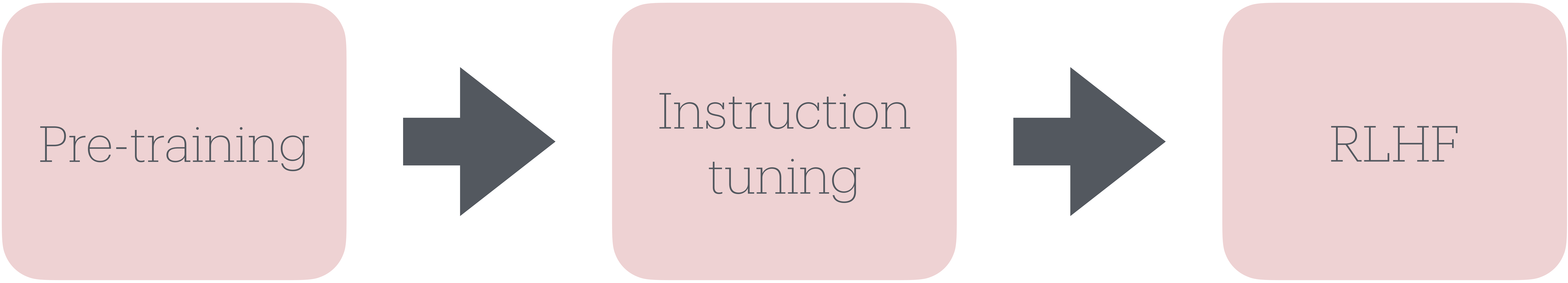
DPO

Direct Preference Optimization

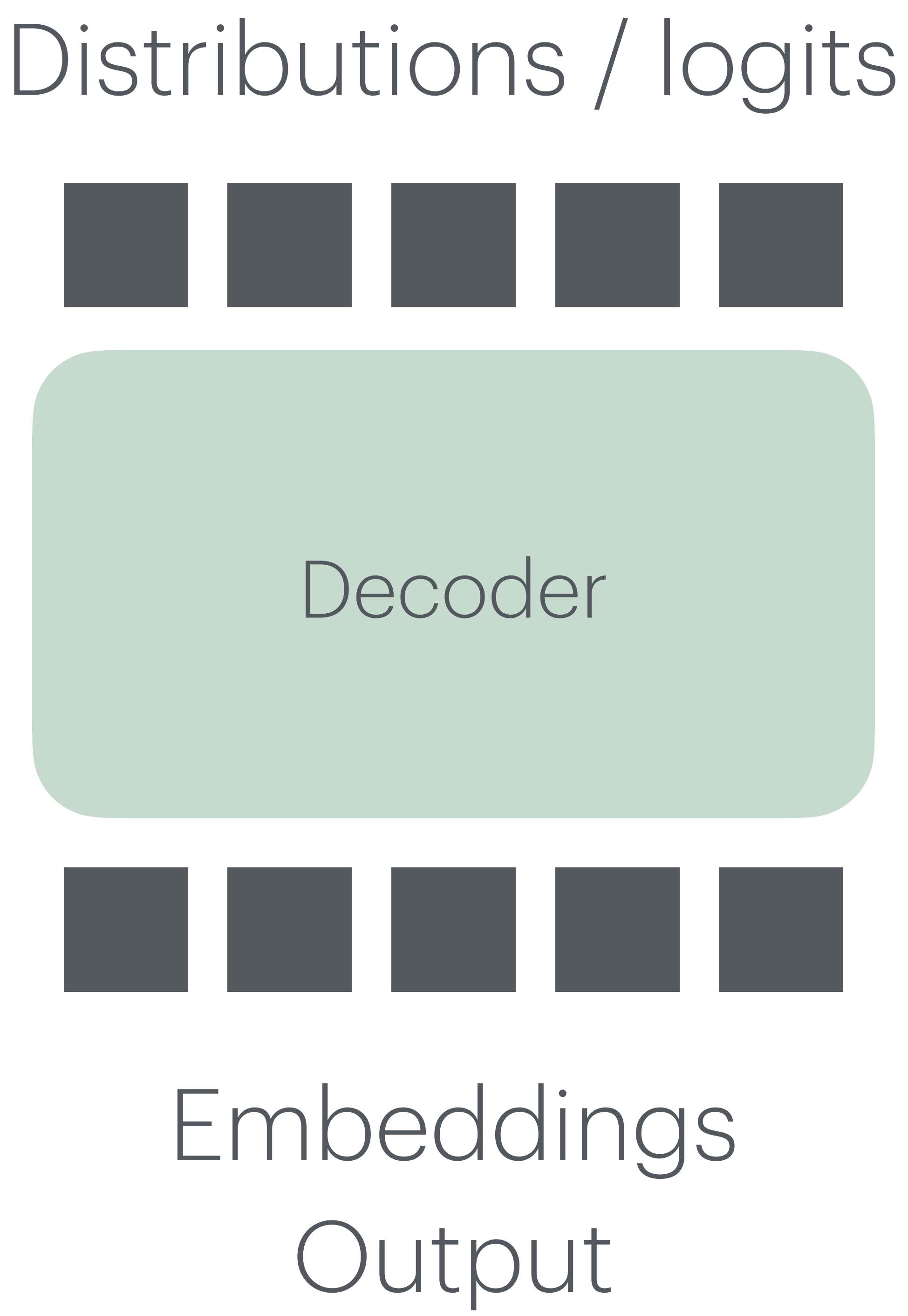
Philipp Krähenbühl, UT Austin

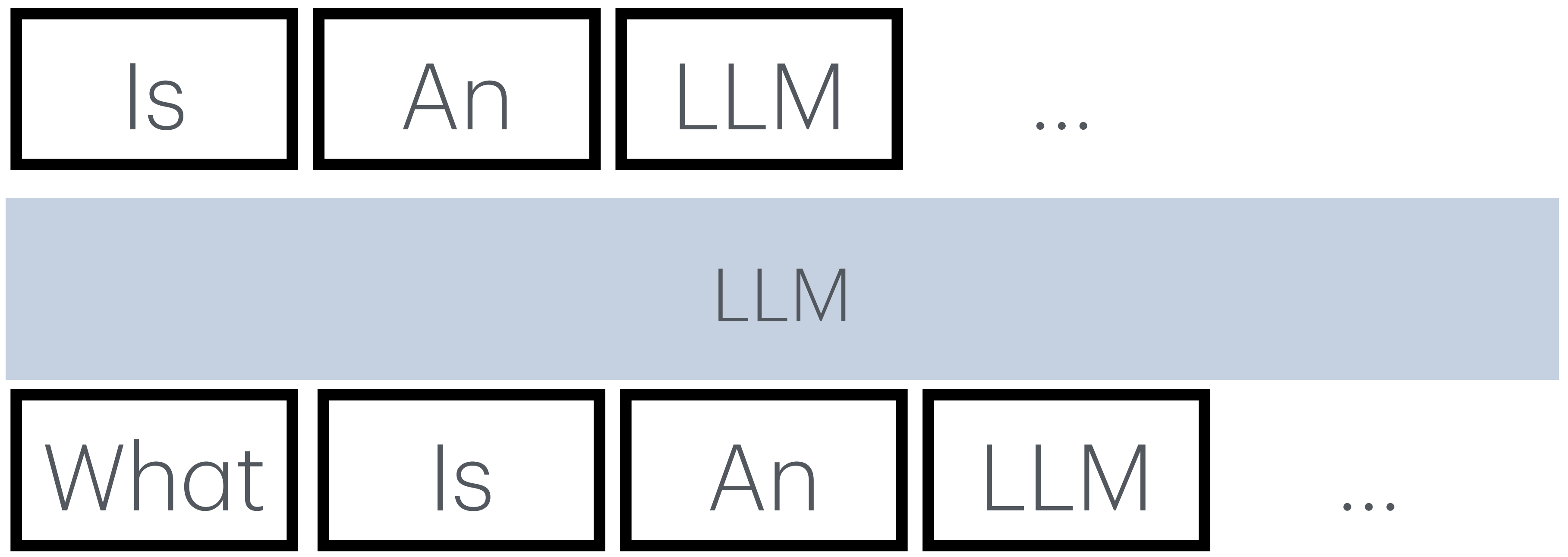
RLHF



Language Models

- Decoder-only LLMs
  - Modeling auto-regressive distribution over tokens
  - $P(\mathbf{t}) = P(t_1)P(t_2 \mid t_1)P(t_3 \mid t_1, t_2)P(t_4 \mid t_1 \ldots t_3)\ldots$
- Generation / Sampling: $\mathbf{t} \sim P$





