

# 1.2 Definitions and Historical Perspectives of Artificial Intelligence (AI)

**10x10 – Introduction to Biomedical Informatics & Artificial Intelligence**  
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# Definitions and historical perspectives

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## Definitions

- Artificial intelligence (AI)
- Machine learning
- Data science
  - Data analytics
- Big Data
- Data mining
  - Text mining
- Other terms

## Historical perspectives

- First (20<sup>th</sup> century) and second (21<sup>st</sup> century) eras of AI

# Artificial intelligence (AI)

AI – information systems and algorithms capable of performing tasks associated with human intelligence (Stanford, 2024)

- Origin of term attributed to summer workshop held at Dartmouth College in 1956 (McCarthy, 2007)

Three “epochs” of AI (Howell, 2024), leading to current classification of

- Predictive AI
- Generative AI

| Approximate beginning year          | 1950s                                                                                                                                 | 2011                                                                                                                                                                                                                                                          | 2018-2022                                                                                                                                                                                     |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                     | AI 1.0 Symbolic AI and probabilistic models                                                                                           | AI 2.0 Deep learning                                                                                                                                                                                                                                          | AI 3.0 Foundation models                                                                                                                                                                      |
| Core functionality and key features | Follows directly encoded rules (if-then rules or decision trees)                                                                      | Predicts and/or classifies information<br>Task-specific (1 task at a time); requires new data and retraining to perform new tasks                                                                                                                             | Generates new content (text, sound, images)<br>Performs different types of tasks without new data or retraining; prompt creates new model behaviors                                           |
| Training method                     | Rules based on expert knowledge are hand-encoded in traditional programming                                                           | Learning patterns based on examples labeled as ground truth                                                                                                                                                                                                   | Self-supervised learning from large datasets to predict the next word or sentence in a sequence                                                                                               |
| Performance capabilities            | Follows decision path encoded in its rules.<br><i>Eg, ask a series of questions to determine whether a picture is a cat or a dog.</i> | Classifies information based on training:<br><i>"Is this a cat or a dog?"</i><br><i>"How many dogs will be in the park at noon?"</i>                                                                                                                          | Interprets and responds to complex questions:<br><i>"Explain the difference between a cat and a dog."</i>                                                                                     |
| Examples of performance             | IBM's Deep Blue beat the world champion in chess<br><b>Health care:</b> Rule-based clinical decision support tools                    | Photo searching without manual tagging, voice recognition, language translation<br><b>Health care:</b> diabetic retinopathy detection, breast cancer and lung cancer screening, skin condition classification, predictions based on electronic health records | Writing assistants in word processors, software coding assistants, chatbots<br><b>Health care:</b> Med-PaLM and Med-PaLM-2, medically tuned large language models, PubMedGPT, BioGPT          |
| Examples of challenges and risks    | Human logic errors and bias in encoded rules lead to limited capability with real-world situations                                    | Out-of-distribution problems (real-time data differs from training data)<br>Catastrophic forgetting (not remembering early parts of a long sequence of text)<br>Bias related to underlying training data                                                      | Hallucinations (plausible but incorrect responses based solely on predictions)<br>Grounding and attribution<br>Bias related to underlying training data and semantics of language in datasets |

# Machine learning (ML)

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Term originally attributed to Arthur Samuel in 1959: “Field of study that gives computers the ability to learn without being explicitly programmed” (McCarthy, 1990)

Derived from

- Mathematics/statistics – learning relationships from data
- Computer science – emphasis on efficient algorithms, especially those involving large amounts of data

Much recent success from deep learning (DL) (Shah, 2022)

- ML associated with use of neural networks that have deep layers requiring substantial processing (Sevilla, 2022)
- Initial success in predictive AI, in areas such as image classification, including in medicine (Esteva, 2021)
- Also has facilitated large language models (LLMs) that drive generative AI (Teo, 2025)

