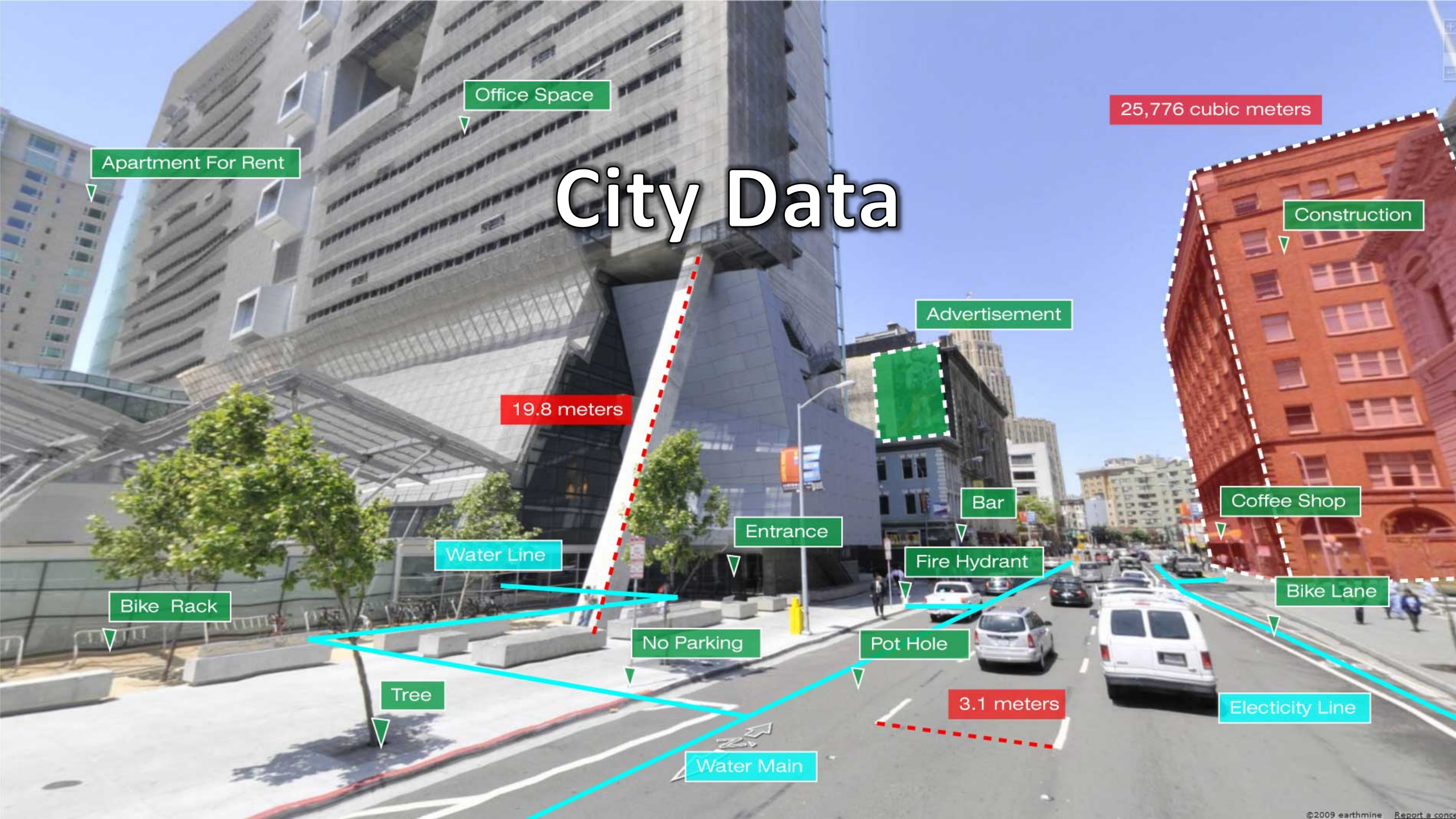
Data Driven World

Abel Sanchez, John R Williams

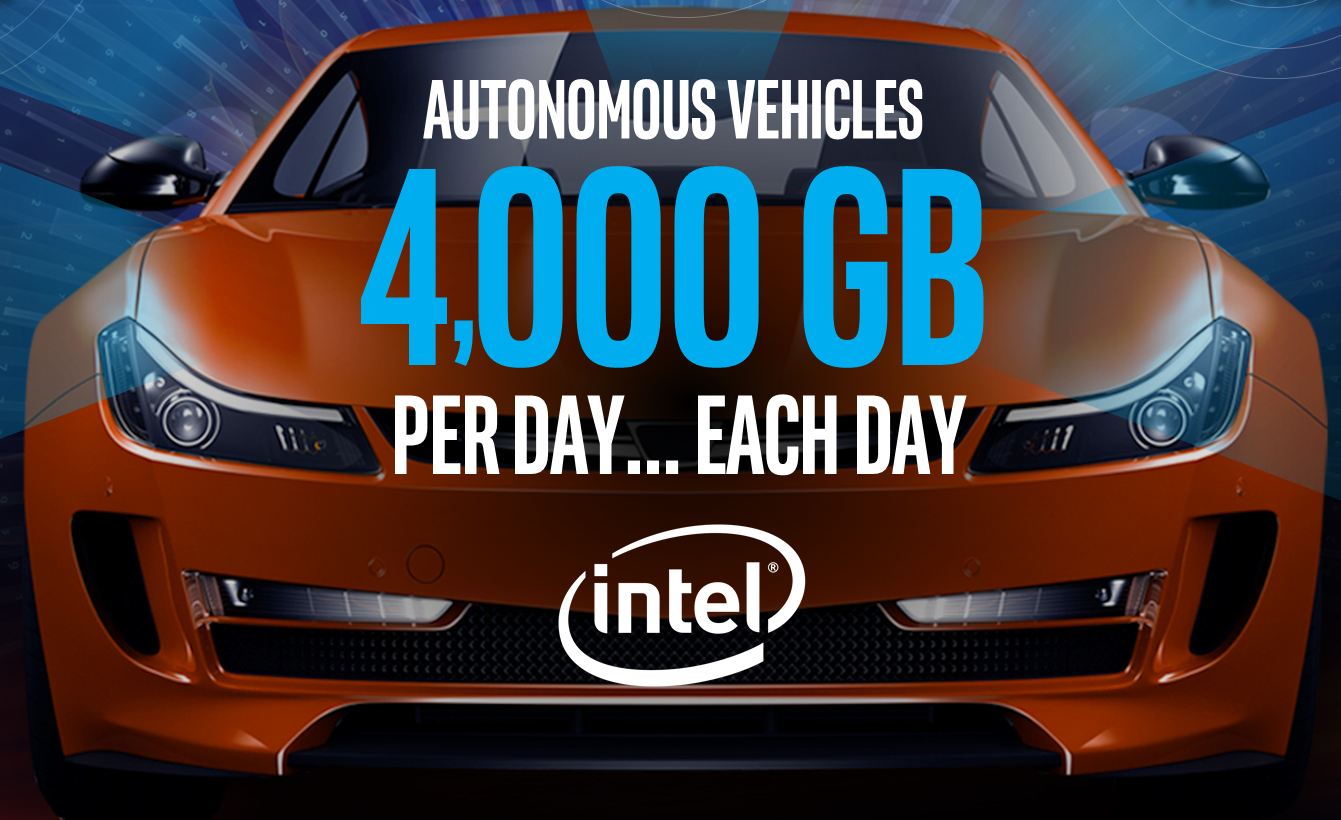

City Data
Office Space
Apartment For Rent
25,776 cubic meters
Construction
Advertisement
19.8 meters
Bar
Coffee Shop
Entrance
Water Line
Fire Hydrant
Bike Rack
Bike Lane
No Parking
Pot Hole
Tree
3.1 meters
Electicity Line
Water Main
©2009 earthmine
Report a conce

THE COMING FLOOD OF DATA IN AUTONOMOUS VEHICLES

RADAR
~10-100 KB
PER SECOND

SONAR
~10-100 KB
PER SECOND

GPS
~50KB
PER SECOND



CAMERAS
~20-40 MB
PER SECOND

AUTONOMOUS VEHICLES
4,000 GB
PER DAY... EACH DAY

LIDAR
~10-70 MB
PER SECOND

intel

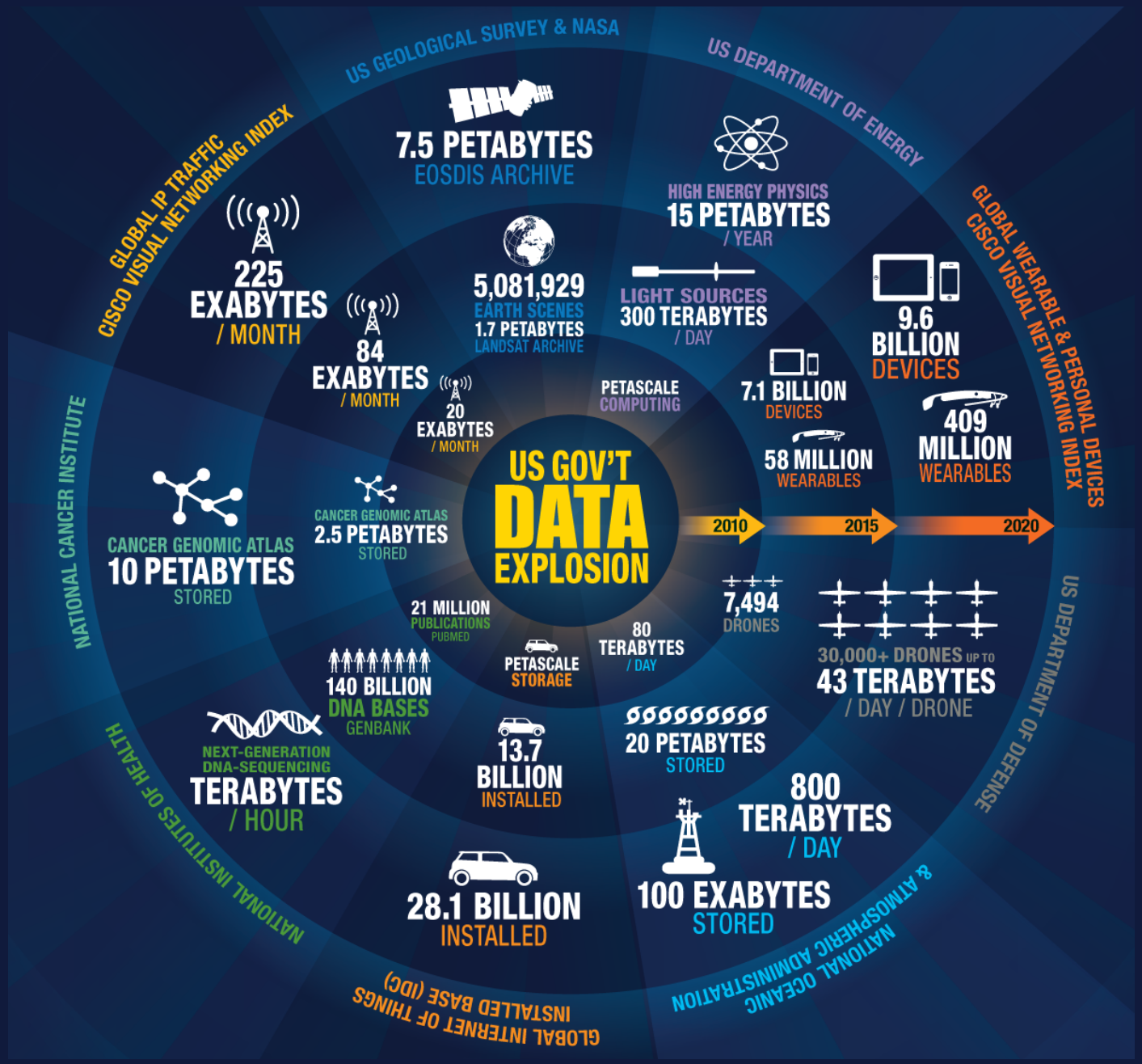

BOSTON
POLICE
FIRST IN THE NATION
1854
MGH
1811
transit
police
energy
health


5 HRS REMAINING
12 PM
1 PM
2 PM
3 PM
4 PM
73°
72°
68°
63°
62°
20 MPH
30 MPH
40 MPH
4" EXPECTED RAINFALL
1 HR
2 HR
STORM DIRECTION

DATA


DATA

Low tech industry that will be data rich in the future? Can you think of one that will not?


