# Overview and History of Databases and Transactions

CSE 305 – Principles of Database Systems

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# Introduction

- What is a Database?

# Introduction

- What is a Database?
  - Collection of data central to some enterprise
  - Essential to operation of enterprise
    - Contains the only record of enterprise activity
  - An asset in its own right
    - Historical data can guide enterprise strategy
    - Of interest to other enterprises
  - State of database mirrors state of enterprise
    - Database is persistent

# Introduction

- What is a Database Management System?

# Introduction

- What is a Database Management System?
  - DBMS is a program that manages a database:
    - Supports a high-level access language (e.g. SQL).
    - Application describes database accesses using that language.
    - DBMS interprets statements of language to perform requested database access.

# Introduction

- What is a Transaction?

# Introduction

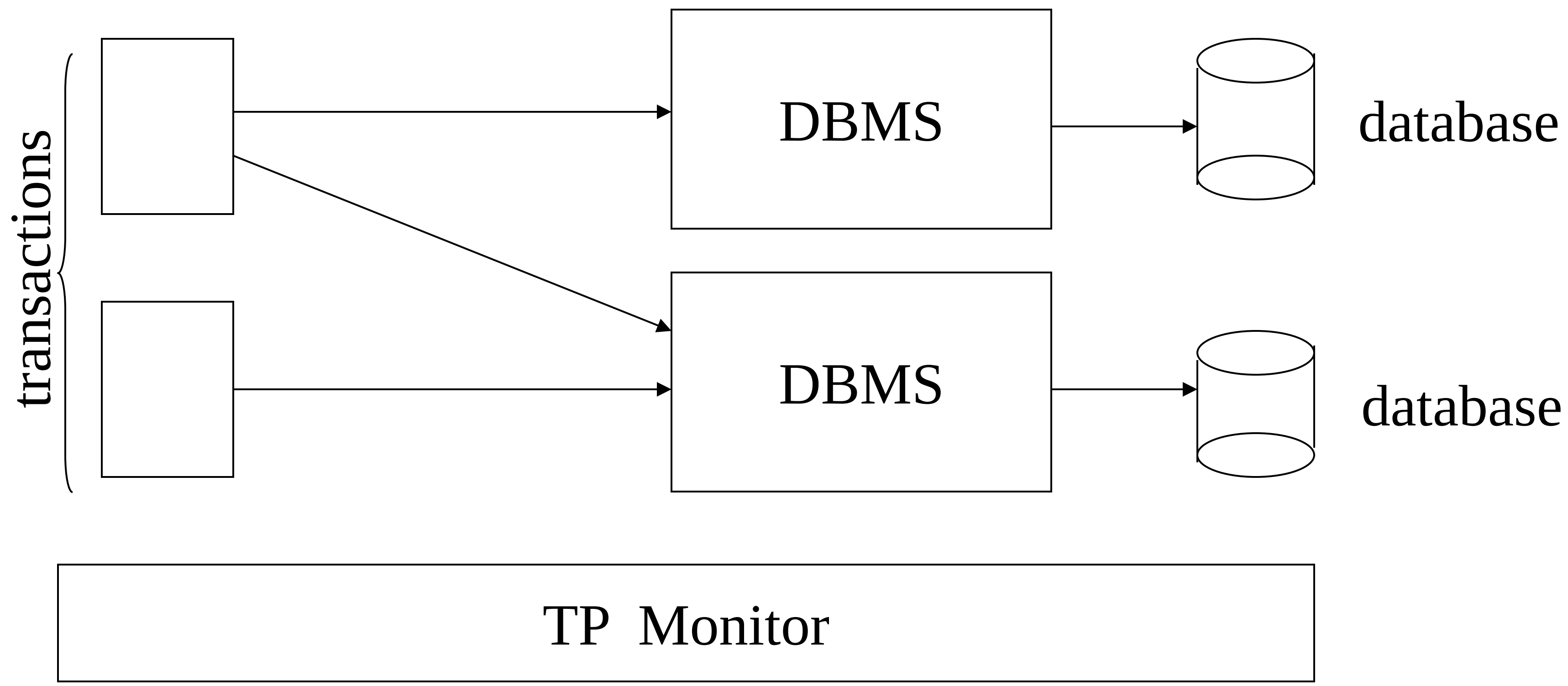
- What is a Transaction?
  - When an event in the real world changes the state of the enterprise, a "*transaction*" is executed to cause the corresponding change in the database state
  - With an on-line database, the event causes the transaction to be executed in real time
  - A transaction is an application program with special properties (i.e., ACID=Atomicity, Consistency, Isolation, Durability) to guarantee it maintains database correctness

# Introduction

- What is a Transaction Processing System?
  - Transaction execution is controlled by a Transaction Processing (TP) monitor
  - Creates the abstraction of a transaction, analogous to the way an operating system creates the abstraction of a process
  - TP monitor and DBMS together guarantee the special properties of transactions
  - A Transaction Processing System consists of TP monitor, possibly multiple databases, and transactions

# Introduction

## Transaction Processing System



# Introduction

- Database Systems Requirements:
  - **High Availability**: on-line => must be operational while enterprise is functioning
  - **High Reliability**: correctly tracks state, does not lose data, controlled concurrency
  - **High Throughput**: many users => many transactions/sec
  - **Low Response Time**: on-line => users are waiting

# Introduction

- Database Systems Requirements:
  - **Long Lifetime**: complex systems are not easily replaced
    - Must be designed so they can be easily extended as the needs of the enterprise change
  - **Security**: sensitive information must be carefully protected since system is accessible to many users
    - Authentication, authorization, encryption

# Introduction

- Roles in Design, Implementation, and Maintenance of a TPS:
  - **System Analyst** - specifies system using input from customer; provides complete description of functionality from customer's and user's point of view
  - **Database Designer** - specifies structure of data that will be stored in database
  - **Application Programmer** - implements application programs (transactions) that access data and support enterprise rules

# Introduction

- Roles in Design, Implementation, and Maintenance of a TPS:
  - **Database Administrator** - maintains database once system is operational: space allocation, performance optimization, database security
  - **System Administrator** - maintains transaction processing system: monitors interconnection of HW and SW modules, deals with failures and congestion

# Introduction

- **On-line Transaction Processing** (OLTP)
  - Day-to-day handling of transactions that result from enterprise operation
  - Maintains correspondence between database state and enterprise state
- **On-line Analytic Processing** (OLAP)
  - Analysis of information in a database for the purpose of making management decisions