DL successes led to Nobel Prizes in 2024 in

- [Chemistry](#) – solving prediction of protein-folding from amino acids (Jumper, 2021; Abramson, 2024)
- [Physics](#) – image classification using DL, leading to biomedical applications (Hinton, 2006)

# Predictive AI in biomedicine

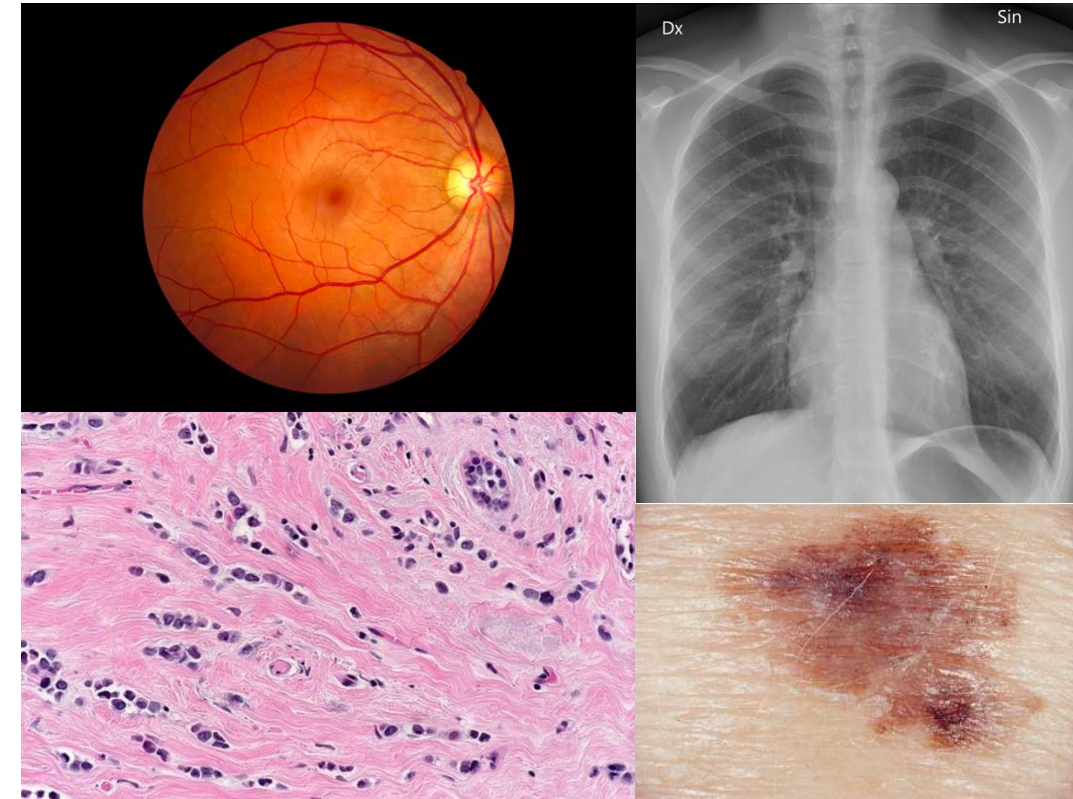
Driven by advances in ML, increasing availability of data, and more powerful computers and networks (Topol, 2019; Rajpurkar, 2022)

Most success in image interpretation (Rajpurkar, 2023); examples include

- Radiology – chest x-rays for diagnosis of pneumonia and tuberculosis
- Ophthalmology – retinal images for diagnosis of diabetic retinopathy
- Dermatology – skin lesions for diagnosis of cancer
- Pathology – breast cancer slides to predict metastasis

Also beyond imaging

- Adverse events in hospitalizations from EHR data (Rajkomar, 2018)
- Semantic reconstruction of continuous language from fMRI brain recordings (Tang, 2023)



