XML XPath XSLT XQuery

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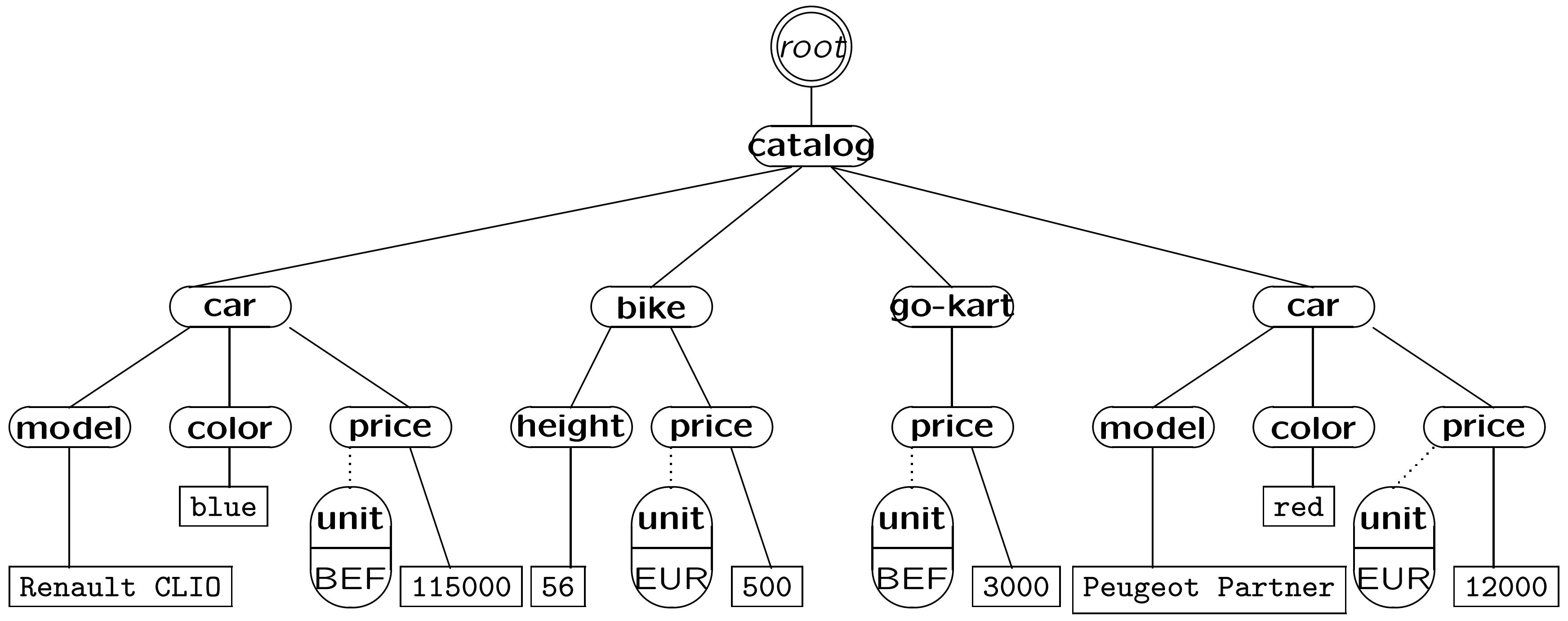
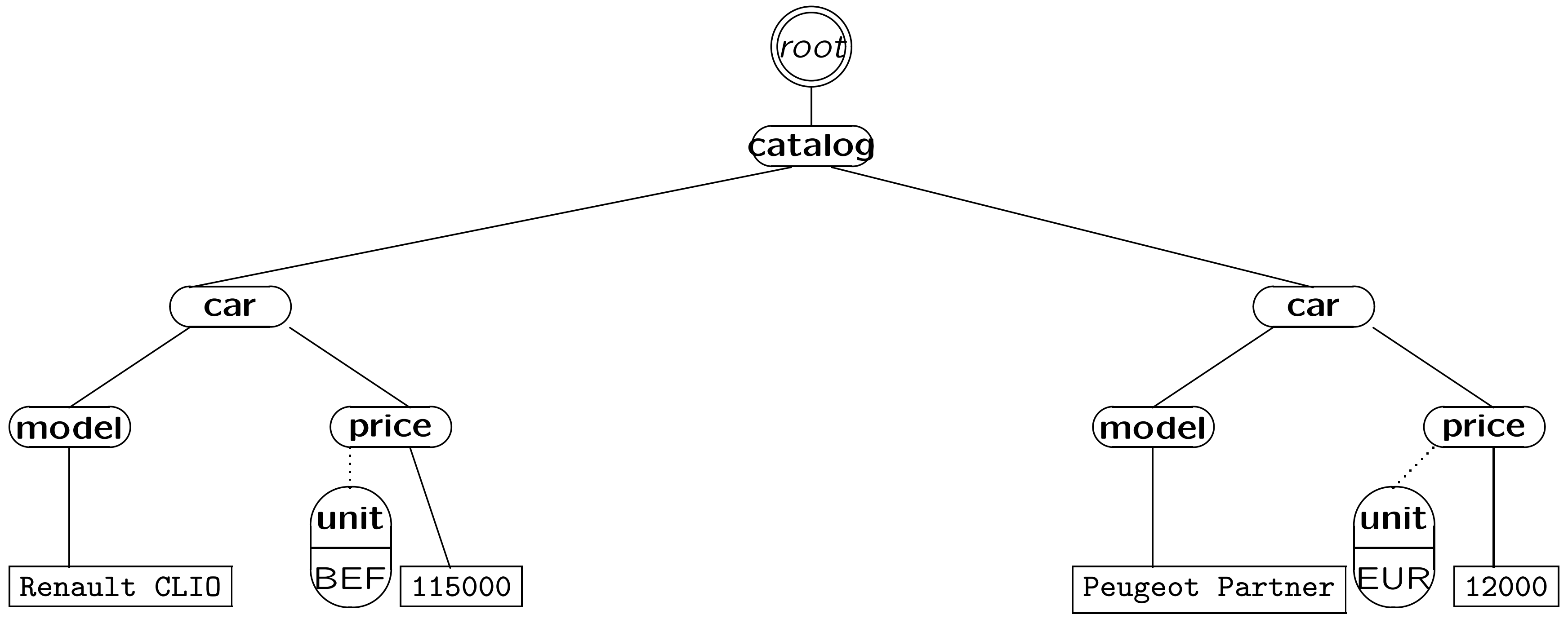
Why XML? Semistructured data

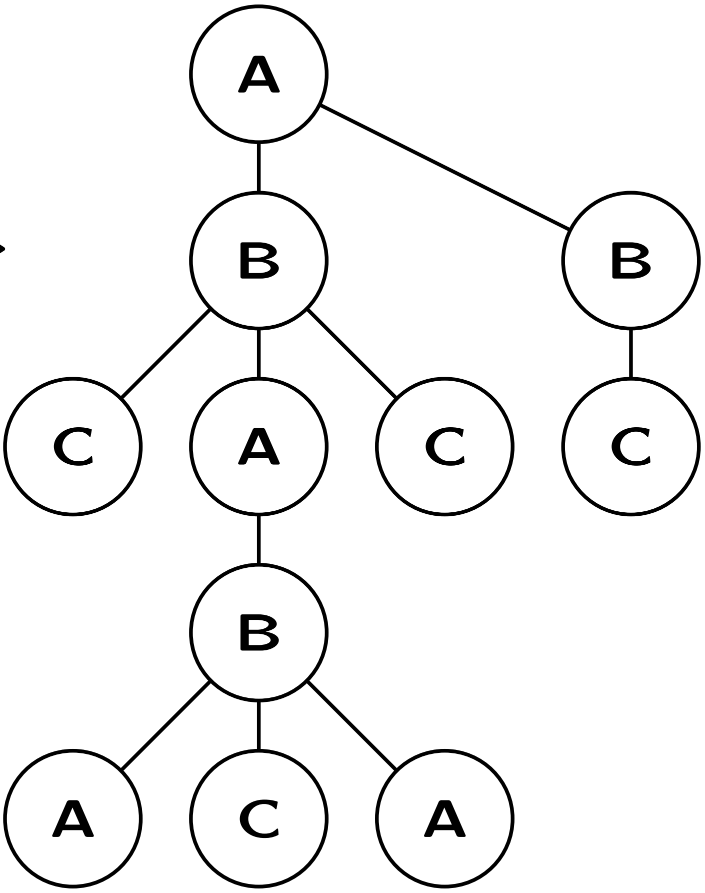


Querying: Get models and prices of all cars.