# Introduction

- **On-line Analytic Processing** (OLAP):
  - Analyzes historical data (terabytes) using complex queries
  - **Summarizes the data and makes forecasts!**
  - Example: it answers operational questions like "*What are the average sales of cars, by region and by year?*"
  - Due to volume of data and complexity of queries, OLAP often uses a data warehouse and mining
- **Data Warehouse -** (offline) repository of historical data generated from OLTP or other sources
- **Data Mining** - use of warehouse data to *discover* relationships (discovers hidden patterns in data) that might influence enterprise strategy

# Introduction

- Example: Supermarket:
  - OLTP
    - For the event of buying 1 milk and 1 box of diapers, the OLTP will **update** the database to reflect that event
  - OLAP
    - Last winter in all stores in northeast, how many customers bought milk and diapers together?
  - Data Mining
    - Are there any interesting combinations of products that customers frequently bought together?

# A Brief History of Database Systems

- Pre-relational era (1970's)
  - Hierarchical (IMS), Network (Codasyl)
  - Complex data structures and low-level query language
- Relational DBMSs (1980s)
  - Edgar F. Codd's relational model in 1970
  - Set of tuples (i.e., tables) as data model
  - Powerful high-level query language
- Object-Oriented DBMSs (1990s)
  - Motivated by "impedance mismatch" between RDBMS and OO PL
  - Persistent types in C++, Java or Small Talk
  - Issues: Lack of high level QL, no standards, performance

# A Brief History of Database Systems

- Object-relational DBMS (OR-DBMS) (1990s)
  - Relational DBMS vendors' answer to OO
  - User-defined types, functions (spatial, multimedia)
  - Nested tables
  - SQL: 1999 (2003) standards. Plus performance.
- XML/DBMS (2000s)
  - Web and XML are merging
  - Native support of XML through ORDBMS extension or native XML DBMS
- Decision support system (DSS) (2000s)
  - Data warehousing and OLAP

# A Brief History of Database Systems

- Data stream management systems (2000s)
  - Continuous query against data streams
- The era of big data (mid 2000-now):
  - Big data: datasets that grow so large (terabytes to petabytes) that they become awkward to work with traditional DBMS
  - Parallel DBMSs continue to push the scale of data
  - MapReduce dominates on Web data analysis
  - "NoSQL" (not only SQL) is fast growing

