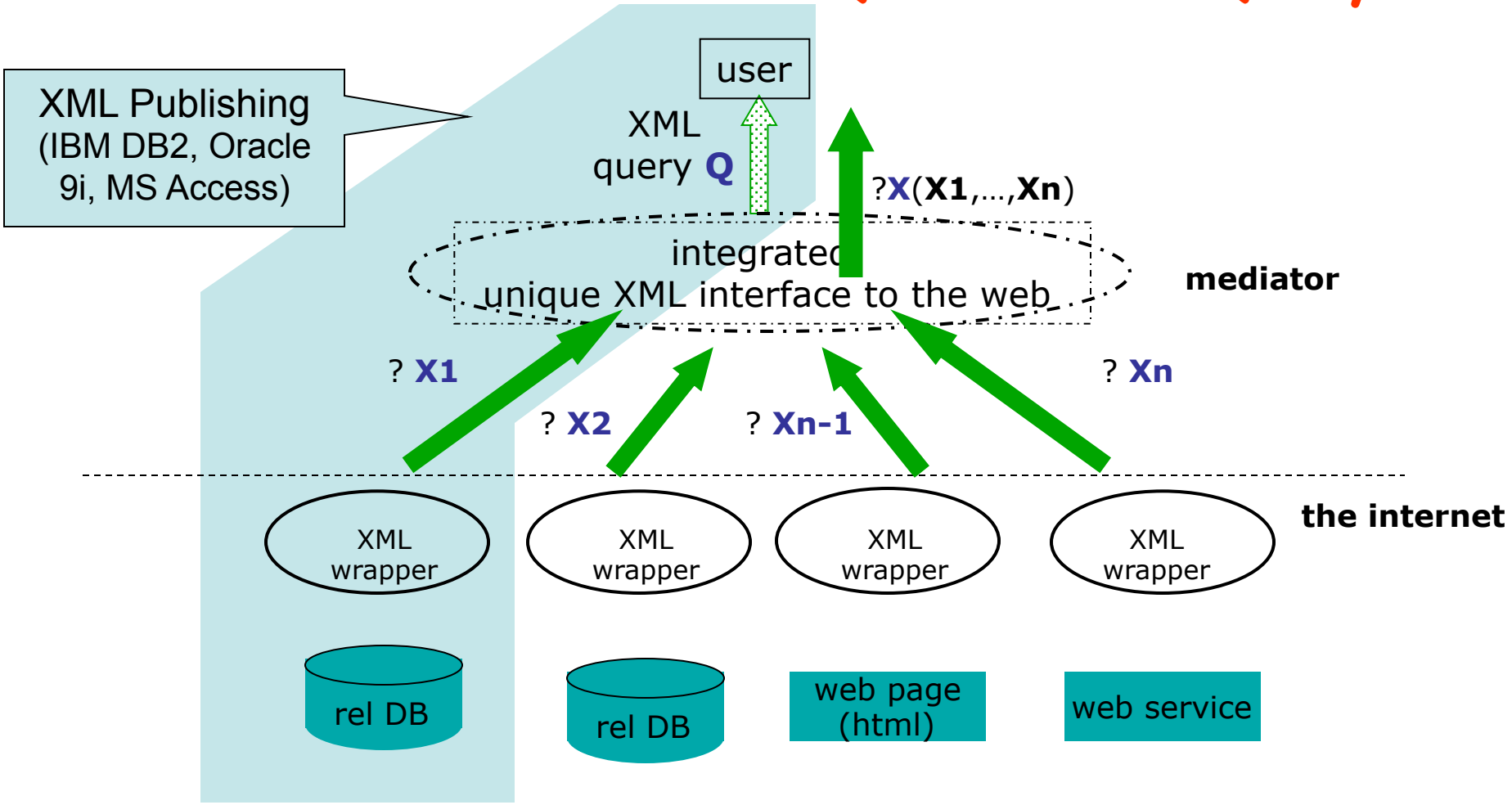
XQuery Advanced Topics

Alin Deutsch

Roadmap

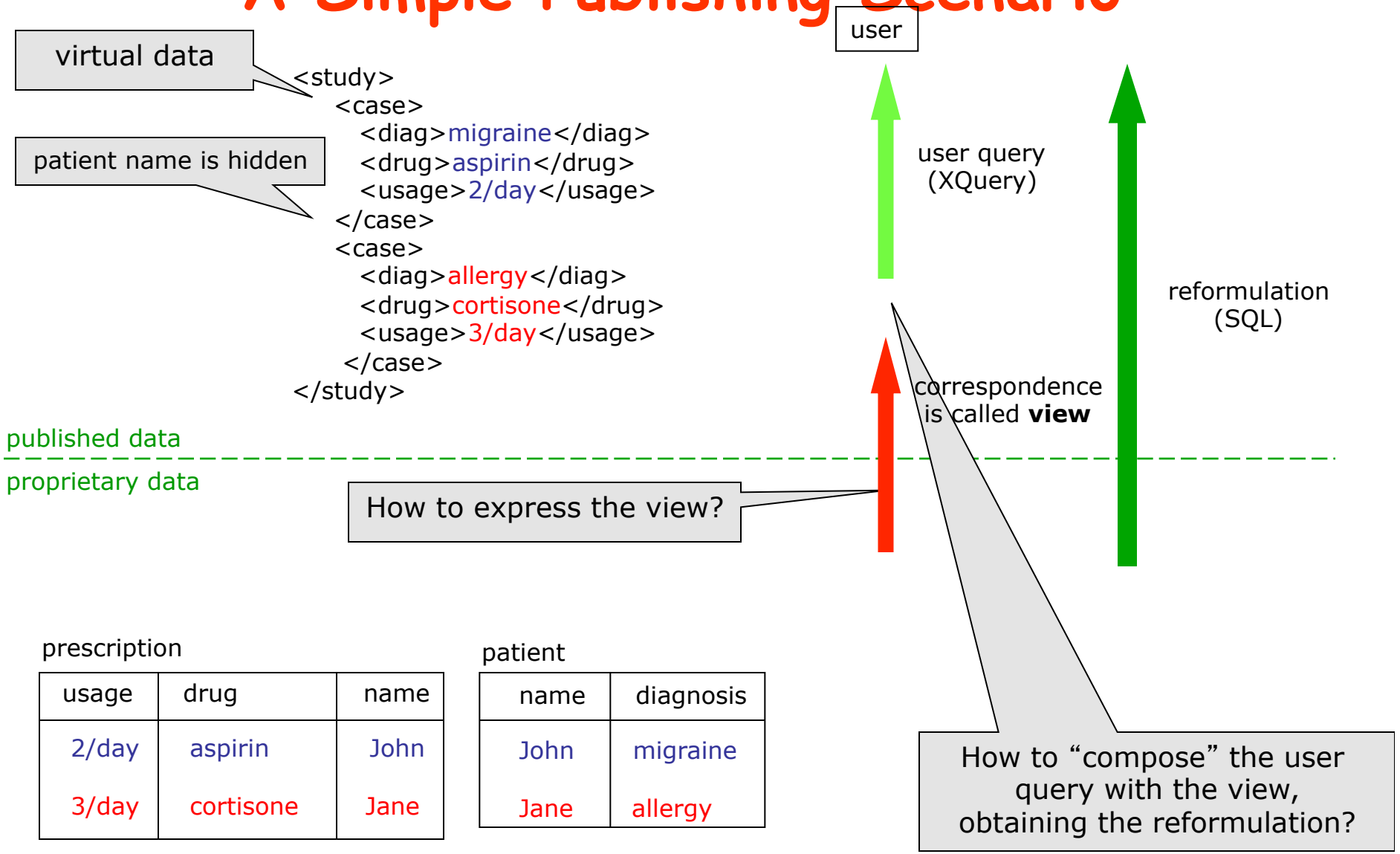
- Use of XQuery for Web Data Integration
- XQuery Evaluation Models
- Optimization
- Flavor of Standardization Issues
  - Equality in XQuery
- More on Optimization

