Medicine to Math: Statistics, Machine Learning, and AI

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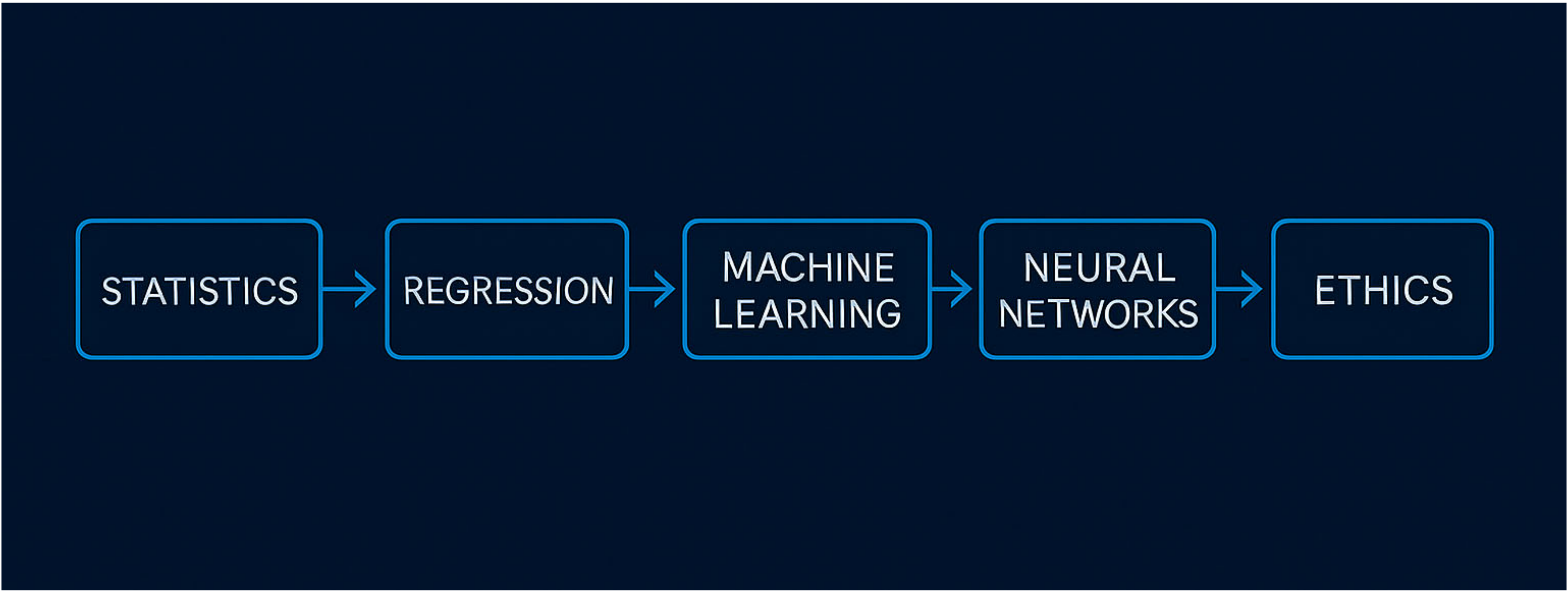
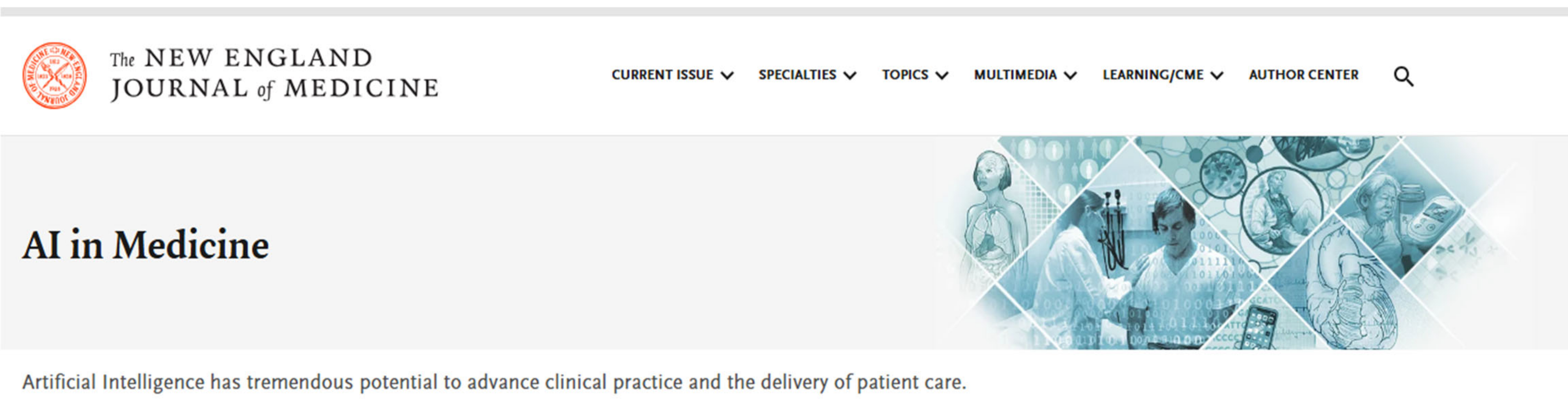

STATISTICS
REGRESSION
MACHINE LEARNING
NEURAL NETWORKS
ETHICS

Agenda

Why This Talk?

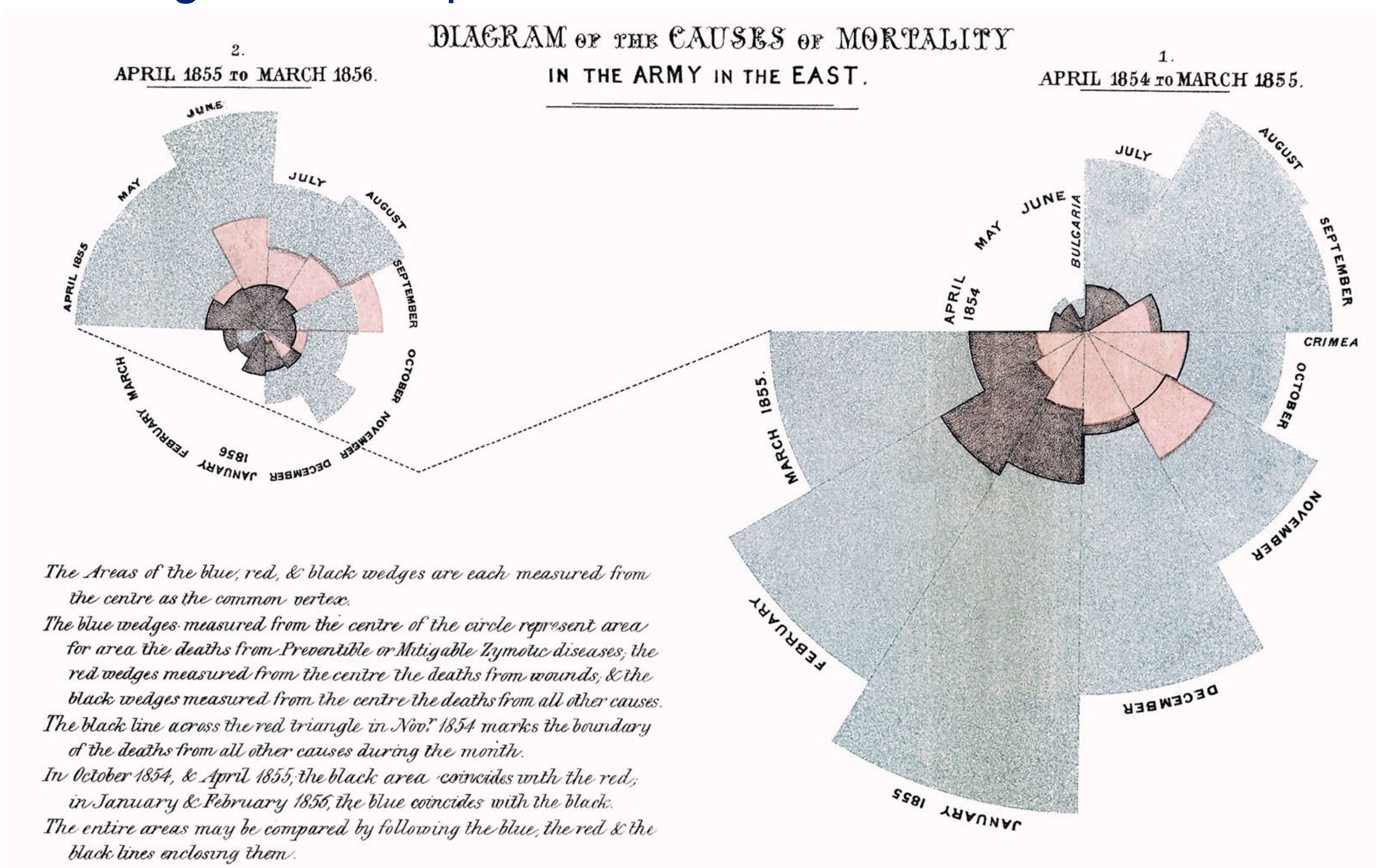
- Medicine increasingly relies on mathematical models
- From bedside decisions to AI-driven care
- Goal: Understand the journey from statistics to AI