# Stay updated

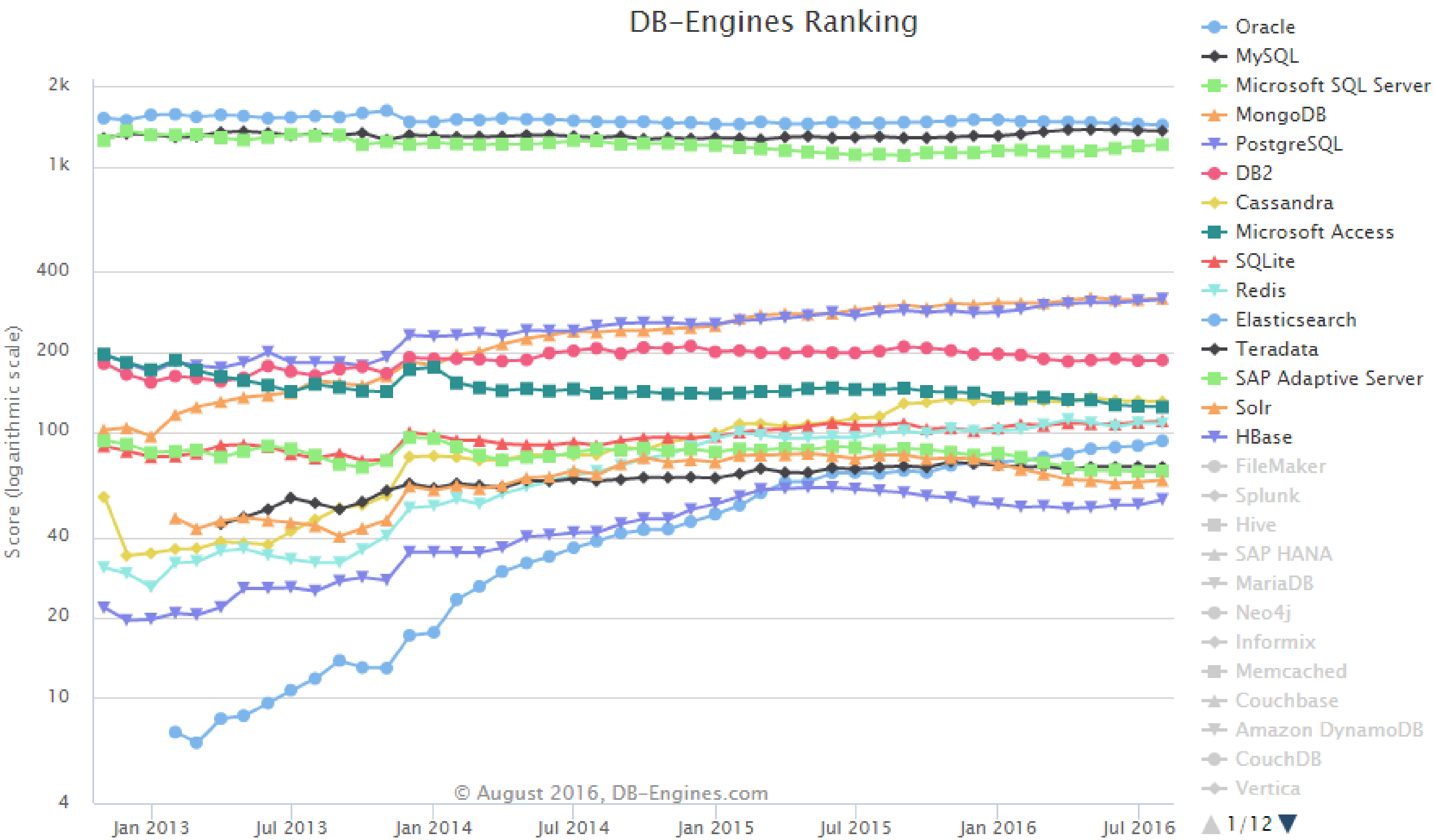
309 systems in ranking, August 2016

| Rank | | | DBMS | Database Model | Score | | |
|---|---|---|---|---|---|---|---|
| Aug 2016 | Jul 2016 | Aug 2015 | | | Aug 2016 | Jul 2016 | Aug 2015 |
| 1. | 1. | 1. | Oracle | Relational DBMS | 1427.72 | -13.81 | -25.30 |
| 2. | 2. | 2. | MySQL | Relational DBMS | 1357.03 | -6.25 | +65.00 |
| 3. | 3. | 3. | Microsoft SQL Server | Relational DBMS | 1205.04 | +12.16 | +96.39 |
| 4. | 4. | 4. | MongoDB | Document store | 318.49 | +3.49 | +23.84 |
| 5. | 5. | 5. | PostgreSQL | Relational DBMS | 315.25 | +4.10 | +33.39 |
| 6. | 6. | 6. | DB2 | Relational DBMS | 185.89 | +0.81 | -15.35 |
| 7. | 7. | ↑ 8. | Cassandra | Wide column store | 130.24 | -0.47 | +16.24 |
| 8. | 8. | ↓ 7. | Microsoft Access | Relational DBMS | 124.05 | -0.85 | -20.15 |
| 9. | 9. | 9. | SQLite | Relational DBMS | 109.86 | +1.32 | +4.04 |
| 10. | 10. | 10. | Redis | Key-value store | 107.32 | -0.71 | +8.51 |
| 11. | 11. | ↑ 14. | Elasticsearch | Search engine | 92.49 | +3.87 | +22.85 |
| 12. | 12. | ↑ 13. | Teradata | Relational DBMS | 73.64 | -0.29 | +0.05 |
| 13. | 13. | ↓ 11. | SAP Adaptive Server | Relational DBMS | 71.04 | +0.31 | -14.07 |
| 14. | 14. | ↓ 12. | Solr | Search engine | 65.77 | +1.08 | -16.13 |
| 15. | 15. | 15. | HBase | Wide column store | 55.51 | +2.37 | -4.43 |
| 16. | 16. | ↑ 17. | FileMaker | Relational DBMS | 55.01 | +3.45 | +3.14 |
| 17. | ↑ 18. | ↑ 18. | Splunk | Search engine | 48.90 | +2.26 | +6.71 |
| 18. | ↓ 17. | ↓ 16. | Hive | Relational DBMS | 47.82 | +0.27 | -6.06 |
| 19. | 19. | 19. | SAP HANA | Relational DBMS | 42.73 | +0.93 | +4.48 |
| 20. | 20. | ↑ 25. | MariaDB | Relational DBMS | 36.88 | +1.08 | +12.76 |
| 21. | 21. | ↑ 22. | Neo4j | Graph DBMS | 35.57 | +1.88 | +2.41 |
| 22. | 22. | ↓ 20. | Informix | Relational DBMS | 29.05 | +0.49 | -7.75 |
| 23. | 23. | ↓ 21. | Memcached | Key-value store | 27.69 | +0.50 | -5.69 |

http://db-engines.com/en/ranking

# Stay updated

August 2016




http://db-engines.com/en/ranking

# A Brief History of DBMS Products

- First hierarchy DBMS: IBM Information Management System (IMS)
  - starting in 1966 for the Apollo program
  - Still going strong over 40 years later
  - Mainframe only
- IDMS (Integrated Database Management System) is a network model based system
  - The roots of IDMS go back to Dr. Charles Bachman's IDS (Integrated Data Store) developed at GE
  - Since 1989 the product has been owned by Computer Associates, who renamed it as CA-IDMS
  - Mainframe only

# A Brief History of DBMS Products

- Two early RDBMS projects started and were operational in late 1970s:INGRES and System R
- INGRES (**IN**teractive **G**raphics **RE**trieval **S**ystem) started at UC Berkeley, by Michael Stonebraker and Eugene Wong
  - In the early 1980s, Ingres competed head-to-head with Oracle, but lost market due to Oracle's marketing and Ingres' own proprietary QUEL
  - Since the mid-1980s, Ingres has spawned into: Sybase, Microsoft SQL Server, NonStop SQL, etc
  - Postgres (Post Ingres) started in the mid-1980s, later evolved into PostgreSQL
  - In the 1990s Stonebraker commercialized Postgres as Illustra, later sold to Informix (sold to IBM in 2001)

# A Brief History of DBMS Products

- IBM System R was a research project at IBM San Jose Research (now IBM Almaden Research) in the 1970s
- SQL/DS was IBM's first commercial DBMS for mainframe built around SQL in early 1980s
- A little later, in 1983, IBM released DB2 on its MVS mainframe platform
- IBM brought DB2 to other platforms (LUW) in 90s. DB2 renamed as DB2 UDB z/OS, DB2 UDB LUW
- Larry Ellison and his friends started Software Development Laboratories (SDL) in 1977, which developed the original version of Oracle
  - The name *Oracle* comes from the code-name of a CIA-funded project Ellison had worked before

# SQL

- SQL: Structured Query Language Invented in 1974 by Donald Chamberlin and Raymond Boyce for IBM
  - Initially called SEQUEL, changed to SQL due to trademark issue
  - In late 1970s, Relational Software, Inc. (now Oracle Corporation) introduced the first commercially available implementation of SQL in Oracle V2
- Multiple standard revisions and multiple flavors (implementations) exist

