Referential Integrity and Database Design Recap: From Conceptual Design to Physical Relational Implementation

University of California, Berkeley

School of Information

IS 257: Database Management

Lecture Outline

- Review
  - Integrity constraints
- Database Design Process Recap
- Building Databases in MySQL with phpMyAdmin
- XML and databases – first look
- Next Week

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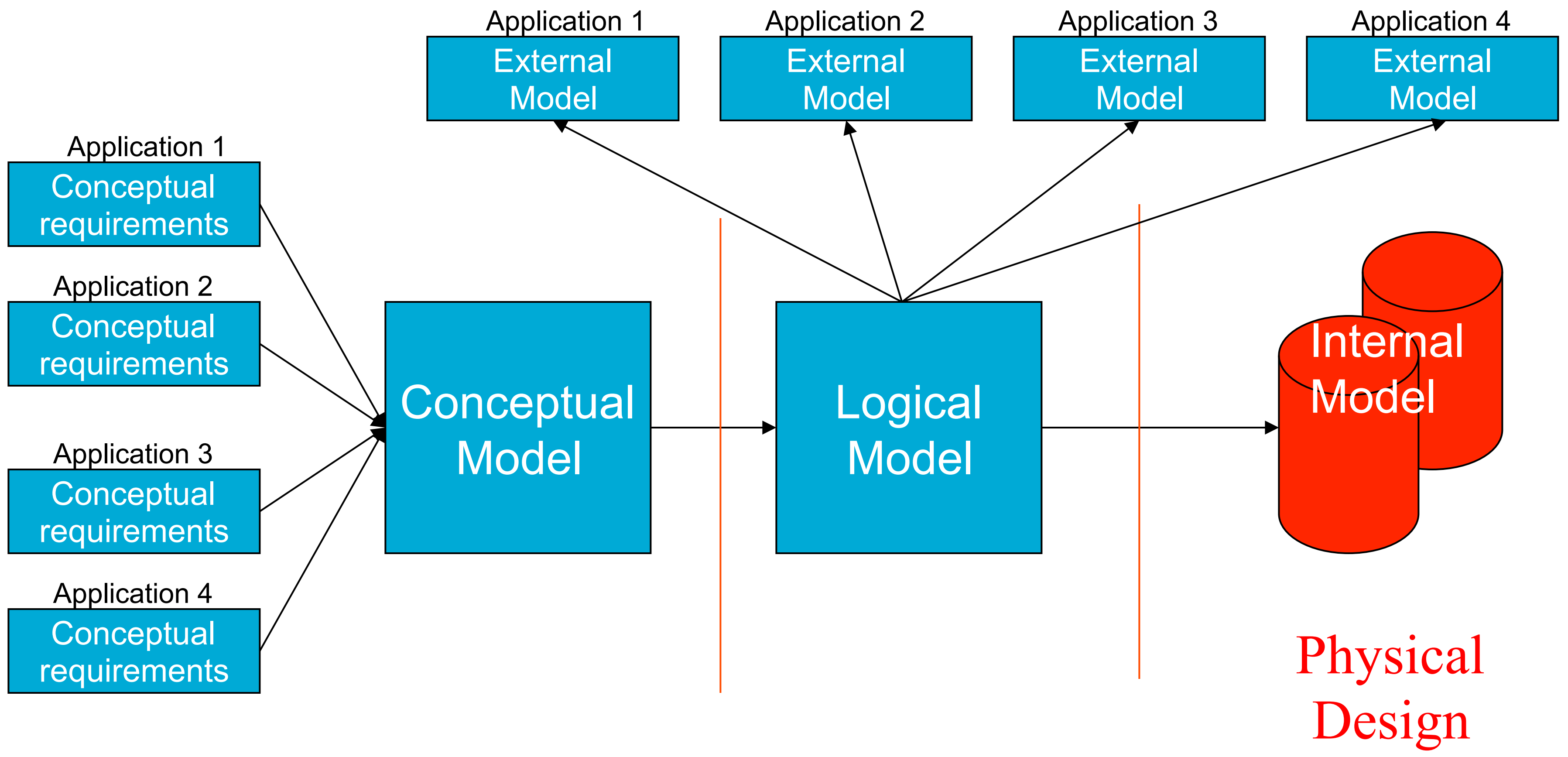
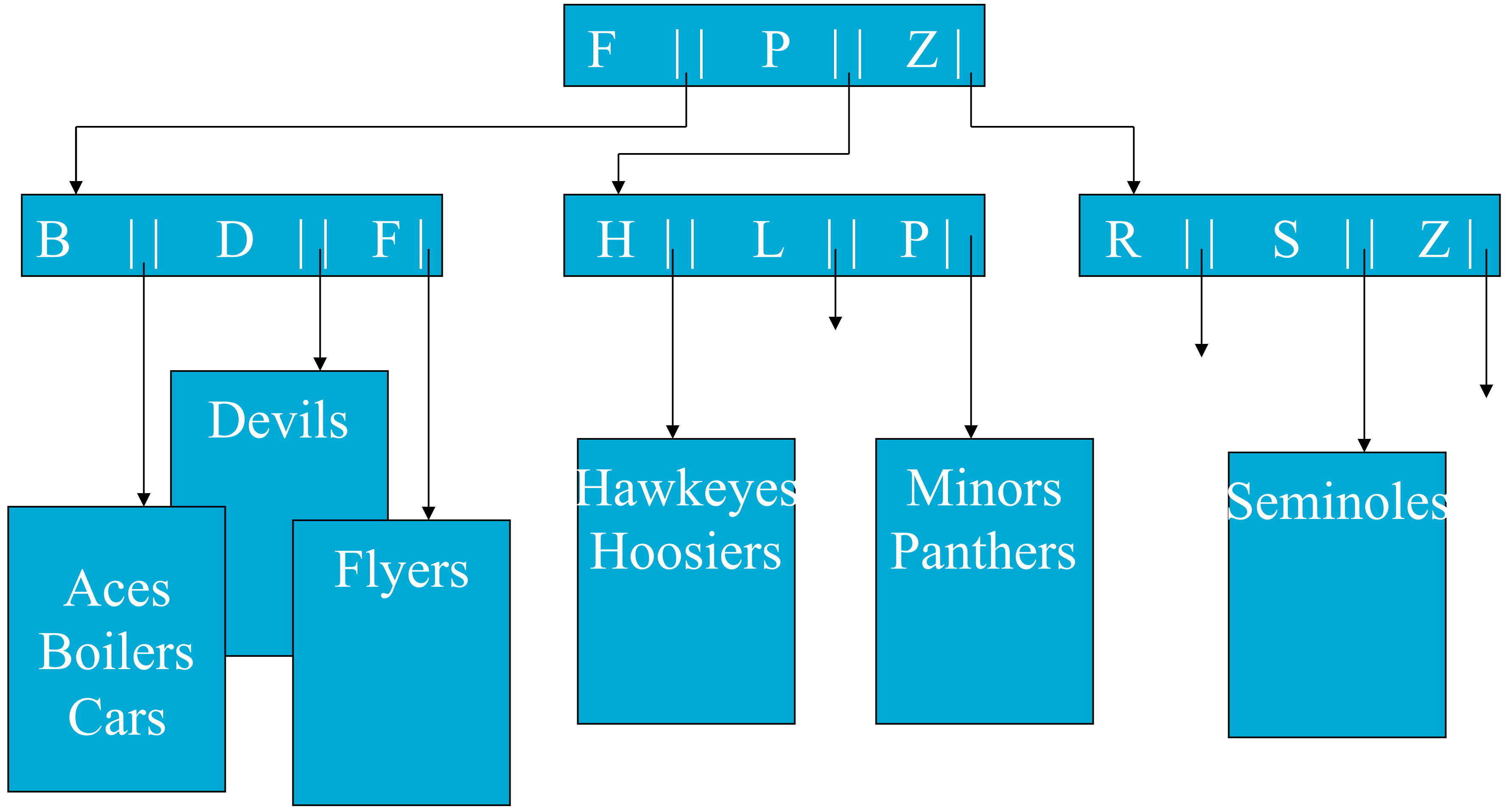
Database Design Process



Physical Database Design

- The primary goal of physical database design is data processing efficiency
- We will concentrate on choices often available to optimize performance of database services
- Physical Database Design requires information gathered during earlier stages of the design process

Btree


F || P || Z |
B || D || F |
H || L || P |
R || S || Z |
Devils
Aces
Boilers
Cars
Flyers
Hawkeyes
Hoosiers
Minors
Panthers
Seminoles

Comparative Access Methods

Factor	Sequential	Indexed	Hashed
Storage space	No wasted space	No wasted space for data but extra space for index	more space needed for addition and deletion of records after initial load
Sequential retrieval on primary key	Very fast	Moderately Fast	Impractical
Random Retr.	Impractical	Moderately Fast	Very fast
Multiple Key Retr.	Possible but needs a full scan	Very fast with multiple indexes	Not possible
Deleting records	can create wasted space	OK if dynamic	very easy
Adding records	requires rewriting file	OK if dynamic	very easy
Updating records	usually requires rewriting file	Easy but requires Maintenance of indexes	very easy