US GEOLOGICAL SURVEY & NASA
US DEPARTMENT OF ENERGY
GLOBAL IP TRAFFIC
CISCO VISUAL NETWORKING INDEX
GLOBAL WEARABLE & PERSONAL DEVICES
CISCO VISUAL NETWORKING INDEX
NATIONAL CANCER INSTITUTE
US DEPARTMENT OF DEFENSE
NATIONAL INSTITUTES OF HEALTH
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
GLOBAL INTERNET OF THINGS INSTALLED BASE (IDC)
7.5 PETABYTES
EOSDIS ARCHIVE
HIGH ENERGY PHYSICS
15 PETABYTES
/ YEAR
225
EXABYTES
/ MONTH
5,081,929
EARTH SCENES
1.7 PETABYTES
LANDSAT ARCHIVE
LIGHT SOURCES
300 TERABYTES
/ DAY
9.6
BILLION
DEVICES
84
EXABYTES
/ MONTH
20
EXABYTES
/ MONTH
PETASCALE
COMPUTING
7.1 BILLION
DEVICES
58 MILLION
WEARABLES
409
MILLION
WEARABLES
US GOV'T
DATA
EXPLOSION
2010
2015
2020
CANCER GENOMIC ATLAS
10 PETABYTES
STORED
CANCER GENOMIC ATLAS
2.5 PETABYTES
STORED
21 MILLION
PUBLICATIONS
PUBMED
7,494
DRONES
30,000+ DRONES UP TO
43 TERABYTES
/ DAY / DRONE
80
TERABYTES
/ DAY
PETASCALE
STORAGE
140 BILLION
DNA BASES
GENBANK
NEXT-GENERATION
DNA-SEQUENCING
TERABYTES
/ HOUR
13.7
BILLION
INSTALLED
20 PETABYTES
STORED
800
TERABYTES
/ DAY
28.1 BILLION
INSTALLED
100 EXABYTES
STORED

DATA.GOV

Agriculture

Climate

Energy

Local Government

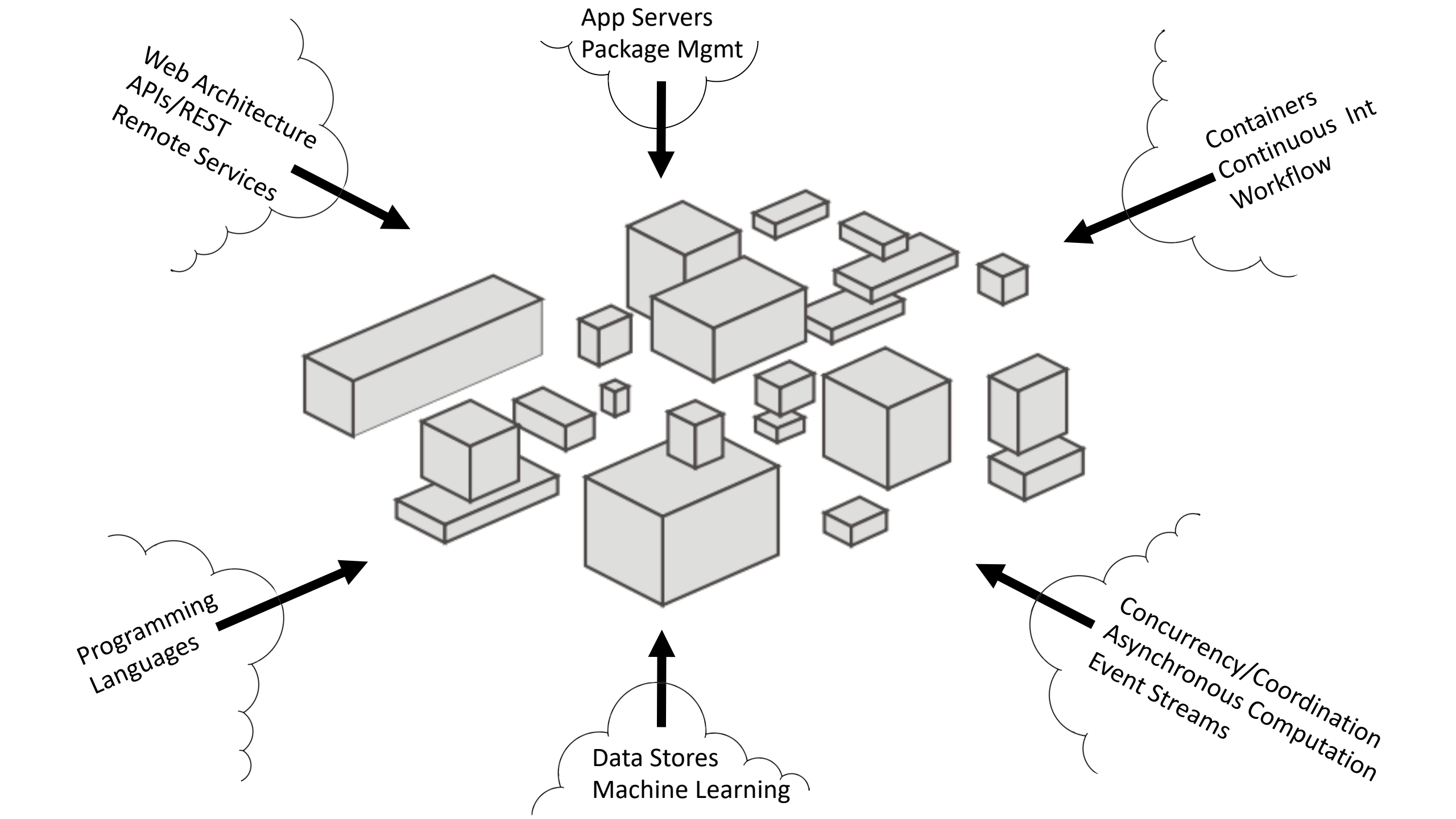
Maritime

Ocean

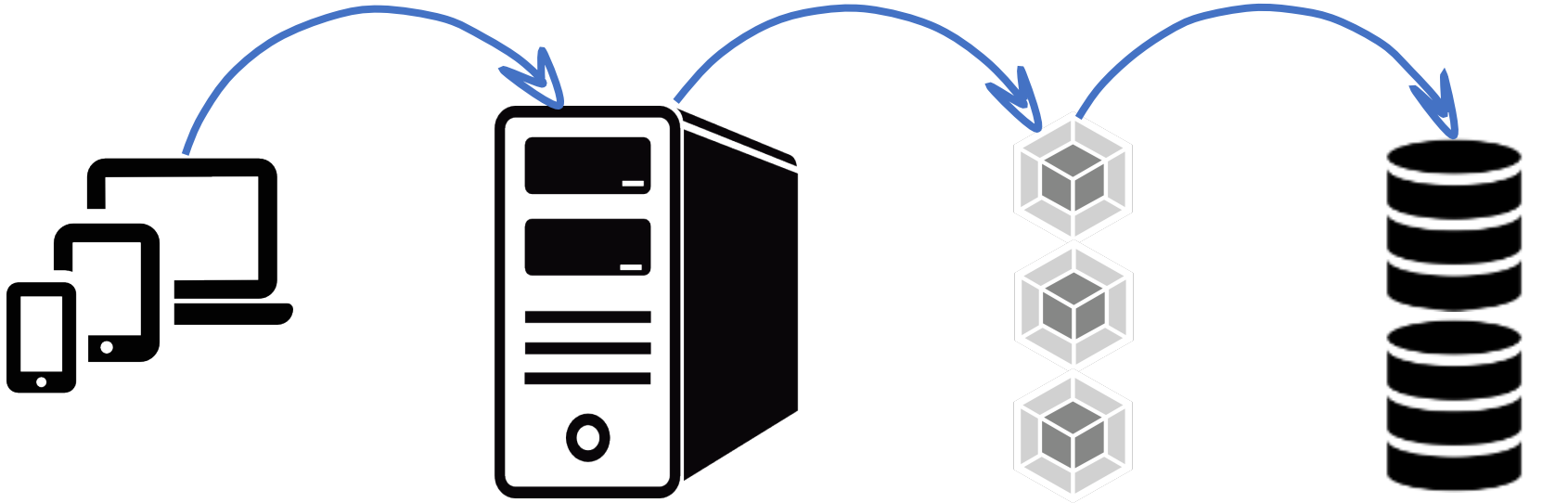
Active learning: Select something – e.g. agriculture. Identify the data producing sub-components.

Building Systems

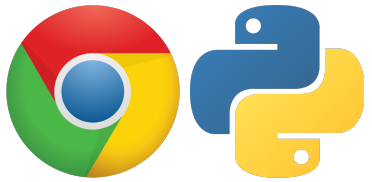
Data lives within a system

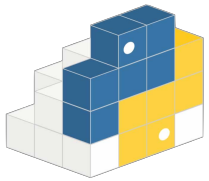

App Servers
Package Mgmt
Web Architecture
APIs/REST
Remote Services
Containers
Continuous Int
Workflow
Programming
Languages
Data Stores
Machine Learning
Concurrency/Coordination
Asynchronous Computation
Event Streams

N Tiers Systems

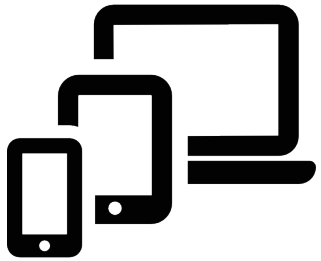


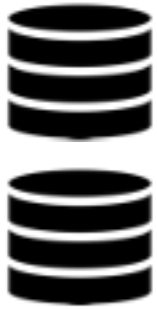
Stack: Open Source, Large Adoption, Fastest Growing





