732A54 / TDDE31 Big Data Analytics 6hp

http://www.ida.liu.se/~732A54
http://www.ida.liu.se/~TDDE31

Teachers

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- Lectures: Patrick Lambrix,
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  Christoph Kessler,
  José M Pena
- Labs: Huanyu Li / Mina Abd Nikooie Pour
  José M Pena
- Director of studies: Patrick Lambrix

Course literature

- Articles (on web/handout)
- Lab descriptions (on web)

Data and Data Storage

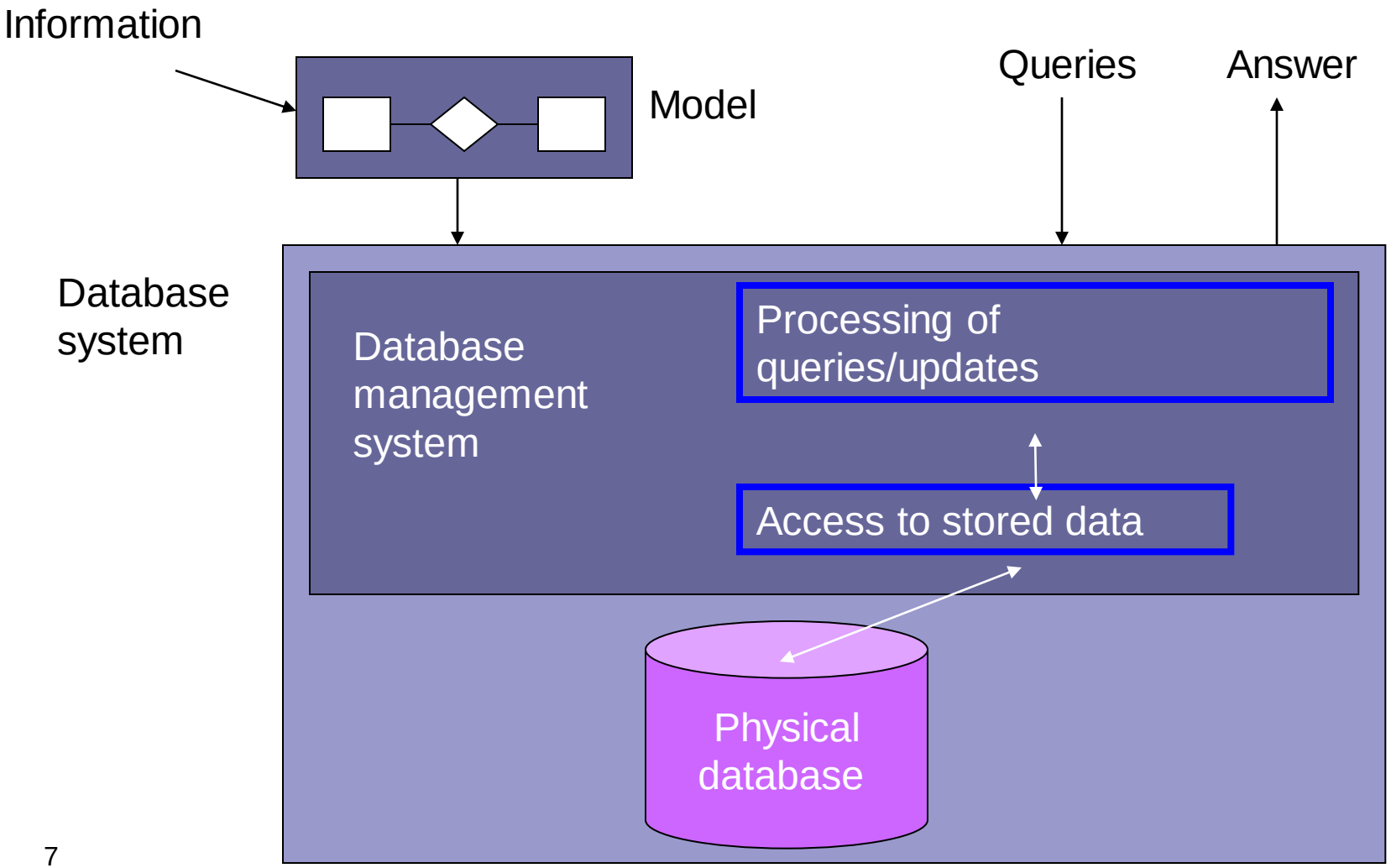
Data and Data Storage

- Database / Data source
- One (of several) ways to store data in electronic format
- Used in everyday life: bank, hotel reservations, library search, shopping

Databases / Data sourcces

- Database management system (DBMS): a collection of programs to create and maintain a database
- Database system = database + DBMS

Databases / Data sources



What information is stored?

- Model the information
  - Entity-Relationship model (ER)
  - Unified Modeling Language (UML)

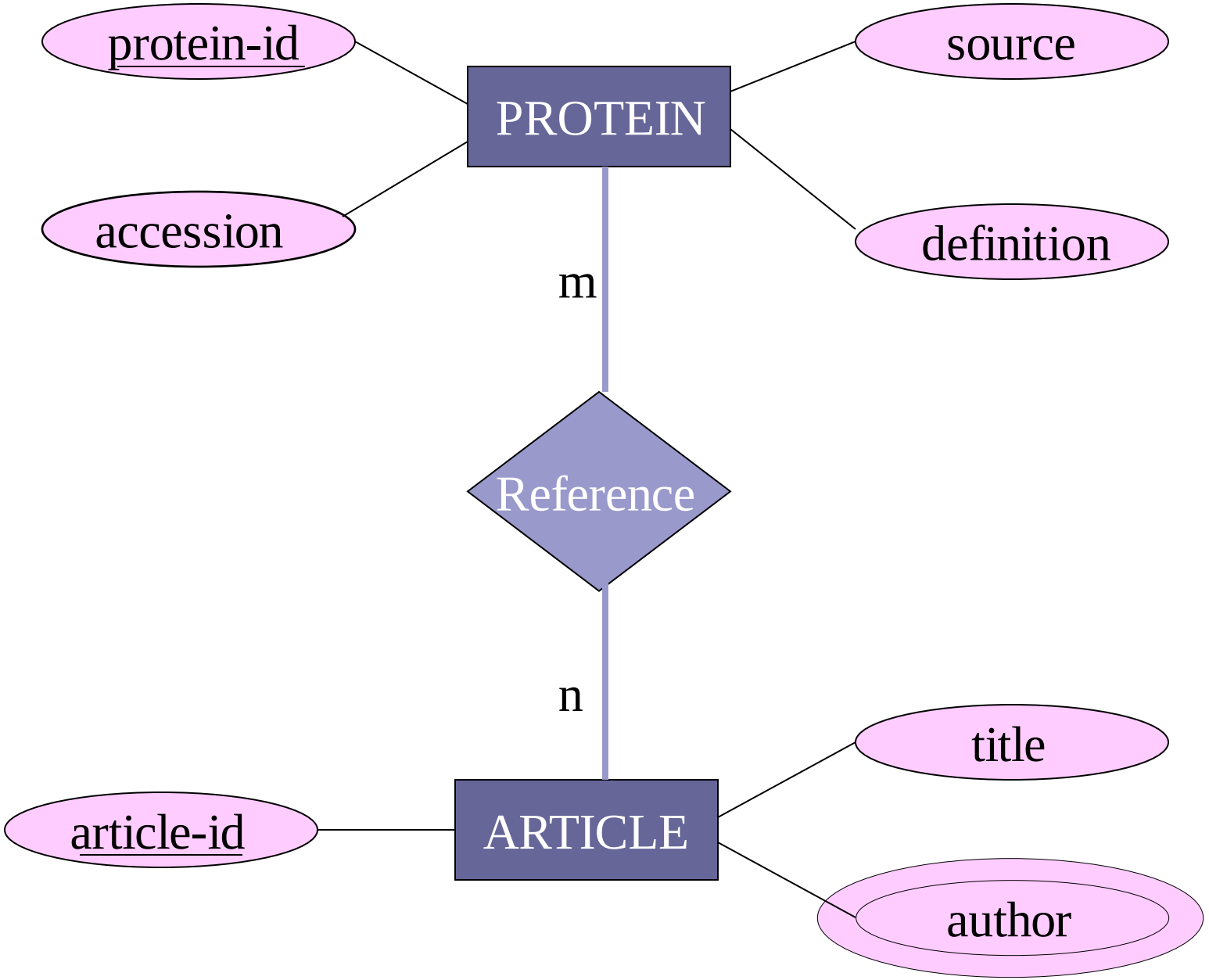
What information is stored? - ER

- entities and attributes
- entity types
- key attributes
- relationships
- cardinality constraints

