Carnegie Mellon Univ.
Dept. of Computer Science
15-415/615 - DB Applications

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Lecture#1: Introduction

Outline

- Introduction to DBMSs
- The Entity Relationship model
- The Relational Model
- SQL: the commercial query language
- DB design: FD, 3NF, BCNF
- indexing, q-opt
- concurrency control & recovery
- advanced topics (data mining, multimedia)

We'll learn:

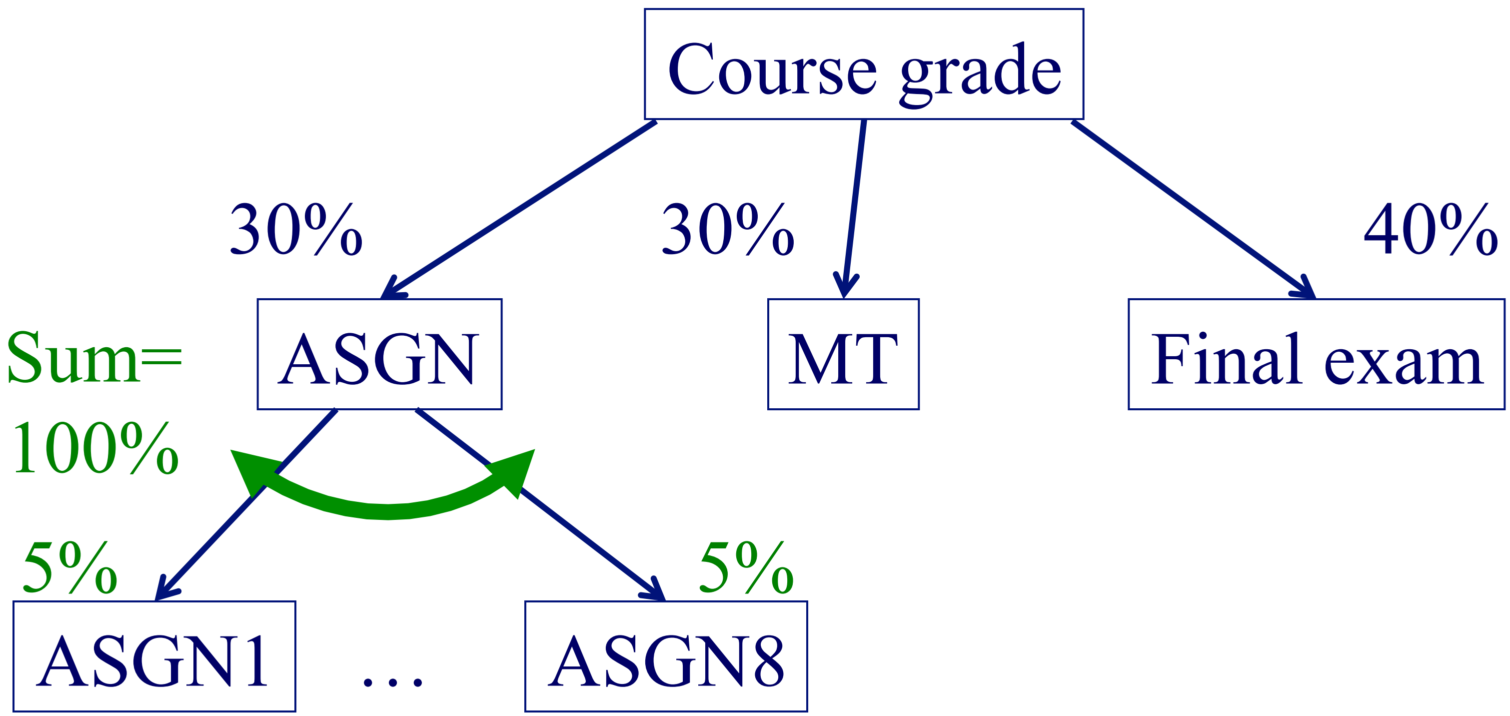
- What are RDBMS
  - when to use them
  - how to model data with them
  - how to store and retrieve information
  - how to search quickly for information
- Internals of an RDBMS: indexing, transactions

We'll learn (cnt'd)

- Advanced topics
  - multimedia indexing (how to find similar, eg., images)
  - data mining (how to find patterns in data)

Administrivia

- Weights: as announced



Administrivia - II

- FYI: ASGN3 and ASGN7 are heavy
- Late policy: 4 ‘slip days’

Detailed outline

- Introduction
  - – Motivating example
  - – How do DBMSs work? DDL, DML, views.
  - – Fundamental concepts
  - – DBMS users
  - – Overall system architecture
  - – Conclusions

What is the goal of rel. DBMSs

(eg., you have 50 friends + phone#;

Or a dentist has 100 customers, addresses, visit-info, treatment-info)

How can RDBMSs help?

What is the goal of rel. DBMSs

Electronic record-keeping:

Fast and convenient access to information.

Definitions

- ‘DBMS’ = ‘Data Base Management System’:

  the (commercial) system, like:

  DB2, Oracle, MS SQL-server, ...
- ‘Database system’: DBMS + data + application programs

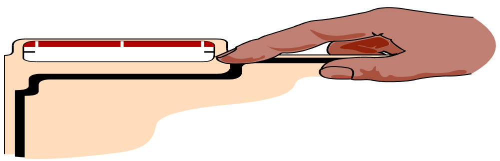
Motivating example

Eg.: students, taking classes, obtaining grades;

- find my gpa
- <and other ad-hoc queries>

Obvious solution: paper-based

- advantages?

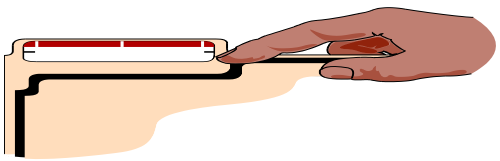


- disadvantages?

eg., student folders,
alpha sorted

Obvious solution: paper-based

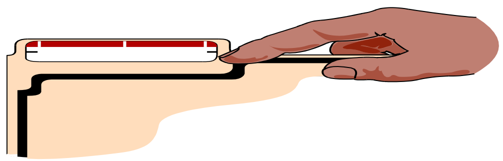
- advantages?
  - – cheap; easy to use
- disadvantages?



eg., student folders,
alpha sorted

Obvious solution: paper-based

- advantages?
  - cheap; easy to use
- disadvantages?
  - no ‘ad hoc’ queries
  - no sharing
  - large physical foot-print



Next obvious solution

- computer-based (flat) files +
- C (Java, ...) programs to access them

e.g., one (or more) UNIX/DOS files, with student records and their courses

Next obvious solution

your layout for the student records?

Next obvious solution

your layout for the student records?

(eg., comma-separated values ‘csv’

Smith,John,123,db,A,os,B

Tompson,Peter,234

Atkinson,Mary,345,os,B,graphics,A

Next obvious solution

your layout for the student records?

(many other layouts are fine, eg.:

Smith,John,123
Tompson,Peter,234
Atkinson,Mary,345

123,db,A
123,os,B
345,os,B
345,graphics,A

Problems?

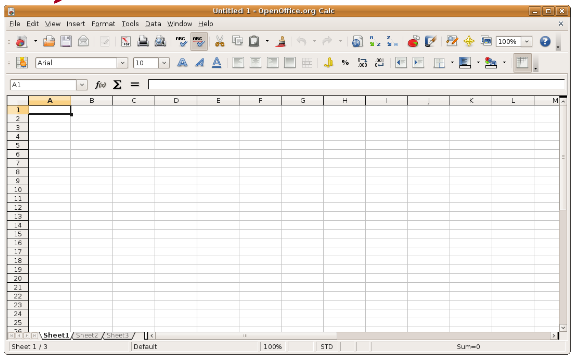
Problems?