# And now, generative AI

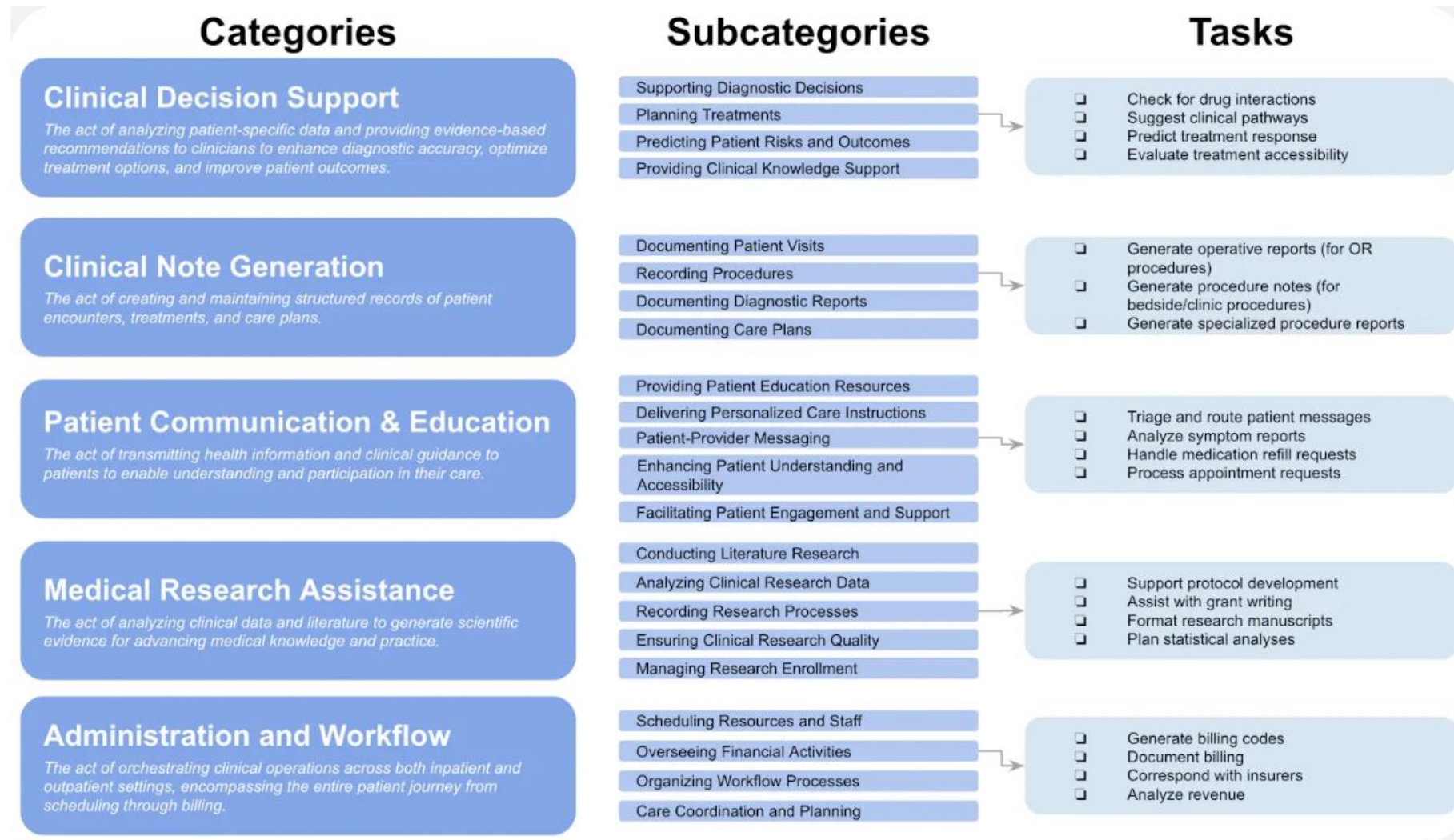
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Introduction of ChatGPT on November 30, 2022 brought this new type of AI into focus