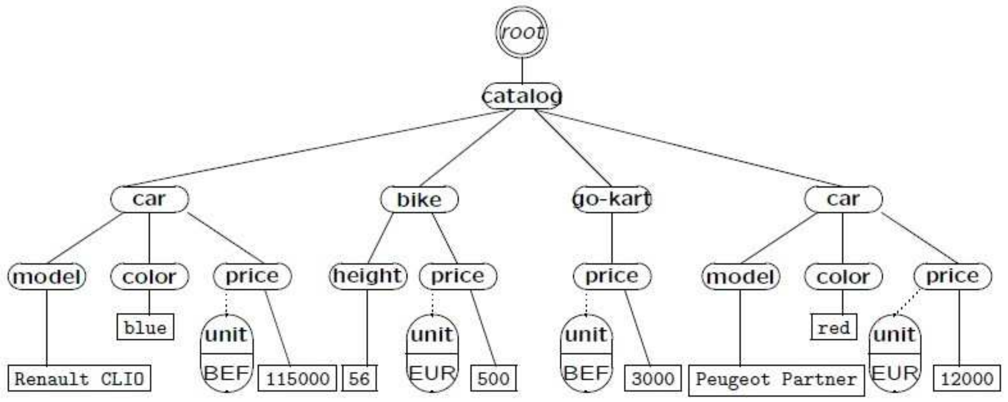
Text $\leftrightarrow$ Tree

```
<A>
 <B>
  <C/>
  <A>
   <B>
    <A/><C/><A/>
   </B>
  </A>
  <C/>
 </B>
 <B>
  <C/>
 </B>
</A>
```

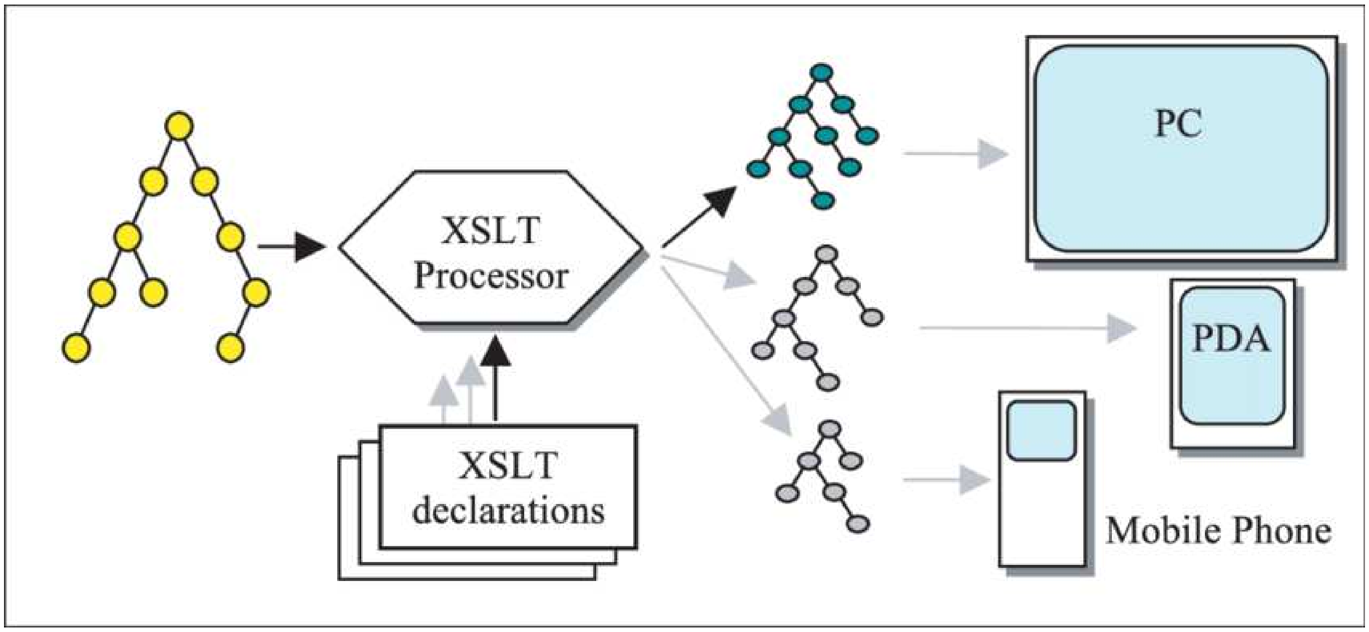


Text ↔ Tree

```
<?xml version="1.0"?>
<!DOCTYPE catalog
  SYSTEM "http://ssi.umh.ac.be/jefXML/cat.dtd">
<catalog>
   <car>
      <model>Renault CLIO</model>
      <color>blue</color>
      <price unit="BEF">115000</price>
   </car>
   <bike>
      <height>56</height>
      <price unit="EUR">500</price>
   </bike>
   <go-kart>
      <price unit="BEF">3000</price>
   </go-kart>
   <car>
      <model>Peugeot Partner</model>
      <color>red</color>
      <price unit="EUR">12000</price>
   </car>
</catalog>
```



Why XML? Separation of content and presentation



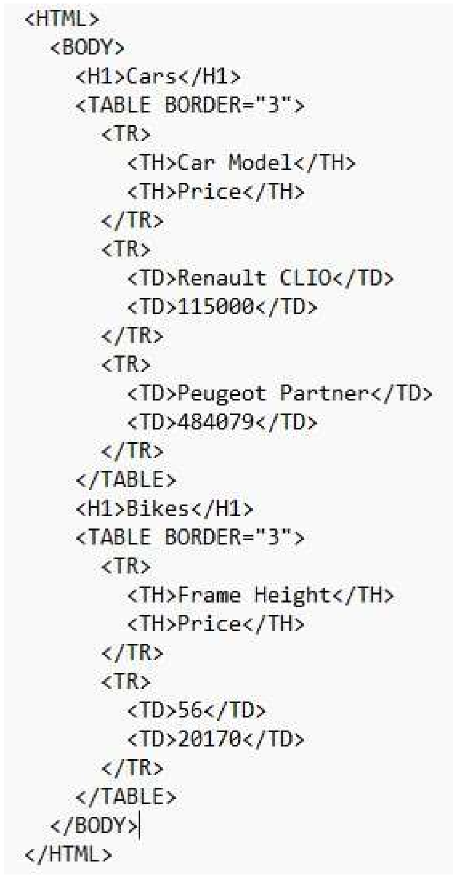
Source: Kurt Cagle: *Why XSLT and XQuery Are Coming Back.*

The Cagle Report, Published on June 19, 2020

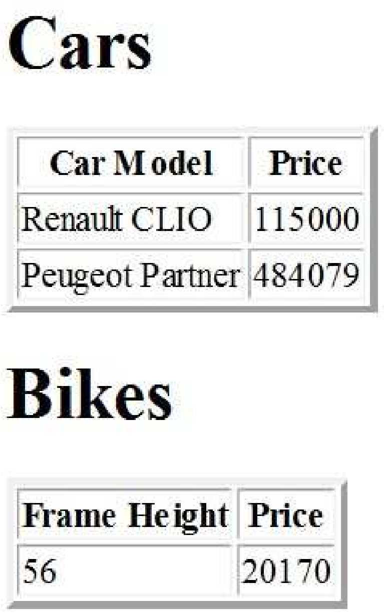
Separation of content and presentation

```
<?xml version="1.0"?>
<!DOCTYPE catalog
  SYSTEM "http://ssi.umh.ac.be/jefXML/cat.dtd">
<catalog>
   <car>
      <model>Renault CLIO</model>
      <color>blue</color>
      <price unit="BEF">115000</price>
   </car>
   <bike>
      <height>56</height>
      <price unit="EUR">500</price>
   </bike>
   <go-kart>
      <price unit="BEF">3000</price>
   </go-kart>
   <car>
      <model>Peugeot Partner</model>
      <color>red</color>
      <price unit="EUR">12000</price>
   </car>
</catalog>
```

