Reflections on Data Science, Machine Learning, AI

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Data Science in the News…

Data Science Word Cloud

What is Data Science?

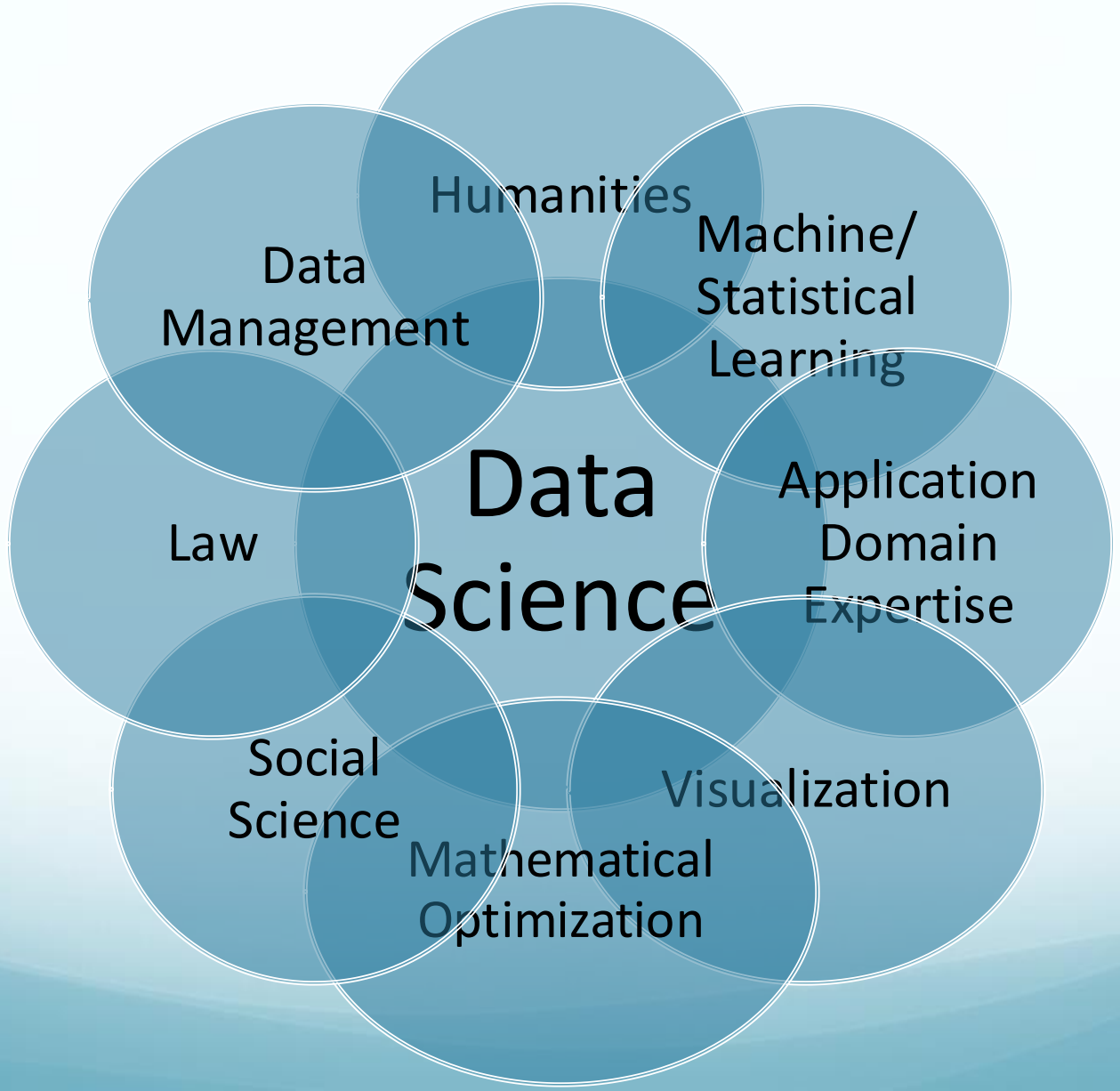
- Refers to methods, processes and tools that allow a user to extract useful information from complex data collections
- An interdisciplinary field:
  - Data mining, machine learning, statistical inference, predictive modeling, databases, visualization, high performance computing, data privacy, security, etc.
- Is critical for organizations and companies to make decisions and drive innovation

Data Science = Big Data??

