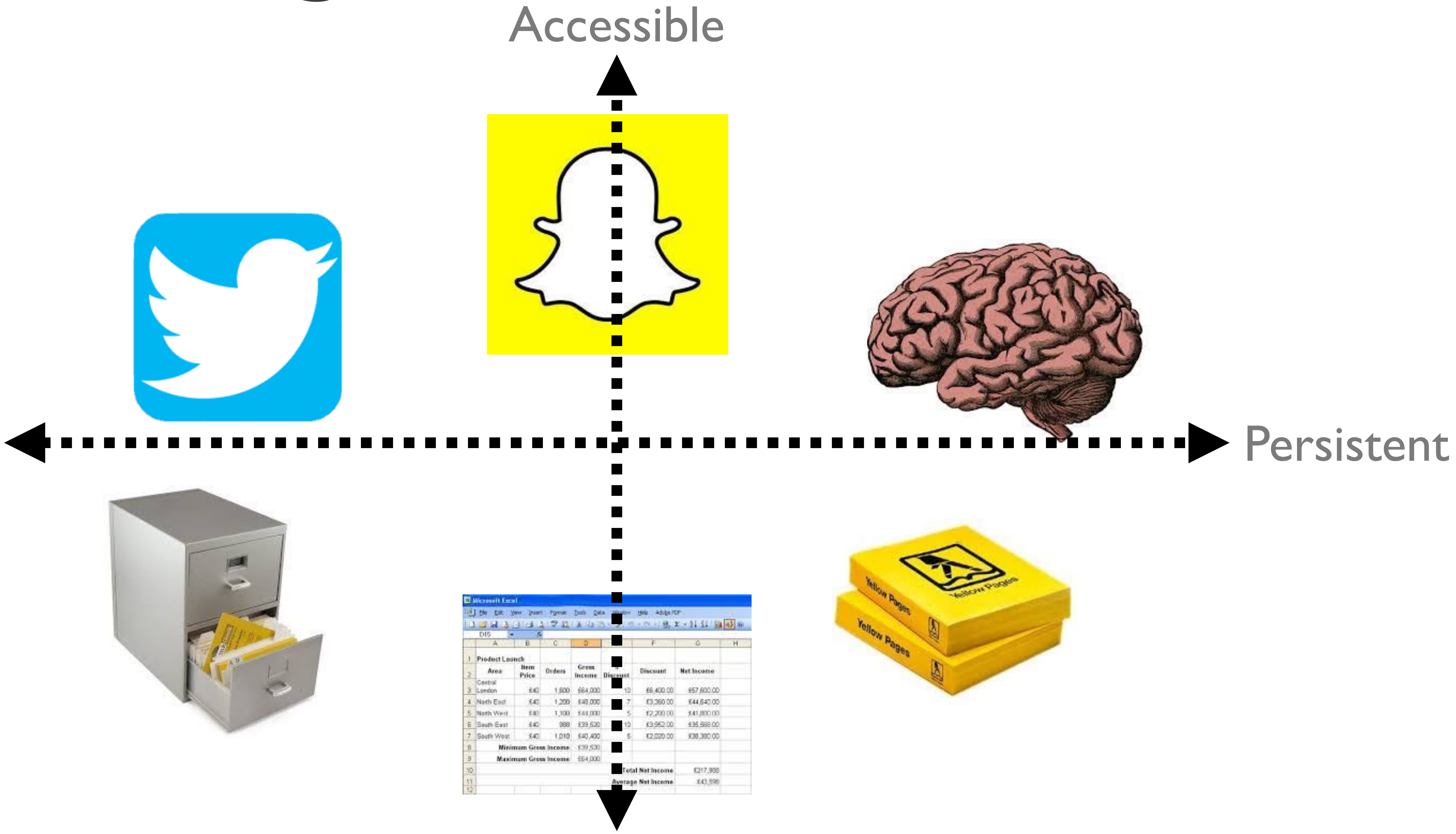
Intro to Databases

SQL

What is a database?