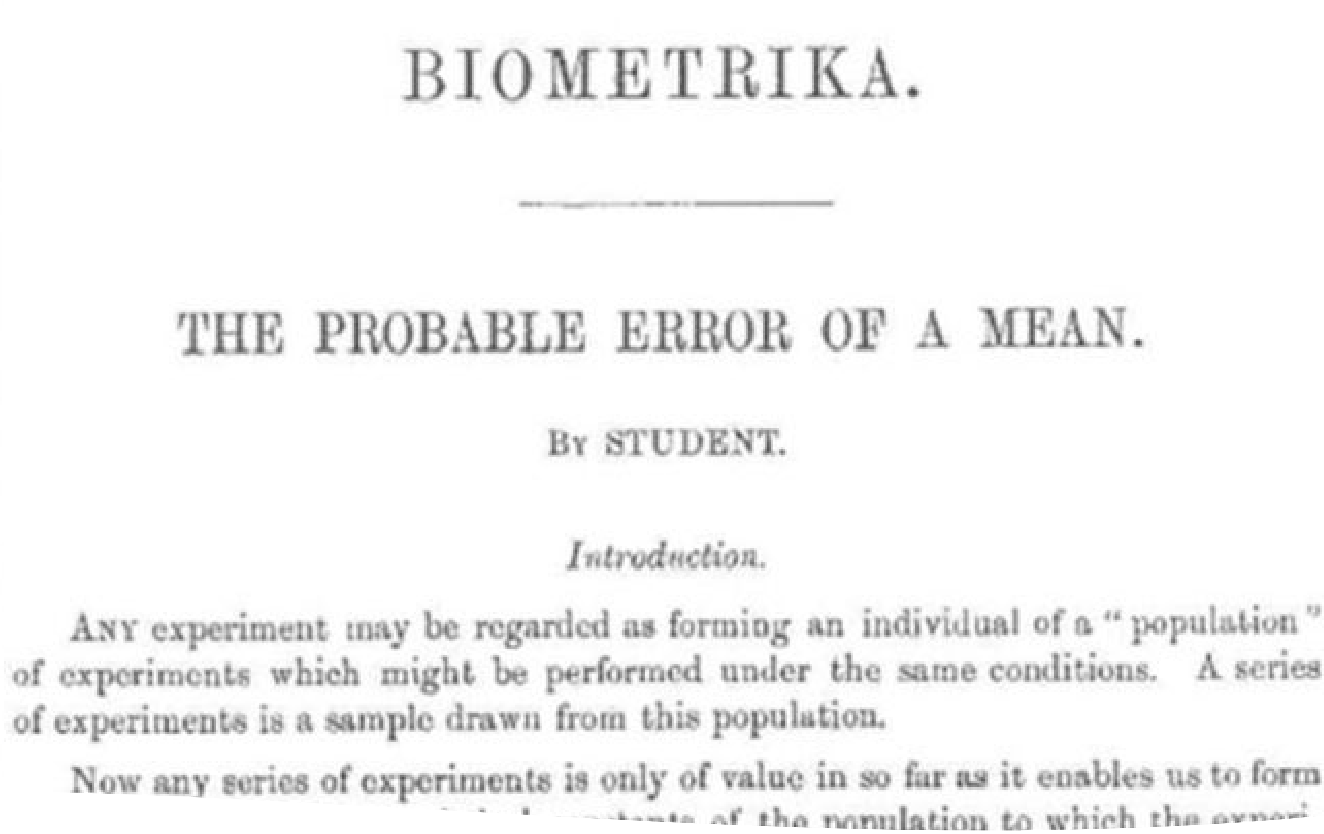


Statistics

Florence Nightingale: Data

- Florence Nightingale: data visualization & mortality stats
- Antiseptic techniques validated statistically
- Math changed clinical practice





BIOMETRIKA.

THE PROBABLE ERROR OF A MEAN.

By STUDENT.

Introduction.

Any experiment may be regarded as forming an individual of a "population" of experiments which might be performed under the same conditions. A series of experiments is a sample drawn from this population.

Now any series of experiments is only of value in so far as it enables us to form

William Gosset: A Beer Story

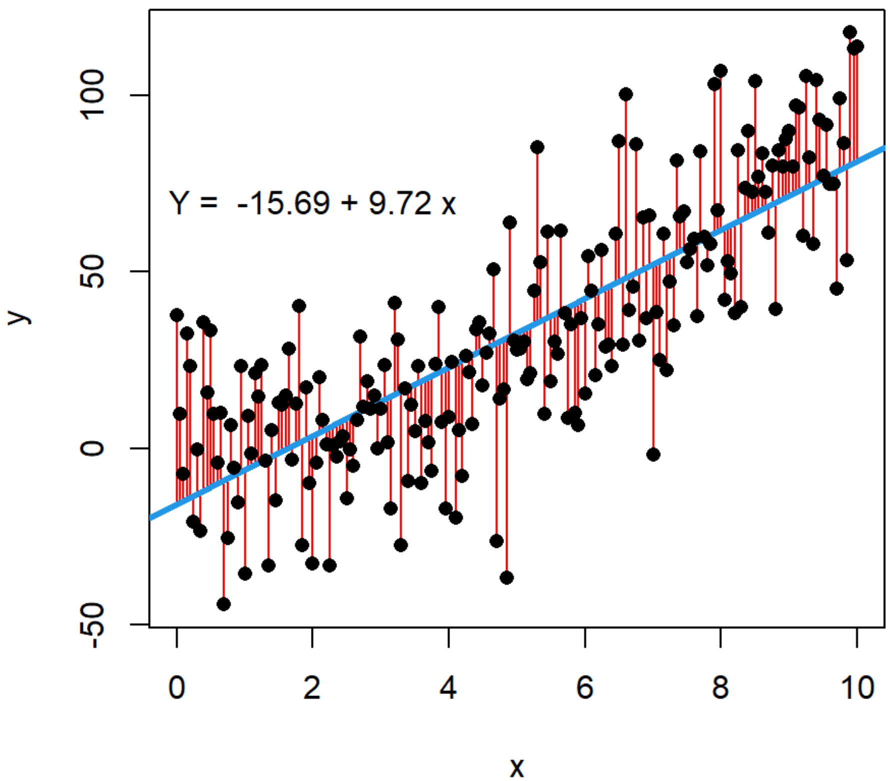
- Developed by William Sealy Gosset at Guinness Brewery
- Used for quality control in beer production
- Compare two small samples to determine significance

From Evidence to Prediction

- Descriptive Statistics
  - T-test used in medicine to compare treatment vs control
  - Introduced concept of statistical significance
  - P-value
- Evidence-Based Medicine (EBM):
  - Treatment A vs. Treatment B
  - Is there a real difference? (p-value, statistical significance)
- But what’s next?
  - Beyond describing differences → predicting outcomes
  - Not just “Which is better?” but “How do variables interact?”
- Shift in focus:
  - From comparing two fields → mapping the landscape
  - Understanding relationships among parameters to forecast what matters most