$\overset{\text{XSLT}}{\rightsquigarrow}$



```
<HTML>
  <BODY>
    <H1>Cars</H1>
    <TABLE BORDER="3">
      <TR>
        <TH>Car Model</TH>
        <TH>Price</TH>
      </TR>
      <TR>
        <TD>Renault CLIO</TD>
        <TD>115000</TD>
      </TR>
      <TR>
        <TD>Peugeot Partner</TD>
        <TD>484079</TD>
      </TR>
    </TABLE>
    <H1>Bikes</H1>
    <TABLE BORDER="3">
      <TR>
        <TH>Frame Height</TH>
        <TH>Price</TH>
      </TR>
      <TR>
        <TD>56</TD>
        <TD>20170</TD>
      </TR>
    </TABLE>
  </BODY>
</HTML>
```



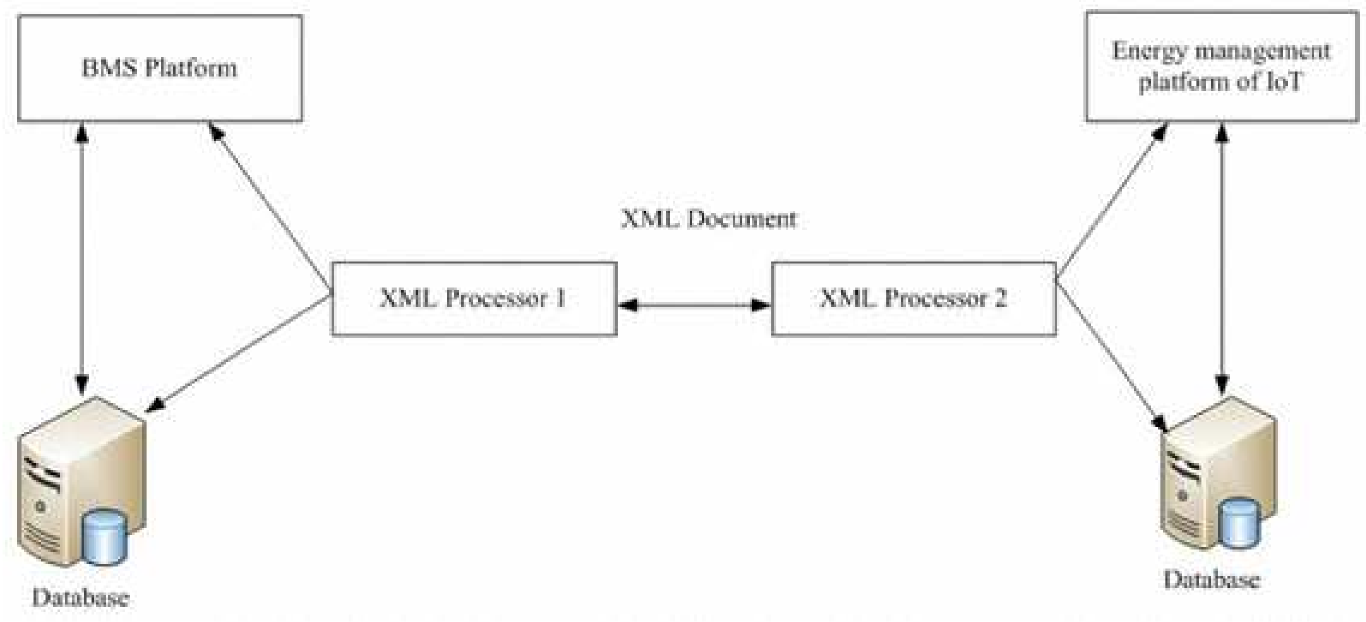
Cars

Car Model	Price
Renault CLIO	115000
Peugeot Partner	484079

Bikes

Frame Height	Price
56	20170

Why XML? Data exchange



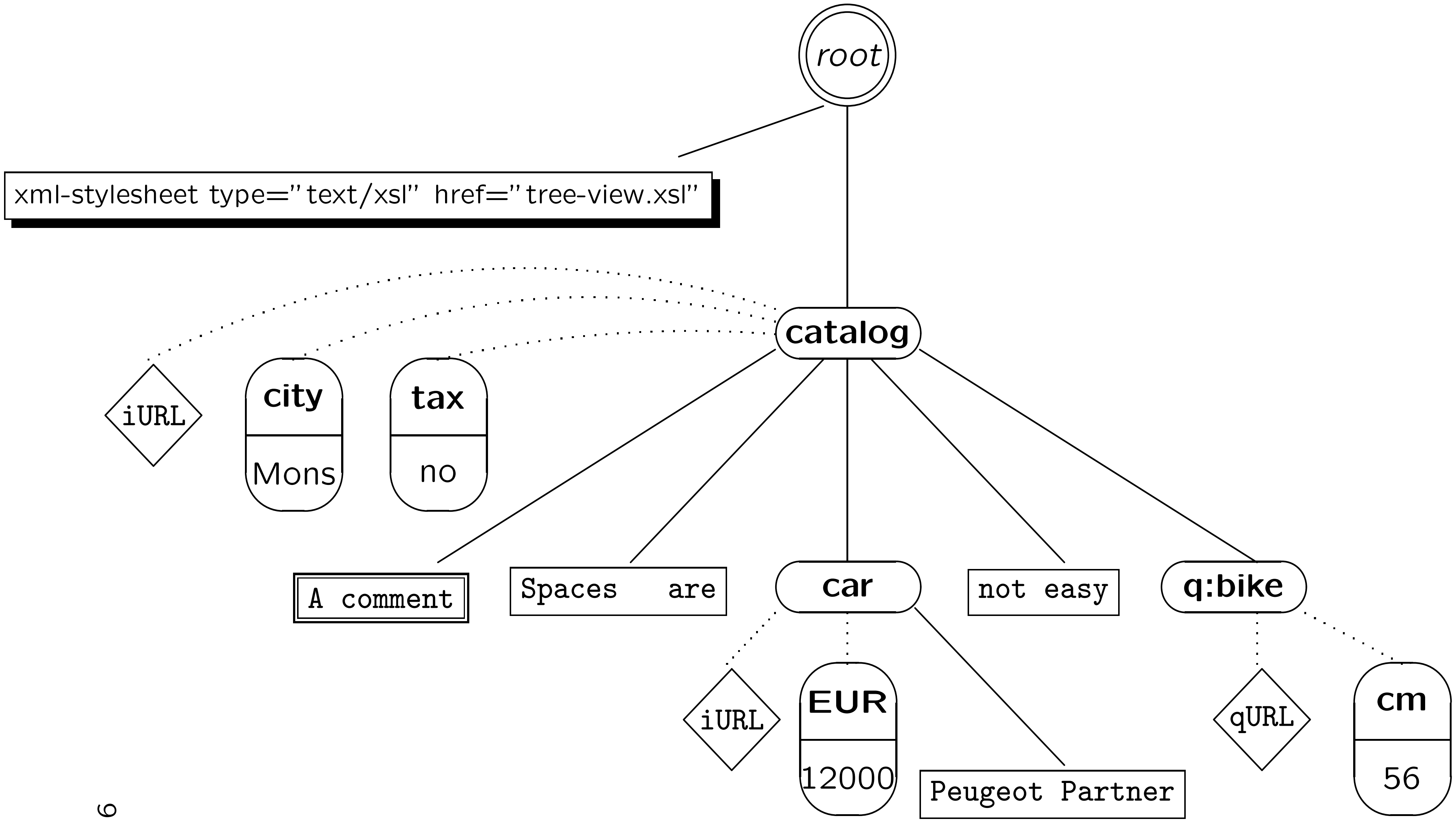
Source: Miao Yu, Guojun Yue, Jinguo Song, Xu Pang: *Research on intelligent city energy management based on Internet of things.* Clust. Comput. 22(Supplement): 8291-8300 (2019)

Well-Formed XML Document

```
<?xml version="1.0"?>
<?xml-stylesheet type="text/xsl"
                 href="tree-view.xsl"?>
<catalog tax="no" city="Mons"
         xmlns="iURL" xmlns:q="qURL">
  <!--A comment-->
  Spaces   are
  <car EUR="12000">Peugeot Partner</car>
  not easy
  <q:bike cm="56"/>
</catalog>
```