- inconvenient access to data (need ‘C++’ expertize, plus **knowledge** of file-layout)
  - data isolation
- data redundancy (and inconcistencies)
- integrity problems
- atomicity problems

Problems? (cont'd)

- ...
- concurrent-access anomalies
- security problems

Problems? (cont'd)



[why?

because of two main reasons:

- **file-layout** description is buried within the C programs and
- **Transactions**: there is no support for them (concurrency and recovery)

]

DBMSs handle exactly these two problems

DBMS solution

- commercial/freeware DBMS &
- application programs

Main vendors/products

Commercial

- Oracle
- IBM/DB2
- MS SQL-server
- Sybase
- (MS Access,
- ...)

Open source

Postgres (UCB)
mySQL/mariaDB
sqlite (sqlite.org)

(www.acm.org/sigmod)

<Demo with sqlite3>

- Insert ‘student’ and ‘takes’ records
- Find the ‘os’ class roster
- Find the GPA of ‘Smith’

www.cs.cmu.edu/~christos/courses/dbms.F15/files/sqldemo.zip

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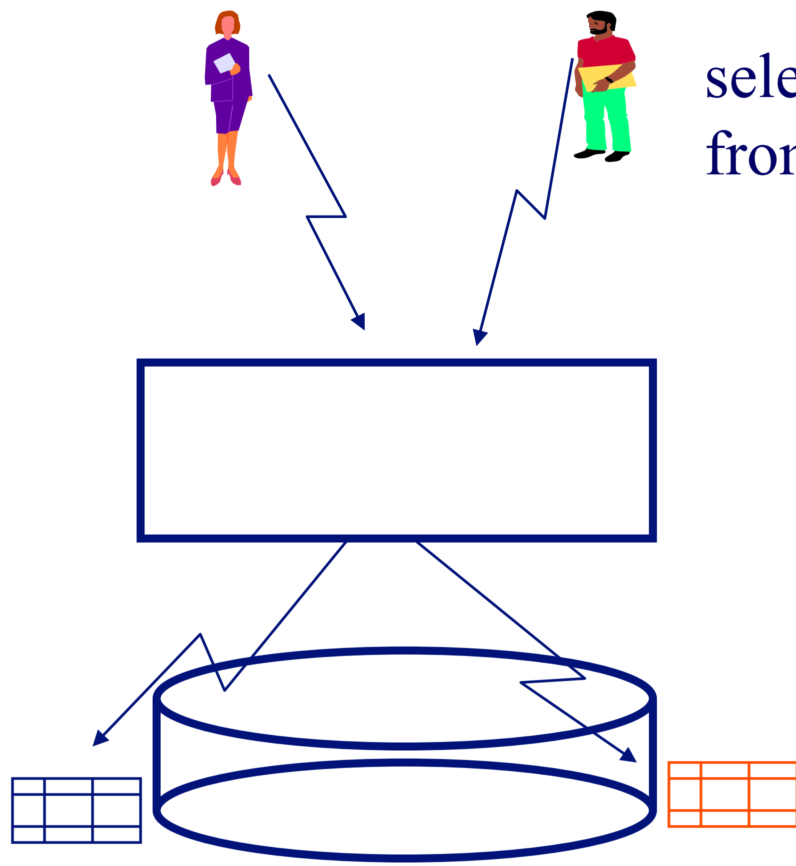
How do DBs work?

Pictorially:

select *
from student

DBMS



data

and meta-data =
catalog =
data dictionary

How do DBs work?

```
% sqlite3 miniu.sql
sqlite>create table student (
    ssn fixed;
    name char(20) );
```

student	
ssn	name

```
Smith,John,      123, db,A,os,B
Tompson,Peter,234
Atkinson,Mary,345, os,B,graphics,A
```

How do DBs work?

```
% sqlite3 miniu.sql
sqlite>create table student (
    ssn fixed;
    name char(20) );
```

student	
ssn	name

Smith,	123, db,4,os,3
Tompson,	234
Atkinson,	345, os,3,graphics,4

How do DBs work?

sqlite>insert into student values (123, “Smith”);

sqlite>select * from student;

student	
ssn	name
123	Smith

```
create table student (ssn fixed, name char(20));
insert into student values(123, "Smith");
insert into student values(234, "Tompson");
insert into student values(345, "Atkinson");

-- see what we have inserted
select * from student;

ssn        name
---------- ----------
123        Smith
234        Tompson
345        Atkinson
```

How do DBs work?

sqlite>create table takes (

ssn fixed,

cid char(10),

grade fixed));

takes		
ssn	cid	grade

```
-- register students in classes and give them grades

drop table if exists takes;
create table takes (ssn fixed, cid char(10), grade fixed);

insert into takes values( 123, "db", 4);
insert into takes values( 123, "os", 3);
insert into takes values( 345, "os", 3);
insert into takes values( 345, "graphics", 4);
```

```
Smith,John,123,db,A,os,B
Tompson,Peter,234
Atkinson,Mary,345,os,B,graphics,A
```

-- see what we inserted

```
select * from takes;

ssn        cid        grade
---------- ---------- ----------
123        db          4
123        os          3
345        os          3
345        graphics    4
```

Smith,John,123,db,A,os,B
Tompson,Peter,234
Atkinson,Mary,345,os,B,graphics,A

How do DBs work - cont'd

More than one tables - joins

Eg., roster (names only) for 'os'

student	
ssn	name

takes		
ssn	cid	grade

How do DBs work - cont'd

sqlite> select name
from student, takes
where student.ssn = takes.ssn
and takes.c-id = 'os'

-- find the os class roster

```
select name from student, takes
    where student.ssn = takes.ssn
    and cid="os";
```

name

Smith
Atkinson

Smith,John,123,db,A,os,B
Tompson,Peter,234
Atkinson,Mary,345,os,B,graphics,A

Views - a powerful tool!

what and why?

- suppose secy is allowed to see **only** ssn's and GPAs, but not individual grades
- -> VIEWS!

Views

```
sqlite> create view fellowship as (
        select ssn,  avg(grade)
        from takes   group by ssn);
```

takes		
ssn	**cid**	**grade**
123	db	4
123	os	3
345	os	3
345	graphics	4

ssn	avg(grade)
123	3.5
345	3.5

Views

Views = ‘virtual tables’

Views

sqlite> select * from fellowship;

takes		
ssn	**cid**	**grade**
123	db	4
123	os	3
345	os	3
345	graphics	4

ssn	avg(grade)
123	3.5
345	3.5

Views

sql> grant select on fellowship to secy;

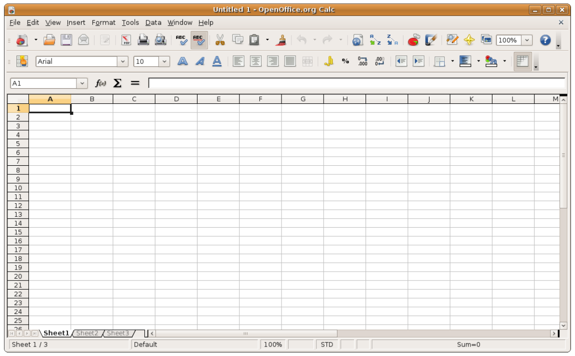
('grant' not supported in sqlite)

takes		
ssn	**cid**	**grade**
123	db	4
123	os	3
345	os	3
345	graphics	4

ssn	avg(grade)
123	3.5
345	3.5

Iterating: advantages over (flat) files

- **logical** and **physical** data independence, because data layout, security etc info: stored **explicitly** on the disk
- concurrent access and transaction support



Disadvantages over (flat) files?