The Web as Database Queried in XQuery



Q, X, X1, …, Xn are XQueries

A Simple Publishing Scenario



prescription

usage	drug	name
2/day	aspirin	John
3/day	cortisone	Jane

patient

name	diagnosis
John	migraine
Jane	allergy

Encoding relational data as XML

Want to specify view from proprietary → published data as XML → XML view expressed in XQuery

prescription

usage	drug	name
2/day	aspirin	John
3/day	cortisone	Jane

patient

name	diagnosis
John	migraine
Jane	allergy

```
<prescription>
    <tuple><usage>2/day</usage>
           <drug>aspirin</drug>
           <name>John</name>
    </tuple>
    <tuple><usage>3/day</usage>
           <drug>cortisone</drug>
           <name>Jane</name>
     </tuple>
</prescription>
```

```
<patient>
    <tuple><name>John</name>
           <diag>migraine</diag>
    </tuple>
    <tuple><name>Jane</name>
           <diag>allergy</diag>
     </tuple>
</patient>
```

Proprietary→Published View: XML → XML

public.xml

```
<study>
    <case><diag>migraine</diag><drug>aspirin</drug>
            <usage>2/day</usage>
    </case>
    <case><diag>allergy</diag><drug>cortisone</drug>
            <usage>3/day</usage>
     </case>
</study>
```

published data

proprietary data

view expressible as XQuery

```
<prescription>
    <tuple><usage>2/day</usage>
            <drug>aspirin</drug><name>John</name>
    </tuple>
    <tuple><usage>3/day</usage>
            <drug>cortisone</drug><name>Jane</name>
     </tuple>
</prescription>
```

encoding.xml

The View

```
<study>
  for     $t1 in document("encoding.xml")//patient/tuple,
              $n1 in $t1/name/text(),
              $di  in $t1/diagnosis/text(),

          $t2 in document("encoding.xml")//prescription/tuple,
              $n2 in $t2/name/text(),
              $dr  in $t2/drug/text(),
              $u   in $t2/usage/text(),
  where
          $n1=$n2
  return
          <case><diag>$di</diag>
                  <drug>$dr</drug>
                  <usage>$u</usage>
          <case>
</study>
```

A Client Query

Find high-maintenance illnesses (require drug usage thrice a day):

```
<results>
  for     $c in document("public.xml")//case,
              $d in $c/diag/text(),
              $u in $c/usage/text(),
  where
          $u="3/day"
  return
          <drug>$d</drug>
</results>
```

Not directly executable, public.xml does not exist

The Reformulated Query

Directly executable, expressed in SQL against the proprietary database:

Select pr.drug

From patient pa, prescription pr

Where pa.name = pr.name and
pr.usage = “3/day”

prescription

usage	drug	name
2/day	aspirin	John
3/day	cortisone	Jane

patient

name	diagnosis
John	migraine
Jane	allergy

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XQuery Semantics: Navigation & Tagging

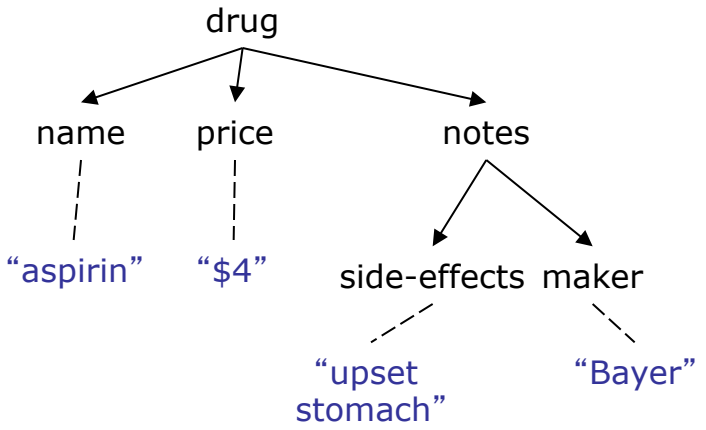
XML data model is a tagged **tree**

```
<drug>
    <name>aspirin</name>
    <price>$4</price>
    <notes>
      <side-effects>upset stomach</side-effects>
      <maker>Bayer</maker>
    </notes>
</drug>
```