XML Trees

Seven types of node: element nodes, the root node, text nodes, attribute nodes, namespace nodes, processing instruction nodes, and comment nodes.


root
xml-stylesheet type="text/xsl" href="tree-view.xsl"
catalog
iURL
city
Mons
tax
no
A comment
Spaces   are
car
not easy
q:bike
iURL
EUR
12000
Peugeot Partner
qURL
cm
56

Hint 1 The XSLT and CSS stylesheets

```
tree-view.xsl
tree-view.css
```

available at

`http://skew.org/xml/stylesheets/treeview/html/`

transform any XML document into an HTML document showing the tree representation of the XML document. Simply download both stylesheets and add to your XML document a processing instruction

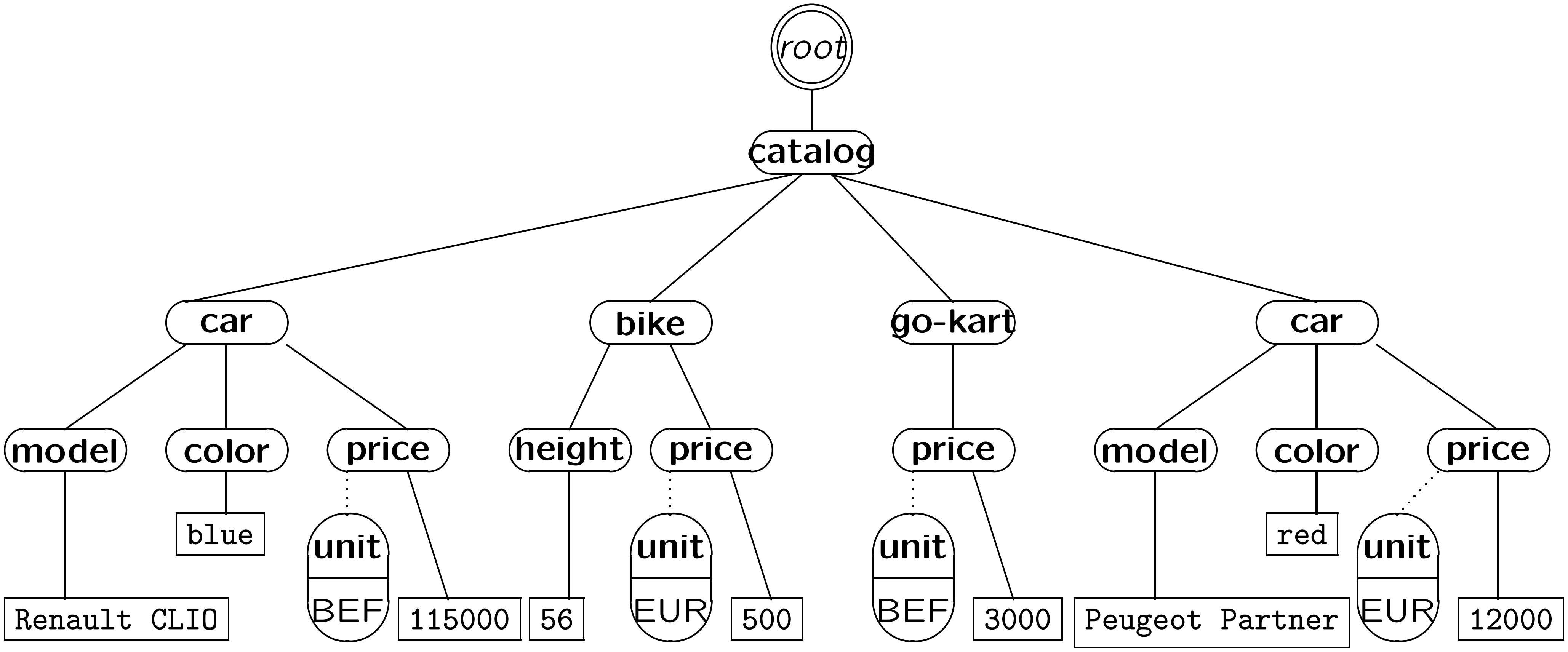
```
<?xml-stylesheet type="text/xsl"
                 href="tree-view.xsl"?>
```

to ask Microsoft Internet Explorer to do the transformation.

Valid XML Document

```
<!ELEMENT catalog (car|bike|go-kart)*>
<!ELEMENT car (model,color?,price)>
<!ELEMENT bike (height,price)>
<!ELEMENT go-kart (price)>
<!ELEMENT model (#PCDATA)>
<!ELEMENT color (#PCDATA)>
<!ELEMENT price (#PCDATA)>
<!ELEMENT height (#PCDATA)>
<!ATTLIST price unit (EUR|BEF) #REQUIRED>
```

```
<?xml version="1.0"?>
<!DOCTYPE catalog
  SYSTEM "http://ssi.umh.ac.be/jefXML/cat.dtd">
<catalog>
   <car>
      <model>Renault CLIO</model>
      <color>blue</color>
      <price unit="BEF">115000</price>
   </car>
   <bike>
      <height>56</height>
      <price unit="EUR">500</price>
   </bike>
   <go-kart>
      <price unit="BEF">3000</price>
   </go-kart>
   <car>
      <model>Peugeot Partner</model>
      <color>red</color>
      <price unit="EUR">12000</price>
   </car>
</catalog>
```


root
catalog
car
bike
go-kart
car
model
color
price
height
price
price
model
color
price
blue
unit
BEF
unit
EUR
unit
BEF
red
unit
EUR
Renault CLIO
115000
56
500
3000
Peugeot Partner
12000

Location Step

A *location step* selects nodes relative to the *context node*; it is of the form:

axis::*node-test*[*predicate*]*

For example,

`child::price[attribute::unit="EUR"]`

selects the `price` element children of the context node that have a `unit` attribute with value `EUR`.

Location Path

A sequence of one or more *location steps* separated by /, and optionally preceded by /.

For example,

`child::*/child::color`

selects all `color` grandchildren of the context node.

Axes

The thirteen axes are:

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

Node Tests

```
node()  mylabel    *
text()  comment()
processing-instruction()
```

Attribute Nodes and Namespace Nodes Precede Their Element Node

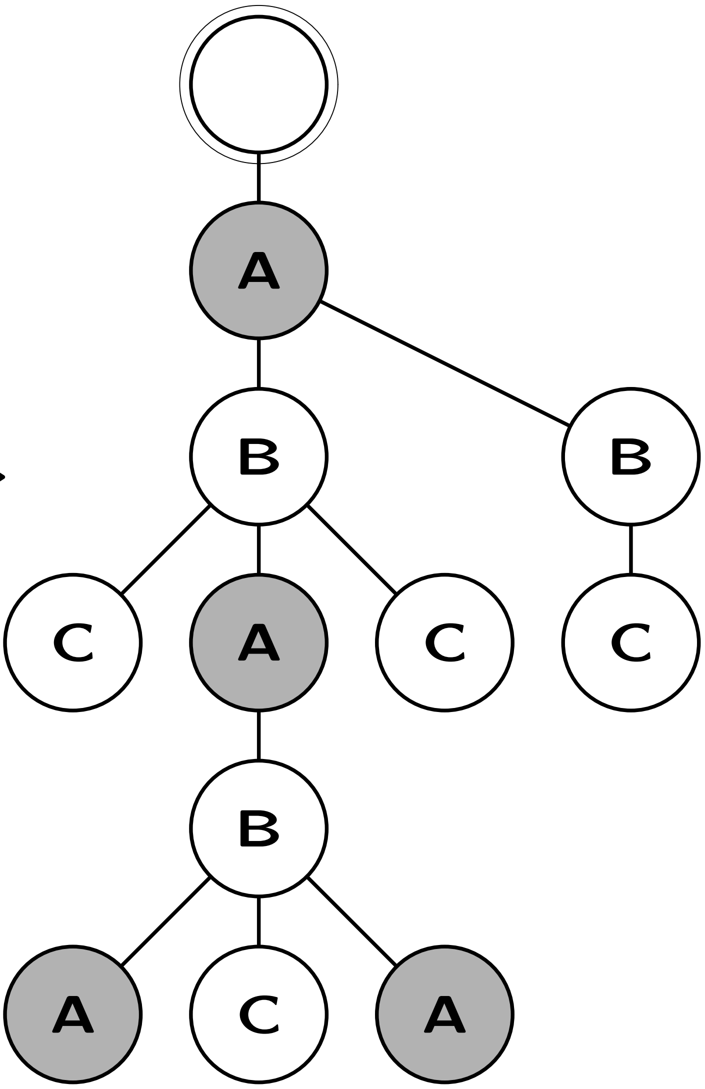
Because the standard says:

> [. . .] if the context node is an attribute node or namespace node, the preceding-sibling axis is empty.

