Big Data Ecology

Databases

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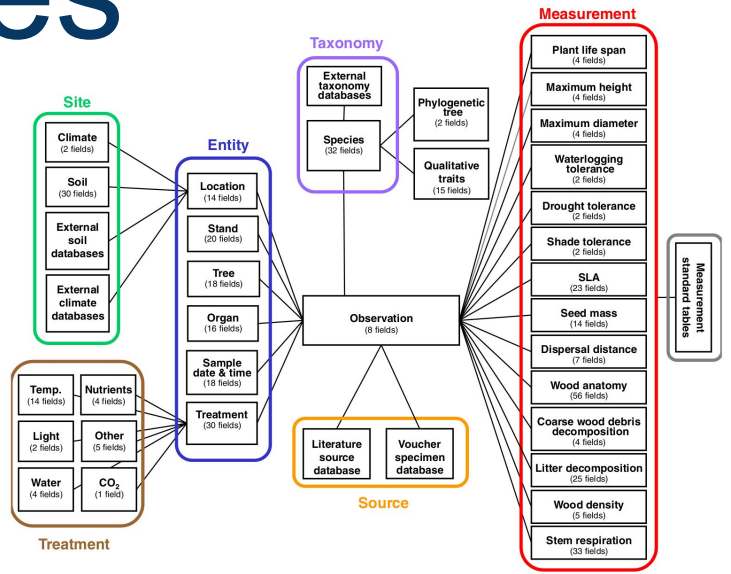


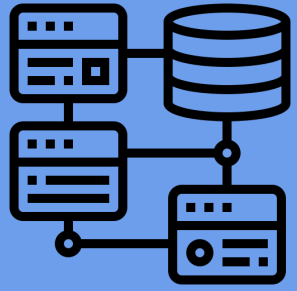
Source: Kattge et al. (2011): 10.1111/j.2041-210X.2010.00067.x

Overview

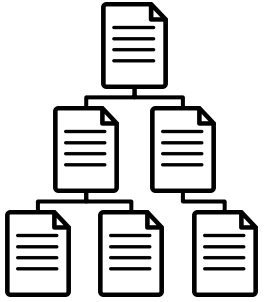
- A database is a collection of electronic data, usually organized for rapid search and retrieval
- The software that manages the data organization and interacts with the end user is called a database management system (DBMS)
- Different DBMS designs for different applications:

Spreadsheets

Relational DBMS

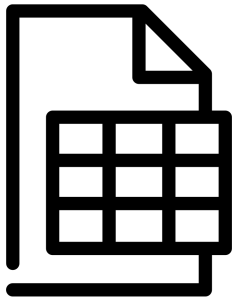


Non-Relational (NoSQL) DBMS



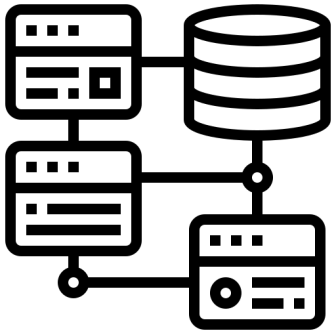
Spreadsheets

- Not a “database” in the traditional sense, but still widely used
- Advantages:
  - Easily accessible and usable, human-readable
  - better than your field notebook
- Drawbacks:
  - Error-prone
  - redundant data storage
  - no user access management
  - [...]



Relational databases

- Data format and relationships are strictly defined
- Advantages:
  - No redundant data storage,
  - Data consistency due to normalization
  - good vertical scalability
  - Fast data search, modification and extraction via SQL
- Drawbacks:
  - Can be complex and inflexible
  - May incur additional hardware and maintenance costs
  - does not scale to really large data (PB and beyond)



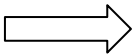
Relational databases - the database schema

- The database schema defines the structure of the data and the relationship among different tables

taxonomy

	Field name	Data type	[...]
🔑	species_id	<unsigned int(10)>	[...]
	species_name	<varchar>	[...]
	genus	<varchar>	[...]