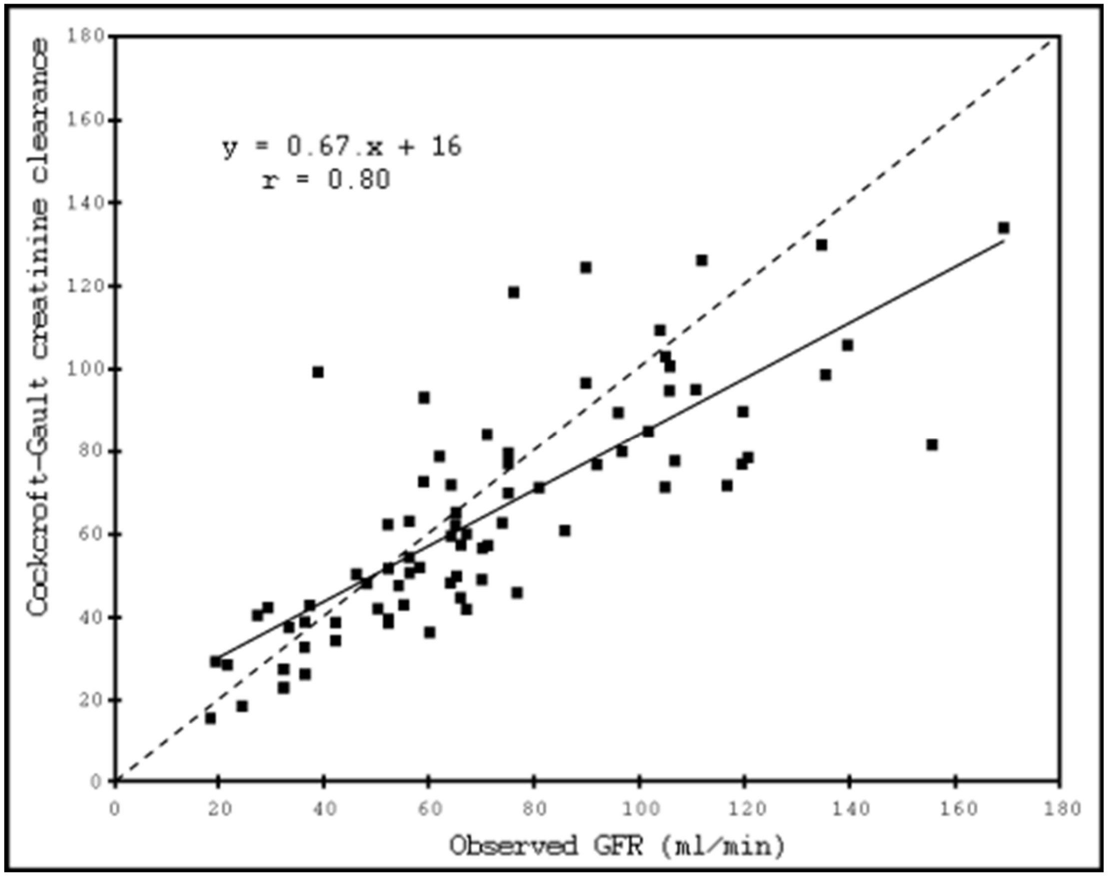
The Rise of Predictive Statistics

- Linear regression: fitting a line through data points
- Predictive formula: y = mx + b

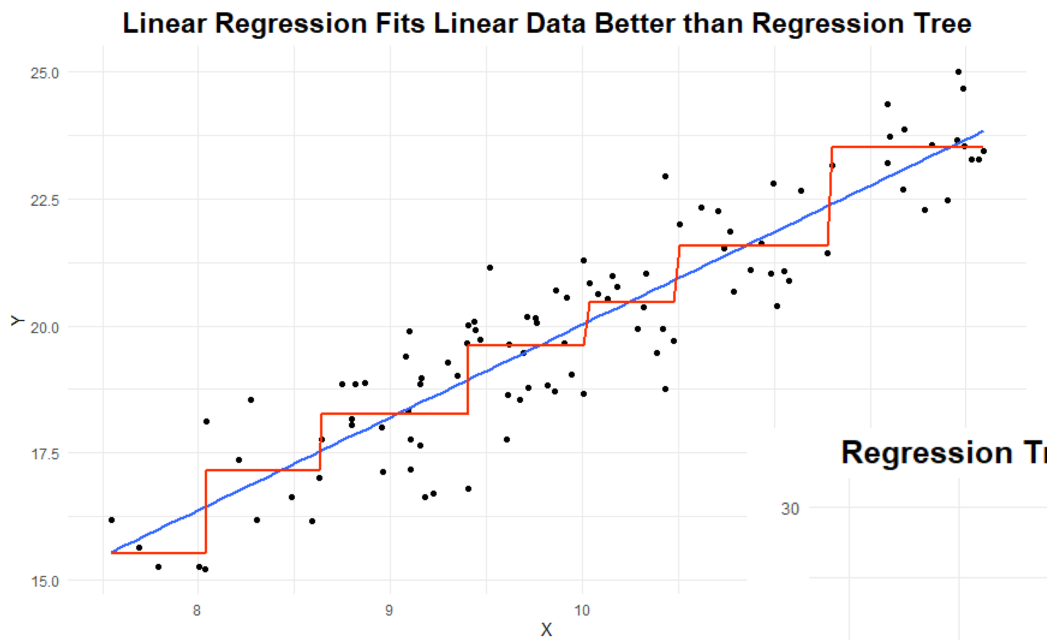


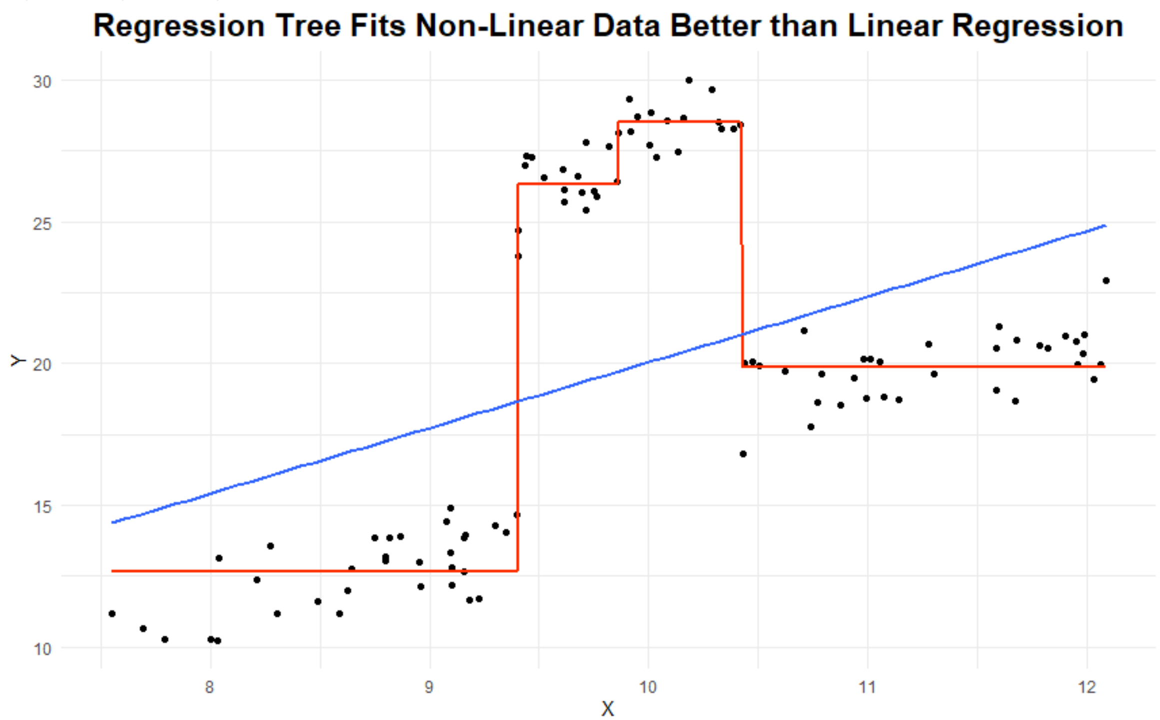
Medical Example

- Creatinine clearance (Cockcroft-Gault equation)
- Predicting GFR from age, weight, serum creatinine

