What is life? – The Free Energy Principle and Active Inference

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Magnus T. Koudahl, Ph.D student

BIASLab, SPS group, Dept. Of Electrical Engineering

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

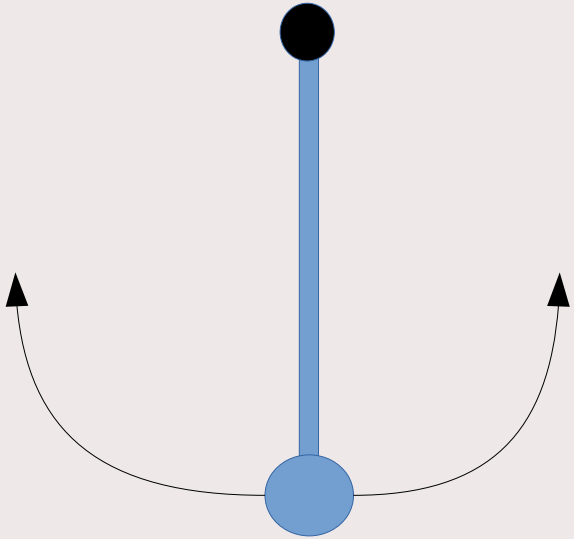
Battleplan

- Premise
- NESS and Biology
- Relation to Bayes
- Markov Blankets

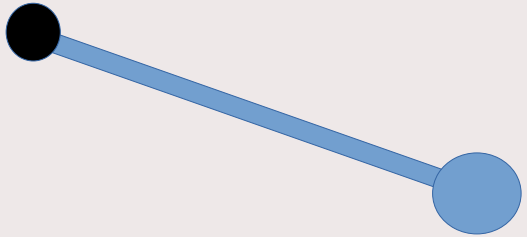
- Bayesian brain hypothesis
- Free Energy Revisited
- Sample structures
- “This goes to 11!”

Premise

Equilibria



Equilibria



Equilibria

Bayes?

Bayes?

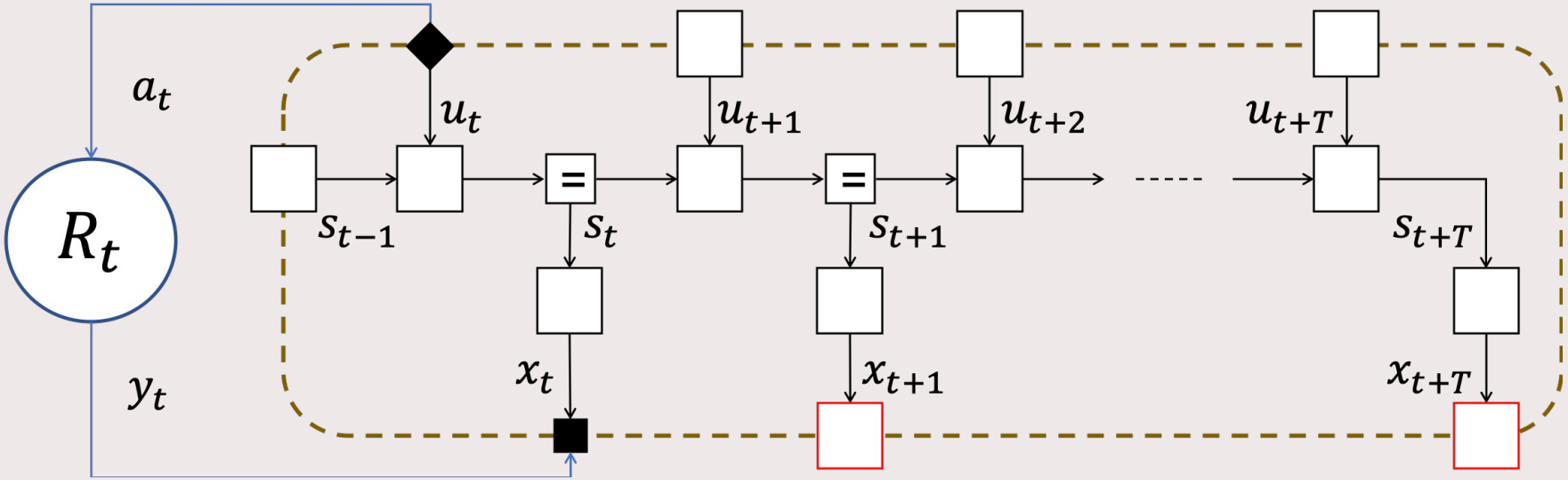
p() = (Target) Prior

Bayes?

