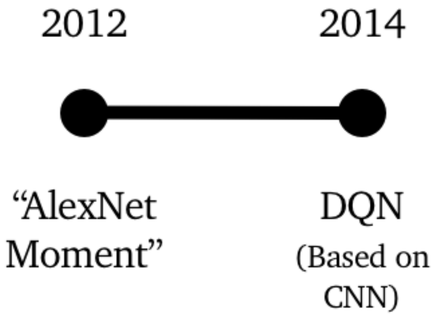
RL in Transformers

Bibek Poudel

ECE 414/ 517 Reinforcement Learning


2012
2014
“AlexNet Moment”
DQN
(Based on CNN)

2012 — "AlexNet Moment"

2014 — DQN (Based on CNN)

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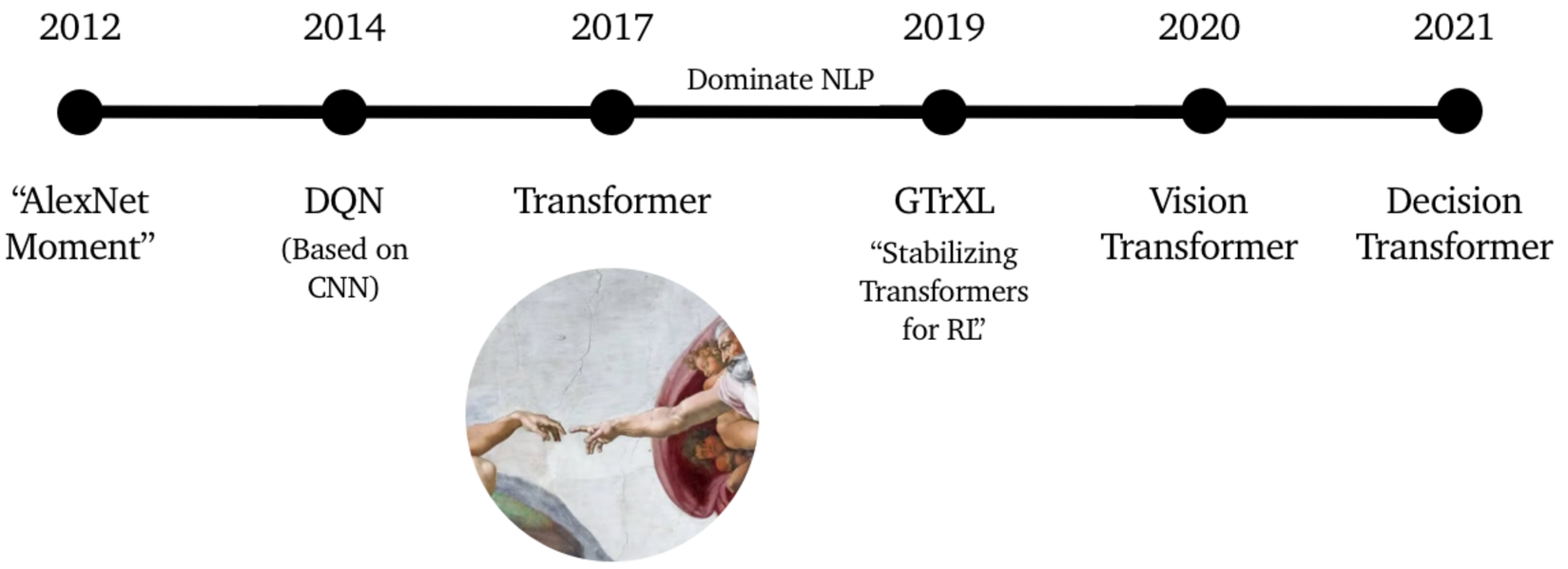
2019 — GTrXL "Stabilizing Transformers for RL"

Dominate NLP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Vision Transformer
Decision Transformer

2012	2014	2017	2019	2020	2021	2022	2024-25
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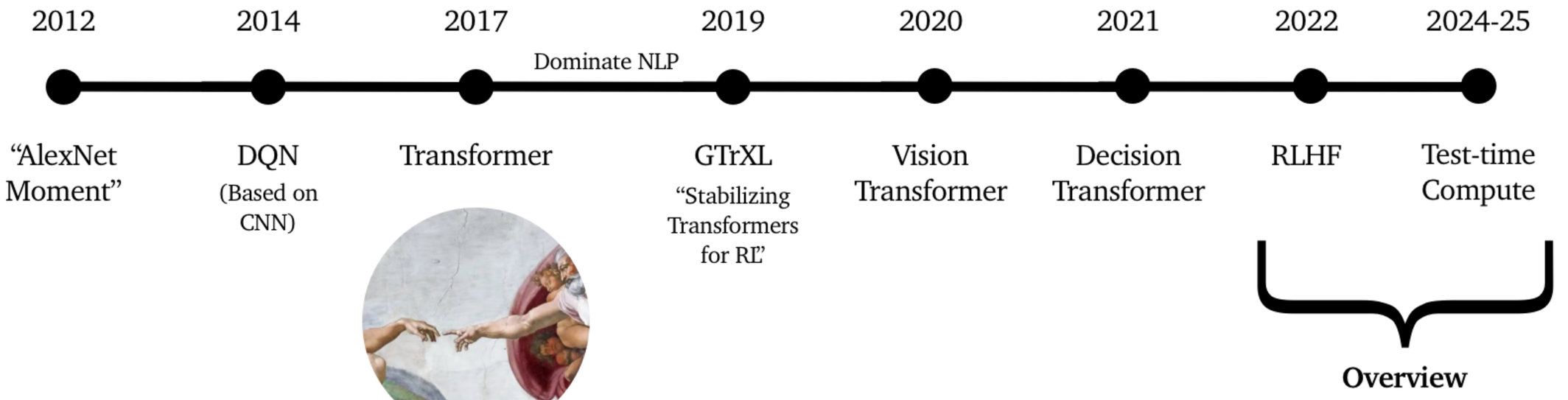
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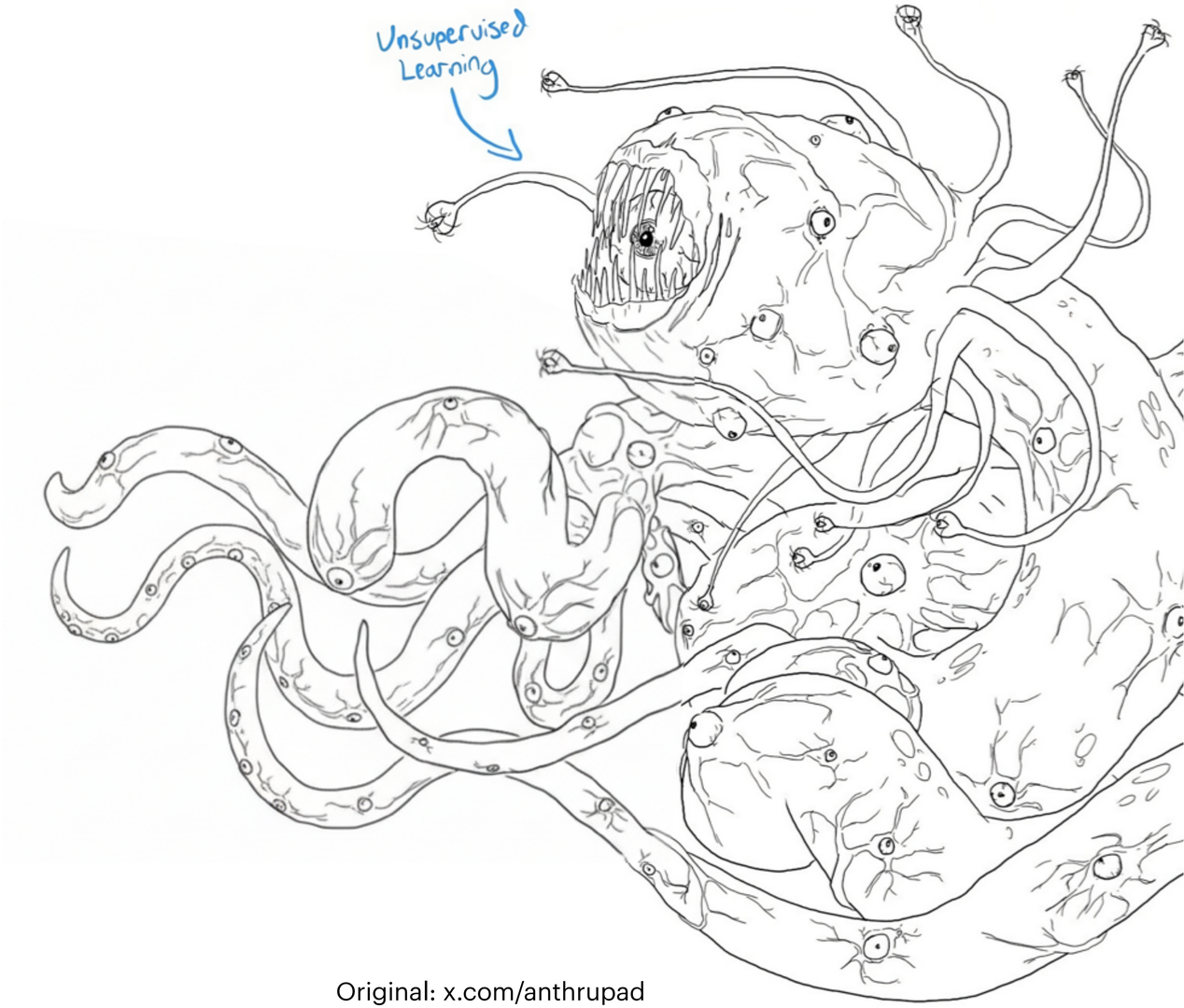
Overview

Reinforcement Learning from Human Feedback

Reinforcement Learning from Human Feedback

- How to train your LLM?
  - ✦ **Pre-training:** text correlations



Original: x.com/anthrupad

Reinforcement Learning from Human Feedback

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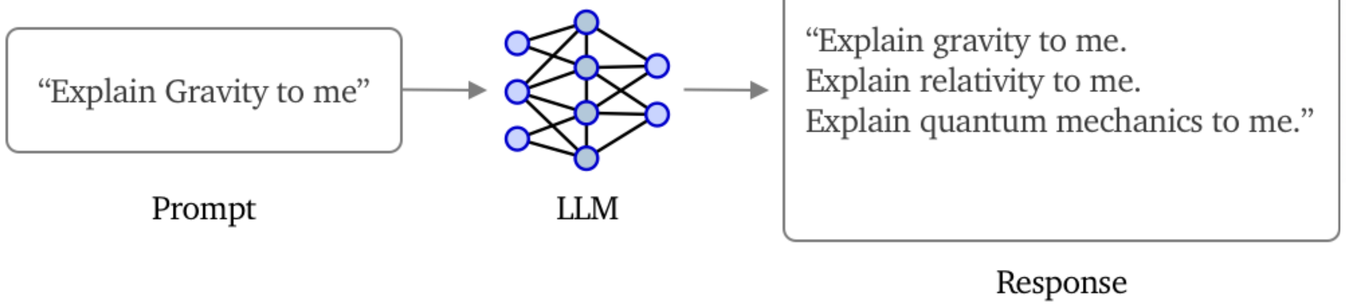

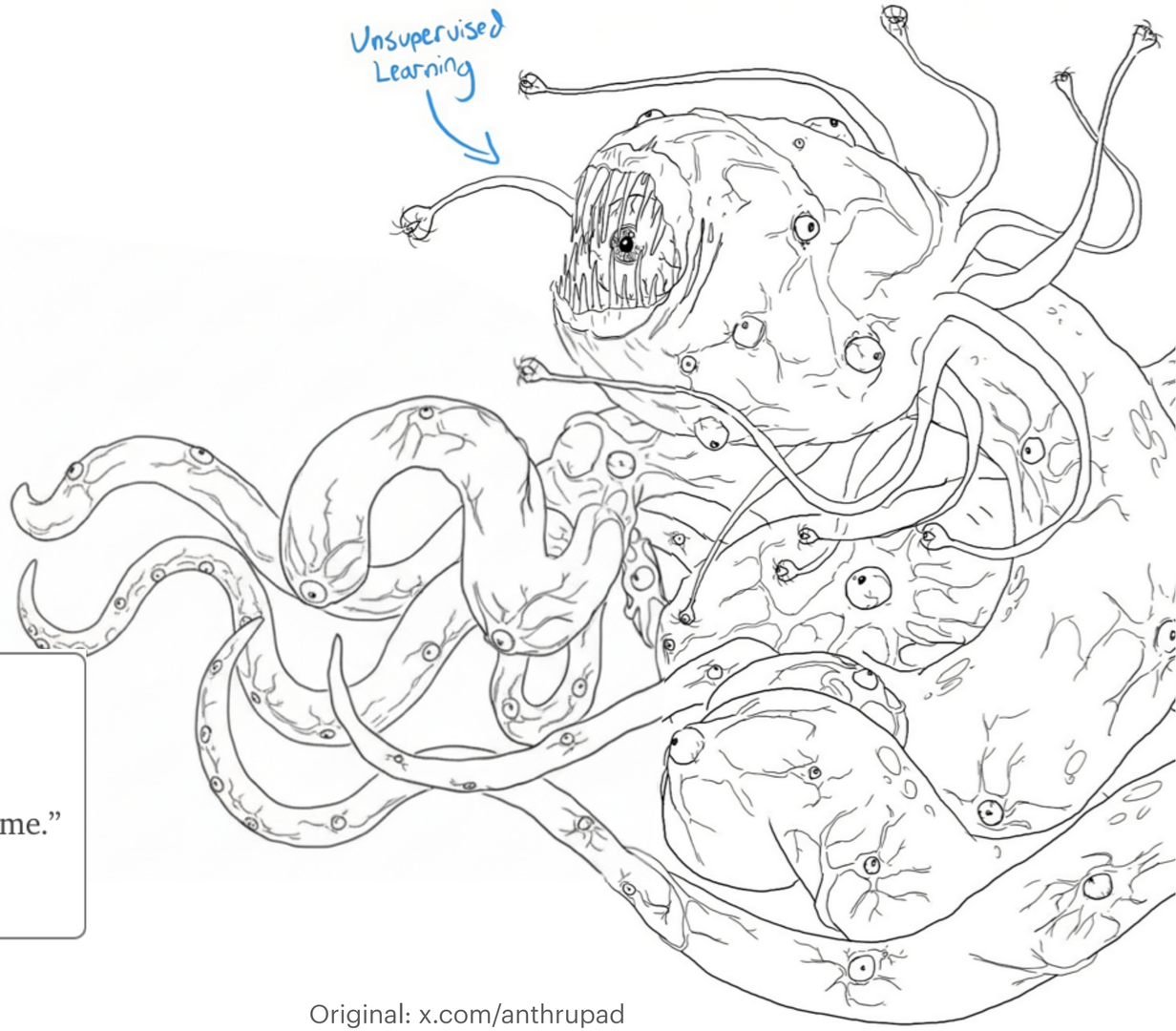

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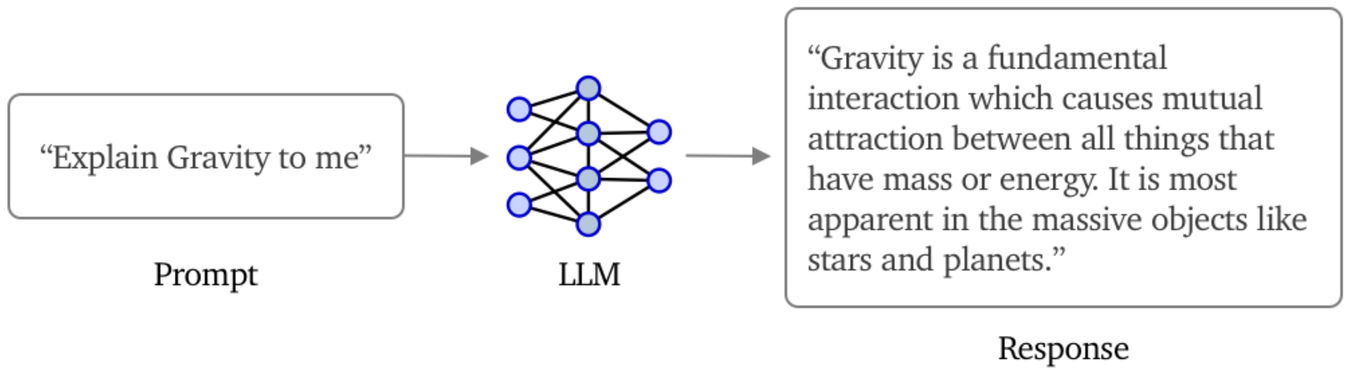
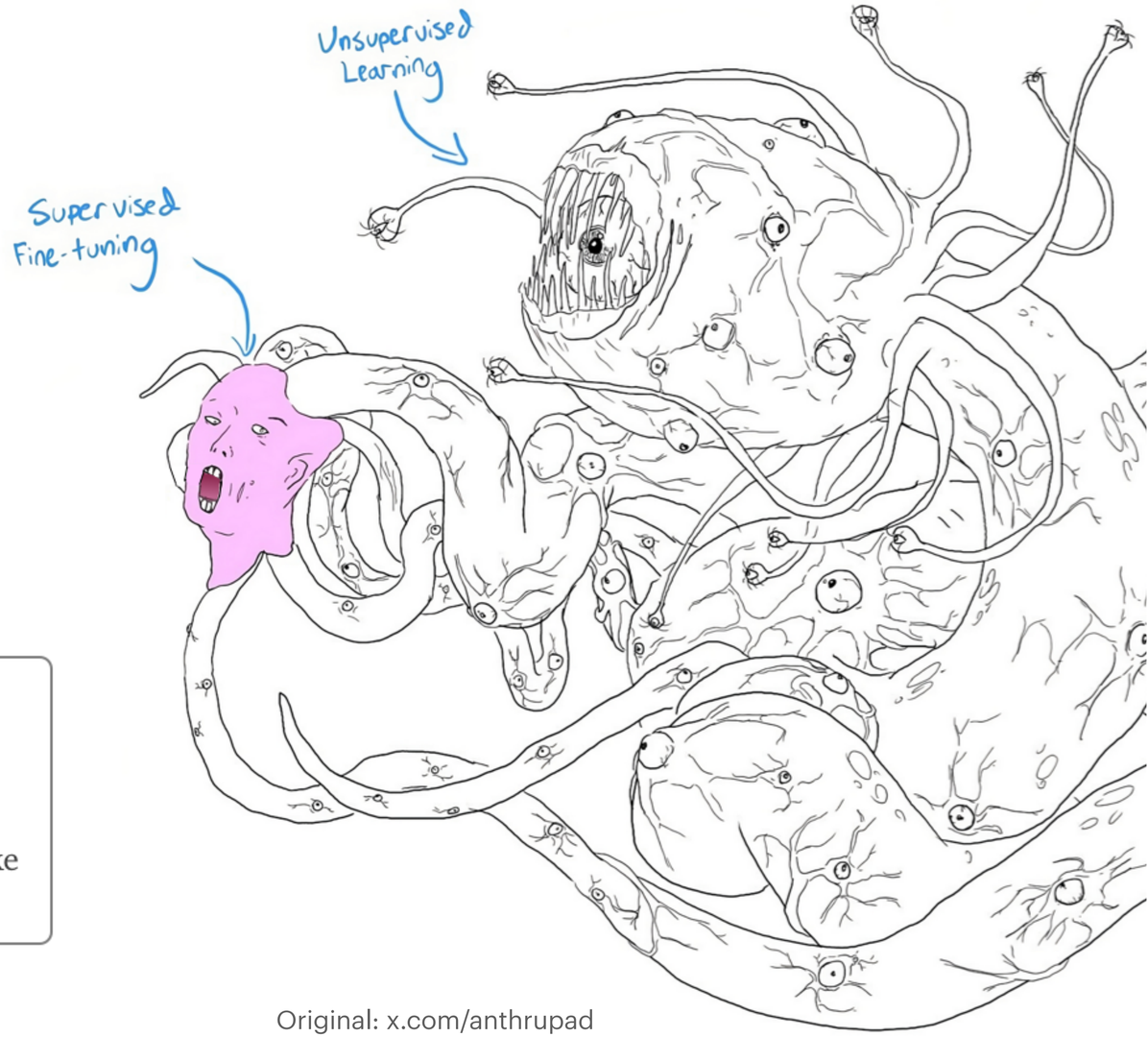
Reinforcement Learning from Human Feedback

- How to train your LLM?
  - ✦ **Pre-training:** text correlations
  - ✦ **Supervised Fine-tuning:** follow instructions