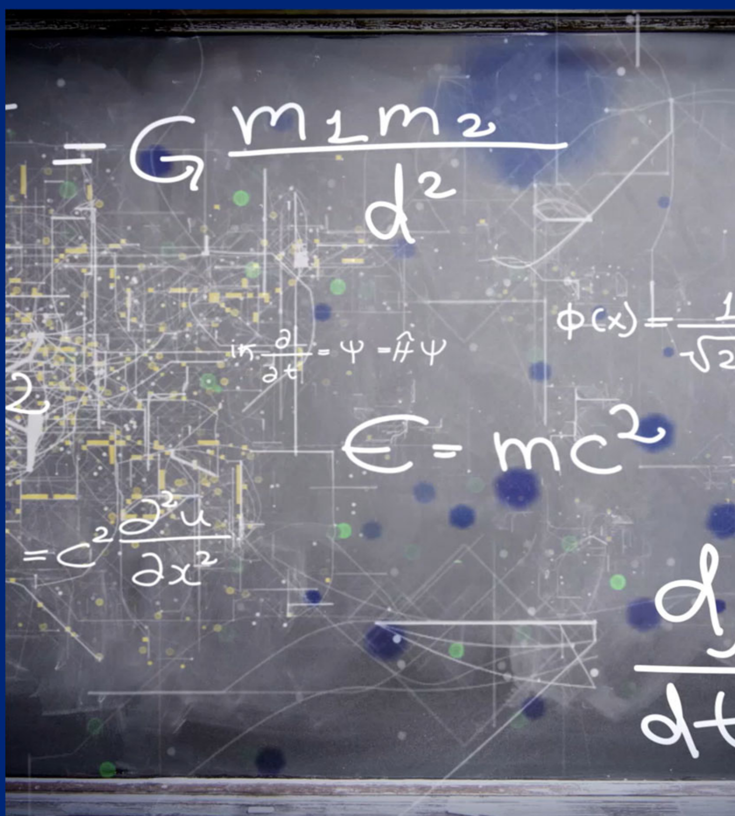


Real life data may not be linear





Machine Learning

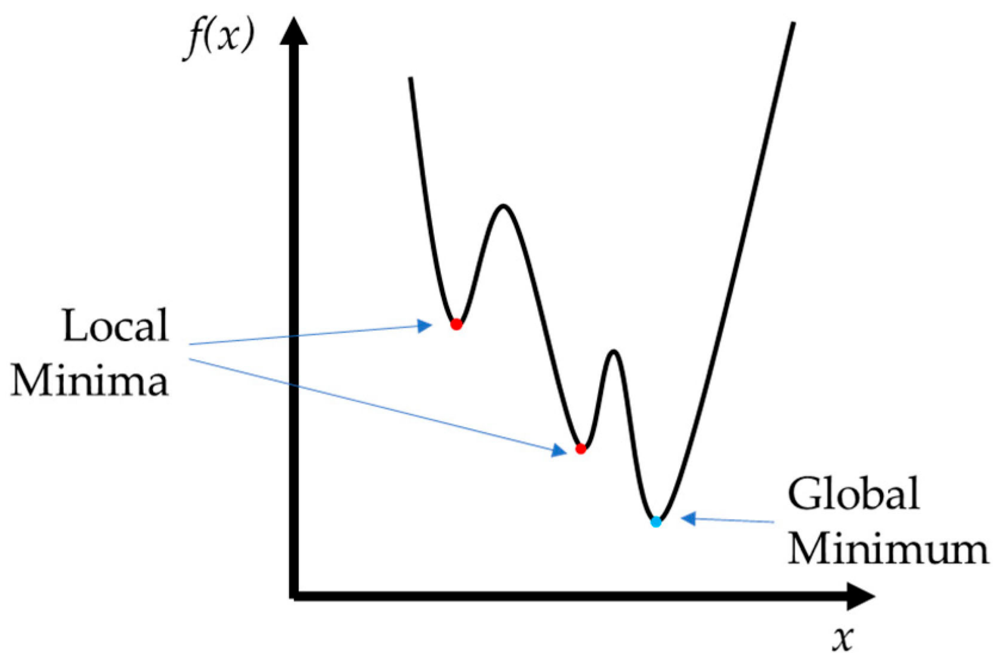


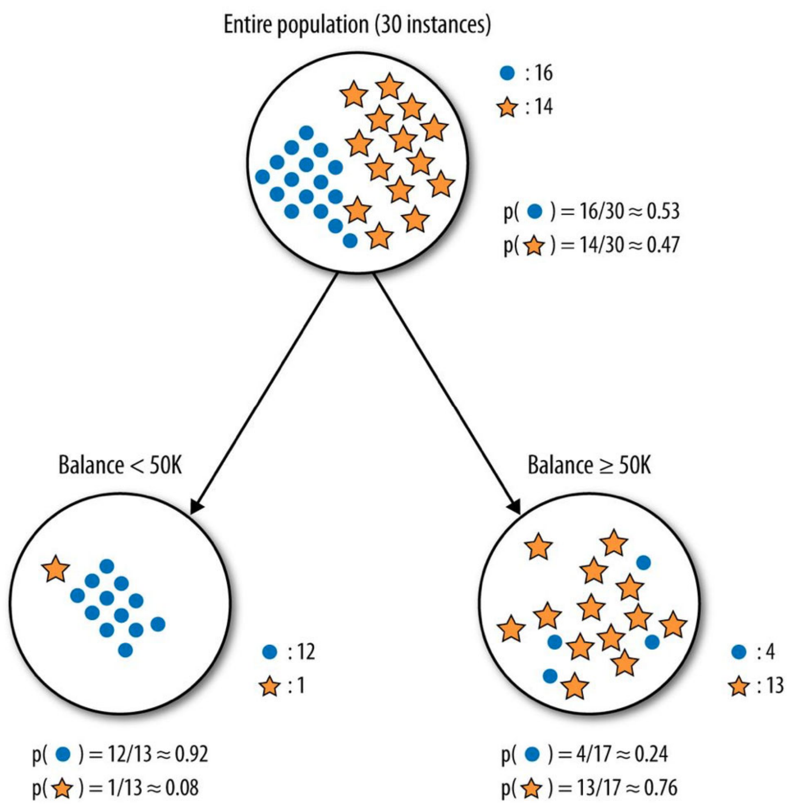
From Regression to Machine Learning

- **Regression:**
  - Fits a single line or curve to predict outcomes
  - Assumes a known functional form (e.g., linear)
- **But real-world data is complex:**
  - Non-linear relationships
  - Multiple interacting variables
- **Enter Machine Learning:**
  - Automates prediction without predefined formulas
  - Uses **branching decisions** (trees) and **iterative optimization**
  - Goal: **Minimize error** across many possible splits and models
- **Think of it as:**
  - Regression on steroids → adaptive, multi-dimensional, data-driven