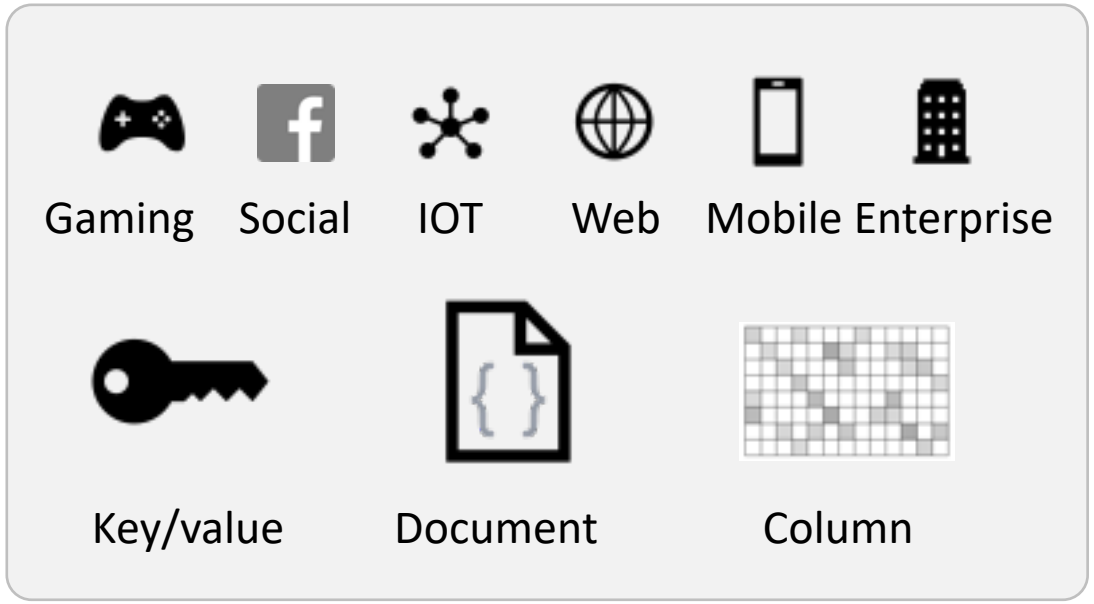
DATA STORE



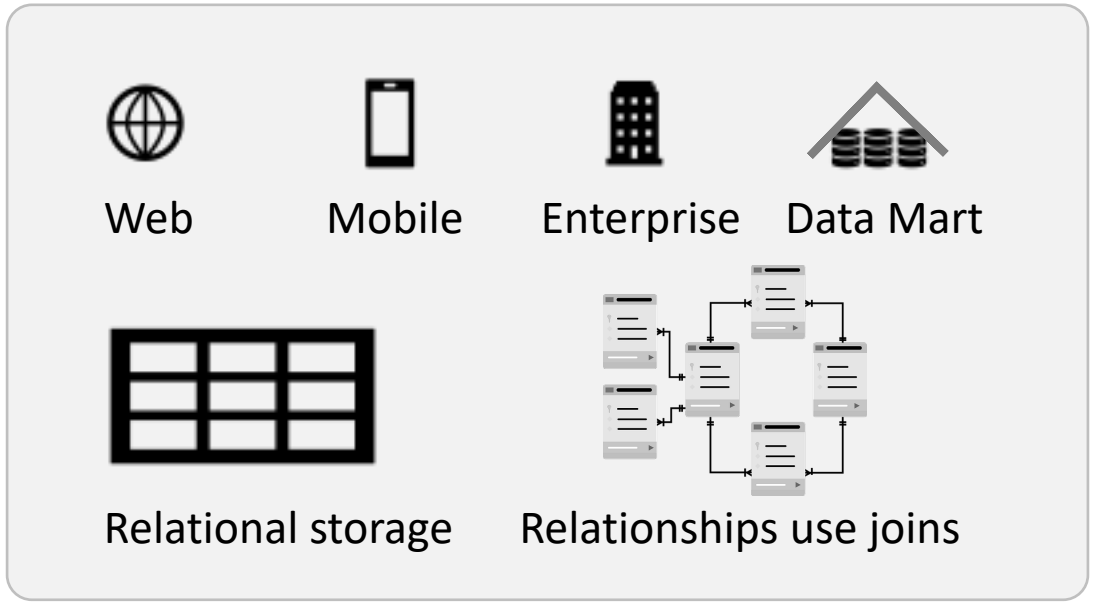


CLIENT SERVER COMPONENTS DATA STORE

Data stores: NoSQL vs SQL

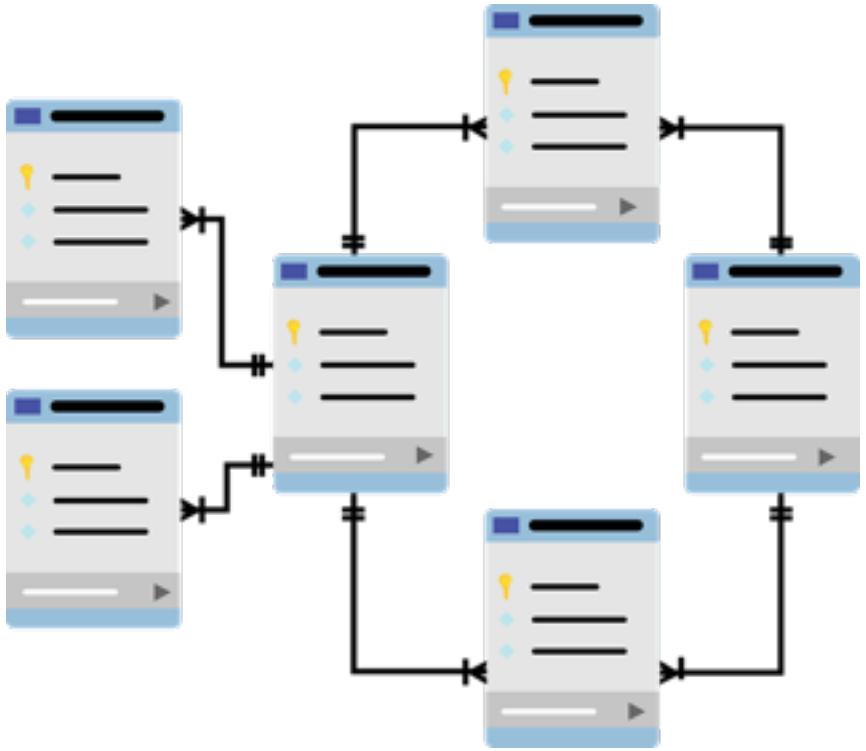


NoSQL



SQL

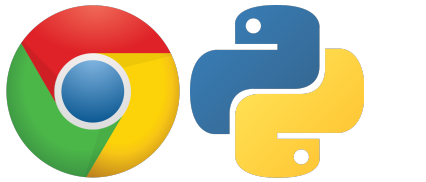
Relational Database Management System (RDBMS)

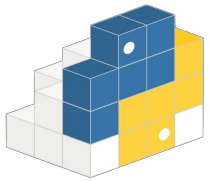


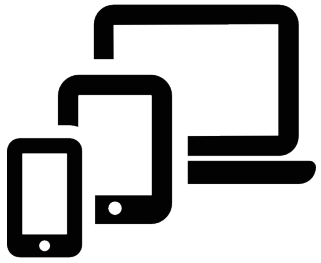
MySQL®

PostgreSQL

Microsoft®
SQL Server®






CLIENT SERVER COMPONENTS DATA STORE

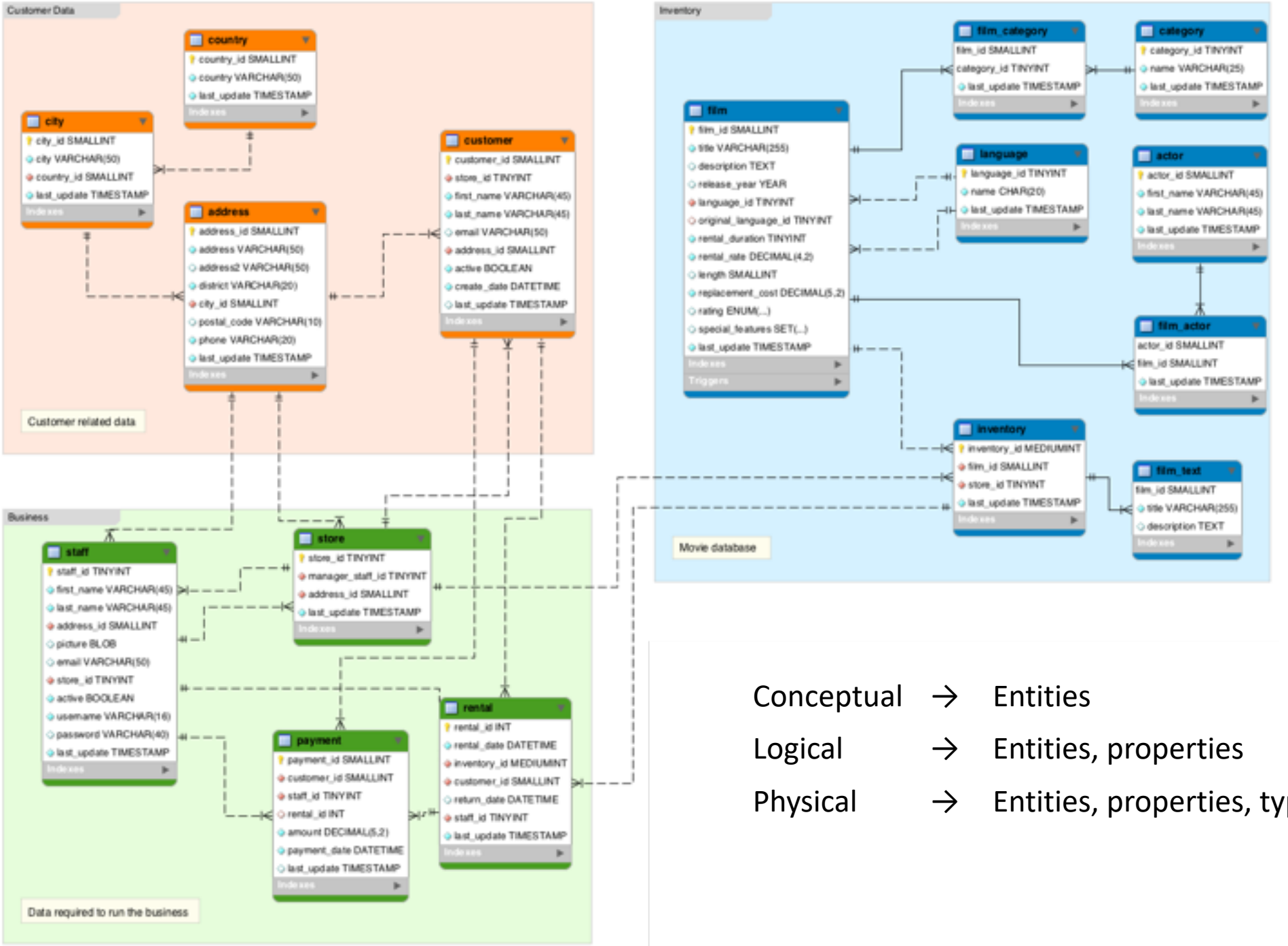
Database Design

conceptual, logical, physical

Today

Sakila

Sample Database

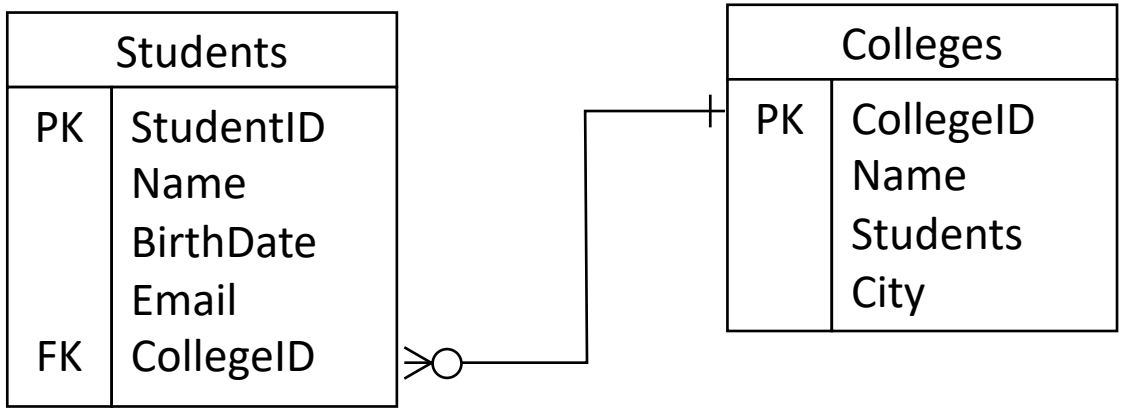


Conceptual → Entities

Logical → Entities, properties

Physical → Entities, properties, types

Example


Students
PK
StudentID
Name
BirthDate
Email
FK
CollegeID
Colleges
PK
CollegeID
Name
Students
City

Relational advantage:
Independence of physical and logical design

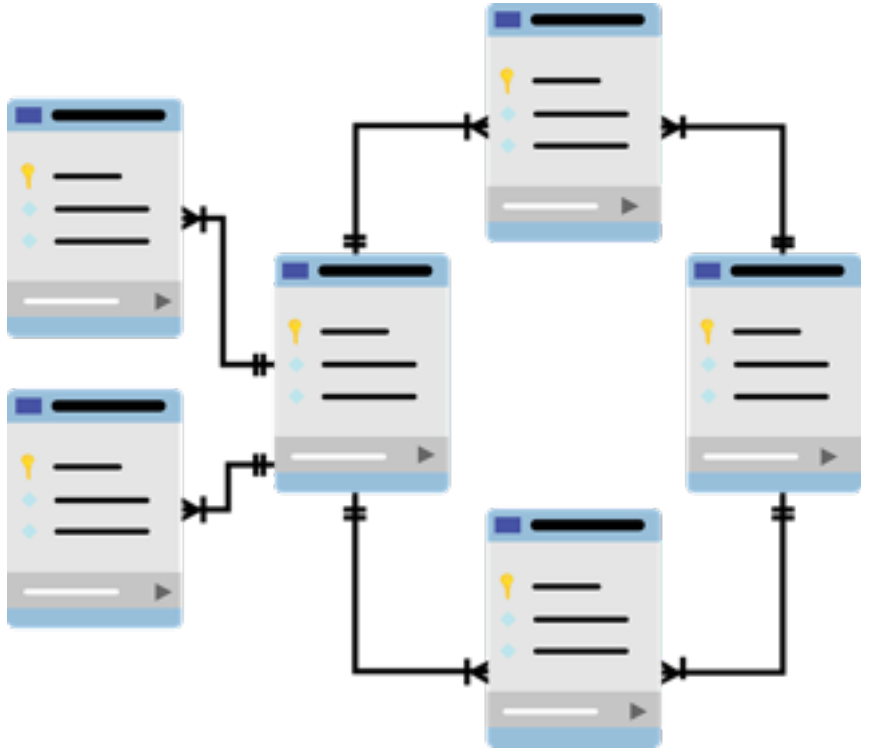
- You do not define physical storage
- You do not define the logical access paths to data
- You can answer questions on the data - others than the original plan

Downside

- No built protections against bad decisions

Database design is deciding:

- The tables
- The columns
- The relationships



Step 1: You need a deep understanding of the world you are trying to model

- Investigate
- Think about the information environment
- Where will information come from? In what form?
- How will input be done? By whom? By what?
- How frequently? How often will it change?
- You need a deep understanding of what you are trying to model!