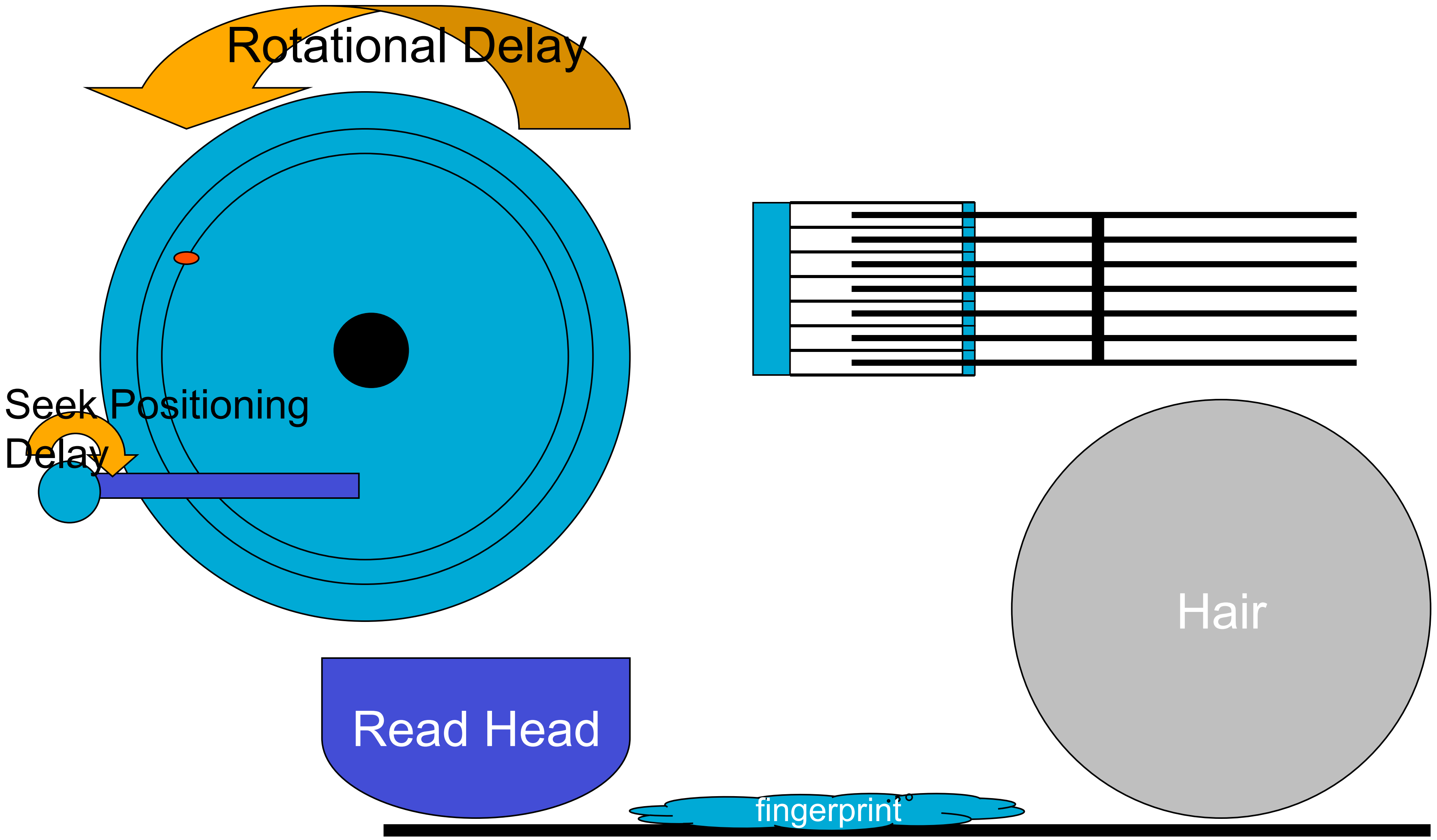
Indexes

- Most database applications require:
  - locating rows in tables that match some condition (e.g. SELECT operations)
  - Joining one table with another based on common values of attributes in each table
- Indexes can greatly speed up these processes and avoid having to do sequential scanning of database tables to resolve queries

When to Use Indexes

- Rules of thumb
  - Indexes are most useful on larger tables
  - Specify a unique index for the primary key of each table (automatically done for many DBMS)
  - Indexes are most useful for attributes used as search criteria or for joining tables
  - Indexes are useful if *sorting* is often done on the attribute
  - Most useful when there are many different values for an attribute
  - Some DBMS limit the number of indexes and the size of the index key values
  - Some indexes will not retrieve NULL values

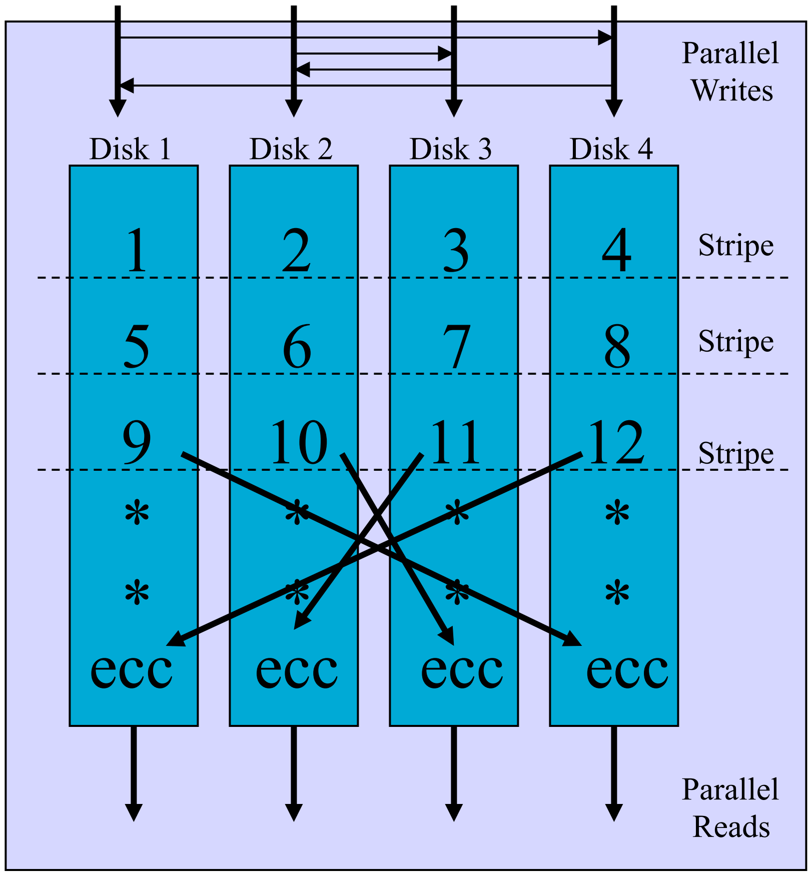
Disk Timing (and Problems)



RAID

- Provides parallel disks (and software) so that multiple pages can be retrieved simultaneously
- RAID stands for "Redundant Arrays of Inexpensive Disks"
  – invented by Randy Katz and Dave Patterson here at Berkeley
- Some manufacturers have renamed the "inexpensive" part (for obvious reasons)

RAID-5



Raid 5 divides blocks across multiple disks with error correcting codes

Integrity Constraints

- The constraints we wish to impose in order to protect the database from becoming inconsistent.
- Five types
  - Required data
  - attribute domain constraints
  - entity integrity
  - referential integrity
  - enterprise constraints

Integrity constraints

- Usually set during table creation in RDBMS
- May also be set or modified by ALTER TABLE

CREATE [TEMPORARY] TABLE [IF NOT EXISTS] *tbl_name* (*create_definition*,...) [*table_options*]

In MySQL …

- **CREATE [TEMPORARY] TABLE [IF NOT EXISTS] *tbl_name* (*create_definition*,...) [*table_options*]**

```
create_definition:
    col_name column_definition
  | [CONSTRAINT [symbol]] PRIMARY KEY [index_type] (index_col_name,...)
      [index_option] ... (e.g. USING BTREE | HASH)
  | {INDEX|KEY} [index_name] [index_type] (index_col_name,...)
      [index_option] ...
  | [CONSTRAINT [symbol]] UNIQUE [INDEX|KEY]
      [index_name] [index_type] (index_col_name,...)
      [index_option] ...
  | {FULLTEXT|SPATIAL} [INDEX|KEY] [index_name] (index_col_name,...)
      [index_option] ...
  | [CONSTRAINT [symbol]] FOREIGN KEY
      [index_name] (index_col_name,...) reference_definition
  | CHECK (expr)
```

Required Data

- Some attributes must always contain a value -- they cannot have a null
- For example:
  - Every employee must have a job title.
  - Every diveshop diveitem must have an order number and an item number.
- Use the "NOT NULL" option in CREATE TABLE

Attribute Domain Constraints

- Every attribute has a domain, that is a set of values that are legal for it to use.
- For example:
  – The domain of sex in the employee relation is “M” or “F”
- Domain ranges can be used to validate input to the database.
- Use the “CHECK” option in CREATE TABLE – but not in MySQL, it ignores CHECK

E.g. – in SQLite

- sqlite> CREATE TABLE tst (num integer CHECK (num < 100));
- sqlite> insert into tst (num) values (1);
- sqlite> select * from tst;
- 1
- sqlite> insert into tst (num) values (80);
- sqlite> insert into tst (num) values (99);
- sqlite> insert into tst (num) values (100);
- Error: constraint failed

Entity Integrity

- The primary key of any entity cannot be NULL.
- In MySQL declaring a primary key automatically sets NOT NULL also

Column Definitions in MySQL

- *column_definition*:

  data_type [NOT NULL | NULL]

  [DEFAULT *default_value*]
  [AUTO_INCREMENT]

  [UNIQUE [KEY] | [PRIMARY] KEY]

  [COMMENT '*string*']

  [COLUMN_FORMAT {FIXED|DYNAMIC|
  DEFAULT}]

  [STORAGE {DISK|MEMORY|DEFAULT}]
  [*reference_definition*]

Referential Integrity

- A “foreign key” links each occurrence in a relation representing a *child* entity to the occurrence of the *parent* entity containing the matching candidate key
- Referential Integrity means that if the foreign key contains a value, that value must refer to an existing occurrence in the parent entity
- For example:
  - Since the Order ID in the diveitem relation refers to a particular diveords item, that item must exist for referential integrity to be satisfied

Referential Integrity

- Referential integrity options are declared when tables are defined (in most systems)
- There are many issues having to do with how particular referential integrity constraints are to be implemented to deal with insertions and deletions of data from the parent and child tables.