# SQL Standard Revisions

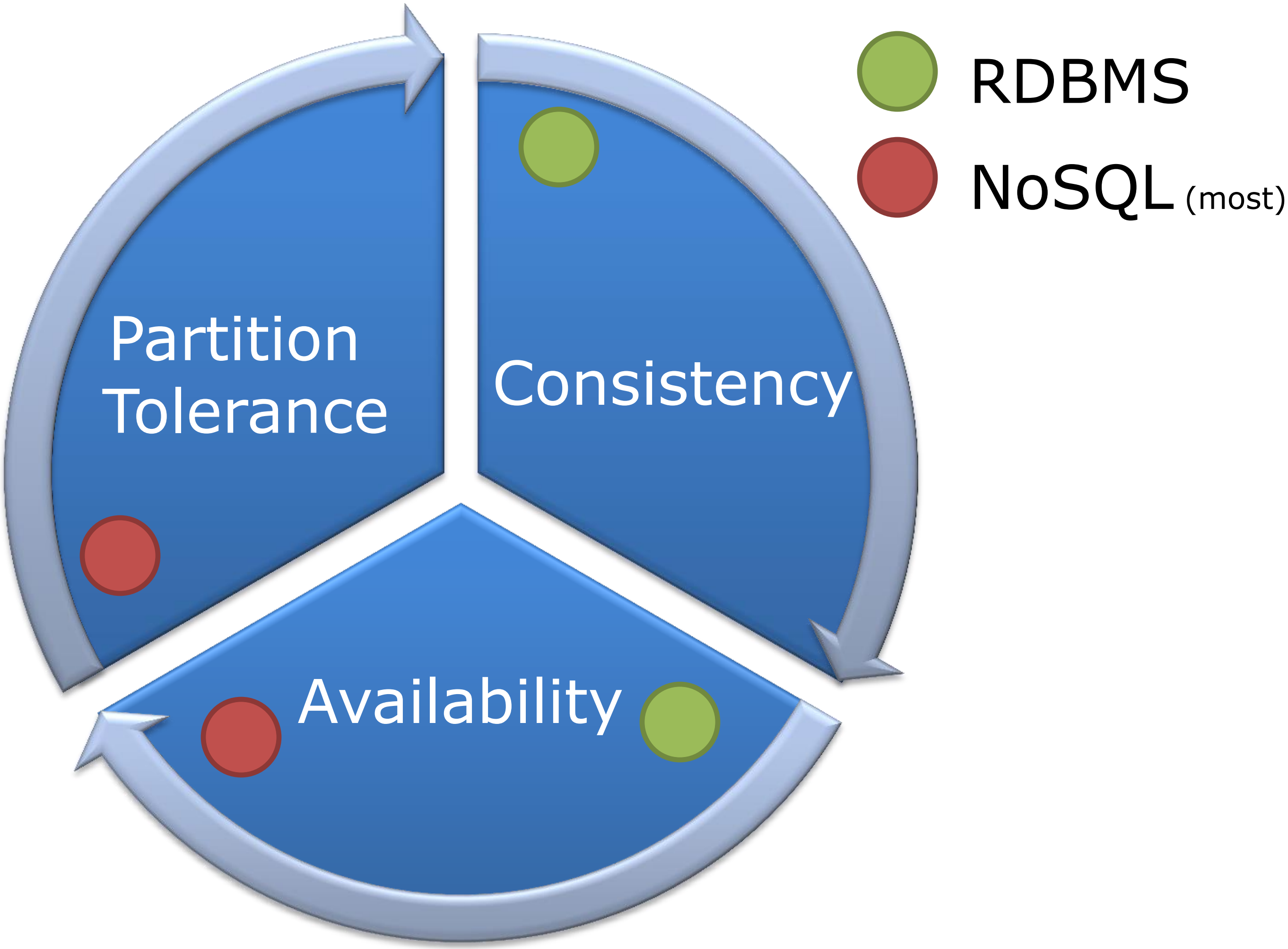
- SEQUEL/Original SQL - 1974
- SQL86: ratification and acceptance of a formal SQL standard by ANSI and ISO
- SQL2 (a.k.a. SQL92): still strictly relational, with new primitive data types, operations and join types
- SQL3: working documents discussing new specs for OR systems, but also for recursion, active rules, OLAP
- SQL:1999: added user defined types, etc
- SQL:2003: added XML-related features, etc
- SQL:2006: increased support for XML support for XQuery, an XML-SQL interface standard
- SQL:2011: added temporal support

And evolution continues…

# NoSQL Systems

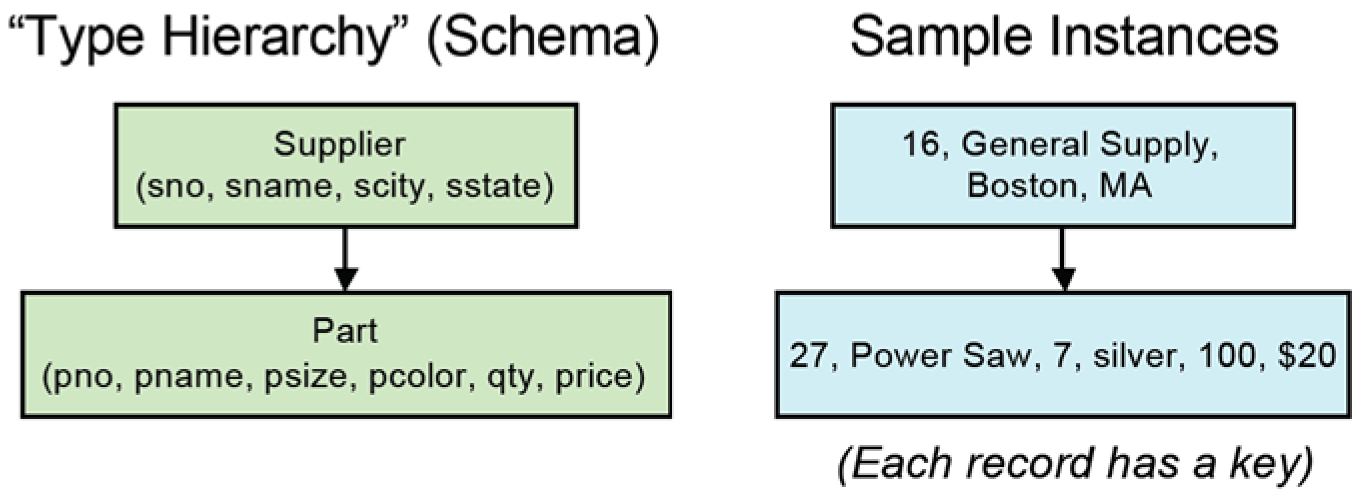
| Category | Data Model | Example Databases |
|---|---|---|
| Key-Value | (Global) collection of K-V pairs | BerkeleyDB, LevelDB, Memcached, Project Voldemort, Redis, Riak |
| Column Families | Big table, column families | Amazon SimpleDB, Cassandra, HBase, Hypertable |
| Document | Collections of K-V Collections | CouchDB, MongoDB, OrientDB, RavenDB, Terrastore |
| Graph | Nodes, relations, K-V on both | Apache Tinkerpop, FlockDB, HerperGraphDB, Infinite Graph, AllegroGraph, Neo4j, OrientDB |
| Search engines | Inverted indexes, tries, Information retrieval | Apache Lucene, Apache Solr, Elasticsearch |

