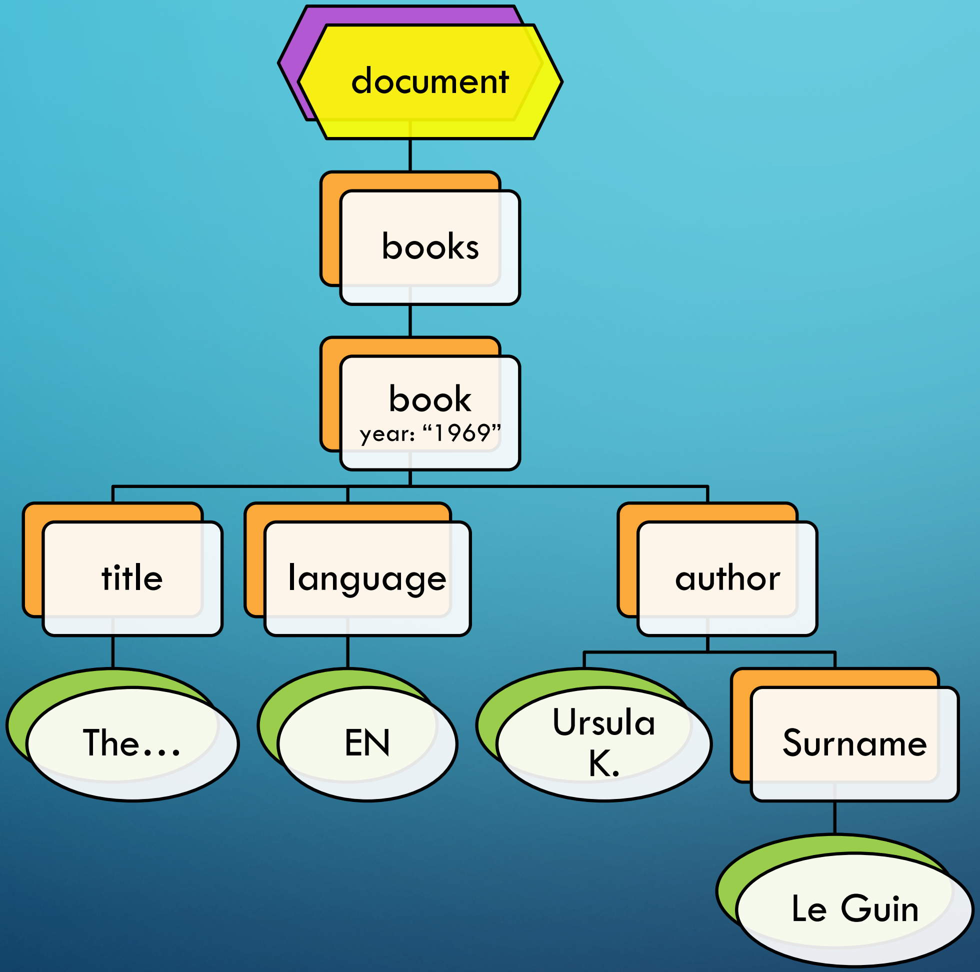
AXES AND NODE TESTS

- The axes in XPath include:
  - **child, parent**
  - **self**
  - **descendant, ancestor**
  - **descendant-or-self, ancestor-or-self**
  - **following-sibling, preceding-sibling**
  - **following, preceding** (in “document order”: preorder depth-first traversal)
  - **attribute** (shorthand: “@” means “`attribute::`”)
- A node test may be
  - The name of an element
  - “*” (any element; unless the axis is attribute)
  - “text()” (also “comment()” and “processing-instruction()”)
  - “node()” (matches anything