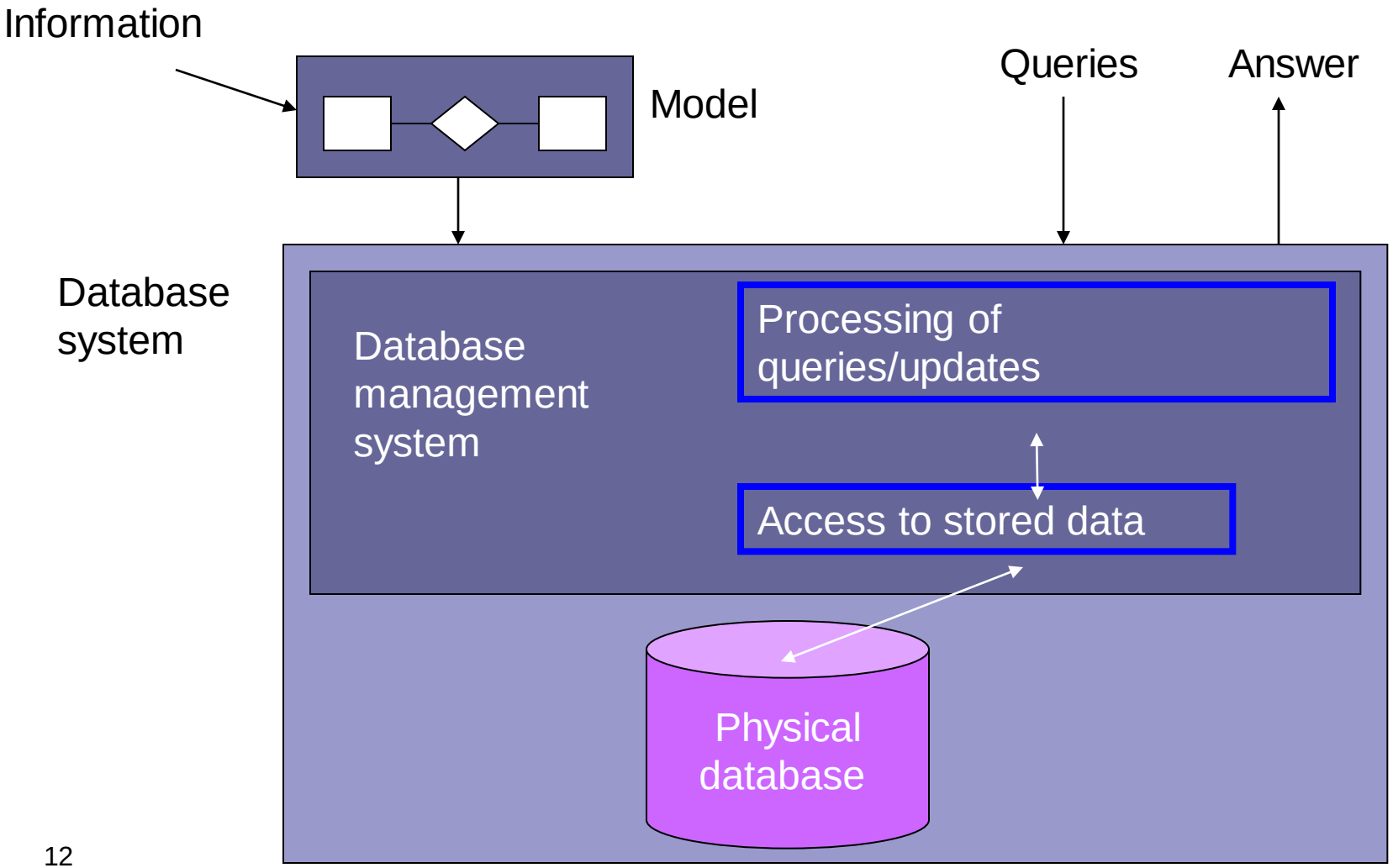
- EER: sub-types

DEFINITION	Homo sapiens adrenergic, beta-1-, receptor
ACCESSION	NM_000684
SOURCE ORGANISM human	
REFERENCE	1
AUTHORS	Frielle, Collins, Daniel, Caron, Lefkowitz, Kobilka
TITLE	Cloning of the cDNA for the human beta 1-adrenergic receptor
REFERENCE	2
AUTHORS	Frielle, Kobilka, Lefkowitz, Caron
TITLE	Human beta 1- and beta 2-adrenergic receptors: structurally and functionally related receptors derived from distinct genes

Entity-relationship

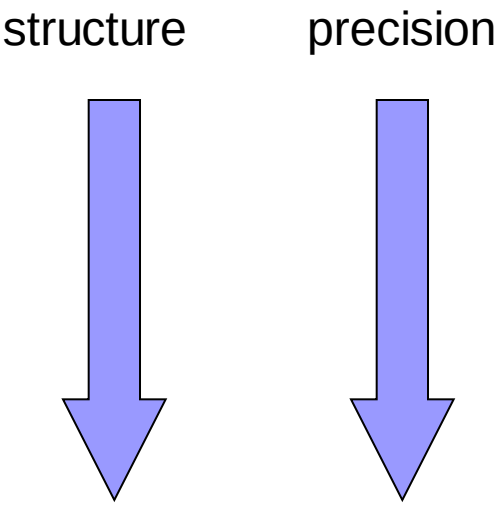


Databases / Data sources



How is the information stored? (high level)
How is the information accessed? (user level)

- Text (IR)
- Semi-structured data
- Data models (DB)
- Rules + Facts (KB)



IR - formal characterization

Information retrieval model: (D,Q,F,R)

- D is a set of document representations
- Q is a set of queries
- F is a framework for modeling document representations, queries and their relationships
- R associates a real number to document-query-pairs (ranking)

IR - Boolean model

	adrenergic	cloning	receptor		
Doc1	yes	yes	no	-->	(1 1 0)
Doc2	no	yes	no	-->	(0 1 0)