p(🌡) = (Target) Prior

q(🌡) = Posterior

Markov Blankets



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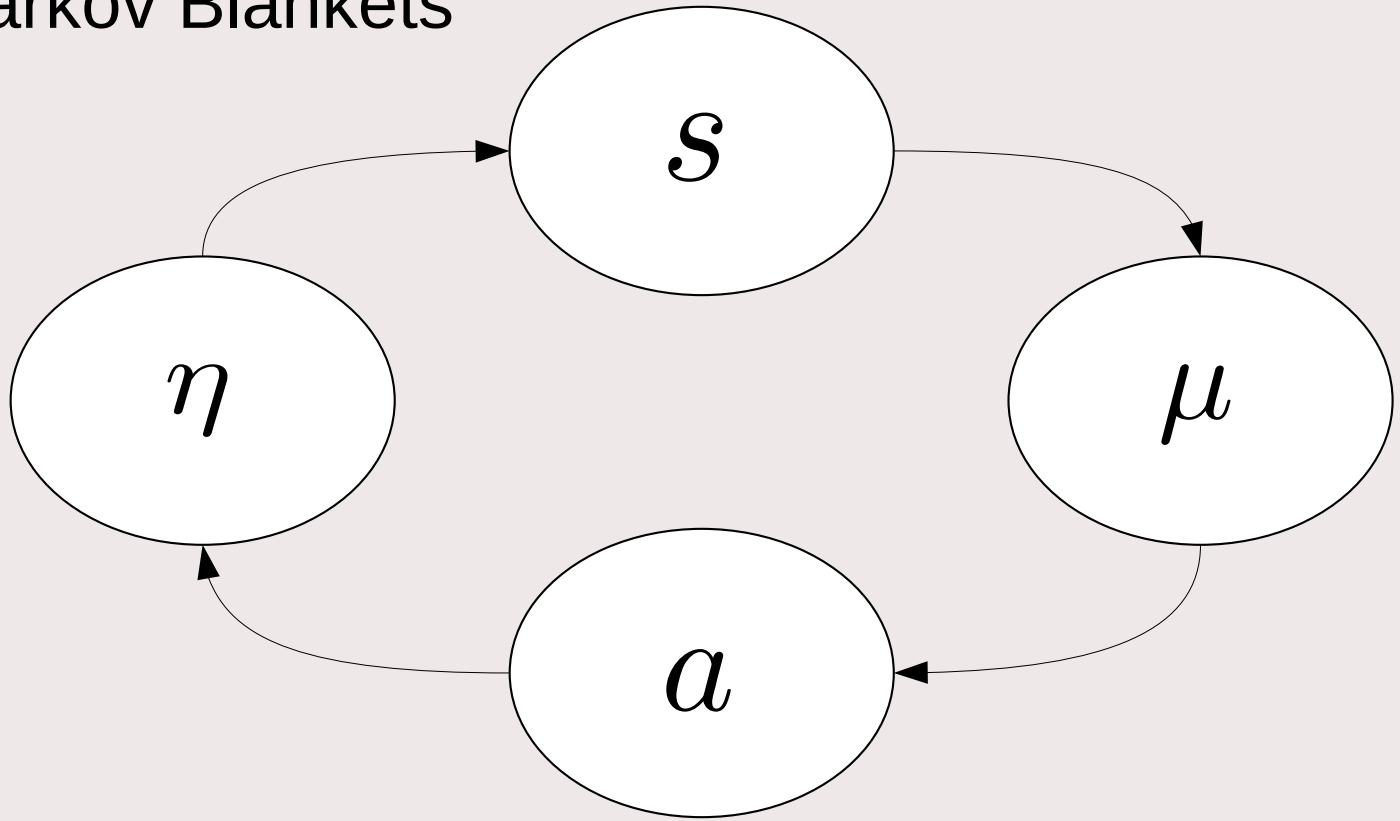
Markov Blankets