Decision Trees

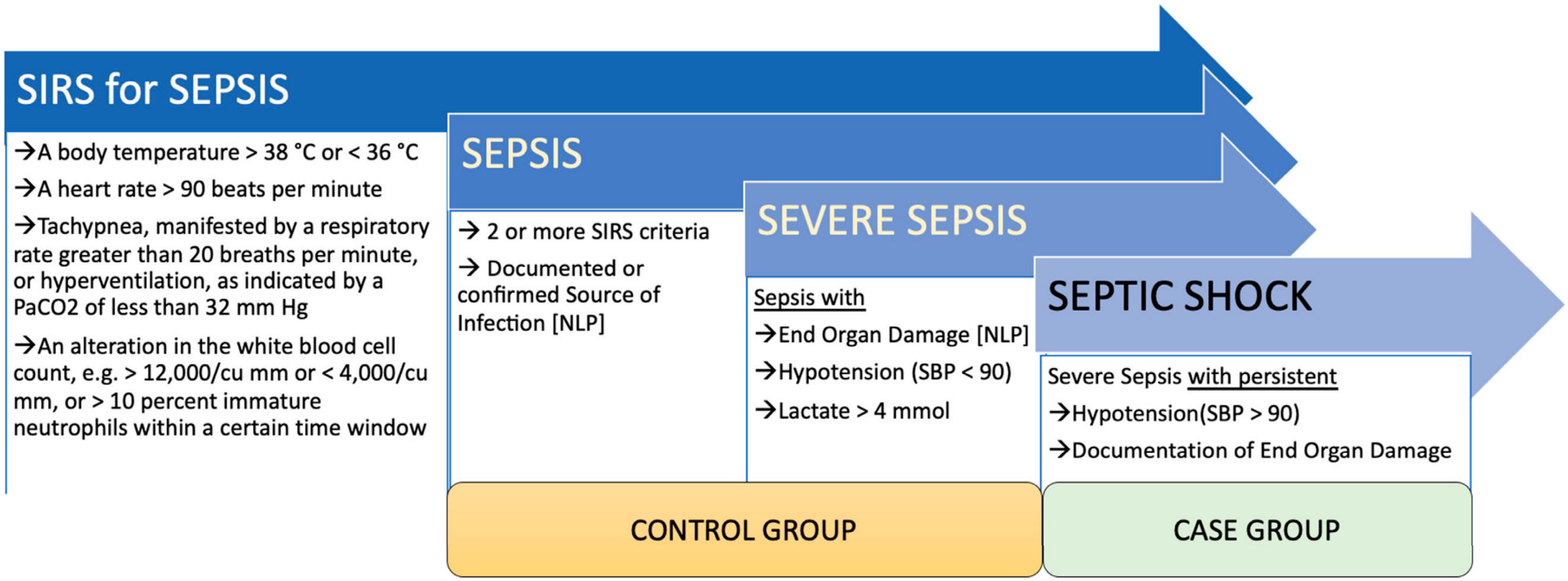
- Splitting data into branches based on features
- Entropy & information gain
- Analogy to calculus finding minima





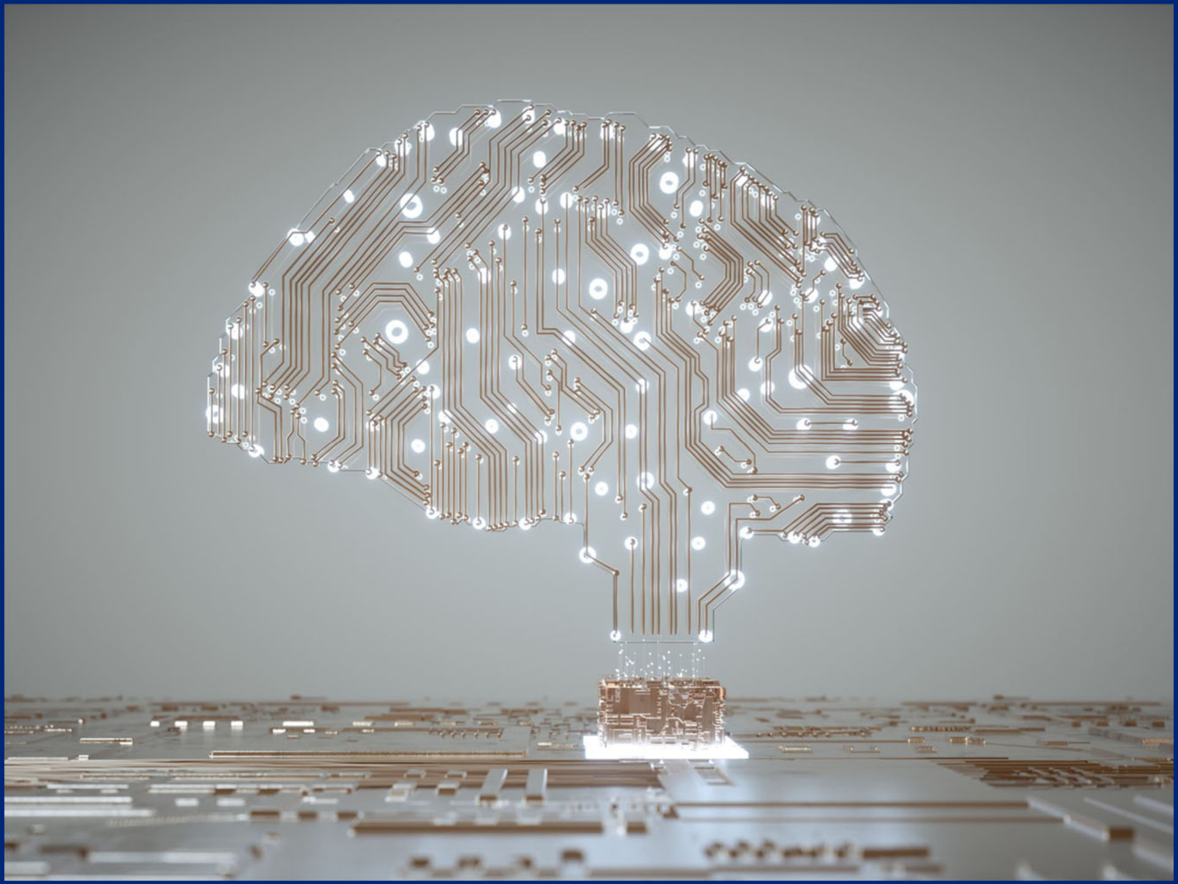
Medical Applications

- Predicting readmissions, sepsis alerts, imaging classification
- Utilization management: predicting if the request is going to be an approval



[NLP]: Data extracted using natural language processing applied to provider notes (unstructured sources)