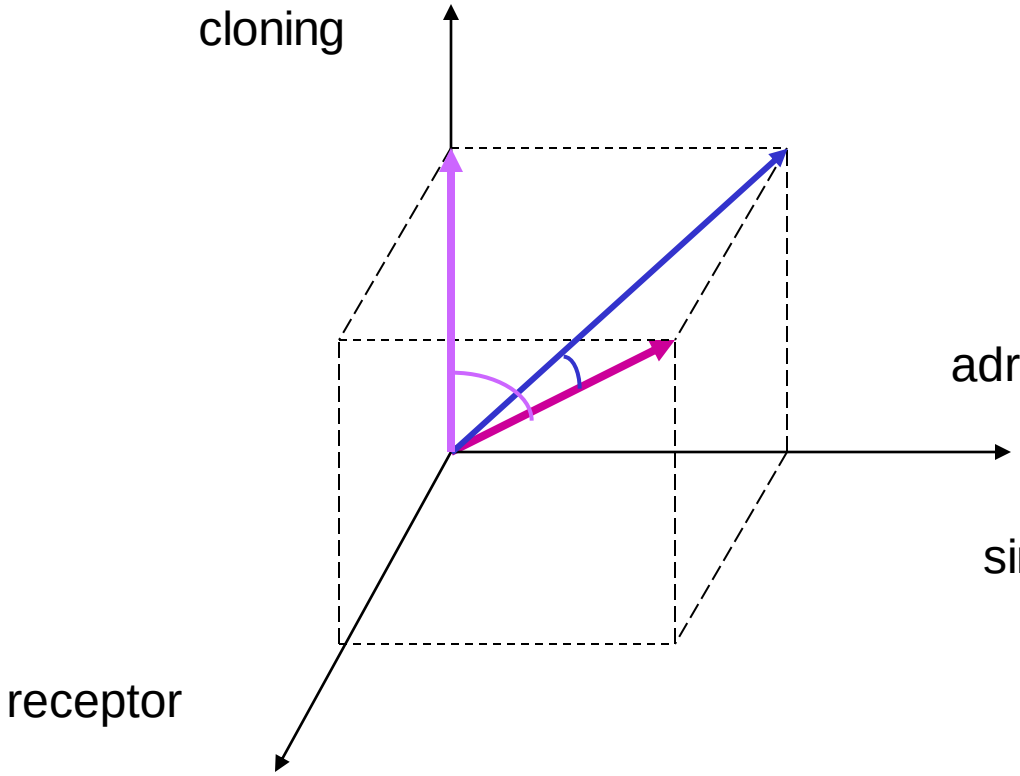
Q1: cloning and (adrenergic or receptor)

--> (1 1 0) or (1 1 1) or (0 1 1) Result: Doc1

Q2: cloning and not adrenergic

--> (0 1 0) or (0 1 1) Result: Doc2

IR - Vector model (simplified)



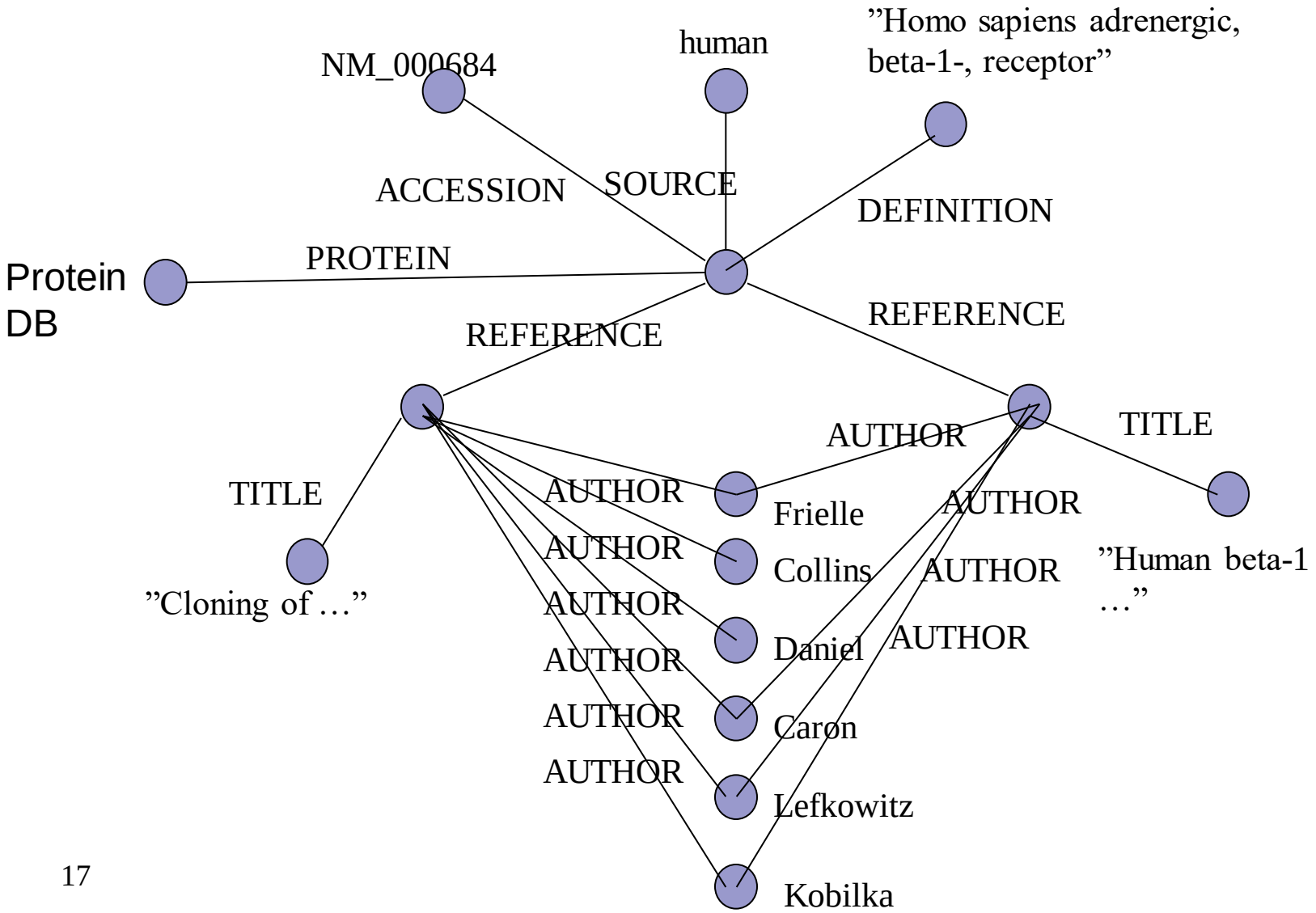
Doc1 (1,1,0)

Doc2 (0,1,0)

Q (1,1,1)

$$sim(d,q) = \frac{d \cdot q}{|d| \times |q|}$$

Semi-structured data



Semi-structured data - Queries

```
select source
from PROTEINDB.protein P
where P.accession  = ”NM_000684”;
```

Relational databases

PROTEIN

PROTEIN-ID	ACCESSION	DEFINITION	SOURCE
1	NM_000684	Homo sapiens adrenergic, beta-1-, receptor	human

REFERENCE

PROTEIN-ID	ARTICLE-ID
1	1
1	2

ARTICLE-AUTHOR

ARTICLE-ID	AUTHOR
1	Frielle
1	Collins
1	Daniel
1	Caron
1	Lefkowitz
1	Kobilka
2	Frielle
2	Kobilka
2	Lefkowitz
2	Caron

ARTICLE-TITLE

ARTICLE-ID	TITLE
1	Cloning of the cDNA for the human beta 1-adrenergic receptor
2	Human beta 1- and beta 2-adrenergic receptors: structurally and functionally related receptors derived from distinct genes

Relational databases - SQL

select source
from protein
where accession = NM_000684;

PROTEIN

PROTEIN-ID	ACCESSION	DEFINITION	SOURCE
1	NM_000684	Homo sapiens adrenergic, beta-1-, receptor	human

Evolution of Database Technology

- 1960s:
  - Data collection, database creation, IMS and network DBMS
- 1970s:
  - Relational data model, relational DBMS implementation
- 1980s:
  - Advanced data models (extended-relational, OO, deductive, etc.)
  - Application-oriented DBMS (spatial, temporal, multimedia, etc.)
- 1990s:
  - Data mining, data warehousing, multimedia databases, and Web databases

Evolution of Database Technology

- 2000s
  - Stream data management and mining
  - Data mining and its applications
  - Web technology (XML, data integration) and global information systems
  - NoSQL databases
- 2010s
  - Big data
  - NoSQL databases, graph databases
  - Knowledge graphs

Knowledge bases

(F) source(NM_000684, Human)
(R) source(P?,Human) => source(P?,Mammal)
(R) source(P?,Mammal) => source(P?,Vertebrate)

Q: ?- source(NM_000684, Vertebrate)

A: yes

Q: ?- source(x?, Mammal)

A: x? = NM_000684

Interested in more?

