XML & DTDs

csc343, Introduction to Databases
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Introduction

- The relational model is very rigid:
  - Everything must be a table.
  - The schema must be defined in advance.
  - Everything must conform to the schema.
- Relational DBMSs exploit this to give us data we can count on and efficient queries.
- But some data doesn't fit the model well. For example, we may have
  - missing information, and
  - indeterminate quantities.

HTML to XML

- XML grew out of HTML, and is intentionally similar:
  - Tags and attributes
  - Tree-structured format
- But there are important differences:
  - XML data must be well-formed.
  - You define your own tags and attributes.
  - These describe the *meaning* of the data, and imply nothing about its presentation.

  - "XML was designed to *carry* data;
    HTML was designed to *display* data."

What's XML for?

- XML is great for
  - Recording data that software needs.
  - Exchange of information between pieces of software.
- XML is said to be "self-describing".
  - Schema-like information is part of the data itself.
  - Example:

```
<student stnum="1234" name="Cindylou Who">
  <address>
    <street>99 Alfalfa Way</street>
    <city>Whoville</city>
  </address>
</student>
```

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Well-formed vs valid XML

- Well-formed XML
  - Just need a single *root* element and proper *nesting* (all elements must have a closing tag).
  - Any tag or attribute can go anywhere.
- Valid XML
  - A valid XML must be well-formed + conforms to a DTD
  - A "DTD" (document type definition) specifies what tags and attributes are permitted, where they can go, and how many there must be.
  - A valid XML file is one that has a DTD and follows the rules specified in its DTD.

Well-formed XML

- Begin the document with a declaration, surrounded by `<?xml … ?>`

- Declaration for a document that is merely well-formed (i.e., it has no DTD):
  `<?xml version=”1.0” standalone=”yes” ?>`

- The rest of the document is a single root tag with tags nested inside it.

Tags

- Tags can be *matched* pairs, leaving room for text or nested tags in between. Example:

```
<tf-question qid="Q637" solution="False">
  <question>
    The Prime Minister, Stephen Harper,
    is Canada's Head of State.
  </question>
</tf-question>
```

Tags

- Tags can be *matched* pairs, leaving room for text or nested tags in between. Example:

```
<tf-question qid="Q637" solution="False">
  <question>
     The Prime Minister, ~~Stephen Harper~~
     Justin Trudeau, is Canada's Head of State.
  </question>
</tf-question>
```

- Or they may be unmatched. Example:

```
<response qid="Q637" answer="False" />
```

  Note the placement of the slash.

- Tag names are case-sensitive.

Attributes

- As we saw, an opening tag can have attribute name-value pairs within it. Example:

```
<tf-question qid="Q637" solution="False">
   <question>
    The Prime Minister, Justin Trudeau,
    is Canada's Head of State.
   </question>
</tf-question>
```

- The pairs are separated by blanks.
- If all the information is in the attributes, the tag becomes empty.

We don’t *need* to use attributes

```
<tf-question qid="Q637" solution="False">
   <question>
      The Prime Minister...
   </question>
</tf-question>
```

could become:

```
<tf-question>
   <qid>Q637</qid>
   <solution>False</solution>
   <question>
      The Prime Minister...
   </question>
</tf-question>
```

The other extreme: all data via attributes

```
<tf-question qid="Q637" solution="False">
   <question>
      The Prime Minister ...
   </question>
</tf-question>
```

could become:

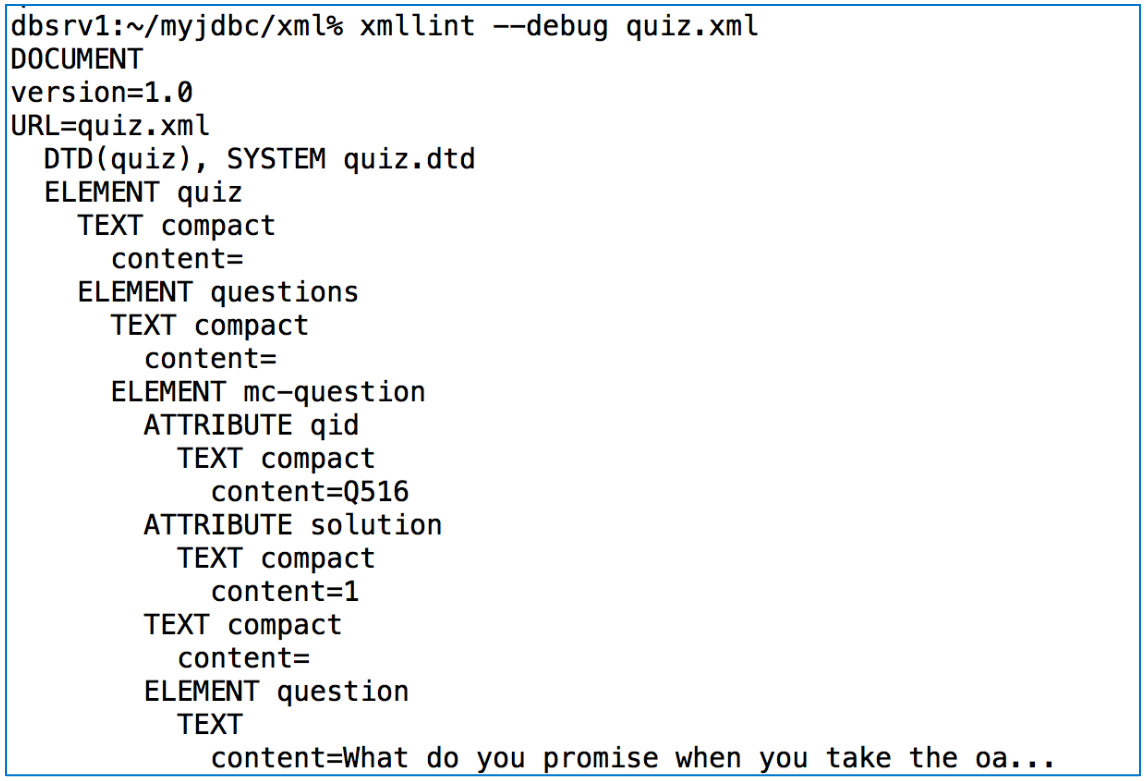
```
<tf-question qid="Q637" solution="False"
   question=”The Prime Minister ...”/>
```

It’s a design decision

- In most cases, something in between makes more sense.
- Matched tags make sense when you need structure within.
- Attributes make sense when you want something like keys and foreign keys. (More on that later.)

Checking for well-formedness

- http://validator.w3.org
- `xmllint` command on cdf.
  Default is to check merely for well-formedness.
- `xmllint --debug`
  Outputs an annotated tree of the parsed document.
  Useful for diagnosis of problems.