Things that hold info


Accessible
Persistent
Microsoft Excel
File Edit View Insert Format Tools Data Window Help Adobe PDF
D15
Yellow Pages

	A	B	C	D	E	F	G	H
1	Product Launch							
2	Area	Item Price	Orders	Gross Income	% Discount	Discount	Net Income	
3	Central London	£40	1,600	£64,000	10	£6,400.00	£57,600.00	
4	North East	£40	1,200	£48,000	7	£3,360.00	£44,640.00	
5	North West	£40	1,100	£44,000	5	£2,200.00	£41,800.00	
6	South East	£40	988	£39,520	10	£3,952.00	£35,568.00	
7	South West	£40	1,010	£40,400	5	£2,020.00	£38,380.00	
8		Minimum Gross Income		£39,520				
9		Maximum Gross Income		£64,000				
10						Total Net Income	£217,988	
11						Average Net Income	£43,598	
12								

A database **persists** information and is **accessible** via code

organized **queryable** **manageable**

Organized: Standard Storage Formatting

- DBs are a collection of Tables (or *relations*)
- Tables have Columns (*attributes* / *fields*) that describe Rows (*instances* / *tuples*)
- Duplicate rows are not allowed
- Rows often have a primary key (unique identifier)

Table / Relation

	Column / Attribute / Field	Column / Attribute / Field	Column / Attribute / Field
	ID	**Name**	**Type**
Row / Tuple / Instance	1	Pikachu	lightning
Row / Tuple / Instance	2	Squirtle	water
Row / Tuple / Instance	3	Charmander	fire
Row / Tuple / Instance	4	Bulbasaur	grass

Queryable: via a Standard Language

- A simple, structured query language: SQL
- Declarative (vs. imperative)
- No more hand-rolled algorithms / data structures
- DBMS picks an efficient execution strategy based on indexes, data, workload etc.

SQL

```sql
-- Pikachu, I choose you!
SELECT id, name
  FROM pokemon
  WHERE type = 'lightning'
  LIMIT 1
```