- 732A57/TDDD12/TDDD37/TDDD81/ Database Technology

  (relational databases)
- TDDD43 Advanced data models and databases

  (IR, semi-structured data, DB, KB)

Analytics

Analytics

- Discovery, interpretation and communication of meaningful patterns in data

Analytics - IBM

- What is happening? Descriptive

  Discovery and explanation
- Why did it happen? Diagnostic

  Reporting, analysis, content analytics
- What could happen? Predictive

  Predictive analytics and modeling
- What action should I take? Prescriptive

  Decision management
- What did I learn, what is best?

  Cognitive

Analytics - Oracle

- Classification
- Regression
- Clustering
- Attribute importance
- Anomaly detection
- Feature extraction and creation
- Market basket analysis

Why Analytics?

- The Explosive Growth of Data
  - Data collection and data availability
    - Automated data collection tools, database systems, Web, computerized society
  - Major sources of abundant data
    - Business: Web, e-commerce, transactions, stocks, …
    - Science: Remote sensing, bioinformatics, scientific simulation, …
    - Society and everyone: news, digital cameras, YouTube
- We are drowning in data, but starving for knowledge!

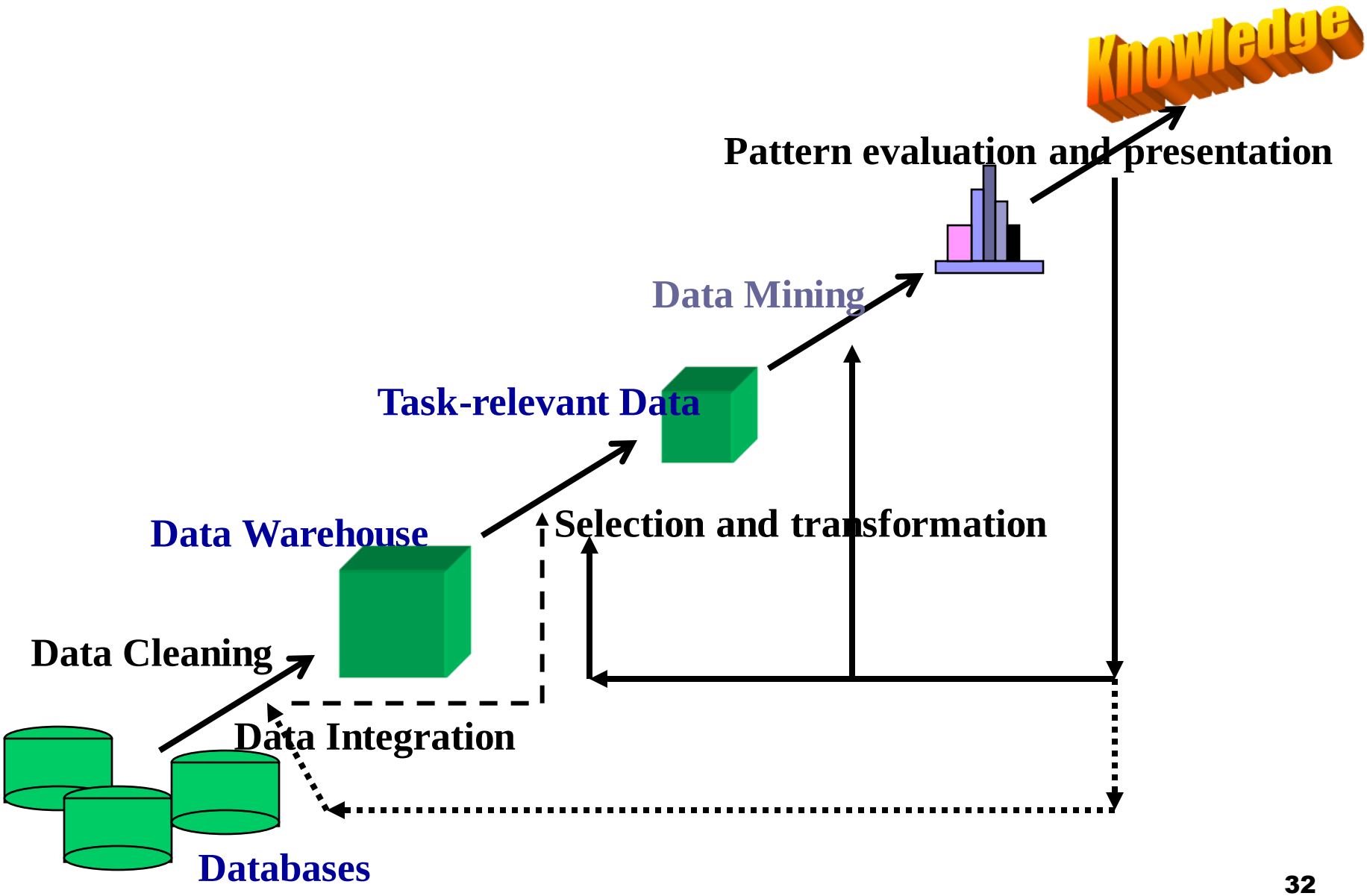
Ex. 1: Market Analysis and Management

- Where does the data come from?—Credit card transactions, loyalty cards, discount coupons, customer complaint calls, plus (public) lifestyle studies
- Target marketing
  - Find clusters of “model” customers who share the same characteristics: interest, income level, spending habits, etc.
  - Determine customer purchasing patterns over time
- Customer profiling
  - What types of customers buy what products (clustering or classification)
- Cross-market analysis
  - Find associations/co-relations between product sales
  - Predict based on such associations
- Customer requirement analysis
  - Identify the best products for different groups of customers
  - Predict what factors will attract new customers

Ex. 2: Fraud Detection & Mining Unusual Patterns

- Approaches: Clustering & model construction for frauds, outlier analysis
- Applications:
  - Auto insurance: ring of collisions
  - Money laundering: suspicious monetary transactions
  - Medical insurance
    - Professional patients, ring of doctors, and ring of references
    - Unnecessary or correlated screening tests

Knowledge Discovery (KDD) Process



Data Mining – what kinds of patterns?

- Concept/class description:
  - Characterization: summarizing the data of the class under study in general terms
    - E.g. Characteristics of customers spending more than 10000 sek per year
  - Discrimination: comparing target class with other (contrasting) classes
    - E.g. Compare the characteristics of products that had a sales increase to products that had a sales decrease last year

Data Mining – what kinds of patterns?