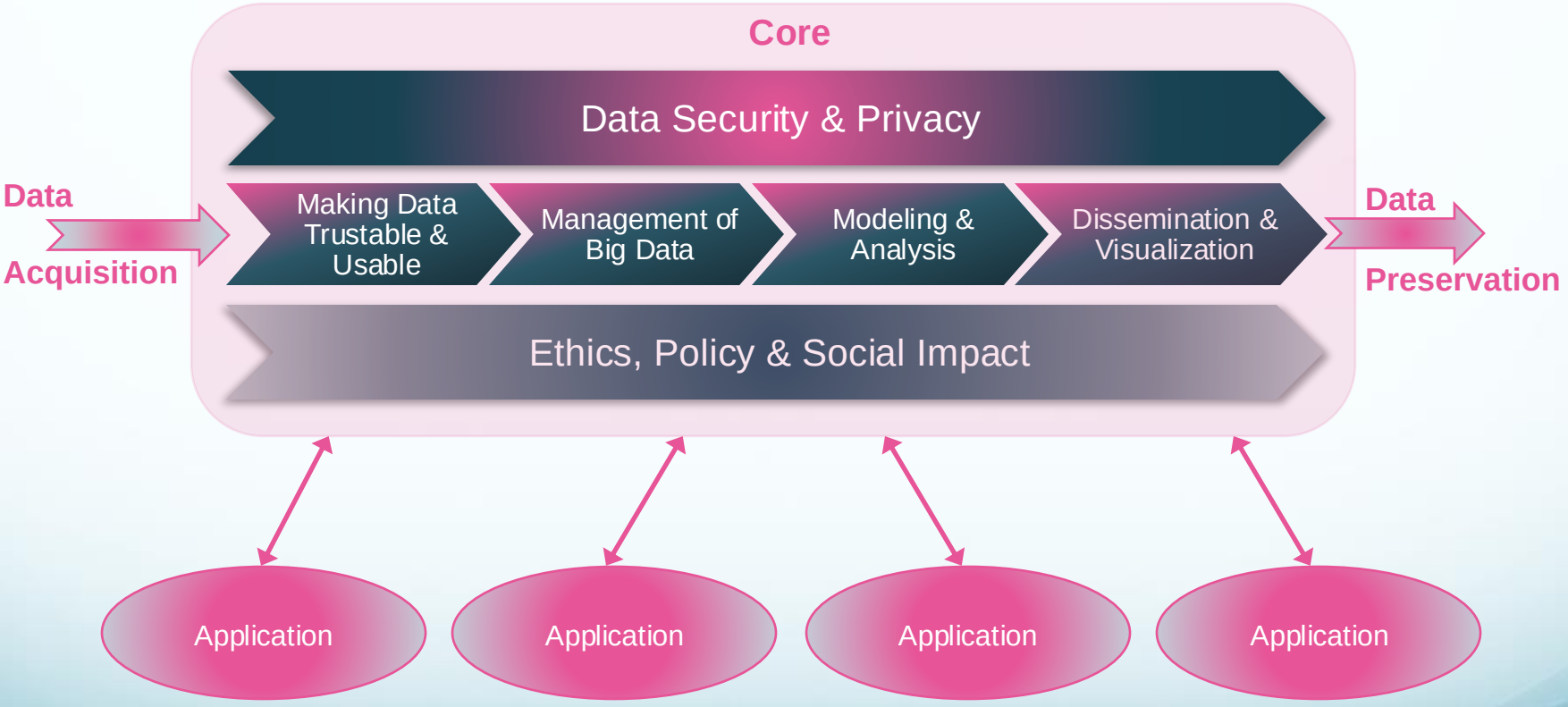
- Not the “same thing”
- If Big data = crude oil
  - Big data is about extracting “crude oil”, transporting it in “mega tankers”, siphoning it through “pipelines”, and storing it in “massive silos”
- Data science is about refining the “crude oil”, i.e., building on top of Big Data