AI: Neural Networks

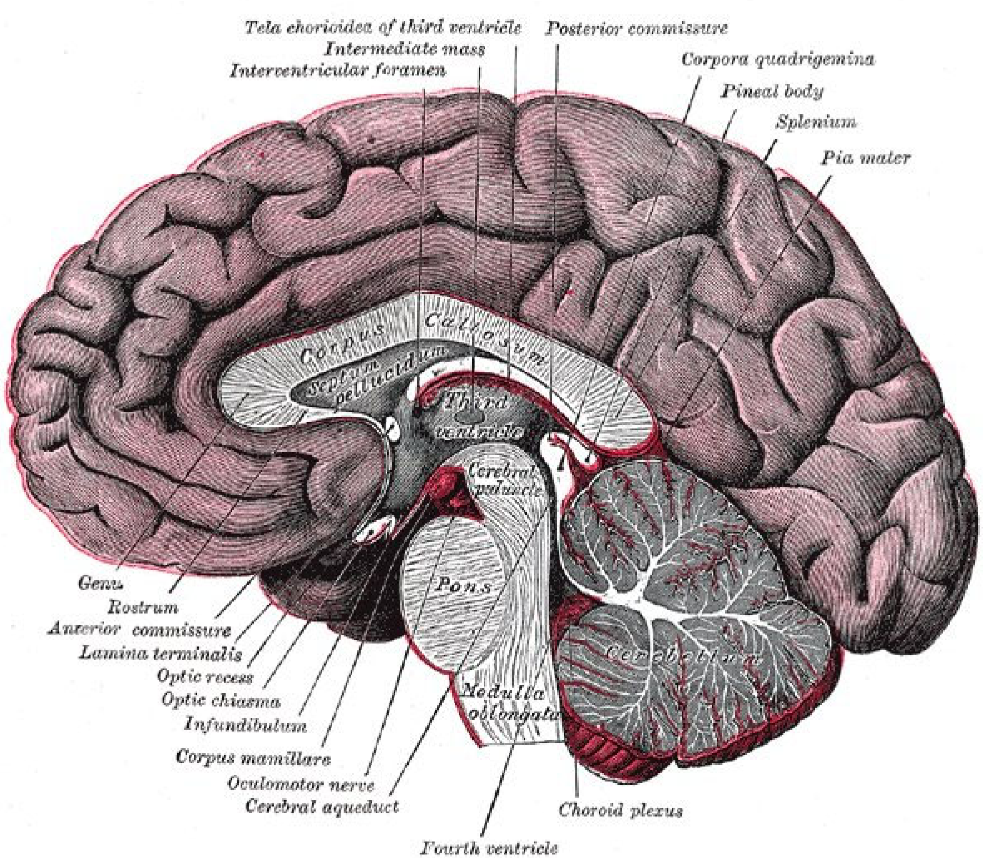


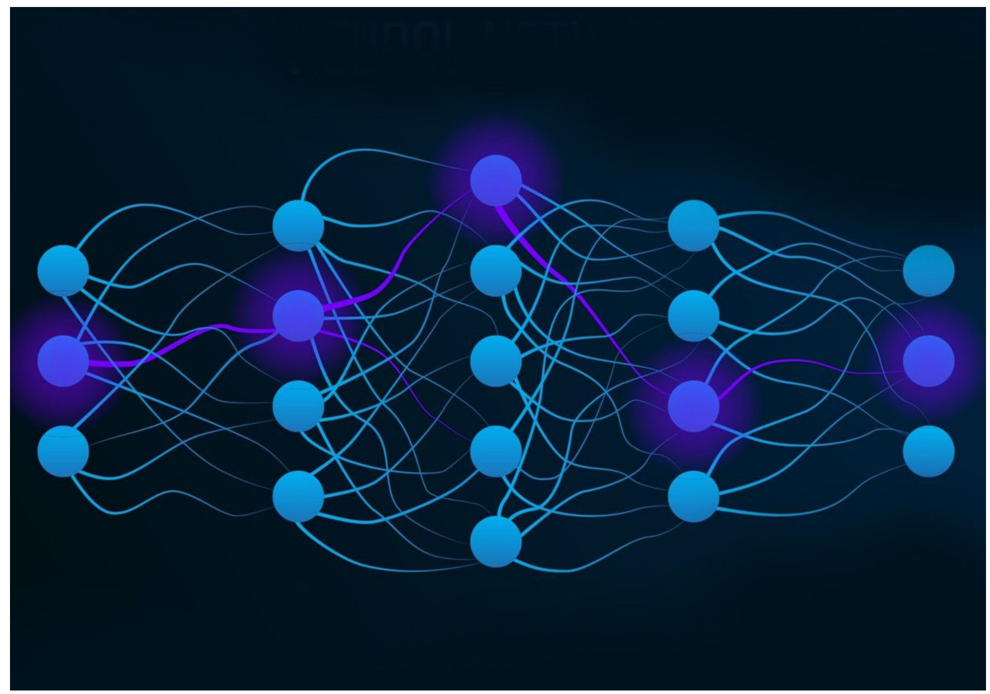
From Features to Context

- **Machine Learning:**
  - Uses features to make predictions
  - Relationships assumed to be fixed
- **But reality is dynamic:**
  - Meaning depends on **order, proximity, and context**
- **Example:**
  - *"Mark, a vegetarian, eats shoots and leaves"*
  - vs *"Mark, the serial murderer, eats, shoots, and leaves"*
- **This is AI today:**
  - Models that **understand patterns in context**, not just features
  - Foundation of **language models and contextual prediction**

Neural Networks: Inspired by the Brain

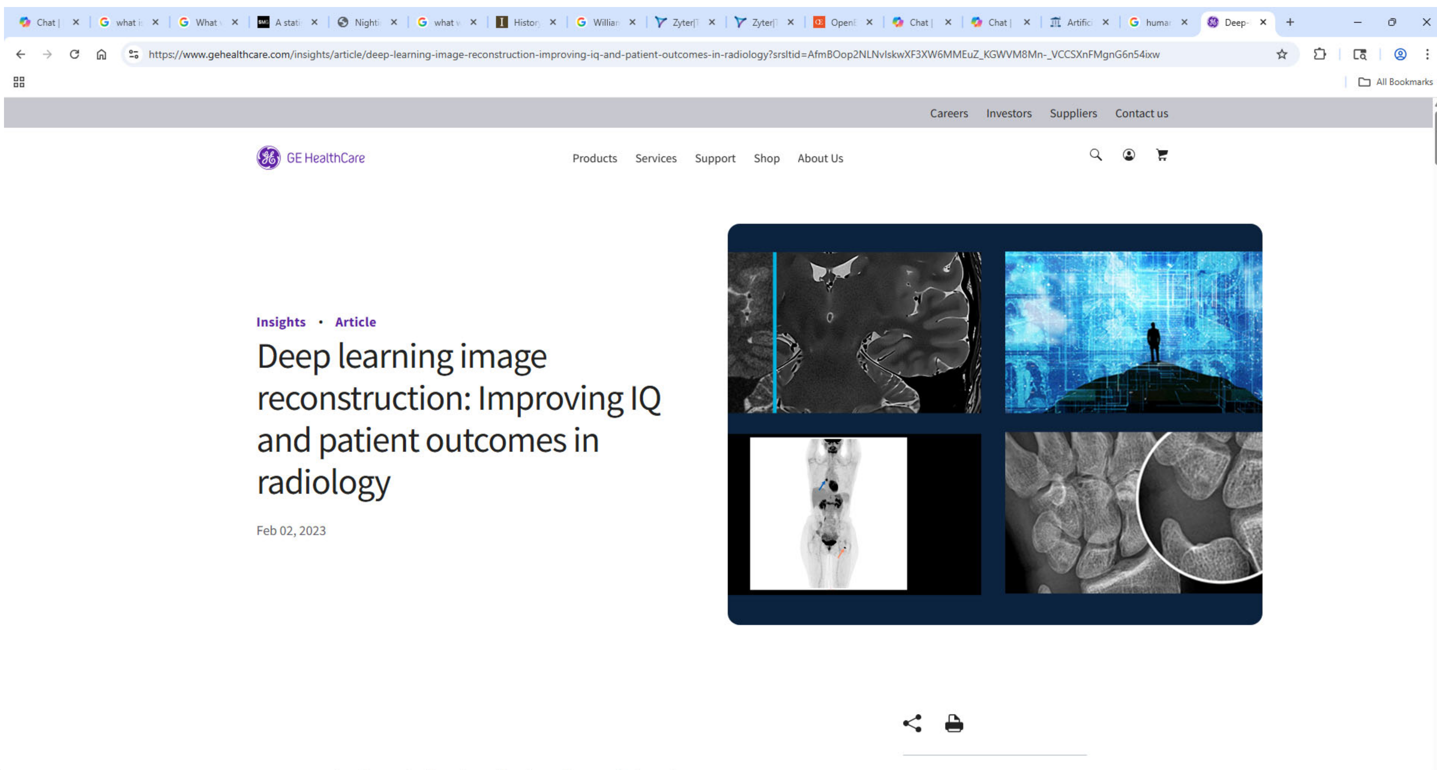
- Layers of nodes with weighted connections
- Goal: minimize cost function (error)
- Backpropagation = learning