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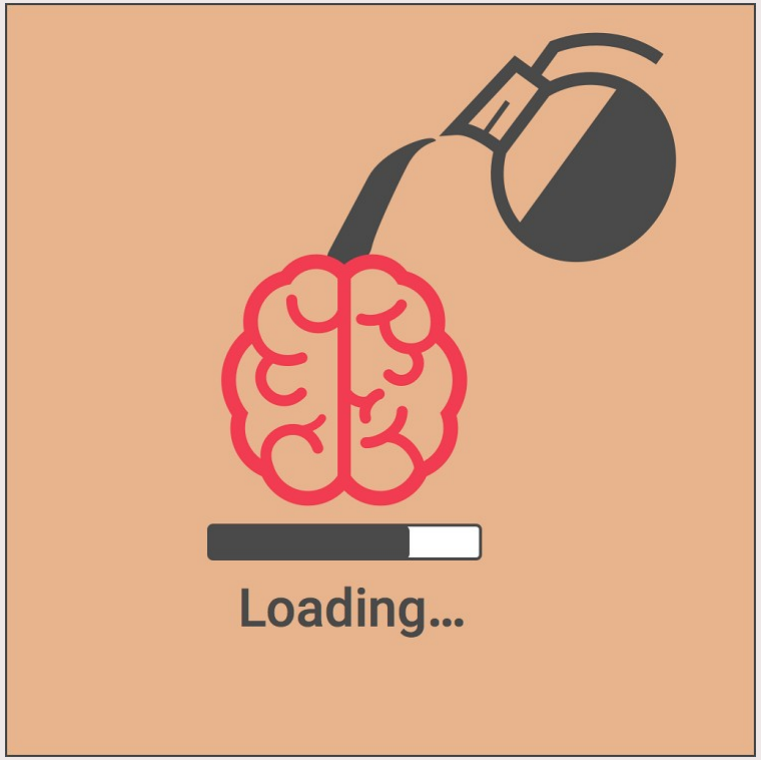
Break time



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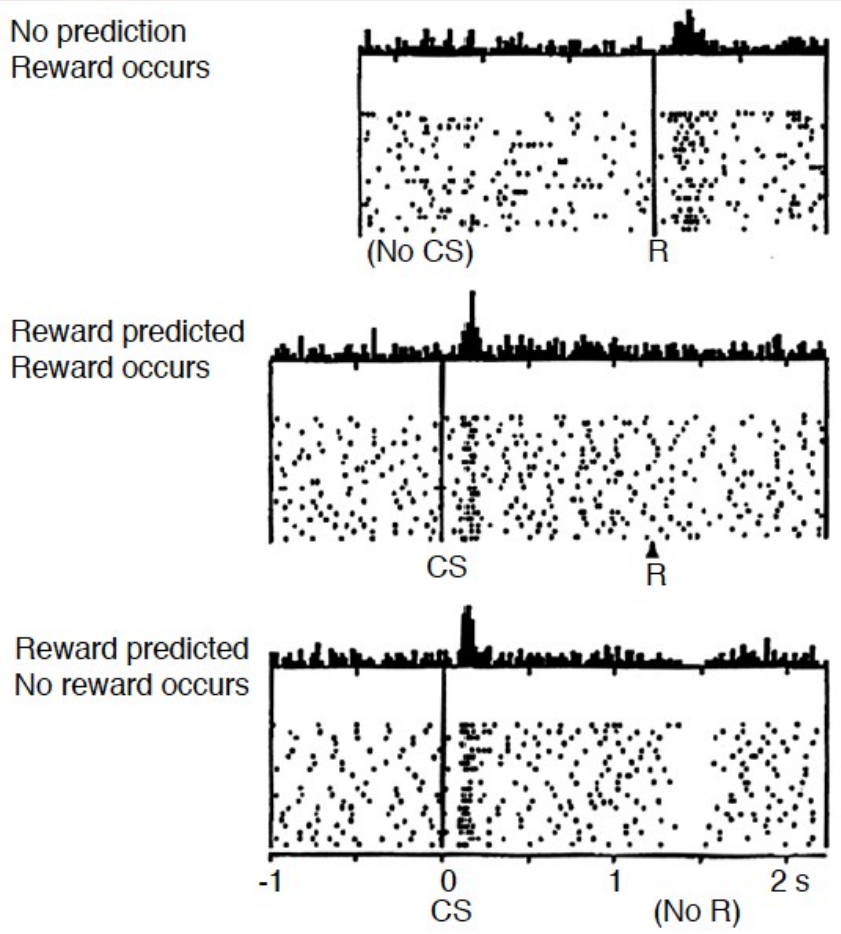
The Bayesian Brain