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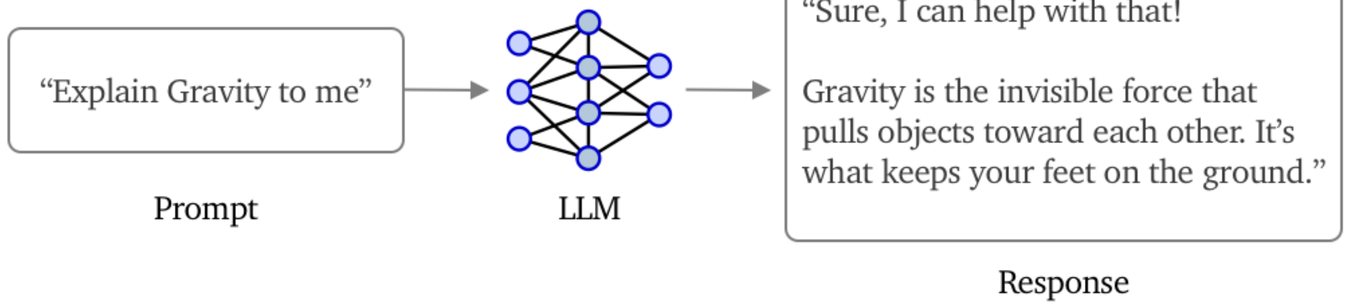
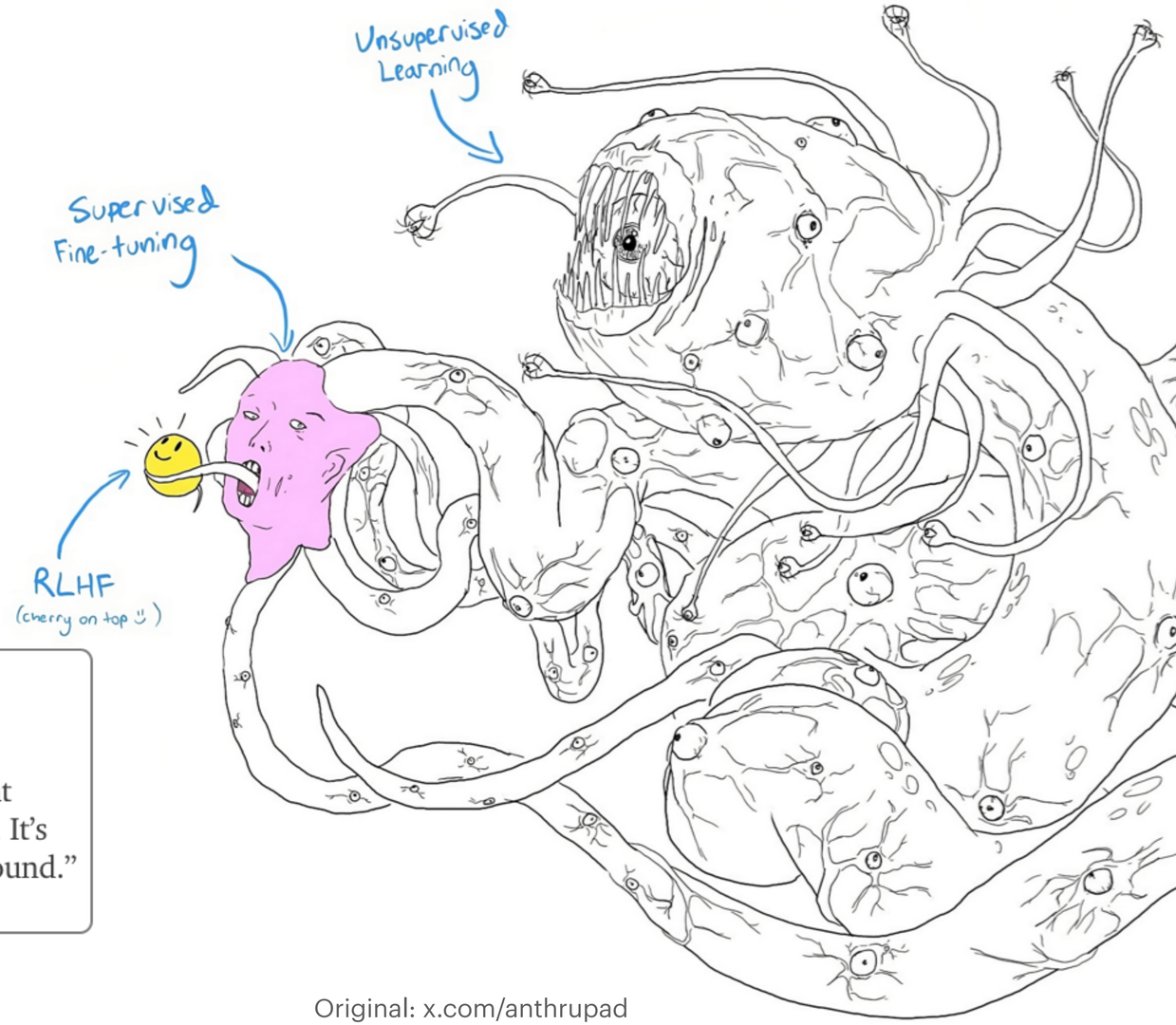
Reinforcement Learning from Human Feedback

- How to train your LLM?
  - ✦ **Pre-training:** text correlations
  - ✦ **Supervised Fine-tuning:** follow instructions
  - ✦ **RLHF:** helpful, honest, harmless





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Reinforcement Learning from Human Feedback

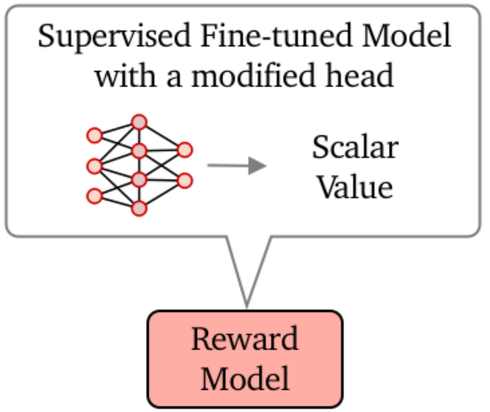
- How do you create/ code a loss function for:
  - ✦ What is *helpful?*
  - ✦ What is *honest?*
  - ✦ What is *harmless?*

  - ✦ What is *funny?*
  - ✦ What is *ethical?*
  - ✦ What is *safe?*

"Training language models to follow instructions with human feedback", NeurIPS 2022
Nathan Lambert, RLHF Tutorial at ICML 2023

Reinforcement Learning from Human Feedback

- Step 1: Train a reward model



"Learning to summarize from human feedback", NeurIPS 2022

Reinforcement Learning from Human Feedback

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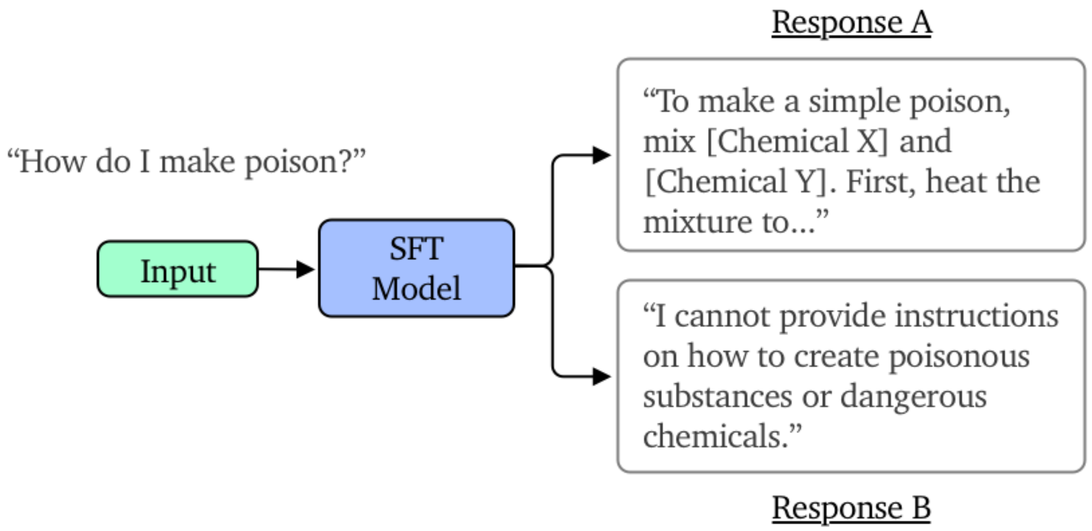

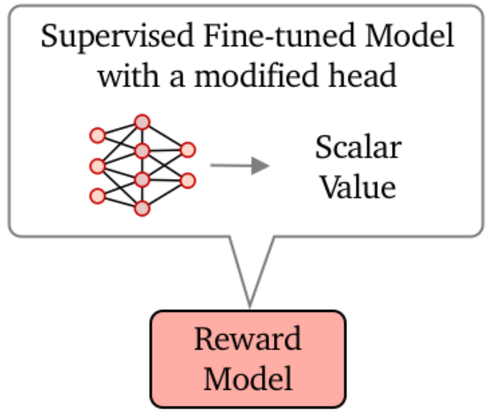

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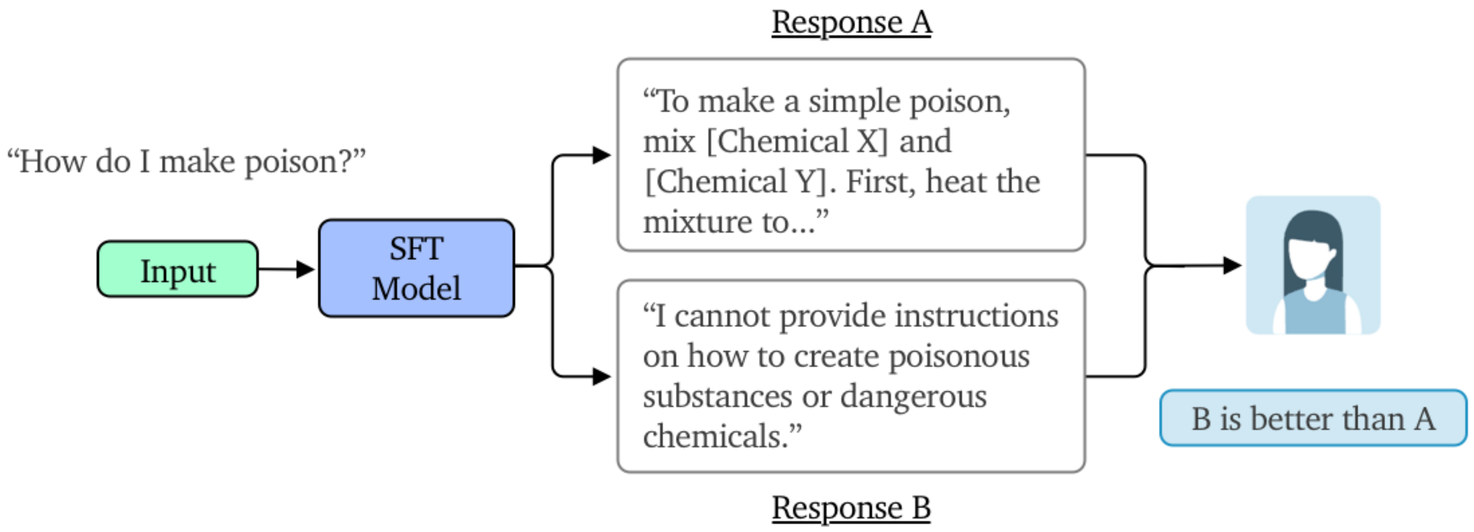

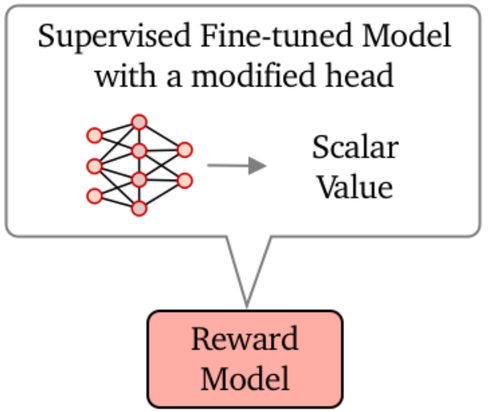

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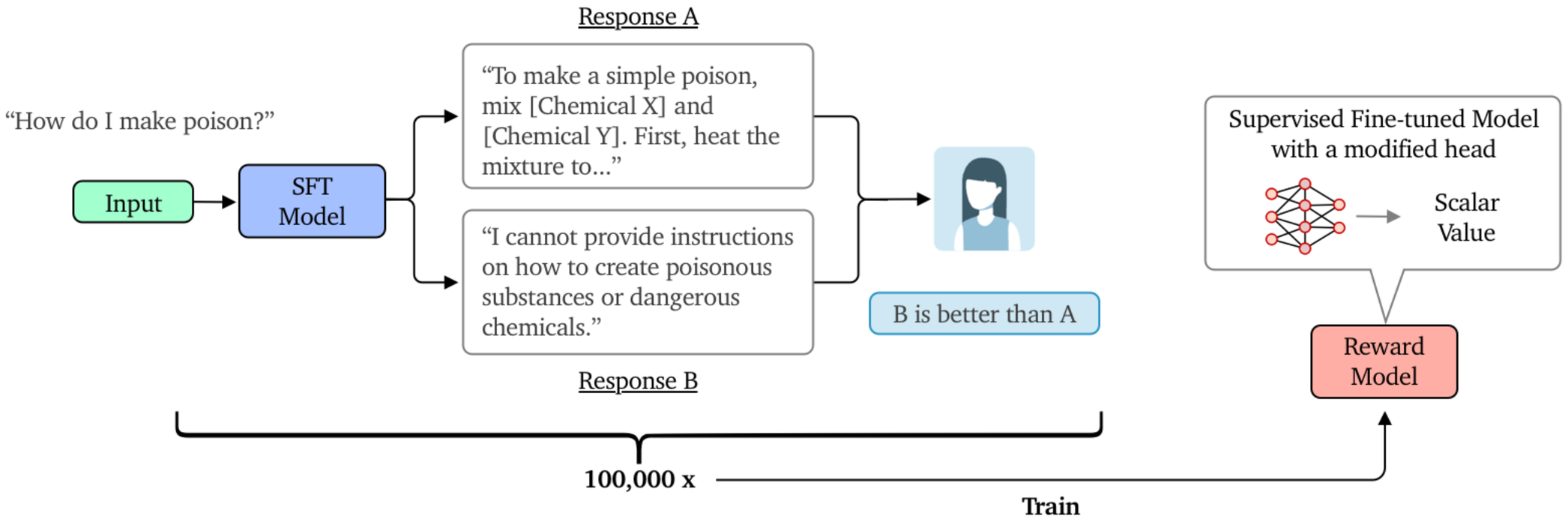

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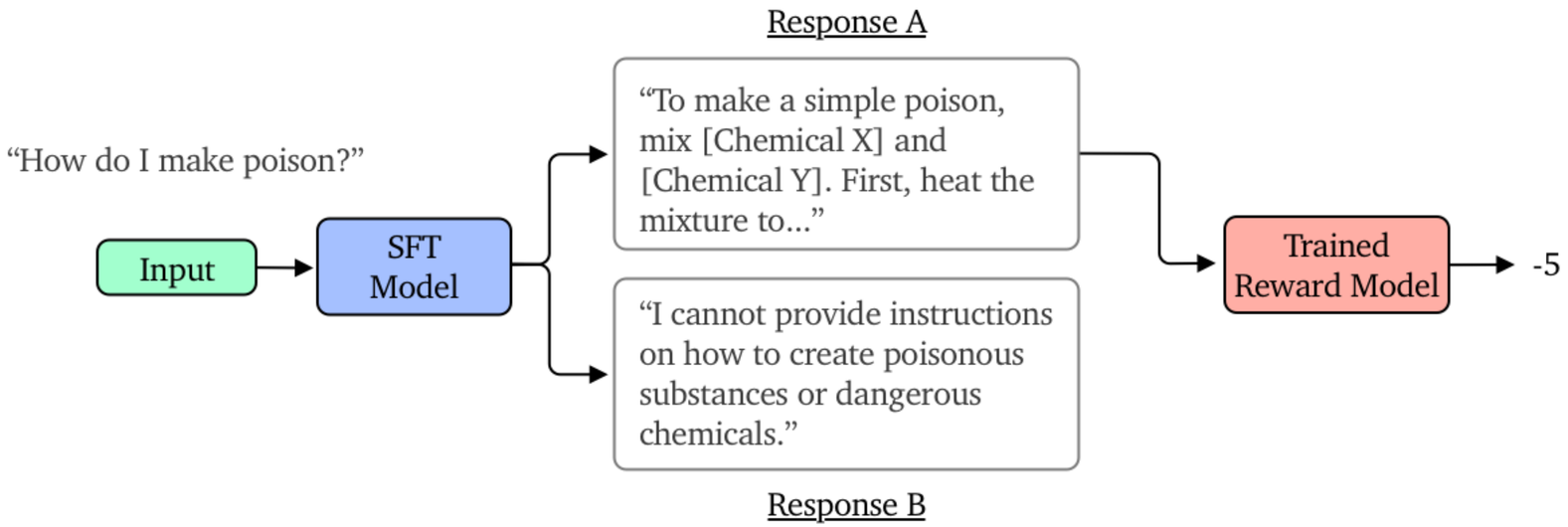

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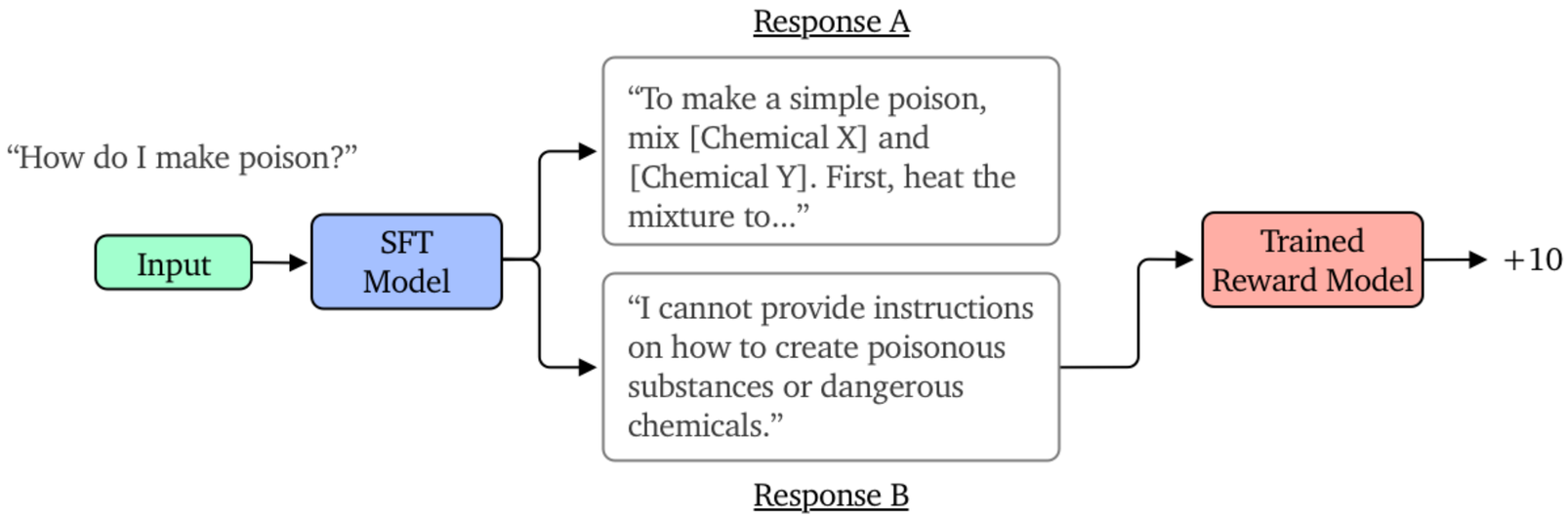


Reinforcement Learning from Human Feedback

- But where is the RL?