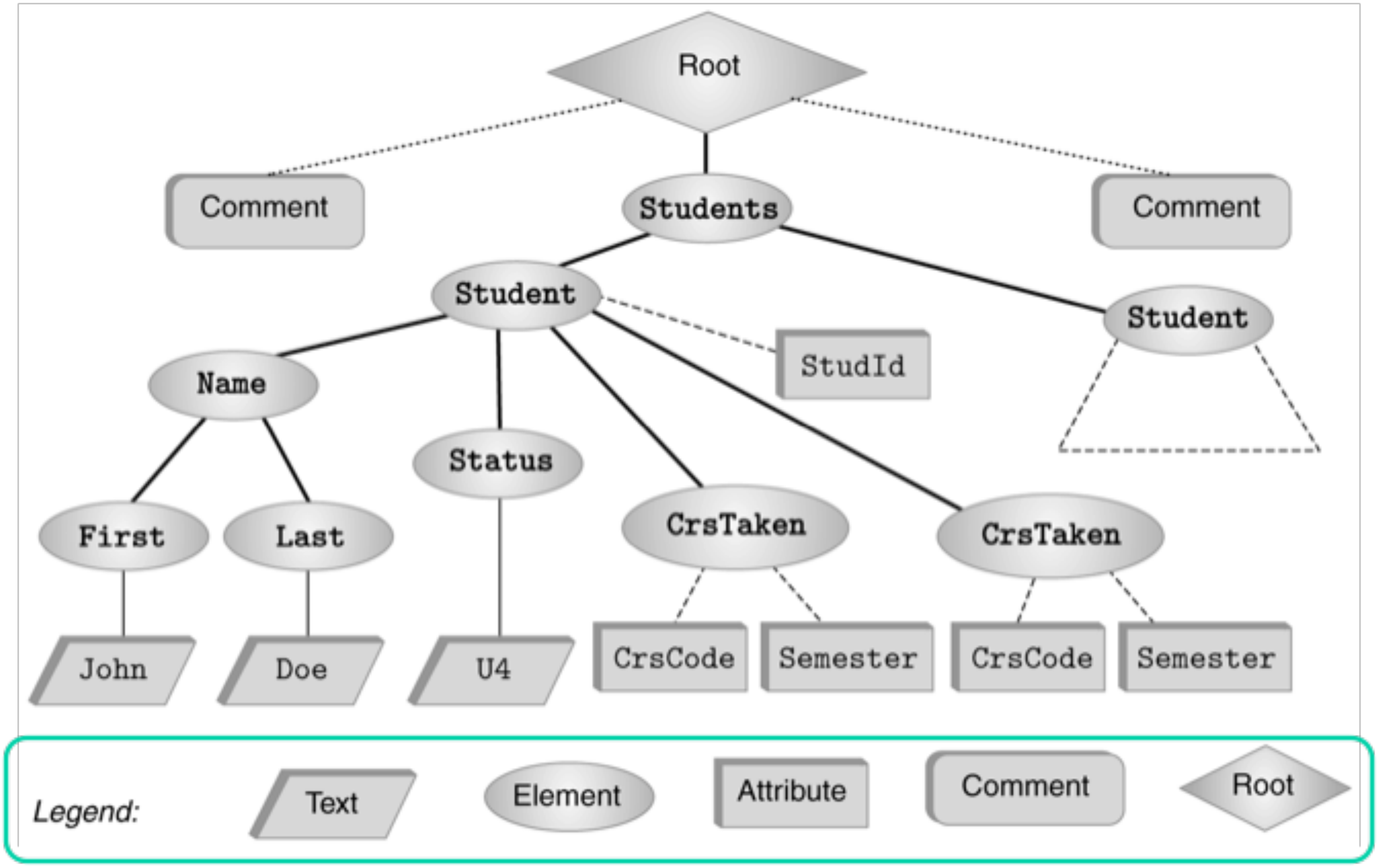


```
dbsrv1:~/myjdbc/xml% xmllint --debug quiz.xml
DOCUMENT
version=1.0
URL=quiz.xml
  DTD(quiz), SYSTEM quiz.dtd
  ELEMENT quiz
    TEXT compact
      content=
    ELEMENT questions
      TEXT compact
        content=
      ELEMENT mc-question
        ATTRIBUTE qid
          TEXT compact
            content=Q516
        ATTRIBUTE solution
          TEXT compact
            content=1
        TEXT compact
          content=
        ELEMENT question
          TEXT
            content=What do you promise when you take the oa...
```

XML documents have a tree structure

```
<?xml  version=“1.0” ?>
<!-- Some  comment -->
<Students>
  <Student StudId=“111111111” >
     <Name><First>John</First><Last>Doe</Last></Name>
     <Status>U2</Status>
     <CrsTaken CrsCode=“CS308” Semester=“F1997” />
     <CrsTaken CrsCode=“MAT123” Semester=“F1997” />
  </Student>
  <Student StudId=“987654321” >
     <Name><First>Bart</First><Last>Simpson</Last></Name>
     <Status>U4</Status>
     <CrsTaken CrsCode=“CS308” Semester=“F1994” />
  </Student>
</Students>
<!-- Some other comment -->
```

The document tree



Problems with merely well-formed XML

- There are no restrictions on
  - what tags are allowed
  - what order, nesting
  - what attributes each tag can have
  - what is mandatory and what is optional

- If a *program* is to process our XML, this information would be very useful to know..

Valid XML with DTDs

Content of a DTD

- A series of rules.
- An `ELEMENT` rule defines an element that may occur, and what can be within its opening and closing tags.
- An `ATTLIST` rule defines an attribute of an element.
- Order of the rules doesn’t matter.

ELEMENT rules

- Form: `<!ELEMENT` *«name»* `(` *«subcomponents»* `)>`
- *name*: the element's tag.
- *subcomponents*: can be
  - A comma-separated list of <u>elements</u>. Meaning: the elements must occur inside, and in the order given.
  - `#PCDATA`
    Meaning: The element contains simply text (no subelements).
  - `EMPTY`
    Meaning: This is an "empty" element. It may have attributes, but not matching opening & closing tags.

Examples

```
<!ELEMENT INGREDIENT (NAME, QUANTITY)>
<!ELEMENT NAME (#PCDATA)>
<!ELEMENT QUANTITY EMPTY>
```

More expressiveness for subcomponents

- We can us the pipe symbol | to indicate alternatives. (*something* | *something2*)
- We specify multiplicity as follows:
  - `*` means zero or more
  - `+` means one or more
  - `?` means zero or one
    (i.e., the subcomponent is optional)
- We can use brackets for grouping.