Based on large language models (LLMs) that use deep neural networks, large amounts of training data, and tuning for specific tasks (Omiye, 2024; Teo, 2025)

- Trained on massive amounts of text and other content, e.g., large Web crawls, books, Wikipedia, and more (Roberts, 2022)
- Use transformer models that predict words in sequence from billions/trillions of words and add measures of importance to “attention” words (Raschka, 2024)
- Fine-tuned with reinforcement learning from human feedback (RLHF) (Lambert, 2022)
- Activated by (and importance of) prompting (Liu, 2023; Meskó, 2023)

# Many uses and research results for generative AI in healthcare (Shah, 2025; Bedi, 2026)



# Data science

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“The science of learning from data; it studies the methods involved in the analysis and processing of data and proposes technology to improve methods in an evidence-based manner” (Donoho, 2017)

“Data science encompasses a set of principles, problem definitions, algorithms, and processes for extracting nonobvious and useful patterns from large data sets” (Kelleher, 2018)

Applications in biomedicine (Hoyt, 2019; Topol, 2019; Patrishkoff, 2023)

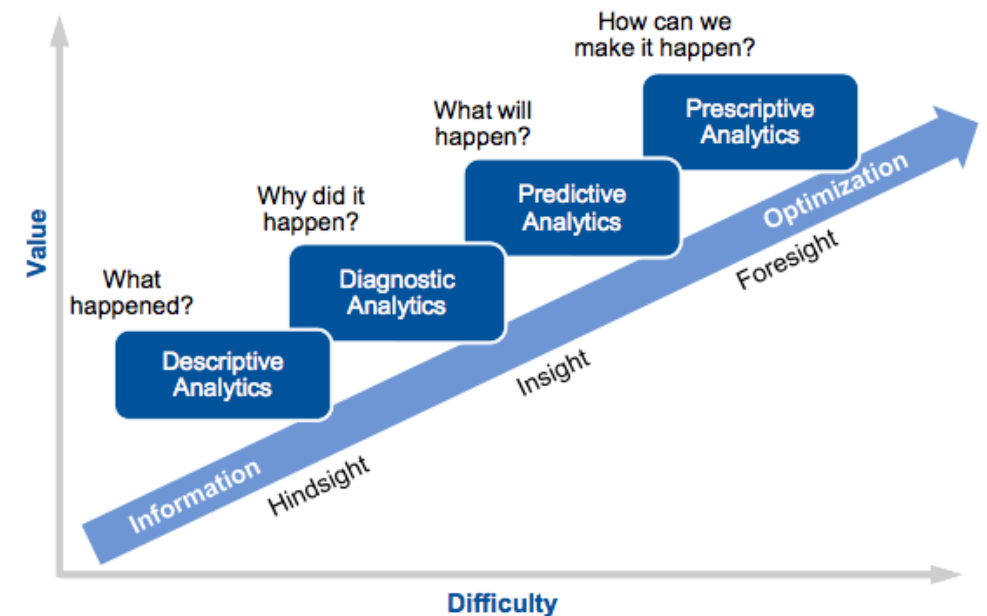
Technical but non-mathematical overview (Spector, 2022)

# Data analytics

“The extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decisions and actions” (Davenport, 2017)

“The systematic use of data and related business insights developed through applied analytical disciplines (e.g. statistical, contextual, quantitative, predictive, cognitive, other [including emerging] models) to drive fact-based decision-making for planning, management, measurement and learning” (IBM, 2012)

Levels of data analytics (Schaap, 2020)