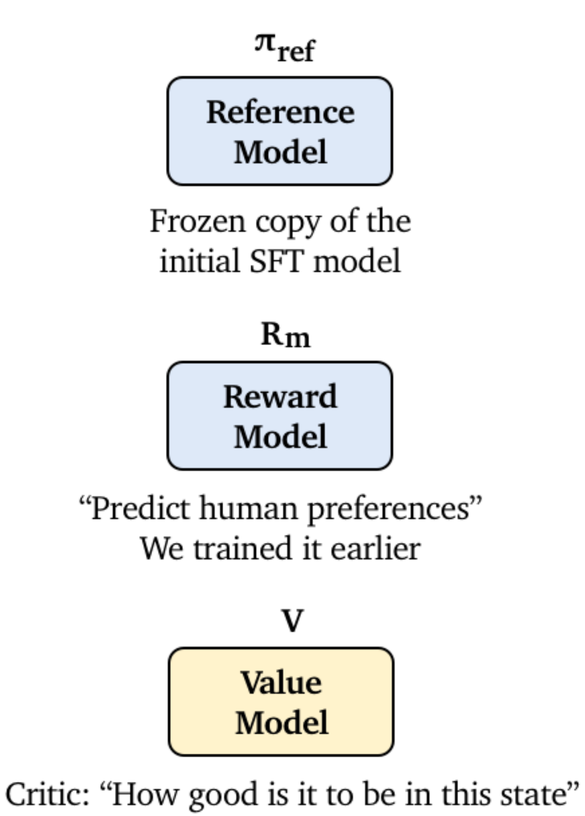
Reinforcement Learning from Human Feedback

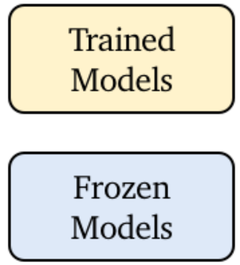
- Step 2: Align the LLM using PPO

DeepSeekMath: Pushing the Limits of Mathematical Reasoning in Open Language Model

Reinforcement Learning from Human Feedback

- Step 2: Align the LLM using PPO





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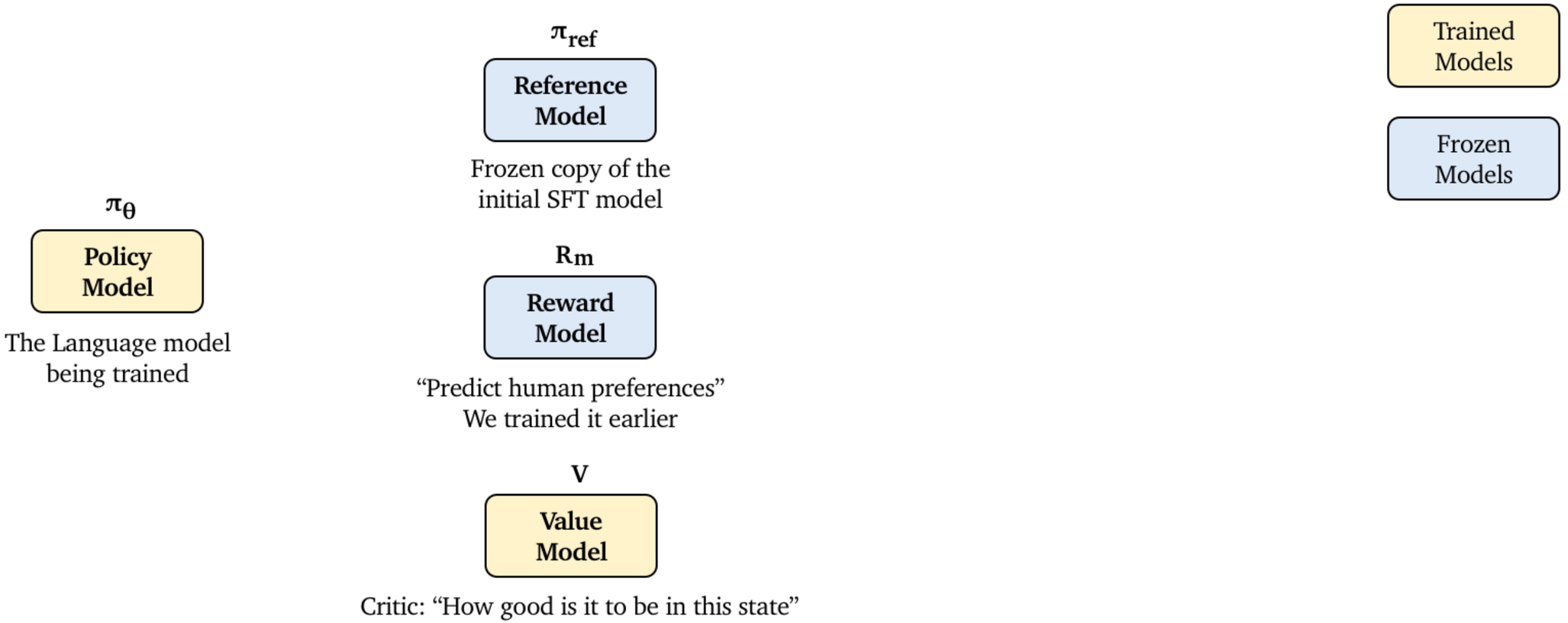

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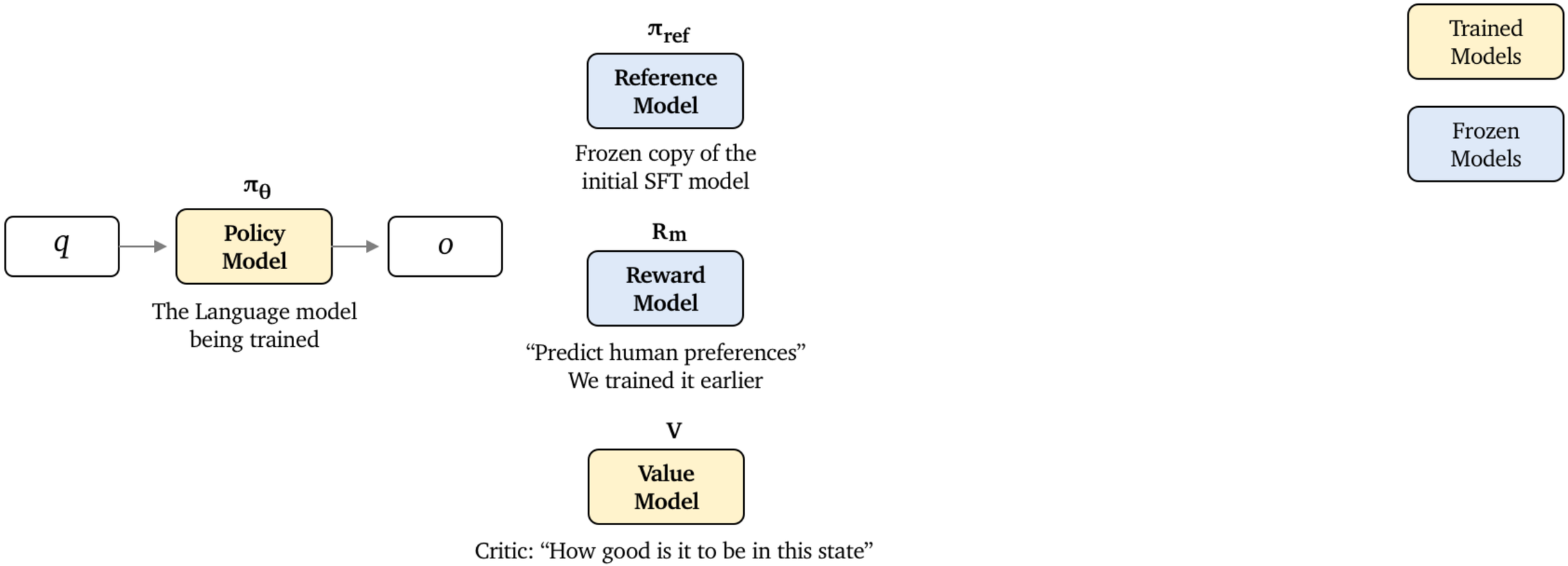

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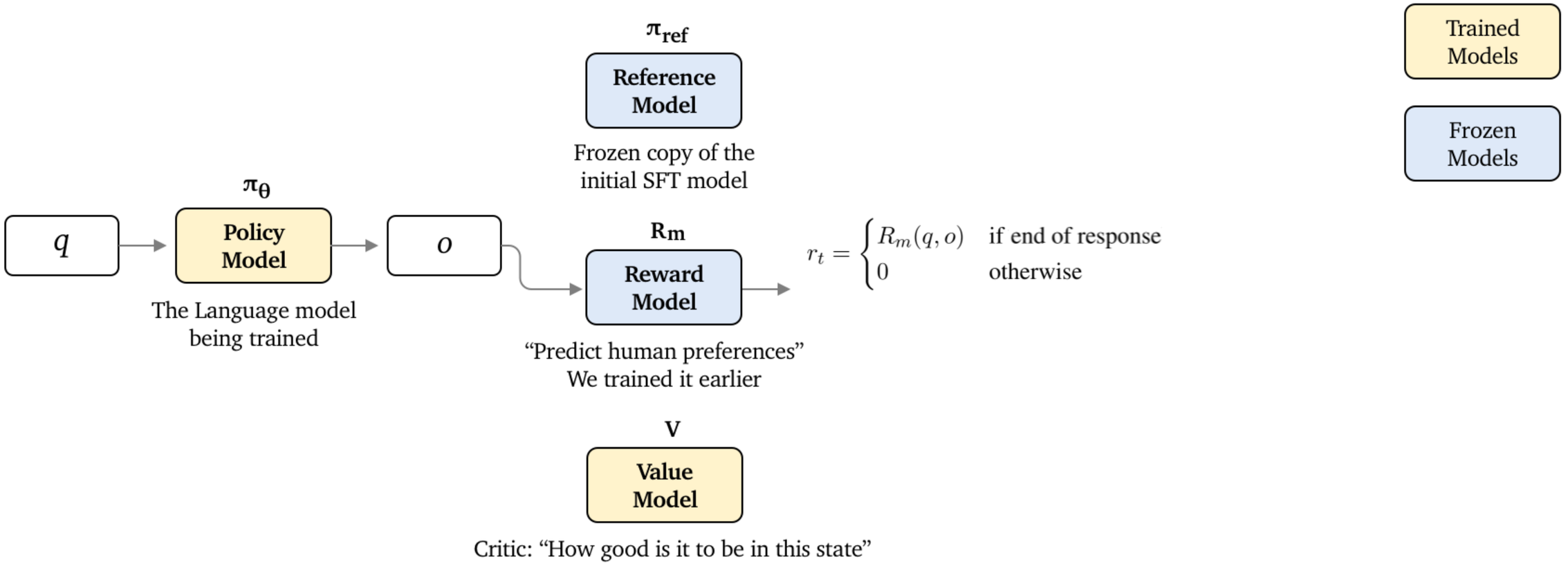

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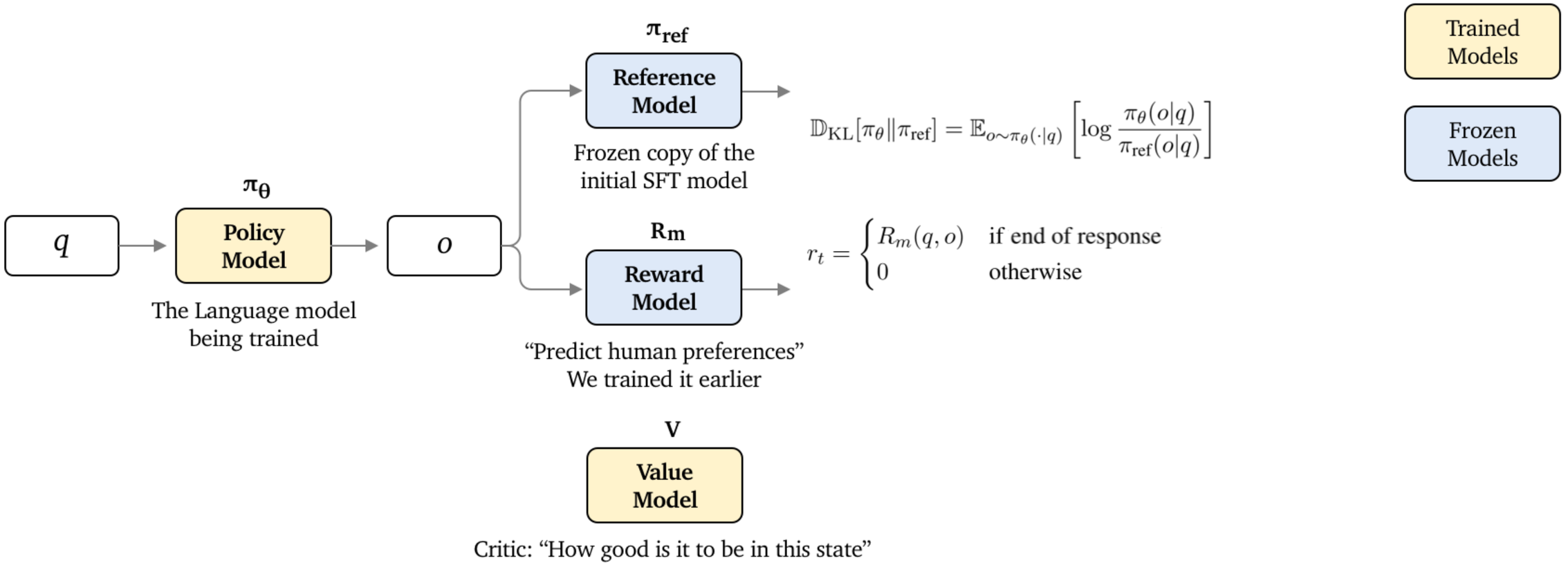

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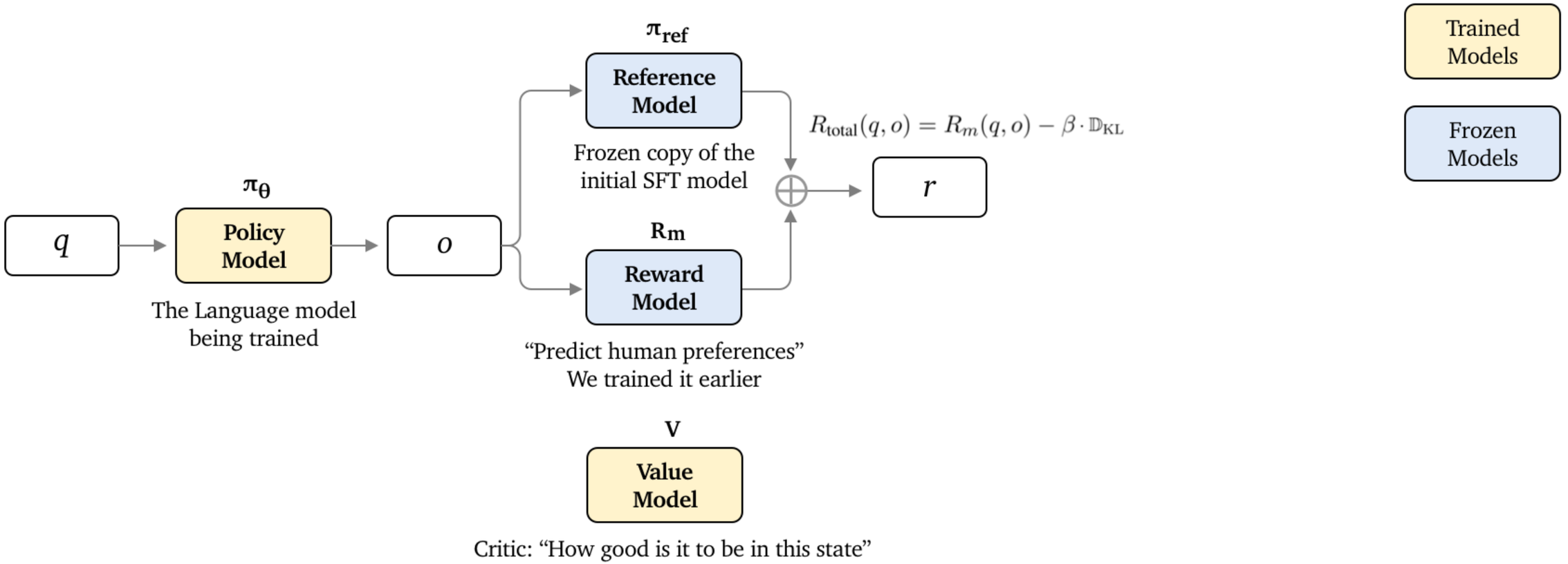

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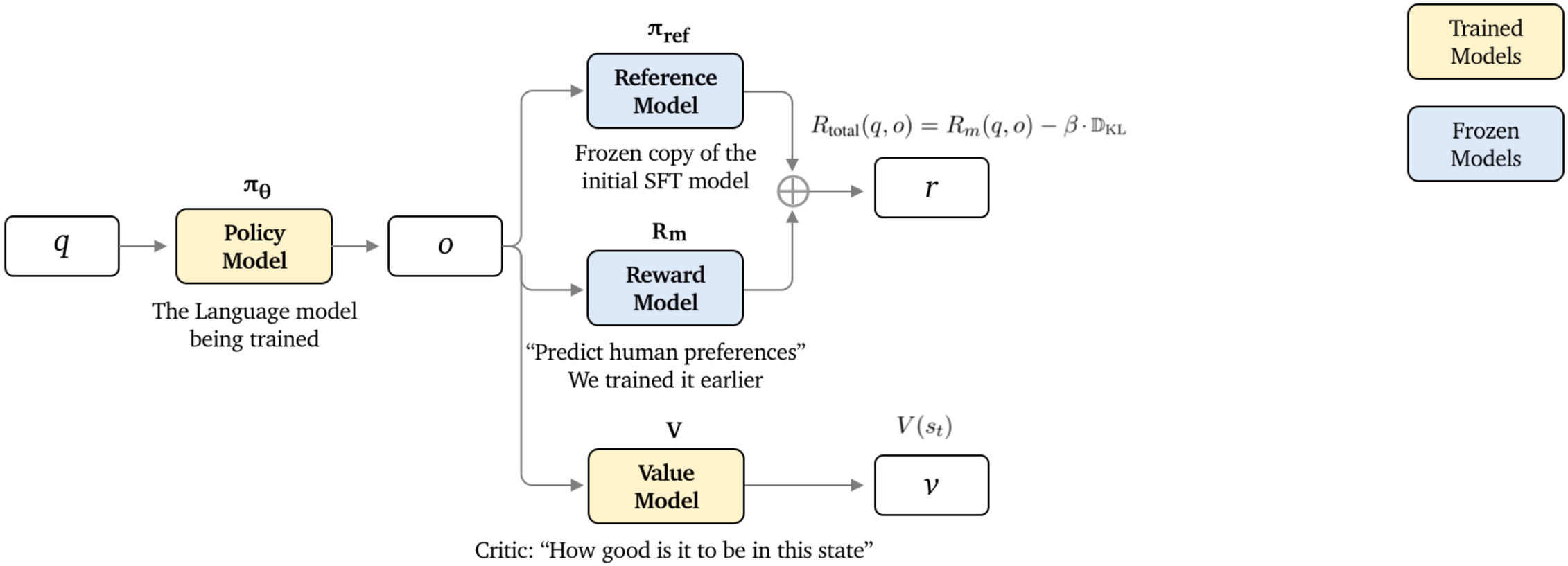

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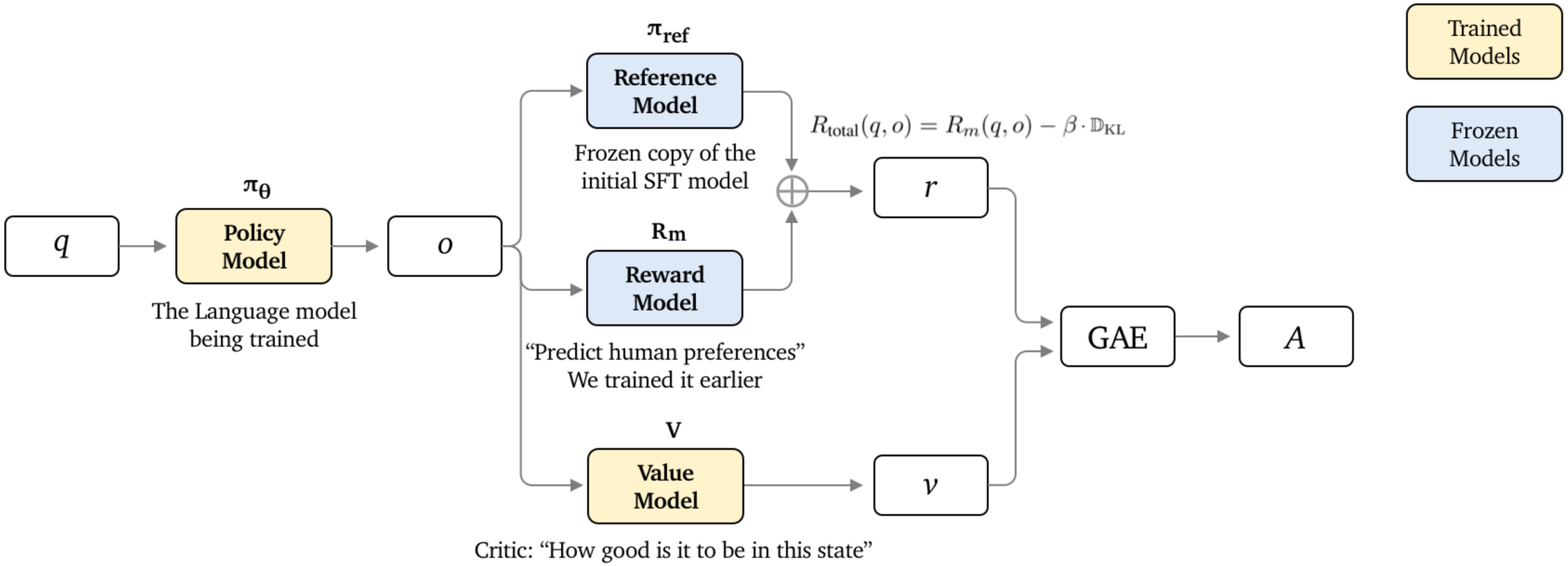

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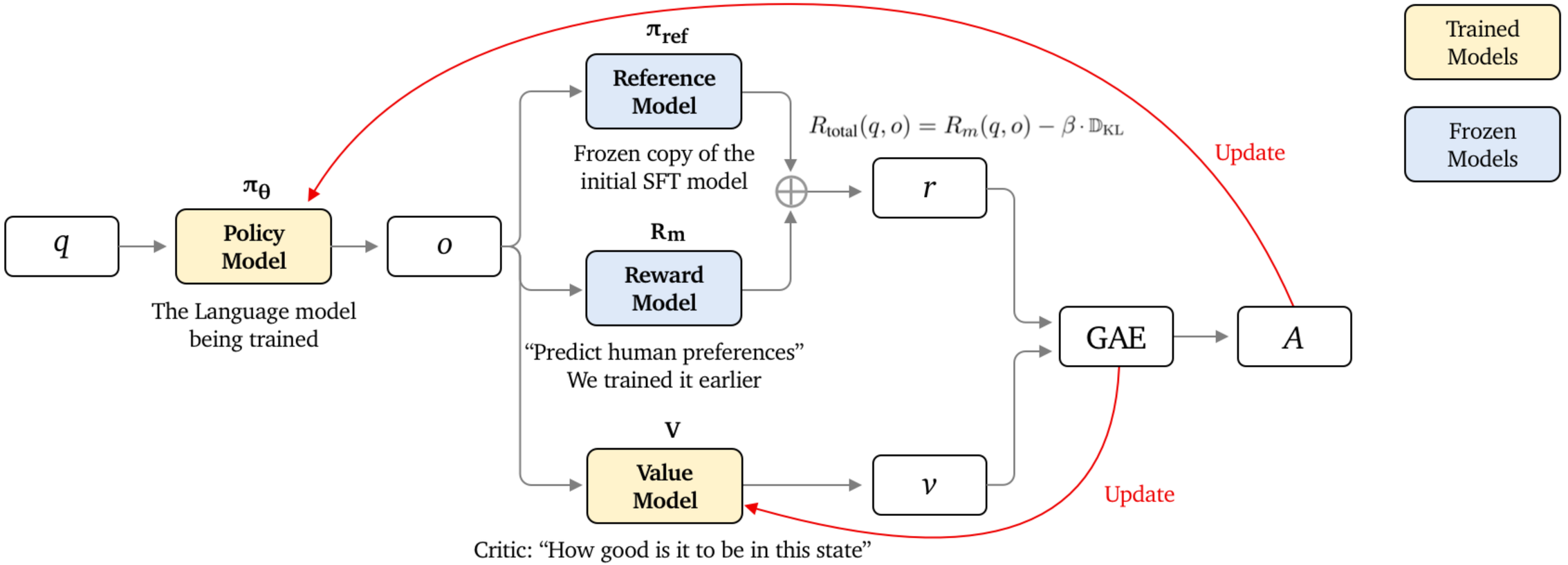