ATTLIST rules

- Form:
  `<!ATTLIST` *«elName»* *«attName»* *«type»* *«optionality»* `>`
- *elname*: the element whose attribute this is.
- *attName*: the name of this attribute.
- *type*: either `CDATA` or a list of possible values, e.g., `True|False`.
- *optionality*: Either `#REQUIRED` or `#IMPLIED` (which means optional).
- You can define multiple attributes at once.

```
<!ATTLIST person SIN CDATA #REQUIRED
                 age CDATA #IMPLIED >
```

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DTD Example

```
<!ELEMENT RECIPES (RECIPE)+>
<!ELEMENT RECIPE (INGREDIENTS, STEPS)>
<!ATTLIST RECIPE name CDATA #REQUIRED>
<!ATTLIST RECIPE type CDATA #IMPLIED>
<!ATTLIST RECIPE keywords CDATA #IMPLIED>
<!ELEMENT INGREDIENTS (INGREDIENT)+>
<!ELEMENT INGREDIENT (NAME, QUANTITY)>
<!ELEMENT NAME (#PCDATA)>
<!ELEMENT QUANTITY EMPTY>
<!ATTLIST QUANTITY amount CDATA #REQUIRED>
<!ATTLIST QUANTITY units CDATA #IMPLIED>
<!ELEMENT STEPS (STEP+)>
<!ELEMENT STEP (#PCDATA)>
```

Using a DTD

- The XML declaration must say that the document is not standalone:
  ```
  <?xml version="1.0" standalone="no" ?>
  ```
- Three possible places for the DTD:
  - In the same file, between the declaration and the XML content.
  - In a separate file on the same computer. Specify the filename, or give the full or relative path.
  - At a URL.
- In all cases, you must specify what the root element will be.

DTD in the same file

```
<?xml version="1.0" standalone="no" ?>
<!DOCTYPE People [
   <!ELEMENT People (Person*)>
   <!ELEMENT Person (#PCDATA)>
]>
<People>
   <Person>Tommy Douglas</Person>
   <Person>Terry Fox</Person>
   <Person>Louise Arbour</Person>
   <Person>Chris Hadfield</Person>
</People>
```

DTD in another file

```
<?xml version="1.0" standalone="no" ?>
<!DOCTYPE People SYSTEM "people.dtd">
<People>
   <Person>Tommy Douglas</Person>
   <Person>Terry Fox</Person>
   <Person>Louise Arbour</Person>
   <Person>Chris Hadfield</Person>
</People>
```

DTD at a URL

```
<?xml version="1.0" standalone="no" ?>
<!DOCTYPE People SYSTEM "
http://www.cs.utoronto.ca/xyyz/people.dtd">
<People>
   <Person>Tommy Douglas</Person>
   <Person>Terry Fox</Person>
   <Person>Louise Arbour</Person>
   <Person>Chris Hadfield</Person>
</People>
```

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“Keys” and “foreign keys”

Motivation

- Just as in the relational model, we sometimes want
  - unique identifiers.
  - the ability to refer in one place to some data in another place.
- We would like the DTD to express these rules and our tools to enforce them.
- DTDs don't have this full capability, but they do have some modest features in this direction.

Using ID to enforce uniqueness

- To specify that values must be unique:
  - Make an attribute of type `ID` rather than `CDATA`.
  - Example:
    `<!ATTLIST mc-question qid ID #REQUIRED>`

- Values of `ID` attributes are restricted.
  - Must not begin with a digit.
  - Must not have blanks.