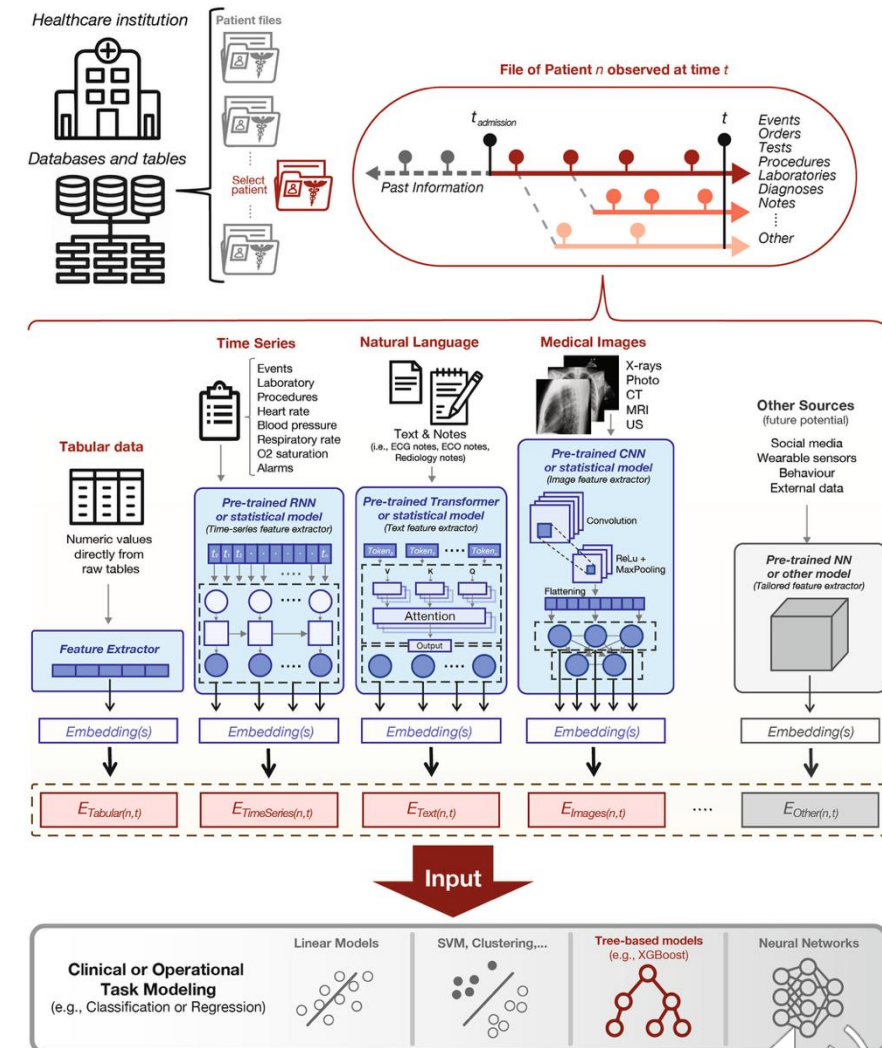
# Big Data

Various 4 Vs, most recent from NIST (Chang, 2019)

- Volume
- Velocity
- Variety
- Variability

Multimodal data (Acosta, 2022; Soenksen, 2022; Topol, 2023)

- Data from many modalities, from cells and molecules; tissues and organs; and organisms, populations, and the global environment



# Data mining

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Processing and modeling of data to discover previously unknown patterns or relationships (Bellazzi, 2008; Zaki, 2020)

Text mining – applying data mining to unstructured textual data (Cohen, 2005; Aggarwal, 2012)

Terms have faded from vernacular but methods still used

# Some other terms

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Data provenance – origin and trustworthiness of data (Doan, 2012)

Business intelligence – use of data to obtain timely, valuable insights into business and clinical data (Brijs, 2012)

Precision medicine (IOM, 2011; Collins, 2015; Denny, 2019); formerly personalized (Hamburg, 2010) or computational medicine (Winslow, 2012)

“Re-use” or “secondary use” of clinical data, especially from the electronic health record (EHR) (Safran, 2007; Meystre, 2017) and other sources (Näher, 2023)