- Frequent patterns, association, correlations
  - Frequent itemset
  - Frequent sequential pattern
  - Frequent structured pattern

  - E.g. buy(X, “Diaper”) → buy(X, “Beer”) [support=0.5%, confidence=75%]
    confidence: if X buys a diaper, then there is 75% chance that X buys beer
    support: of all transactions under consideration 0.5% showed that diaper and beer were bought together
  - E.g. Age(X, ”20..29”) and income(X, ”20k..29k”) → buys(X, ”cd-player”) [support=2%, confidence=60%]

Data Mining – what kinds of patterns?

- Classification and prediction
  - Construct models (functions) that describe and distinguish classes or concepts for future prediction.

    The derived model is based on analyzing training data – data whose class labels are known.
    - E.g., classify countries based on (climate), or classify cars based on (gas mileage)
  - Predict some unknown or missing numerical values

Data Mining – what kinds of patterns?

- Cluster analysis
  - Class label is unknown: Group data to form new classes, e.g., cluster customers to find target groups for marketing
  - Maximizing intra-class similarity & minimizing interclass similarity
- Outlier analysis
  - Outlier: Data object that does not comply with the general behavior of the data
  - Noise or exception? Useful in fraud detection, rare events analysis
- Trend and evolution analysis
  - Trend and deviation

Interested in more?

- 732A95/TDDE01 Introduction to machine learning
- 732A75/TDDD41 Advanced data mining / Data mining – clustering and association analysis

Big Data

Big Data

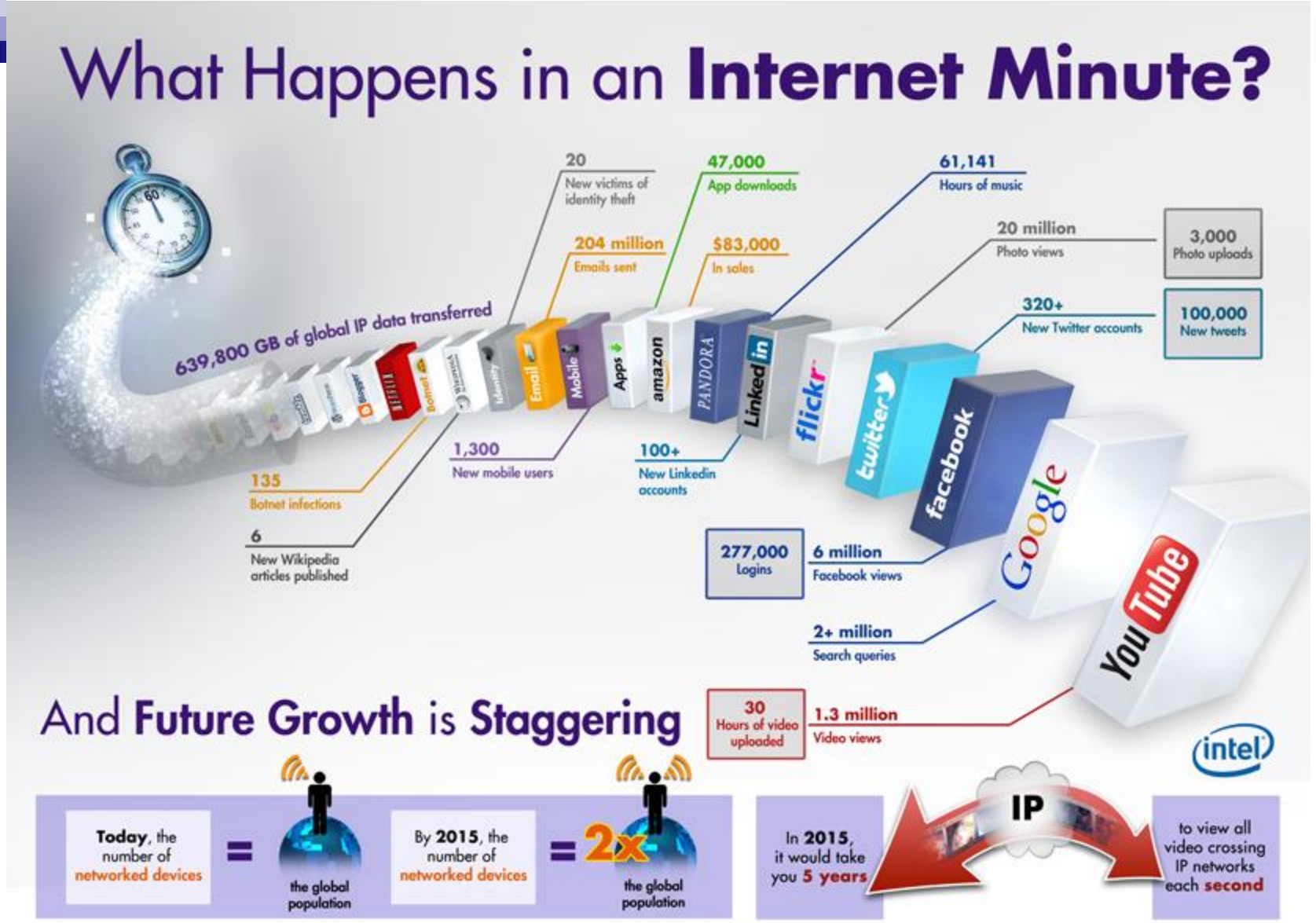
- So large data that it becomes difficult to process it using a ’traditional’ system