Carlos Samohano
Founder, Data Science London

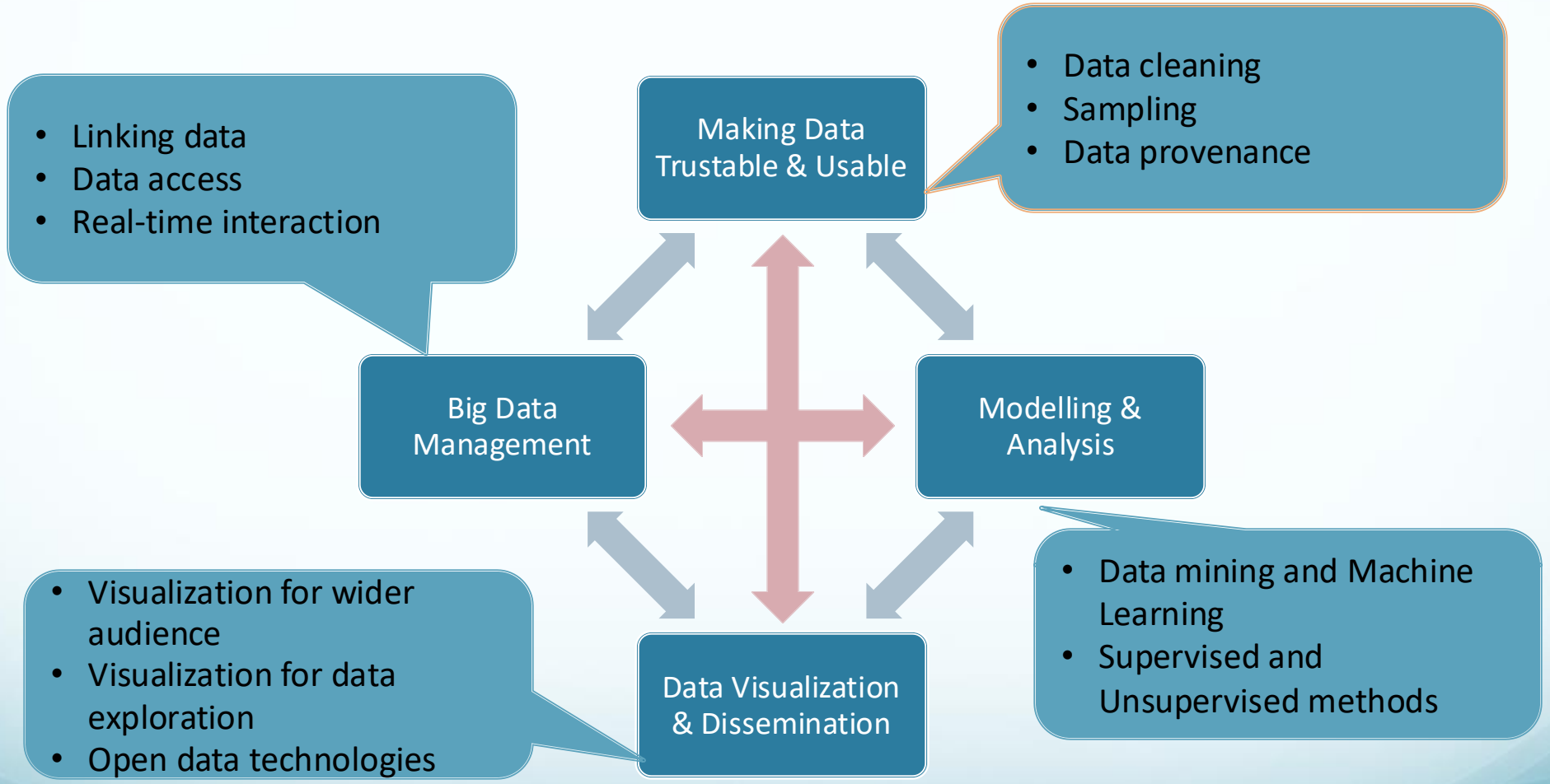
Data Science as a Unifier



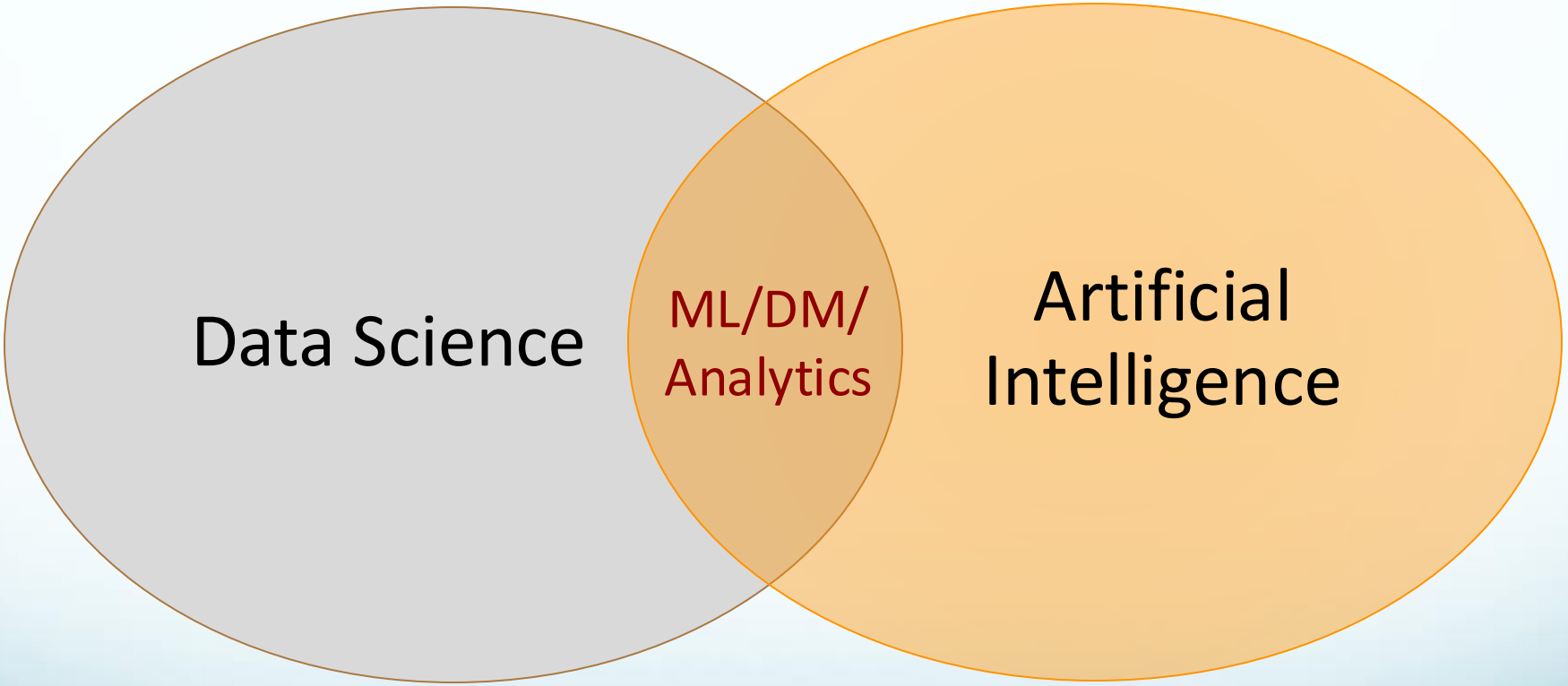
Holistic Approach to Data Science



Core Issues


Making Data Trustable & Usable
• Data cleaning
• Sampling
• Data provenance
• Linking data
• Data access
• Real-time interaction
Big Data Management
Modelling & Analysis
• Visualization for wider audience
• Visualization for data exploration
• Open data technologies
Data Visualization & Dissemination
• Data mining and Machine Learning
• Supervised and Unsupervised methods