## Other terms (cont.)

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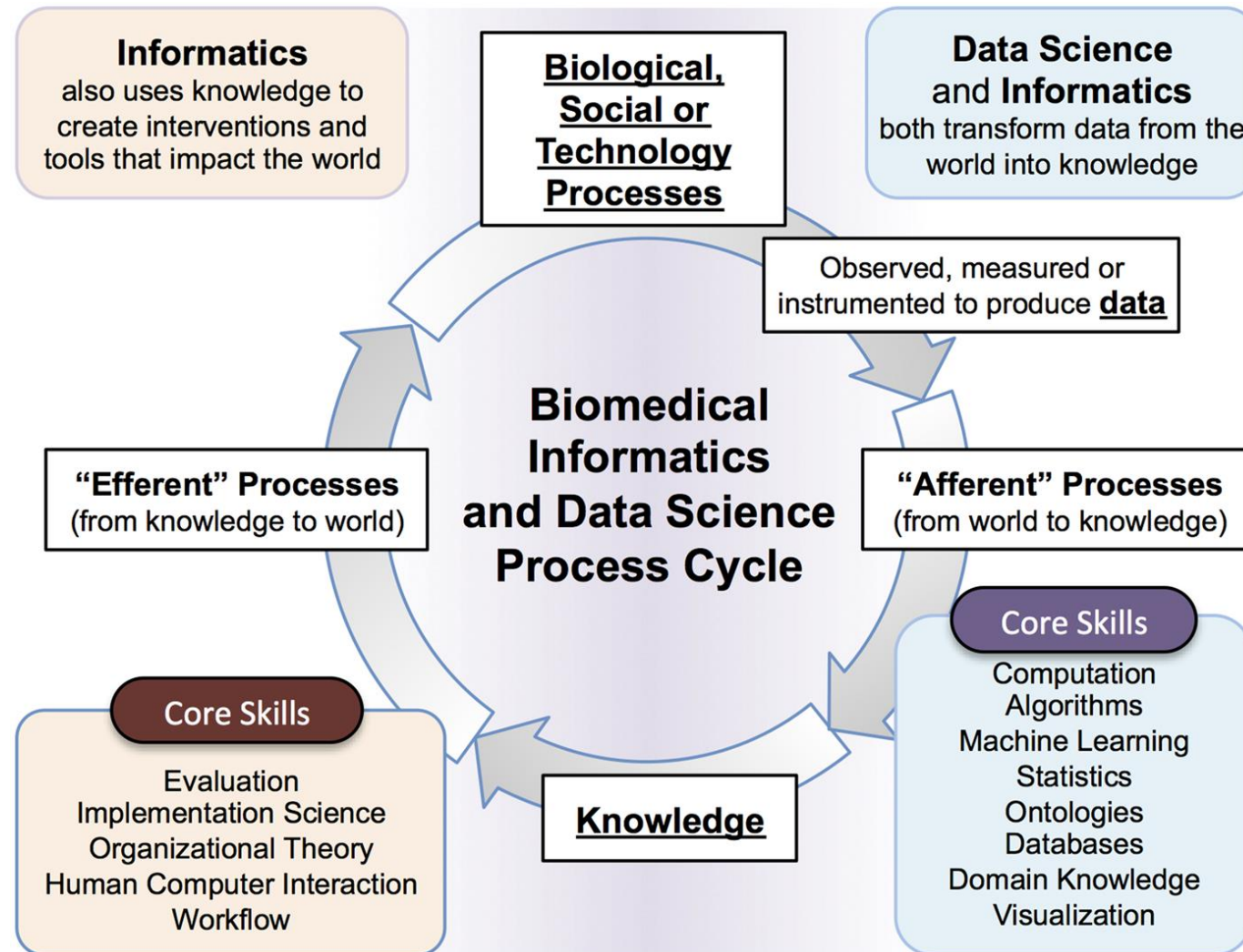
Metadata – data about data (Riley, 2017)

Model – representation of data, structure, and relationships for ML (and other tasks) (Shin, 2020)

Data visualization – applying visual methods to “tell the story” about the data (Wilke, 2019)

Data wrangling – processing data into format suitable for analytics, learning, visualization, etc.