Big Data – 3Vs

- Volume
  - size of the data

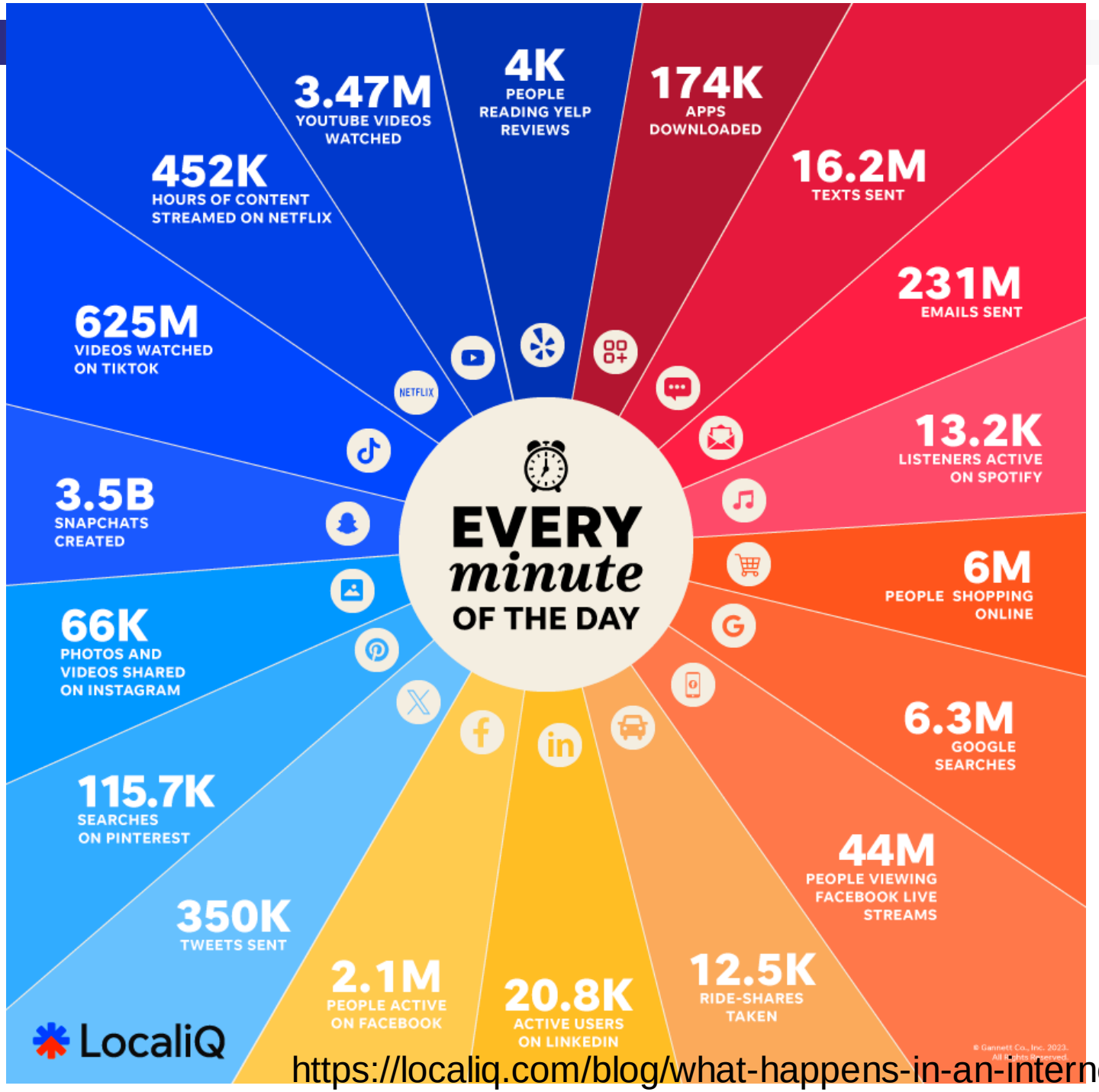
Volume - examples

- Facebook processes 500 TB per day
- Walmart handles 1 million customer transactions per hour
- Airbus generates 640 TB in one fligth (10 TB per 30 minutes)
- 500 hours of video uploaded to youtube every minute
- SMS, e-mail, internet, social media



https://y2socialcomputing.files.wordpress.com/2012/06/social-media-visual-last-blog-post-what-happens-in-an-internet-minute-infographic.jpg