PREDICATES

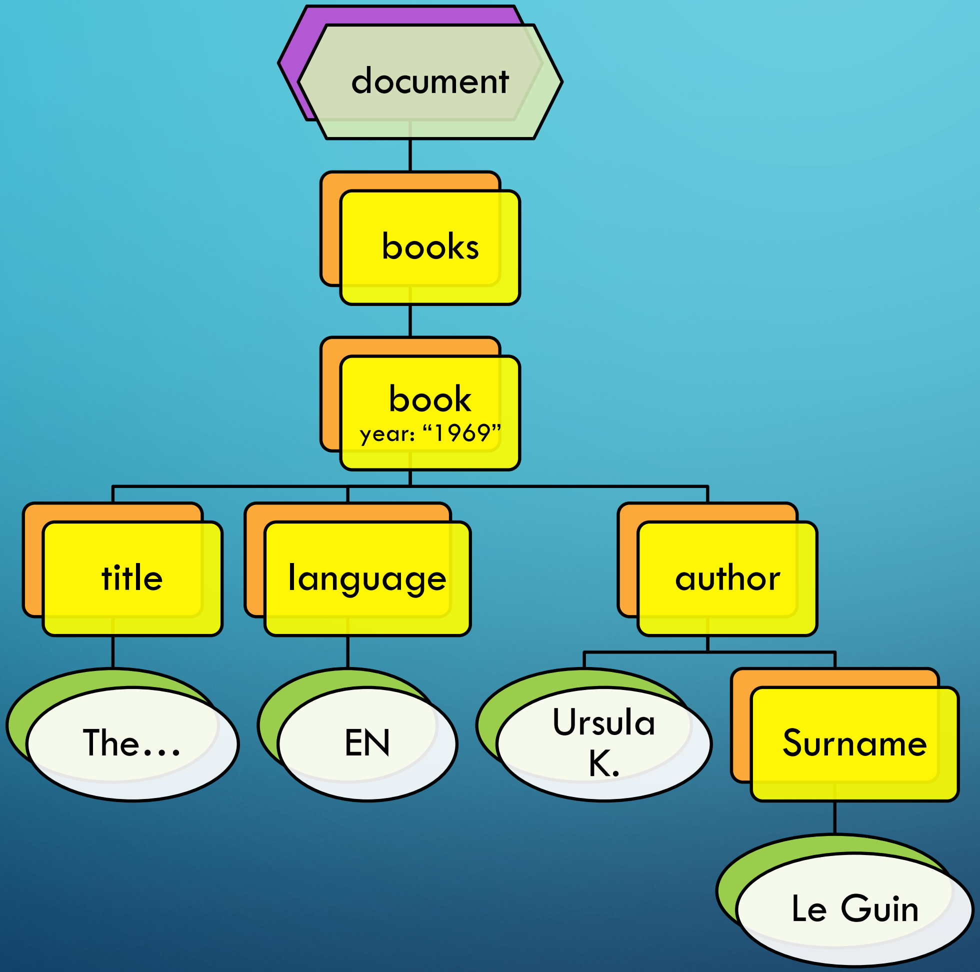
- A location step may end with any number of **predicates** to further filter results
  - Written as [*expression*]
  - The full syntax for expressions is too much to cover here, but it can include location paths, logical operators, relational operators, arithmetic, and calls to built-in functions
  - If the result of the expression is a number, only select the node whose position in the results of this step (so far) is that number
    - `/descendant::book[2]` (select the second "book" element in the entire document)
    - `/descendant::book[2][1]` (the same (!): the first of the nodes selected by book[2])
  - Otherwise, only select the node if the expression converted to boolean is **true**
    - `/descendant::book[position() > 2]` (all books after the second; already boolean)
    - Most often a node set: Empty node sets are **false**, non-empty are **true**
    - `//book[author/pseudonym]` (books that have an author that has a pseudonym)

/DESCENDANT::*[TEXT()]/*



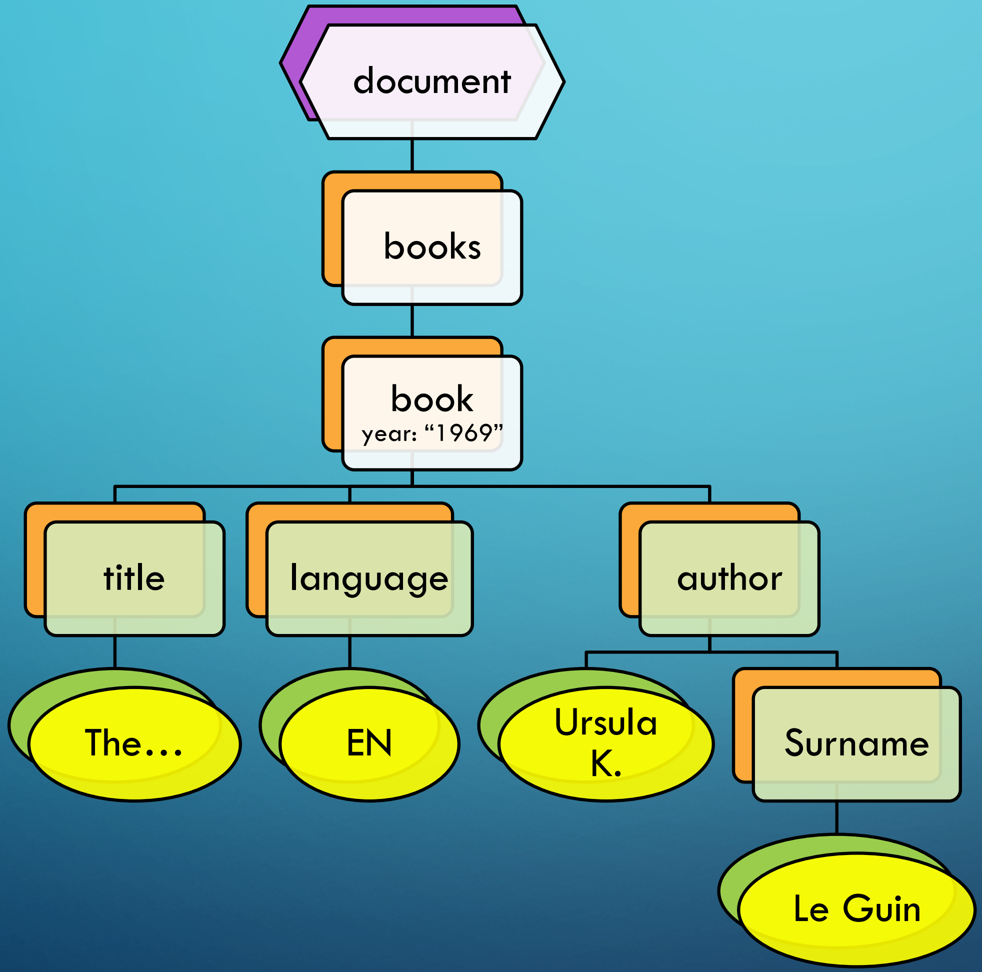
The leading slash means this is an absolute path, so the initial context node is the document