opening tag

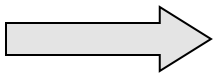
text

matching closing tag

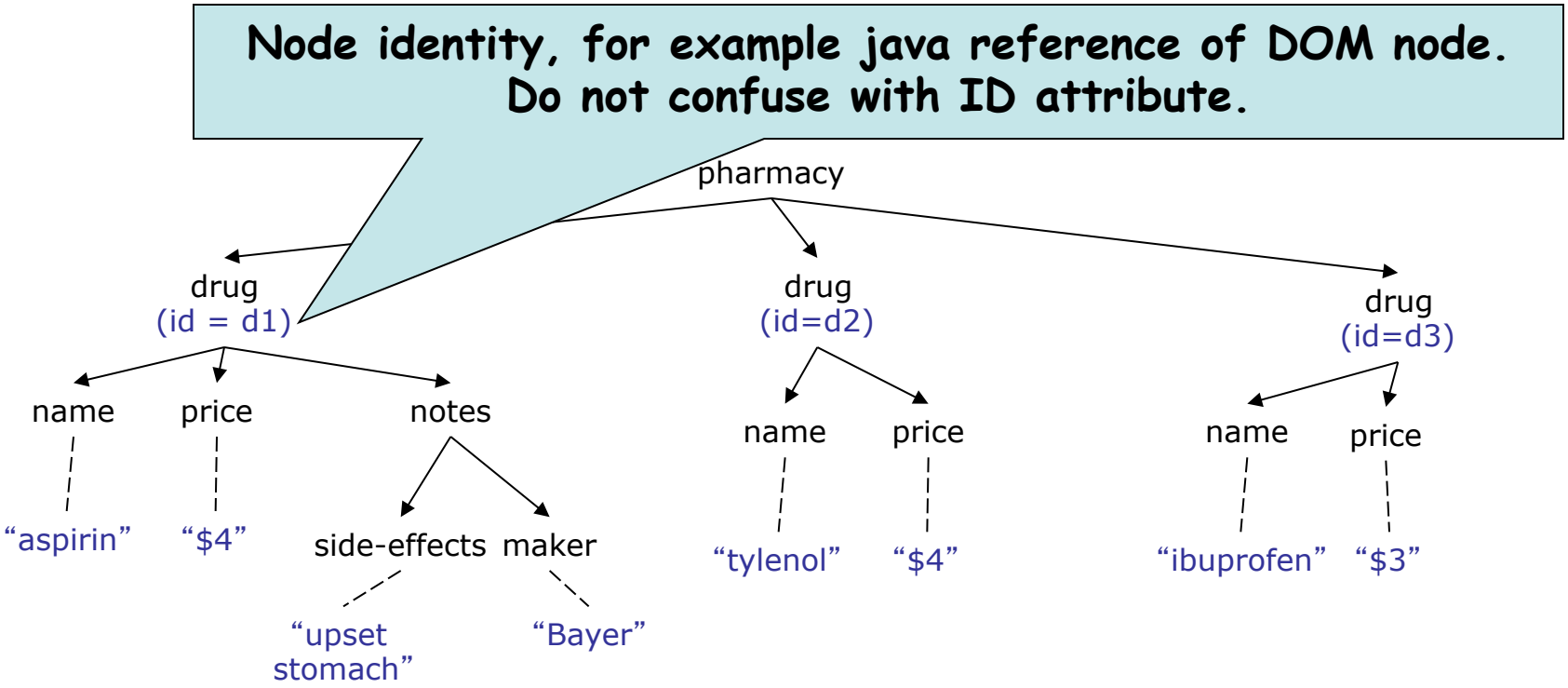


XQueries compute in two stages:

navigation in XML tree:
binds variables to
nodes, text, tags, etc.



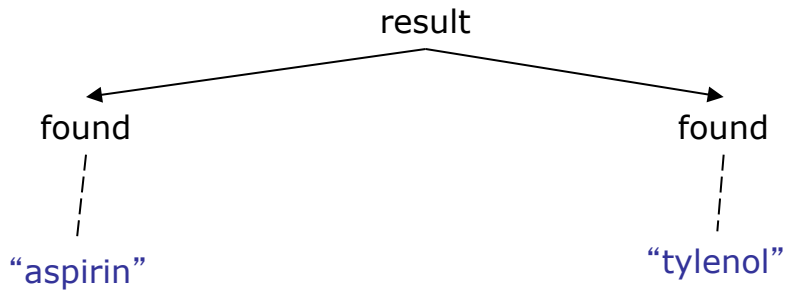
Tagging:
Output of a new XML element,
for every tuple of variable bindings




```
let $d = document("drugs.xml")
<result>
  for    $x in $d//drug, $n in $x//name/text(),
         $p in $x//price/text()
  where $p = "$4"
  return
         <found>$n</found>
</result>
```

$x	$n	$p
d1	"aspirin"	"$4"
d2	"tylenol"	"$4"
d3	"ibu"	"$3"

XQuery Semantics: Tagging




```
let $d = document(“drugs.xml”)
<result>
  for     $x in $d//drug, $n in $x//name/text(),
          $p in $x//price/text()
  where $p = “$4”
  return
          <found>$n</found>

</result>
```

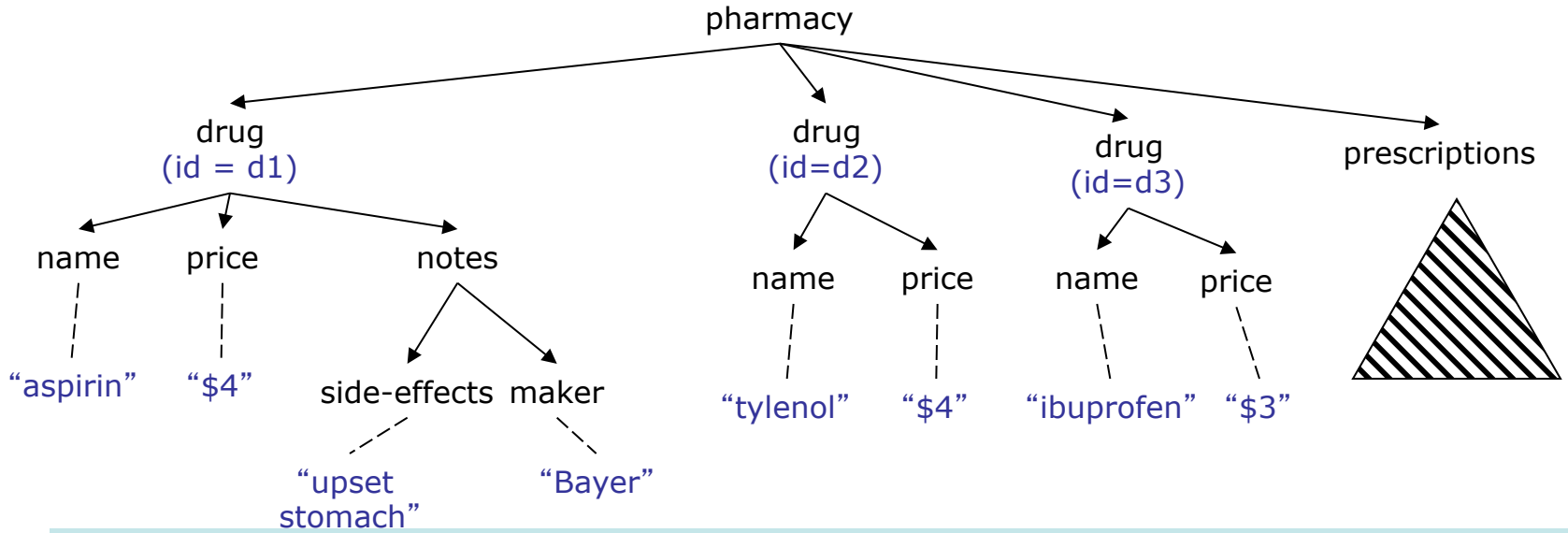
$x	$n	$p
d1	“aspirin”	“$4”
d2	“tylenol”	“$4”