Structure



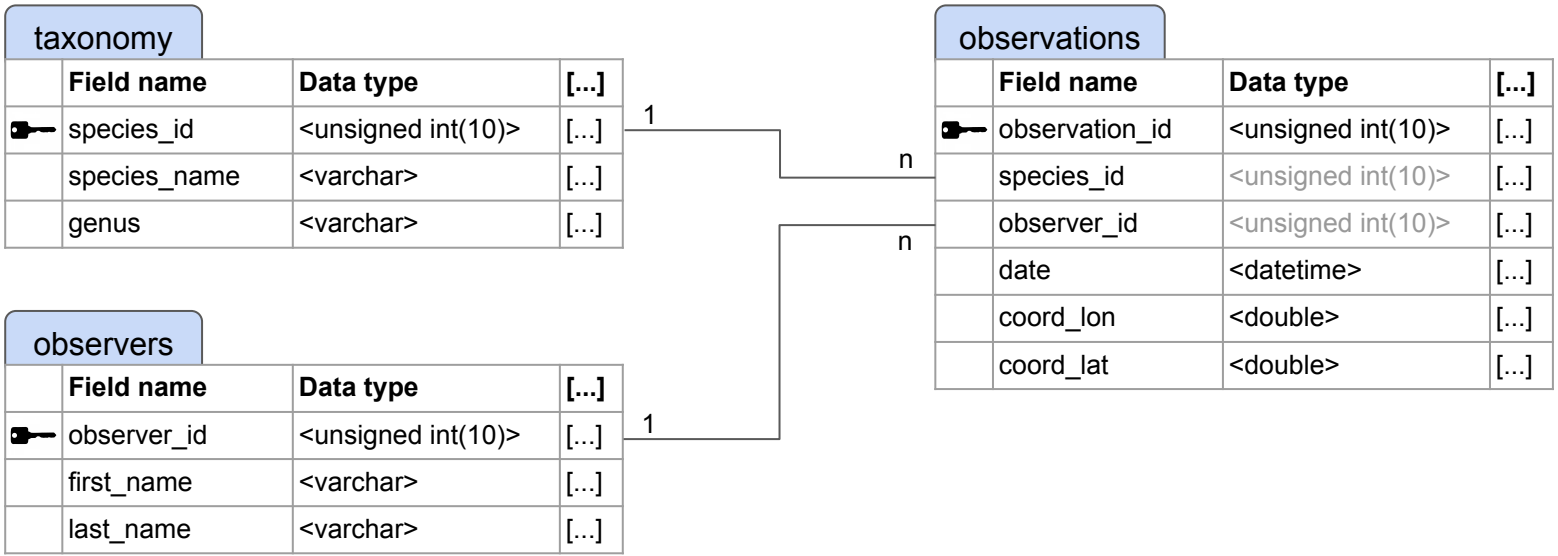
taxonomy

species_id	species_name	genus
1	Circus aeruginosus	Circus
2	Circus cyaneus	Circus
3	Circus pygargus	Circus
4	Circus macrourus	Circus
5	[...]	[...]

Data

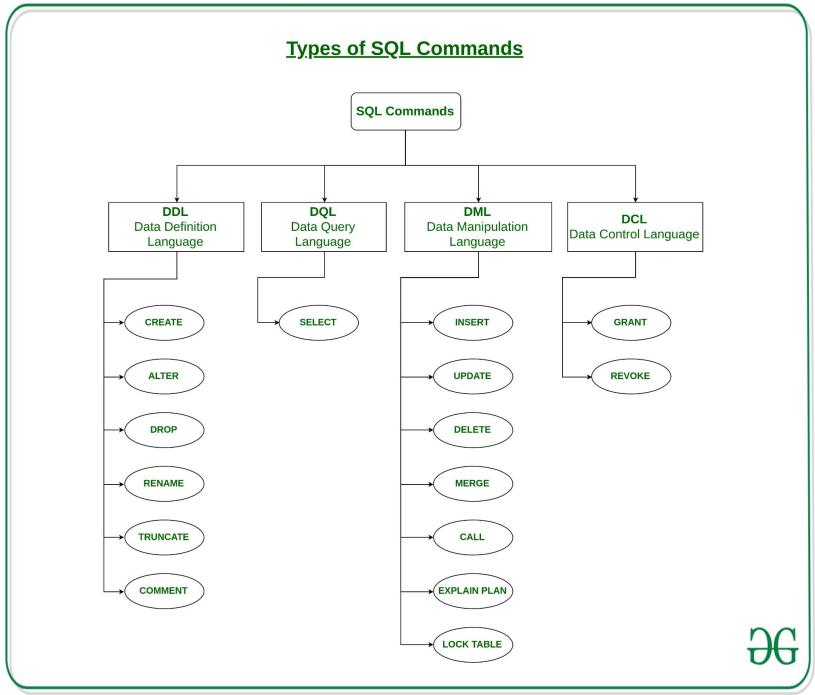
Relational databases - the database schema