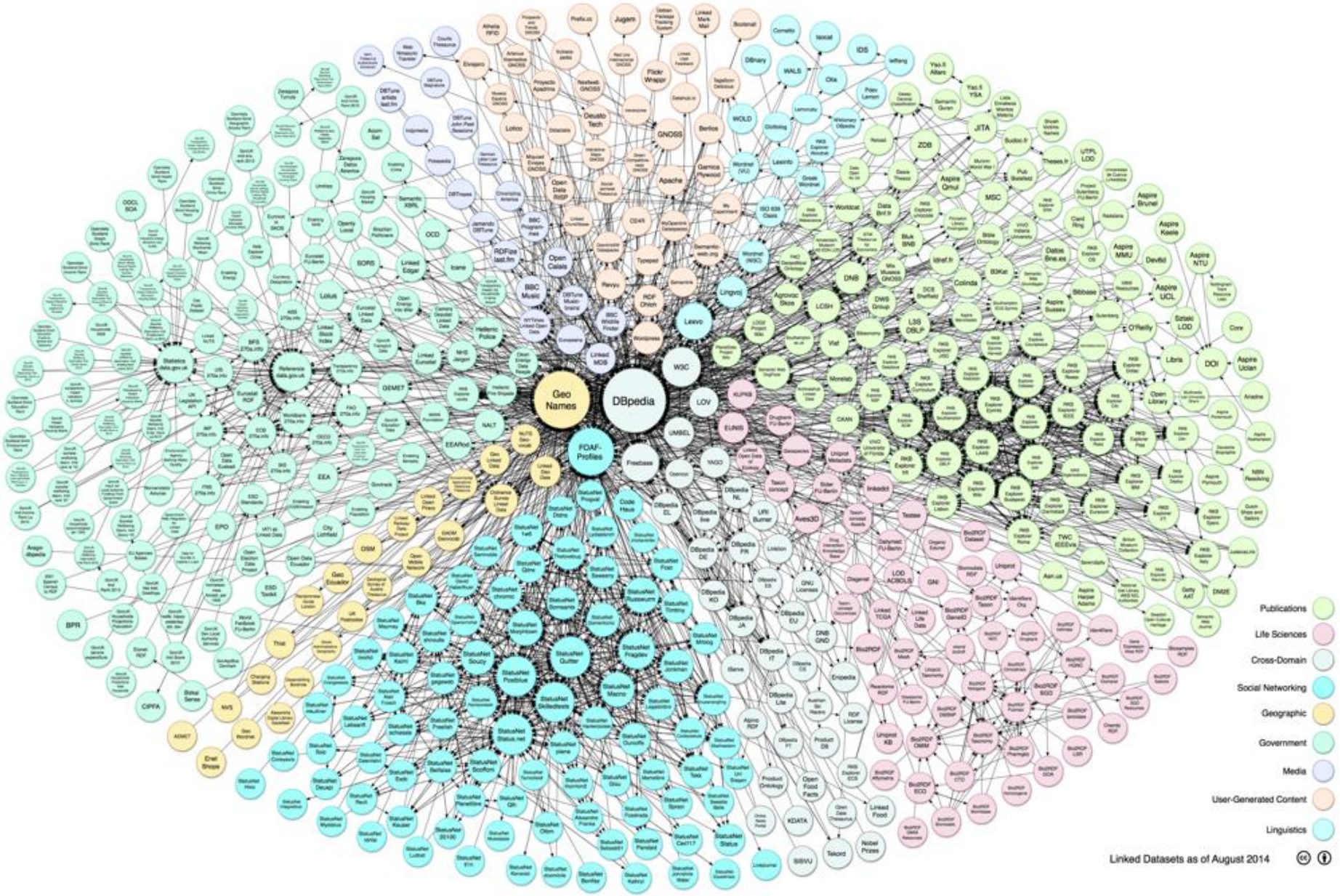
2024



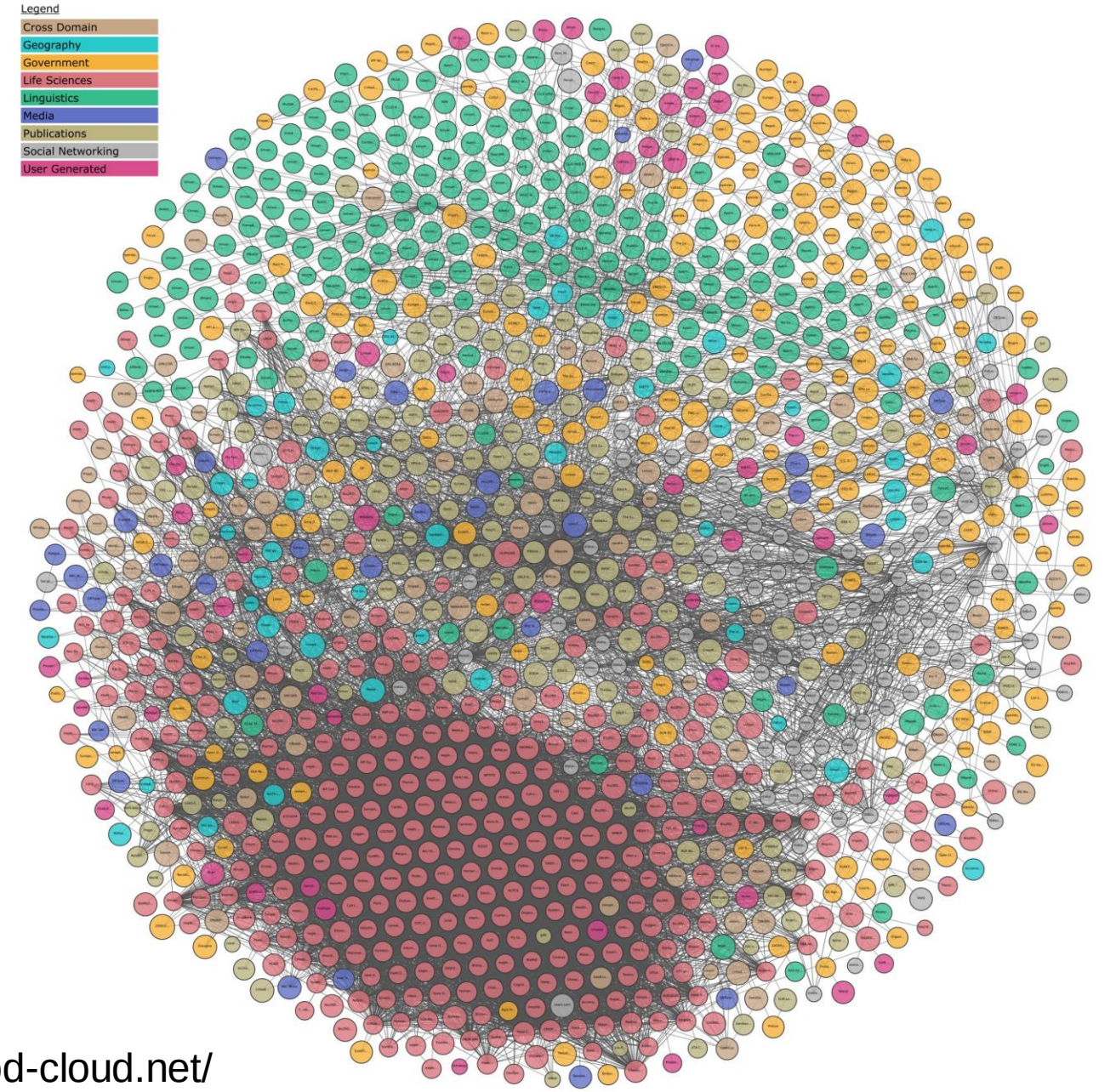
https://localiq.com/blog/what-happens-in-an-internet-minute/

Big Data – 3Vs

- Volume
  - size of the data
- Variety
  - type and nature of the data
    - text, semi-structured data, databases, knowledge bases



Linking Open Data cloud diagram 2014, by Max Schmachtenberg, Christian Bizer, Anja Jentzsch and Richard Cyganiak.
http://lod-cloud.net/



https://lod-cloud.net/

The Linked Open Data Cloud from lod-cloud.net

Linked open data of US government

Format (# Datasets) **http://catalog.data.gov/**

- XML (143853)
- HTML (100718)
- ZIP (94373)
- PDF (37297)
- CSV (24ä684)
- Esri REST (17391)
- JSON (15808)
- TEXT (15569)
- TIFF (14421)
- SID (12795)

Big Data – 3Vs

- Volume
  - size of the data
- Variety
  - type and nature of the data
- Velocity
  - speed of generation and processing of data

Velocity - examples

- Traffic data
- Financial market
- Social networks

The FOUR V's of Big Data

From traffic patterns and music downloads to web history and medical records, data is recorded, stored, and analyzed to enable the technology and services that the world relies on every day. But what exactly is big data, and how can these massive amounts of data be used?

As a leader in the sector, IBM data scientists break big data into four dimensions: **Volume, Velocity, Variety and Veracity**

Depending on the industry and organization, big data encompasses information from multiple internal and external sources such as transactions, social media, enterprise content, sensors and mobile devices. Companies can leverage data to adapt their products and services to better meet customer needs, optimize operations and infrastructure, and find new sources of revenue.

By 2015
4.4 MILLION IT JOBS
will be created globally to support big data, with 1:9 million in the United States

Volume
SCALE OF DATA

40 ZETTABYTES
[43 TRILLION GIGABYTES]
of data will be created by 2020, an increase of 300 times from 2005

It's estimated that
2.5 QUINTILLION BYTES
[2.3 TRILLION GIGABYTES]
of data are created each day

6 BILLION PEOPLE
have cell phones

WORLD POPULATION: 7 BILLION

Most companies in the U.S. have at least
100 TERABYTES
[100,000 GIGABYTES]
of data stored

Variety
DIFFERENT FORMS OF DATA

As of 2011, the global size of data in healthcare was estimated to be
150 EXABYTES
[161 BILLION GIGABYTES]

By 2014, it's anticipated there will be
420 MILLION WEARABLE, WIRELESS HEALTH MONITORS

4 BILLION+ HOURS OF VIDEO
are watched on YouTube each month

30 BILLION PIECES OF CONTENT
are shared on Facebook every month

400 MILLION TWEETS
are sent per day by about 200 million monthly active users

Velocity
ANALYSIS OF STREAMING DATA

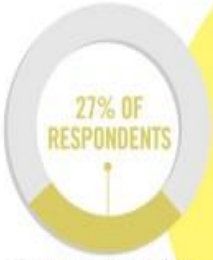
The New York Stock Exchange captures
1 TB OF TRADE INFORMATION
during each trading session

Modern cars have close to
100 SENSORS
that monitor items such as fuel level and tire pressure

By 2016, it is projected there will be
18.9 BILLION NETWORK CONNECTIONS
– almost 2.5 connections per person on earth

Veracity
UNCERTAINTY OF DATA

1 IN 3 BUSINESS LEADERS
don't trust the information they use to make decisions



in one survey were unsure of how much of their data was inaccurate

Poor data quality costs the US economy around
$3.1 TRILLION A YEAR

Sources: McKinsey Global Institute, Twitter, Cisco, Gartner, EMC, SAS, IBM, MEPTEC, QAS