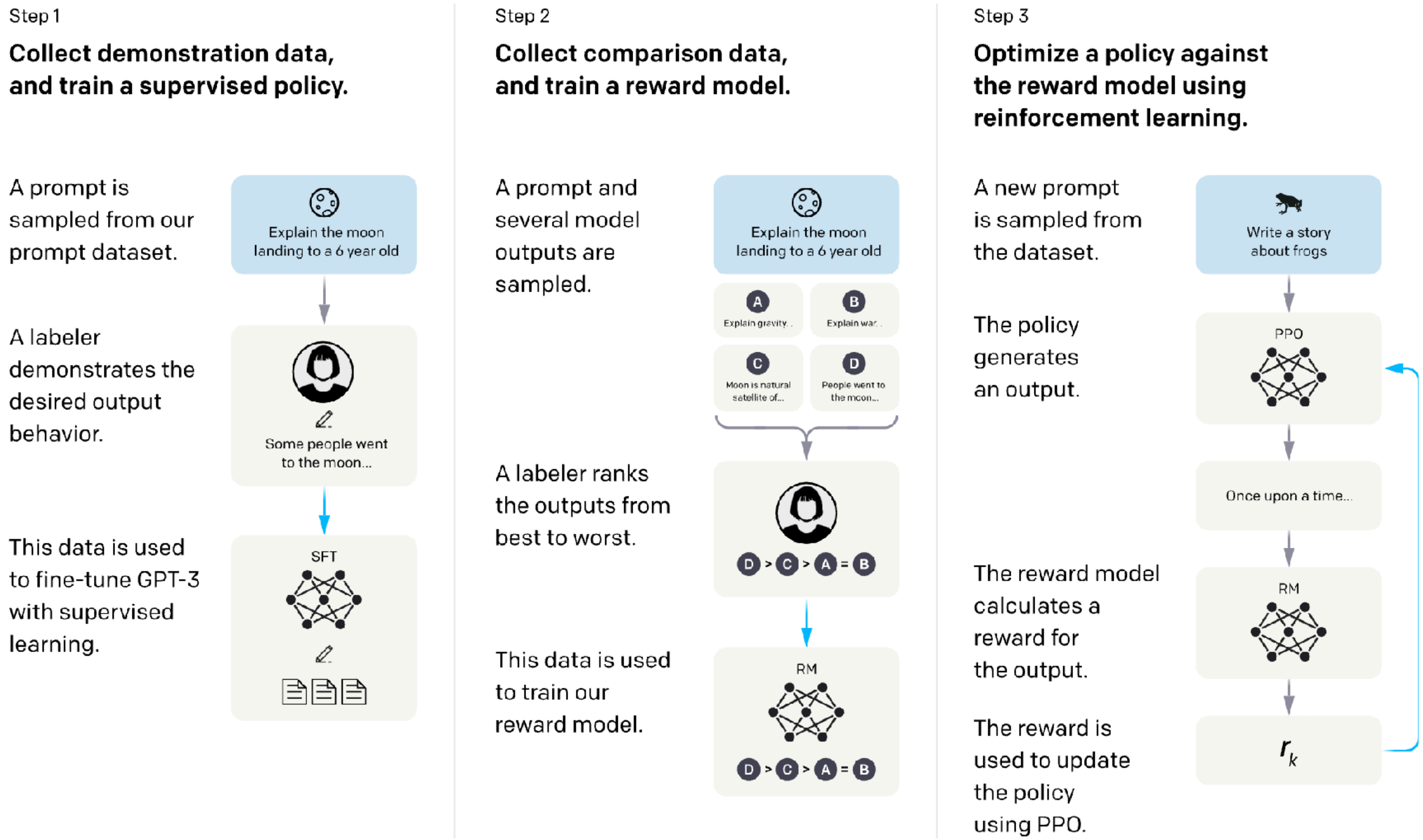
Instruction tuning

- Teach a LLM to follow a certain template in answering
  - Tell LLM **what to do**
  - Does **not** tell LLM **what not to do**

```
> I want to refocus my diet on only
eating Apples and supplements.
Let me provide information on how to
make the most of eating apples as a
primary food source.

**Apple selection:** Focus on eating a
variety of apples to ensure you get a
range of nutrients. Some apple varieties
are higher in certain nutrients than
others. For example:

* Granny Smith and Braeburn apples have
more malic acid, which can help with
digestion.

* Gala and Fuji apples contain more
vitamins A and C.

…
```

RLHF

Reinforcement Learning from Human Feedback



Training language models to follow instructions with human feedback. Ouyang etal 2022

RLHF - a recap

- Learn reward: $\ell = E_{x,y_+,y_-}\left[\log \sigma\left(r(x,y_+) - r(x,y_-)\right)\right]$