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Reinforcement Learning from Human Feedback

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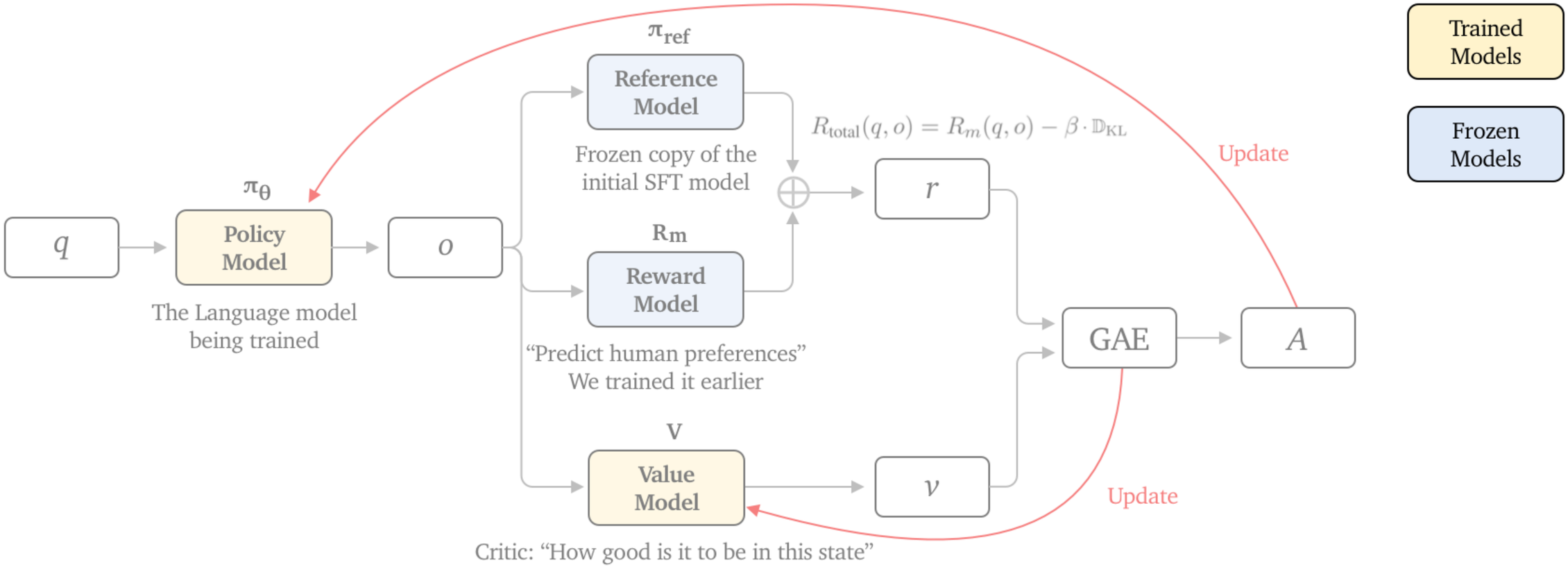

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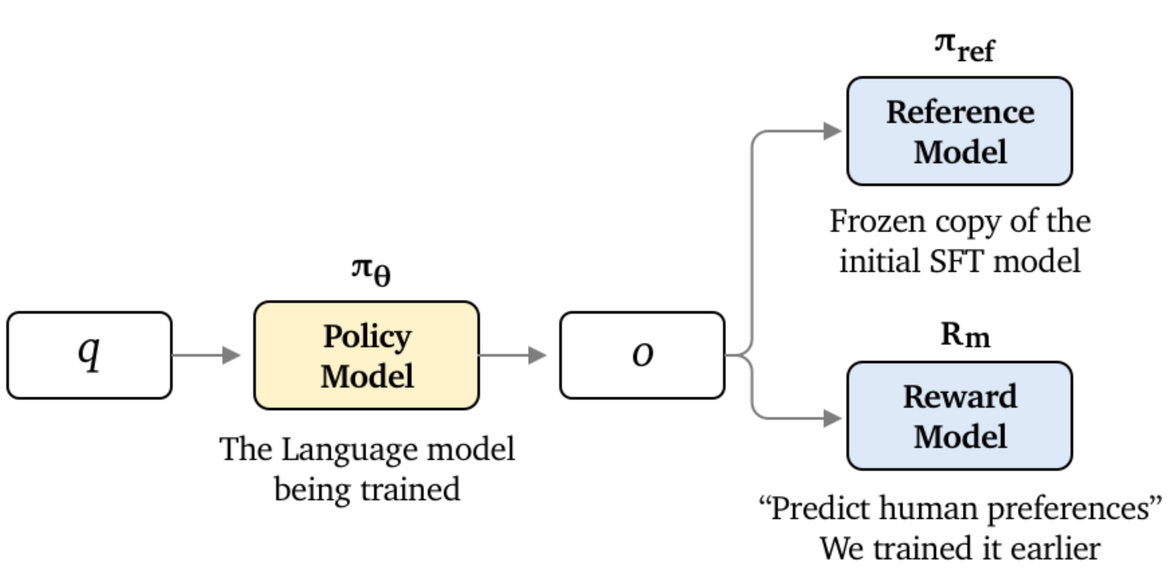

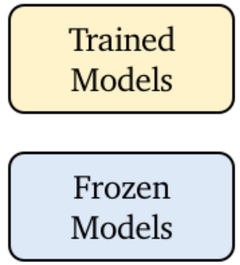

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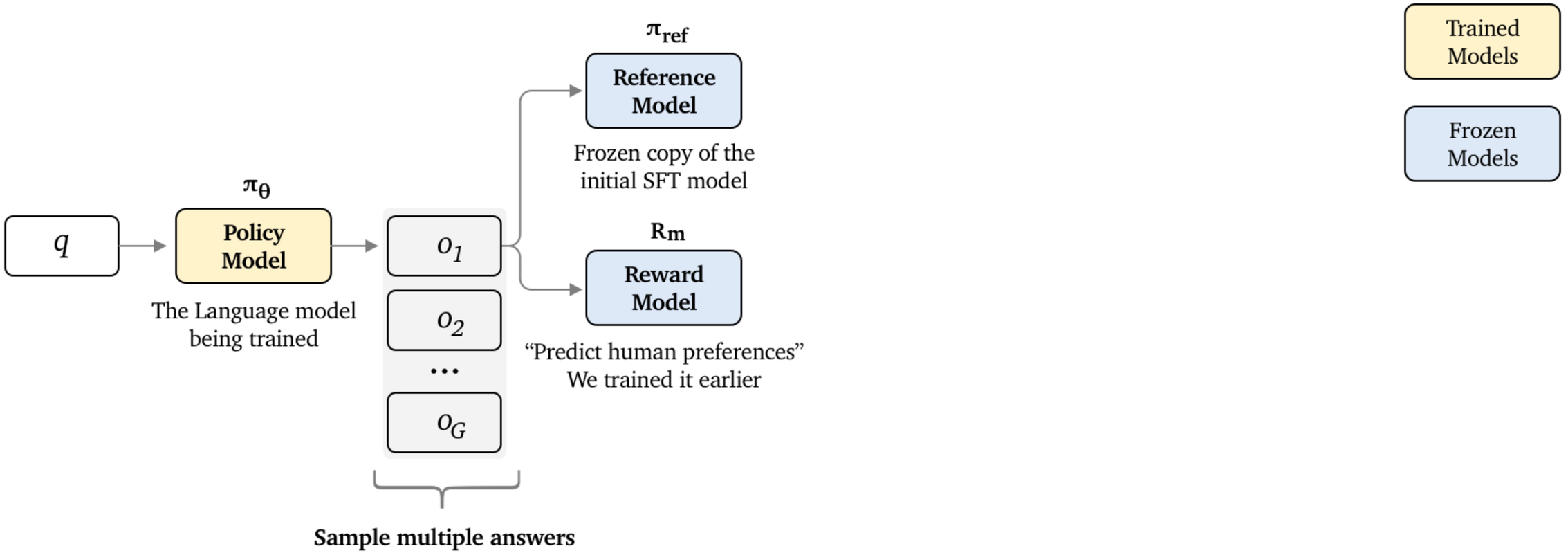

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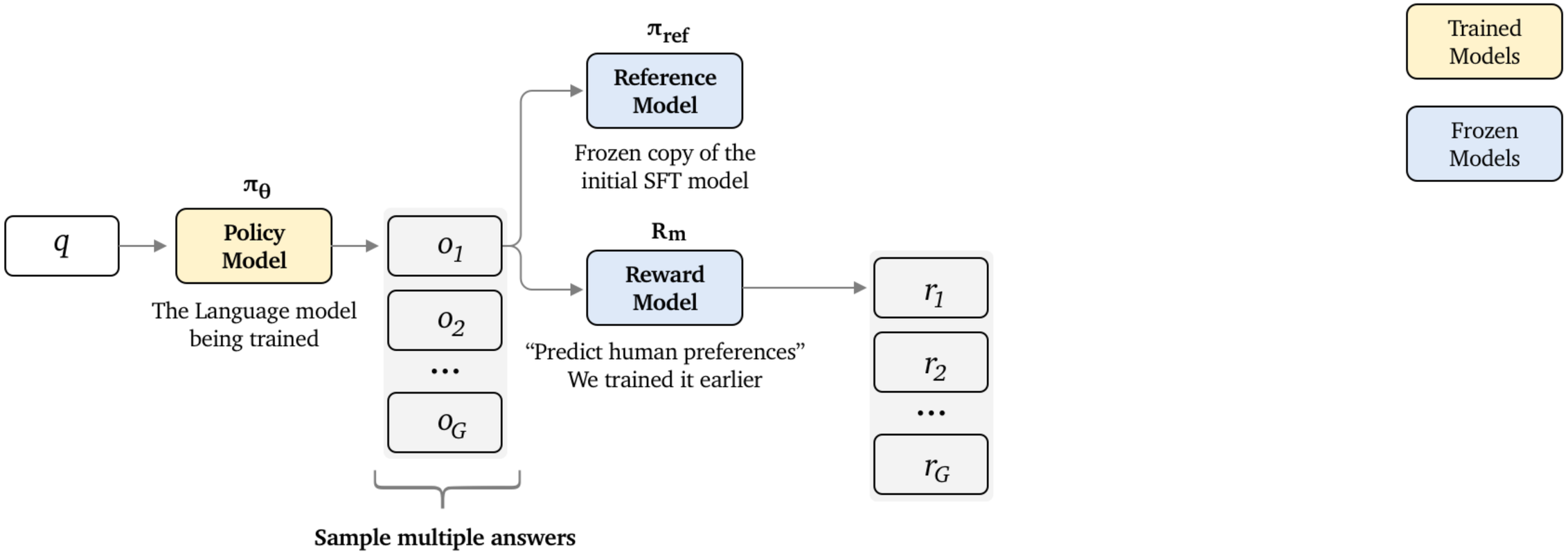

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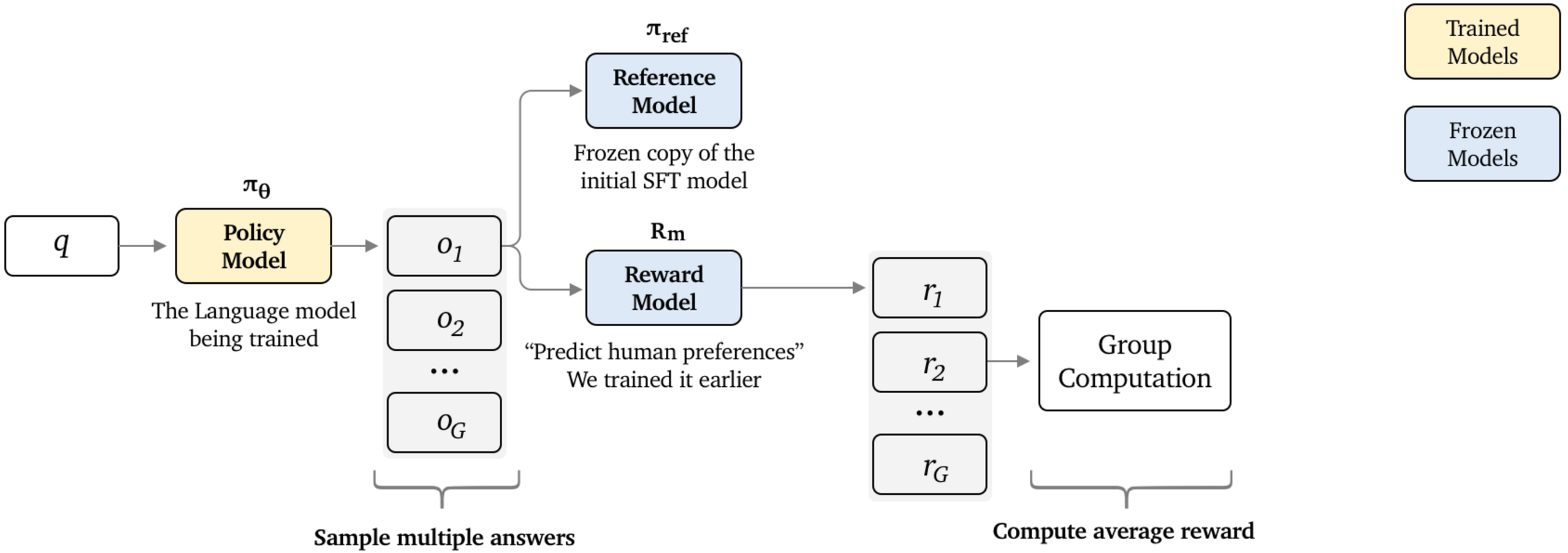

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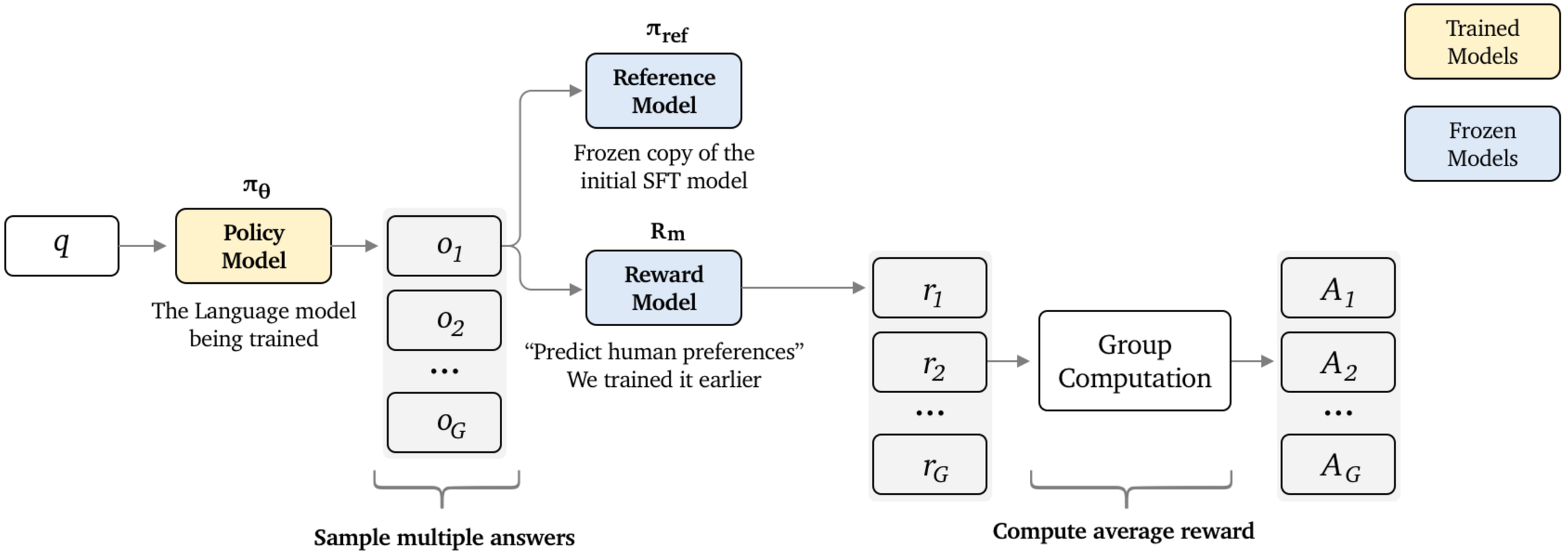

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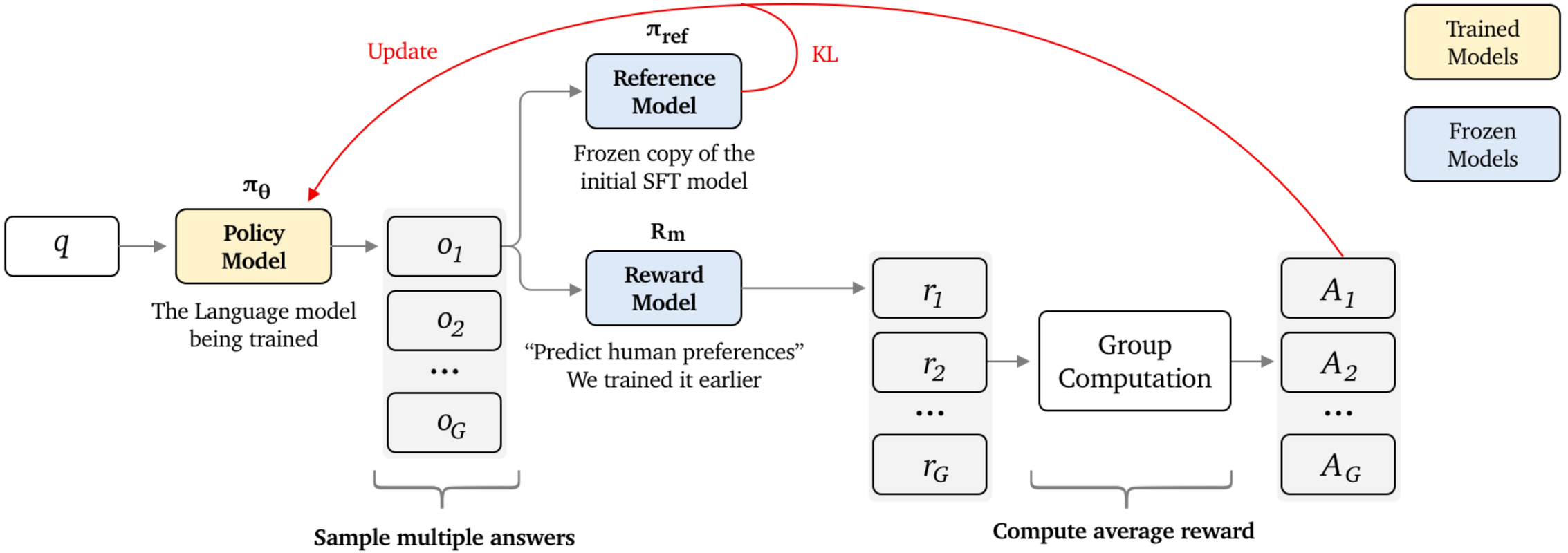

DeepSeekMath: Pushing the Limits of Mathematical Reasoning in Open Language Model

Alignment with RLHF Summary

- Reward model is central to the process
- PPO: Need a value model to calculate advantage
- GRPO: No value model (less GPU memory), use group average for advantage

Test-time Compute

Test-time Compute

- Neural Scaling Laws: how does performance (test error) change with
  - ✦ Compute
  - ✦ Dataset size
  - ✦ Number of parameters

“Scaling Laws for Neural Language Models”, 2020
https://www.youtube.com/watch?v=5eqRuVp65eY

Test-time Compute

- Neural Scaling Laws: how does performance (test error) change with
  - ✦ Compute
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- Finding: “Performance has a power-law relationship with each of the three scale factors”

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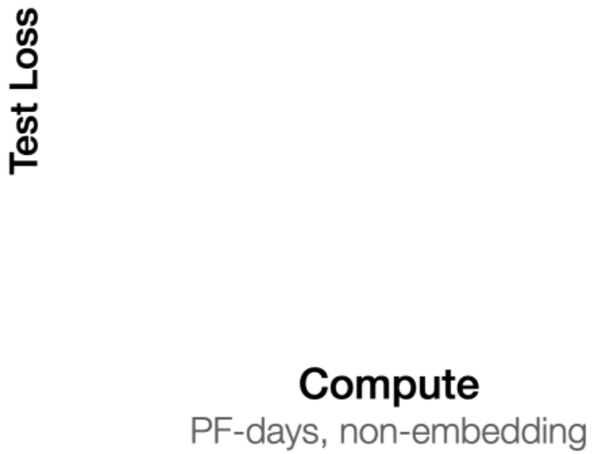
Test-time Compute

- “Performance has a power-law relationship with each of the three scale factors”