# Distributed DBMS: CAP



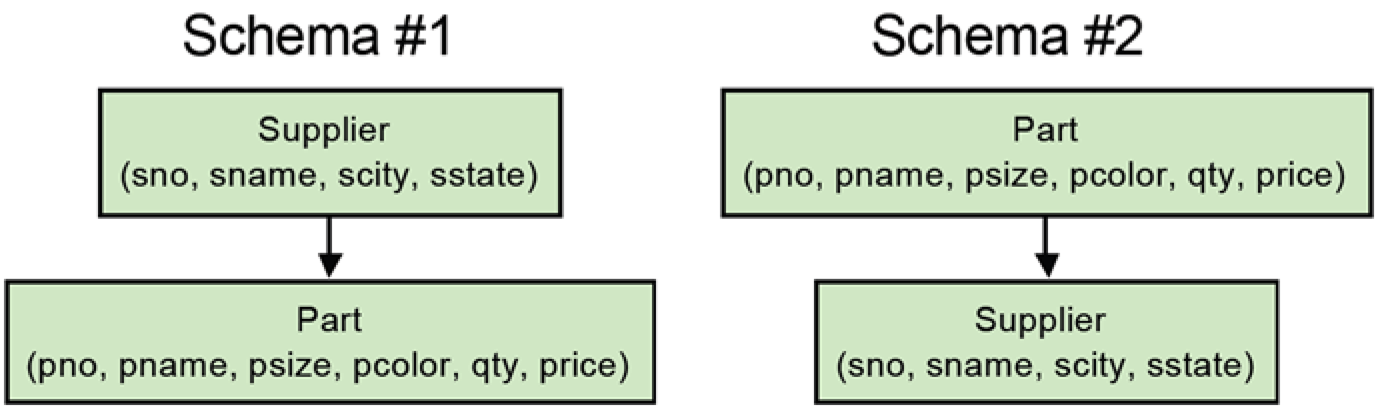
# More on evolution of DBMS

- Hierarchical model (~1968):
  - record types arranged as a hierarchy
  - each type has a single parent



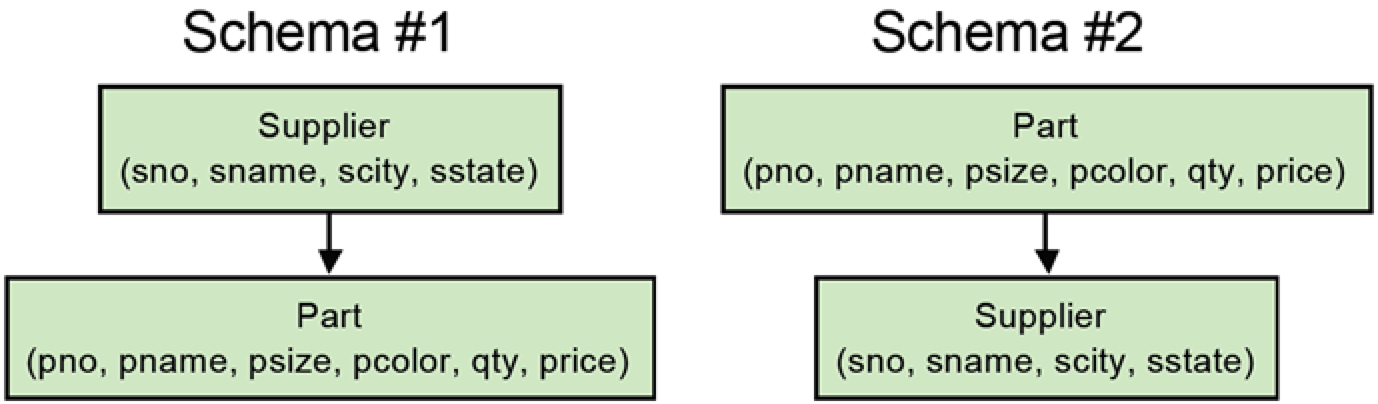
# More on evolution of DBMS

- Hierarchical model (~1968):
  - some problems:
    - Information repeated:
      - Schema#1: part info repeated for each supplier that supplies the part
      - Schema#2: supplier info repeated for each part



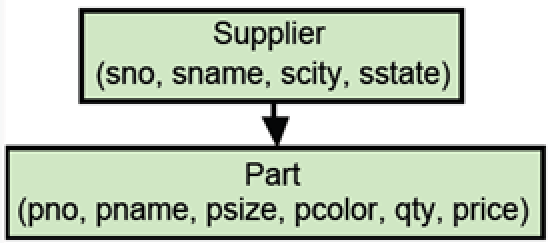
# More on evolution of DBMS

- Hierarchical model (~1968):
  - some problems:
    - Existence depends on parent data
      - Schema#1: what if there is a part not currently supplied by anyone?



# More on evolution of DBMS

- Hierarchical model (~1968):
  - DL/1 programming language for IMS: "*record-at-a-time*" language: the programmer constructs an algorithm for solving a query and IMS executes it