*“Perception is inference of the causes of observed impressions upon our sensorium!”**

**Paraphrasing Helmholtz, 1866*

Do dopamine neurons report an error in the prediction of reward? *



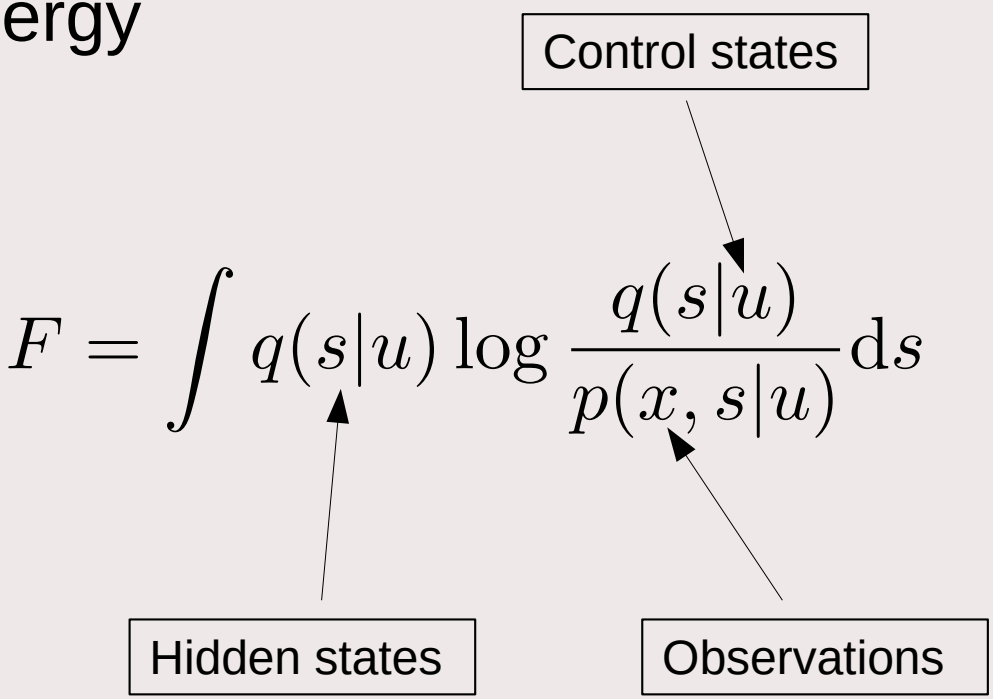
The Bayesian Brain

*Figure reproduced from Schultz, Dayan and Montague, 1997, *A Neural Substrate of Prediction and Reward*