Step 1: Understand what you model (contd)

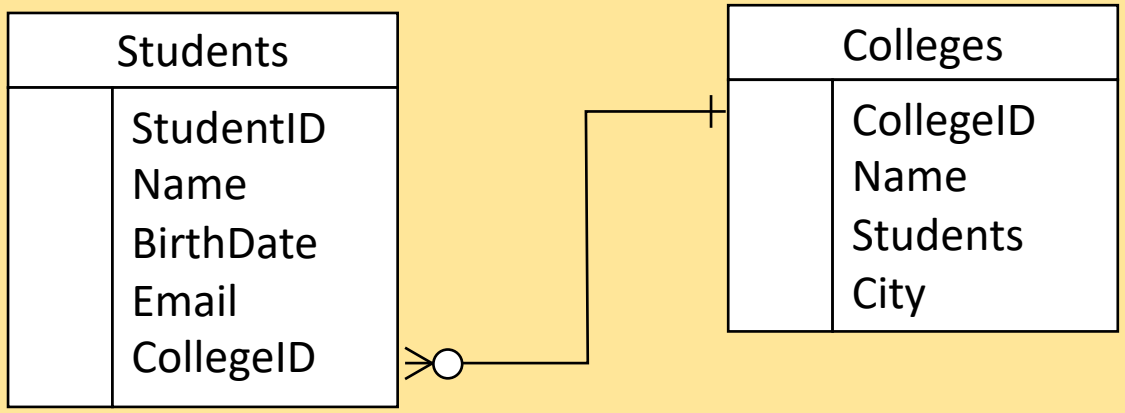
- Review files and forms
- Track data through the organization
- Departments/functions
- Talk to data consumers, producers
- Consider what output is needed
  - Reports, purchase orders, statistical information
- Getting the data model wrong is painful

Step 2: identify entities and attributes

- An entity is a thing that has properties. For example:
  - Entity: person
  - Properties(attributes): name, DOB, email, address
- Make a list of entities and corresponding properties
- Entities are potential tables
- Properties are potential columns
- Questions to ask yourself:
  - Did I miss any entities, properties
  - Are your properties attached to the right entity – easy to get wrong

Active learning: Select something – e.g. agriculture. Identify the data producing sub-components.

1. Understand what you are going to model
2. Identify entities and attributes



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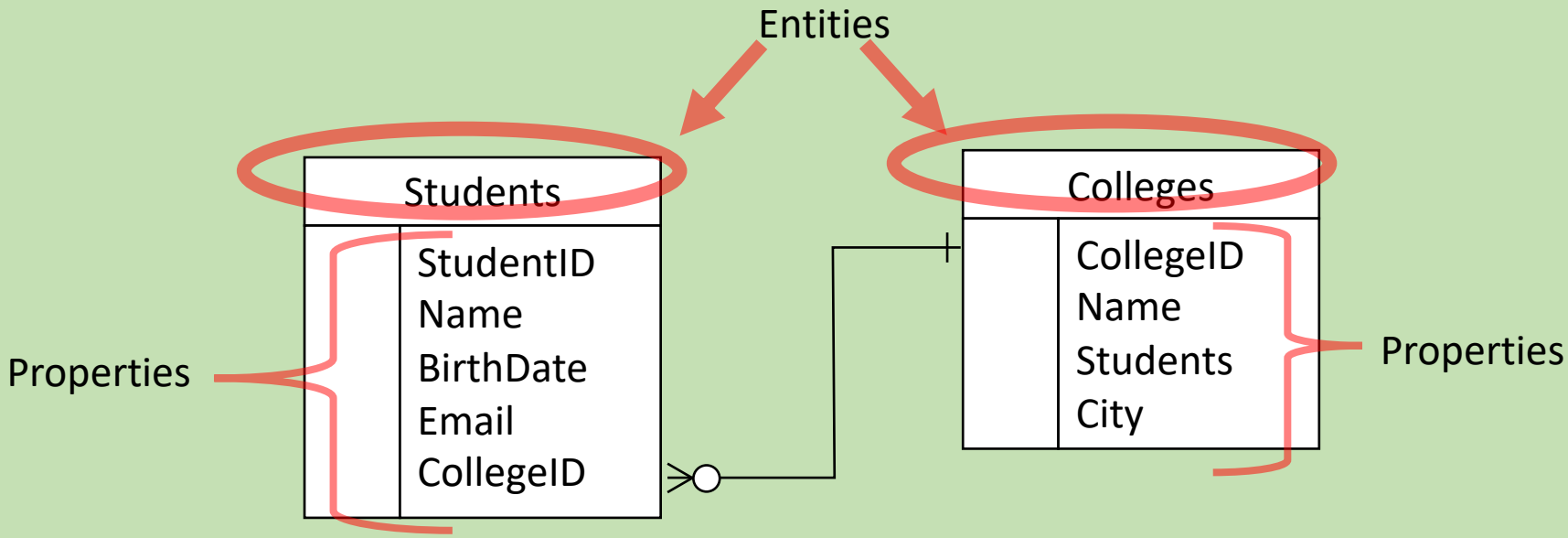
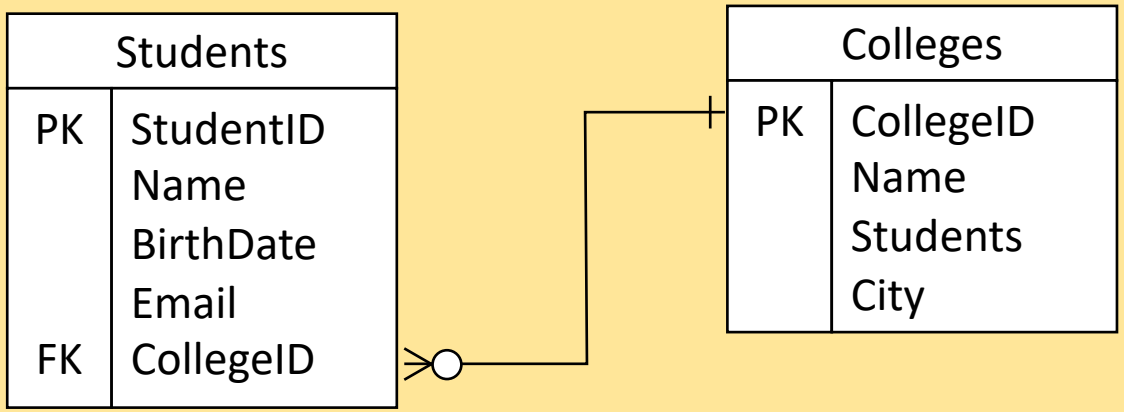
2. Identify entities and attributes



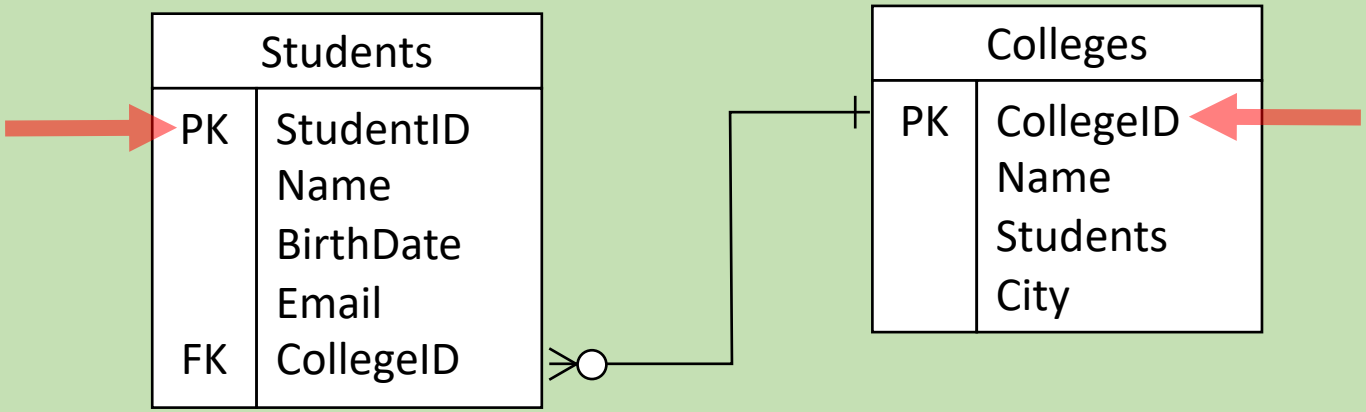
Step 3: Unique identifiers – Primary Keys

- Identify unique identifier per entity
- You will use the unique identifier to uniquely identify any row
- The unique identifier is the primary key
- If it does not exist, add column

Active learning: add unique identifiers



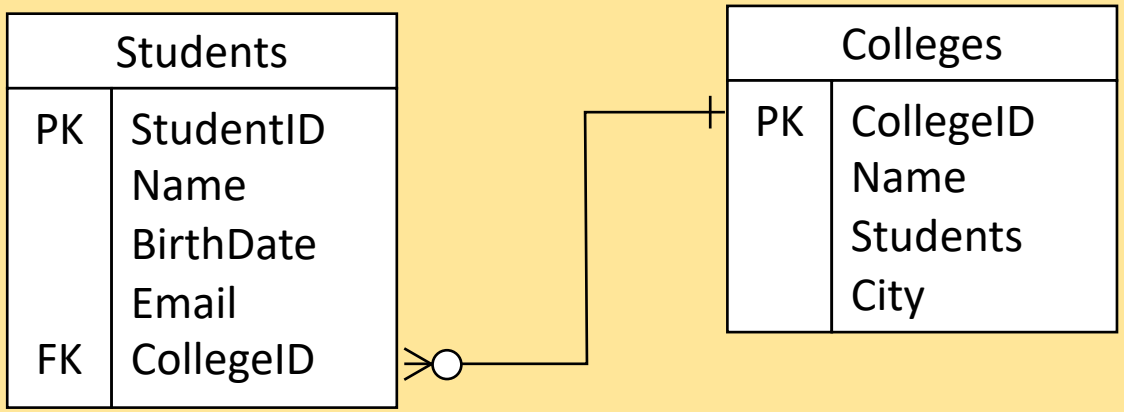
Active learning: add unique identifiers



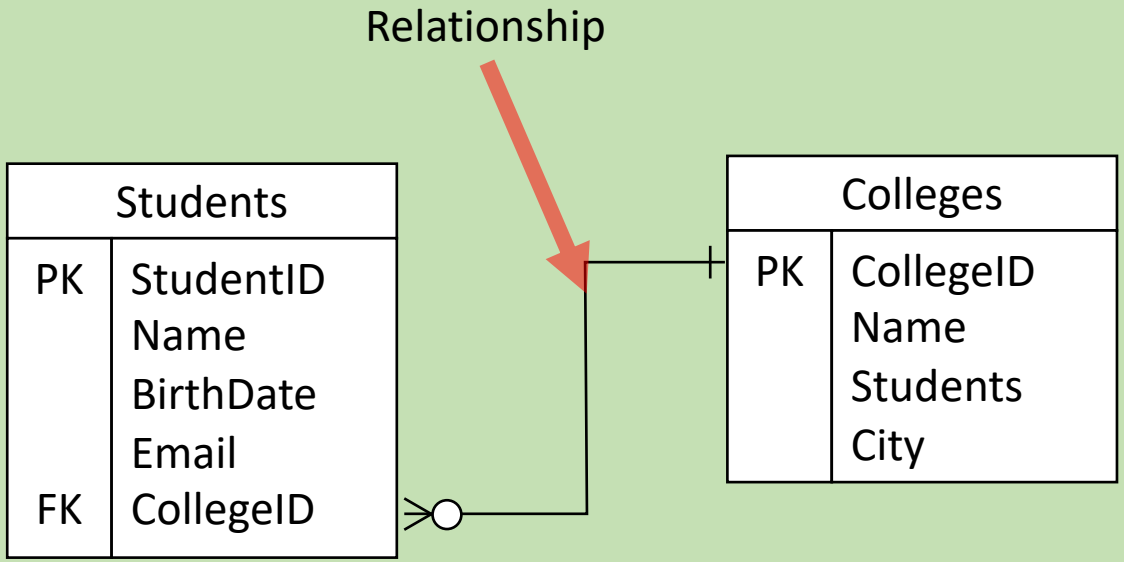
Step 4: Relationships

- What are your table relationships?
- Formally, cardinality is how one table relates to another.
- Cardinality can be 1-to-1, 1-to-N, N-to-N

Active learning: add relationships



Active learning: add relationships



Summary: Database design is Entity Relationship Modeling

- The things, the entities
- The properties of entities
- The relationships between tables

Avoid

- Forcing redundant data entry
- Increasing the risk of introducing data inconsistencies
- Increasing misunderstanding of your design
- Rigid designs that make it difficult to change the structure of tables

The Entity-Relationship Model—Toward a Unified View of Data

PETER PIN-SHAN CHEN

Massachusetts Institute of Technology

A data model, called the entity-relationship model, is proposed. This model incorporates some of the important semantic information about the real world. A special diagrammatic technique is introduced as a tool for database design. An example of database design and description using the model and the diagrammatic technique is given. Some implications for data integrity, information retrieval, and data manipulation are discussed.