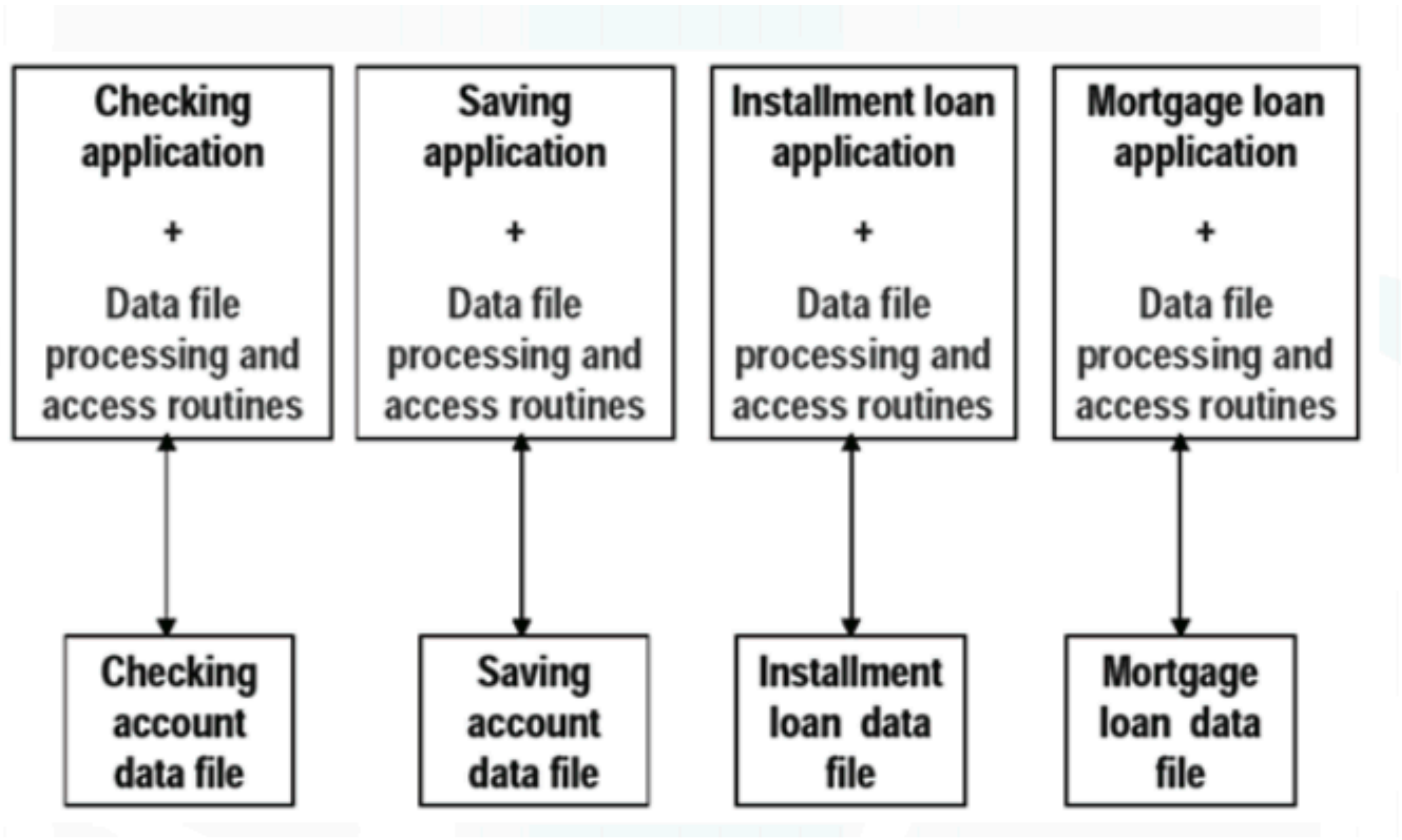
Manageable: Easy, Safe, Performant

- Offloads work and requisite understanding of programming
- Knowledge is portable
- Abstraction
- Transfer data between systems
- DBMS can make certain guarantees
  - prevent unsafe operations
  - built-in redundancies
  - handle multiple users, threads

How Did We End Up Here?

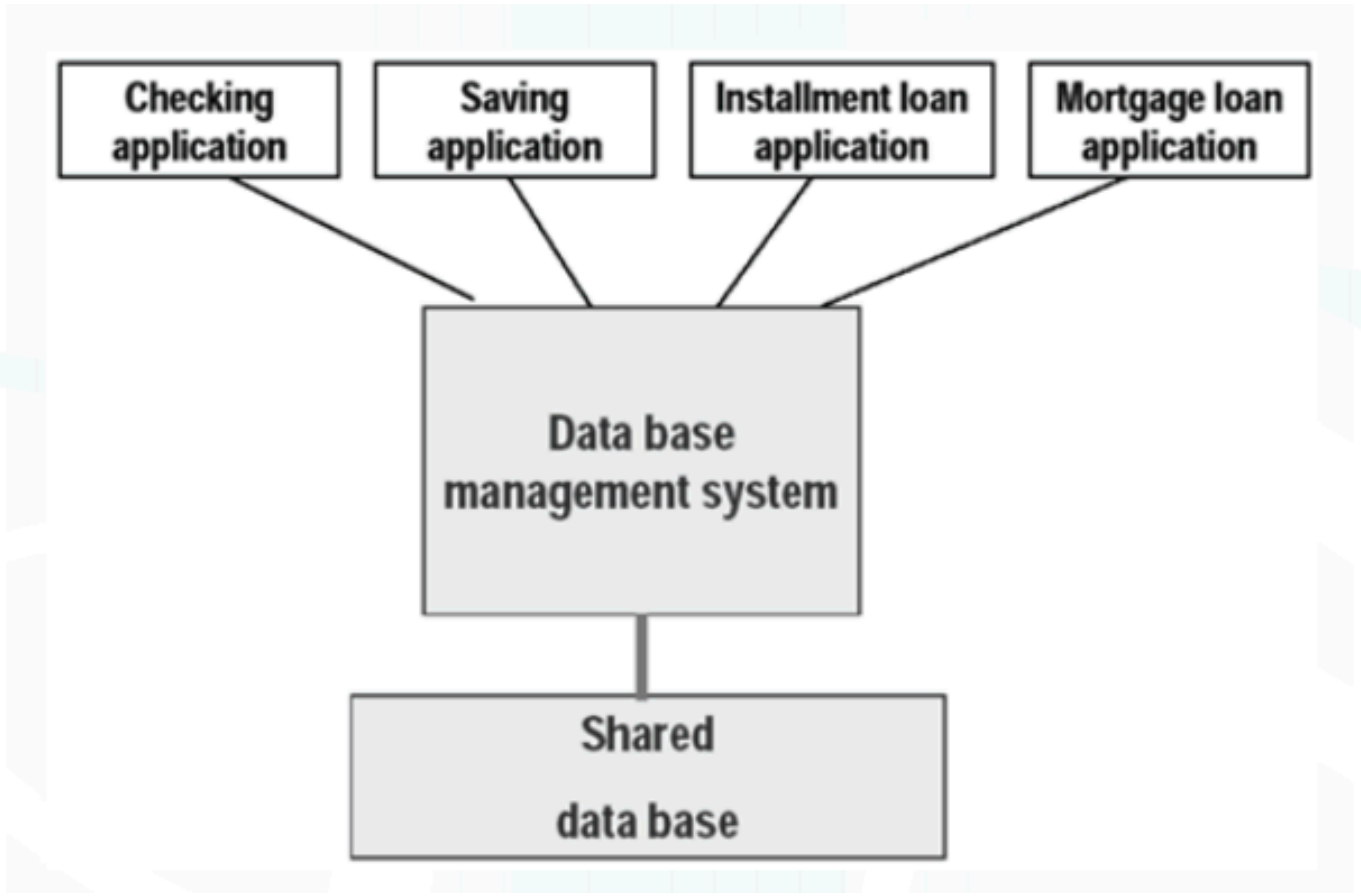
Before Relational DBs (ca. < 1970s)