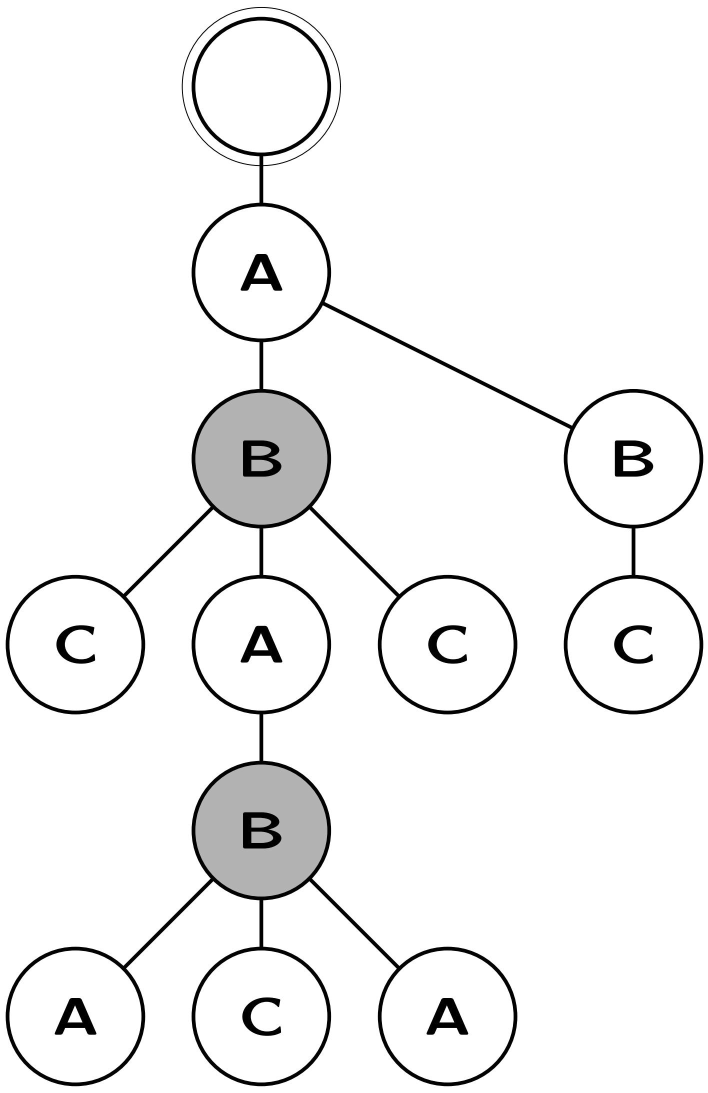
Different Versions of XPath

- XPath 1.0 (1999)
  `http://www.w3.org/TR/1999/REC-xpath-19991116`
- XPath 2.0, Second Edition (2010)
- XPath 3.0 (2014)
- XPath 3.1 (2017)
  `https://www.w3.org/TR/xpath-3/`

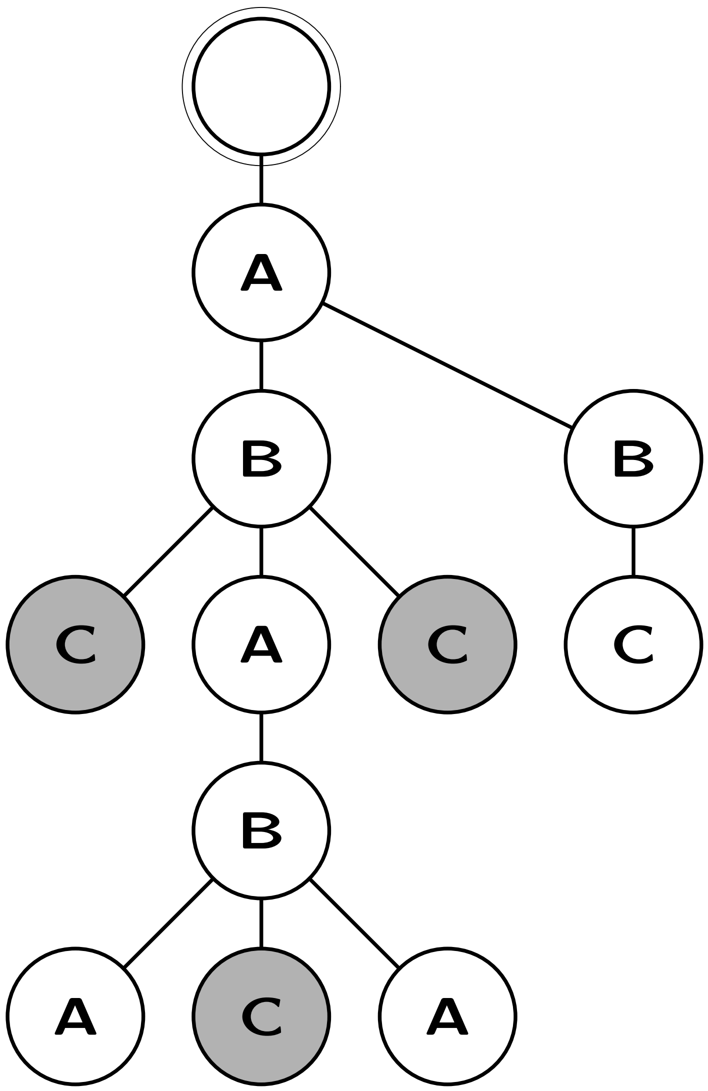
```
<A>
 <B>
  <C/>
  <A>
   <B>
    <A/><C/><A/>
   </B>
  </A>
  <C/>
 </B>
 <B>
  <C/>
 </B>
</A>
```



/descendant::A



`/descendant::A/parent::B`



`/descendant::A/parent::B/child::C`

Predicates

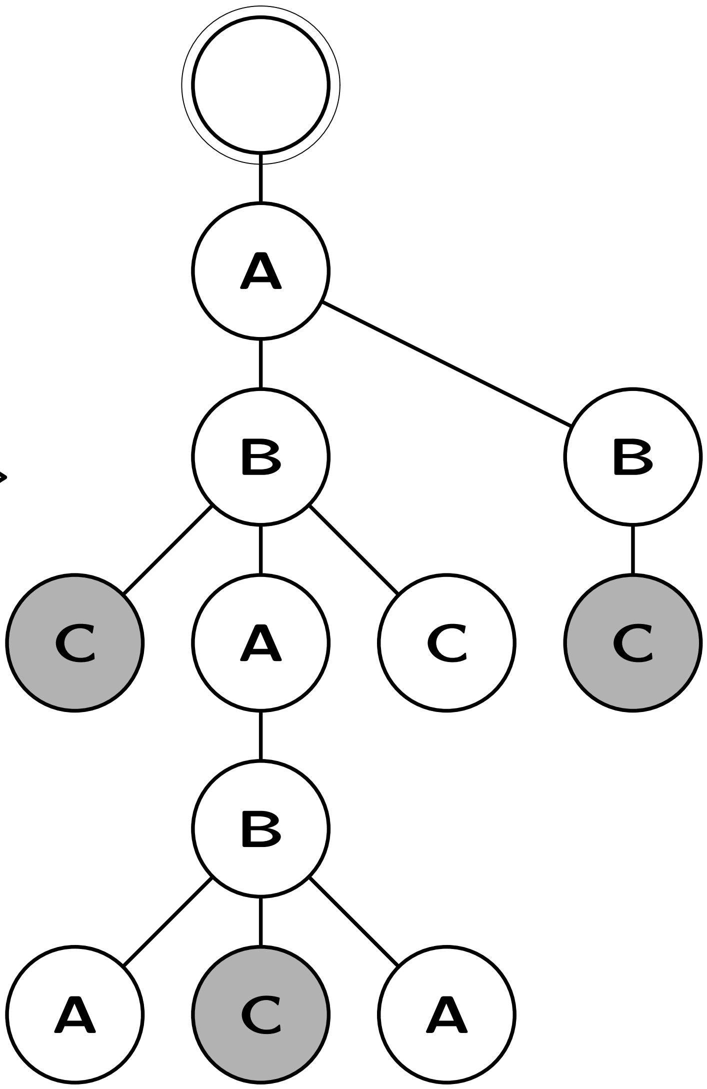
- `child::car[descendant::color]`
- `car[color='blue']`
- `car[count(color)>1]`
- `car[not(starts-with(model,'R'))]`
- `descendant::car[position()=2]` can be abbreviated as `descendant::car[2]`
- `descendant::car[position()=last()-1]`
-
```
descendant::car[(price*40.3399>500000 and
                     price/@unit='EUR')
                 or (price>500000 and
                     price/@unit='BEF')]
```
-
```
descendant::car[(price[@unit='BEF']>500000)
      or (40.3399*price[@unit='EUR']>500000)]
```
- `catalog[sum(*/price)>999999]`