Descendant Navigation

Direct implementation of descendant navigation is wasteful:

for $x in $d//drug

Go to all descendants of the root (all elements), keep <drug>-tagged ones



To find the 3 <drug> elements, a direct implementation visits **all elements** in the document (e.g. <notes>). The full query does so repeatedly.
In general, a query with n descendant steps may visit |doc size|^n elements!

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  - Stream-based
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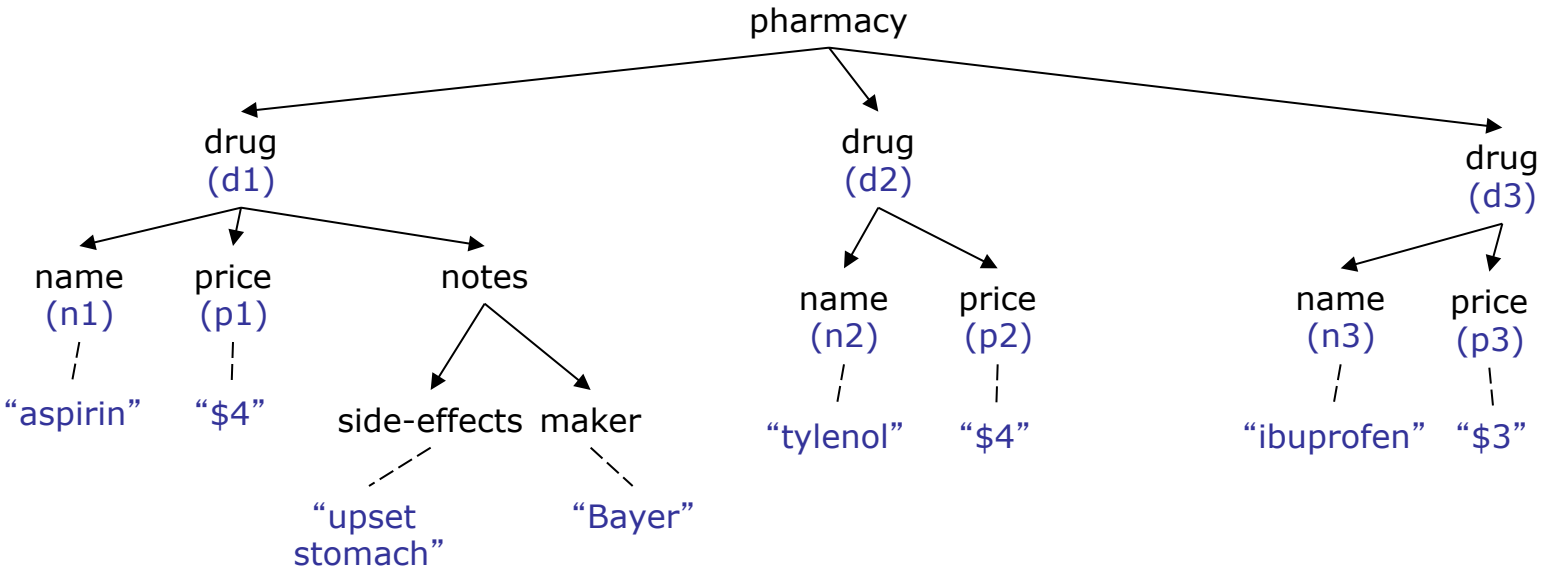
Index-based Evaluation



Idea 1: keep an index (associative array, hash table) associating tags with lists of node ids. Allows random access into XML tree.

idx:

tag	node ids
drug	d1,d2,d3
name	n1,n2,n3
price	p1,p2,p3

lookup operation: idx[price] = [p1,p2,p3]

Index-based Evaluation (2)

idx:

tag	node ids
drug	d1,d2,d3
name	n1,n2,n3
price	p1,p2,p3

lookup operation: idx[price] = [p1,p2,p3]

```
foreach $p in idx[price]                          // p1, p2, p3
    if $p/text() = "$4"                           // p1, p2
        foreach $x in idx[drug]                   // d1, d2, d3
            if $p descendant_of $x                // p1 of d1, p2 of d2
                foreach $n in idx[name]           // n1, n2, n3
                    if $n descendant_of $x        // n1 of d1, n2 of d2
                    return <found>$n</found>
```

Only 9 elements visited, regardless of size of irrelevant XML subtrees.

But doesn't the implementation of descendant_of require more visiting?

