

# Beyond Prediction: Can AI Make Treatment Decisions?

Choosing the Right Treatment for the Right Patient at the Right Time

*The Core Dilemma: Imagine two patients with the same diagnosis, receiving the same treatment... yet one improves dramatically, while the other does not. Why does this happen?*

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## 1. The Challenge: Beyond the Average

Traditional clinical trials look at Average Treatment Effects (ATE). This research shifts the focus to **Predicted Individual Treatment Effects (PITE)** because patients are complex, non-linear, and heterogeneous.

### High-Dimensional Data

Navigating complex interactions.

### Non-Gaussian / nonlinear response structures

Domain Restrictions.

### The Missing Link

Standard models treat molecular data (genomics, transcriptomics) as mere auxiliary variables instead of core biological mechanisms.

### The Predictive Trap

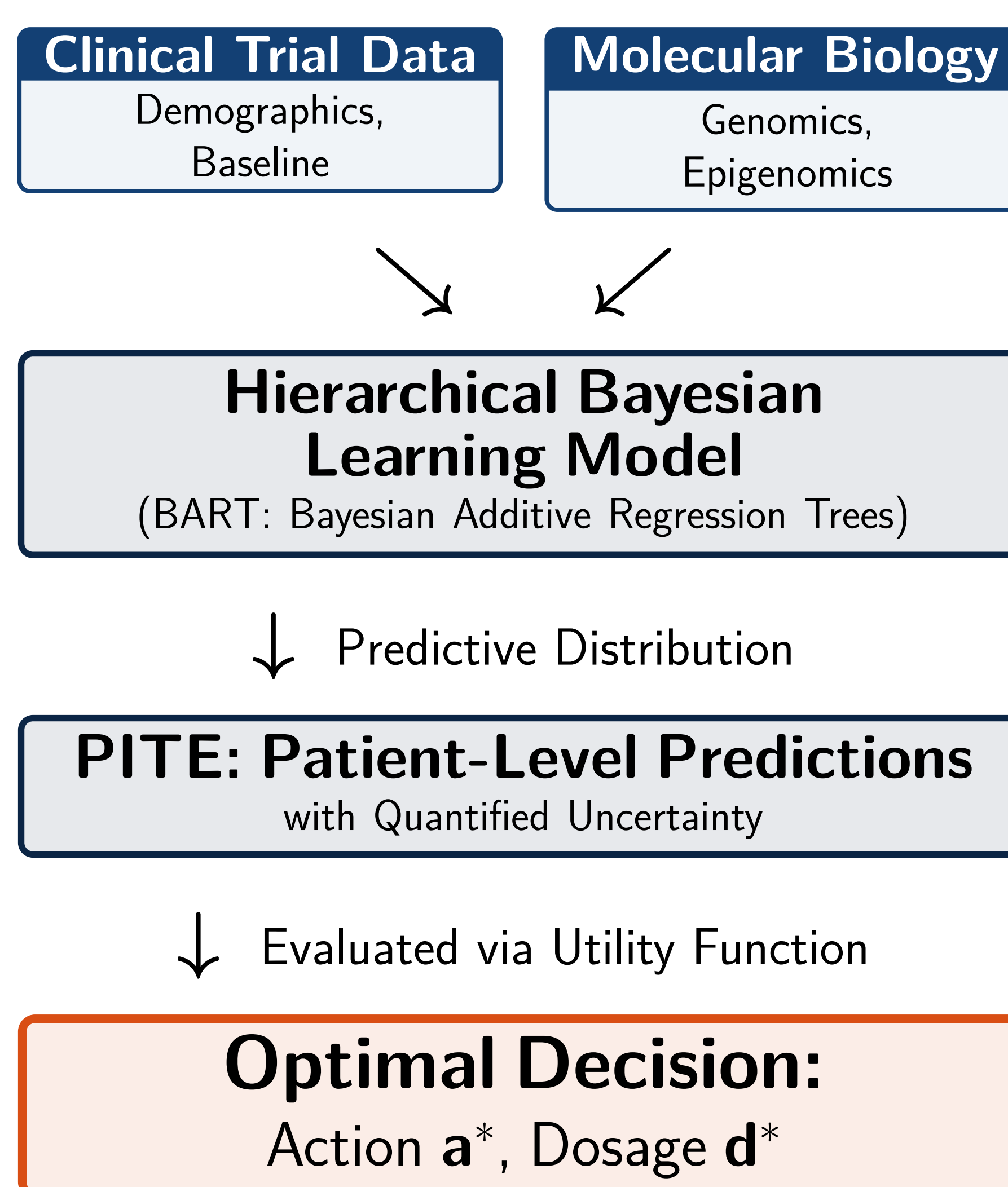
**A model that predicts well does not necessarily recommend well.** We must move from prediction validity to decision validity.

## 2. The Core Solution: The iPITE Framework

The integrated PITE (iPITE) model bridges the gap between raw data and clinical action by feeding Clinical Trials (CT) and Molecular Biology (MB) into a Bayesian Engine, outputting a precise, actionable decision.

### The iPITE Directed Acyclic Graph (DAG)

This diagram maps out exactly how data flows into an optimal clinical decision under uncertainty:



## 3. The Decision Theory: Maximizing Patient Utility

Clinical reality is rarely a simple binary choice (Treatment A vs. Treatment B). It involves adjusting packages of care (**dose  $d$ , timing, frequency, dietary restrictions**) against competing outcomes (efficacy vs. toxicity).

We formalize optimal individualized treatment selection using decision theory:

$$a^*(x) = \arg \max_{a,d} \mathbb{E} [ U(Y(a, d), x) | x ]$$

### Main components:

- ▶  $a^*(x)$ : The optimal treatment strategy tailored to the specific patient profile  $x$ .
- ▶  $\mathbb{E}[\cdot | x]$ : The expected value calculated over the predictive posterior distribution, naturally incorporating data uncertainty.
- ▶  $U(\cdot)$ : A clinically meaningful **Utility Function** that dynamically balances:
  - ▶ **Efficacy** (Does it work?)
  - ▶ **Toxicity & Risks** (Is it safe?)
  - ▶ **Quality of Life** (How will the patient feel?)

## Crucial Research Questions for Discussion

- ▶ **Propagation of uncertainty:** CT vs MB
- ▶ **Robustness Criteria in Decision Making:** Missingness/ Small/early-phase CT?
- ▶ **Identify/Validate:** Optimal Treatment Regimen/Predictive accuracy?