Insertion rules

- A row should not be inserted in the referencing (child) table unless there already exists a matching entry in the referenced table.
- Inserting into the parent table should *not* cause referential integrity problems
  - Unless it is itself a child…
- Sometimes a special NULL value may be used to create child entries without a parent or with a "dummy" parent.

Deletion rules

- A row should not be deleted from the referenced table (parent) if there are matching rows in the referencing table (child).
- Three ways to handle this
  - **Restrict** -- disallow the delete
  - **Nullify** -- reset the foreign keys in the child to some NULL or dummy value
  - **Cascade** -- Delete all rows in the child where there is a foreign key matching the key in the parent row being deleted

Referential Integrity

- This can be implemented using external programs that access the database
- newer databases implement executable rules or built-in integrity constraints

E.g. – in MySQL

- *reference_definition*:

  REFERENCES *tbl_name* (*index_col_name*,...)
  [MATCH FULL | MATCH PARTIAL | MATCH SIMPLE]

  [ON DELETE *reference_option*]

  [ON UPDATE *reference_option*]

- *reference_option*:

  RESTRICT | CASCADE | SET NULL | NO ACTION

DIVEORDS SQL

```
CREATE TABLE `DIVEORDS` (
`Order_No` int(11) NOT NULL,
`Customer_No` int(11) default NULL,
`Sale_Date` datetime default NULL,
`Ship_Via` varchar(255) default NULL,
`Ship_Cost` double default NULL,
…some things deleted for space…,
`VacationCost` double default NULL,
PRIMARY KEY (`Order_No`),
KEY `Customer_No` (`Customer_No`),
KEY `DESTDIVEORDS` (`Destination`),
KEY `DIVECUSTDIVEORDS` (`Customer_No`),
KEY `DIVEORDSShip_Via` (`Ship_Via`),
KEY `SHIPVIADIVEORDS` (`Ship_Via`)
) ENGINE=InnoDB DEFAULT CHARSET=latin1;
```

DIVEITEM SQL

```
CREATE TABLE `DIVEITEM` (
`Order_No` int(11) NOT NULL,
`Item_No` int(11) default NULL,
 `Rental_Sale` varchar(255) default NULL,
`Qty` smallint(6) default NULL,
`Line_Note` varchar(255) default NULL,
KEY `DIVEORDSDIVEITEM` (`Order_No`),
KEY `DIVESTOKDIVEITEM` (`Item_No`),
KEY `Item_No` (`Item_No`),
FOREIGN KEY (`Order_No`) REFERENCES
        DIVEORDS(`Order_No`) ON DELETE CASCADE )
ENGINE=InnoDB DEFAULT CHARSET=latin1;
```

Note that only the InnoDB or NDB Engines in MySQL support actual actions and checking for Foreign Keys

Enterprise Constraints

- These are business rule that may affect the database and the data in it
  - for example, if a manager is only permitted to manage 10 employees then it would violate an enterprise constraint to manage more

- Usually implemented by triggers or rules

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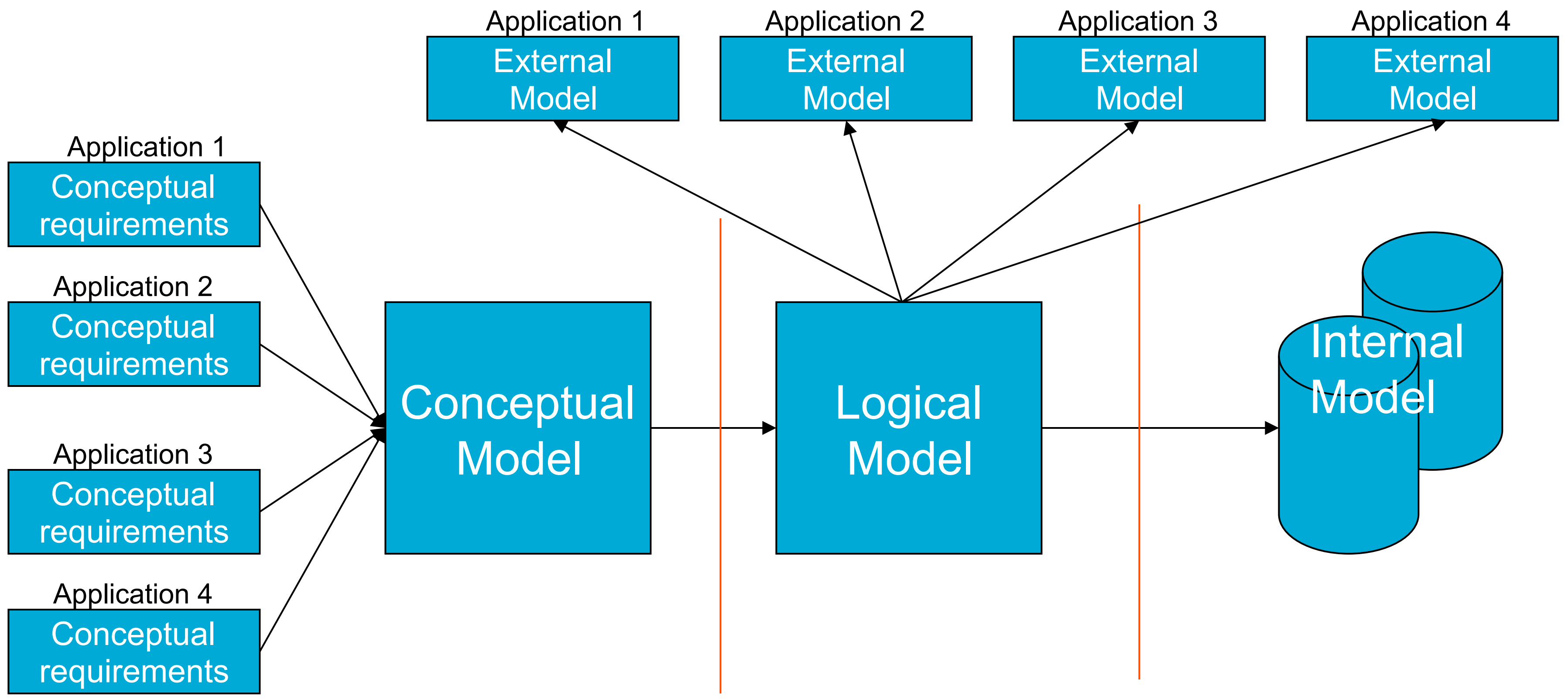
Database Design Process



Today: New Design

- Today we will build the COOKIE database from (rough) needs assessment through the conceptual model, logical model and finally physical implementation in Access.

Cookie Requirements

- Cookie is a bibliographic database that contains information about a hypothetical union catalog of several libraries.
- Need to record which books are held by which libraries
- Need to search on bibliographic information
  - Author, title, subject, call number for a given library, etc.
- Need to know who publishes the books for ordering, etc.

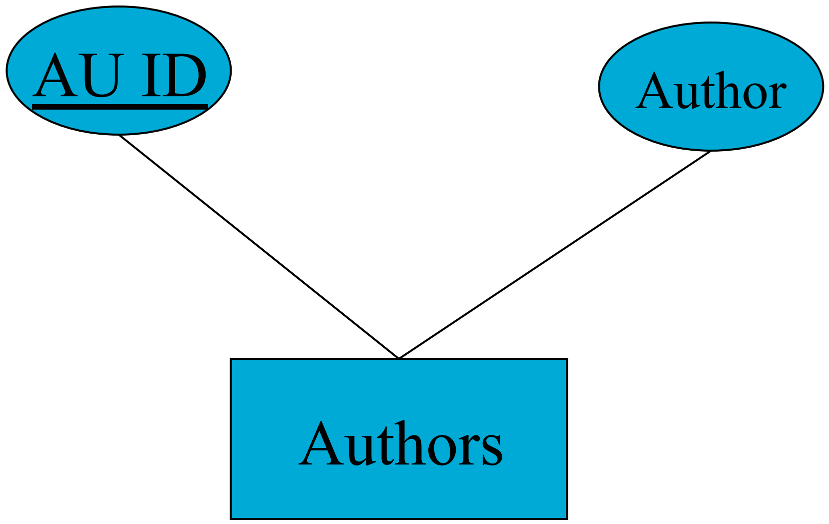
Cookie Database

- There are currently 6 main types of entities in the database
  - Authors (Authors)
    - Note: we created authors from the former design when talking about normalization (a few weeks ago)
  - Books (bibfile)
  - Local Call numbers (callfile)
  - Libraries (libfile)
  - Publishers (pubfile)
  - Subject headings (subfile)
  - Additional entities
    - Links between subject and books (indxfile)
    - Links between authors and books (AU_BIB)