Data Science vs Machine Learning vs AI



"Data science systems produce **insights**;
Machine learning systems generate **predictions;**
AI systems make **decisions** and take **actions"**

Data Science Meets Health Science:
Info Tech Meets Bio Tech

Advances in:

- CPU/storage capacity
- data capture
- searching and database mgmt
- Cloud, Hadoop
- algorithms
- statistics
- mathematics, etc.

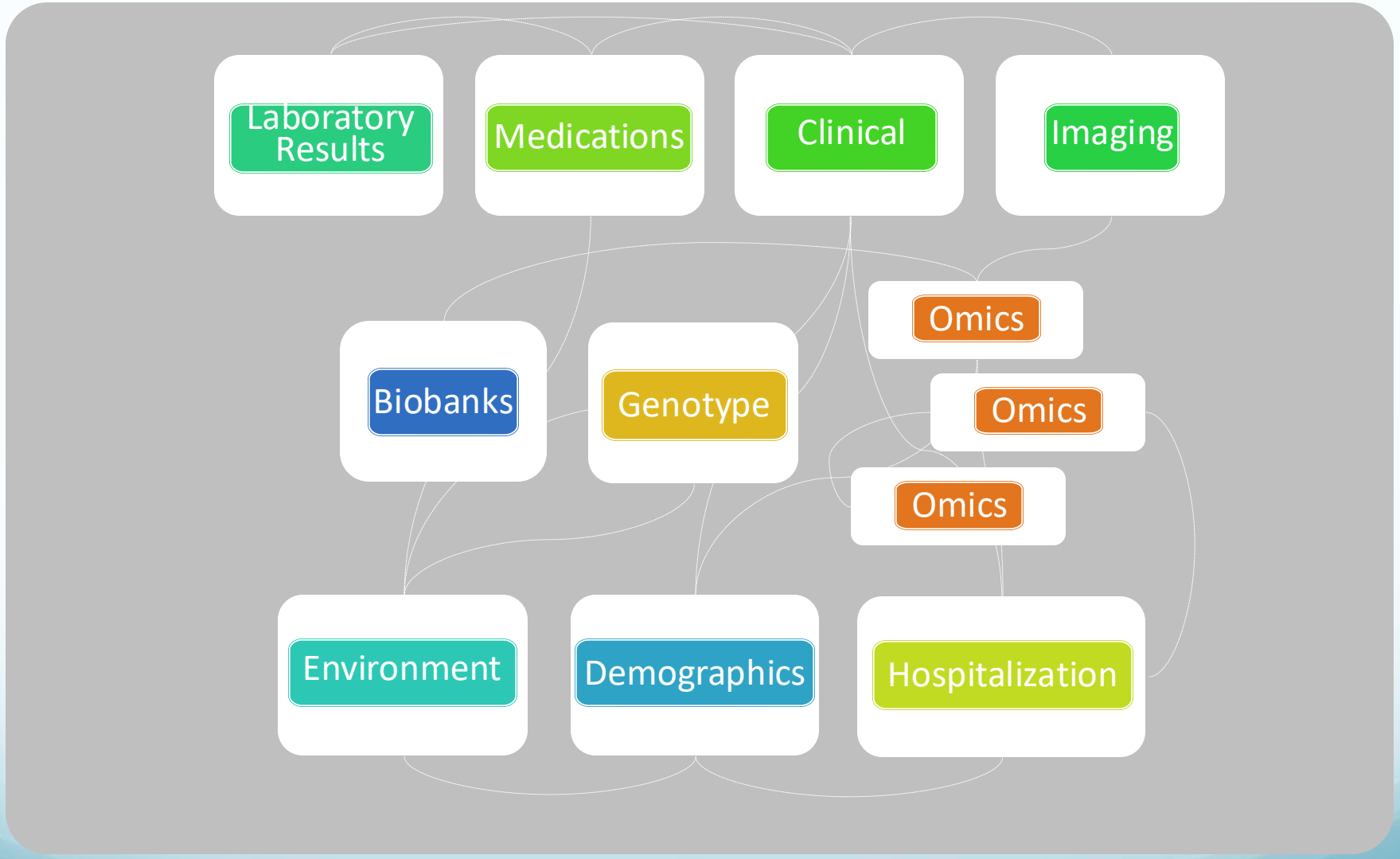
Very Exciting Times!