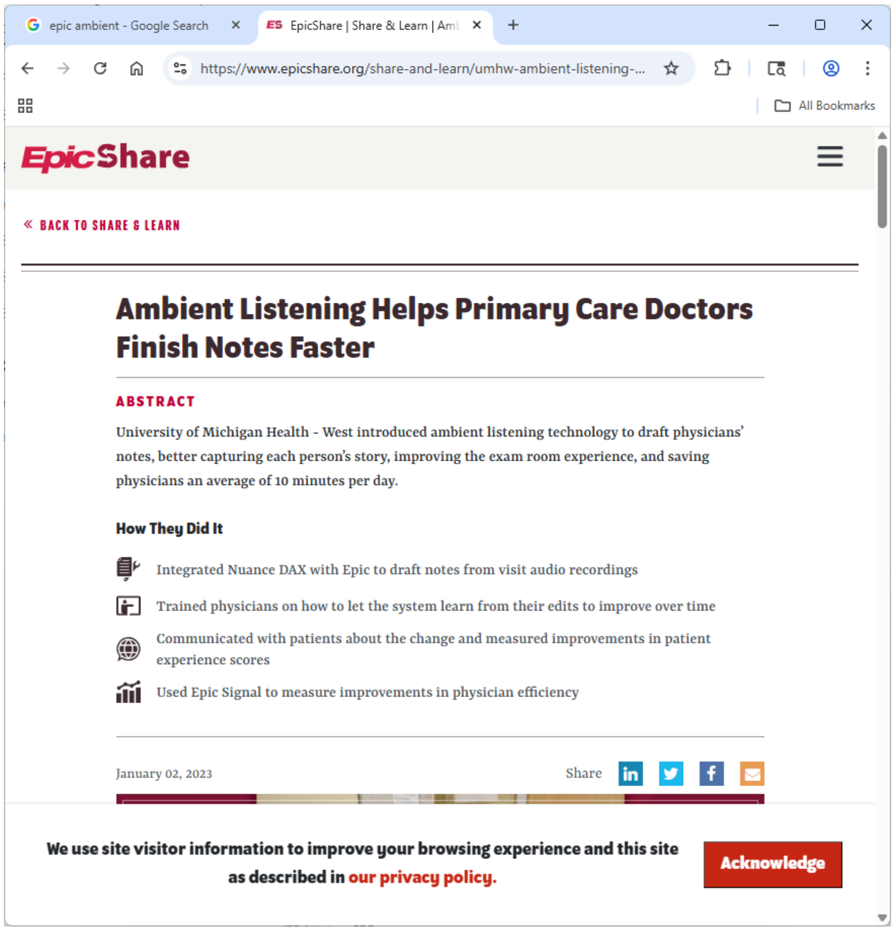
Deep Learning in Medicine

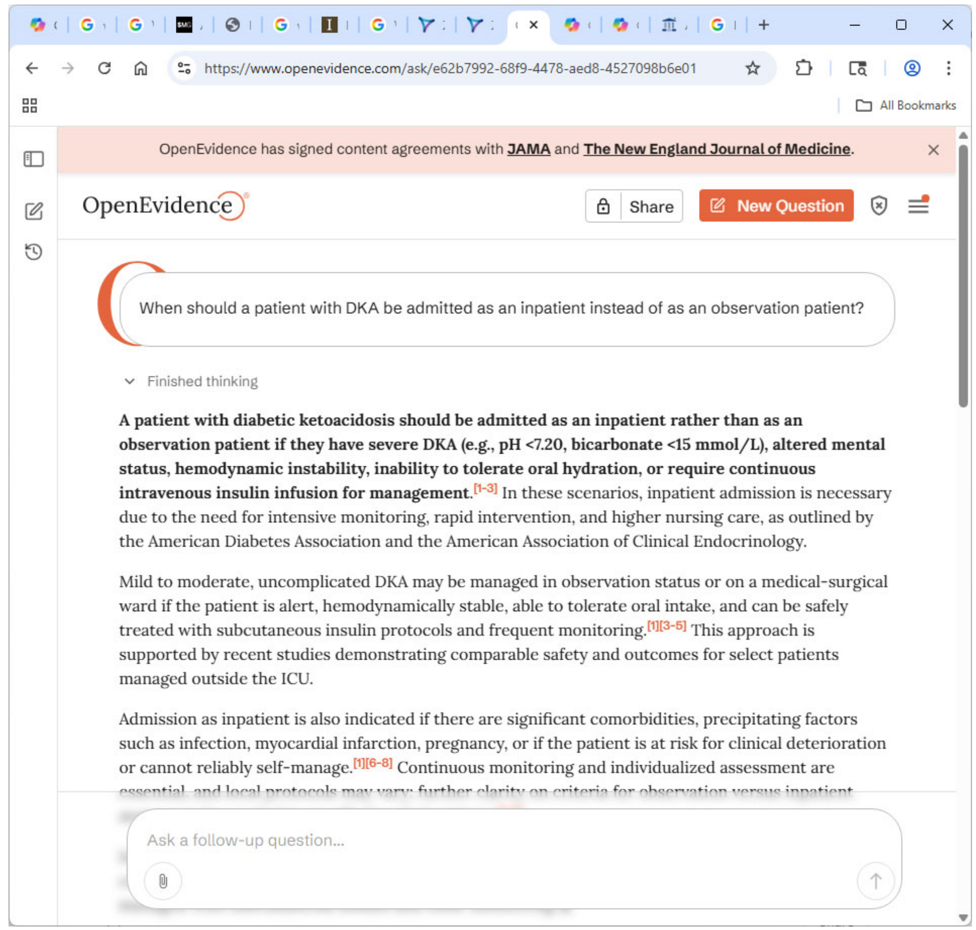
- Radiology: image interpretation
- Pathology: pattern recognition
- Predictive models for disease progression



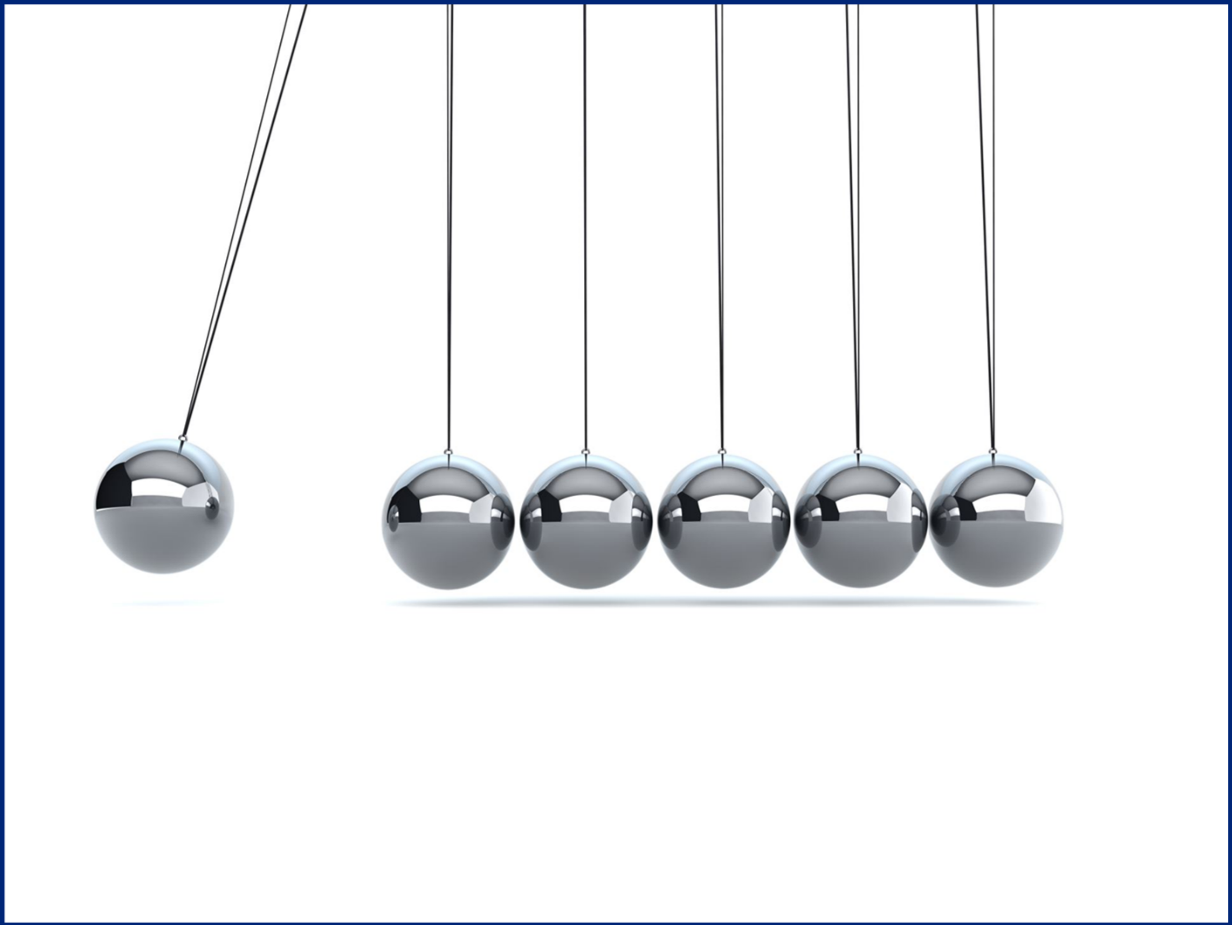
Large Language Models (LLMs)