# Where does informatics fit into data science/AI/ML (Payne, 2018)?

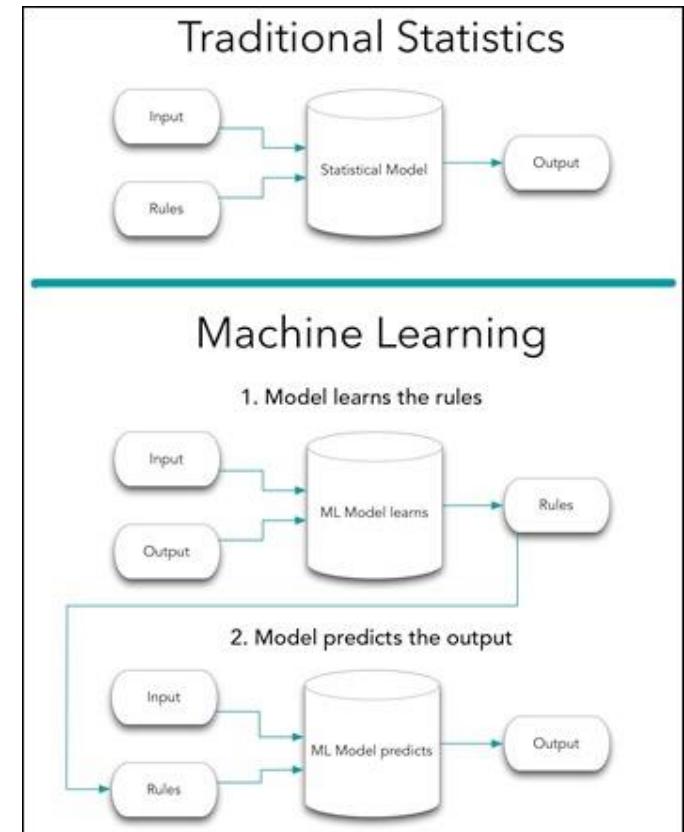


# How does data science/ML differ from statistics?

Statistics draws population inferences from samples; ML finds generalizable predictive patterns (Bzdok, 2018)

- Diagrammed by Scarlat (2019)
- A false dichotomy? (Finlayson, 2023)

Data scientist is a “person who is better at statistics than any software engineer and better at software engineering than any statistician” (Donoho, 2017)



# Historical developments of AI in biomedicine

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Early focus on “expert systems” that performed diagnosis

Functions of systems tightly linked to methods for knowledge representation

Four general approaches

- Clinical algorithms (flowcharts)
- Bayesian statistics (Warner, 1961)
- Production rules (if-then rules) (MYCIN, Shortliffe, 1975)
- Scoring and heuristics (profiles of diseases and findings) (INTERNIST-1/QMR, Miller, 1982; [DxPlain](#), Barnett, 1987)

# End of first era of (20<sup>th</sup> century) AI

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By the late 1980s and early 1990s, it was apparent that

- Diagnostic process too complex for computer programs
- Systems took long time to use and did not provide information clinicians truly needed
- Manual construction of algorithms, rules, and knowledge bases not efficient or scalable (Haigh, 2024)
- “Greek Oracle” model inappropriate to medical usefulness (Miller, 1990)

Rule-based approaches evolved into clinical decision support in the 1990s with recognition of value within EHR

# Into second era of (21<sup>st</sup> century) AI

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From “AI winter” to resurgence of predictive AI due to advances in

- Machine learning, especially deep learning applied to image classification
- Growth in quantity of data, including electronic health records (EHRs), omics, social media, mobile devices, etc.
- Improvements in computers and networks

Further advances in generative AI and large language models (LLMs), starting with ChatGPT in late 2022 (Angus, 2025, Teo, 2025)

And perhaps a role for 20<sup>th</sup> century systems? – DxPlain outperforming LLMs at differential diagnosis on new clinical cases (Feldman, 2025)