Abbreviations

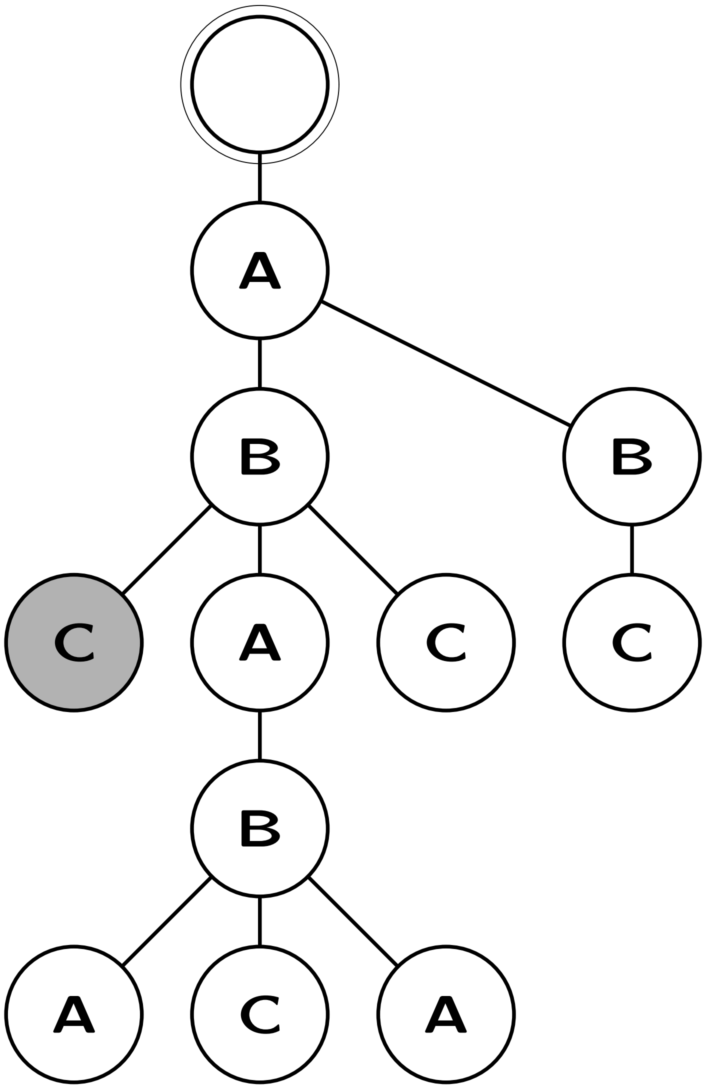
Shorthand	Unabbreviated syntax
can be omitted	`child::`
`//`	`/descendant-or-self::node()/`
`@`	`attribute::`
`.`	`self::node()`
`..`	`parent::node()`

Pitfall

```
<A>
 <B>
  <C/>
  <A>
   <B>
    <A/><C/><A/>
   </B>
  </A>
  <C/>
 </B>
 <B>
  <C/>
 </B>
</A>
```