- Data stored in custom “data files”
- Queried via application-specific code
- Advantages
  - Middle layer not needed
  - Solutions customized for each application
- Disadvantages
  - Hard to change the system
  - Knowledge not compounding
  - Data-transfer is difficult



Checking application + Data file processing and access routines
Saving application + Data file processing and access routines
Installment loan application + Data file processing and access routines
Mortgage loan application + Data file processing and access routines
Checking account data file
Saving account data file
Installment loan data file
Mortgage loan data file

Database Management Systems (DBMS)

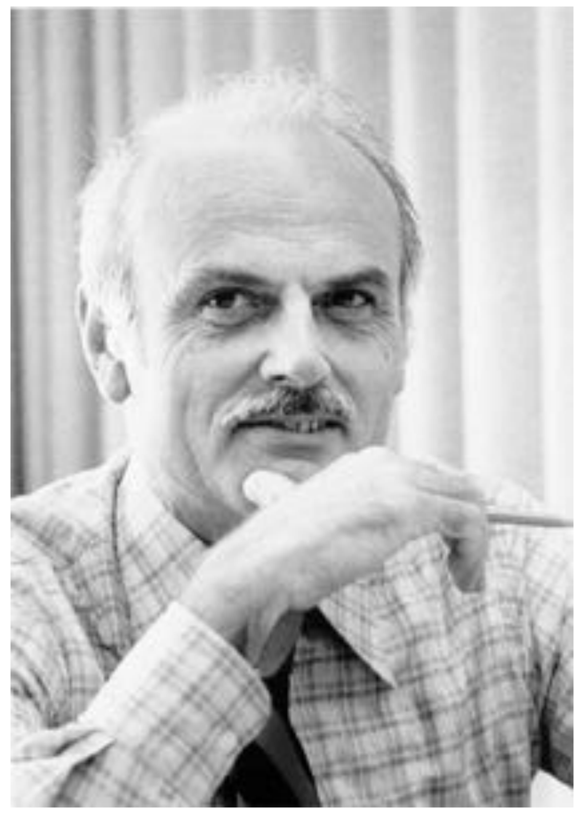

Checking application
Saving application
Installment loan application
Mortgage loan application
Data base management system
Shared data base

- One layer and language to store and access data
- Sold as a way for "non-technical people" to manage data

“Future users of large data banks must be protected from having to know how the data is organized in the machine (the internal representation).”

– E. F. CODD,
A RELATIONAL MODEL OF DATA FOR
LARGE SHARED DATA BANKS

Relational Databases & Logic



- 1969: Edgar Frank "Ted" Codd outlines *relational model* of data
- Wrote Alpha (never implemented) as a *query language*
- IBM slow to adopt his ideas
  - Competitors started to do so
  - IBM team formed without Codd, created **S**tructured **E**nglish **Qu**ery **L**ang
- SEQUEL way better than what came before
  - 1979: copied by Larry Ellison (from pre-launch papers / talks!) as "SQL"
- SQL became the standard (ANSI 1986, ISO 1987)
  - Codd continued to fault SQL compared to his theoretical model
  - The Third Manifesto: solve the *object-relational impedance mismatch*

Appreciating Databases

- Ubiquitous
- Standardized
- Complex / deep
- Powerful: database admins are
  - Feared by developers
  - …but also taken for granted until things break
  - Befriended by business people
  - Contacted by the government for secret data (e.g. NSA)

ACID Guarantees

- Atomicity
- Consistency
- Isolation
- Durability

What happens if the database crashes?