/DESCENDANT::*[TEXT()]/*



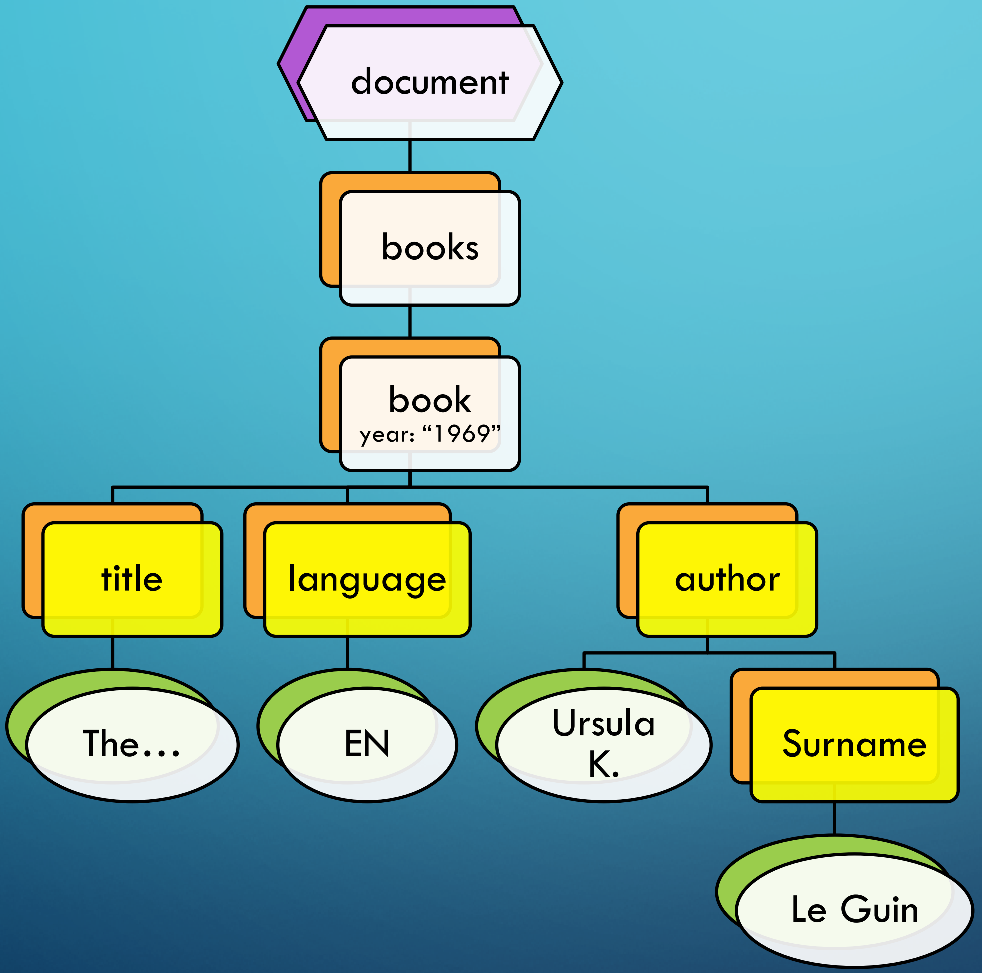
Select all **element** descendants of the document.