Find red parts supplied by Supplier 16

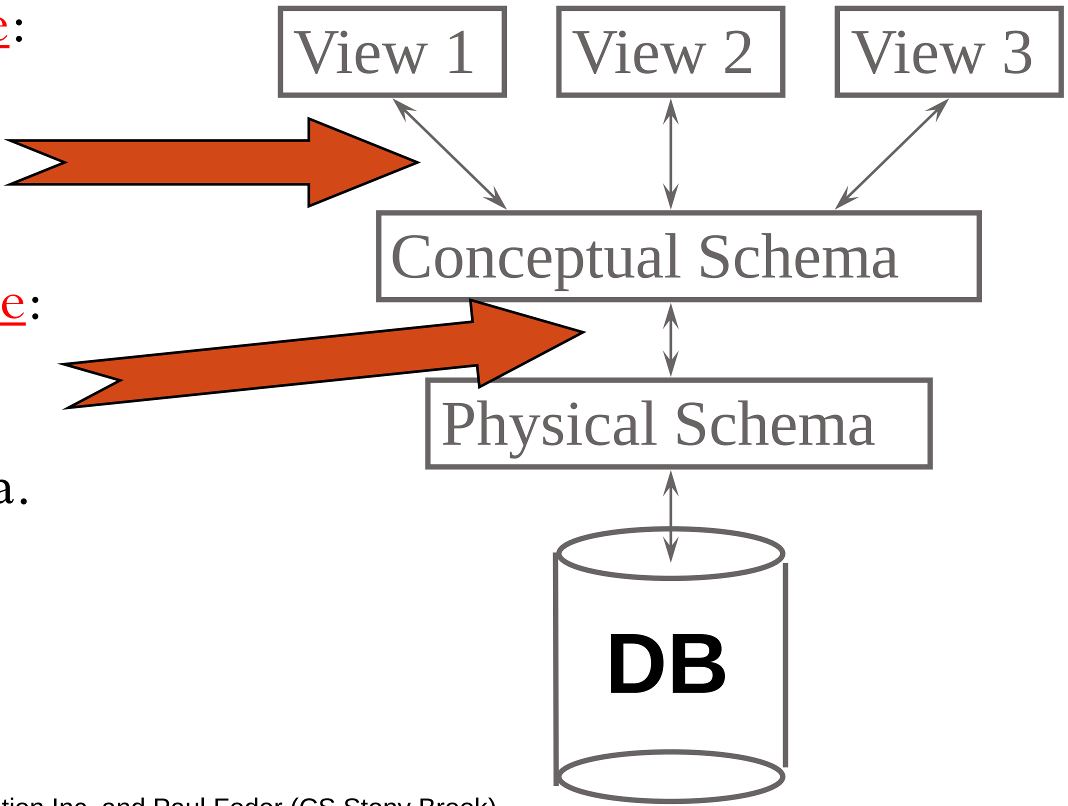
```
Get unique Supplier (sno = 16)
Until no-more {
        Get next within parent (color = red)
}

Until no-more {
        Get next Part (color = red)
}
```

# More on evolution of DBMS

- Hierarchical model (~1968):
  - Different underlying storage = different restrictions on commands: heavy coupling between storage format used (sequential/B-tree/hashed) and client application
  - Different sets of data = different optimization opportunities
    - even if the optimization is programmed by the programmer

# More on evolution of DBMS

- Data Independence:
  - A Simple Idea: Applications should be insulated from how data is structured and stored
- Logical data independence: protection from changes in the logical structure of data.
- Physical data independence: protection from changes in the physical structure of data.

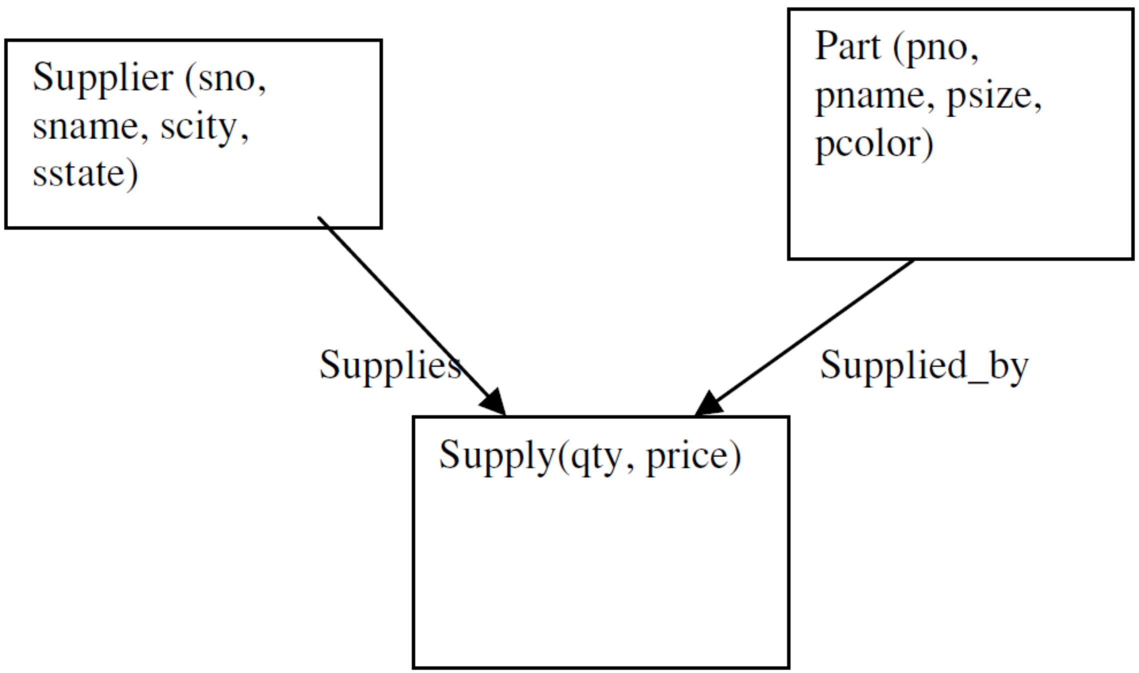


# More on evolution of DBMS

- Logical data independence:
  - changes to physical/logical structure should not require changes at the application level (ideally)
  - in general, should not require expensive changes to apps
- Impossible to achieve in the hierarchical model, where:
  - trees are difficult to reorganize
  - the record-at-a-time language delegates the optimization to the programmer