- Optimize: $E_{y\sim P(\cdot|x)}\left[(r(y,x))\,\nabla \log P(y\,|\,x)\right] - \beta D_{KL}\left[P(y\,|\,x)\,|\,P_{ref}(y\,|\,x)\right]$

DPO

- Learn reward: $\ell = E_{x,y_+,y_-}\left[\log\sigma\left(r(x,y_+) - r(x,y_-)\right)\right]$

- Optimize: $E_{y\sim P(\cdot|x)}\left[(r(y,x))\,\nabla\log P(y\,|\,x)\right] - \beta D_{KL}\left[P(y\,|\,x)\,|\,P_{ref}(y\,|\,x)\right]$

    - Closed form solution: $P(y\,|\,x) = \dfrac{1}{Z(x)}P_{ref}(y\,|\,x)\exp\left(\dfrac{1}{\beta}r(x,y)\right)$

Direct Preference Optimization: Your Language Model is Secretly a Reward Model, Rafailov etal 2023

DPO

- Learn reward: $\ell = E_{x,y_+,y_-}\left[\log \sigma\left(r(x,y_+) - r(x,y_-)\right)\right]$

- Optimize: $E_{y\sim P(\cdot|x)}\left[(r(y,x))\,\nabla \log P(y\,|\,x)\right] - \beta D_{KL}\left[P(y\,|\,x)\,|\,P_{ref}(y\,|\,x)\right]$