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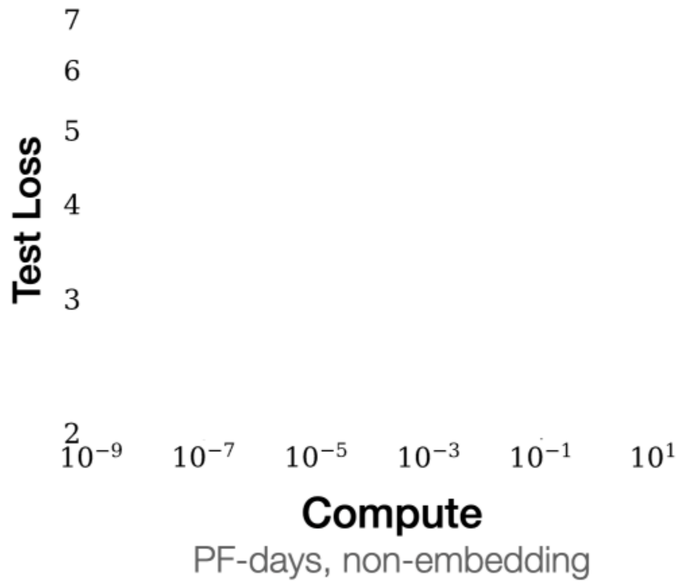
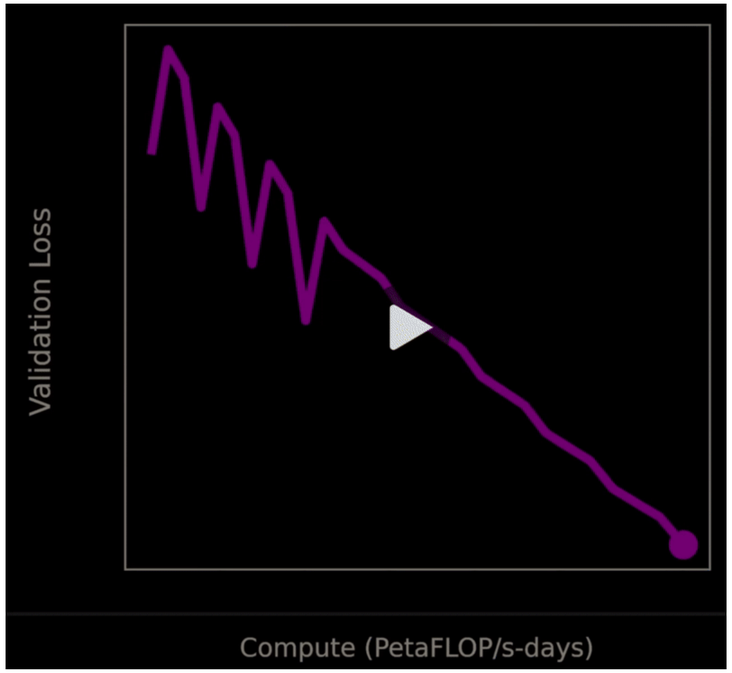
Test-time Compute

- “Performance has a power-law relationship with each of the three scale factors”





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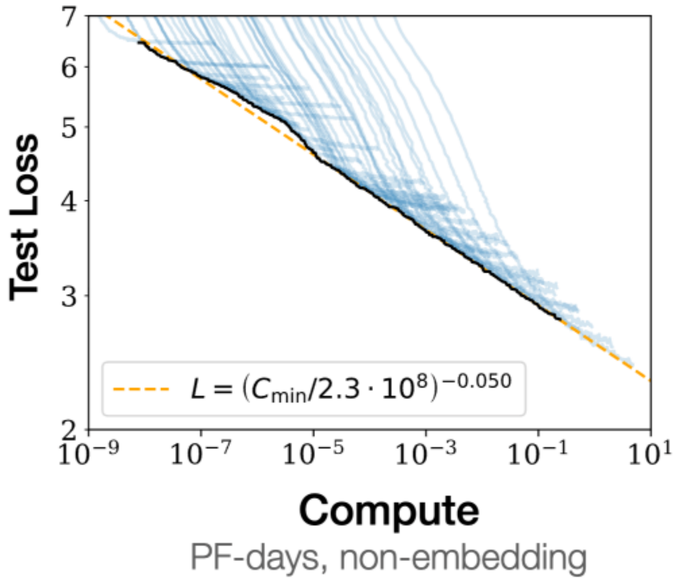

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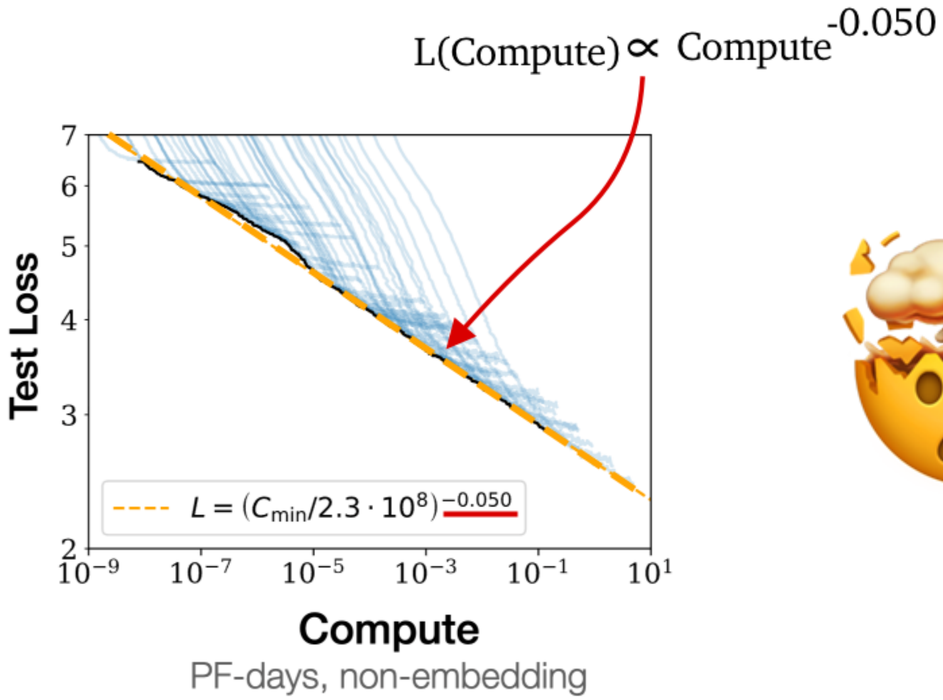
Test-time Compute

- “Performance has a power-law relationship with each of the three scale factors”



“Scaling Laws for Neural Language Models”, 2020
https://www.youtube.com/watch?v=5eqRuVp65eY

Test-time Compute

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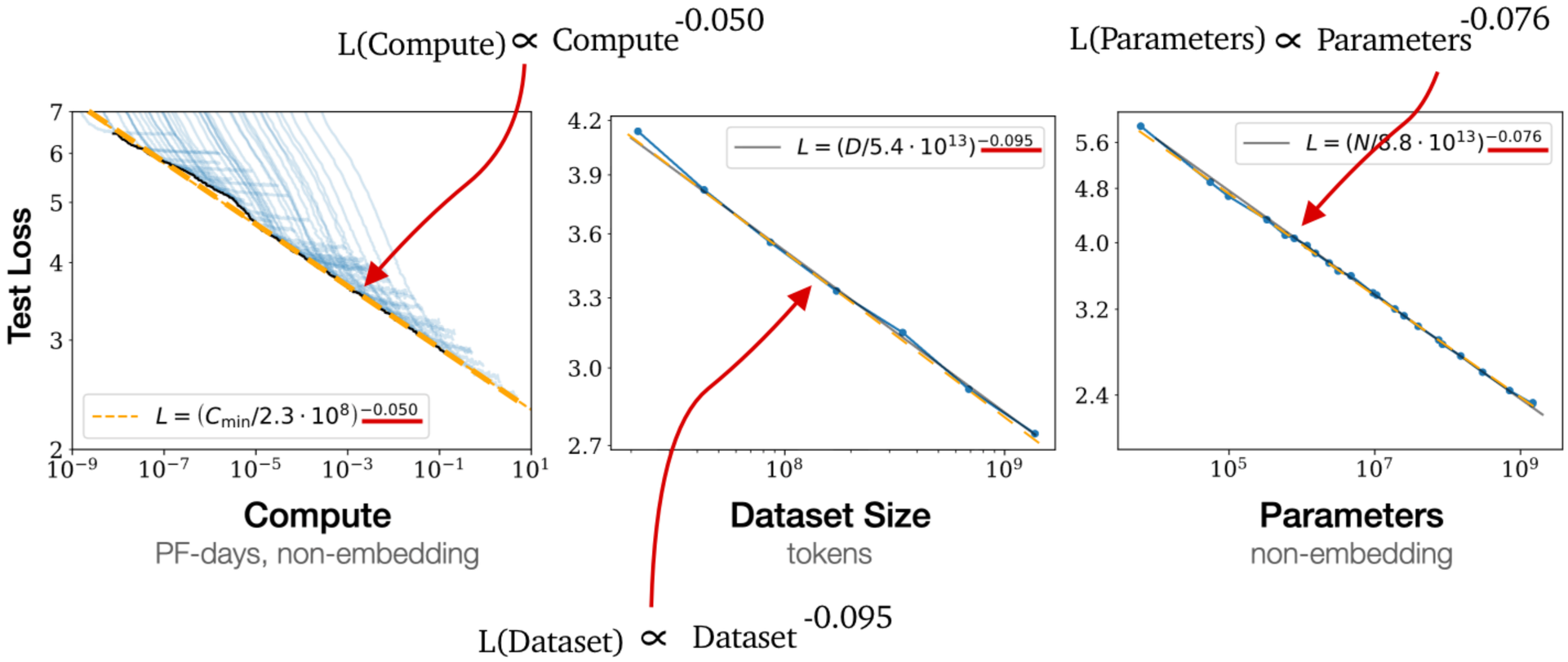

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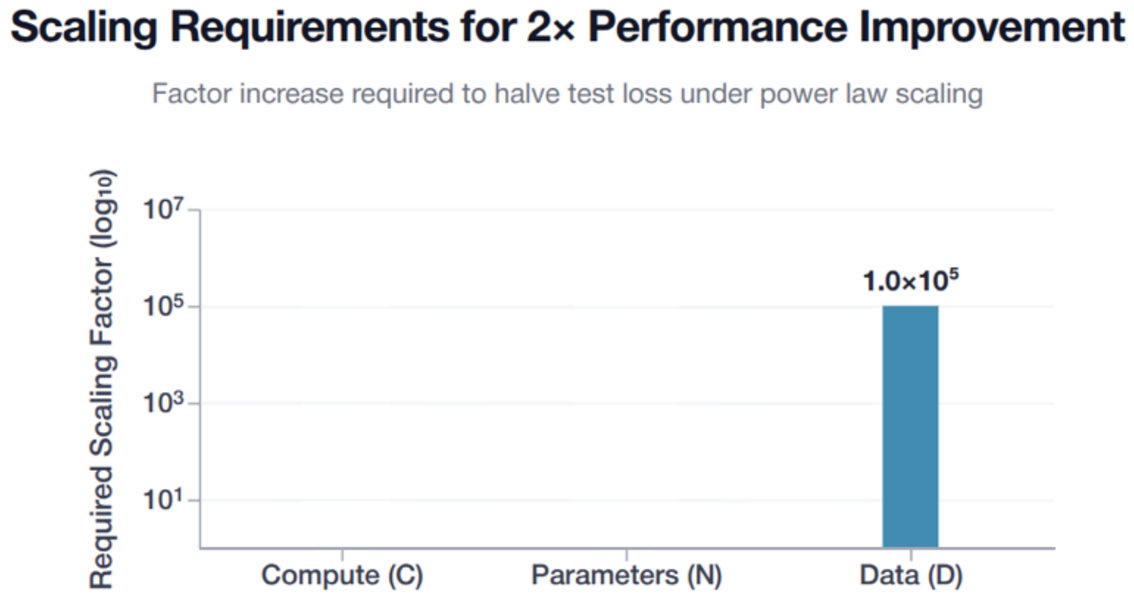
Test-time Compute

Computation at Scale > Algorithmic Breakthrough *

Test-time Compute (~3 years later)

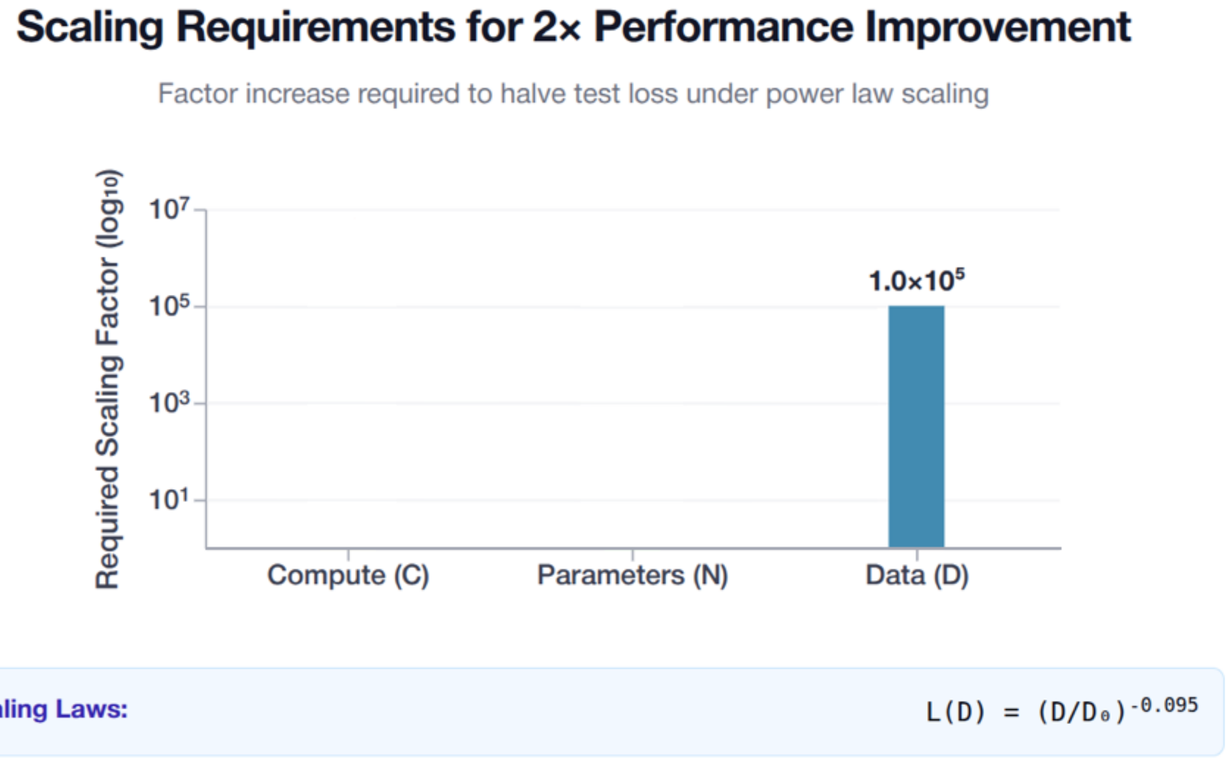
- But… napkin math



Scaling Laws: $L(D) = (D/D_0)^{-0.095}$

Test-time Compute (~3 years later)

- But… napkin math
- Useful tokens from internet ~10T tokens
- GPT-4 and Llama 3.1 ~ 15T tokens
- Increase that by 10^5 = 1.5 Quintillion



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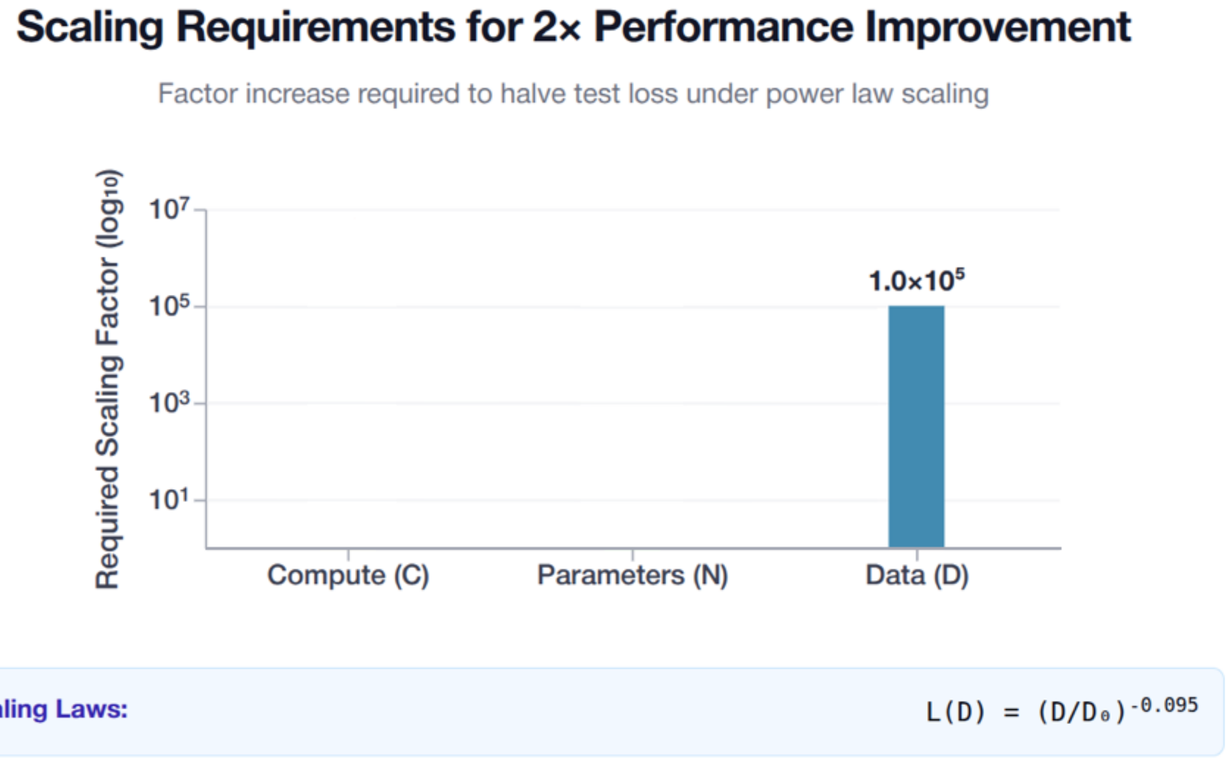
Test-time Compute (~3 years later)

- But… napkin math
- Useful tokens from internet ~10T tokens
- GPT-4 and Llama 3.1 ~ 15T tokens
- Increase that by 10^5 = 1.5 Quintillion

“the data is not growing,
we have but one internet”

“we have achieved peak data,
there will be no more”



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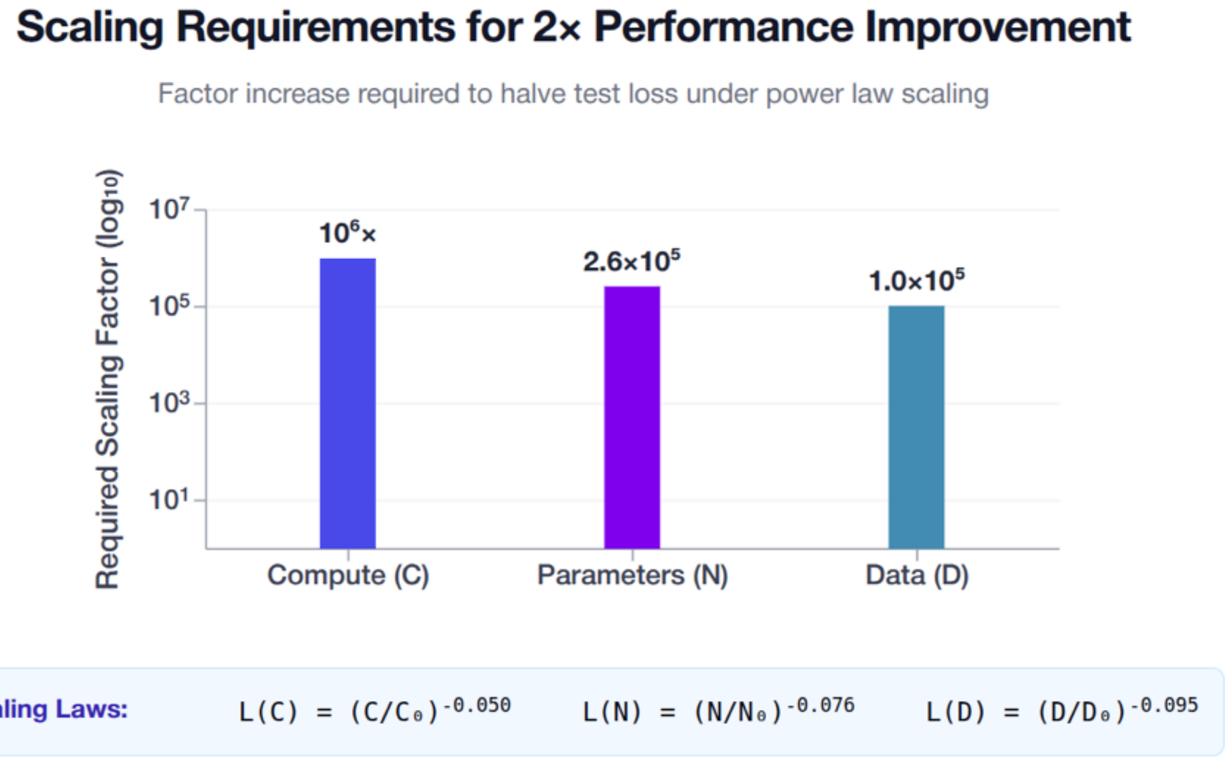
Test-time Compute (~3 years later)

- But… napkin math
- Scaling other dimensions, diminishing returns

“Intelligence scales with the log of compute”