- **Suppose we have a banking system with client accounts**
- **Every debit must have a matching credit.**
- **Imagine a crash results in only one table being updated.**
  - Database inconsistency → unexpected data and software crashes/bugs
  - Financial risk for clients

Atomic Transactions

- atomic transaction: A set of database operations that must occur together
  - i.e. A debit to one bank account, and a credit to another
- A transaction must either succeed or fail; it cannot partially complete.
- Every database query is represented by a transaction

Consistency

- **Specify rules that columns need to follow**
  - Gender column can only contain M, F, or U.
  - Savings account must start with S or checking with C
  - Column cannot be null

- **Protect the database from inconsistencies and simplify software logic**
  - Allows software to make assumptions about underlying data

Resource Management

- Processes and can be readers and writers
- Files can have many readers
- If a process has a writer, no other process can read from it, and no other process can write to it

Proposed File Scheme

- Suppose that we have decided not to use a database and instead store our data in a series of files.

- How might our setup fail to serve queries from multiple users?

Deadlock

Databases give us concurrency (Isolation)

- Multiple clients can make queries to read and update without the risk of deadlock or starvation.

Persistence/Durability

- Files are also persistence (store information without power)

Progression of Databases

- **Navigational (< 1970s)**
  - More common during tape era; entries had references to next entries.
- **Relational (> 1970s)**
  - Based on relational (table-based) logic, see E.F. Codd.
- **NoSQL (> 2000s)**
  - "Not only SQL" — document storage, for example.

RDBMS vs NoSQL

- **A DBMS doesn't *have* to be relational**
  - Remember, DBMS is just an application that intelligently stores data and can answer requests to manage that data
- **Lately, many "NoSQL" or non-relational DBMSs have been gaining popularity**
  - Graph databases (e.g. GraphQL)
  - Document databases (e.g. MongoDB)
  - Hybrids (e.g. PostgreSQL)
- **RDBMSs still remain the #1 DB option for now**

Some well-known rDBMSs

PostgreSQL

SQLite

MySQL®

PostgreSQL

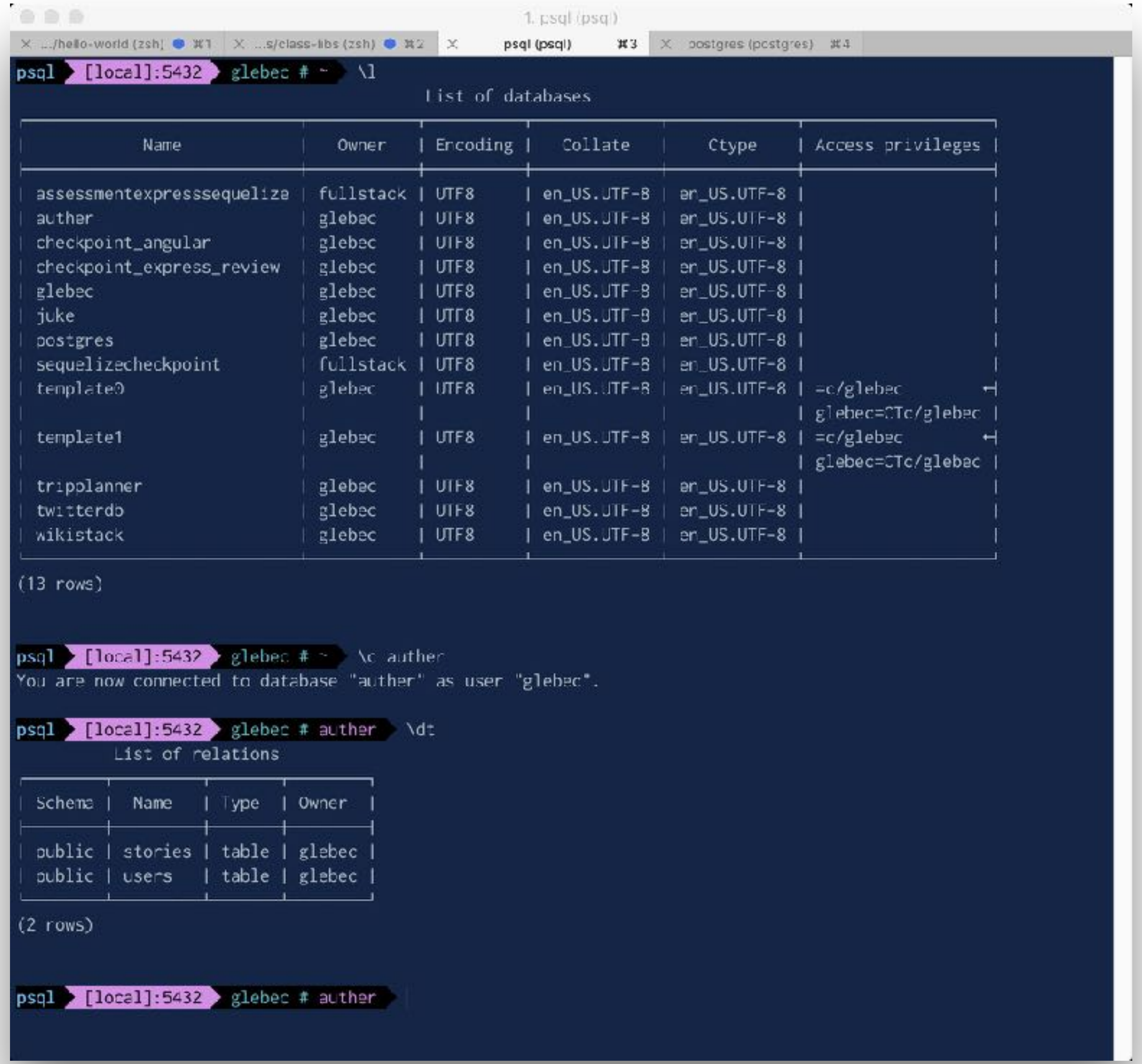
Why PostgreSQL?