Ancestor-Descendant Testing in O(1)

Idea 2: identify each node n by a pair of integers pre(n),post(n), with

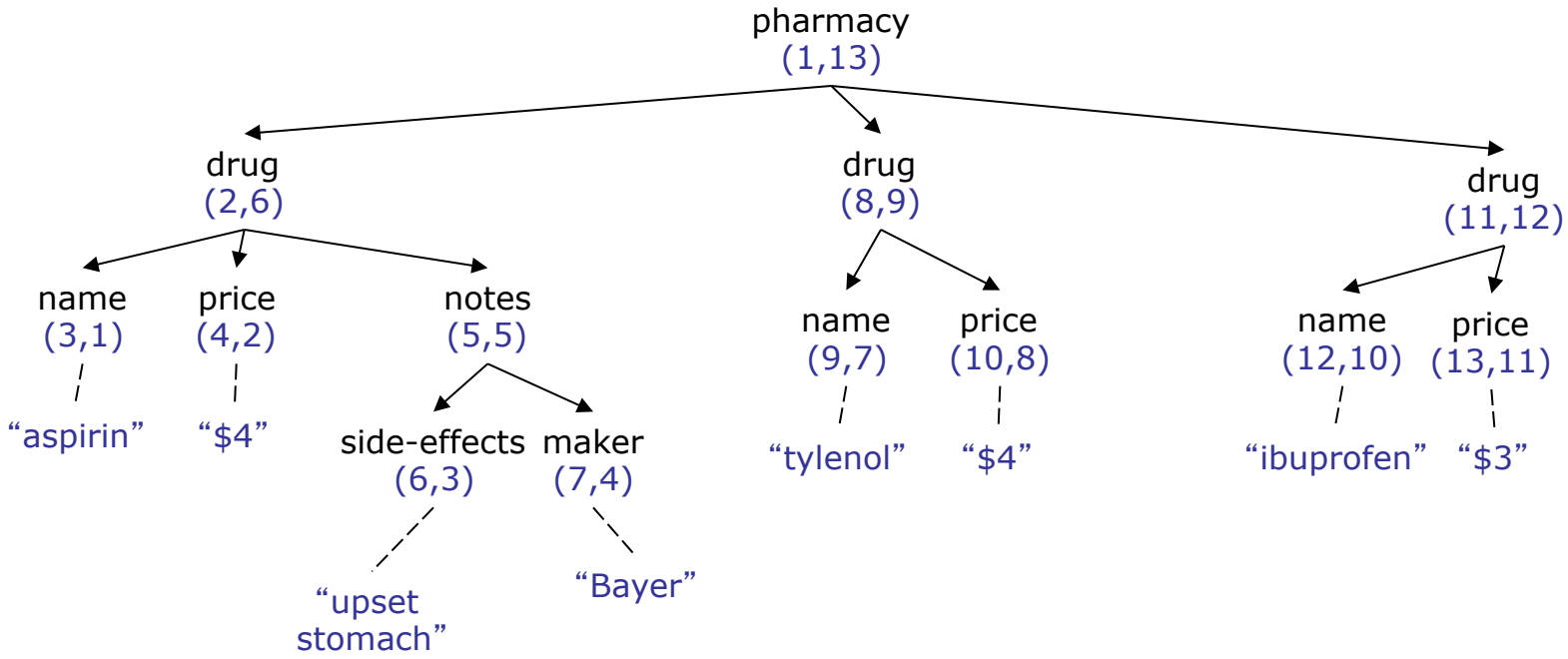
pre(n) = the rank of n in the preorder traversal of the tree
post(n) = the rank of n in the postorder traversal

Then

d is descendant of a

pre(d) >= pre(a) and post(d) <= post(a)

Example post-preorder node ids



Additional advantage: node identity independent of particular in-memory representation of DOM objects.

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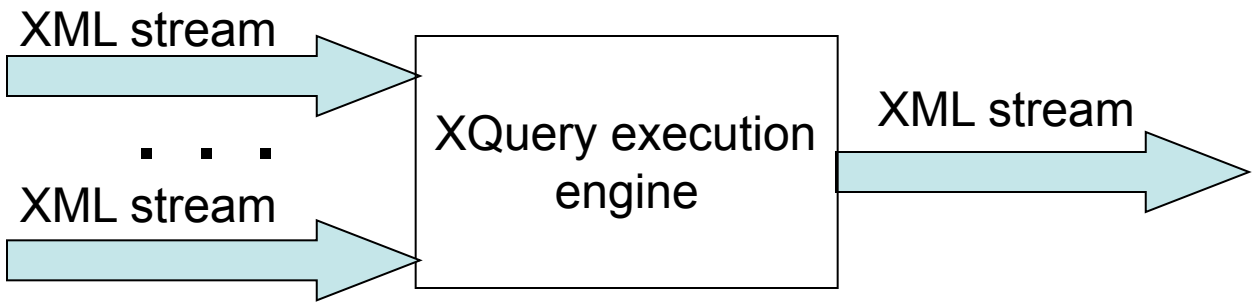
Stream-based XQuery Execution

- So far, we assumed construction of DOM tree in memory.
- XML documents can be XML representations of databases. The DOM approach does not scale to typical database sizes.
- We want an execution model that minimizes the memory footprint of the XQuery engine.



Applications of Stream-based Execution

- Besides scaling to database sizes. There are applications where the data is inherently received in streamed form:
- Sensor networks (attend faculty candidate Sam Madden's talk)
- Network monitoring/XML packet routing
- XML document publish/subscribe systems

Stream-based XML Parsing

- A parser generates a stream of predefined events (according to the standard SAX API)
- Applications consume these events.
- Each event triggers a handler. The application is coded by providing the code for the handlers.

XML input to parser	stream of events output by parser
<a>	open(“a”)
	open(“b”)
<c>	open(“c”)
someText	text(“someText”)
</c>	close(“c”)
	close(“b”)
<d>	open(“d”)
moreText	text(“moreText”)
</d>	close(“d”)
	close(“a”)

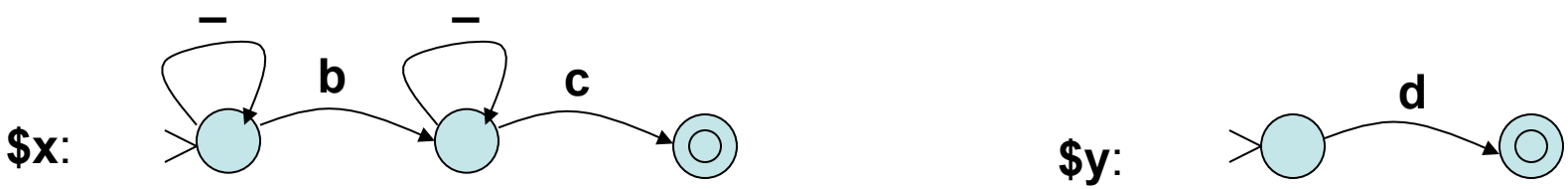
- A free SAX parser: http://xml.apache.org/xerces-j/

Stream-Based XQuery Navigation

Idea: turn path expressions into Finite Automata over alphabet containing the set of element tags

E.g. **for $x in //b//c, $y in $x/d**

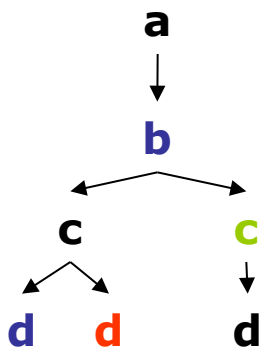
compiles to



Only one automaton active at any moment.