AUTHORS

- Author -- The author's name (We do not distinguish between Personal and Corporate authors)
- Au_id – a unique id for the author

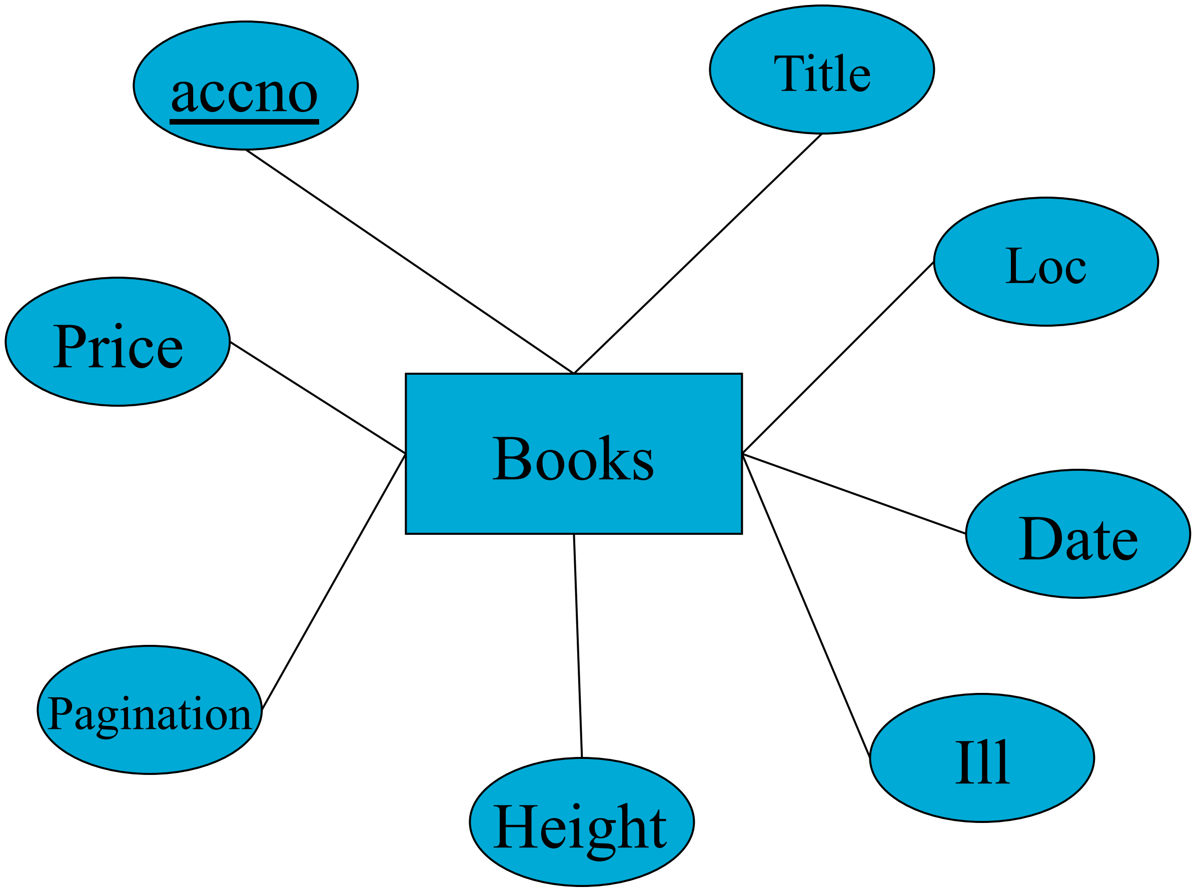
AUTHORS



BIBFILE

- Books (BIBFILE) contains information about particular books. It includes one record for each book. The attributes are:
  - accno -- an “accession” or serial number
  - title -- The title of the book
  - loc -- Location of publication (where published)
  - date -- Date of publication
  - price -- Price of the book
  - pagination -- Number of pages
  - ill -- What type of illustrations (maps, etc) if any
  - height -- Height of the book in centimeters

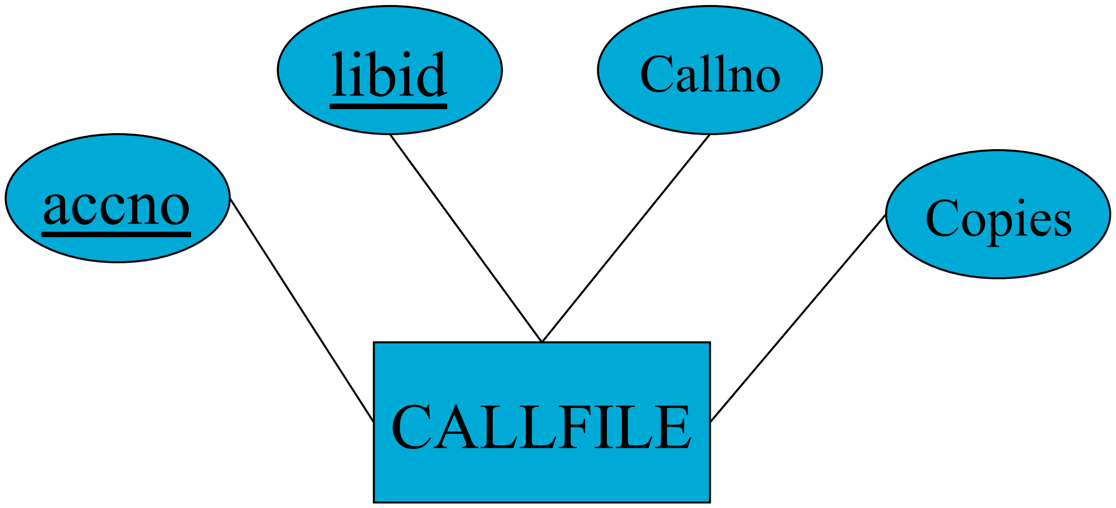
Books/BIBFILE



CALLFILE

- CALLFILE contains call numbers and holdings information linking particular books with particular libraries. Its attributes are:
  - accno -- the book accession number
  - libid -- the id of the holding library
  - callno -- the call number of the book in the particular library
  - copies -- the number of copies held by the particular library

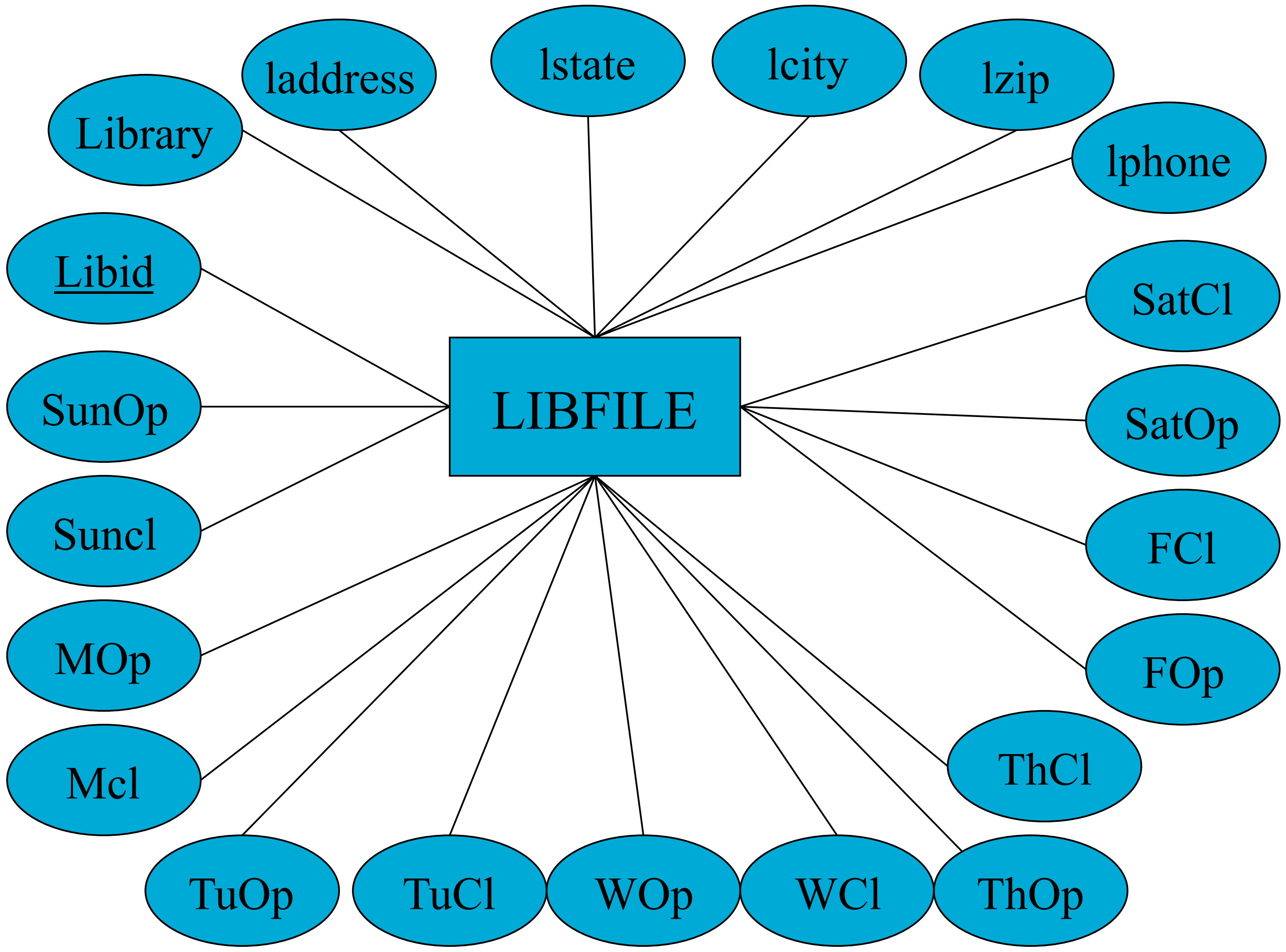
LocalInfo/CALLFILE



LIBFILE

- LIBFILE contain information about the libraries participating in this union catalog. Its attributes include:
  - libid -- Library id number
  - library -- Name of the library
  - laddress -- Street address for the library
  - lcity -- City name
  - lstate -- State code (postal abbreviation)
  - lzip -- zip code
  - lphone -- Phone number
  - mop - suncl -- Library opening and closing times for each day of the week.