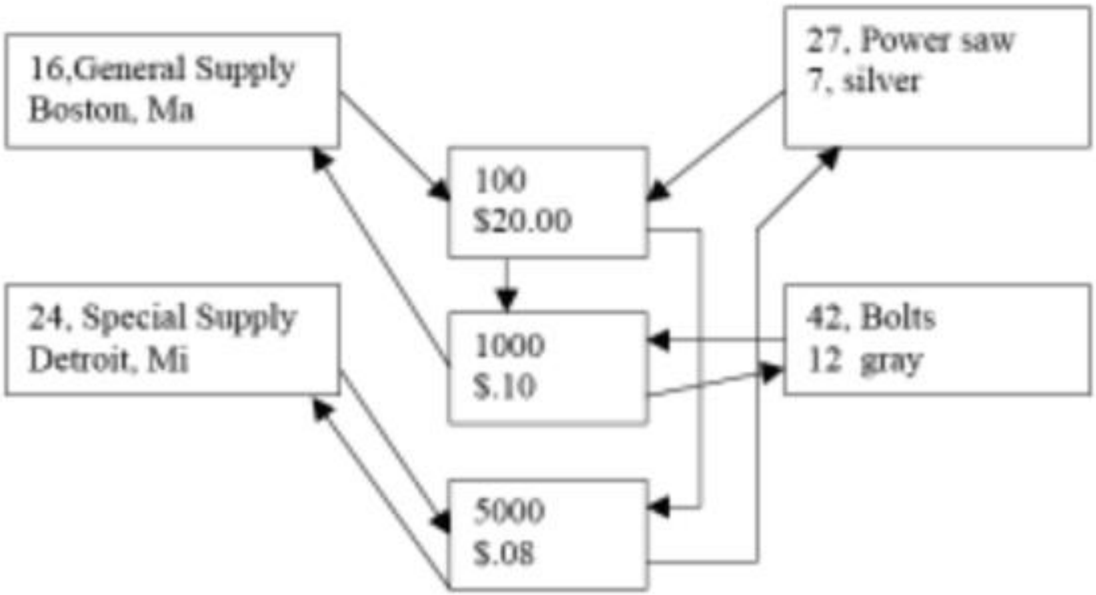
# More on evolution of DBMS

- Graph / Network model (CODASYL 1969):
  - Schema arranged in a graph model



# More on evolution of DBMS

- Graph / Network model (CODASYL 1969):
  - Instances



# More on evolution of DBMS

- Graph / Network model (CODASYL 1969):
  - Improvement:
    - entities can exist without their parents
  - Limitations:
    - still using the record-at-a-time DML language
    - still no physical independence
    - more difficult to program against a graph than a tree
    - graphs are more complex: the whole graph must be loaded at once (IMS trees could be loaded individually)

# More on evolution of DBMS

- Relational model (1970)
  - Ted Codd was motivated by the heavy maintenance required by the IMS applications
  - data stored in tables **(see next class)**
  - High level, set oriented DML
  - underlying physical storage is up to vendors

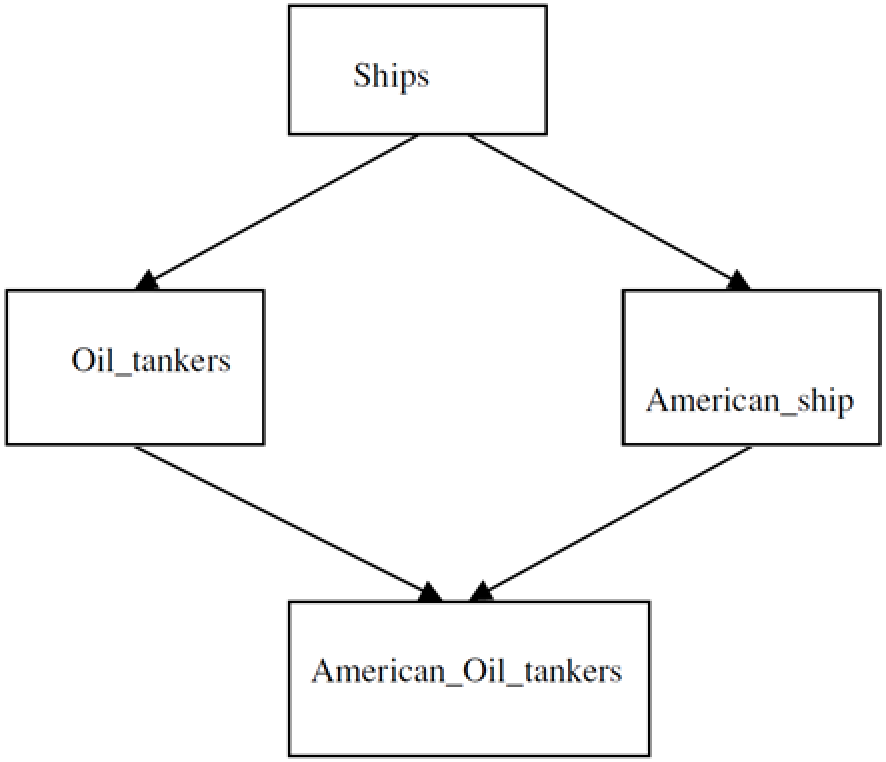
# More on evolution of DBMS

- Entity Relationship (mid 1970s)
  - Proposed by Peter Chen
  - Relationships with attributes and multiplicities


  - As a physical model: never caught on (little benefit)
  - As a conceptual model: widely used for database schema design because it offers a methodology for creating initial tables and some normalization on E-R models can be done automatically

# More on evolution of DBMS

- Semantic data model (early 1980s)
  - View relations as classes
    - multiple inheritance
    - class-wide attributes
  - Vendors were more concerned with performance
  - Can be simulated with relational



# More on evolution of DBMS

- OO DBs (mid 1980s)
  - Integrate data persistency into OO programming languages
    - extend a OO programming language (e.g., C++) with database functionality to support data persistence
    - initial work targeted towards engineering niche market (e.g., CAD)

```
Persistent part p;
Persistent int i;
```

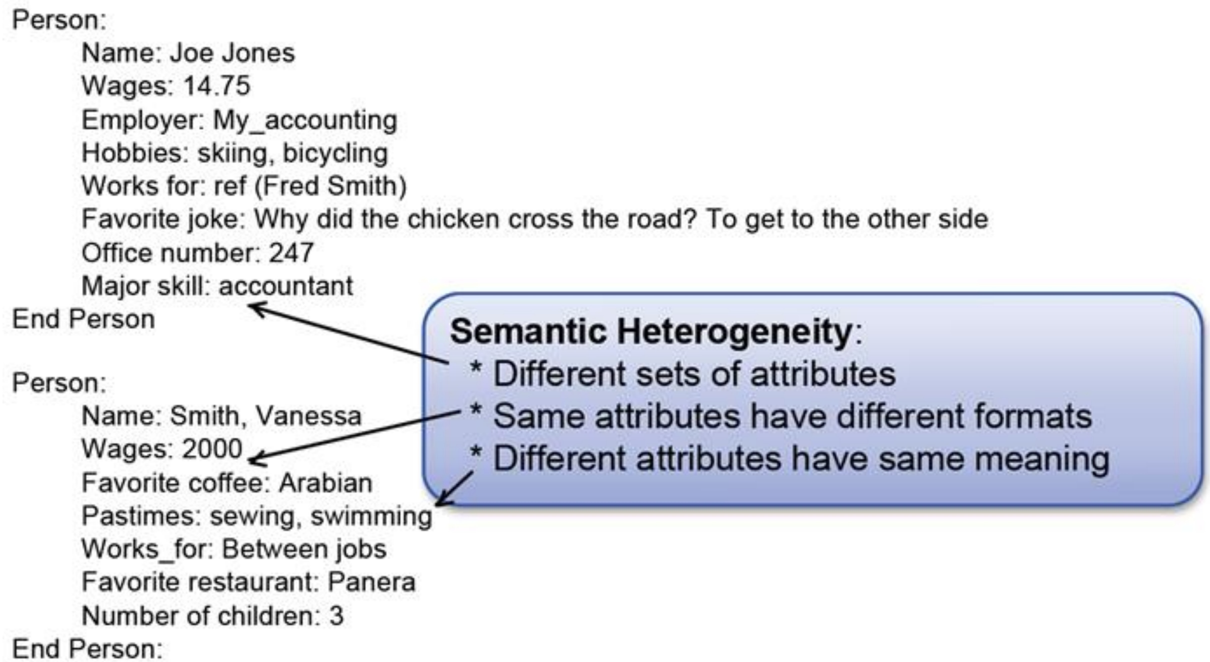
    - Did not go because vendors did not want change!