- The database schema defines the structure of the data and the relationship among different tables



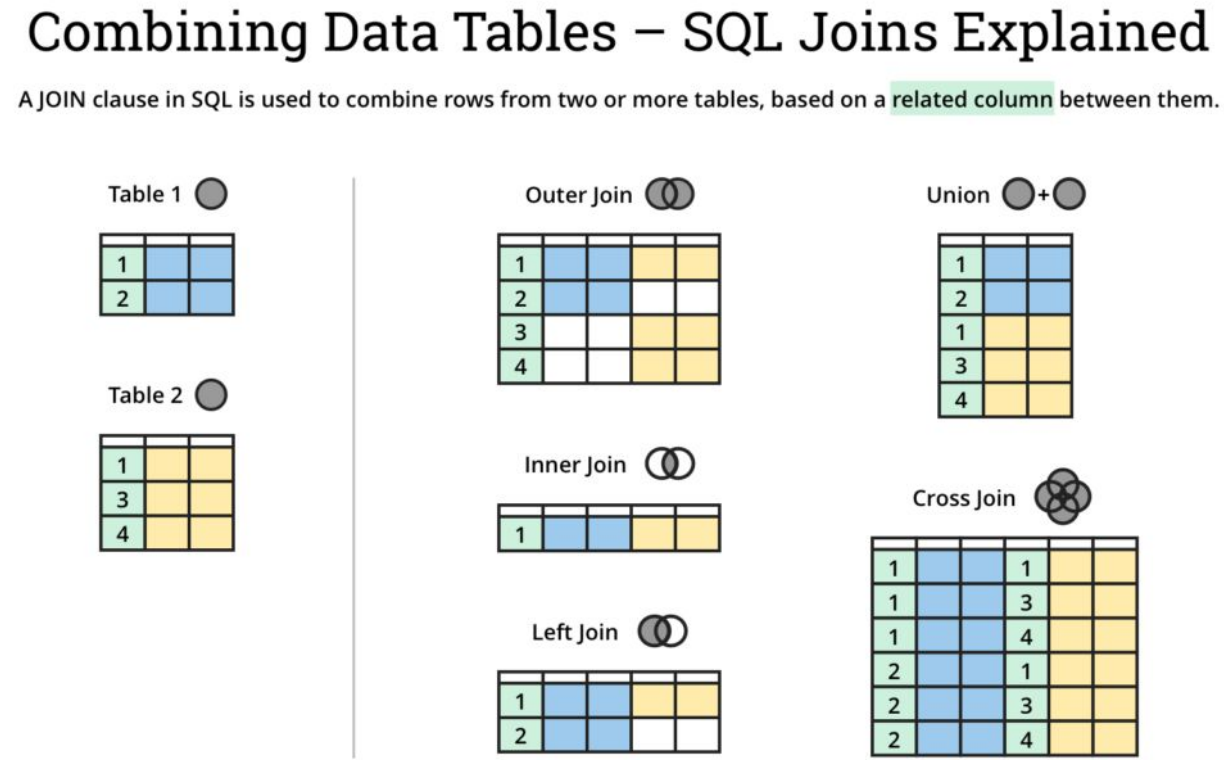
Relational databases - SQL

- SQL is a standardized language to interact with relational databases
- SQL allows you to:
  - Modify the database structure
  - Query the data
  - Manipulate the data
  - Manage access to the database



Source: https://www.geeksforgeeks.org/sql-ddl-dql-dml-dcl-tcl-commands/

Relational databases - SQL Joins



Source: https://dataschool.com/how-to-teach-people-sql/sql-join-types-explained-visually/