- Advanced, powerful, and popular
- Rapid open source development
- Highly extensible (stored procedures)
- Deep SQL standards compliance
- NoSQL ("Not Only SQL"), objective support
- Excellent transactions / ACID reliability; focus on integrity
- Multi-user management / administration

History of PostgreSQL

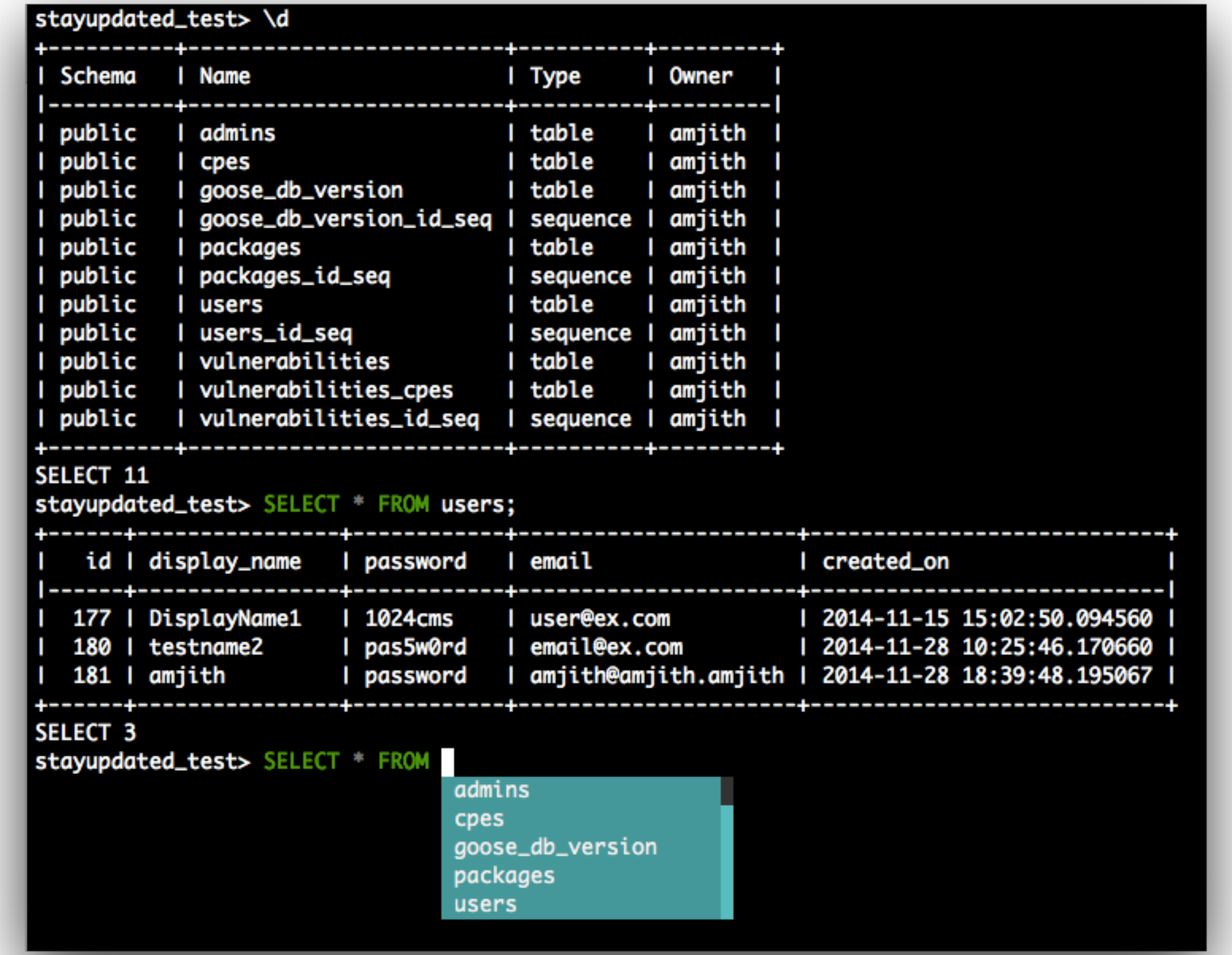
- 1970s at UC Berkeley:
  INteractive **G**raphics **RE**trieval **S**ystem (INGRES)
- 1980s: POSTGRES ("Post-Ingres")
- 1995: POSTQUEL and Postgres95.
  - `monitor -> psql`
- 1996: Adopted by the open source community
  - Ongoing: stability, testing, documentation, new features
  - PostgreSQL