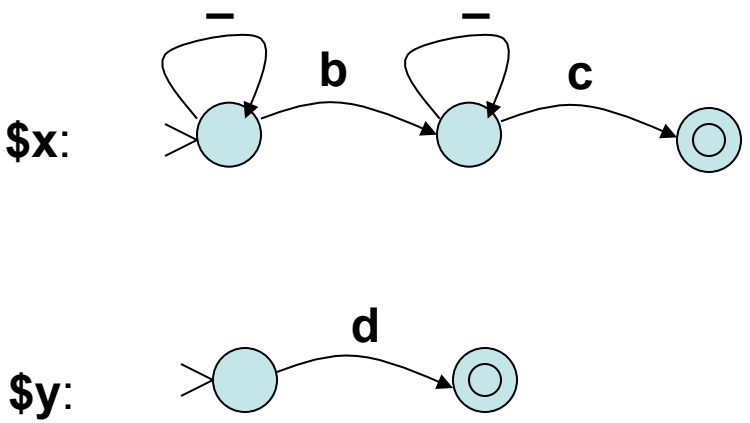
Automaton of $y is active only as long as that of $x is in final state

Matching XPaths Against Streams



o(a),
  o(b),
    o(c), o(d), c(d), o(d), c(d), c(c),
    o(c), o(d), c(d), c(c),
  c(b),
c(a)

for $x in //b//c, $y in $x/d



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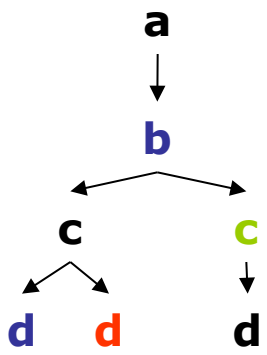
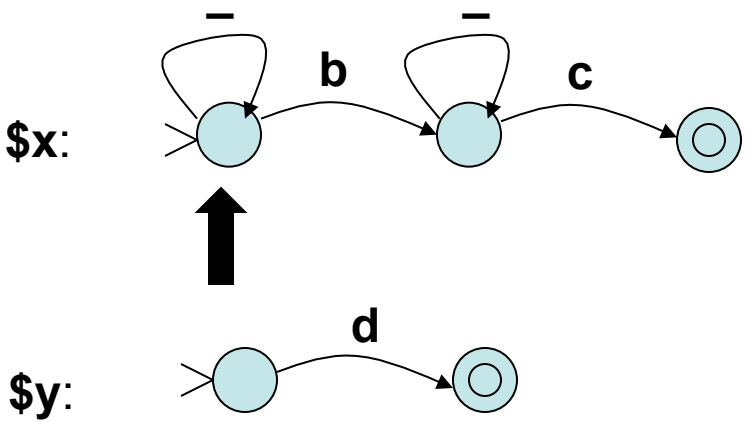


o(a),
  o(b),
    o(c), o(d), c(d), o(d), c(d), c(c),
    o(c), o(d), c(d), c(c),
  c(b),
c(a)

for $x in //b//c, $y in $x/d



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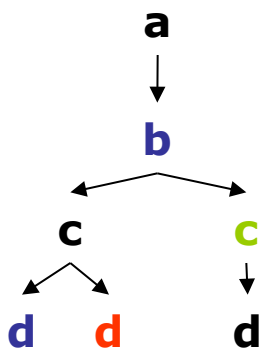

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    o(c), o(d), c(d), o(d), c(d), c(c),
    o(c), o(d), c(d), c(c),
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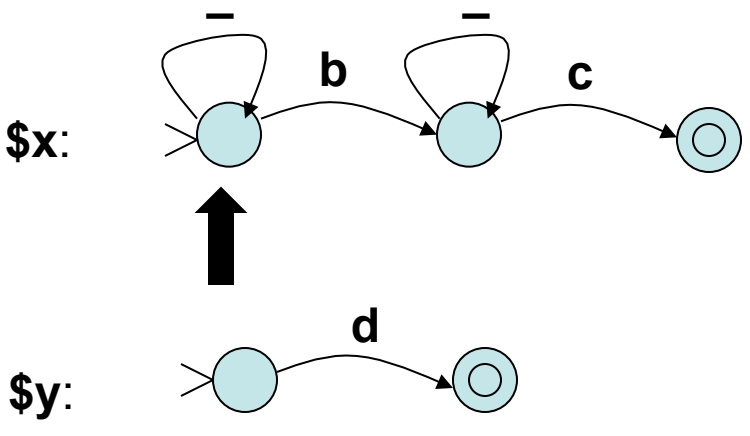
for $x in //b//c, $y in $x/d



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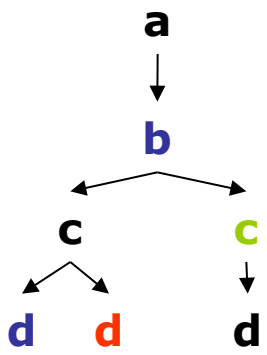

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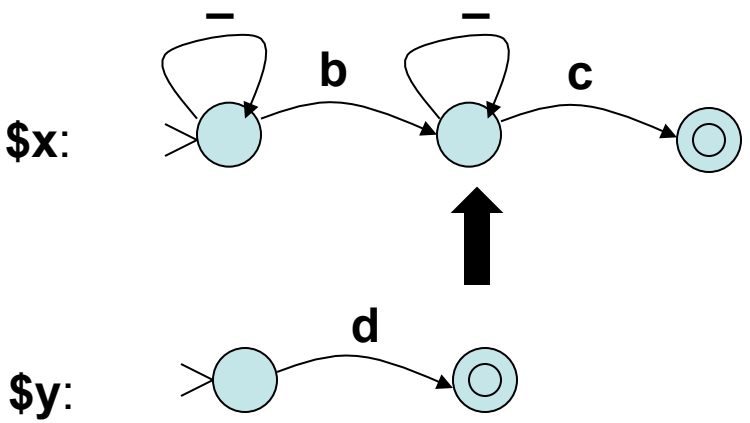