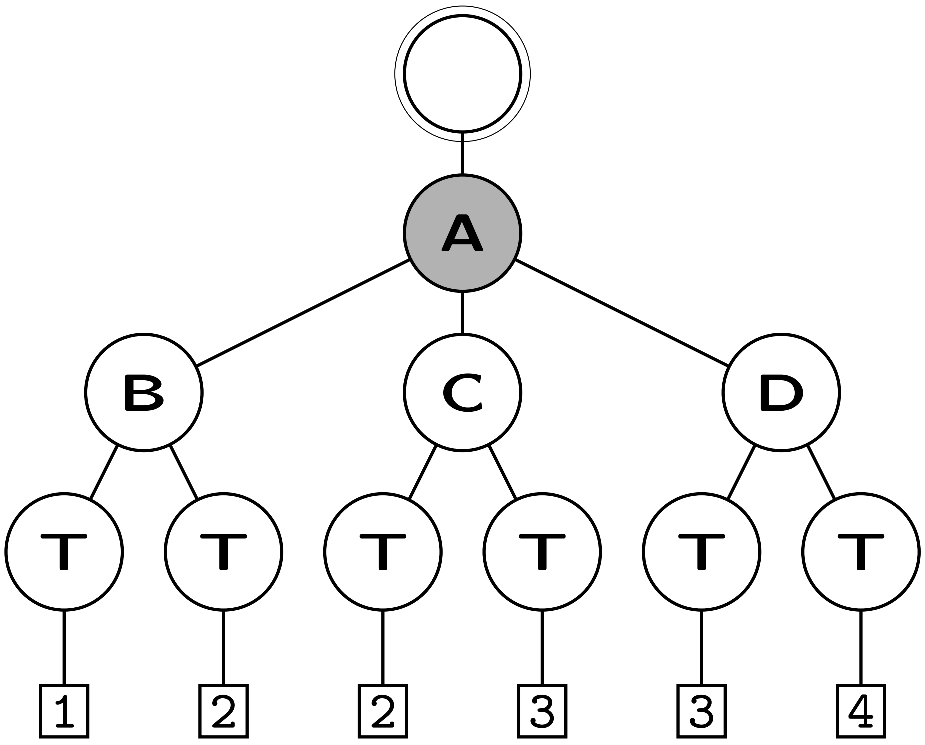


`//C[1]`

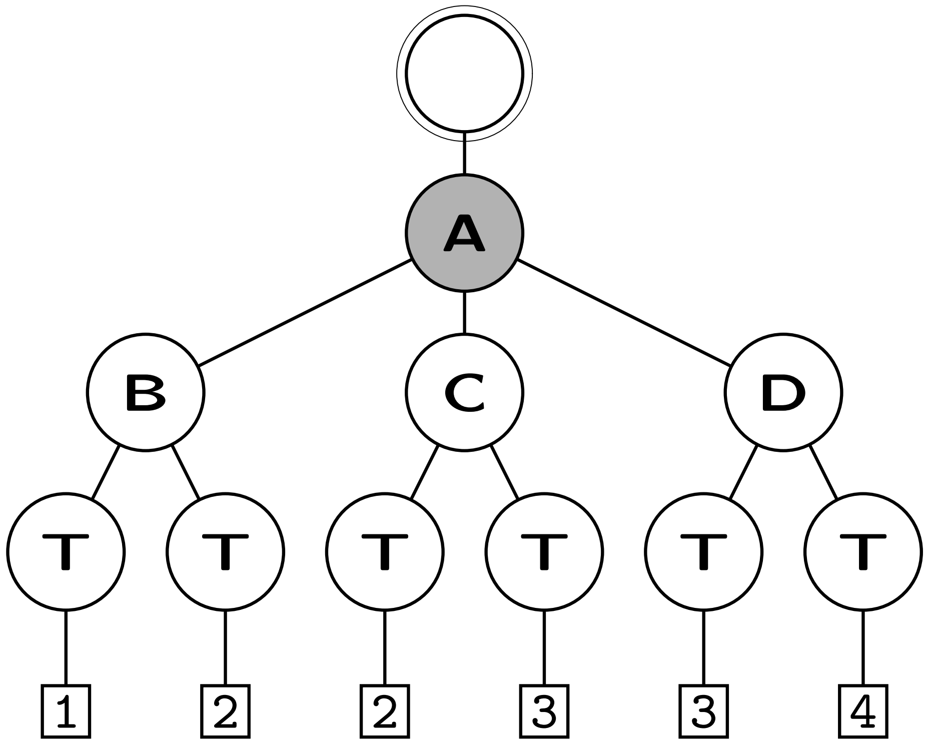


`(//C)[1]`

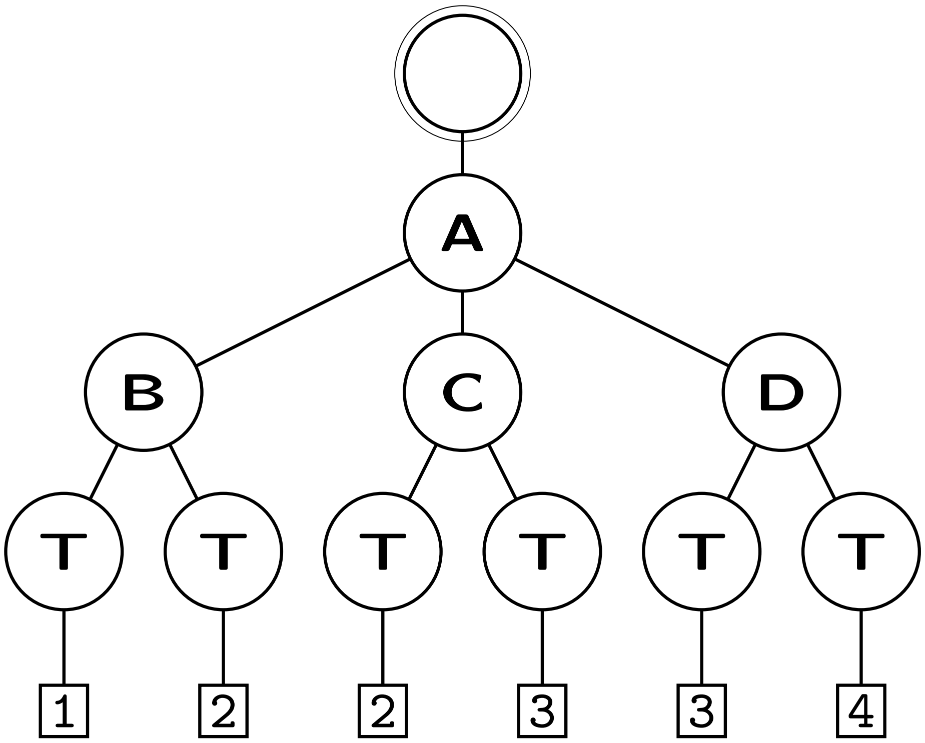
Equality



`/A[B/T=C/T]`



/A[C/T=D/T]



/A[B/T=D/T]

Exercice films.xml

```
<?xml version="1.0"?>
<!DOCTYPE filmotheque SYSTEM "films.dtd">
<filmotheque>
<ACTEURS>
 <acteur id="IC" gendre="M" naissance="1949" mort="1990">Ian Charleson
      </acteur>
 <acteur id="CC" gendre="F" naissance="1949">Cheryl Campbell</acteur>
 <acteur id="NH" gendre="M" naissance="1949">Nigel Havers</acteur>
 <acteur id="BM" gendre="M" naissance="1950">Bill Murray</acteur>
 <acteur id="MR" gendre="F" naissance="1959">Miranda Richardson</acteur>
 <acteur id="JM" gendre="F" naissance="1960">Julianne Moore</acteur>
</ACTEURS>
<FILMS>
   <film annee="1981">
      <titre >Chariots of Fire</titre>
      <directeur naissance="1936">Hugh Hudson</directeur>
      <cast>
         <acteur id="IC"/><acteur id="CC"/><acteur id="NH"/>
      </cast>
   </film>
   <film annee="1980">
      <titre>McVicar</titre>
      <directeur naissance="1936">Tom Clegg</directeur>
      <cast>
         <acteur id="CC"/><acteur id="BM"/>
      </cast>
   </film>
   <film annee="1987">
      <titre >Empire of the Sun</titre>
      <directeur naissance="1946">Steven Spielberg</directeur>
      <cast>
         <acteur id="MR"/><acteur id="NH"/>
      </cast>
   </film>
</FILMS>
</filmotheque>
```

```
<!-- This file is called films.dtd -->
<!ELEMENT filmotheque (ACTEURS, FILMS)>
<!ELEMENT ACTEURS (acteur)*>
<!ELEMENT FILMS (film)*>
<!ELEMENT film (titre, directeur, cast)>
   <!ATTLIST film annee CDATA #REQUIRED>
<!ELEMENT cast (acteur)*>
<!ELEMENT acteur (#PCDATA)>
   <!ATTLIST acteur id CDATA #REQUIRED>
   <!ATTLIST acteur naissance CDATA #IMPLIED>
   <!ATTLIST acteur mort CDATA #IMPLIED>
   <!ATTLIST acteur gendre CDATA #IMPLIED>
<!ELEMENT titre (#PCDATA)>
<!ELEMENT directeur (#PCDATA)>
   <!ATTLIST directeur naissance CDATA #REQUIRED>
   <!ATTLIST directeur mort CDATA #IMPLIED>
```

Question 1 Écrivez une expression **XPath** qui rend les titres des films dont le régisseur est né en 1936. Il y en a deux :

```
<titre>Chariots of Fire</titre>
<titre>McVicar</titre>
```

Question 2 Écrivez une expression **XPath** qui rend les titres des films dans lesquels a joué Nigel Havers. L'expression doit rester valide si on change l'identifiant de Nigel Havers (par exemple, si on remplaçait NH par NiHa). Il y en a deux :

```
<titre>Chariots of Fire</titre>
<titre>Empire of the Sun</titre>
```

Question 3 Traduisez l'expression XPath suivante en français simple.

```
//film[cast/acteur/@id=/filmotheque/ACTEURS/acteur[@mort]/@id]/titre
```

Question 4 Écrivez un programme **XSLT** qui rend tous les noms d'acteur et, pour chaque acteur, les titres de tous les films dans lesquels il a joué. L'output est formaté comme un document XML, comme suit :

```
<ACTEURS>
<acteur>
   <nom>Ian Charleson</nom>
   <FILMS>
      <film>Chariots of Fire</film>
   </FILMS>
</acteur>
<acteur>
   <nom>Cheryl Campbell</nom>
   <FILMS>
      <film>Chariots of Fire</film>
      <film>McVicar</film>
   </FILMS>
</acteur>
<acteur>
   <nom>Nigel Havers</nom>
   <FILMS>
      <film>Chariots of Fire</film>
      <film>Empire of the Sun</film>
   </FILMS>
</acteur>

     ⋮

<acteur>
   <nom>Julianne Moore</nom>
   <FILMS></FILMS>
</acteur>
</ACTEURS>
```

Exercice ListOfLists

```
<?xml version="1.0" encoding="utf-8"?>

<!DOCTYPE ListOfLists [
<!ELEMENT ListOfLists (list)*>
<!ELEMENT list (e)*>
<!ELEMENT e (#PCDATA)>
<!ATTLIST e a CDATA #REQUIRED>
]>

<ListOfLists>
<list><e a="1"/><e a="2"/><e a="3"/></list>
<list><e a="1"/><e a="2"/><e a="4"/></list>
<list><e a="22"/><e a="11"/><e a="44"/></list>
<list><e a="1"/><e a="1"/><e a="1"/><e a="7"/></list>
</ListOfLists>
```

Ce document XML encode:

$$((1,2,3),(1,2,4),(22,11,44),(1,1,1,7))$$

Écrivez des expressions XPath pour les problèmes suivants:

- Renvoyer les listes qui ont le plus d'éléments.

  $\rightsquigarrow$

  ```
  <list><e a="1"/><e a="1"/><e a="1"/><e a="7"/></list>
  ```

  – en utilisant count et max;

  – en utilisant count mais sans utiliser max.

- Renvoyer les listes qui ont le plus d'éléments *distincts*, sans utiliser `distinct-values`.