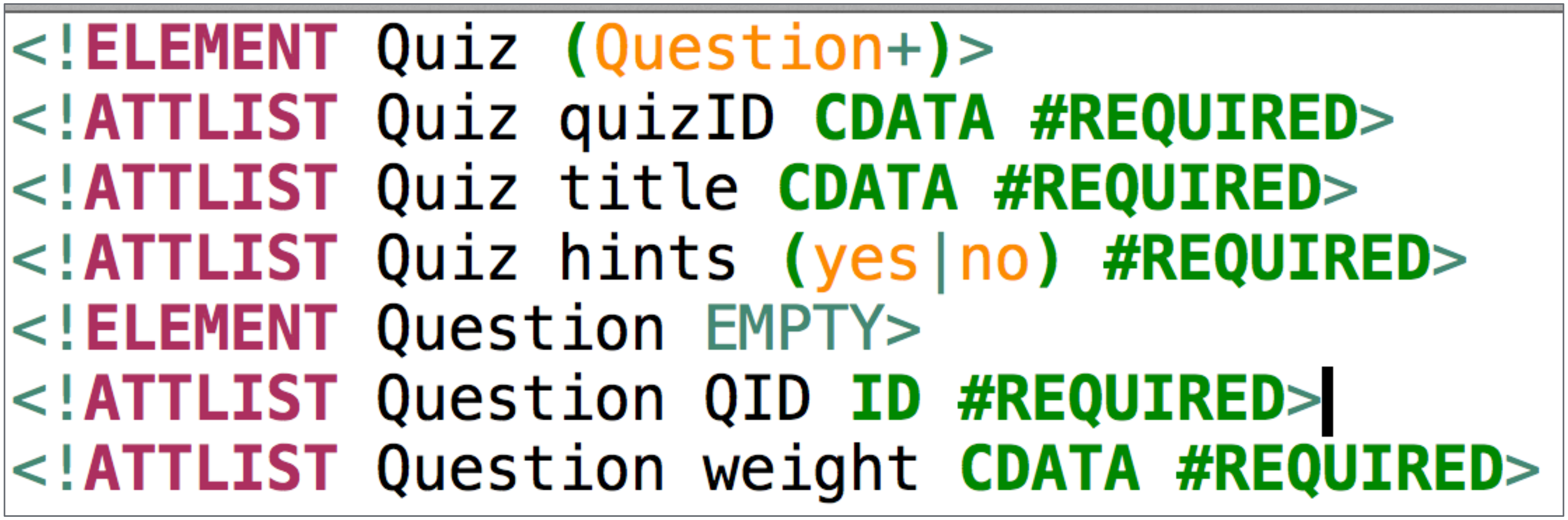
Limitations of ID

- Uniqueness is enforced across *all* IDs in the file.
- Example: If within quiz.xml:
  - questions have an `ID` attribute called `qid` and
  - students have an `ID` attribute called `sid`.
- Implications:
  - If two questions have the same `qid`, or if two students have the same `sid`, is considered an error. ✓
  - If a question's `qid` is the same as a student's `sid`, this is considered an error. ✗

Quiz.xml (Example)

```
<?xml version="1.0" standalone="no" ?>
<!DOCTYPE  Quiz   SYSTEM "quiz.dtd">
<Quiz  quizID="csc343"  title="Homework Set 1”>
   <Question  QID="N-15"  weight="2"/>
   <Question  QID="TF-01"  weight="1"/>
   <Question  QID="MC-05”  weight="3"/>
   <Question  QID="MC-08”  weight="2"/>
</Quiz>
```

Quiz.dtd Example



```
<!ELEMENT Quiz (Question+)>
<!ATTLIST Quiz quizID CDATA #REQUIRED>
<!ATTLIST Quiz title CDATA #REQUIRED>
<!ATTLIST Quiz hints (yes|no) #REQUIRED>
<!ELEMENT Question EMPTY>
<!ATTLIST Question QID ID #REQUIRED>
<!ATTLIST Question weight CDATA #REQUIRED>
```

Using IDREF to enforce referential integrity

- To specify that a value must refer to some ID:
  - Make an attribute of type `IDREF`.
  - Example:
    ```
    <!ATTLIST response qid IDREF #REQUIRED>
    ```
  - We can allow an attribute to have a *list* of values, each of which references some ID:
    ```
    <!ATTLIST response qid IDREFS #REQUIRED>
    ```

Limitations of IDREF

- An IDREF attribute needs only to refer to any ID in the file, not specifically to one of a particular type.
- Example: In quiz.xml,
  - If a response has a `qid` that is an `IDREF`
- Implications:
  - If a response's `qid` refers to nothing, this is considered an error. ✓
  - If a response's `qid` refers to a student's `sid`, this is considered fine. ✗

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Checking for validity

- `xmllint --valid` command on cdf.

Limitations of DTDs

- ID and IDREF are a pale imitation of keys and foreign keys.
  - All ID values are treated as a single set.
- ID and IDREF only work within a single file.
  - References to an ID in another file are flagged as errors.
  - Duplicate ID values across files cannot be detected.
- There are no other types of constraints.
- The only data type is string.
- It is very inconvenient to specify contents but allow them in any order.

XML Schema

- XML Schema has greater expressive power.
  - Rich set of built-in types, plus user-defined types
  - Finer control over sequences of sub-elements.
  - More effective keys and foreign keys
- It is also much more complex.
- Note: XML Schema Definitions (XSDs) are themselves XML documents.
  - They describe "elements" and
  - the things doing the describing are themselves "elements".