# More on evolution of DBMS

- Object-Relational DBs (mid 1980s)
  - motivated by spatial queries: INGRES team had a "haunting" interest in GIS (geographical information system)
    - B-trees are inefficient to solve such queries
    - User defined data types (box) and operators (box intersects box, R-tree indexing)
  - Major prototype: Postgres showed how to build a DBMS engine so new types and functions can be plugged in
  - Also Sybase contributed with stored procedures: user defined functions for application logic, not just operators
  - Postgres was commercialized by Illustra (acquired by Informix)

# More on evolution of DBMS

- Semi-structured era (~2000+)
  - Schema Evolution / Schema "later": data is self describing

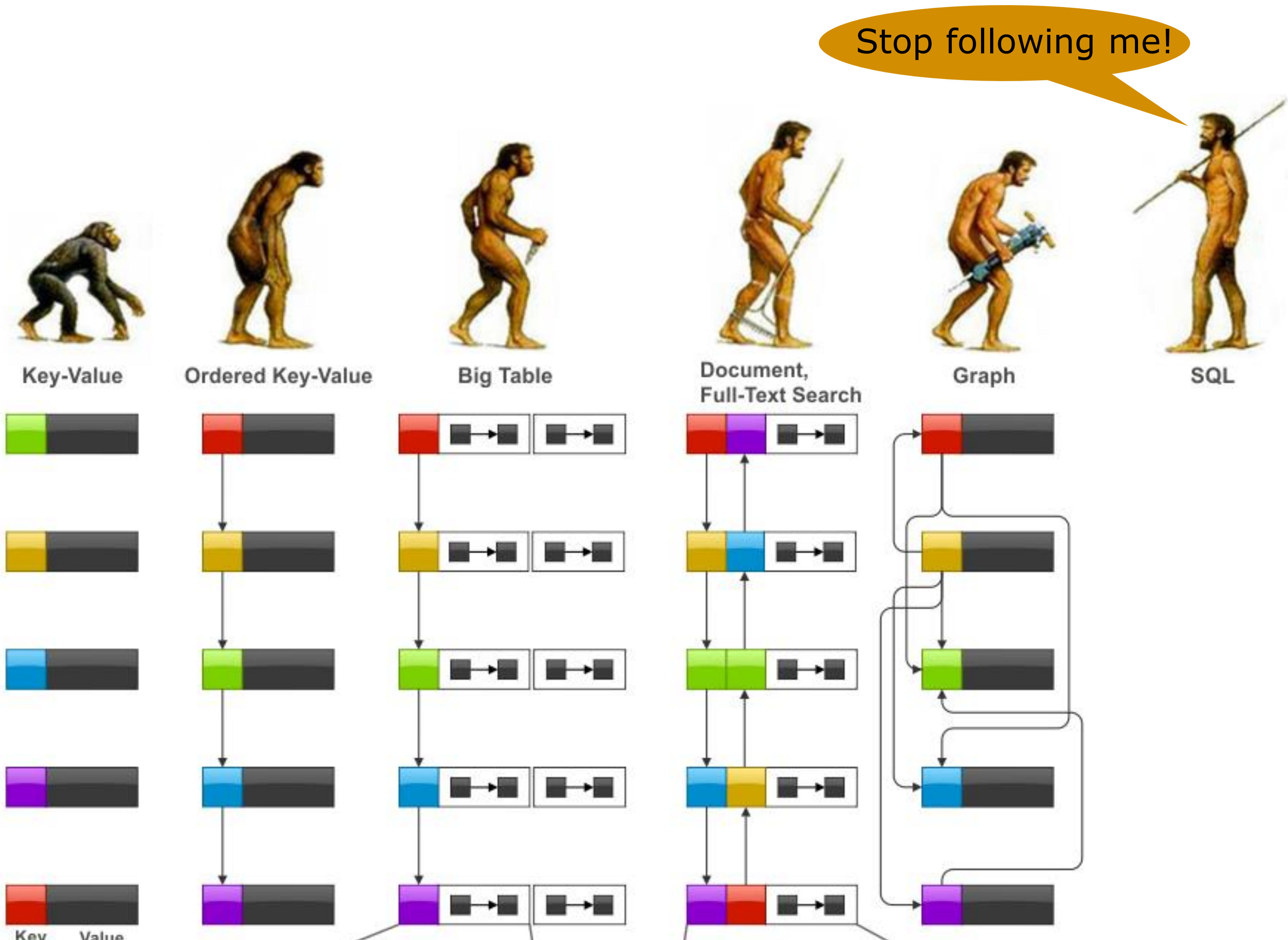



  - Complex graph oriented data models
  - Also, a Response to the growth of Web services and XML as a language (same for JSON as Javascript)

# More on evolution of DBMS

- Semi-structured era (~2000+)
  - Schema Evolution / Schema "later": data is self describing
    - Relational DBMS have heavy-weight mechanisms to change schema (ALTER)
    - XML and JSON as a data model:
      - records can be hierarchical,
      - records can reference to other records
      - schema can be defined "later" in DTDs and XMLSchema
      - XQuery is essentially an Object-Relational SQL
      - OR DBMSs adapted to support XML

# Finally




http://highlyscalable.wordpress.com/2012/03/01/nosql-data-modeling-techniques