Free Energy

$$F = \int q(s|u) \log \frac{q(s|u)}{p(x, s|u)} \mathrm{d}s$$

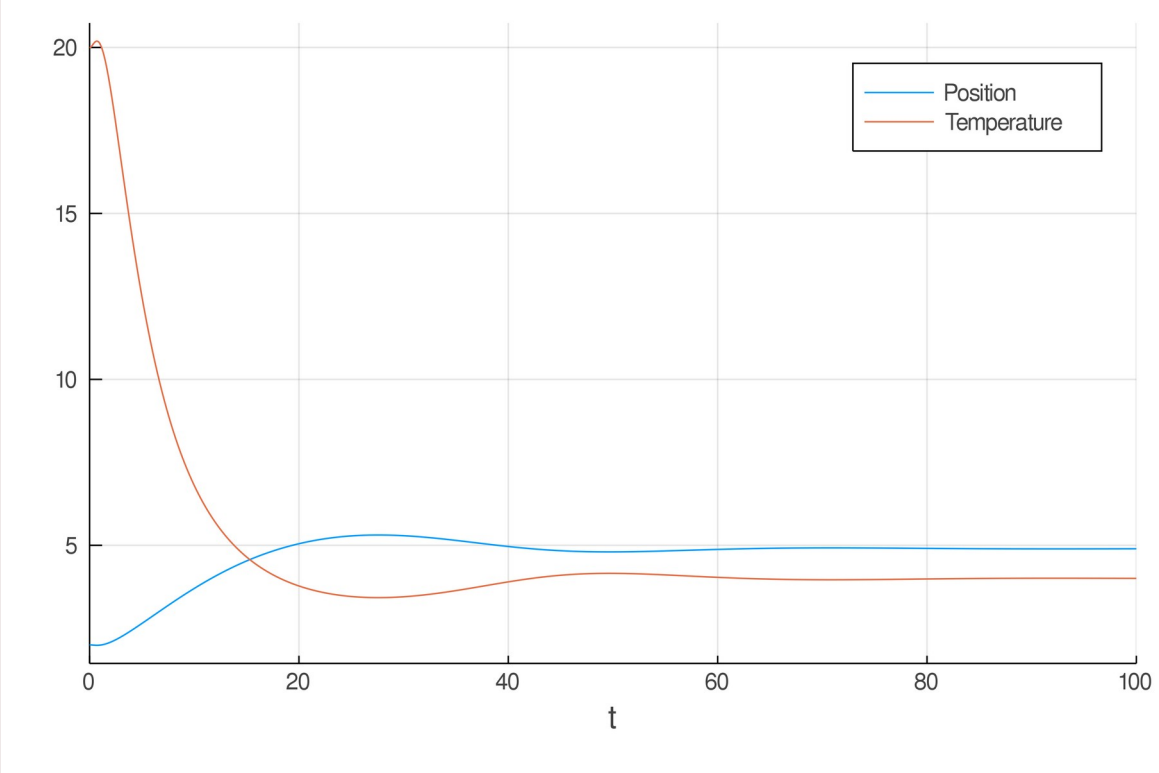
Free Energy


Control states
$F = \int q(s|u) \log \frac{q(s|u)}{p(x,s|u)} \mathrm{d}s$
Hidden states
Observations