How the 4V's Challenge Health Care and Health Research?

#1 Volume:

- Rapid advances in biotech, e.g., sequencing of all flavours, mass spectrometry, point-of-care diagnostics
- Electronic Health Records: governments (e.g., MoH) making longitudinal data (e.g., months, years) on whole population available
- Data sharing across jurisdictions, collaborators also increase the dataset size
- Many new ways of collecting data, e.g., health apps

#2 Variety



Potential of modelling across these modalities is HUGE

#3 Velocity

- The speed that data are collected or generated, e.g., health monitoring apps
- E.g., Text data, e.g., whatsapp, clinical trials
  - Patients describing their own sentiments – a "window" into their psychological states, their cognitive states, etc.
  - *Longitudinal* text – capturing changes over time -can be the basis of a powerful predictive model
  - Building a joint model using *multi-omics and text* to monitor chronic disease management (e.g., even covid recovery) is not far away

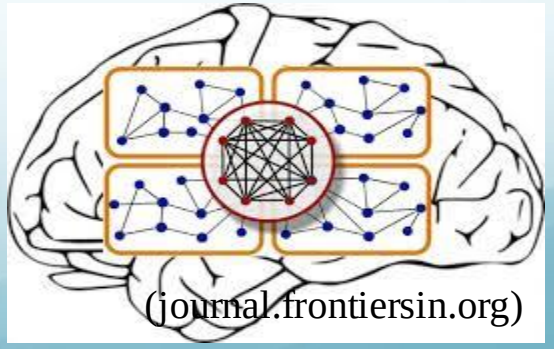
#4 Veracity

- The truthfulness/reliability/quality of data and data sources, e.g.,
  - public repositories vs MoH data
  - Missing values or errors in EHR
  - Self-declared survey data, sentiment data
  - Accuracies of devices

Neural Network Learning for Biomedical Research

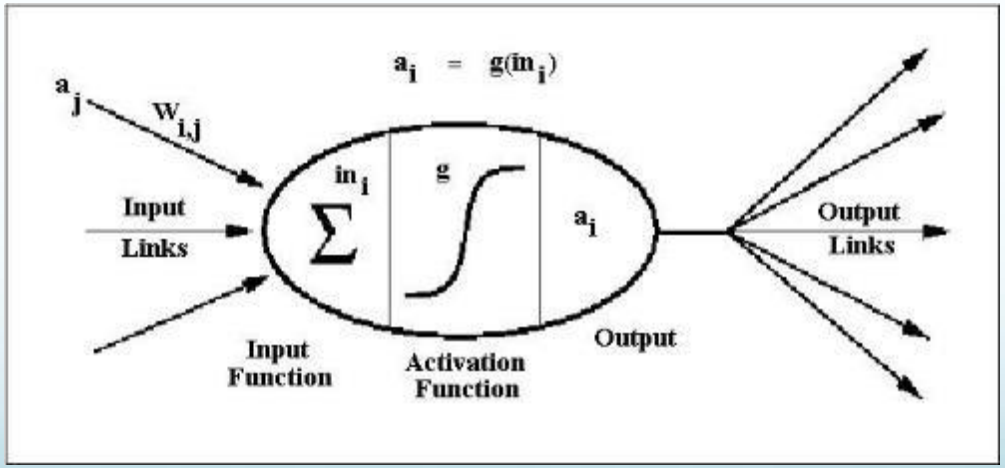
Neural Networks: Simulating Human Brains?