psql



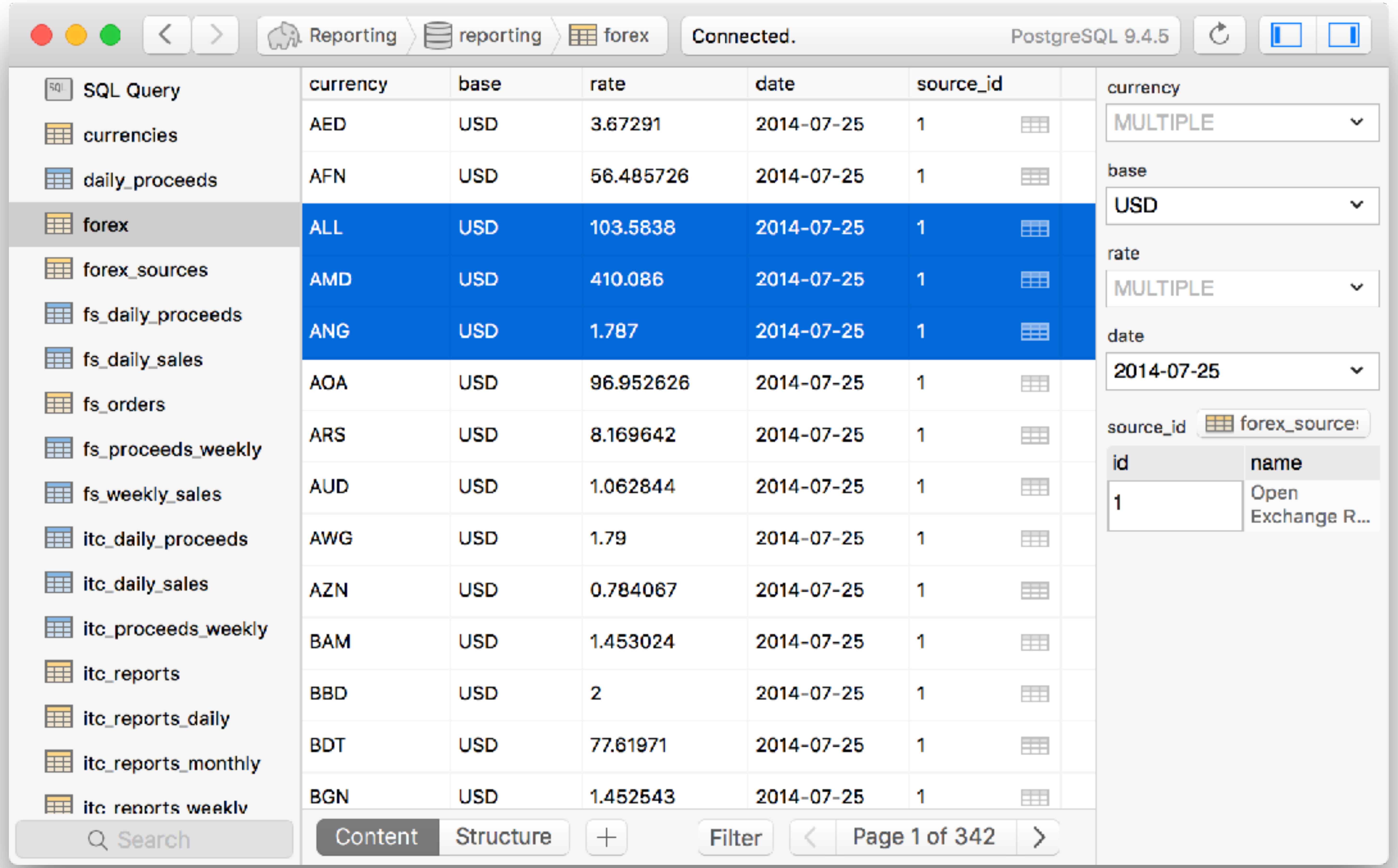
```
psql  [local]:5432  glebec # ~  \l
                                       List of databases
            Name             |   Owner   | Encoding |   Collate   |    Ctype    | Access privileges
-----------------------------+-----------+----------+-------------+-------------+-------------------
 assessmentexpresssequelize  | fullstack | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 auther                      | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 checkpoint_angular          | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 checkpoint_express_review   | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 glebec                      | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 juke                        | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 postgres                    | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 sequelizecheckpoint         | fullstack | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 template0                   | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 | =c/glebec        +
                             |           |          |             |             | glebec=CTc/glebec
 template1                   | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 | =c/glebec        +
                             |           |          |             |             | glebec=CTc/glebec
 tripplanner                 | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 twitterdb                   | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 wikistack                   | glebec    | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
(13 rows)


psql  [local]:5432  glebec # ~  \c auther
You are now connected to database "auther" as user "glebec".

psql  [local]:5432  glebec # auther  \dt
           List of relations
 Schema |  Name   | Type  | Owner
--------+---------+-------+--------
 public | stories | table | glebec
 public | users   | table | glebec
(2 rows)


psql  [local]:5432  glebec # auther
```