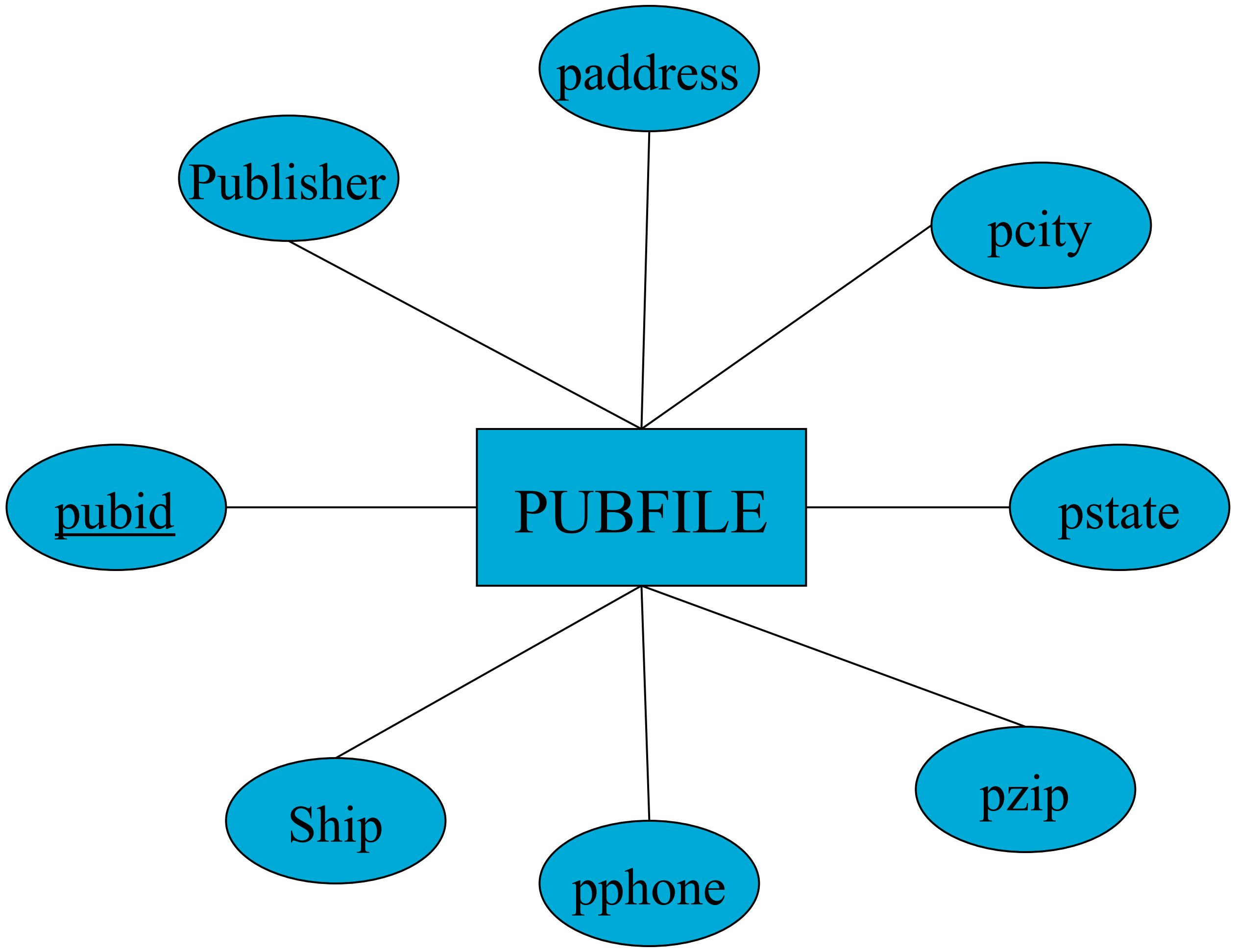
Libraries/LIBFILE



PUBFILE

- PUBFILE contain information about the publishers of books. Its attributes include
  - pubid -- The publisher’s id number
  - publisher -- Publisher name
  - paddress -- Publisher street address
  - pcity -- Publisher city
  - pstate -- Publisher state
  - pzip -- Publisher zip code
  - pphone -- Publisher phone number
  - ship -- standard shipping time in days

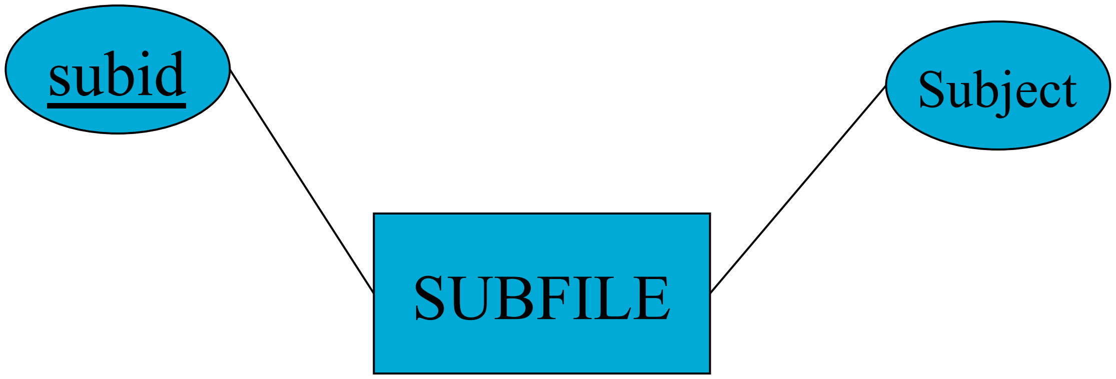
Publisher/PUBFILE



SUBFILE

- SUBFILE contains each unique subject heading that can be assigned to books. Its attributes are
  - subcode -- Subject identification number
  - subject -- the subject heading/description

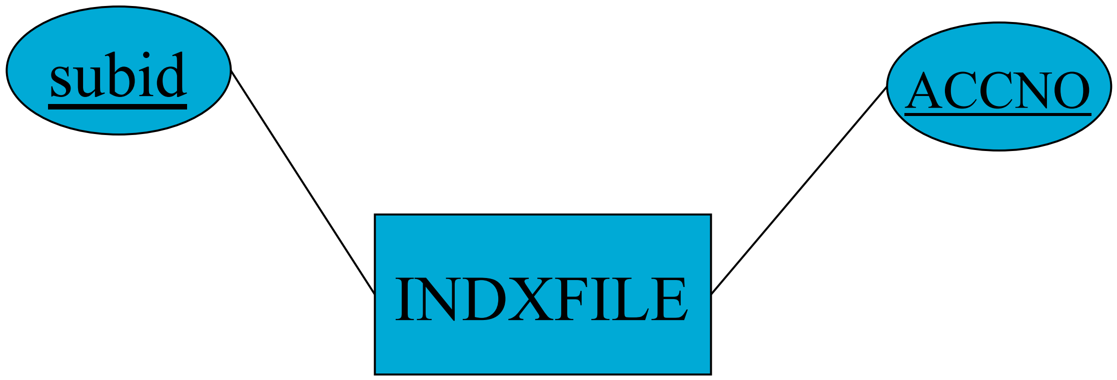
Subjects/SUBFILE



INDXFILE

- INDXFILE provides a way to allow many-to-many mapping of subject headings to books. Its attributes consist entirely of links to other tables
  - subcode -- link to subject id
  - accno -- link to book accession number

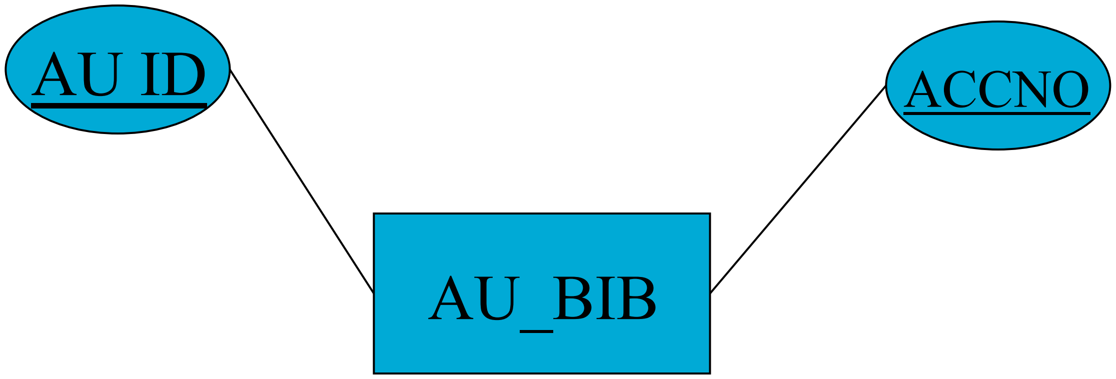
Linking Subjects and Books



AU_BIB

- AU_BIB provides a way to allow many to many mapping between books and authors. It also consists only of links to other tables
  - AU_ID – link to the AUTHORS table
  - ACCNO – link to the BIBFILE table