  - Closed form solution: $P(y\,|\,x) = \dfrac{1}{Z(x)}P_{ref}(y\,|\,x)\exp\left(\dfrac{1}{\beta}r(x,y)\right)$

  - $r(x,y) = \beta\dfrac{P(y\,|\,x)}{P_{ref}(y\,|\,x)} + \beta \log Z(x)$

Direct Preference Optimization: Your Language Model is Secretly a Reward Model, Rafailov etal 2023

DPO

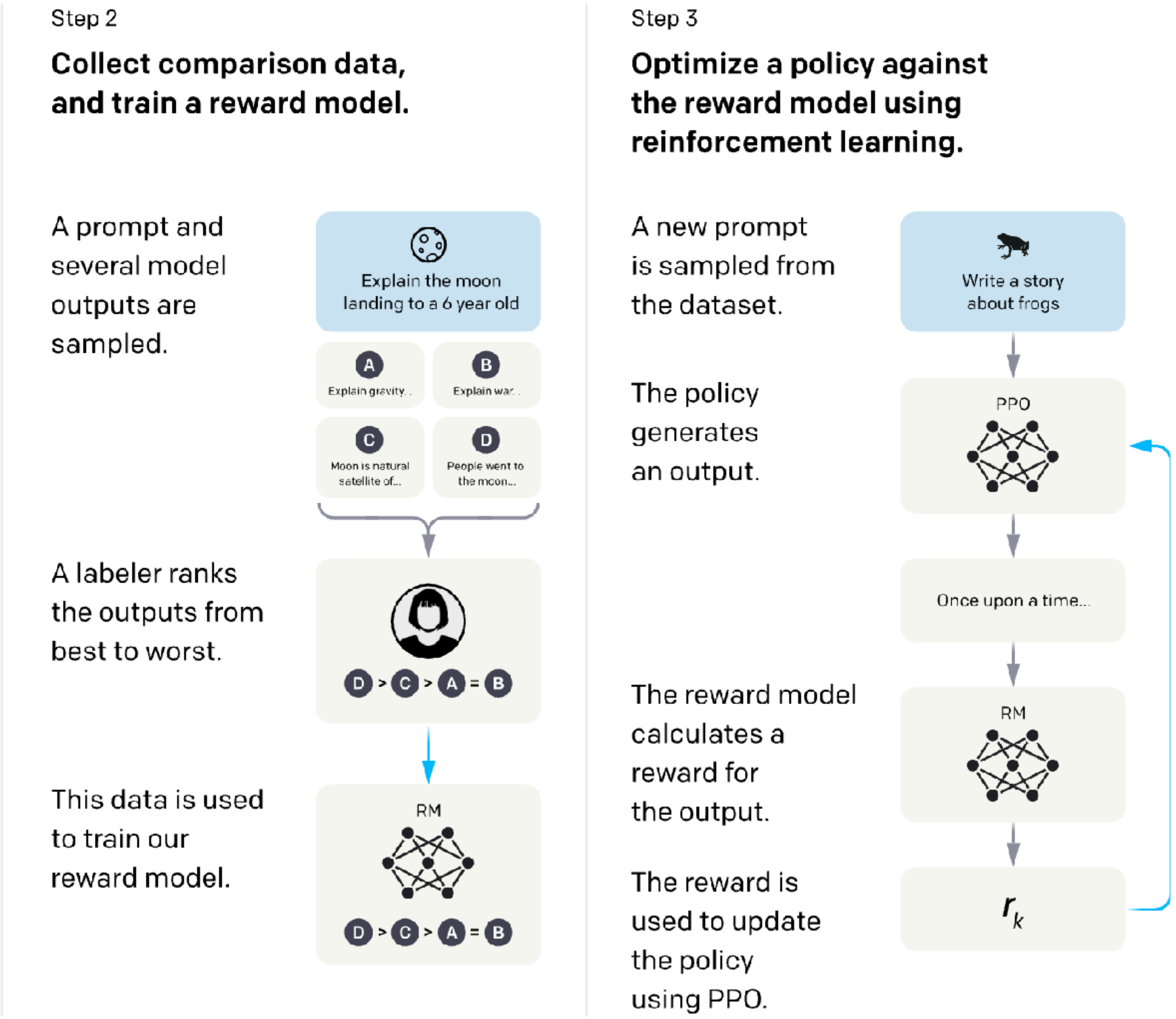
- Learn reward: $\ell = E_{x,y_+,y_-}\left[\log \sigma\left(r(x,y_+) - r(x,y_-)\right)\right]$
  - Closed form $\ell_{DPO} = E_{x,y_+,y_-}\left[\log \sigma\left(\beta \frac{rP(x,y_+)}{P_{ref}(x,y_+)} - \beta \frac{rP(x,y_-)}{P_{ref}(x,y_-)}\right)\right]$
- Optimize: $E_{y\sim P(\cdot|x)}\left[(r(y,x))\,\nabla \log P(y\,|\,x)\right] - \beta D_{KL}\left[P(y\,|\,x)\,|\,P_{ref}(y\,|\,x)\right]$
  - Closed form solution: $P(y\,|\,x) = \frac{1}{Z(x)} P_{ref}(y\,|\,x) \exp\left(\frac{1}{\beta} r(x,y)\right)$
  - $r(x,y) = \beta \frac{P(y\,|\,x)}{P_{ref}(y\,|\,x)} + \beta \log Z(x)$