- To build a predictive model, why not do what a human brain can do?
- In particular, neuroscience reveals the existence of massively connected networks of neurons
- In 1943, McCulloch and Pitts proposed a simple mathematical model for neurons, now known as neural networks



Basic Structure of a Network Unit

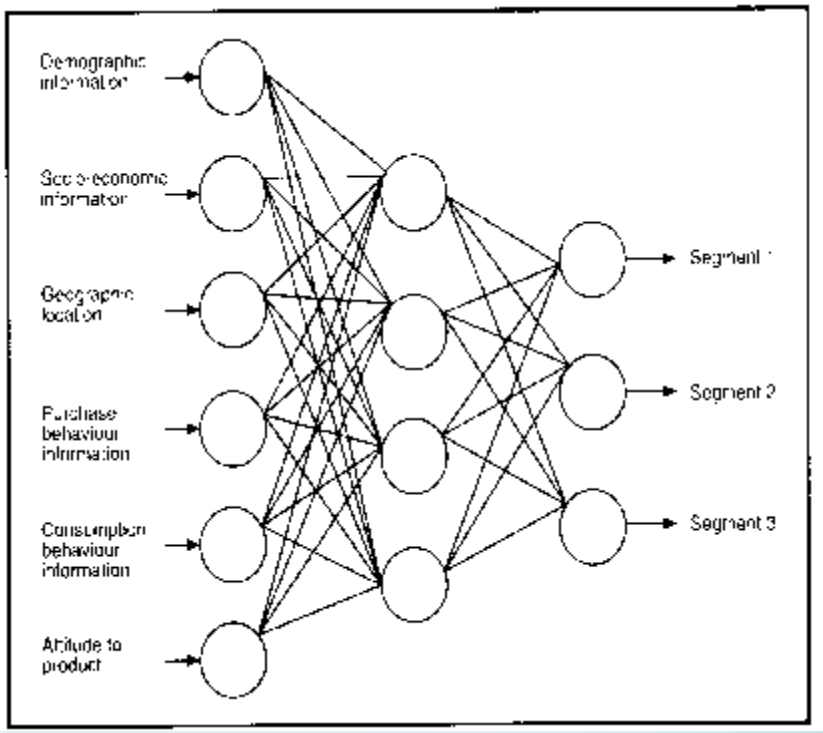
- A Neural network composed on nodes/units connected by links
- A link from unit i to unit j propagates an activation a_i to possibly trigger an activation a_j



(en.wikibooks.org)

Feed-forward and Recurrent Networks

- This network determines to which segment a customer belongs
- This is an example of a feed-forward network
  - No loops, forming an acyclic graph
- A recurrent network has loops and may take time to reach a steady state



Hidden Layers and Deep Networks

- Our example has a hidden layer of units
  - allow us to model quantities not directly measured
  - *features* are being “learned”
- Common to have units arranged in layers, i.e., inputs from the preceding layer and outputs to the next layer
- ”*Deep*" in "deep learning" refers to the number of layers through which the data are transformed
  - called the *credit assignment path* (CAP) depth
  - for a feed-forward network, the depth is 1 + the number of hidden layers
  - ”deep” means CAP > 2
  - extra layers are intended to ”extract/engineer” better features