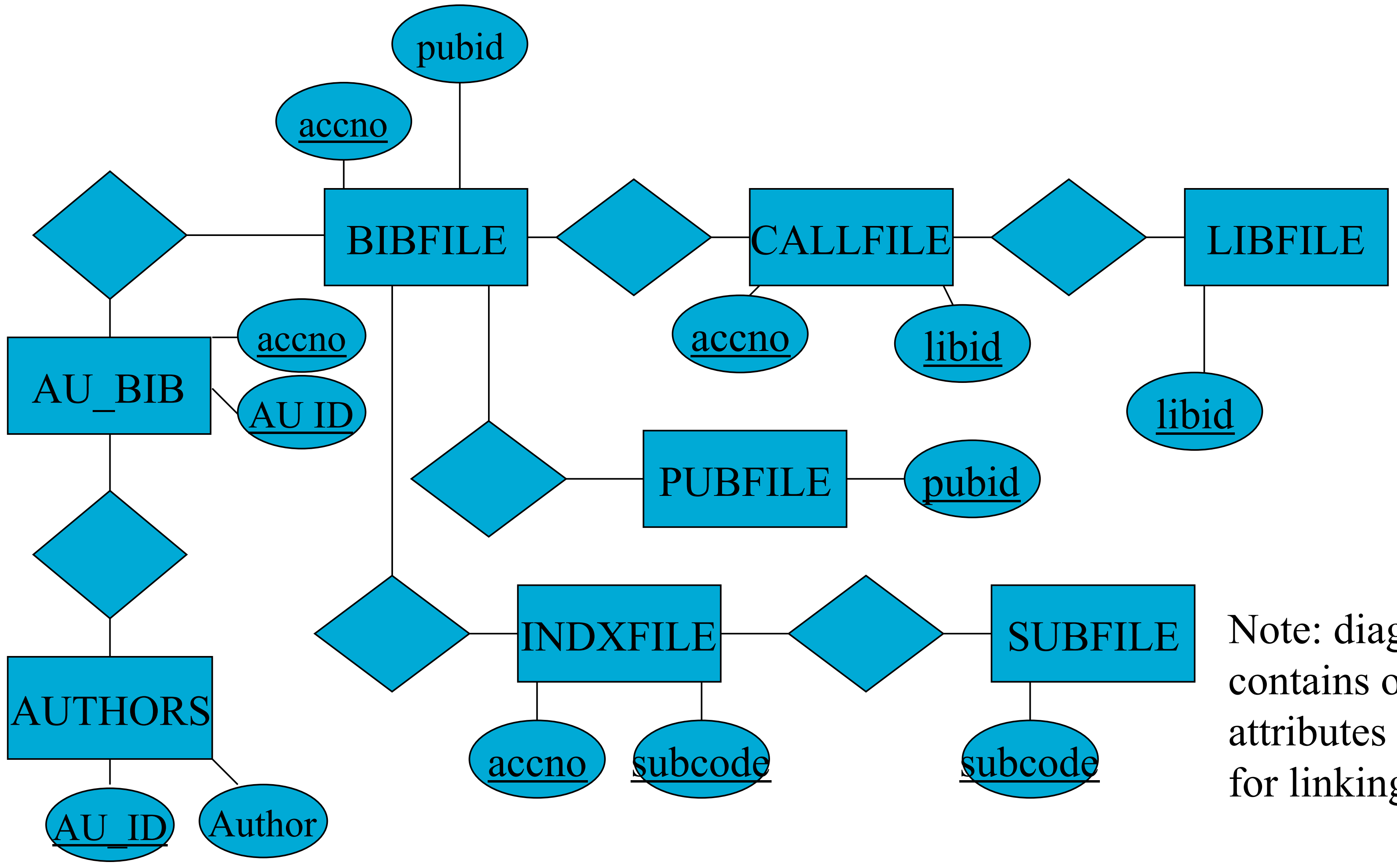
Linking Authors and Books



Some examples of Cookie Searches

- Who wrote Microcosmographia Academica?
- How many pages long is Alfred Whitehead's The Aims of Education and Other Essays?
- Which branches in Berkeley's public library system are open on Sunday?
- What is the call number of Moffitt Library's copy of Abraham Flexner's book Universities: American, English, German?
- What books on the subject of higher education are among the holdings of Berkeley (both UC and City) libraries?
- Print a list of the Mechanics Library holdings, in descending order by height.
- What would it cost to replace every copy of each book that contains illustrations (including graphs, maps, portraits, etc.)?
- Which library closes earliest on Friday night?

Cookie ER Diagram



Note: diagram contains only attributes used for linking

What Problems?

- What sorts of problems and missing features arise given the previous ER diagram?

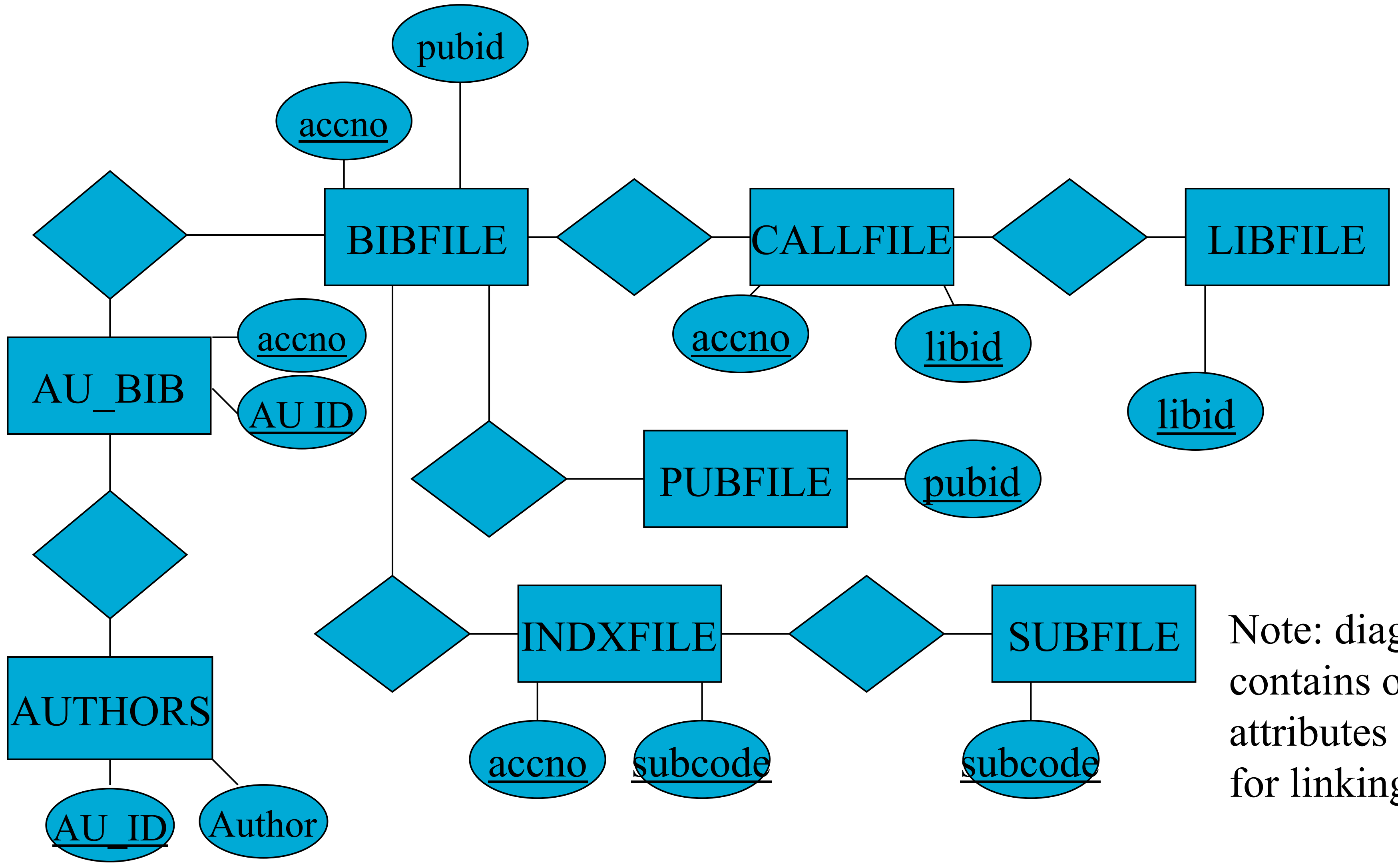
Problems Identified

- Subtitles, parallel titles?
- Edition information
- Series information
- lending status
- material type designation
- Genre, class information
- Better codes (ISBN?)
- Missing information (ISBN)
- Authority control for authors
- Missing/incomplete data
- Data entry problems
- Ordering information
- Illustrations
- Subfield separation (such as last_name, first_name)
- Separate personal and corporate authors

Problems (Cont.)