Disadvantages over (flat) files

- Price
- additional expertise (SQL/DBA)

hence: over-kill for small, single-user data sets

But: mobile phones (eg., android) use sqlite; some versions of firefox do, too: ./mozilla/.../cookies.sqlite etc

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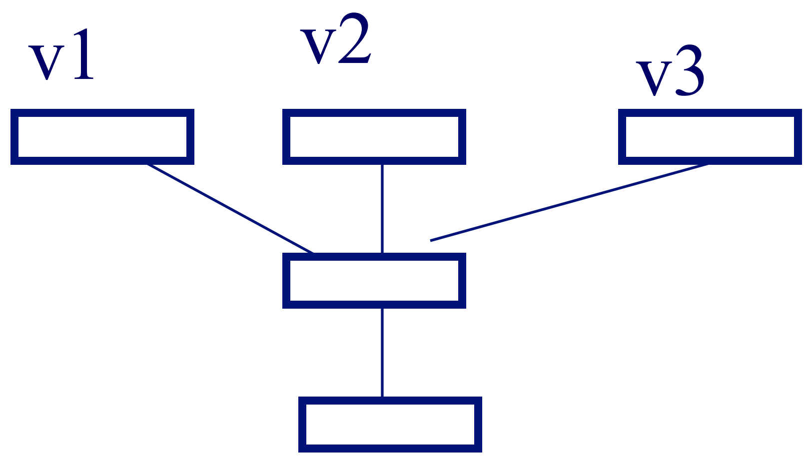
Fundamental concepts

- 3-level architecture
- logical data independence
- physical data independence

3-level architecture

- view level
- logical level
- physical level



3-level architecture

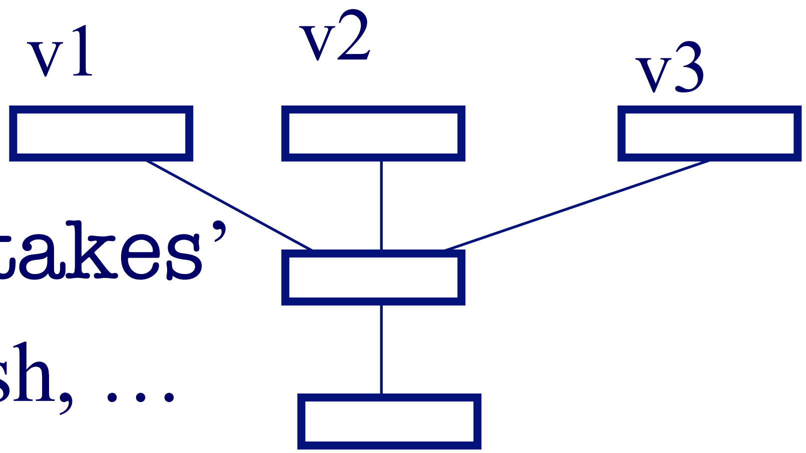
- view level
- logical level: eg., tables
  - STUDENT(ssn, name)
  - TAKES (ssn, cid, grade)
- physical level:
  - how are these tables stored, how many bytes / attribute etc

3-level architecture

- view level, eg:
  - v1: select ssn from student
  - v2: select ssn, c-id from takes
- logical level
- physical level

3-level architecture

- view level -> ‘fellowship’
- logical level -> ‘student’ ‘takes’
- physical level -> indices, hash, …



3-level architecture

- -> hence, **physical** and **logical** data independence:
- logical D.I.:
  - ???
- physical D.I.:
  - ???

3-level architecture

- -> hence, **physical** and **logical** data independence:
- logical D.I.:
  - can add (drop) column; add/drop table
- physical D.I.:
  - can add index; change record order

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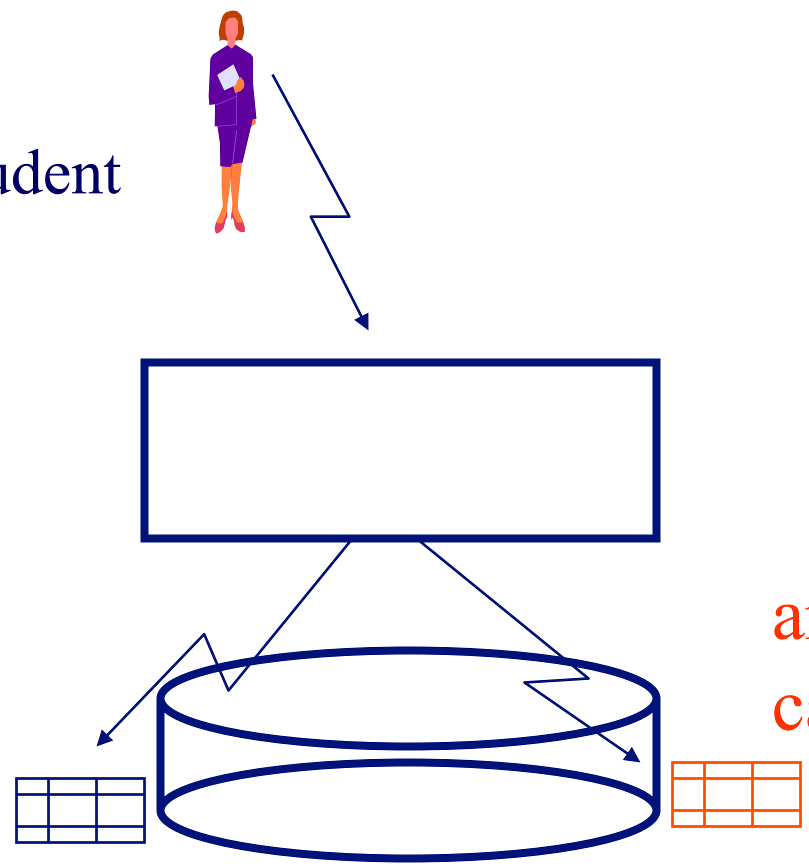
Database users

- ‘naive’ users
- casual users
- application programmers
- [DBA (Data base administrator)]