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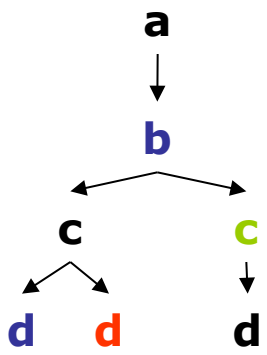

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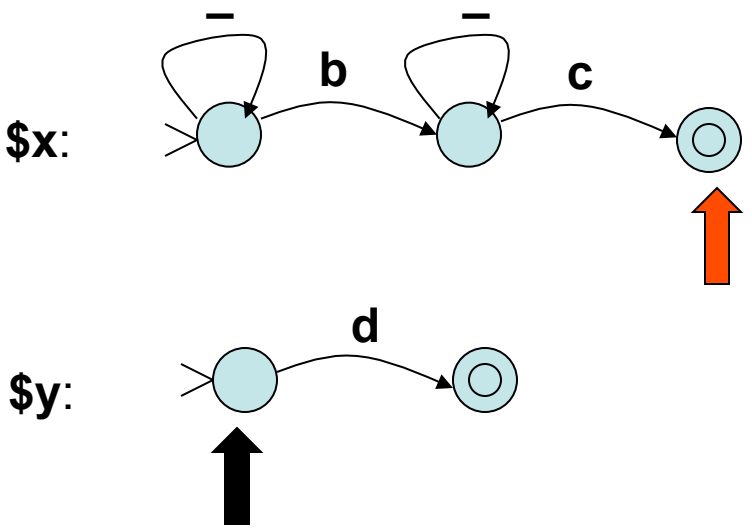
for $x in //b//c, $y in $x/d



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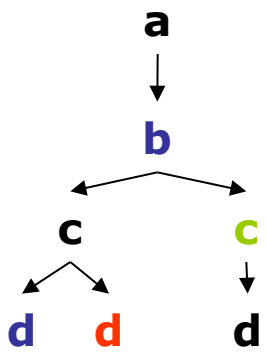

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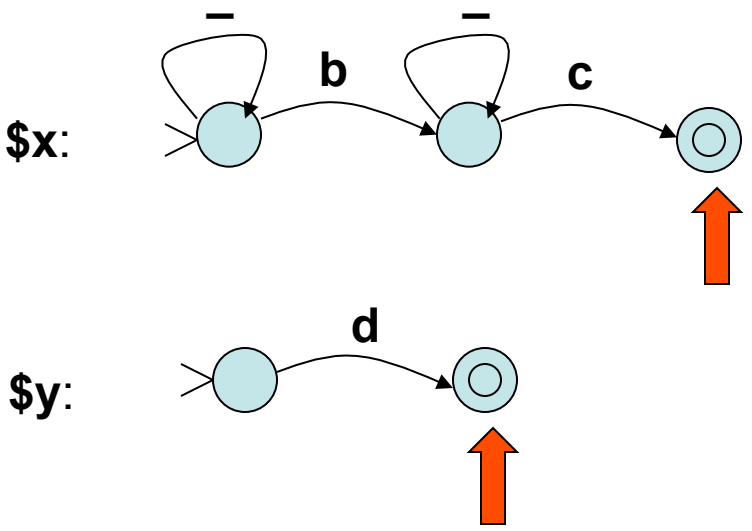
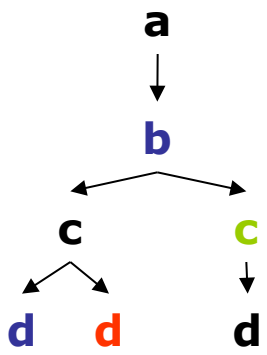


Need to reset automaton for $y

Matching XPaths Against Streams



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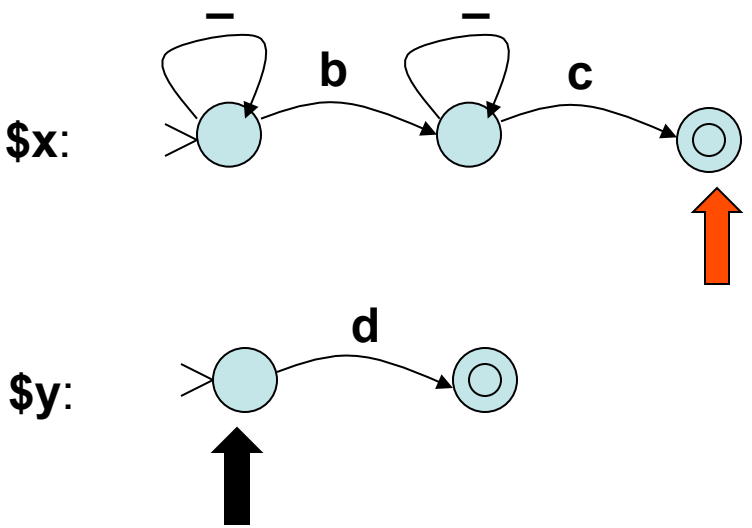

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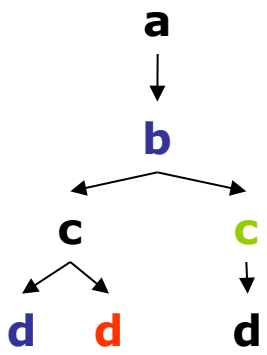

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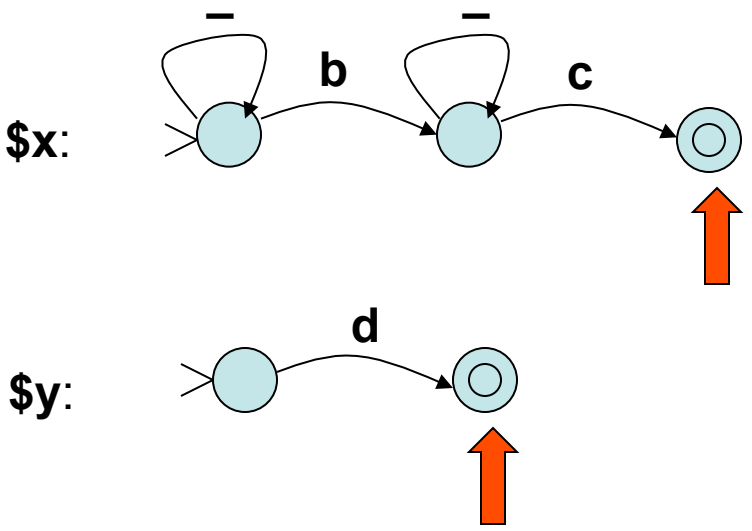