pgcli



```
stayupdated_test> \d
+----------+------------------------+----------+---------+
| Schema   | Name                   | Type     | Owner   |
|----------+------------------------+----------+---------|
| public   | admins                 | table    | amjith  |
| public   | cpes                   | table    | amjith  |
| public   | goose_db_version       | table    | amjith  |
| public   | goose_db_version_id_seq | sequence | amjith  |
| public   | packages               | table    | amjith  |
| public   | packages_id_seq        | sequence | amjith  |
| public   | users                  | table    | amjith  |
| public   | users_id_seq           | sequence | amjith  |
| public   | vulnerabilities        | table    | amjith  |
| public   | vulnerabilities_cpes   | table    | amjith  |
| public   | vulnerabilities_id_seq | sequence | amjith  |
+----------+------------------------+----------+---------+
SELECT 11
stayupdated_test> SELECT * FROM users;
+------+----------------+------------+----------------------+----------------------------+
|   id | display_name   | password   | email                | created_on                 |
|------+----------------+------------+----------------------+----------------------------|
|  177 | DisplayName1   | 1024cms    | user@ex.com          | 2014-11-15 15:02:50.094560 |
|  180 | testname2      | pas5w0rd   | email@ex.com         | 2014-11-28 10:25:46.170660 |
|  181 | amjith         | password   | amjith@amjith.amjith | 2014-11-28 18:39:48.195067 |
+------+----------------+------------+----------------------+----------------------------+
SELECT 3
stayupdated_test> SELECT * FROM 
                                 admins
                                 cpes
                                 goose_db_version
                                 packages
                                 users
```

Postico



Reporting › reporting › forex

Connected. PostgreSQL 9.4.5

SQL Query
currencies
daily_proceeds
forex
forex_sources
fs_daily_proceeds
fs_daily_sales
fs_orders
fs_proceeds_weekly
fs_weekly_sales
itc_daily_proceeds
itc_daily_sales
itc_proceeds_weekly
itc_reports
itc_reports_daily
itc_reports_monthly
itc_reports_weekly

currency	base	rate	date	source_id
AED	USD	3.67291	2014-07-25	1
AFN	USD	56.485726	2014-07-25	1
ALL	USD	103.5838	2014-07-25	1
AMD	USD	410.086	2014-07-25	1
ANG	USD	1.787	2014-07-25	1
AOA	USD	96.952626	2014-07-25	1
ARS	USD	8.169642	2014-07-25	1
AUD	USD	1.062844	2014-07-25	1
AWG	USD	1.79	2014-07-25	1
AZN	USD	0.784067	2014-07-25	1
BAM	USD	1.453024	2014-07-25	1
BBD	USD	2	2014-07-25	1
BDT	USD	77.61971	2014-07-25	1
BGN	USD	1.452543	2014-07-25	1

currency: MULTIPLE
base: USD
rate: MULTIPLE
date: 2014-07-25
source_id: forex_sources

id	name
1	Open Exchange R...

LAB