Direct Preference Optimization: Your Language Model is Secretly a Reward Model, Rafailov etal 2023

DPO

$$\ell_{DPO} = E_{x,y_+,y_-}\left[\log\sigma\left(\beta\frac{rP(x,y_+)}{P_{ref}(x,y_+)} - \beta\frac{rP(x,y_-)}{P_{ref}(x,y_-)}\right)\right]$$

- Closed form solution to reward models + RL
  - Supervised learning
  - Easy to implement
  - Efficient

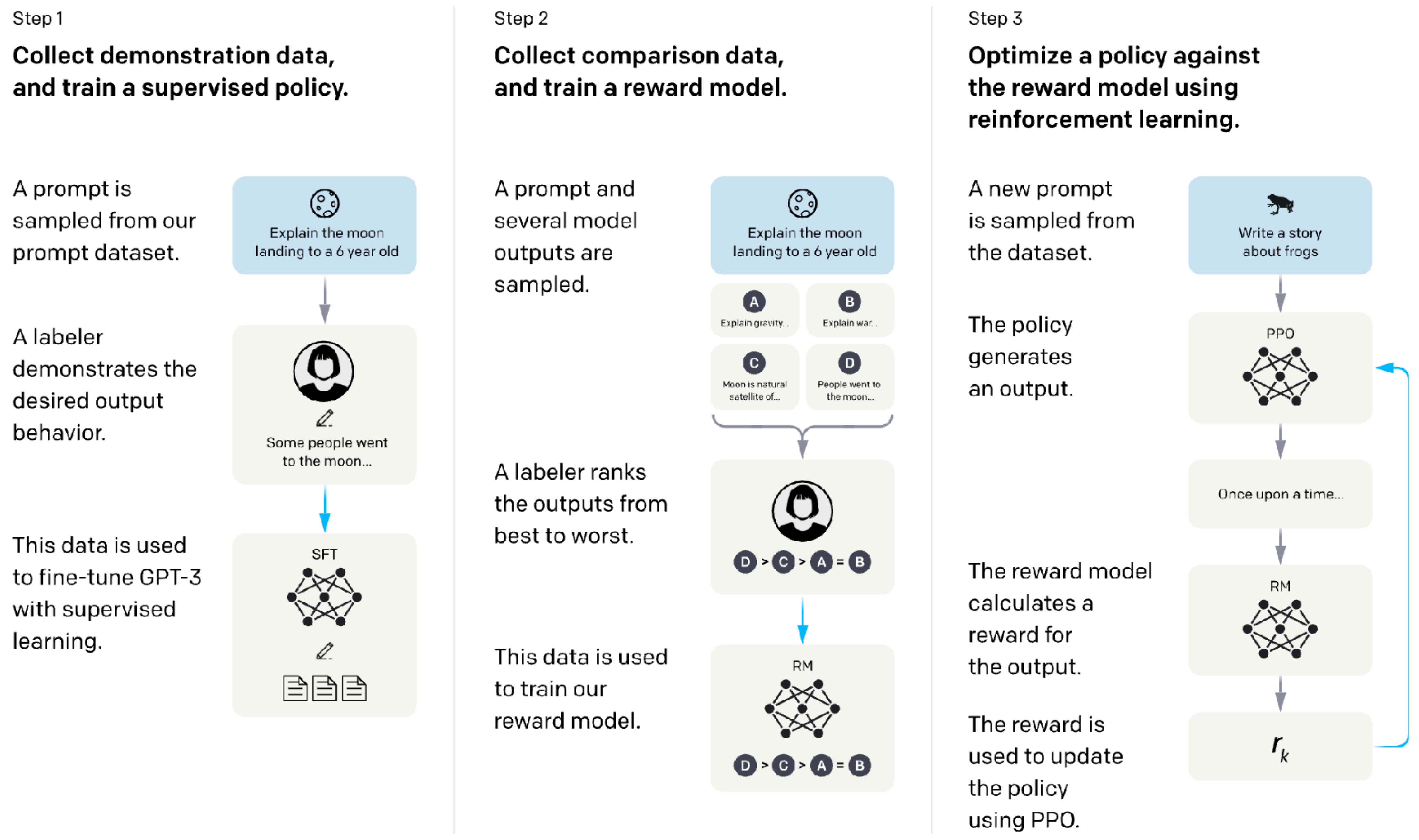


Direct Preference Optimization: Your Language Model is Secretly a Reward Model, Rafailov etal 2023

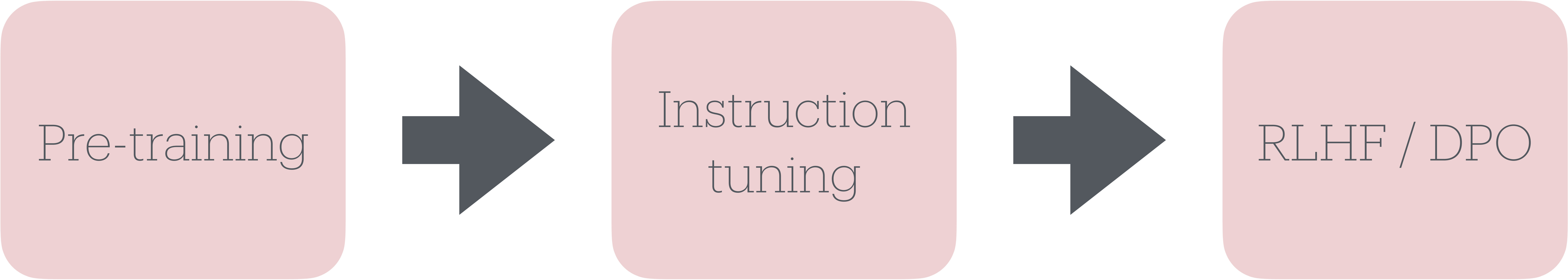
DPO vs RLHF

$$\ell_{DPO} = E_{x,y_+,y_-}\left[\log\sigma\left(\beta\frac{rP(x,y_+)}{P_{ref}(x,y_+)} - \beta\frac{rP(x,y_-)}{P_{ref}(x,y_-)}\right)\right]$$

- DPO
  - Easier to make work
  - Can only learn on preference data
  - Generally produces long outputs
- RLHF
  - Requires quite a bit of RL knowledge
  - Higher ceiling (can use smaller preference data, larger fine-tuning data)



Full Picture



References

- [1] Training language models to follow instructions with human feedback. Ouyang etal 2022.
- [2] Direct Preference Optimization: Your Language Model is Secretly a Reward Model, Rafailov etal 2023.