Casual users

select *
from student

DBMS

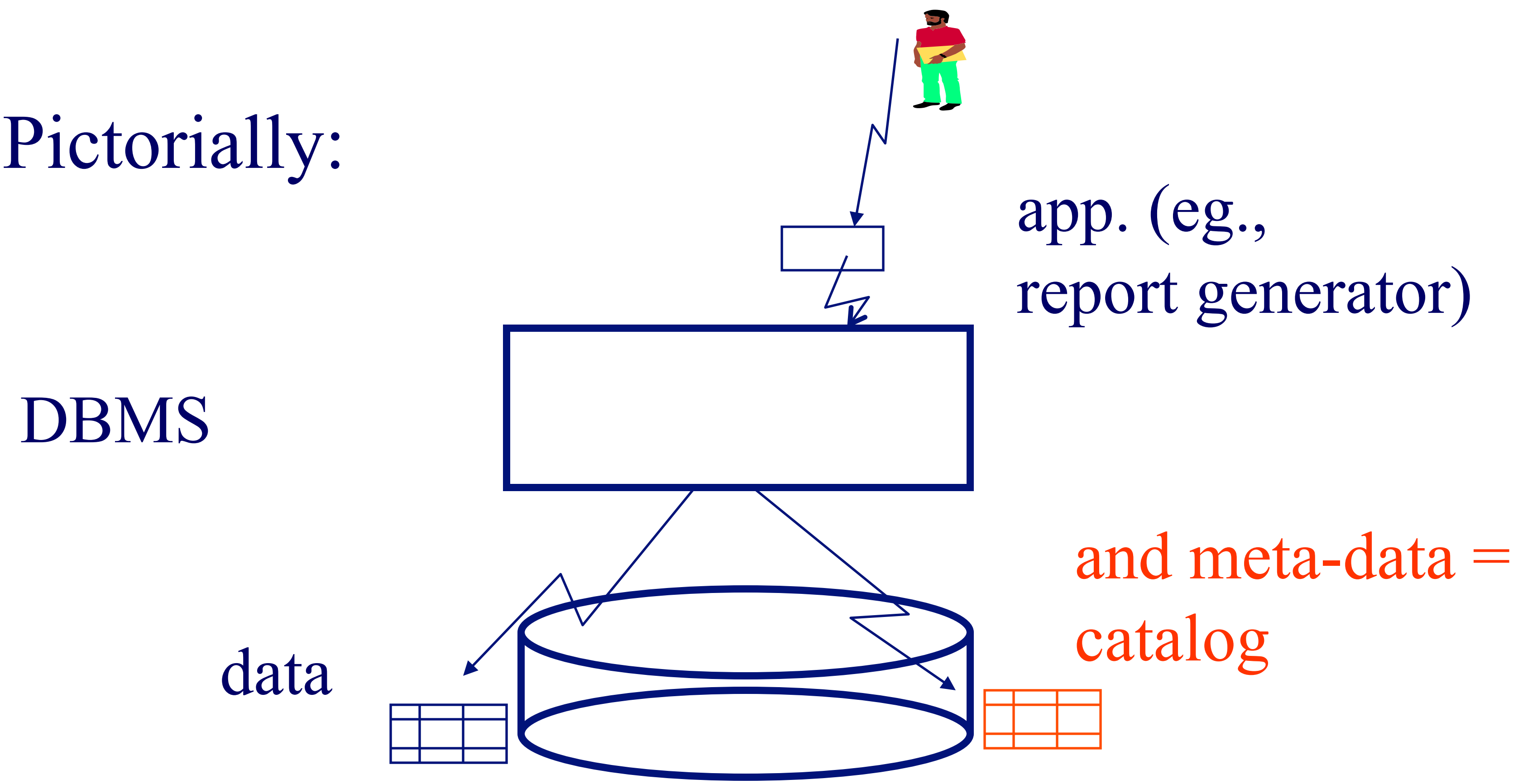


data

and meta-data = catalog

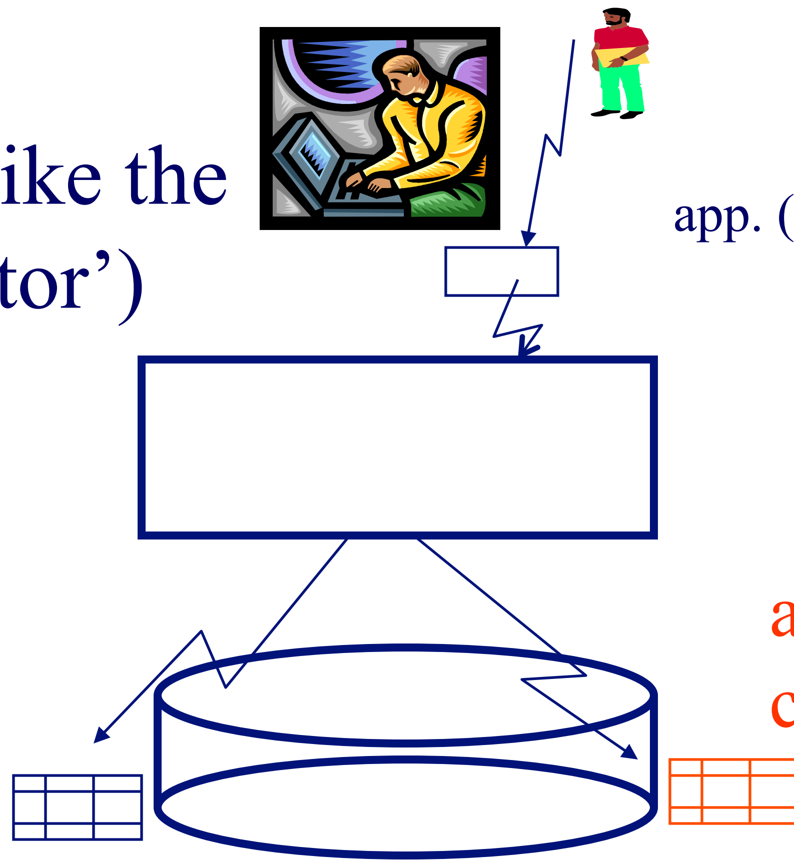
``Naive'' users

Pictorially:

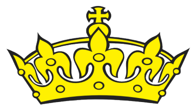


App. programmers

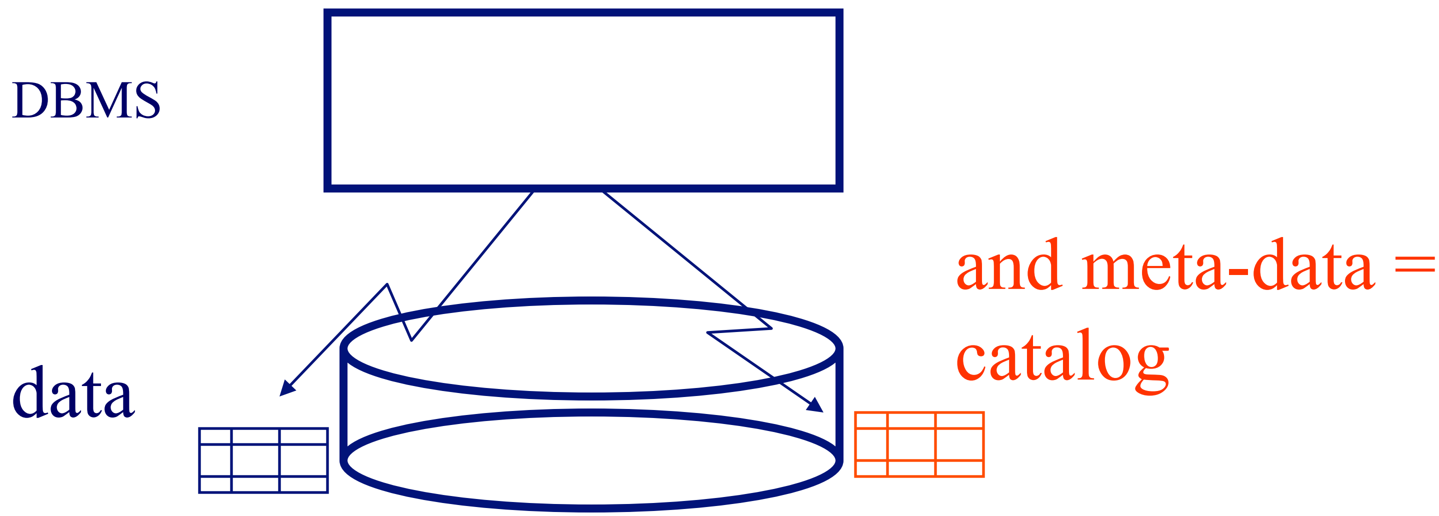
- Authors of applications (like the ‘report generator’)



DB Administrator (DBA)



- Duties?



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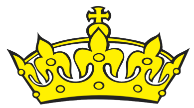