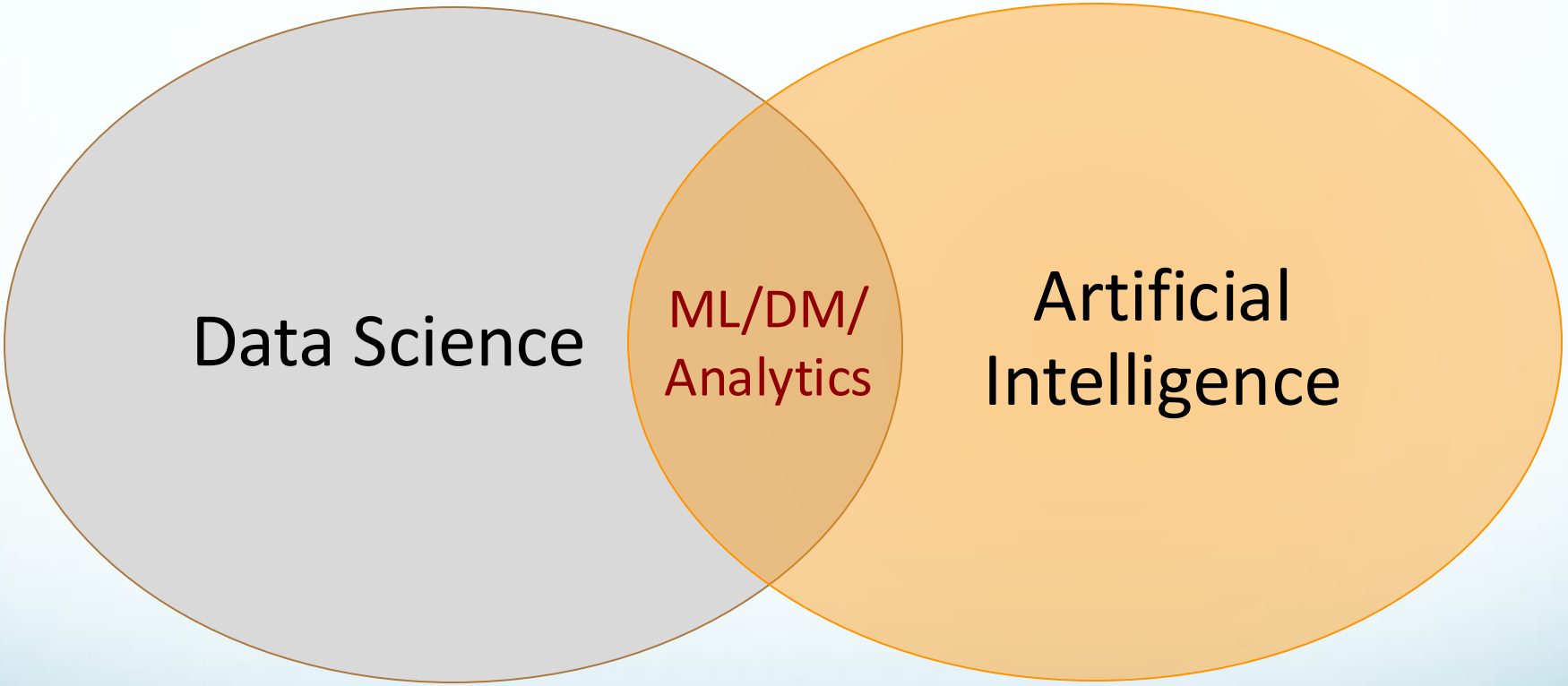
Some Deep Learning Applications

- **Image recognition**: computational radiology
  - E.g., Imperial College to provide image-based assessments of traumatic brain injuries
- **Drug design and toxicology**
  - E.g., AtomNet for virtual drug screening and target discovery
- **Modeling of EHR data**
  - E.g., Children's Hospital Los Angeles to improve pediatric intensive care diagnosis
- **Bioinformatics**
  - E.g., regulatory genomics (Montgomery et al., Nature 2010)

But Buyers Beware…

- Neural networks have many parameters to “estimate”
  - Deeper networks have even more parameters to fit
  - Paramount to have a lot of high quality (training) data
  - Much easier to overfit than many other methods
- The structure of a network is not known a priori
  - Yet results typically sensitive to the structure
- Interpretation is hard
  - A key strength of a deep network is feature engineering
  - But the features may not have natural ”real world” meanings

Summary: Machine Learning, AI Opportunities and Boundaries



Take home: Remember that high quality data is the pre-requisite of ML and AI methods

Thank You!

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Summary

- The new “crude oil”, Big Data present great opportunities
- Data Science “refines crude oil” to bring great value:
  - More jobs: lots of work to do to exploit these data assets
  - New insights leading to smarter decisions/policies
  - When applied to health, better care and more advanced research
  - This program covers all these aspects and more