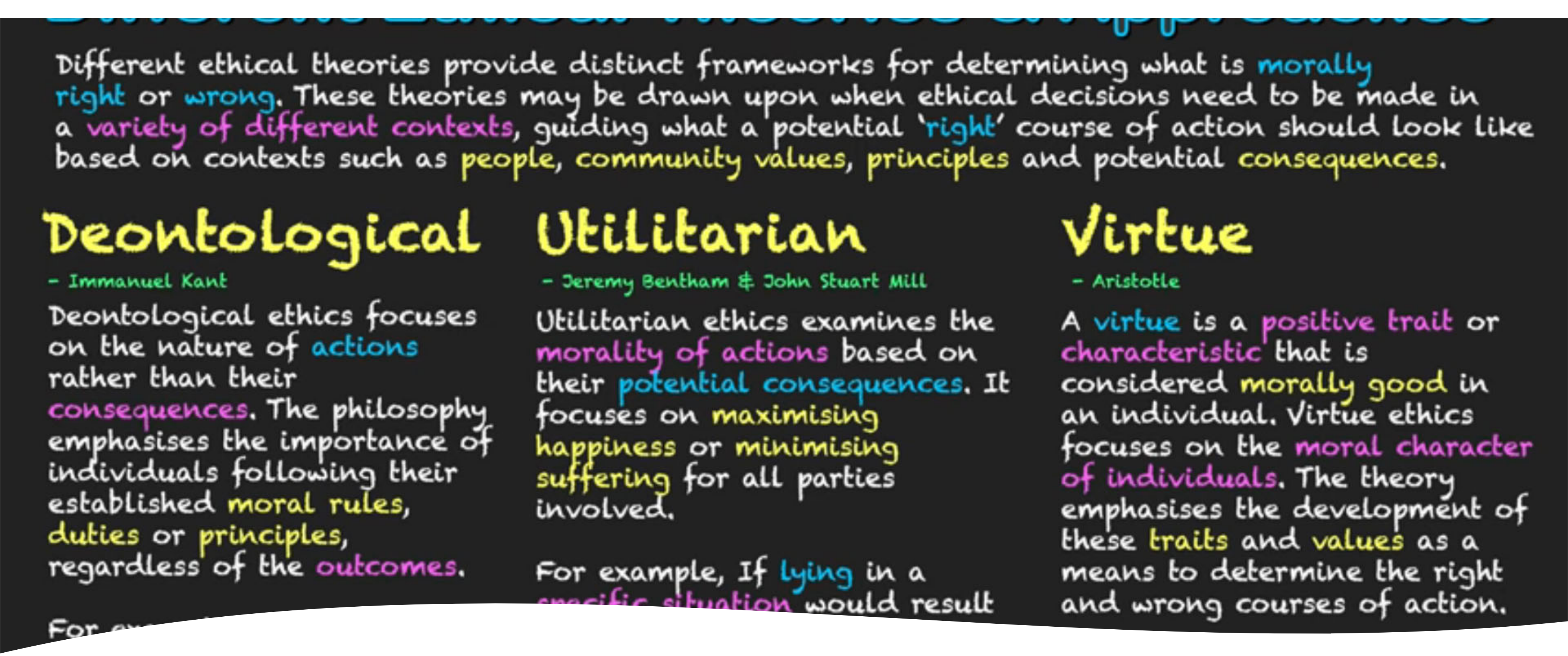
- Predicting next word using probabilities
- Trained on massive text corpora
- Emergent reasoning





Ethics



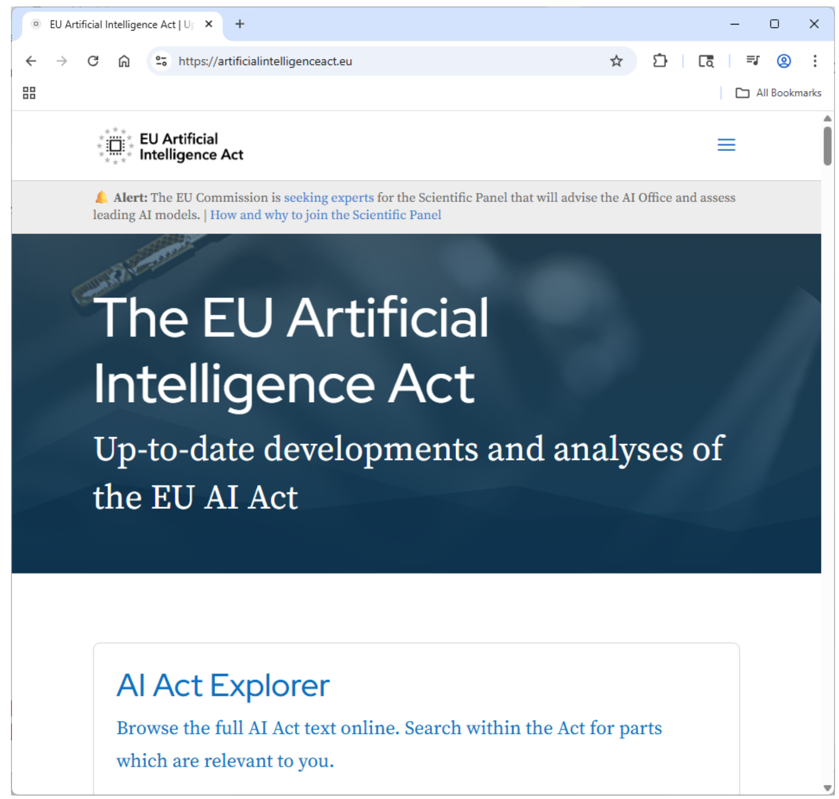


Ethical Foundations: Principlism in AI

- Autonomy → Transparent AI systems with informed consent and explainability
- Beneficence → AI that enhances clinical outcomes and supports decision-making
- Non-maleficence → Rigorous testing and post-market surveillance to prevent harm
- Justice → Bias mitigation and equitable access to AI-driven healthcare

EU AI Act: A Global Benchmark

- World's first comprehensive AI legislation (2024)
- High-risk AI systems must meet strict requirements:
  - Transparency and explainability
  - Human oversight
  - Bias detection and mitigation
  - Data governance and privacy
  - Fundamental rights impact assessments
- Prohibited practices include:
  - Social scoring
  - Biometric categorization based on sensitive traits
  - Emotion recognition in sensitive contexts



Bias Prevention & Sensitive Group Protection

- Demographics drive health outcomes
- AI can amplify existing disparities
- Medicine is heterogeneous
- Variance matters
- Unaddressed bias will lead to real-world harm

Human Oversight & Clear Regulatory Guidance

- AI mimics human intelligence—but inherits human flaws
- Imagine medicine without human oversight
- Humans must stay in the loop
  - Auditing and review of critical decisions
  - Predefined oversight mechanisms and checkpoints
- Oversight and regulation must be designed a priori, not retrofitted

Transparency & Explainability

- Ability to **check the reasoning process** builds trust
- **Explainability = Trust**
- Neural networks are **flexible but opaque** → often a "black box"
- **Noise vs. Information**
    - Humans must perform **sanity checks** to ensure noise is filtered and conclusions make sense
- **Testing must be transparent**
    - Processes should be **repeatable, auditable, and explainable**

Conclusion: The Dawn of a New Era

- **The Age of AI is here**
  - Like past revolutions: agriculture, industry, electricity, computation, internet
- **You don’t need to code to understand AI**
  - Just as you don’t need anatomy biochemistry to understand humans
- **AI is your new coworker and assistant**
- **Our responsibility:**
  - Understand its underpinnings, **strengths,** and **weaknesses**.
  - Understand the **philosophy** and **ethics** of this new creation
- **Shape this tool for the good of our communities**