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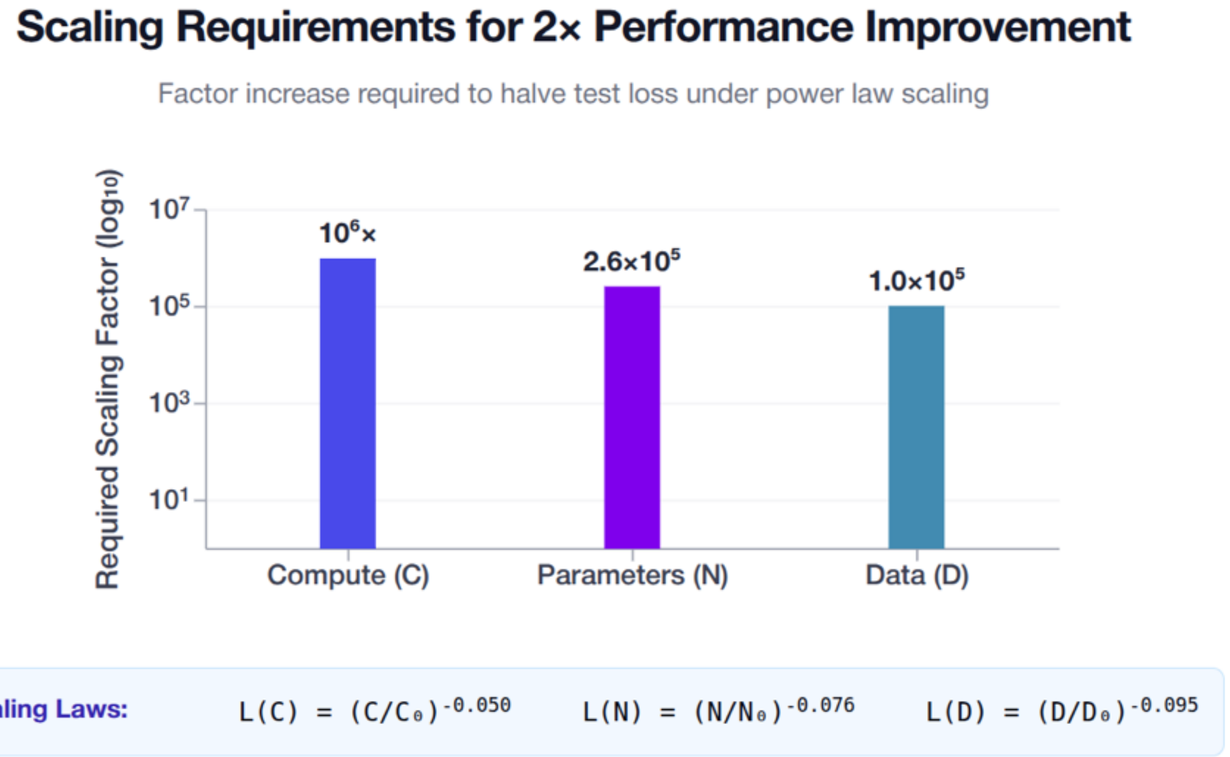
Test-time Compute (~3 years later)

- But… napkin math
- Scaling other dimensions, diminishing returns

“Intelligence scales with the log of compute”

“The age of pre-training scaling has ended”

“Deep learning has hit a wall”



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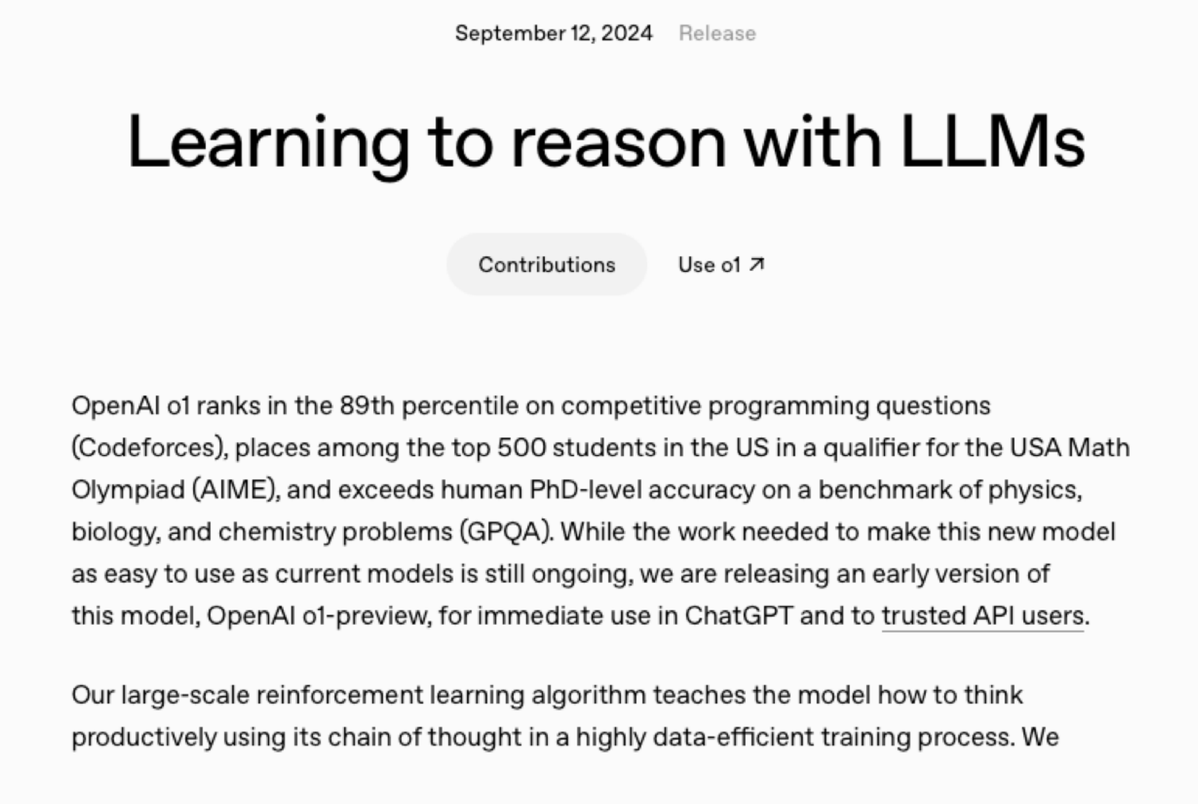
Test-time Compute

- Until… RL to the rescue

Test-time Compute

- OpenAI o1, a new kind of model: “*Spend more time thinking before they respond*”
- *“Can reason through complex tasks and solve harder problems than previous models”*



https://openai.com/index/introducing-openai-o1-preview/

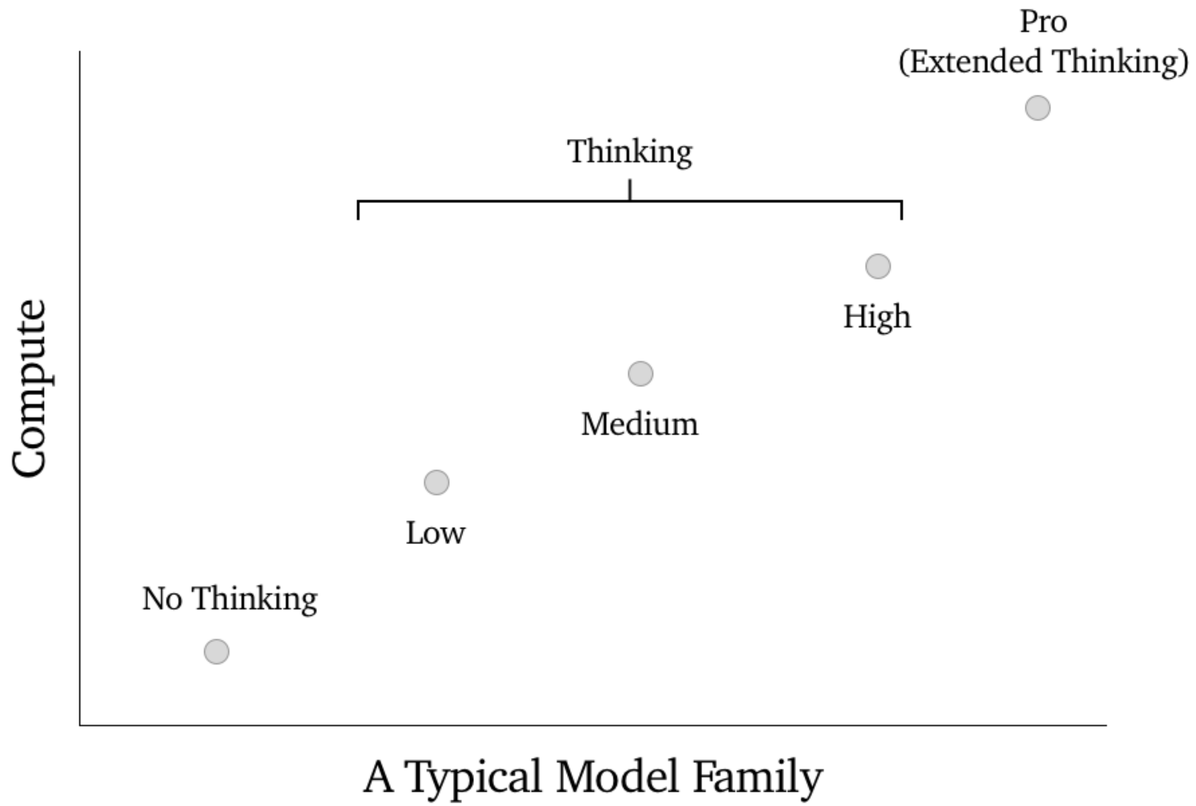
Test-time Compute

- OpenAI o1, a new kind of model: “*Spend more time thinking before they respond*”
- *“Can reason through complex tasks and solve harder problems than previous models”*
- A new scaling law:

“**Performance scales with the amount of compute applied during generation of an answer**”

https://openai.com/index/introducing-openai-o1-preview/

Test-time Compute



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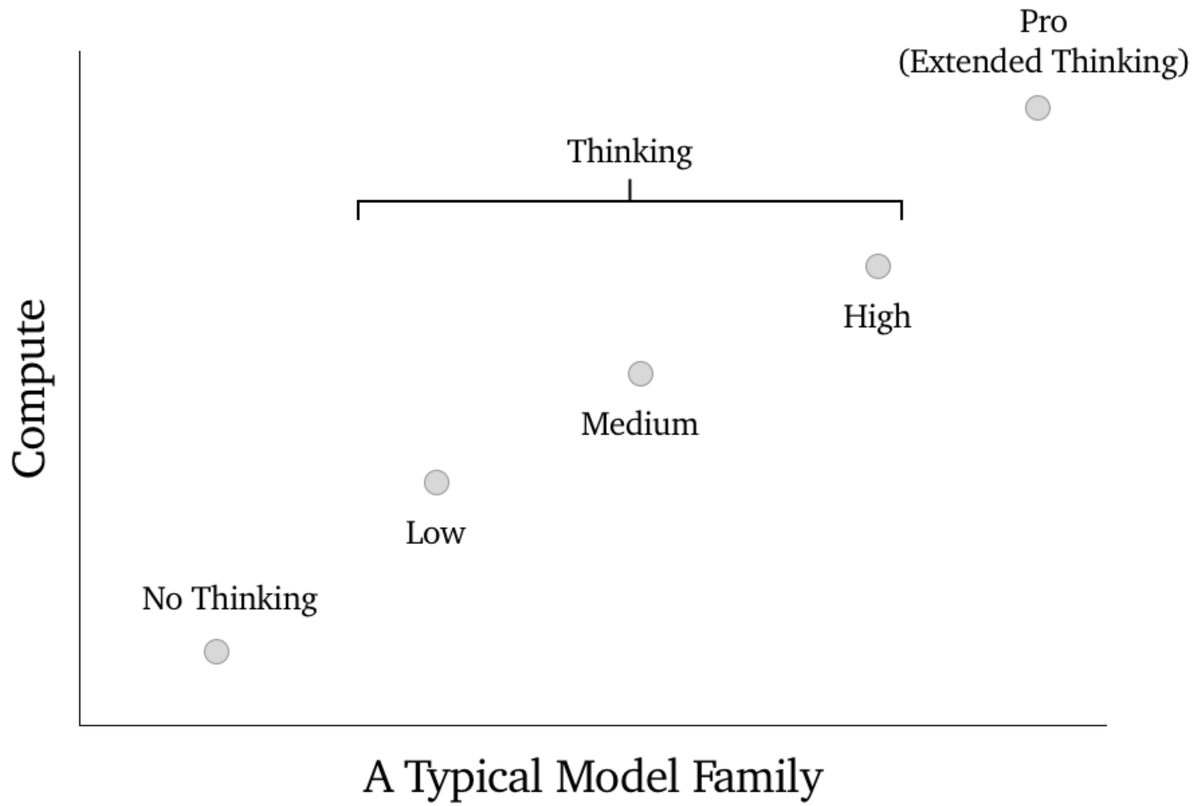
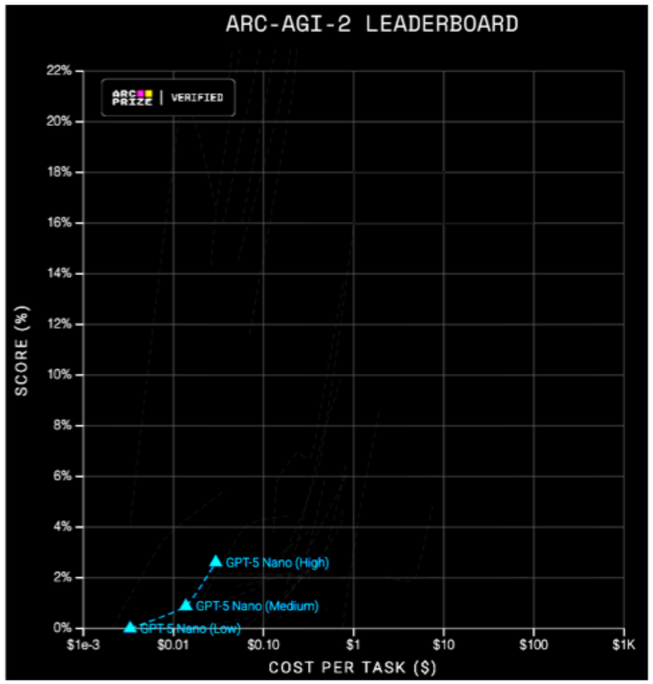
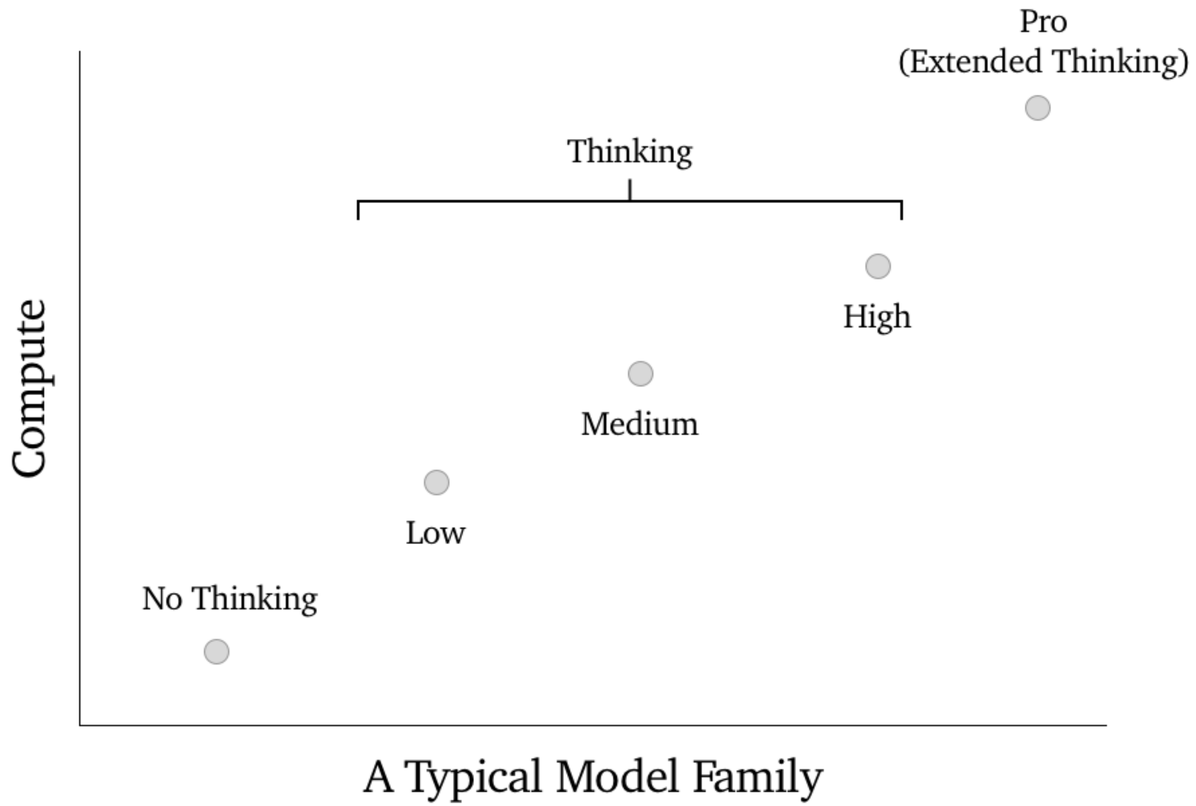
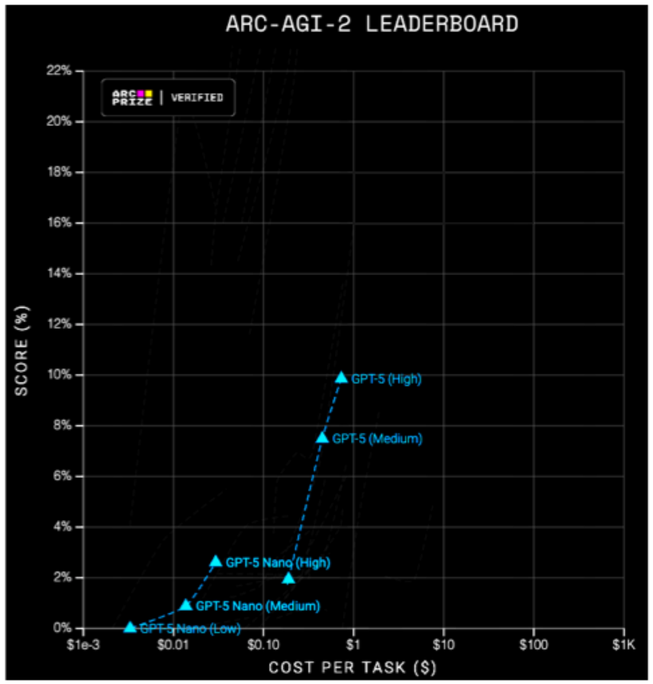




https://arcprize.org/leaderboard

Test-time Compute





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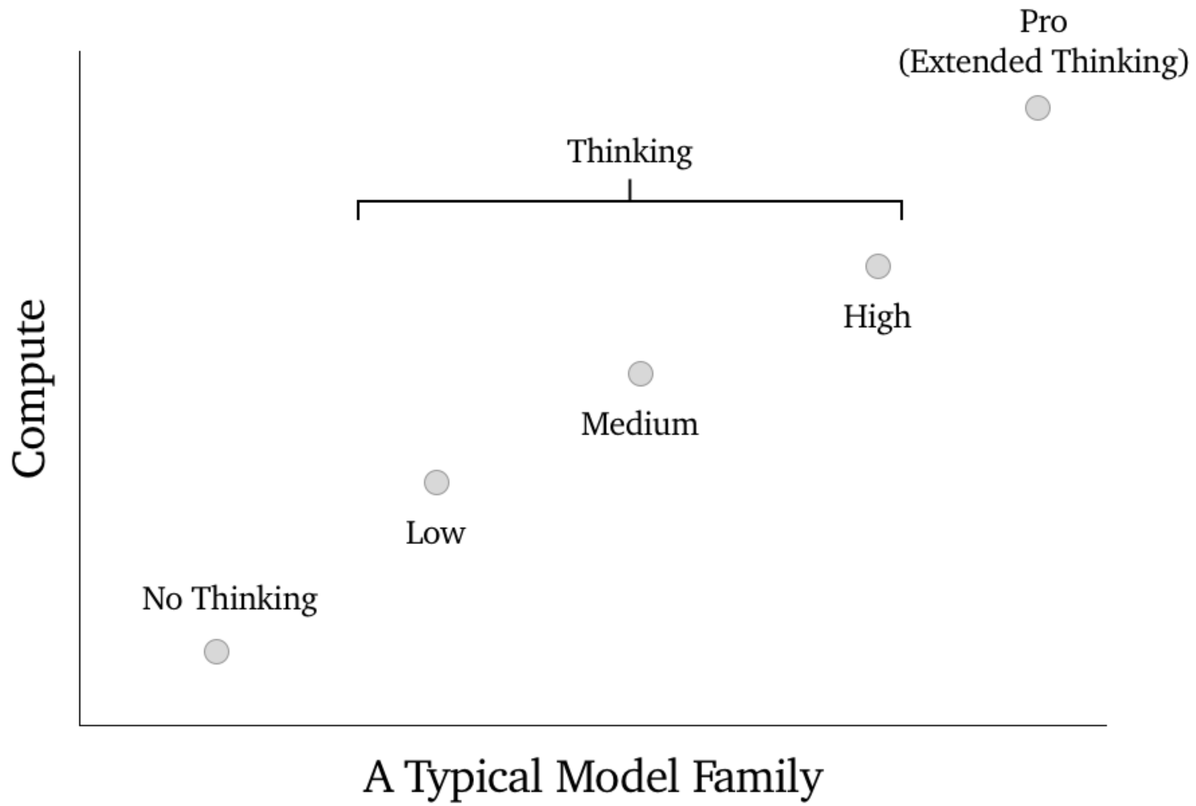

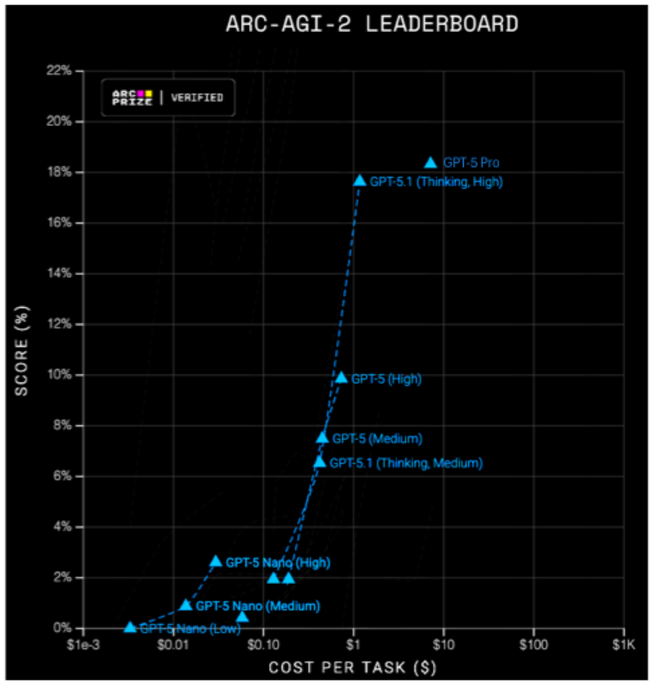

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Test-time Compute

- But where is the RL?