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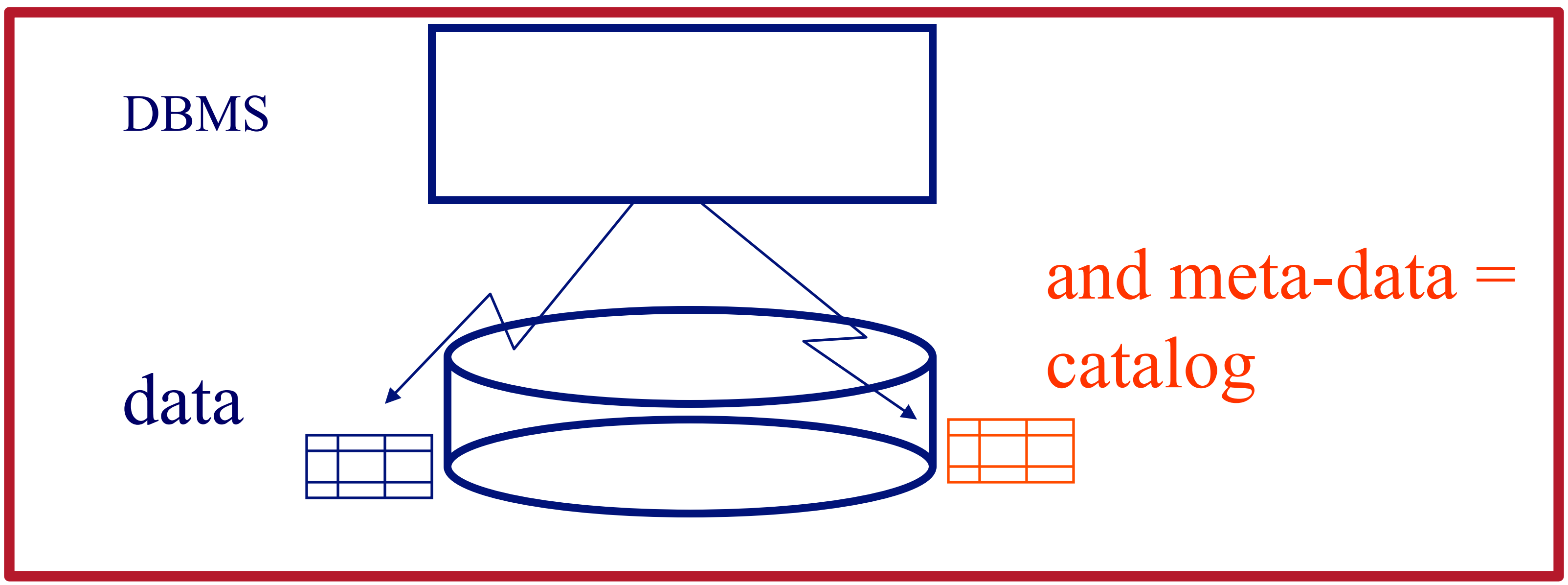

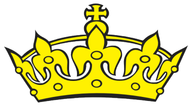

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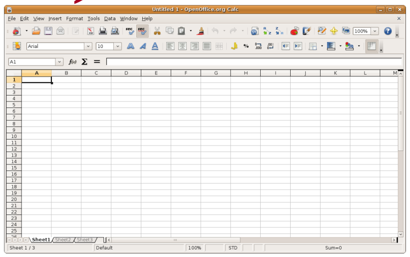

- schema definition (‘logical’ level)
- physical schema (storage structure, access methods
- schema modifications
- granting authorizations
- integrity constraint specification

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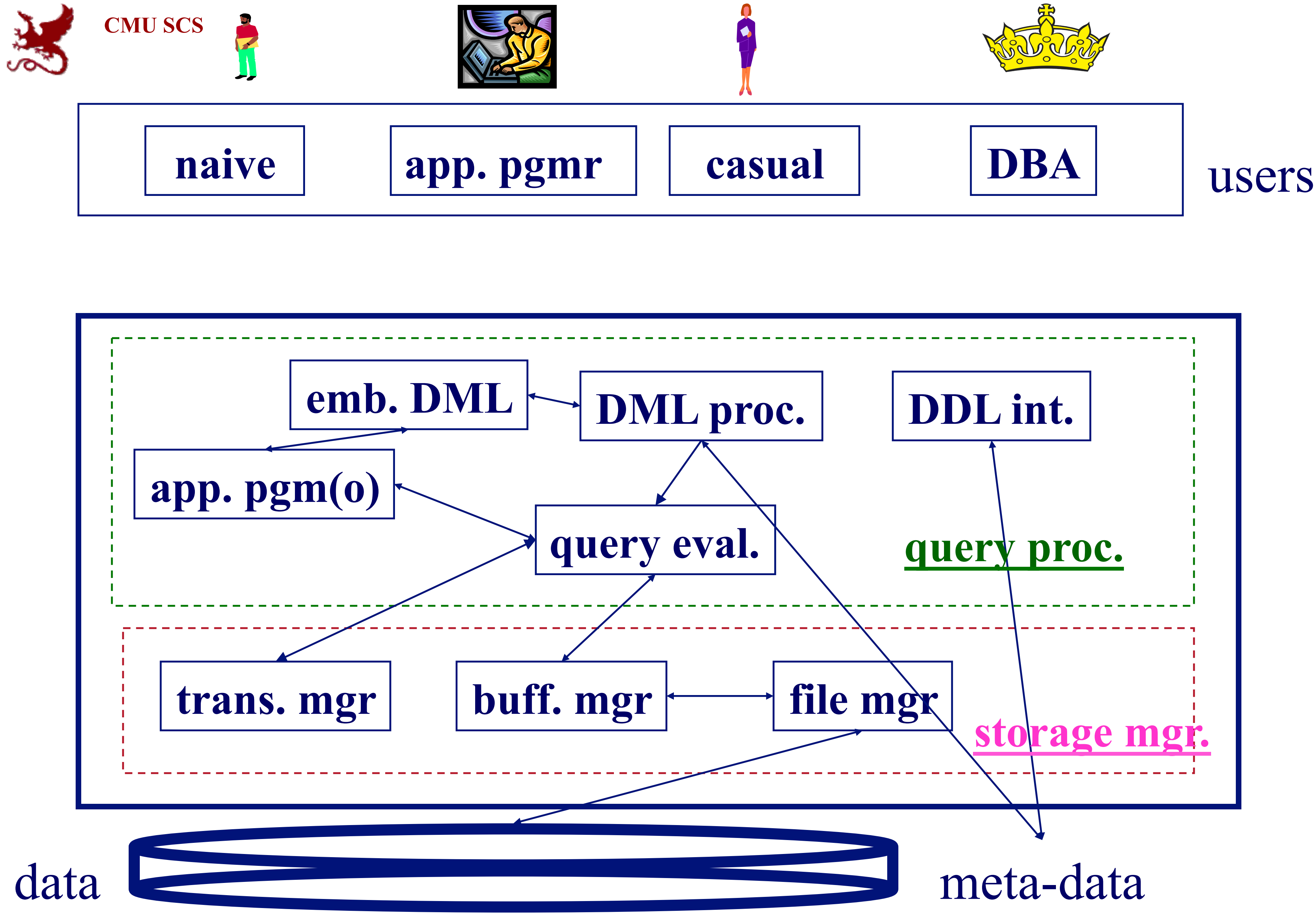
Overall system architecture

- [Users]
- DBMS
  - query processor
  - storage manager
- [Files]


naive
app. pgmr
casual
DBA
users
emb. DML
DML proc.
DDL int.
app. pgm(o)
query eval.
query proc.
trans. mgr
buff. mgr
file mgr
storage mgr.
data
meta-data

Overall system architecture

- query processor
  - DML compiler
  - embedded DML pre-compiler
  - DDL interpreter
  - Query evaluation engine

Overall system architecture (cont'd)

- storage manager
  - authorization and integrity manager
  - transaction manager
  - buffer manager
  - file manager