The entity-relationship model can be used as a basis for unification of different views of data: the network model, the relational model, and the entity set model. Semantic ambiguities in these models are analyzed. Possible ways to derive their views of data from the entity-relationship model are presented.

ACM Transactions on Database Systems, Vol. 1, No. 1. March 1976, Pages 9-36.

Lets design a Sample database

Book business database

- A good practice is to ask yourself sample questions:
  - Which authors live in Massachusetts
  - Which books cost more than $15
  - Which author has written the most books
  - Which author has sold the most books
  - Which publisher has sold the most books
  - Which store has sold the most books?
  - Who has edited the most books?

Consider what policies you are hard coding

- Can author can have more than one book?
- Can a book have more than one author?
- Can a sales order request many titles?
- Can a book have more than one editor?

Entity and Relationship Modeling

- The things, the entities
- The properties of entities
- The relationships

Active Learning:
Identify entities – things that have properties

Active Learning:
Identify entities – things that have properties

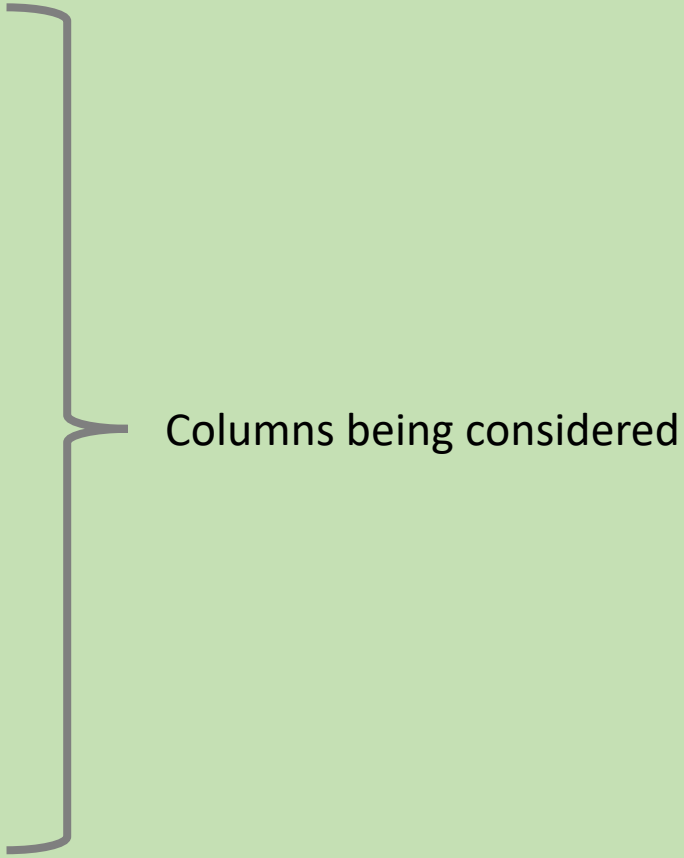
- Authors
- Books
- Editors
- Publishers

Tables being considered

Active learning:
Identify entity properties

Active learning:
Identify entity properties

- Book title
- Book price
- Book date
- Author name
- Author address
- Author contact
- Editor name
- Editor address
- Publisher name
- Publisher address



Naming Conventions

Naming considerations

- Clarity – perceived meaning
- Brevity – meaningful but not long

Naming convention

- Plural tables names
- Singular columns names
- Pascal casing

Naming convention (contd)

- Primary key → "[SingularOfTableName]ID”
    - Table name: Customers
    - Primary key: CustomerID
- Foreign key → Same name of PK
- Do not very naming
    - DateOfBirth and DOB
- Pascal naming example – DateOfBirth
- If possible, do not abbreviate

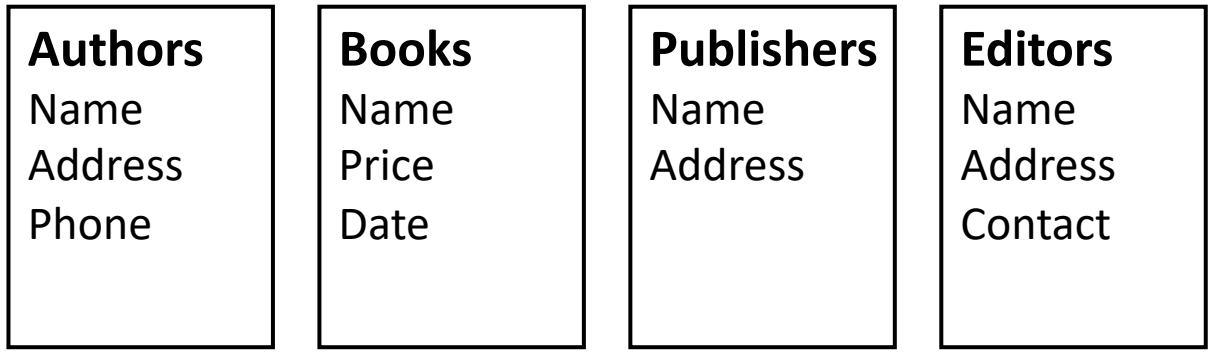
Consistency most important

- The naming convention is not just for yourself
- Like all code, it must communicate intent – you'll thank your self later
- Strive for transparency
- Like UI design, consider user expectation and knowledge
- Take into account unofficial conventions
- Above all be consistent

Sample Database

contd

Preliminary entity-relationship diagram

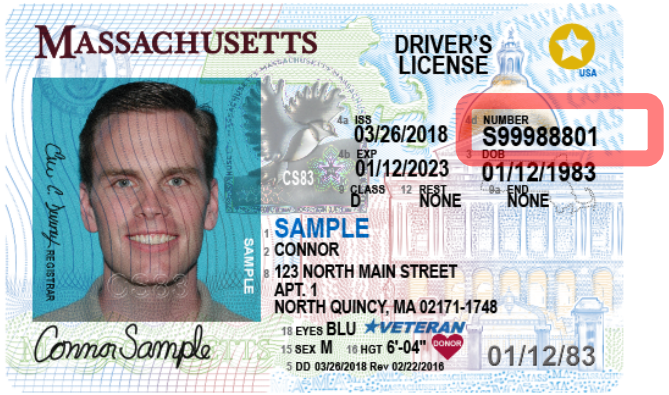


Primary keys, unique identifiers, for tables?

Authors	**Books**	**Publishers**	**Editors**
Name	Name	Name	Name
Address	Price	Address	Address
Phone	Date		Contact

Are there problems with “name” as a primary key?
Is it a good idea to combine first and last name?
How long with that work? What else could we combine?
What could be a problem with combinations?

Numbers as PKs – a world full of numbers



Disadvantages of numbers

- Readability
- Speaking codes
- Advantage: speed, index simplicity

Active learning:
Choose primary keys

Authors
Name
Address
Phone

Books
Name
Price
Date

Publishers
Name
Address

Editors
Name
Address
Contact

Choosing PKs is one the crucial steps in database design

Active learning:
Choose primary keys

Authors
AuthorID
Name
Address
Phone

Books
BookID
Name
Price
Date

Publishers
PublisherID
Name
Address

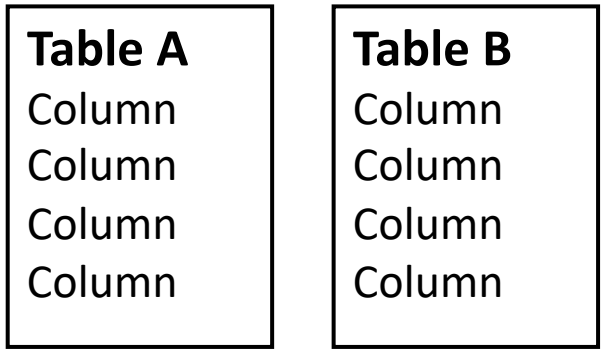
Editors
EditorID
Name
Address
Contact

Choosing PKs is one the crucial steps in database design

Cardinality
Sample Database
contd

Cardinality - how one table relates to another

- 1-to-1, one row in table A relates to one row in table B
- 1-to-N, one row in table A relates to many rows in table B
- N-to-N, Many rows in table A relate to many rows in table B



So far our samples database has …

- 4 tables: authors, books, publishers, editors
- Entity properties
- Primary keys
- But we are missing relationships between tables
  - Example: what books has a publisher published?

So far our samples database has …

- 4 tables: authors, books, publishers, editors
- Entity properties
- Primary keys
- But we are missing relationships between tables
  - Example: what books has a publisher published?

Authors
AuthorID
Name
Address
Phone

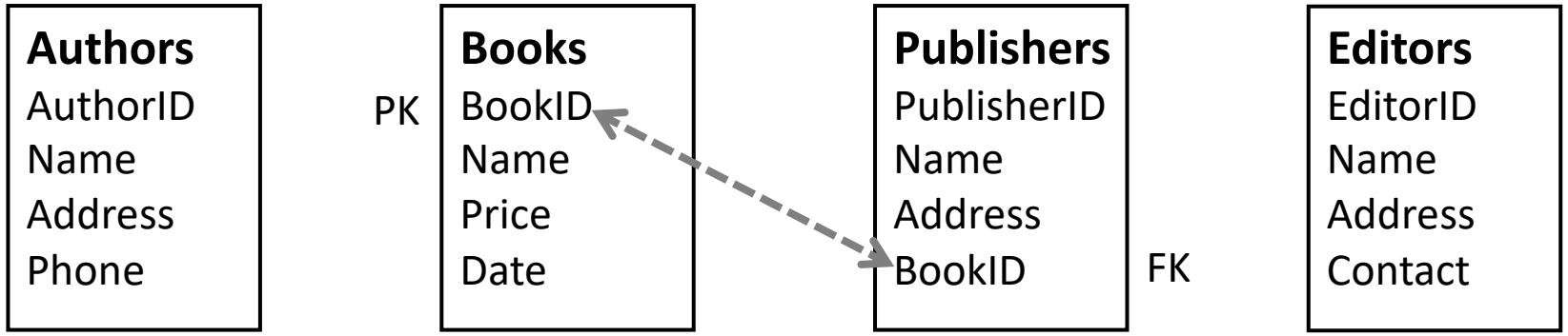
Books
BookID
Name
Price
Date

Publishers
PublisherID
Name
Address

Editors
EditorID
Name
Address
Contact

One-to-many relationships, 1-to-N, or 1:N

- The relationship between publishers and books is **one-to-many**.
- Would the following work?



How would you enter multiple books for the same publisher?

How would you enter multiple books for the same publisher?

- You cannot repeat the primary key, the unique identifier
- You do not want to put multiple values in one cell, more on that later

BookID	Name	Price	Date
1	Educated	$13	02/20/2018
2	Victoria	$9.86	11/22/2016
3	Sapiens	$20.99	02/15/2015

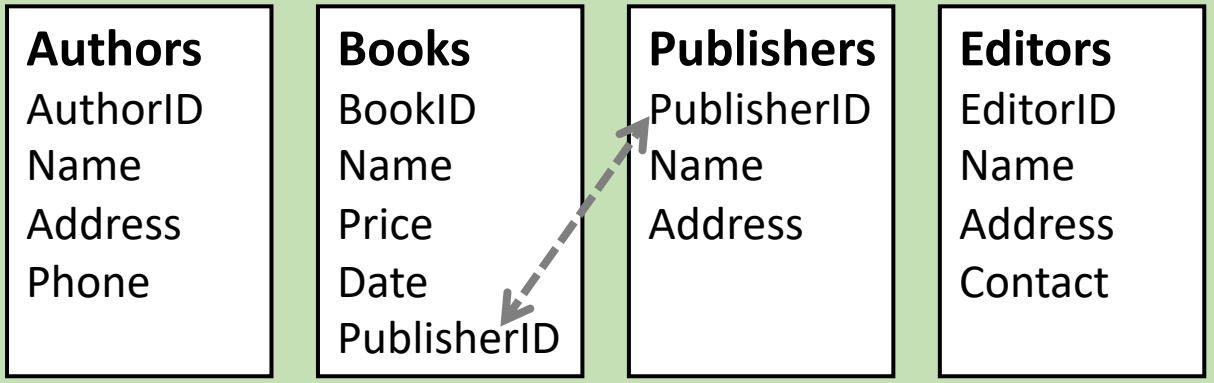
Redundancy

PublisherID	Name	Address	BookID
1	Random House	NY, NY	1
1	Random House	NY, NY	2
1	Random House	NY, NY	3

A better approach?