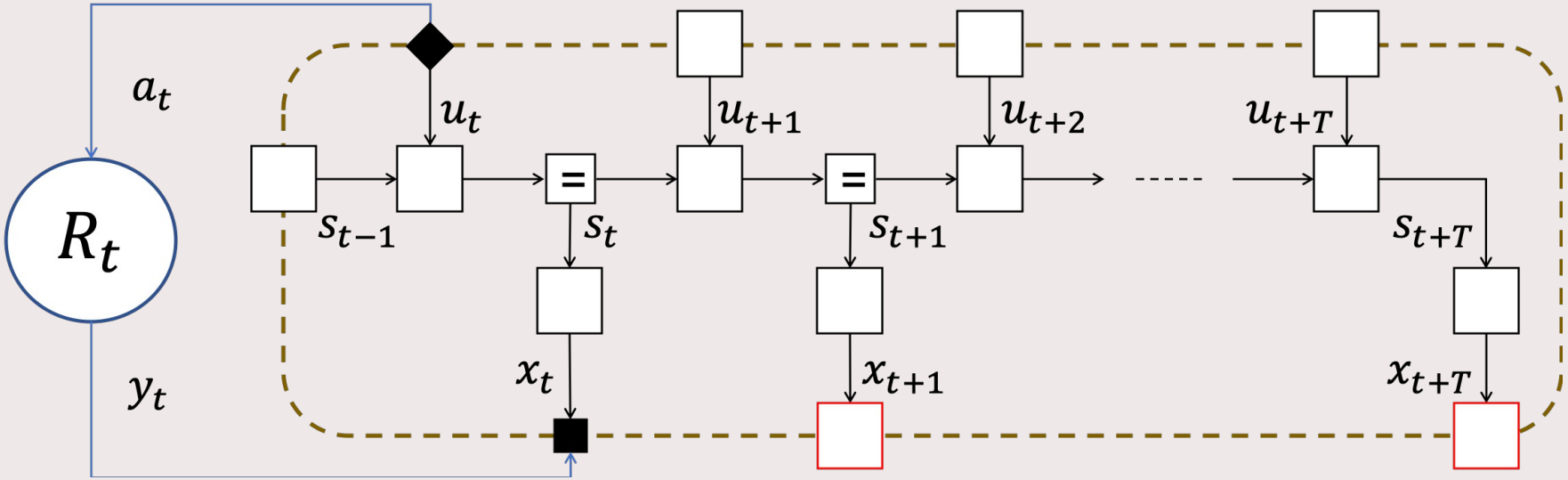
Free Energy

$$F = \int q(s|u) \left[\underbrace{\log \frac{q(s|u)}{p(s|u)}}_{\text{Complexity}} \underbrace{- \log p(x|s)}_{\text{Accuracy}} \right] \mathrm{d}s$$

Free Energy



Introducing the future



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Free Energy revisited

$$G = \underbrace{\iint q(x|s) \underbrace{\left[q(s|u) \log \frac{q(s|u)}{p(x,s|u)} \mathrm{d}s \right]}_{F} \mathrm{d}x}_{\text{Expectation of } F}$$

Free Energy revisited

$$G = \iint q(x|s) \left[q(s|u) \log \frac{q(s|u)}{p(s|x,u)} - \log p(x) \mathrm{d}s \right] \mathrm{d}x$$