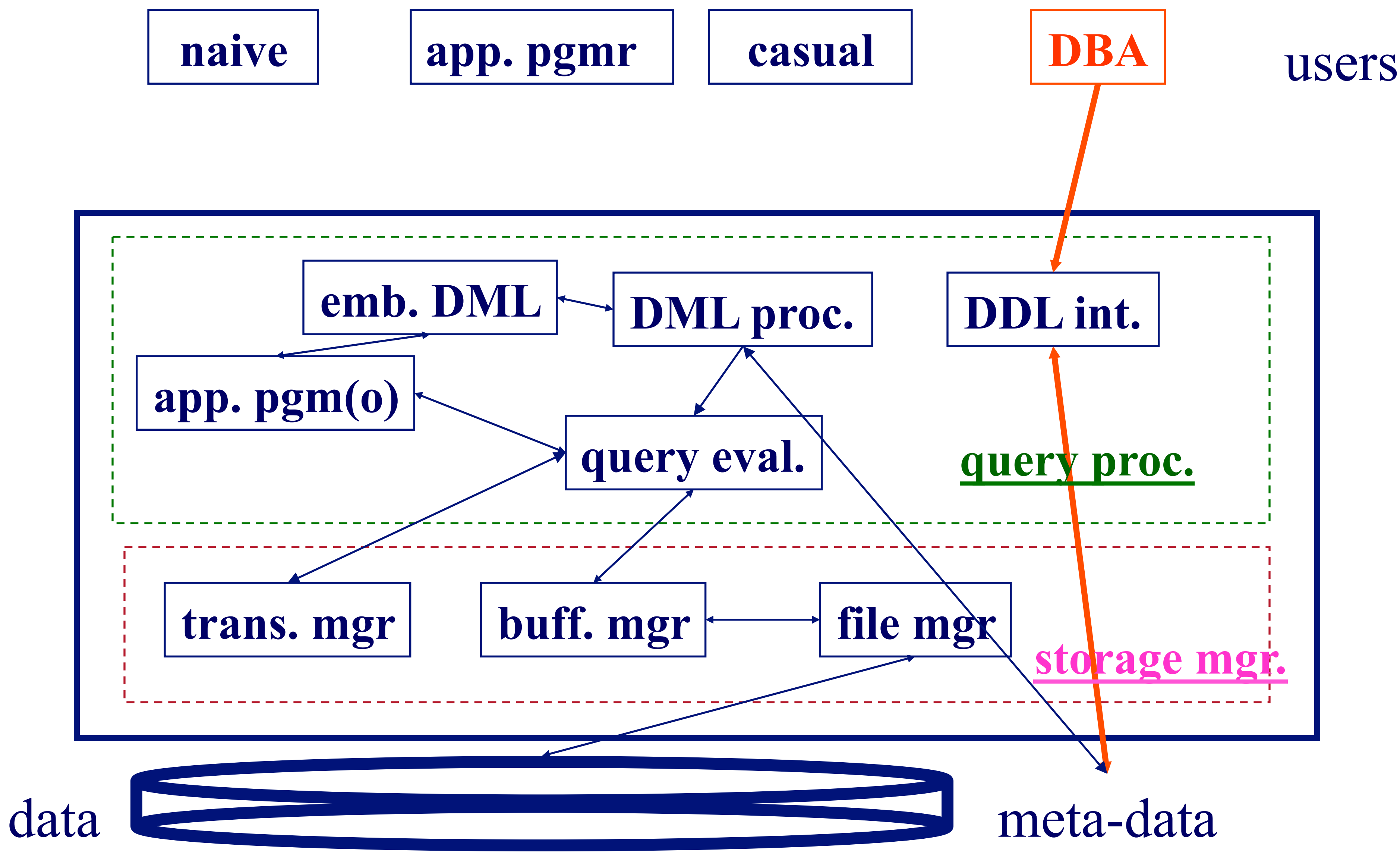
Overall system architecture (cont'd)

- Files
  - data files
  - data dictionary = catalog (= meta-data)
  - indices
  - statistical data

Some examples:

- DBA doing a DDL (data definition language) operation, eg.,

  create table student ...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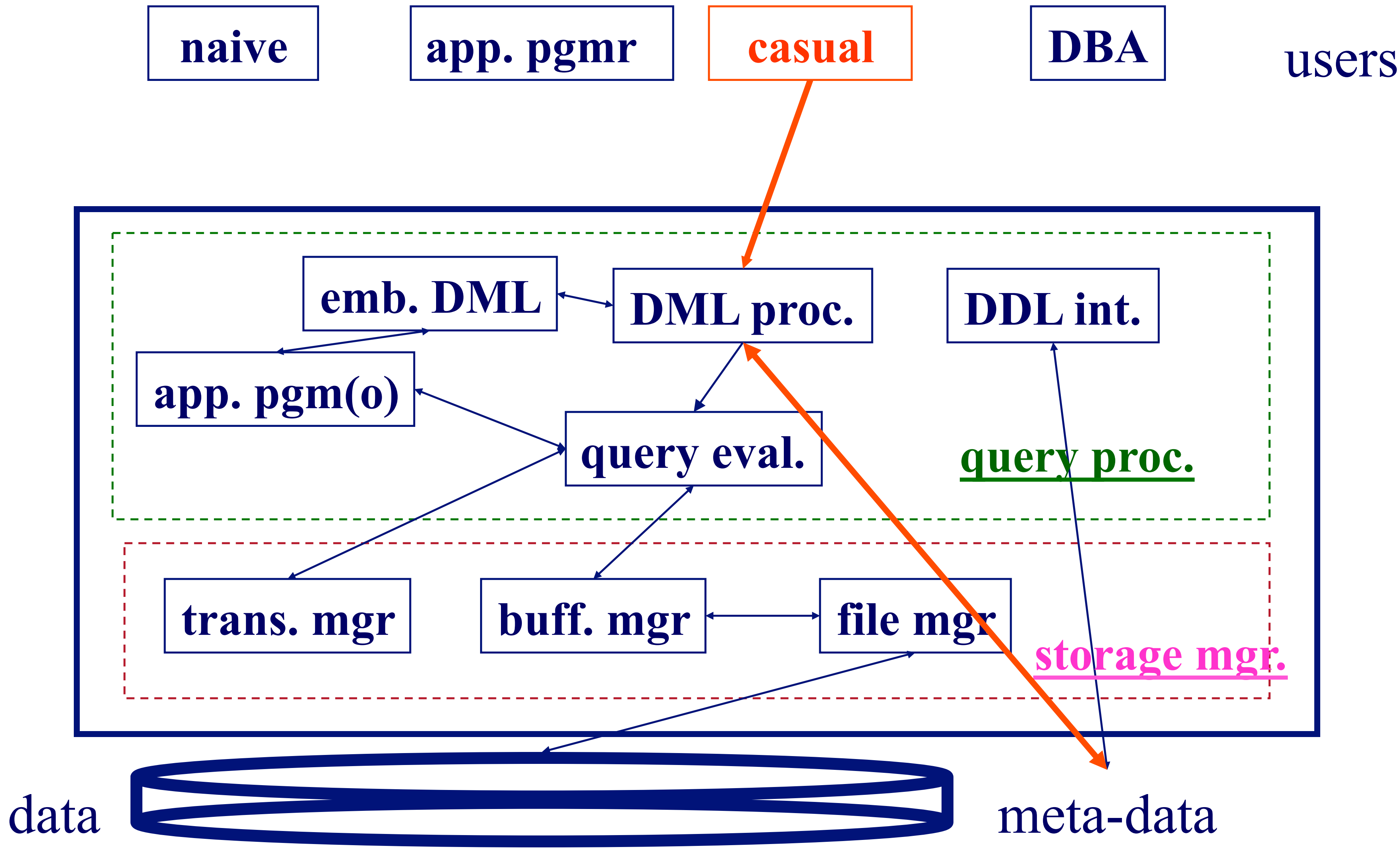
Some examples:

- casual user, asking for an update, eg.:

  update student

  set name to ‘smith’

  where ssn = ‘345’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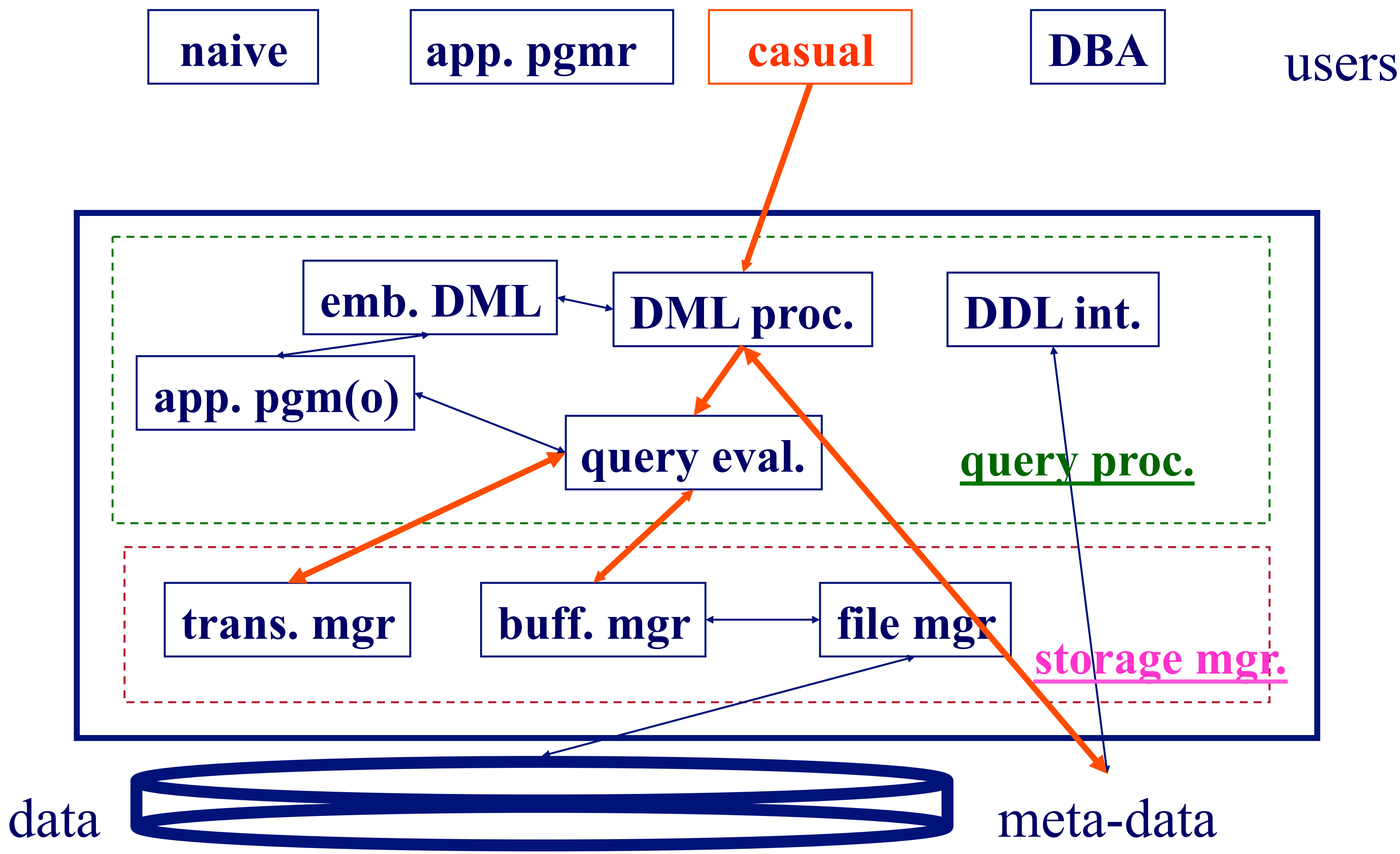
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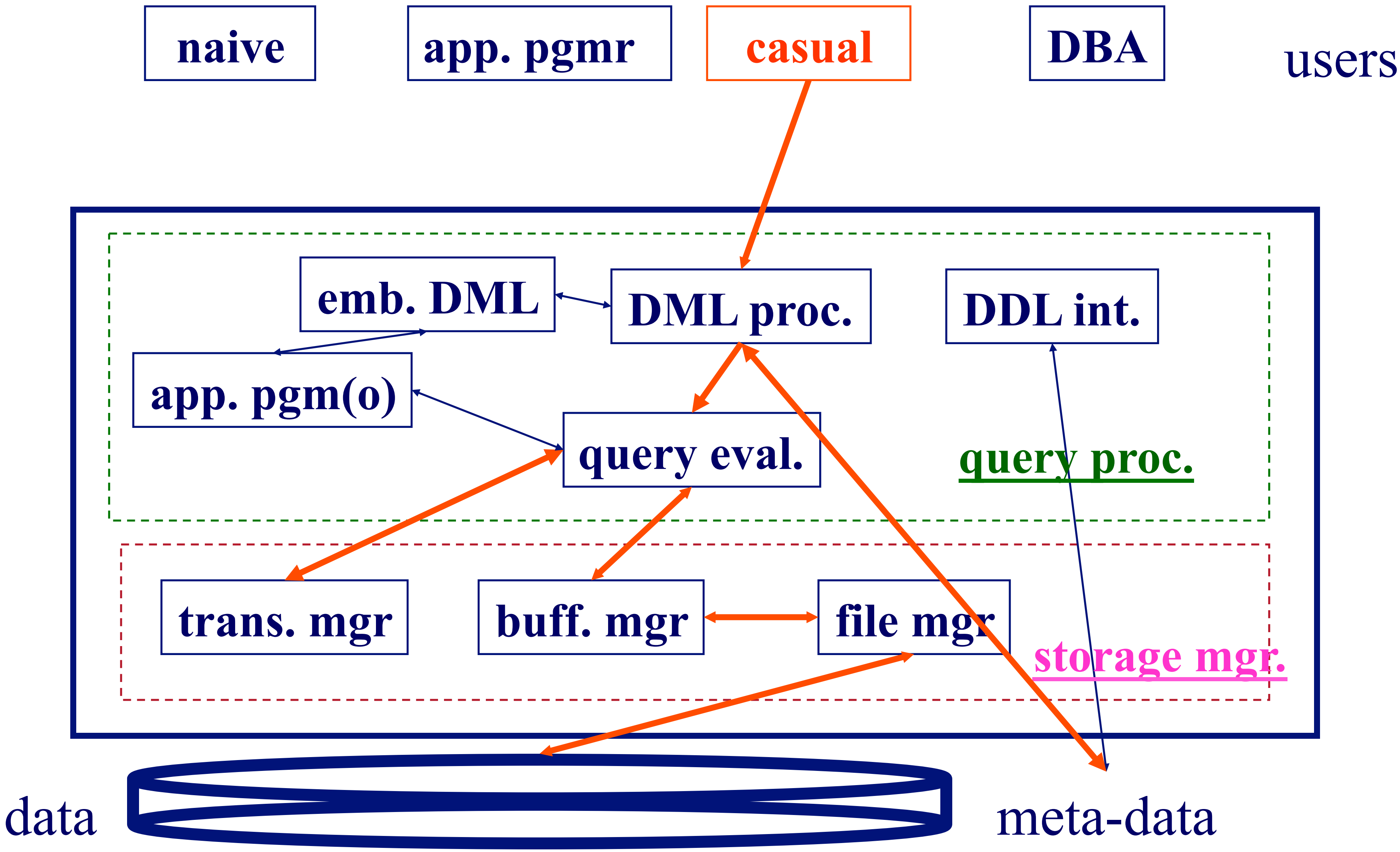
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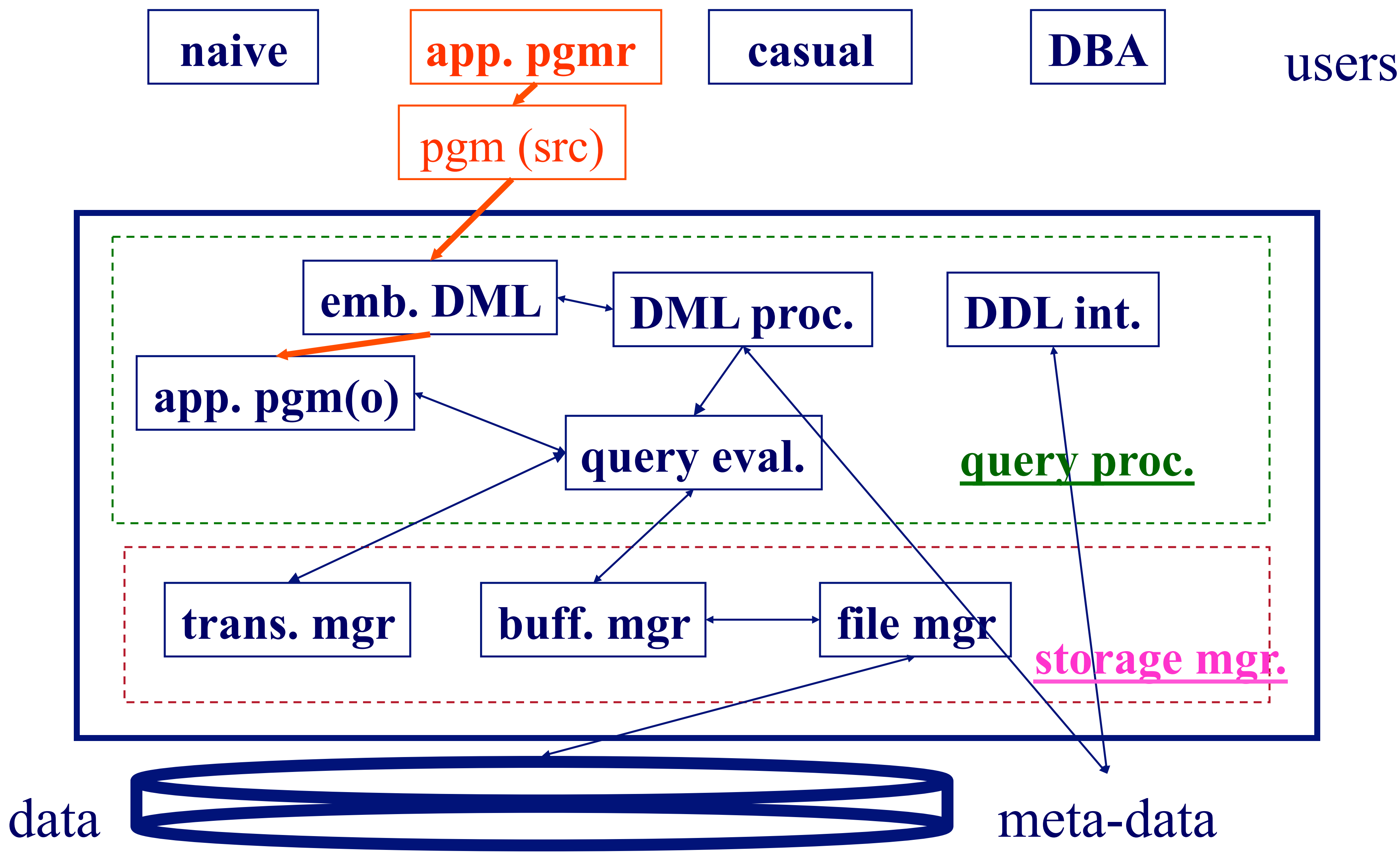
Some examples:

- app. programmer, creating a report, eg

```
main(){
....
exec sql "select * from student"
...
}
```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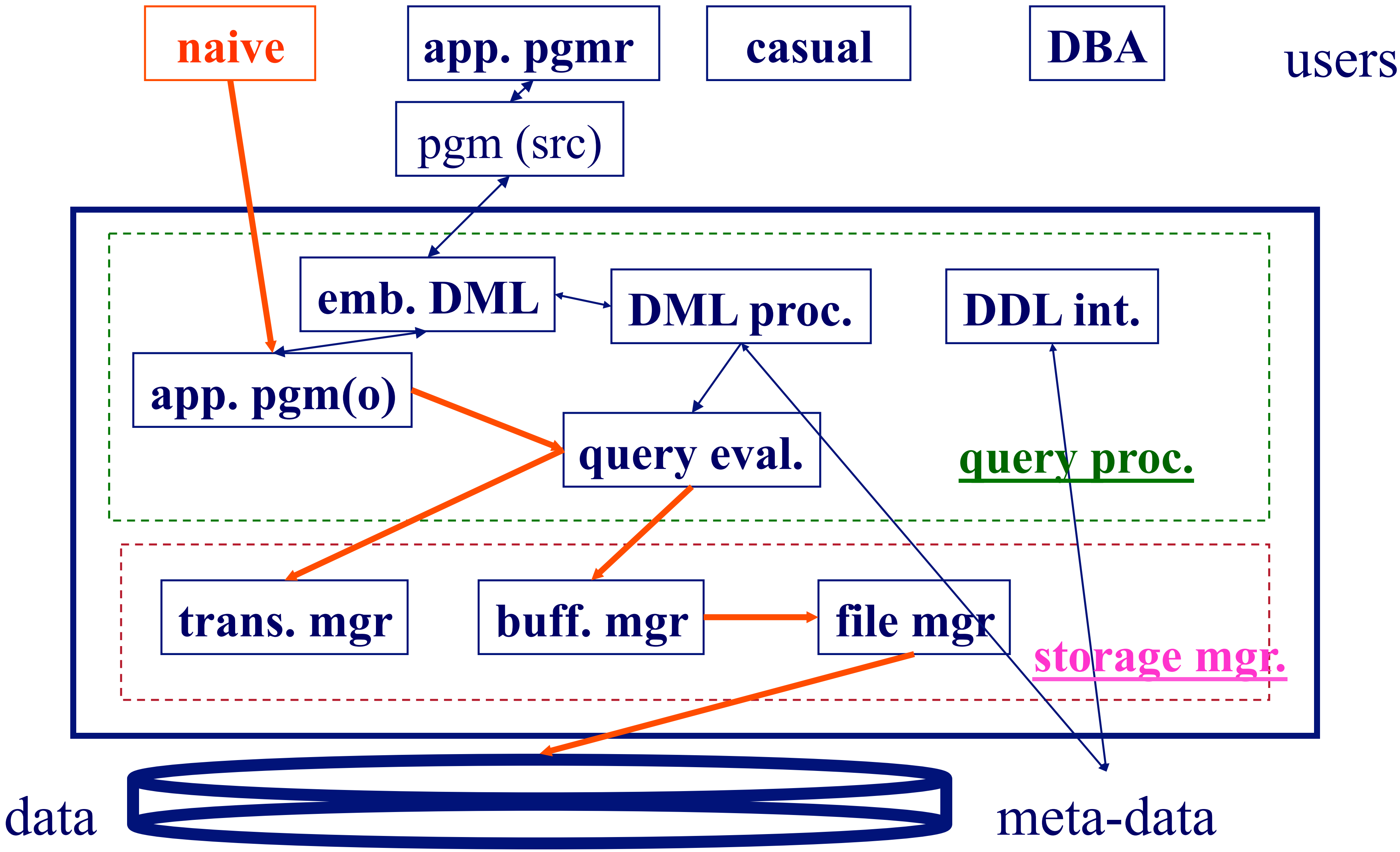
Some examples:

- 'naive' user, running the previous app.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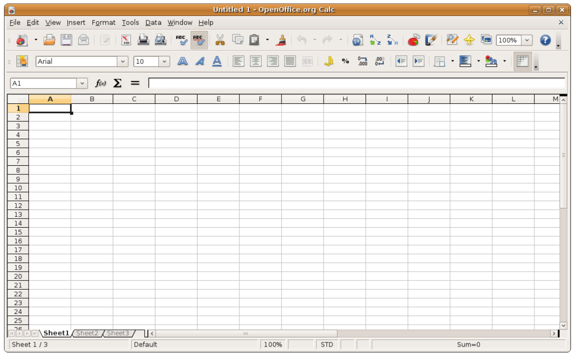
Conclusions

- (relational) DBMSs: electronic record keepers
- customize them with **create table** commands
- ask SQL queries to retrieve info

Conclusions cont'd

main advantages over (flat) files & scripts:



- **logical + physical data independence** (ie., flexibility of adding new attributes, new tables and indices)
- **concurrency control** and **recovery**