  $\rightsquigarrow$

  ```
  <list><e a="1"/><e a="2"/><e a="3"/></list>
  <list><e a="1"/><e a="2"/><e a="4"/></list>
  <list><e a="22"/><e a="11"/><e a="44"/></list>
  ```

- Renvoyer les listes qui n'ont aucun élément en commun avec une autre liste.

  $\rightsquigarrow$

  ```
  <list><e a="22"/><e a="11"/><e a="44"/></list>
  ```

- Renvoyer les listes qui ne sont pas triées par ordre croissant.

  $\rightsquigarrow$

  ```
  <list><e a="22"/><e a="11"/><e a="44"/></list>
  ```

Exercice Catalog

- Expliquez la différence entre les trois requêtes suivantes:

  `/catalog/car[.="blue"]`

  `/catalog/car[text()="blue"]`

  `/catalog/car[descendant::text()="blue"]`

- Quel est le résultat des requêtes suivantes sur le catalog?

  `/*[descendant::color != descendant::color]`

  et

  `/*[descendant::bike != descendant::bike]`

XSL Stylesheet

A *template rule* has the form:

```
<xsl:template match="the match pattern">
   the template
</xsl:template>
```

An XSL *stylesheet* is a family of such template rules.

XSLT Processing Model

$$\text{XML document} + \text{XSL stylesheet} \xrightarrow{\text{xslt}} \text{result}$$

The xslt program can be understood as follows:

```
program xslt
   procedure process(aNode)
   begin
   find the template rule with pattern
           that best matches aNode
   execute the template
           with aNode as the current node
   end
begin
process(theRootNode)
end
```

Matching

The *match pattern* is a restricted location path.

A pattern p is defined to *match* a node n if and only if there is a possible context node c such that when the pattern p is evaluated relative to c, the node n is a member of the resulting node-set.

	`match=`				
	`"node()"`	`"*"`	`"@*"`	`"/"`	`"text()"`
root	–	–	–	+	–
element	+	+	–	–	–
text	+	–	–	–	+
comment	+	–	–	–	–
processing -instruction	+	–	–	–	–
attribute	–	–	+	–	–
namespace	–	–	–	–	–

Executing the Template

Typically the template contains one or more of the following elements:

- `<xsl:apply-templates select="`*node-set*`"/>`

  for each node n in *node-set*, process(*n*) ,

- `<xsl:copy-of select="`*node-set*`"/>`

- `<xsl:value-of select="`*node-set*`"/>`
  Create a text node in the result tree. The text node is obtained by converting *node-set* into a string.

Built-In Template Rules

```
<xsl:template match="/|*">
   <xsl:apply-templates/>
</xsl:template>

<xsl:template match="text()|@*">
  <xsl:value-of select="."/>
</xsl:template>

<xsl:template
 match="processing-instruction()|comment()"/>
```

Illustration of Built-In Template Rules

```
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"/>
```

$\leadsto$

```
Renault CLIOblue115000565003000Peugeot Partnerred12000
```

Priority Processing

```
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
   <xsl:template match="/">
      <HTML>
      <xsl:apply-templates select="//car"/>
      </HTML>
   </xsl:template>
   <xsl:template match="car[price>99999]"
                 priority="2">
      <FONT COLOR="red">
      <xsl:value-of select="model"/>
      </FONT>
   </xsl:template>
   <xsl:template match="car[price>10000]"
                 priority="1">
      <FONT COLOR="green">
      <xsl:value-of select="model"/>
      </FONT>
   </xsl:template>
   <xsl:template match="car"/>
</xsl:stylesheet>
```

Multiple Processing

```
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
   <xsl:template match="/">
      <HTML>
      <xsl:apply-templates select="//car"
                           mode="theblues"/>
      <xsl:apply-templates select="//car"
                           mode="blackout"/>
      </HTML>
   </xsl:template>
   <xsl:template match="car" mode="theblues">
      <FONT COLOR="blue">
      <xsl:value-of select="."/>
      </FONT>
   </xsl:template>
   <xsl:template match="car" mode="blackout">
      <FONT COLOR="black">
      <xsl:value-of select="."/>
      </FONT>
   </xsl:template>
</xsl:stylesheet>
```

Context and Current Node

Context node: `self::node()`
Current node: `current()`, new in XSLT

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
 version="1.0">

  <xsl:template match="/">
   <xsl:apply-templates
    select="//price/@unit"/>
  </xsl:template>

  <xsl:template match="@unit">
   <BR/>
   <xsl:value-of select=
    "count(/catalog/*[price/@unit=current()])"/>
   vehicle prices are expressed in
   <xsl:value-of select="current()"/>
  </xsl:template>

</xsl:stylesheet>
```

$\leadsto$

```
2 vehicle prices are expressed in BEF
2 vehicle prices are expressed in EUR
2 vehicle prices are expressed in BEF
2 vehicle prices are expressed in EUR
```

Eliminating Duplicates

```
<xsl:stylesheet
xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
 version="1.0">

  <xsl:template match="/">
    <xsl:apply-templates
     select=
"//price/@unit[not(.=preceding::*/@unit)]"/>
  </xsl:template>

  ...

</xsl:stylesheet>
```

Variables

```
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform">

<xsl:template match="catalog">
 <xsl:variable name="eurtobef" select=
  "round(40.3399*sum(.//price[@unit='EUR']))"/>

 <xsl:variable name="bef" select=
  "sum(.//price[@unit='BEF'])"/>

 <xsl:value-of select="$eurtobef+$bef"/>
</xsl:template>

</xsl:stylesheet>
```

Creating Element and Attribute Nodes

The desired result:

```
<LIST-OF-CARS>
  <Renault-CLIO prix="115000"/>
  <Peugeot-Partner prix="12000"/>
</LIST-OF-CARS>
```

The stylesheet:

```
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
<xsl:template match="/">
 <xsl:element name="LIST-OF-CARS">
      <xsl:apply-templates select="//car"/>
 </xsl:element>
</xsl:template>

<xsl:template match="car">
 <xsl:variable
         name="var"
         select="translate(./model,' ','-')"/>
 <xsl:element name="$var">
      <xsl:attribute name="prix">
           <xsl:value-of select="price"/>
      </xsl:attribute>
 </xsl:element>
</xsl:template>
</xsl:stylesheet>
```

Elaborated Example

```
<xsl:stylesheet version="1.0"
xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
<xsl:template match="/">
            <HTML>
            <BODY>
            <H1>Cars</H1>
            <TABLE BORDER="3">
            <TR><TH>Car Model</TH>
                <TH>Price</TH></TR>
   <xsl:apply-templates select="//car"/>
            </TABLE>
            <H1>Bikes</H1>
            <TABLE BORDER="3">
            <TR><TH>Frame Height</TH>
                <TH>Price</TH></TR>
   <xsl:apply-templates select="//bike"/>
            </TABLE>
            </BODY>
            </HTML>
</xsl:template>
```

```
<xsl:template match="car">
               <TR><TD>
   <xsl:value-of select="model"/>
               </TD><TD>
   <xsl:apply-templates select="price"/>
               </TD></TR>
</xsl:template>

<xsl:template match="bike">
               <TR><TD>
   <xsl:value-of select="height"/>
               </TD><TD>
   <xsl:apply-templates select="price"/>
               </TD></TR>
</xsl:template>

<xsl:template match="price[@unit='BEF']">
   <xsl:value-of select="."/>
</xsl:template>

<xsl:template match="price[@unit='EUR']">
   <xsl:value-of select="round(40.3399*.)"/>
</xsl:template>
</xsl:stylesheet>
```

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```
<HTML>
  <BODY>
    <H1>Cars</H1>
    <TABLE BORDER="3">
      <TR>
        <TH>Car Model</TH>
        <TH>Price</TH>
      </TR>
      <TR>
        <TD>Renault CLIO</TD>
        <TD>115000</TD>
      </TR>
      <TR>
        <TD>Peugeot Partner</TD>
        <TD>484079</TD>
      </TR>
    </TABLE>
    <H1>Bikes</H1>
    <TABLE BORDER="3">
      <TR>
        <TH>Frame Height</TH>
        <TH>Price</TH>
      </TR>
      <TR>
        <TD>56</TD>
        <TD>20170</TD>
      </TR>
    </TABLE>
  </BODY>
</HTML>
```