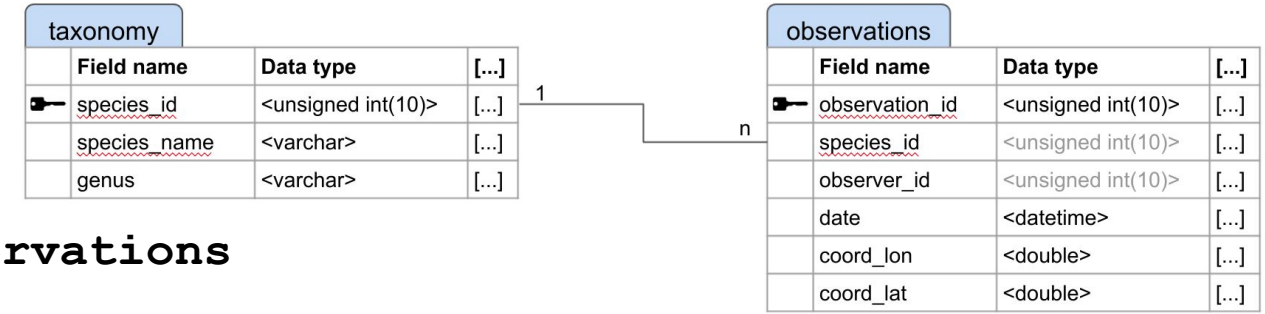
Relational databases - some more SQL keywords

`SELECT`	Select data (entire tables or specific columns)
`WHERE`	Filter by rows
`ORDER BY`	Sort results by column in `ASC` or `DESC` order
`GROUP BY`	Group results by column values and apply summary functions (`MIN()`, `MAX()`, `AVG()`,...)
`AND, OR, NOT`	Combine logical statements

see https://www.w3schools.com/sql/ for more

Relational databases - a query example

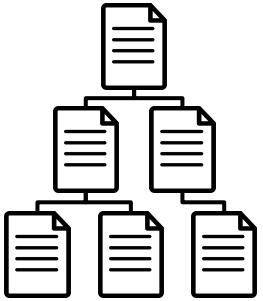
Aim: From our example database on slide 6, select all observations of *Circus* above a latitude of 50°




```
SELECT * FROM observations

LEFT JOIN taxonomy

ON observations.species_id = taxonomy.species_id

WHERE taxonomy.genus = "Circus"

AND observations.latitude > 50;
```

NoSQL databases

- Umbrella term for different DBMS designs with a non-relational approach, e.g. document-based, key-value, graph or wide-column stores
- Advantages:
  - Highly flexible data schemas that can cope with unstructured data
  - High horizontal scalability
  - Simple queries can be very fast
- Drawbacks:
  - No standardized querying language
  - Problems with concurrency



Application programming interfaces (API)

- An API allows communication with a database using specified protocols and services
- Main benefits are **abstraction** (APIs offer a stable interface to the database) and **isolation** (APIs do not expose the database itself to the client)
- APIs enable a connected network of database and applications
- An example: the GBIF web API

  https://api.gbif.org/v1/occurrence/search?taxonKey=2480481

  https://api.gbif.org/v1/occurrence/search?continent=EUROPE&country=SE&taxon_key=2480481&year=1900,2021

Where do these different technologies fit into a global biodiversity data landscape

Practical

Work through the R practical `databases.md`

Further readings

Publications:

Kattge, J. et al. 2011. A generic structure for plant trait databases. - Methods Ecol Evol 2: 202–213.

McIntosh, A. C. et al. 2007. Database design for ecologists: composing core entities with observations. - Ecological informatics 2: 224–236.

Schulman, L. et al. 2021. The Finnish Biodiversity Information Facility as a best-practice model for biodiversity data infrastructures. - Sci Data 8: 137.

Weigelt, P. et al. 2020. GIFT – A Global Inventory of Floras and Traits for macroecology and biogeography. - J Biogeography 47: 16–43.

List of biodiversity databases:

https://en.wikipedia.org/wiki/List_of_biodiversity_databases

https://ecologicaldata.org/find-data

Technical background:

https://support.microsoft.com/en-us/office/database-design-basics-eb2159cf-1e30-401a-8084-bd4f9c9ca1f5

https://www.ibm.com/cloud/blog/sql-vs-nosql