A better approach?

Publisher ID in books table



PublisherID	Name	Address
1	Random House	NY, NY

BookID	Name	Price	Date	PublisherID
1	Educated	$13	02/20/2018	1
2	Victoria	$9.86	11/22/2016	1
3	Sapiens	$20.99	02/15/2015	1

Redundancy

Much better

Much better

- The publishers table has one row for each publisher
- The books table has one row for each book
- Publisher ID numbers are repeated in books table but far less redundancy.
- You can use the PublisherID and BookID to join the tables.
- It’s always important to consider how you are going to join data.

Foreign keys

- Informally, a column that matches the PK in another table.

Referential integrity

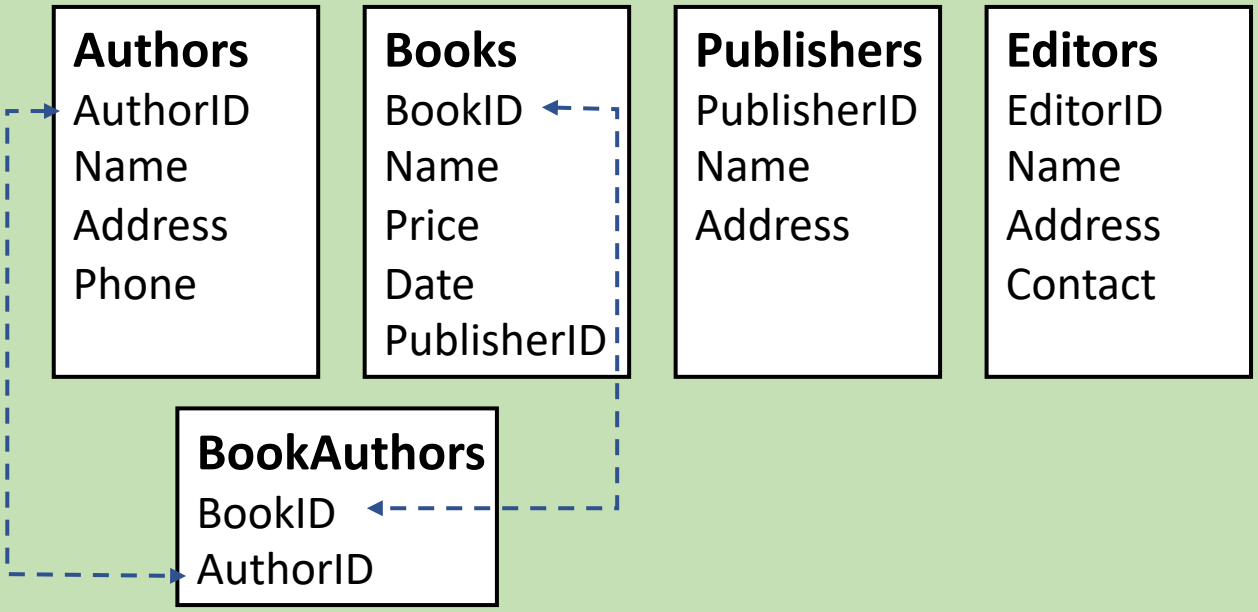
- A complete database design should include planning for PK and FK consistency
- Example
  - What happens if someone enters book with an invalid publisher ID?
  - What happens if a publisher PK is updated or deleted?
- We will return to these points

Find the many-to-many relationships, N-to-N, or N:N. Add to diagram.

- How are authors and books related?
  - Some books have more than one author
  - Some authors have written more than one book

Many-to-many relationships, N-to-N, or N:N

- How are authors and books related?
  - Some books have more than one author
  - Some authors have written more than one book
- N-to-N relationships are represented as tables of their own.



Book authors is an N-to-N relationship

BookAuthors is an N-to-N relationship

- It’s a table but not an independent entity
  - You need to do a join to find a book’s authors
- Dependent tables are also called associations
- Participant in an association are FKs
- It’s often the case that the FKs are the PK

One-to-one, 1:1

- 1:1 relationships can be collapsed into one table
- Justification can be speed
- Think of a list of definitions

Entity-Relationship Summary

Entity-Relationship Summary

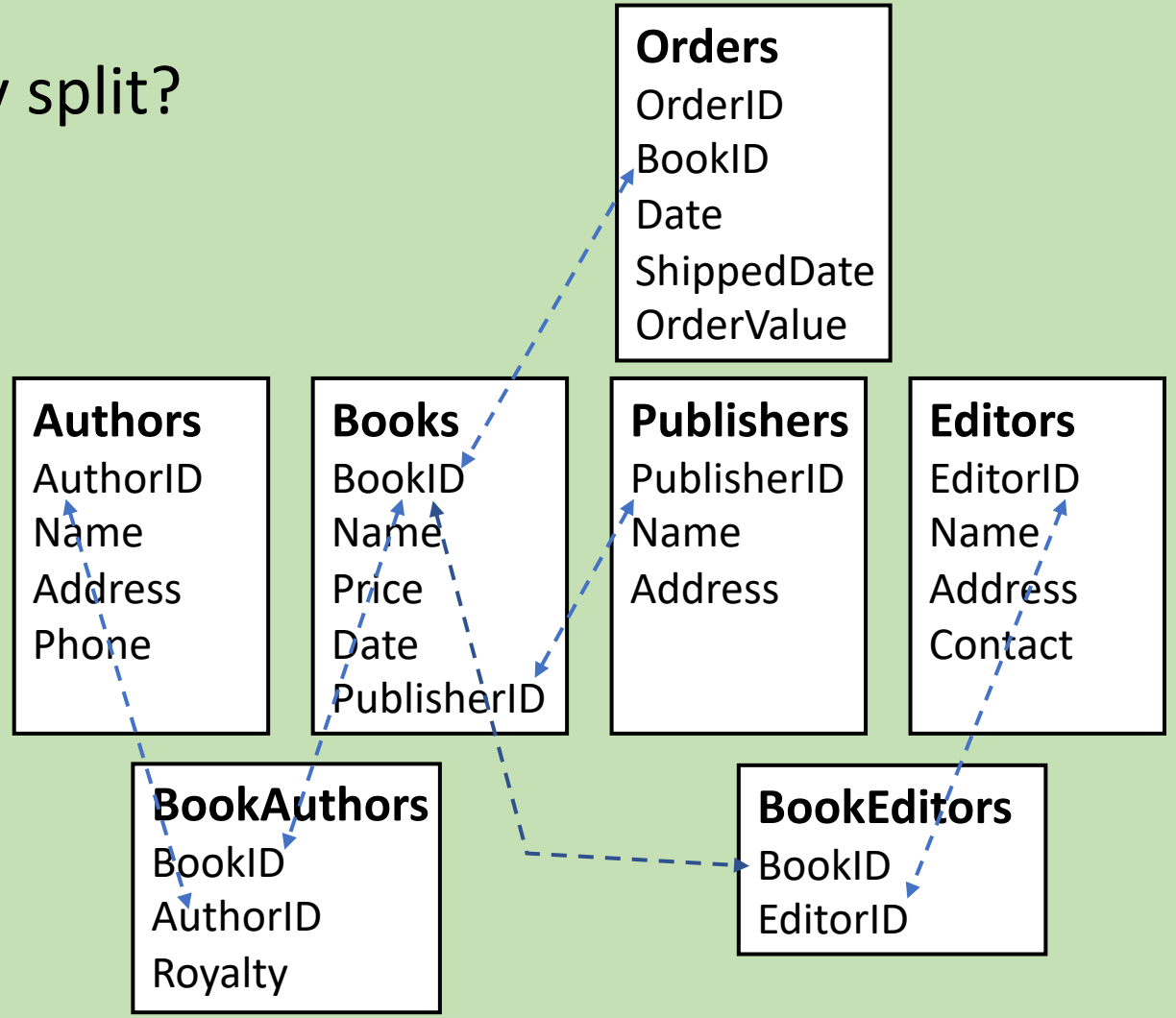
- Represent each independent entity as a table
- Represent each property of an entity as a column in a table
- Make sure each table has a primary key
- Identify one-to-many relationships between tables, PK & FK
- Represent each many-to-many relationship as a mapping table between to independent entities

Is your intended data model logic captured?

- Can you capture author royalty split?
- How about sales?
- Book editors?

Is your intended data model logic captured?

- Can you capture author royalty split?
- How about sales?
- Book editors?



Normalization

Normalization goals

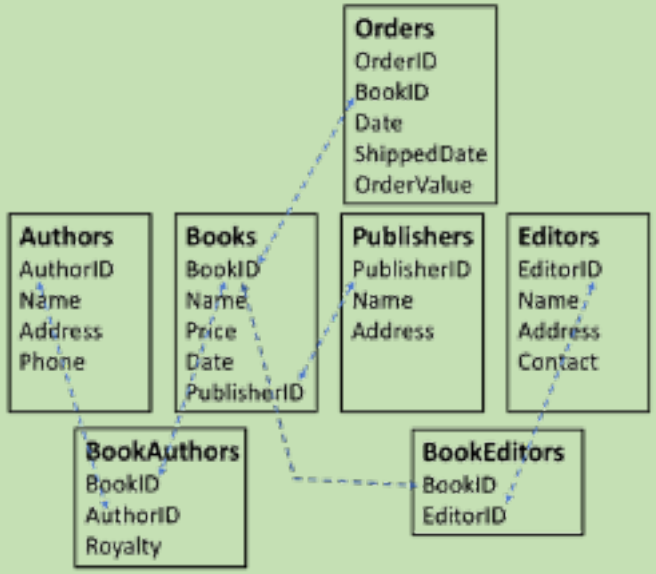
- Reduction of data redundancy within tables
- Simpler data integrity by avoiding duplicate data
- Splitting up tables into two or more related tables that can be put back together with joins.
- Non-loss decomposition
  - Splitting up a table into smaller tables without losing information.

First normal form

- Each row-and-column cell has only one value
- Value must be atomic (one entry)
- How would handle one order with multiple books?

First normal form

- Each row-and-column cell has only one value
- Value must be atomic (one entry)
- How would handle one order with multiple books?
  - Bad: You could add more book columns
  - Bad: You could add multiple books in one cell



Second normal form

- Every non-key must depend on the entire primary key
- Every entity property must depend on the PK
- Irrelevant when the PK is only one column

Second normal form

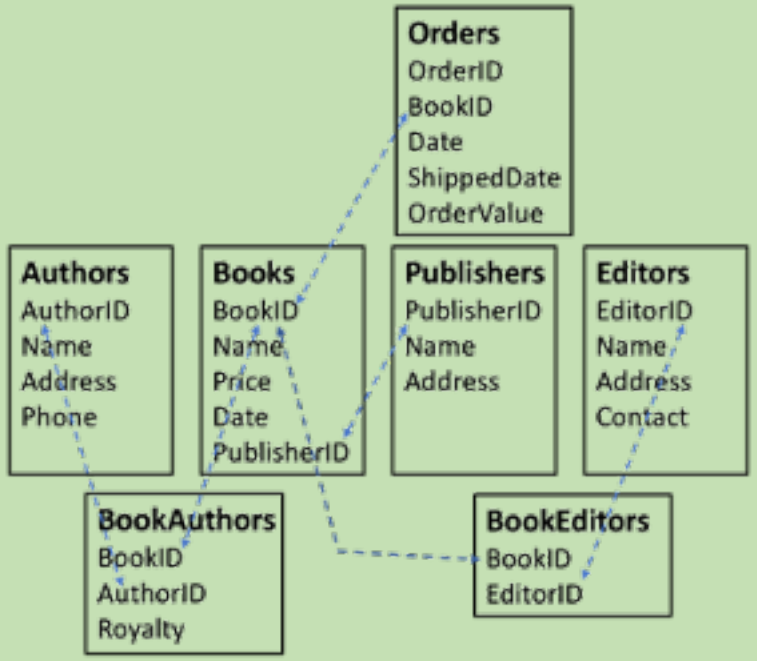
- Every non-key must depend on the entire primary key
- Every entity property must depend on the PK
- Irrelevant when the PK is one column only
- Example:
  - Every royalty in BookAuthors depends on book and author