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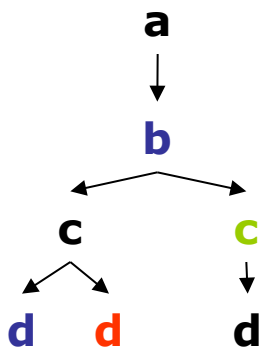

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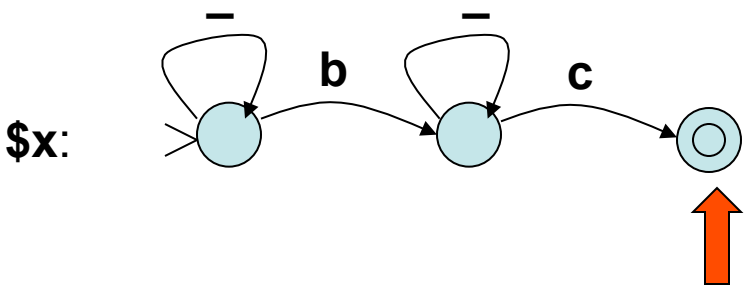
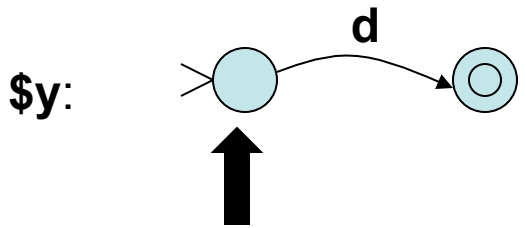
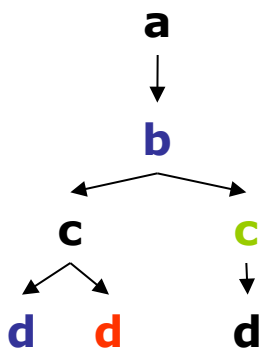
for $x in //b//c, $y in $x/d





Need to reset automaton for $x to state prior to reading black c element

Matching XPaths Against Streams



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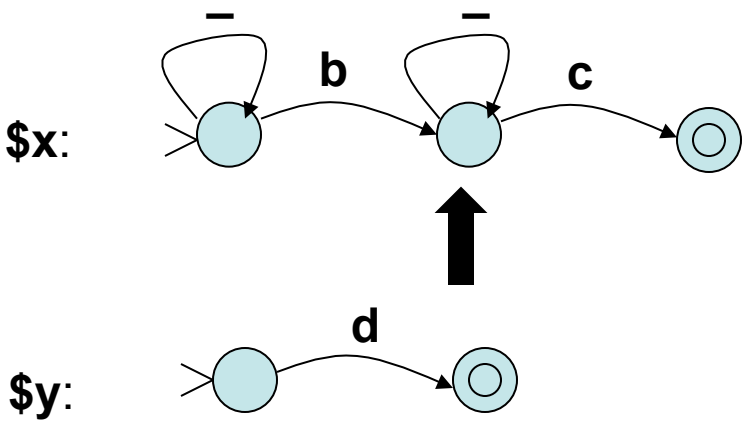

Automaton Extended with Stack

Let d be the transition function of automaton A. The corresponding extension of A with a stack is defined as follows:

current state	current event in stream	stack action	next state
Q	open(tag)	push(Q)	d(Q)
Q	close(tag)	Q' =pop()	Q'

Convince yourselves that the run of this automaton on the stream in the example corresponds to the intended sequence of states.

An additional use of PDAs, aside from parsing.

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Semantic Optimization

- Sometimes, we can translate away descendant computation.
- Consider the following DTD describing the structure of drug.xml

```
<!ELEMENT pharmacy (drug*)>
<!ELEMENT drug (name,price,notes?)>
```

- Then for all documents satisfying DTD:

for $x **in** $d//drug, $n **in** $x//name/text() is equivalent to
for $x **in** $d/drug, $n **in** $x/name/text()

Semantic Optimization As Typechecking

For all XML documents conforming to the DTD

```
<!ELEMENT pharmacy (drug*)>
<!ELEMENT drug (name,price,notes?)>
```

we can determine statically that

```
for $x in $d//drug, $m in $d/maker
```

returns the empty answer.

Roadmap

- Use of XQuery for Web Data Integration
- XQuery Evaluation Models
- Optimization
- Flavor of Standardization Issues
  - Equality in XQuery
- More on Optimization

Element Equality in XQuery

- Two kinds of equality:
  - "==" id-based (an element node is equal only to itself)
  - "=" value-based
- Value-based equality underwent several drafts,
- Initially (about one year into standardization process):
  text-centric point of view. XML elements are value-equal iff their text values are equal after stripping away the XML annotations.

  E.g. <a>f<c>oo</c> = <m>foo</m>
- Currently:
  XML elements are equal iff their corresponding trees are isomorphic

Id-based Element Equality

Let $x be bound to an XML tree. Then

<a>$x

creates a new XML tree (fresh node ids) and it is short for

<a>recursive copy of $x

Always true:

(<a>$x)/a/* = $x (value-based equality)

Always false:

(<a>$x)/a/* == $x (id-based equality)

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More on XQuery Optimization

- There are many ways to write the same query (i.e. there are many distinct XQuery expressions with identical semantics)
- Some of these expressions lead to cheaper execution than their counterparts.
- Goal of query optimization:
  given a query Q, find the optimal query Q' with identical semantics (we say that Q and Q' are equivalent)
- Basic test in query optimization: checking query equivalence
- The more expressive a language, the harder it is to test equivalence
- Various classes of XQueries have distinct complexity:

  PTIME (1), NP-complete (1), Π_2^P-complete (4), PSPACE-complete (1), EXPTIME-complete, undecidable

The UCSD Database Lab

- Main Focus: XML Query Optimization
- Check out the weekly DB Research Meeting
- Faculty
  - Victor Vianu
  - Yannis Papakonstantinou
  - Alin Deutsch

- San Diego SuperComputer Resaerchers
  - Ilkay Altintas
  - Amarnath Gupta

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