- Location field inconsistent
- No notes field
- No language field
- Zipcode doesn’t support plus-4
- No publisher shipping addresses
- No (indexable) keyword search capability
- No support for multivolume works
- No support for URLs
  – to online version
  – to libraries
  – to publishers

Original Cookie ER Diagram



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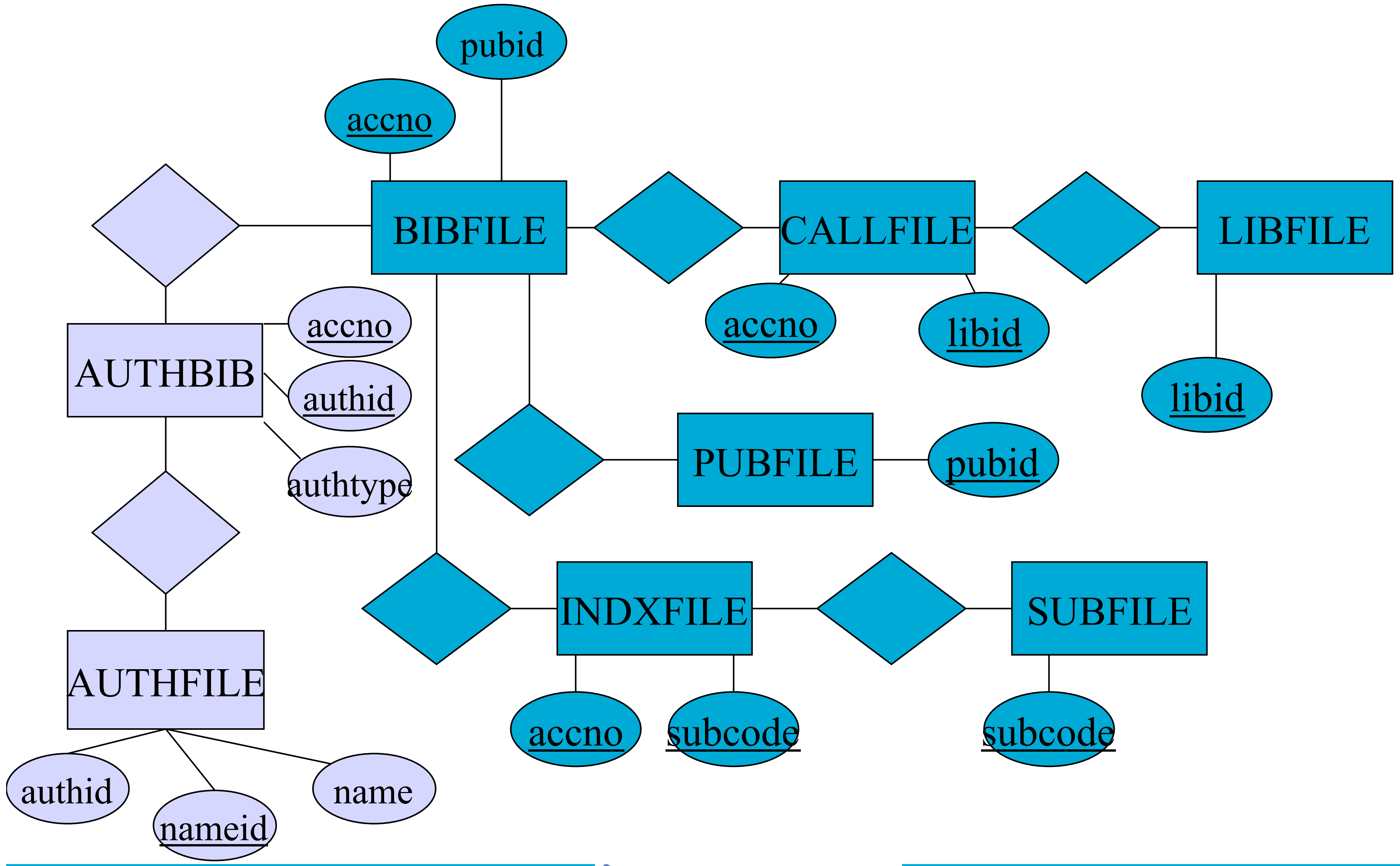
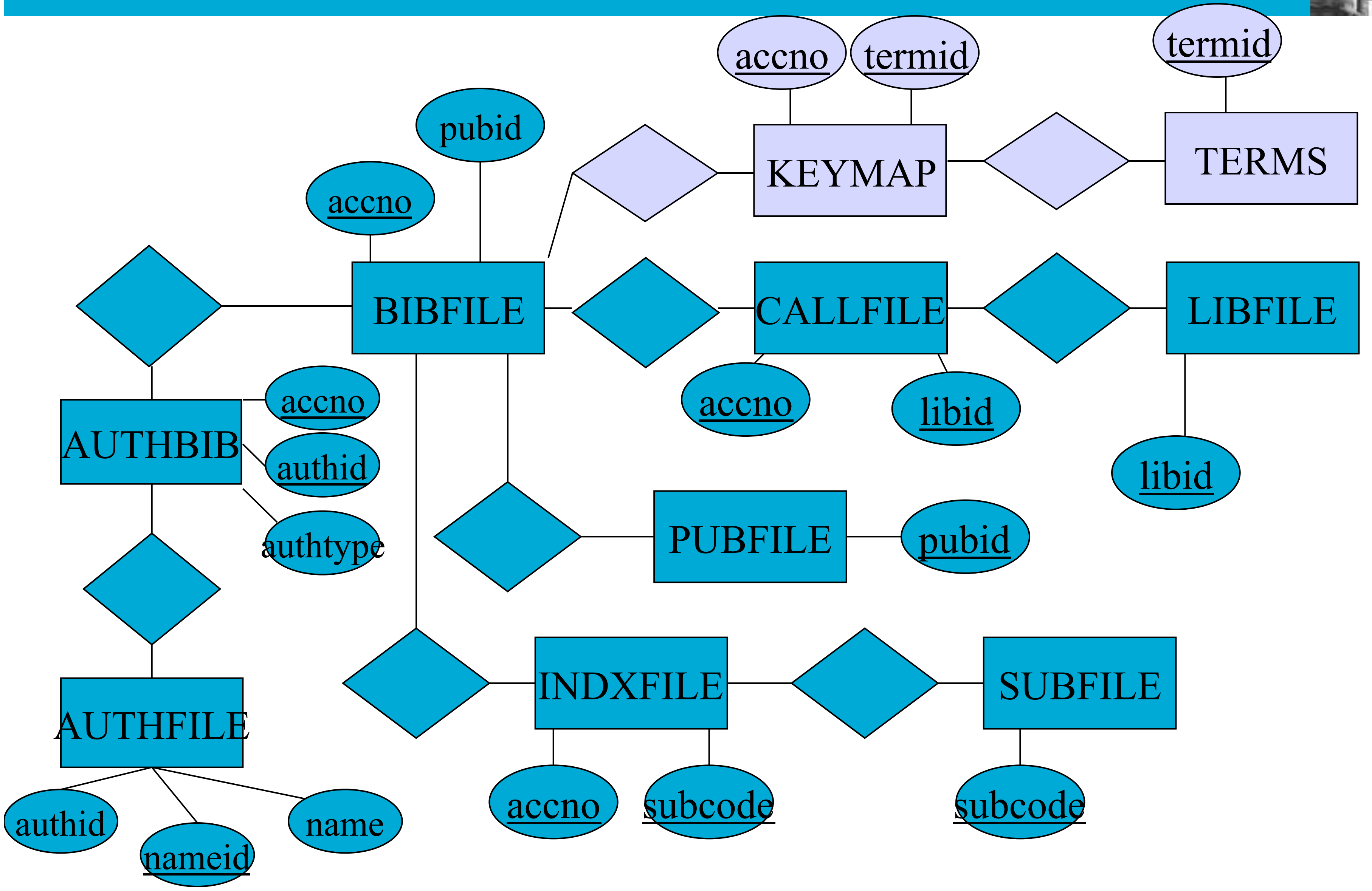
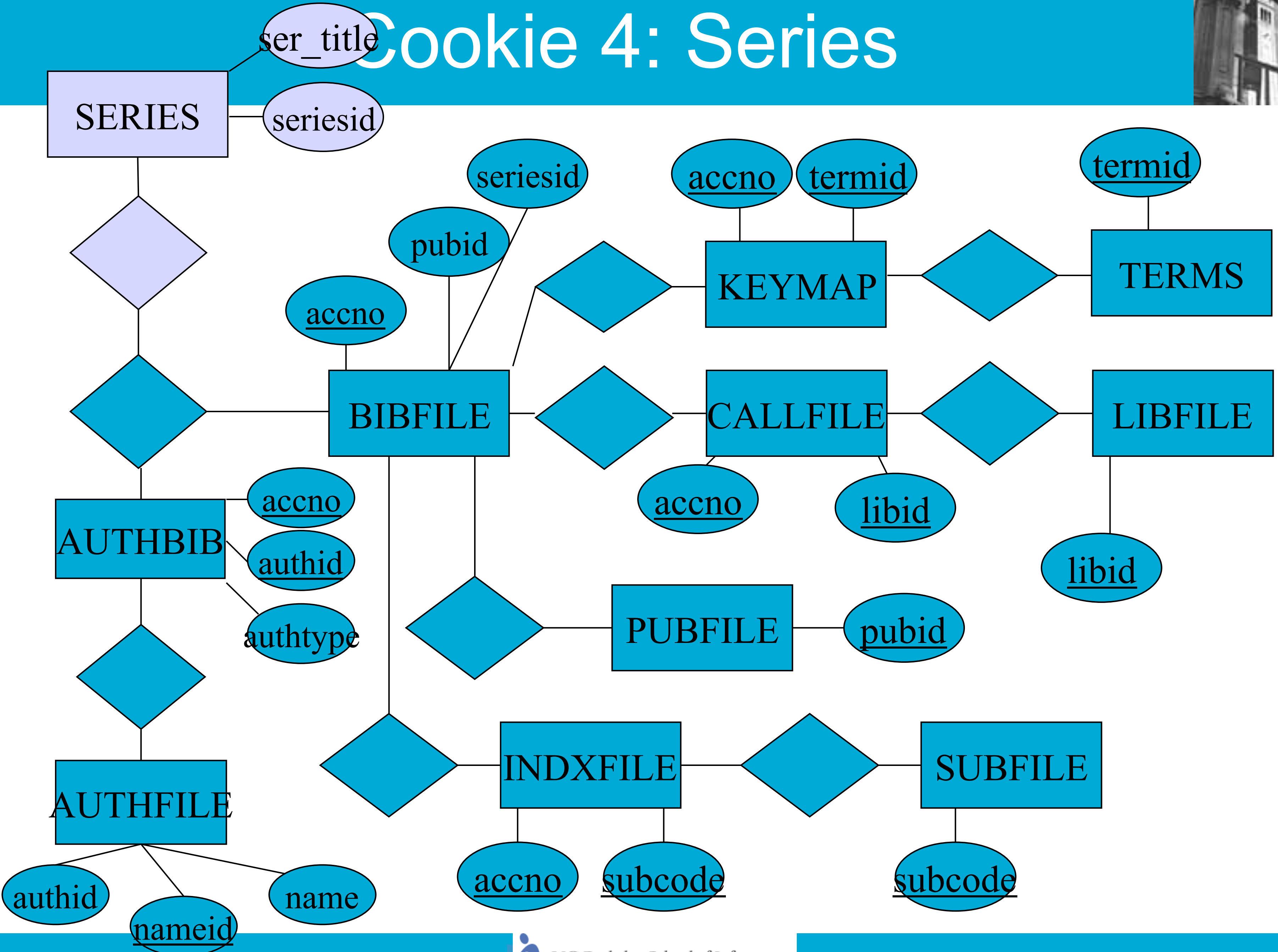
Cookie2: Separate Name Authorities