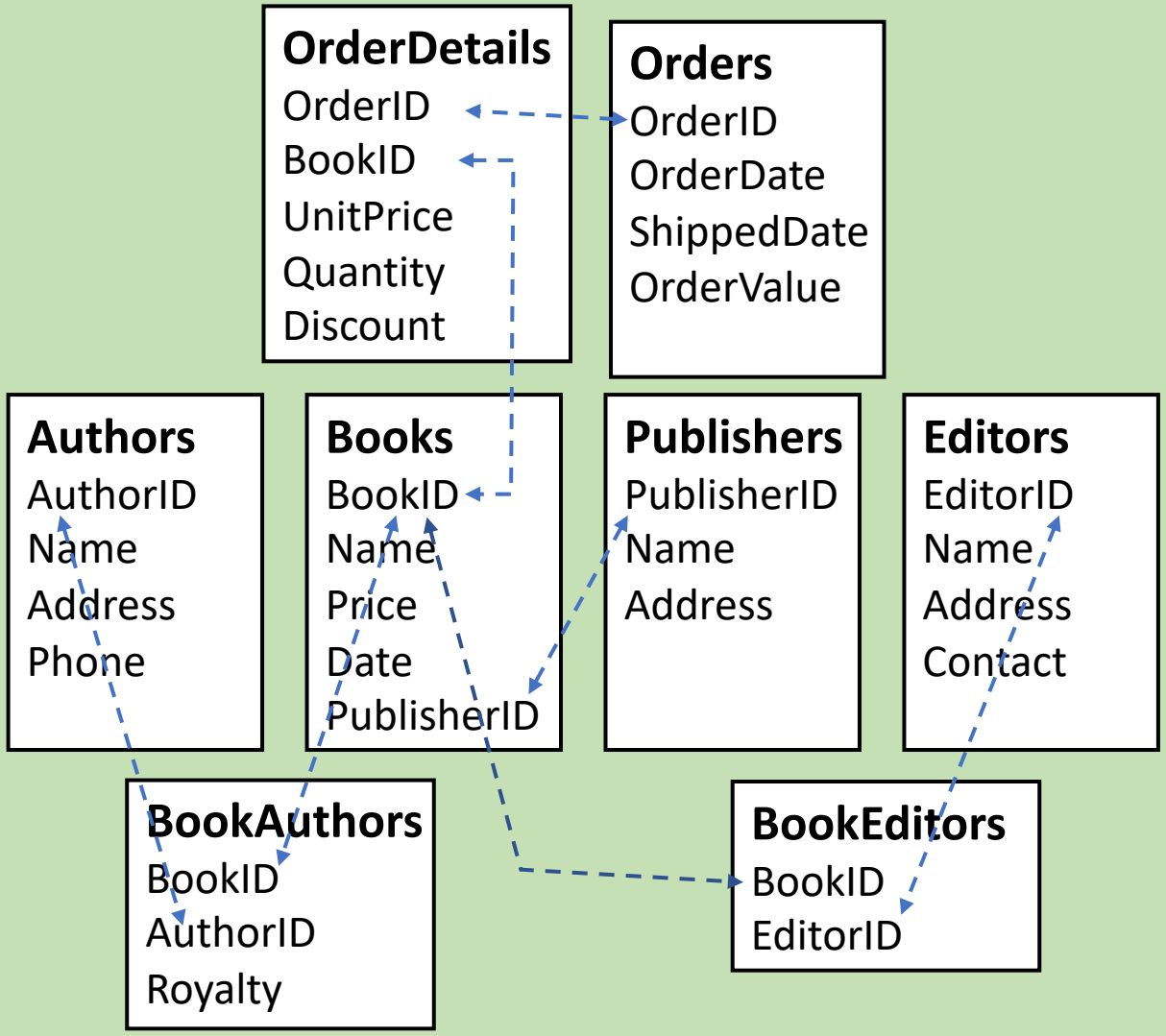
Third normal form

- Non-key column must not depend on another non-key column
- Each non-key column must be a fact about the PK column

Third normal form

- Non-key column must not depend on another non-key column
- Each non-key column must be a fact about the PK column
- In the Orders table, book can be multiple, incomplete fact

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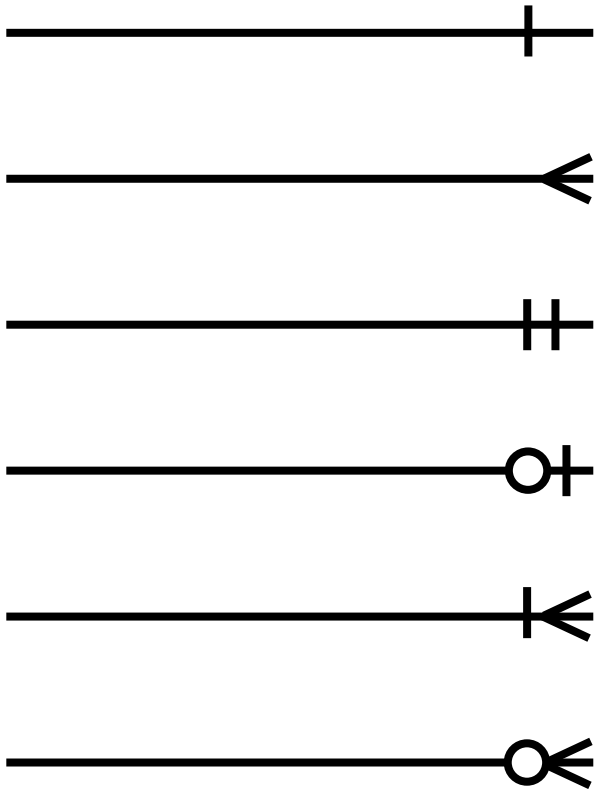
ER Diagram Symbols

Cardinality – how one table relates to another



One

Many

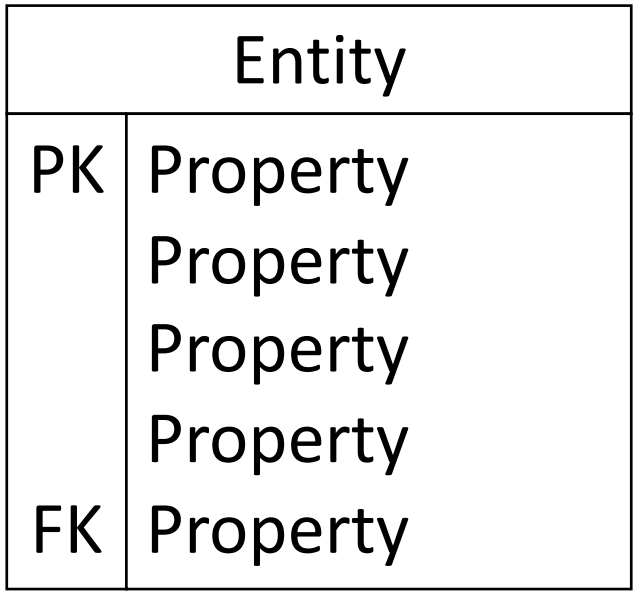
One (and only one)

Zero or one

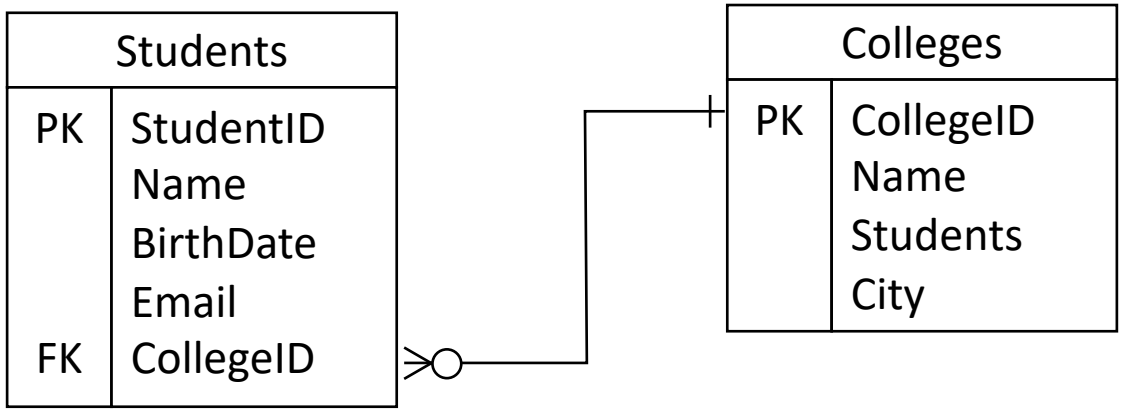
One or many

Zero or many

Entities, properties, PK, FK



Example


Students
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StudentID
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FK
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Colleges
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CollegeID
Name
Students
City

Tools

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.github	14.2.6 release	2 months ago
etc	14.3.0 release	28 days ago
src/main	14.4.4 release	4 days ago
.gitignore	ignoing vscode config	7 months ago
.travis.yml	Adds ant install	2 years ago
CODE_OF_CONDUCT.md	Update CODE_OF_CONDUCT.md	14 months ago
ChangeLog	14.4.4 release	4 days ago
LICENSE	Changed to Apache 2.0 license	4 years ago
README.md	14.2.8 release	last month
VERSION	14.4.4 release	4 days ago