/DESCENDANT::*[TEXT()]/*



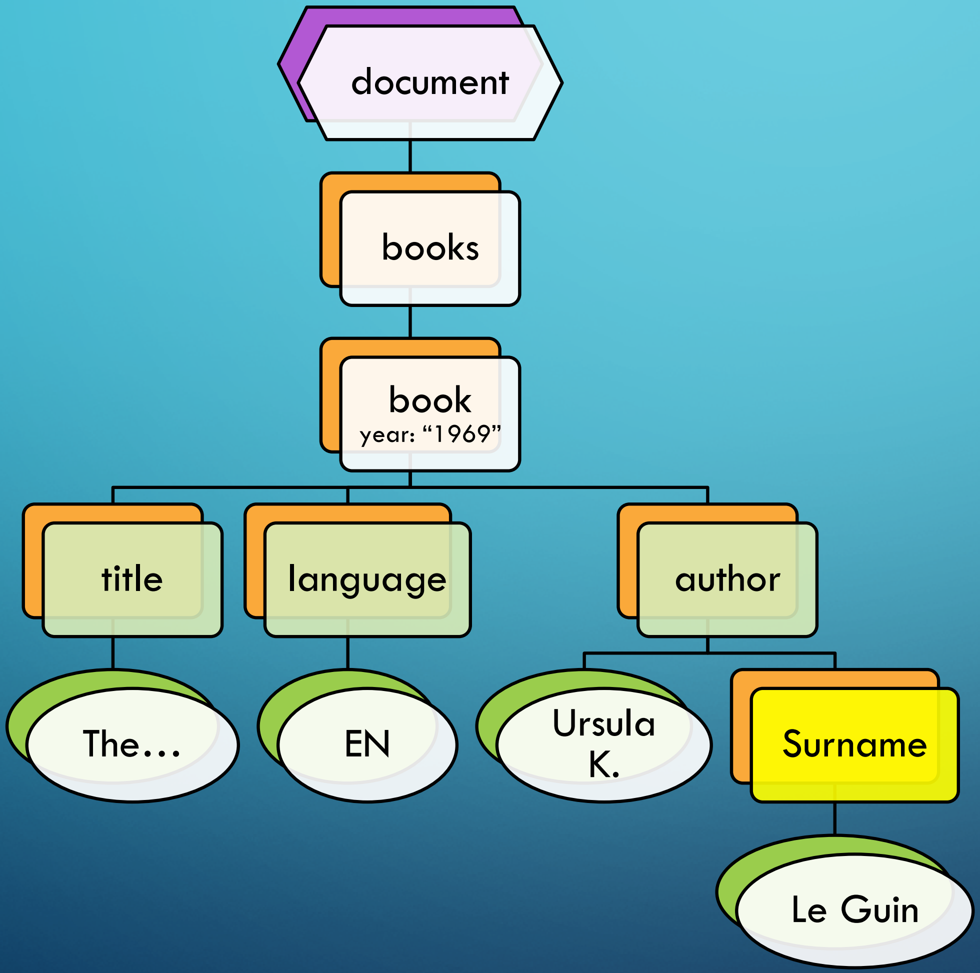
For each selected node, find child text nodes.

/DESCENDANT::*[TEXT()]/*



Only keep the selected nodes where the predicate was true (there was a text child)

/DESCENDANT::*[TEXT()]/*



Take the element children of the context nodes.

So this gives us all elements that have a text node sibling: Not the only way to express that!

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EXAMPLES AND DEMO

- We’ll start with an expanded version of the list of books
- We’ll issue various queries and discuss why they return what they do
- Using the website: **xpather.com**
  - Could instead issue queries in your browser’s Javascript console with `$x(“/blah”)`
  - But it’s easier to see the resualts this way.
  - http://xpather.com/4gcYRTs6 (preloaded with our example document)

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FOR ALL THE DETAILS

- We have covered just the basics of XPath 1.0
  - And occasionally simplified, perhaps over-simplified
- Online tutorials:
  - https://developer.mozilla.org/en-US/docs/Web/XPath
  - https://www.w3schools.com/xml/xpath_intro.asp
- Full specifications: https://www.w3.org/TR/xpath/
  - Not the easiest thing in the world to read!
- Formal semantics: https://www.w3.org/TR/xquery-semantics/ (XPath 2.0)

COMPUTATIONAL COMPLEXITY

- Naïve recursive evaluation of location steps can take exponential
  - Alternating sequences of **descendant** and **ancestor** axes
  - Nested predicates are even harder to deal with: /descendant:a[ancestor:b[descendant:a[ancestor:b[…]]]
- Georg Gottlob, Christoph Koch, and Reinhard Pichler. 2005. Efficient algorithms for processing XPath queries. *ACM Trans. Database Syst.* **30**:2 (June 2005), 444–491. DOI: https://doi.org/10.1145/1071610.1071614
  - Shows XPath can be evaluated in polynomial time (on the sizes of the expression and of the document)
  - Some useful subsets of XPath can be evaluated in linear time O(|expr| * |document|)
  - The trick: evaluate predicates "bottom up" (start with the most deeply nested)

THANK YOU!