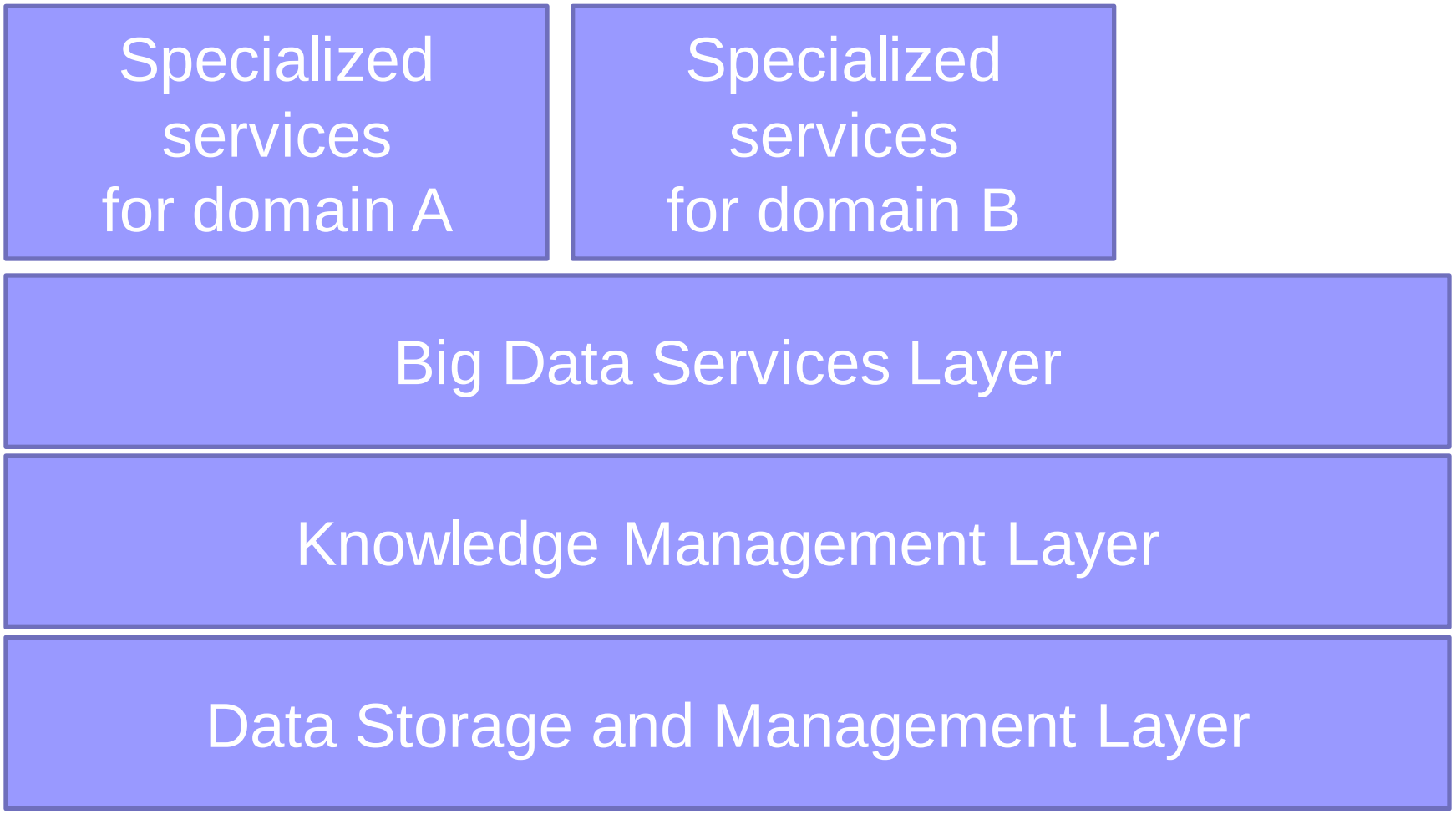
http://www.ibmbigdatahub.com/infographic/four-vs-big-data

IBM

Big Data – other Vs

- Variability
  - inconsistency of the data
- Veracity
  - quality of the data
- Value
  - useful analysis results
- …

BDA system architecture



BDA system architecture

- Large amounts of data, distributed environment
- Unstructured and semi-structured data
- Not necessarily a schema
- Heterogeneous
- Streams
- Varying quality

Data Storage and Management Layer

Data Storage and management – this course

- Data storage:
  - NoSQL databases
  - OLTP vs OLAP
  - Horizontal scalability
  - Consistency, availability, partition tolerance
- Data management
  - Hadoop
  - Data management systems

BDA system architecture

- Semantic technologies
- Integration
- Knowledge acquisition

Knowledge Management Layer

Knowledge management – this course

- Not a focus topic in this course
- For semantic and integration approaches see TDDD43

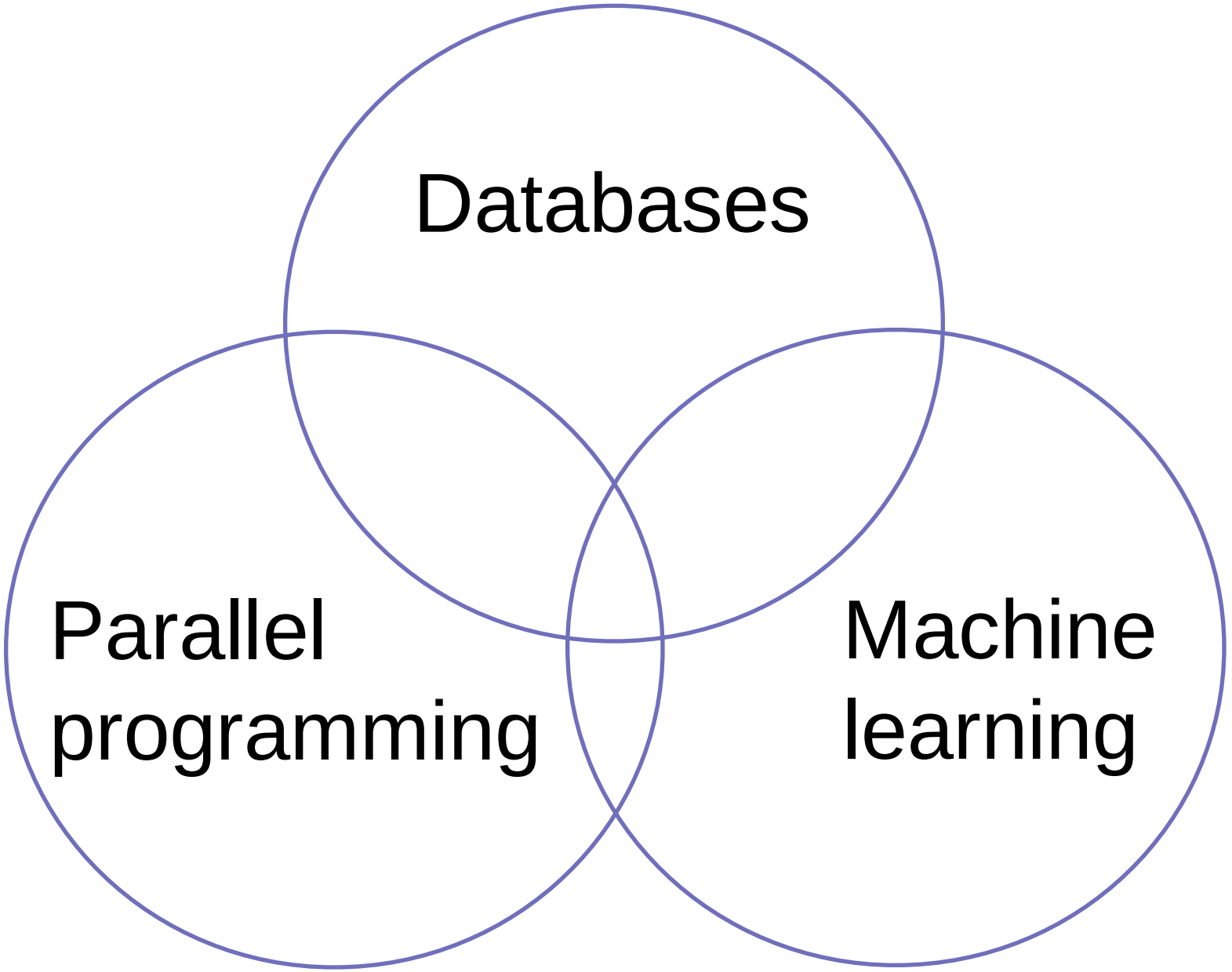
BDA system architecture

- Analytics services for Big Data

Big Data Services Layer

Big Data Services – this course

- Big data versions of analytics/data mining algorithms


Databases
Parallel programming
Machine learning

Course overview

- Databases for Big Data (lectures + lab)
- Parallel algorithms for processing Big Data (lectures + lab + exercise session)
- Machine Learning for Big Data (lectures + lab)

- Visit to National Supercomputer Centre – organization ongoing

Info

- Results reported in connection to exams
- Info about handing in labs on web; strong recommendation to hand in as soon as possible
- Sign up for labs via web (in pairs)

Info

- BDA labs require special access to NSC resources

  → fill out forms

(Resources only guaranteed during course.)

Examination

- Exam
- Labs

Changes w.r.t. last year

Returning teacher.

Recent changes:

- Extra exercise session
- Extra lecture for parallel programming (same content)

https://www.youtube.com/watch?v=LrNlZ7-SMPk