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+ 658 releases

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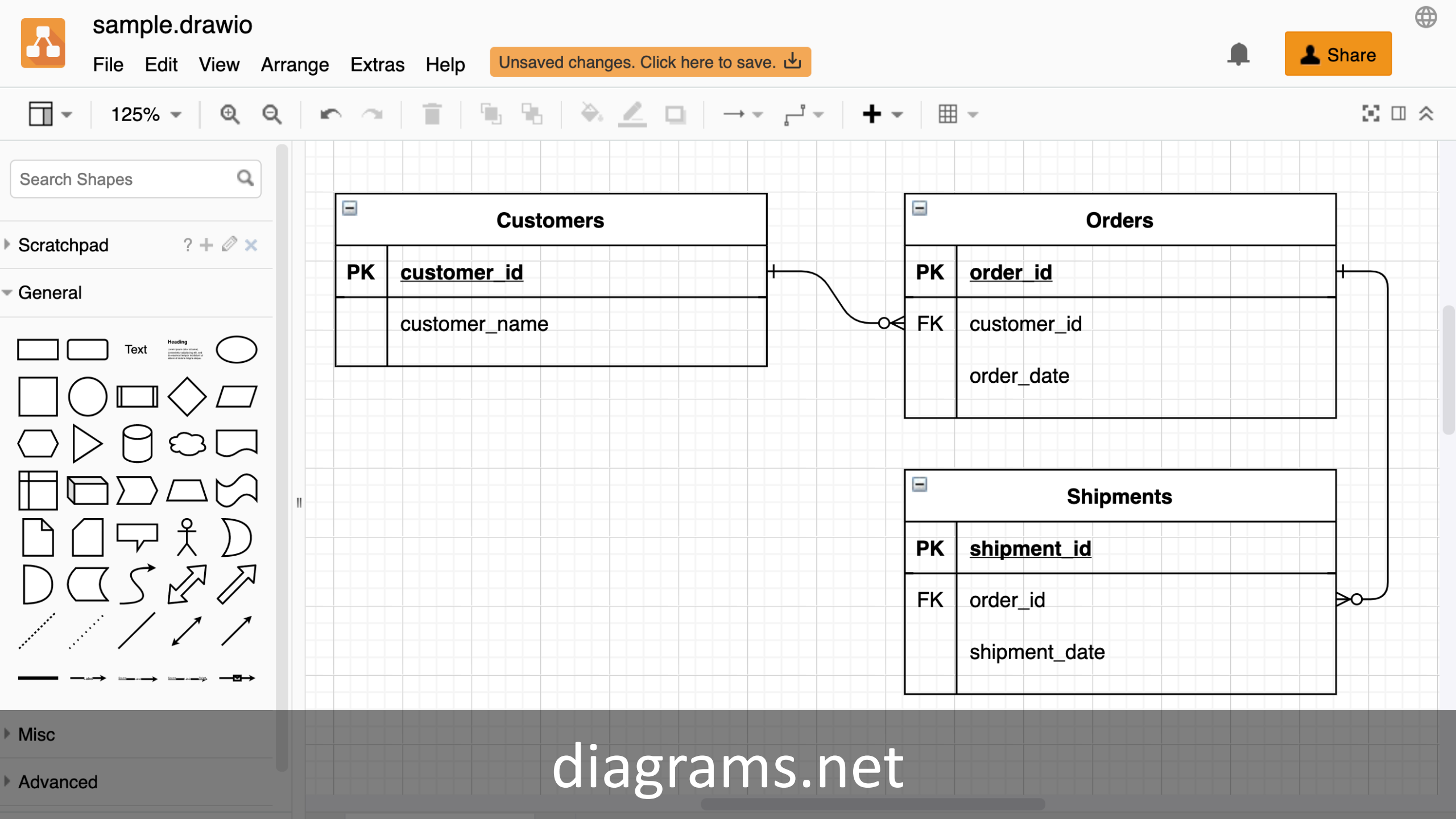
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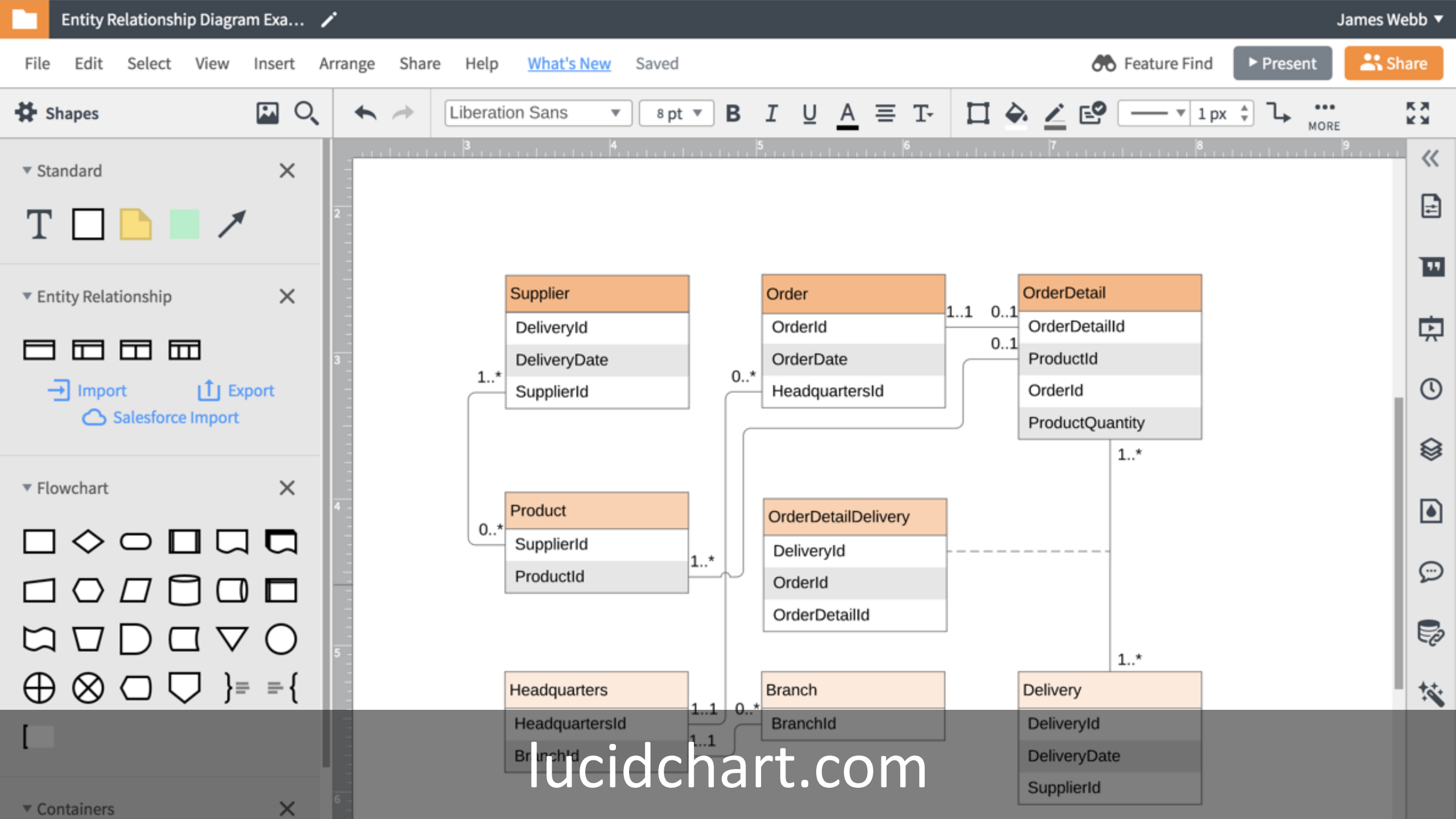
Entity Relationship Diagram Exa...
James Webb
File
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Select
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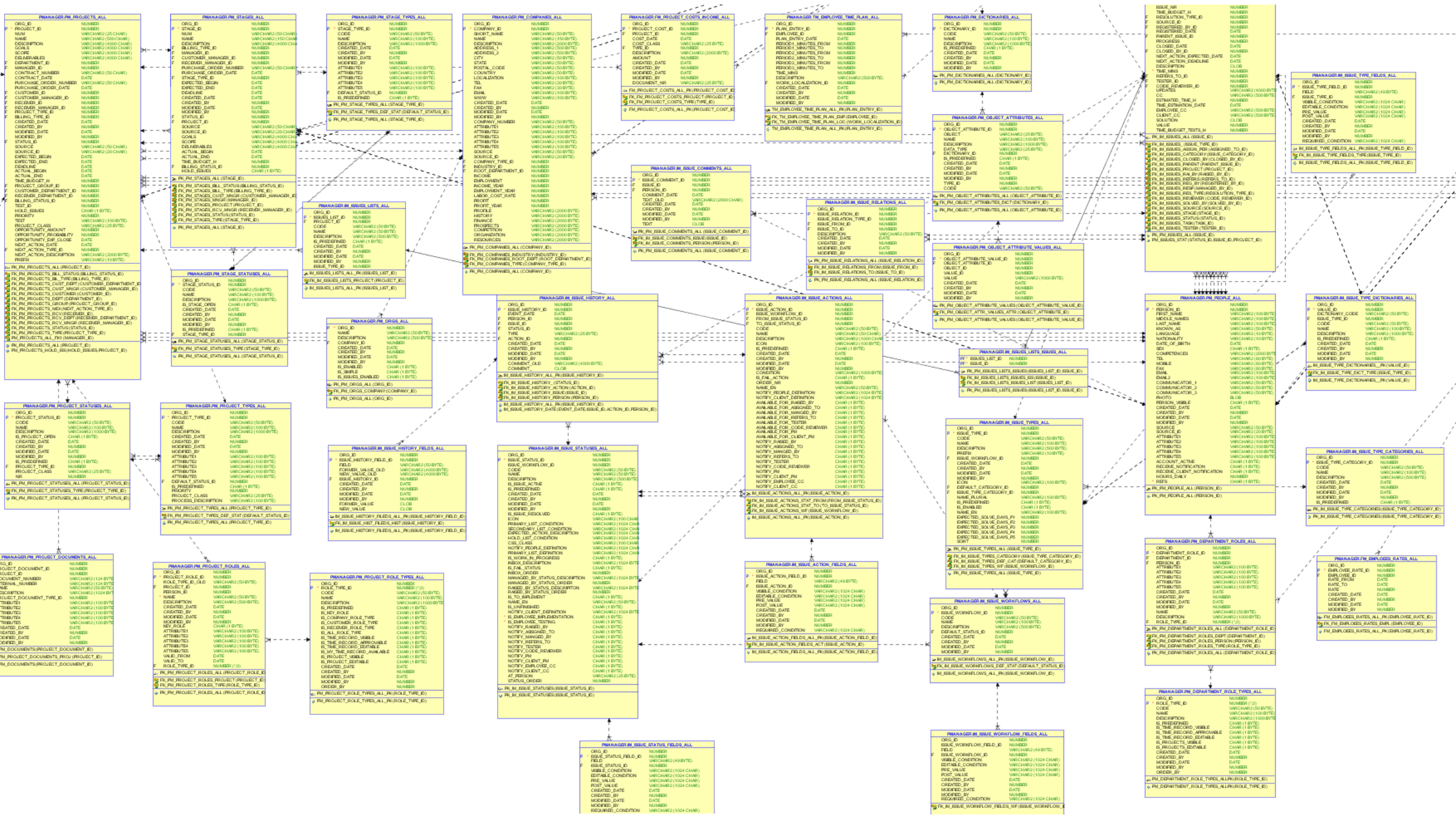
Active learning

- Finish Entity-Relationship diagram
- Submit diagram
- http://bit.ly/3bnw3WG

Database Size

number of tables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PORTAL 7.3 ENTITY RELATIONSHIP DIAGRAM

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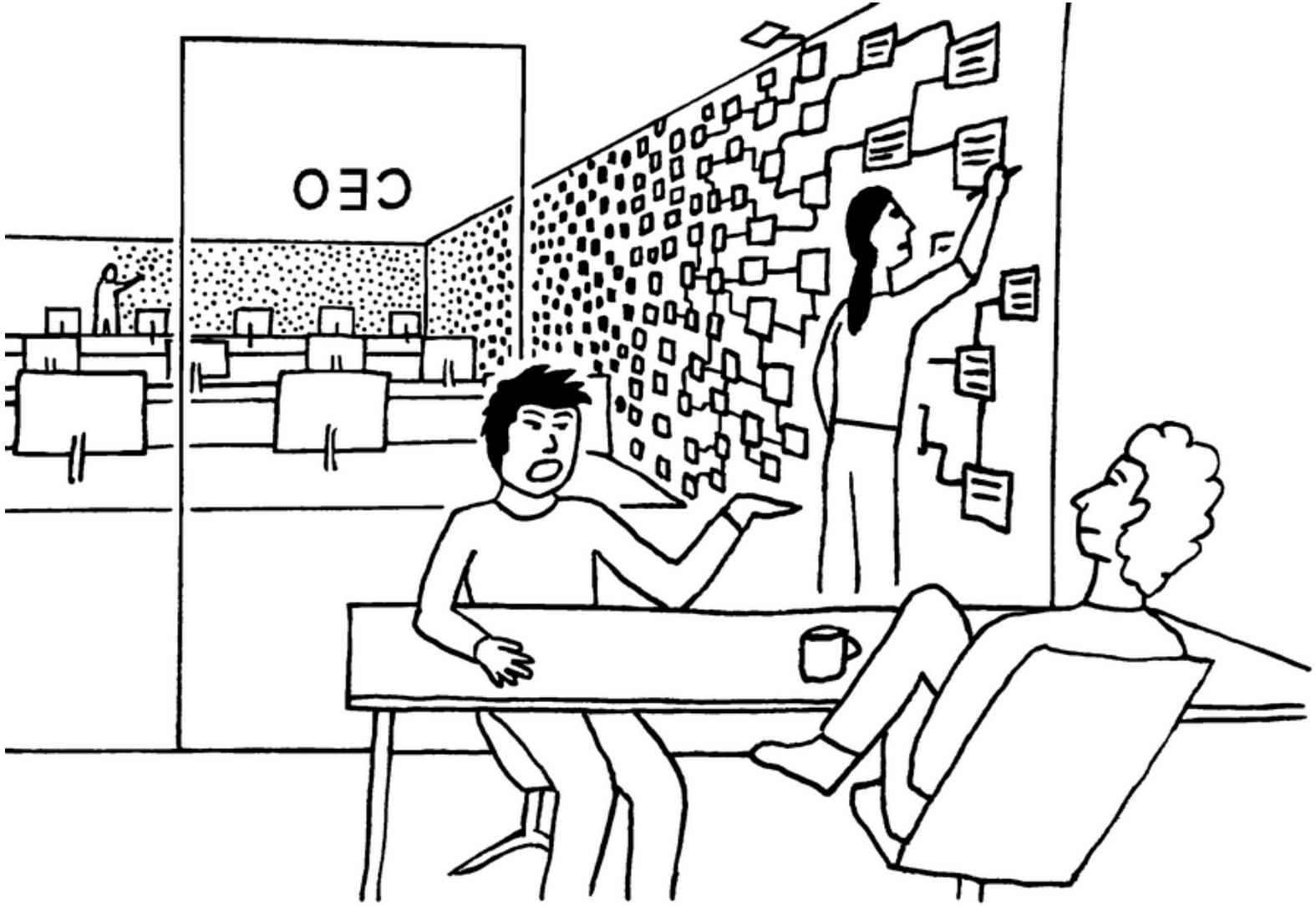

Oracle EBS
24,000 tables

Remember when you asked us to create an entity-relationship diagram for the whole company? Well, we're going to need a bigger office …

Divide and conquer

Start small, like in code, separate blocks as you grow – 20 tables or less