Test-time Compute

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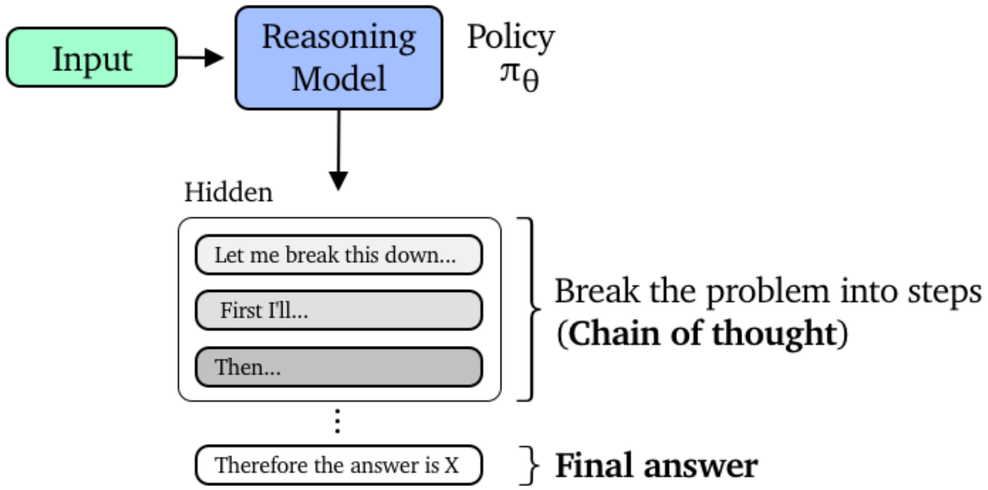

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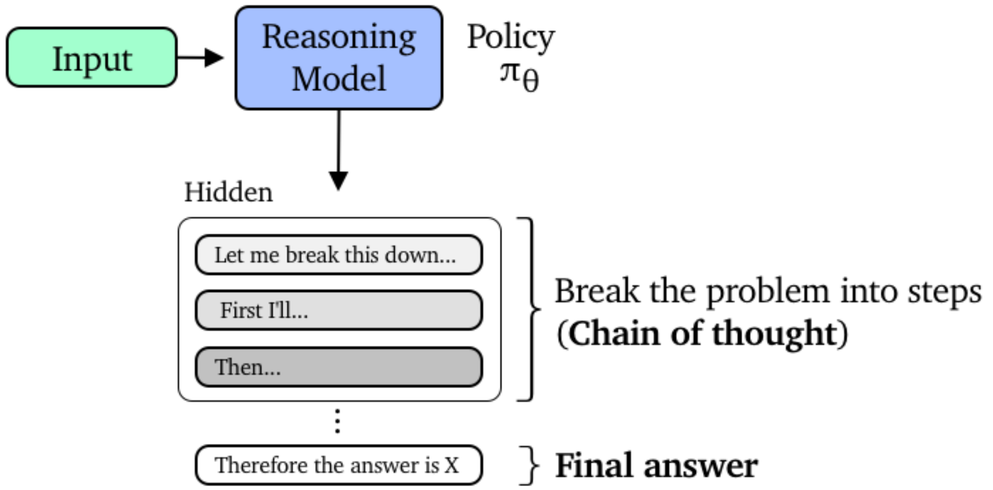
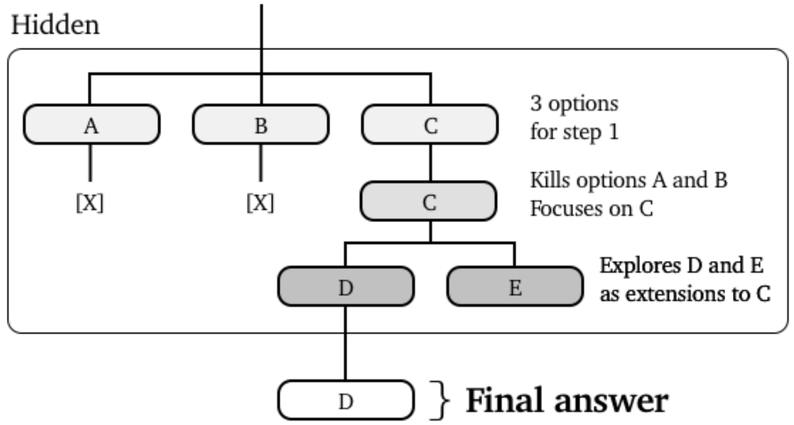


Branches into multiple possibilities (**Tree of thought**)

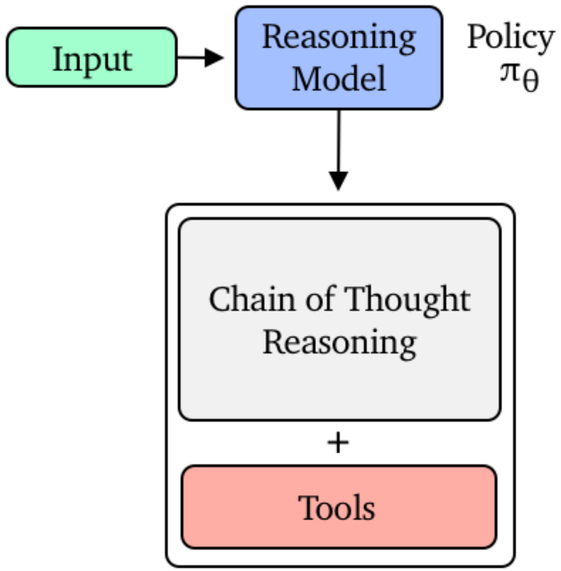


More complex traces (**Graph of thought**)

- Self-correction
- Merge
- Backtrack

Test-time Compute

- But where is the RL?



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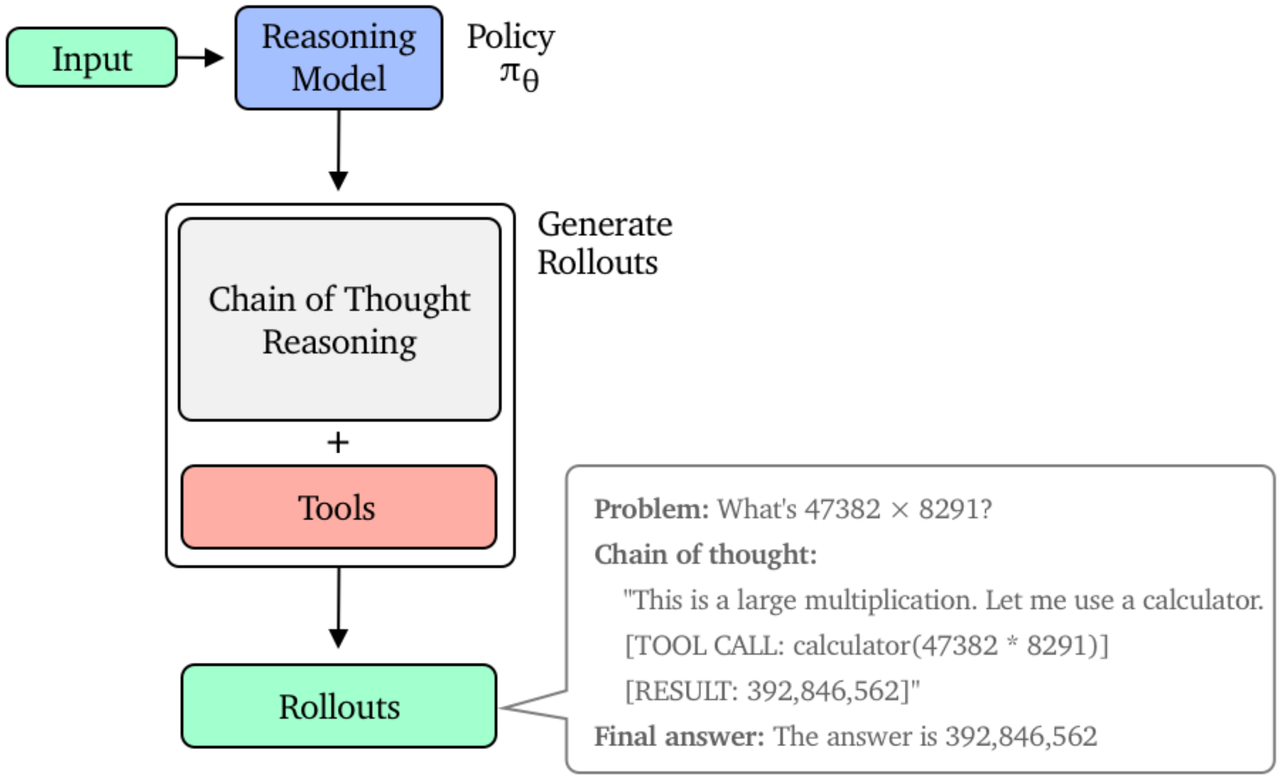

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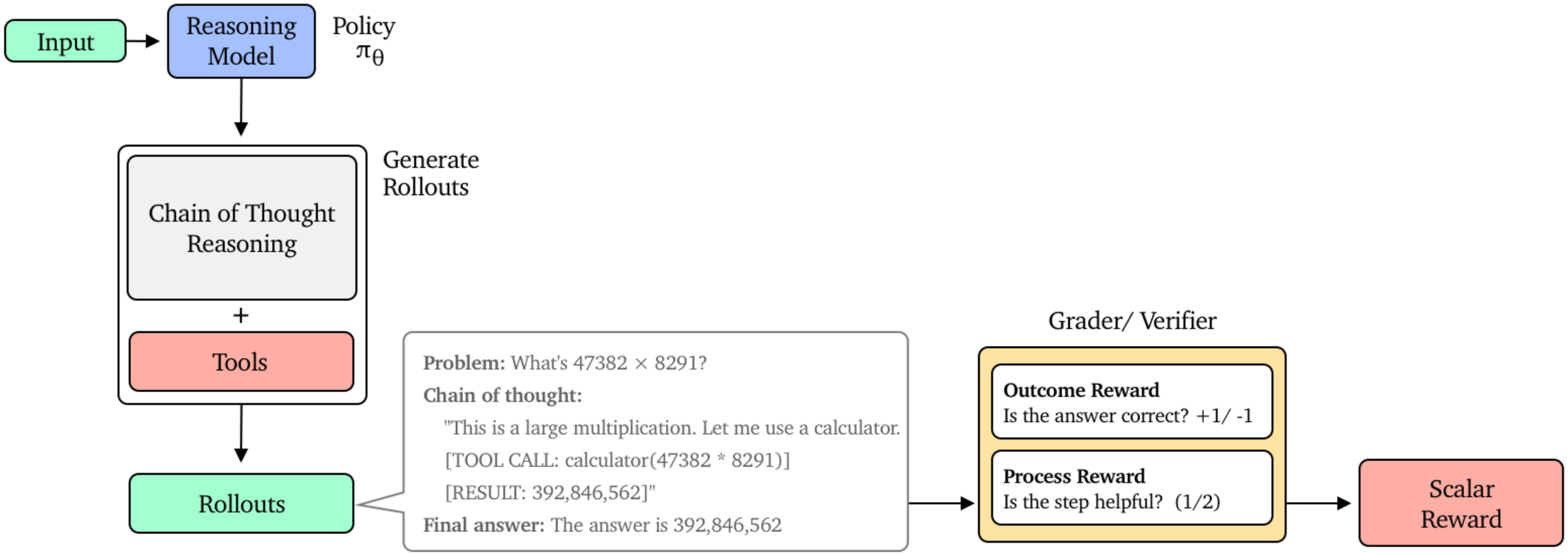

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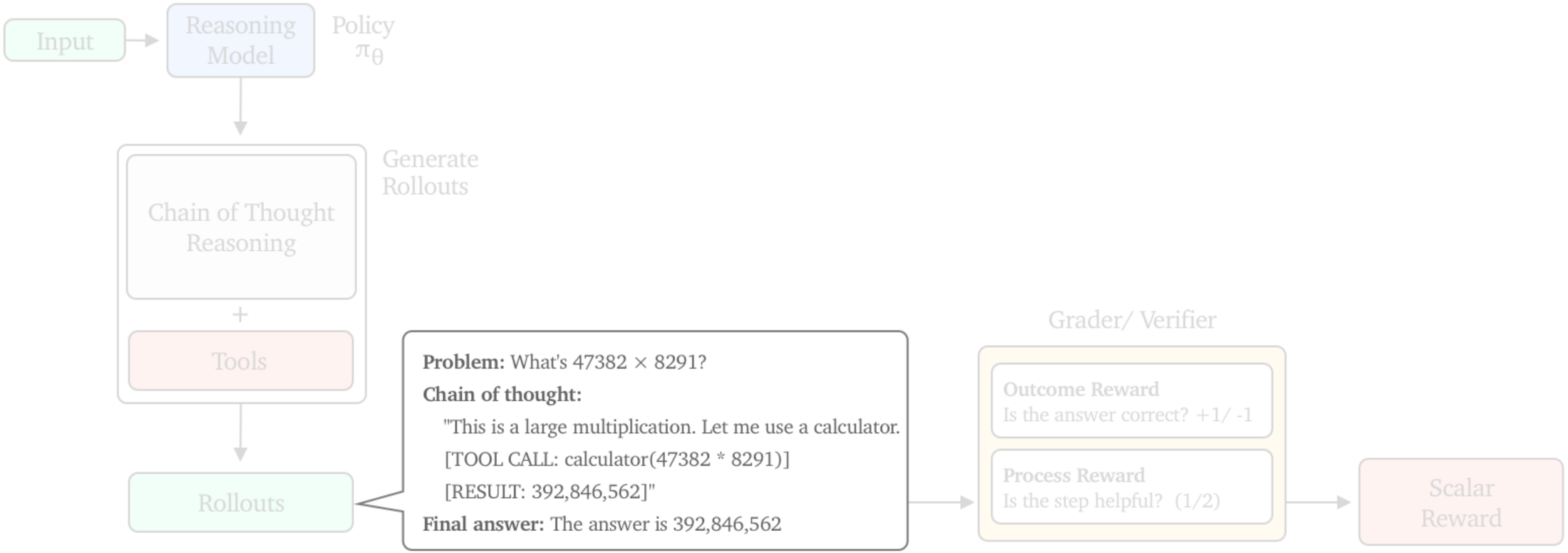

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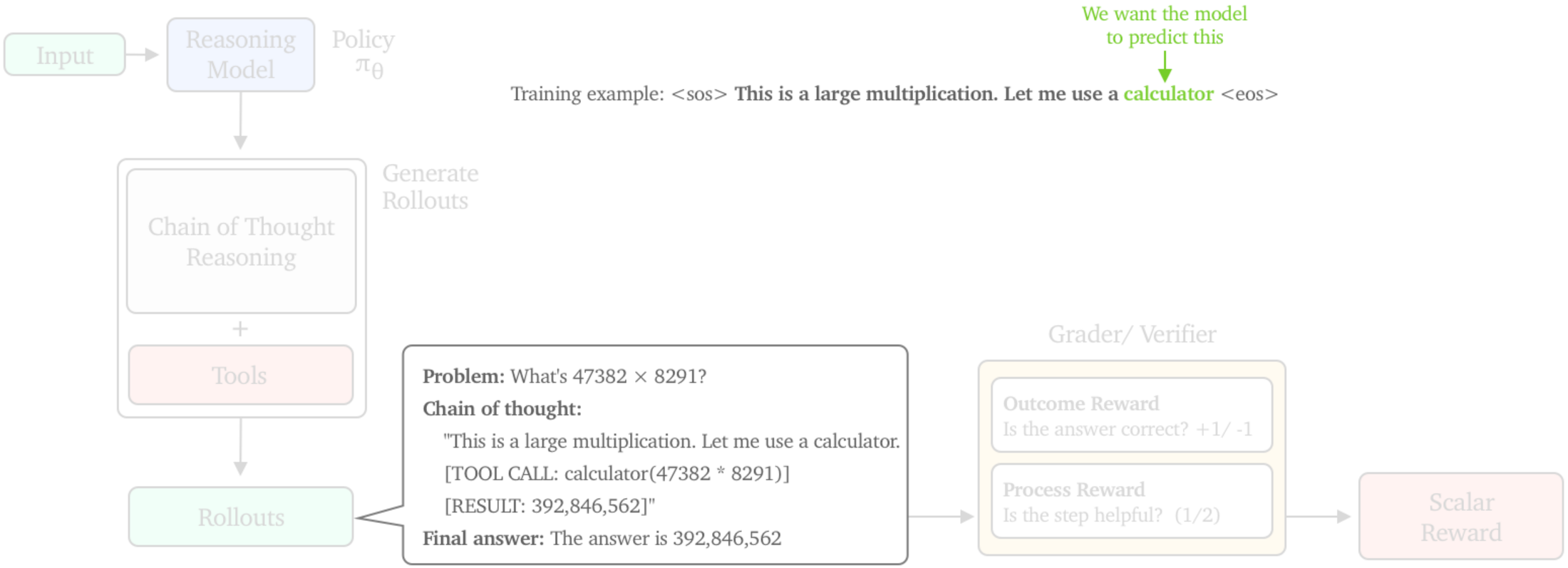

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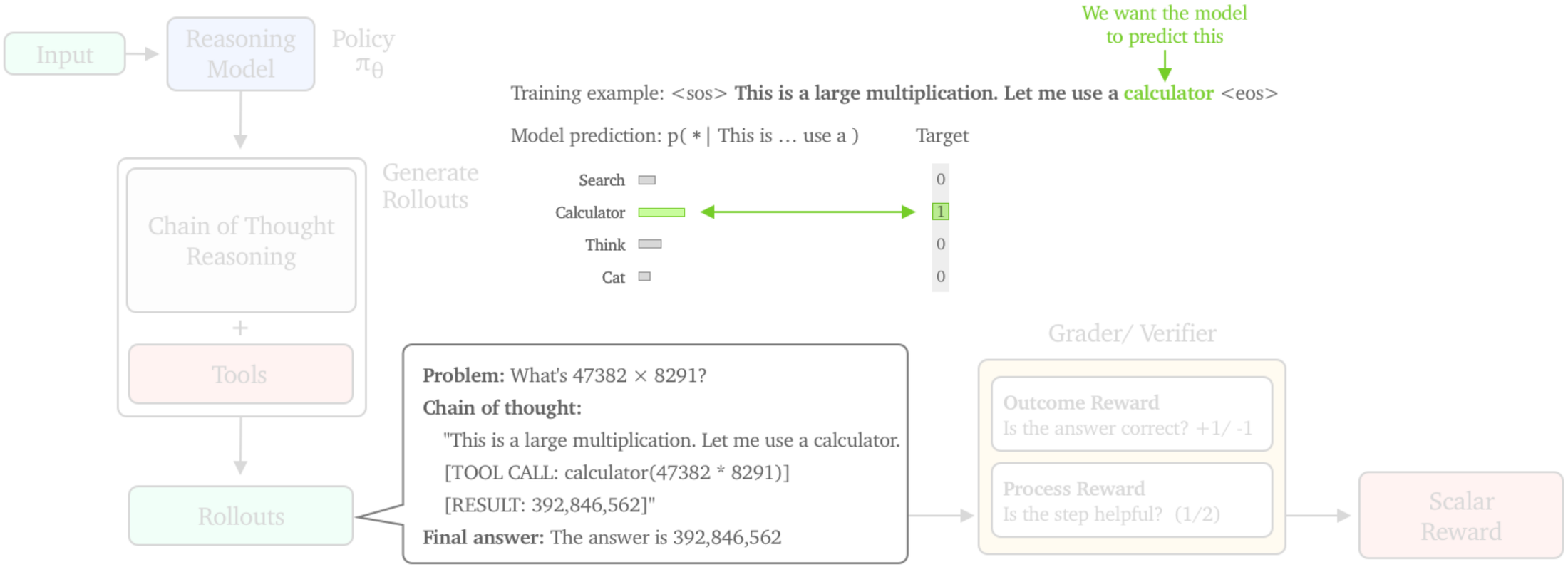