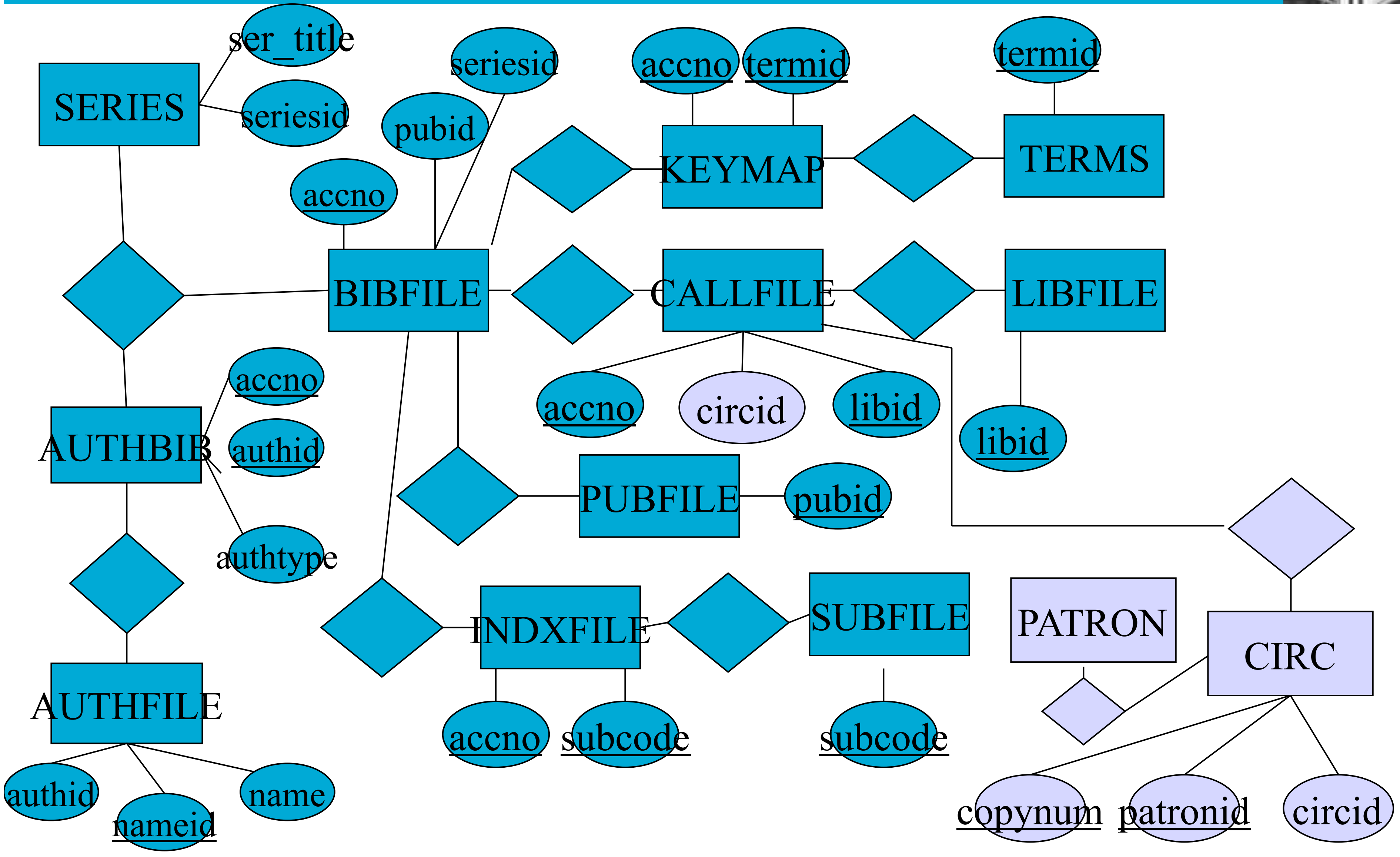
Cookie 3: Keywords



Cookie 4: Series



Cookie 5: Circulation



Logical Model: Mapping to Relations

- Take each entity
  - Authors
  - BIBFILE
  - LIBFILE
  - CALLFILE
  - SUBFILE
  - PUBFILE
  - INDXFILE
  - AU_BIB
- And make it a table...

Implementing the Physical Database...

- For each of the entities, we will build a table…
- Loading data
- Entering data
- Data entry forms

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Database Creation in phpMyAdmin

- Select database (not a table)
- Click Operations tab,
  - Enter table name and number of fields (attributes)
  - then click Go
- Fill in form for each attribute
- Helps to know what the primary key is, or if one is to be created automatically
  - Automatic creation is more complex in other RDBMS and ORDBMS, but pretty simple in MySQL
- Need to make decision about the physical storage of the data (data types, etc)

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Why XML?

- As part of the SQL Standards there is an extension providing a mapping from XML to DBMS is being created called XML/SQL
- The (draft) standard is very complex, but the ideas are actually pretty simple
- Suppose we have a table called EMPLOYEE that has columns EMPNO, FIRSTNAME, LASTNAME, BIRTHDATE, SALARY

Standards: XML/SQL

- That table can be mapped to:

```
<EMPLOYEE>
<row><EMPNO>000020</EMPNO>
<FIRSTNAME>John</FIRSTNAME>
<LASTNAME>Smith</LASTNAME>
<BIRTHDATE>1955-08-21</BIRTHDATE>
<SALARY>52300.00</SALARY>
</row>
 <row> … etc. …
 </EMPLOYEE>
```

Standards: XML/SQL

- In addition the standard says that XMLSchemas must be generated for each table, and also allows relations to be managed by nesting records from tables in the XML.
- Variants of this are incorporated into the latest versions of ORACLE and in MySQL
- But what if you want to deal with more complex XML schemas (beyond "flat" structures)?

Native XML Database (NXD)

- Native XML databases have an XML-based internal model
  - That is, their fundamental unit of storage is XML
- However, different native XML databases differ in What they consider the fundamental unit of storage
  - Document vs element or segment
- And how that information or its subelements are accessed, indexed and queried
  - E.g., SQL vs. Xquery or a special query language

Database Systems supporting XQuery

- The following database systems offer XQuery support:
  - *Native XML Databases:*
    - Berkeley DB XML
    - eXist
    - MarkLogic
    - Software AG Tamino
    - Raining Data TigerLogic
    - Documentum xDb (X-Hive/DB) (now EMC)
  - *Relational Databases (also support SQL):*
    - IBM DB2
    - Microsoft SQL Server
    - Oracle

Further comments on NXD

- Native XML databases are most often used for storing “document-centric” XML document
  - I.e. the unit of retrieval would typically be the entire document and not a particular node or subelement
- This supports query languages like Xquery
  - Able to ask for “all documents where the third chapter contains a page that has boldfaced word”
  - Very difficult to do that kind of query in SQL

Next time

- Database applications
- Intro to Coldfusion and PHP for database applications