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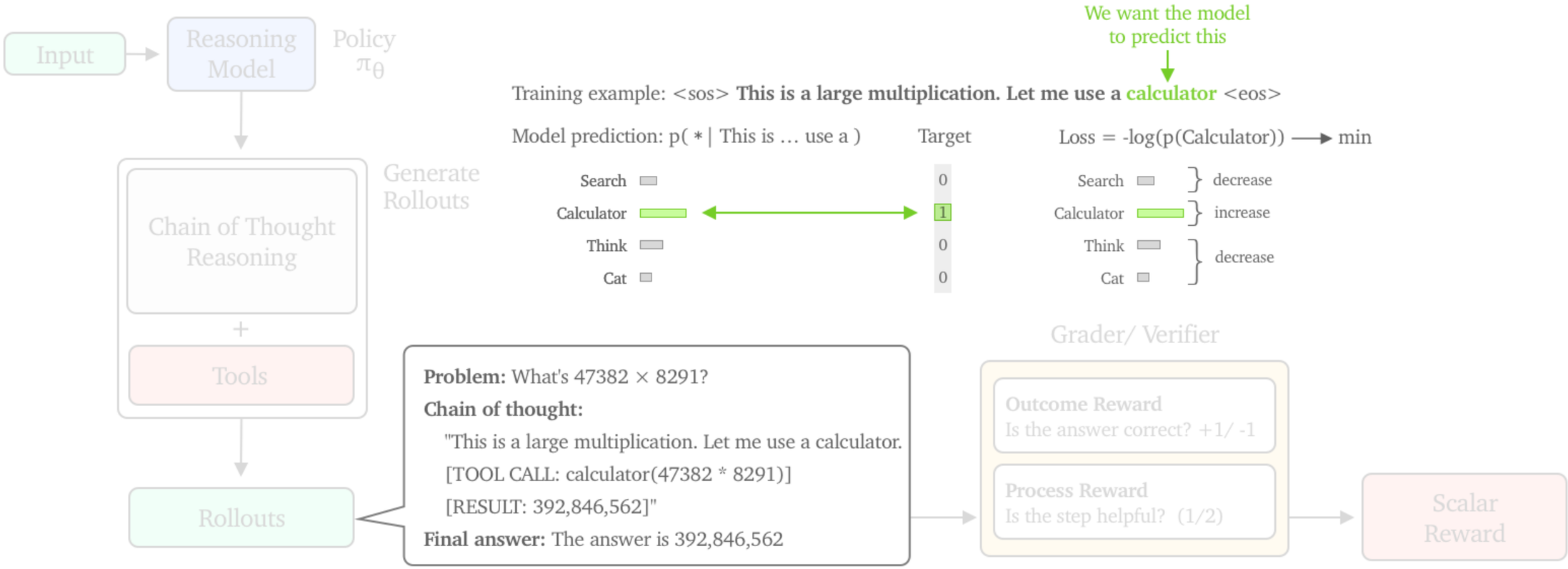

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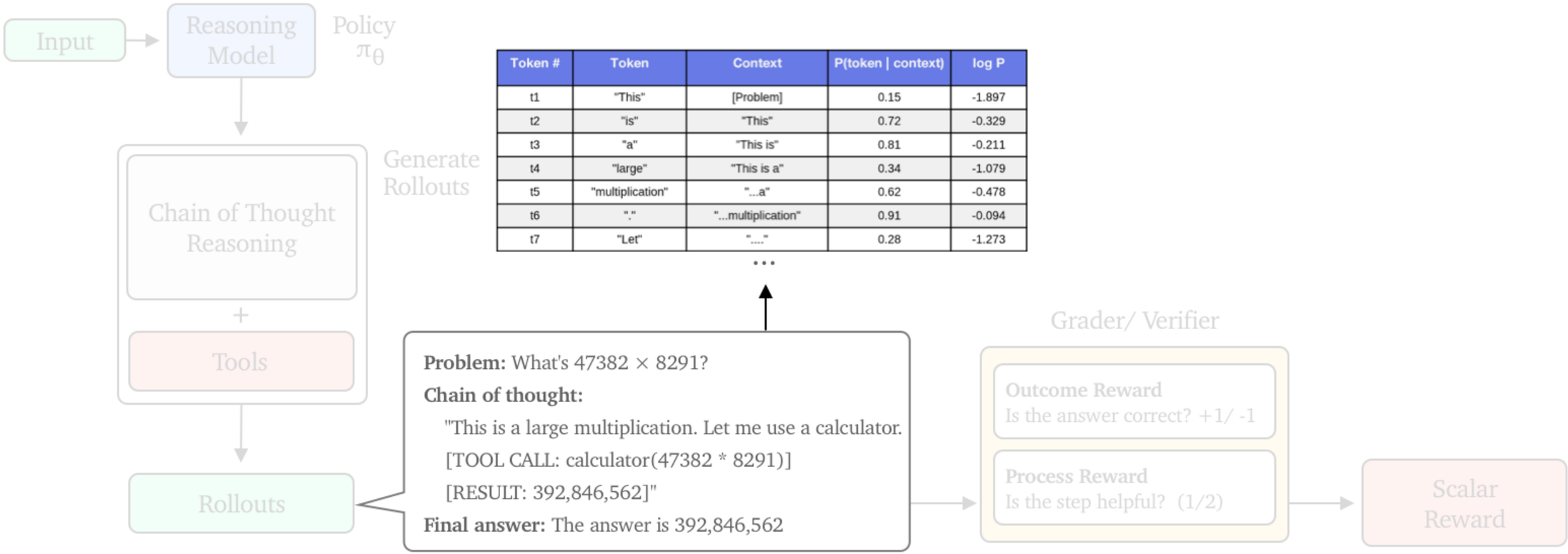

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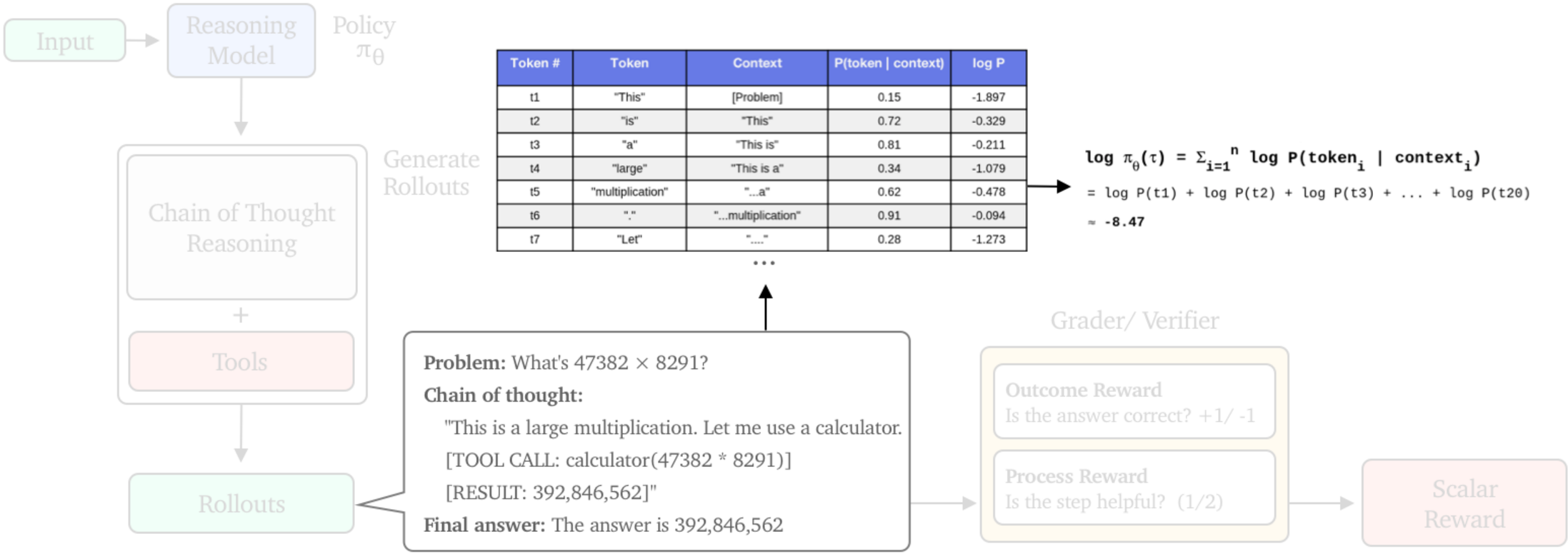

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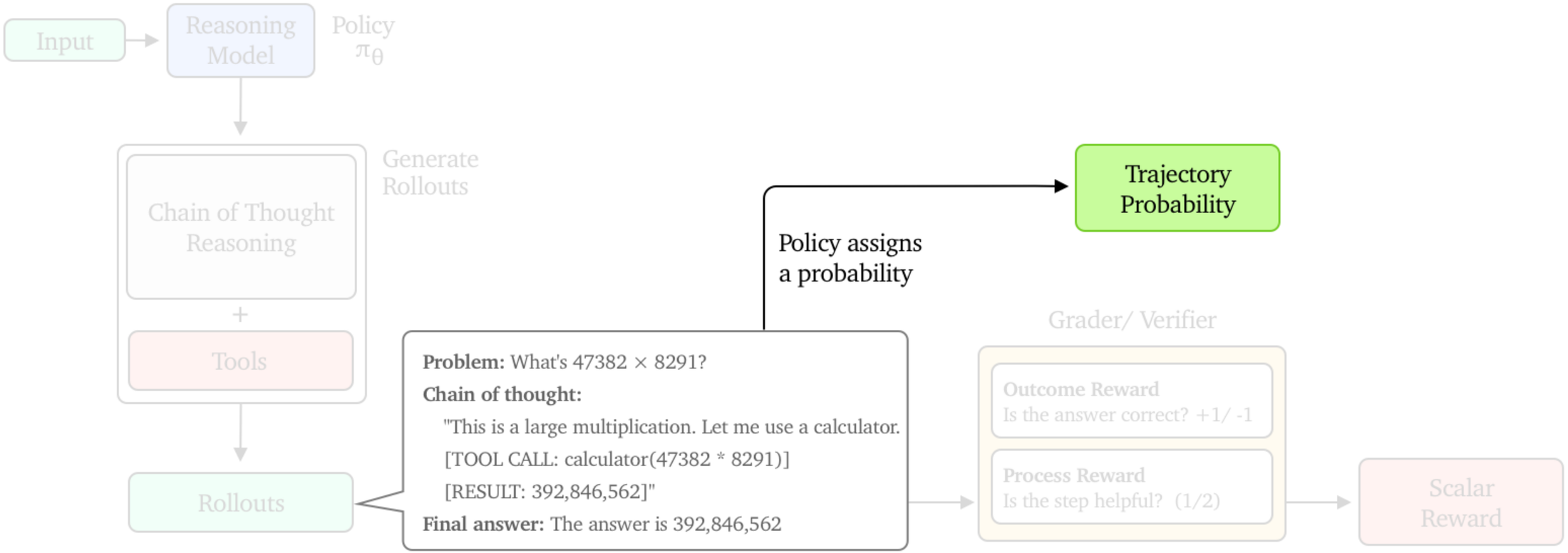

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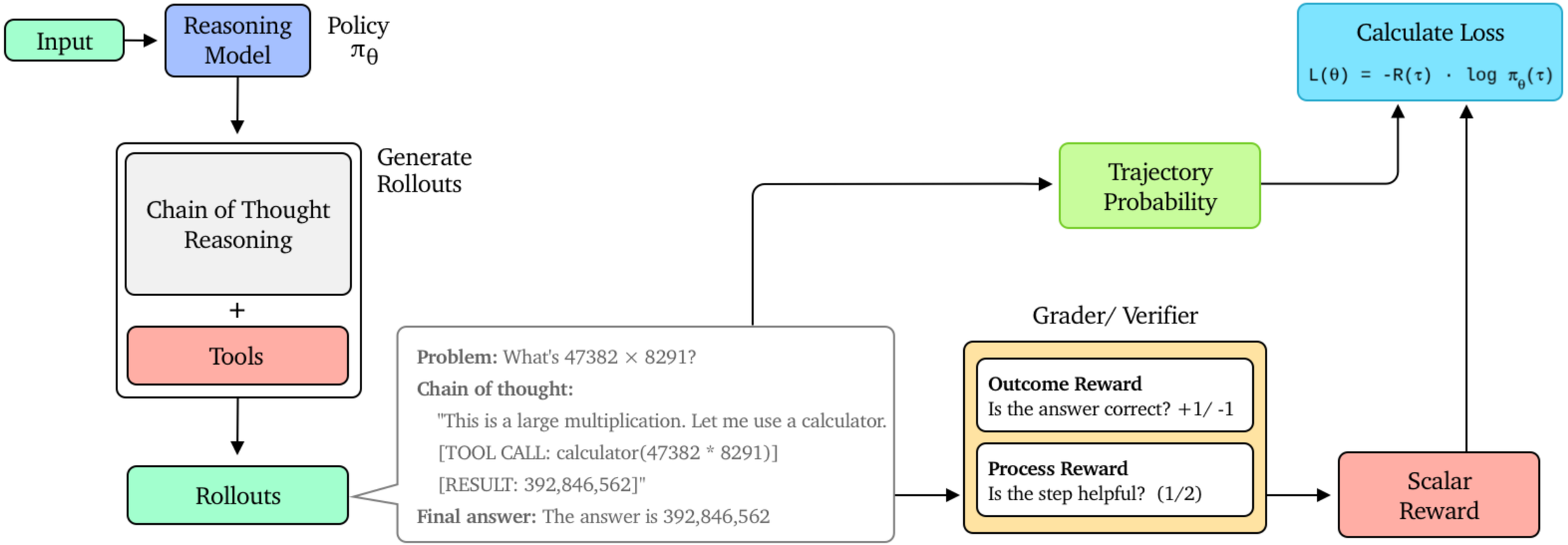

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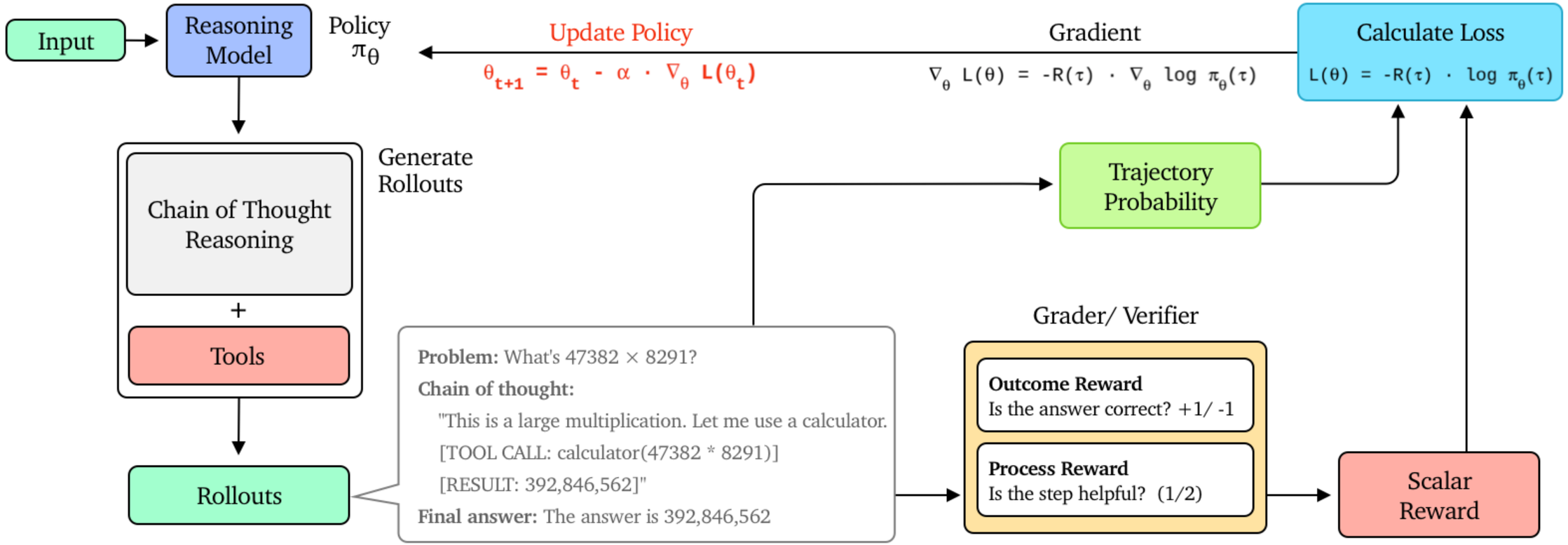

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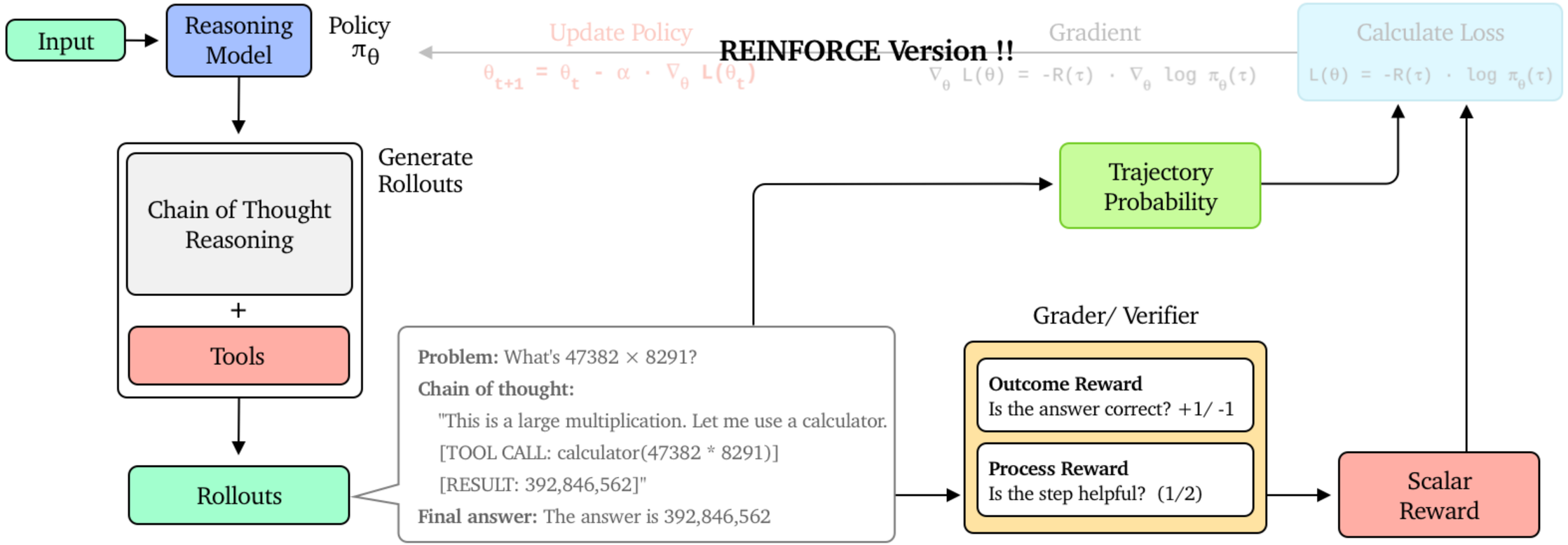
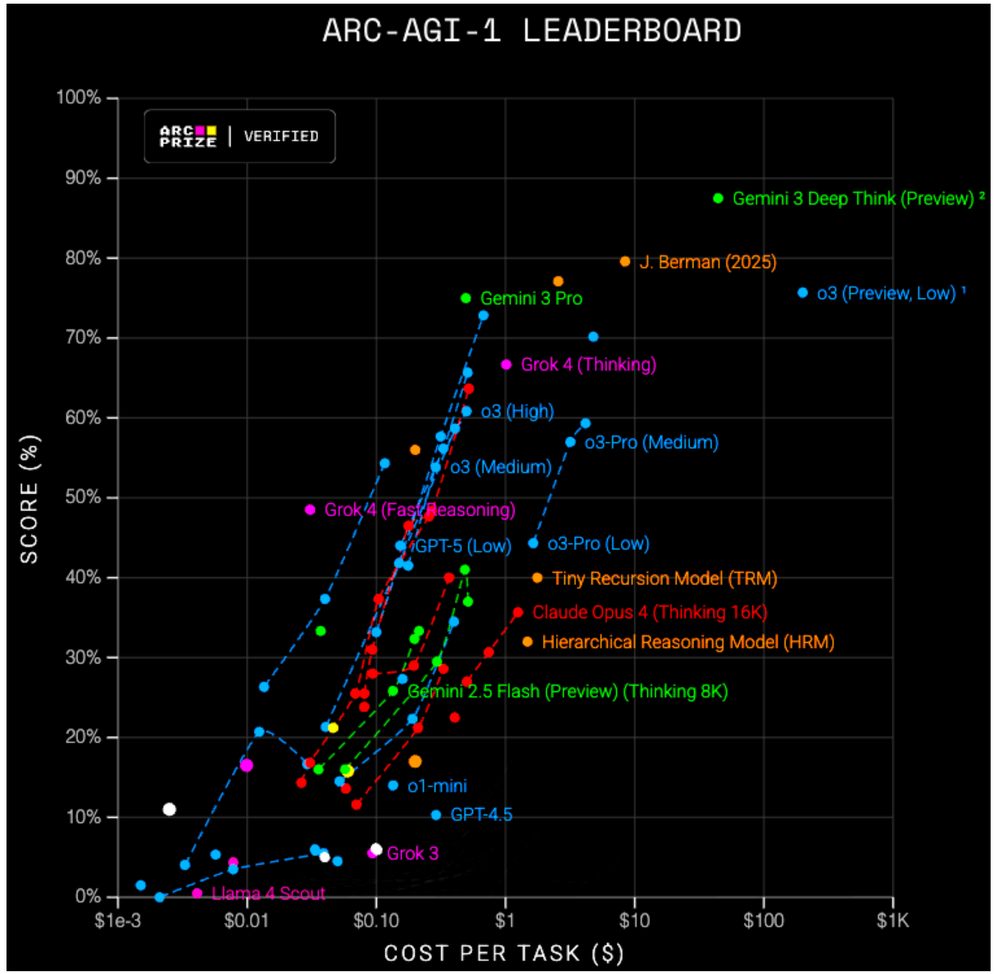


Test-time Compute Summary

- RL can be used to reinforce the thinking process of models
- Using REINFORCE, PPO, GPRO algorithms

Test-time Compute Summary

- RL can be used to reinforce the thinking process of models
- Using REINFORCE, PPO, GPRO algorithms
- Does it work?



Thank You!