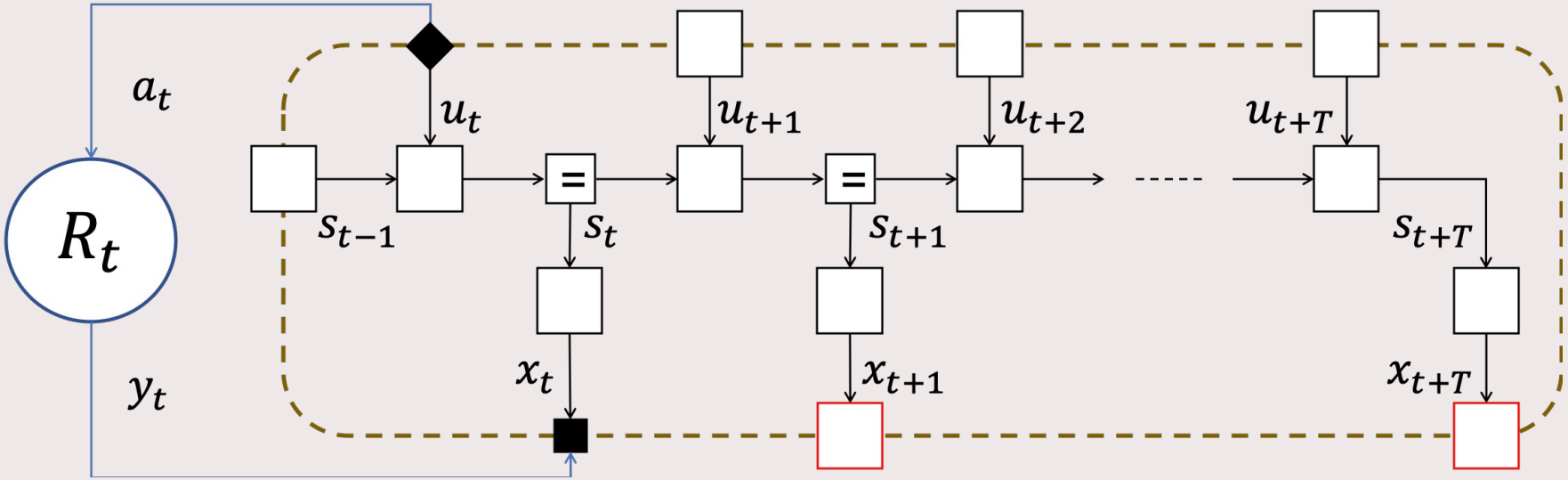
Free Energy revisited

$$G = \underbrace{\iint q(x, s|u) \log \frac{q(s|u)}{p(s|x, u)} \mathrm{d}s\mathrm{d}x}_{\text{"Information Gain"}} \underbrace{- \iint q(x, s|u) \log p(x) \mathrm{d}s\mathrm{d}x}_{\text{Crossentropy}}$$

Free Energy revisited

$$G = \underbrace{\iint q(x, s|u) \log \frac{q(s|u)}{p(s|x, u)} \mathrm{d}s\mathrm{d}x}_{\text{Epistemic Value}} \underbrace{- \iint q(x, s|u) \log p(x) \mathrm{d}s\mathrm{d}x}_{\text{Instrumental Value}}$$

This one goes to 11!



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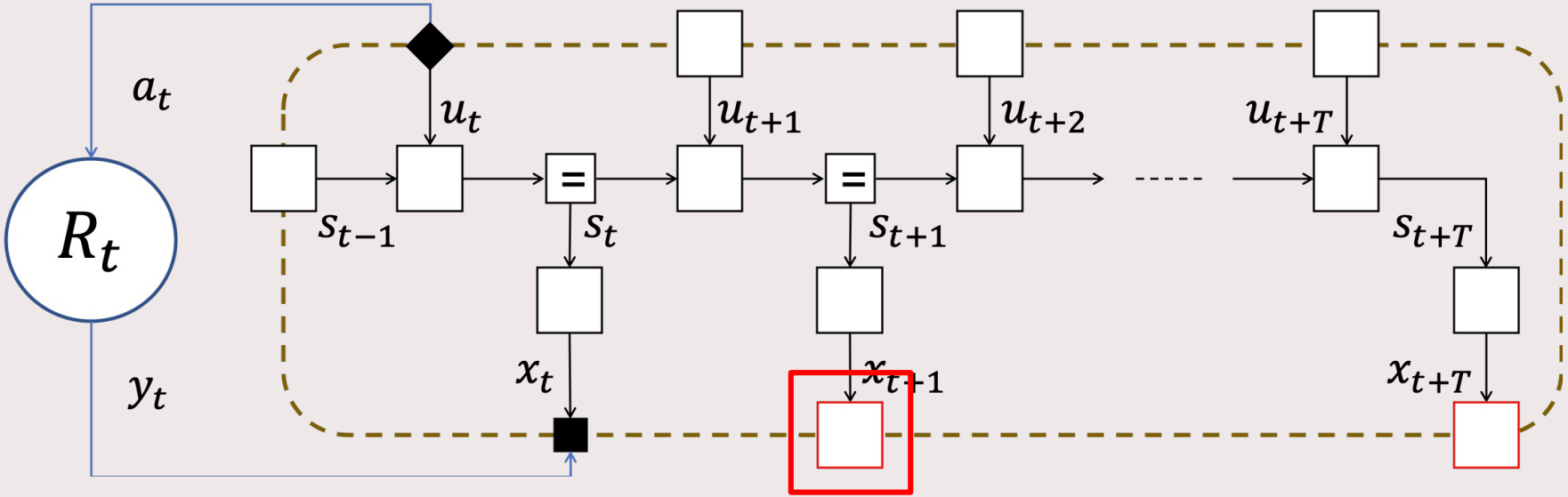

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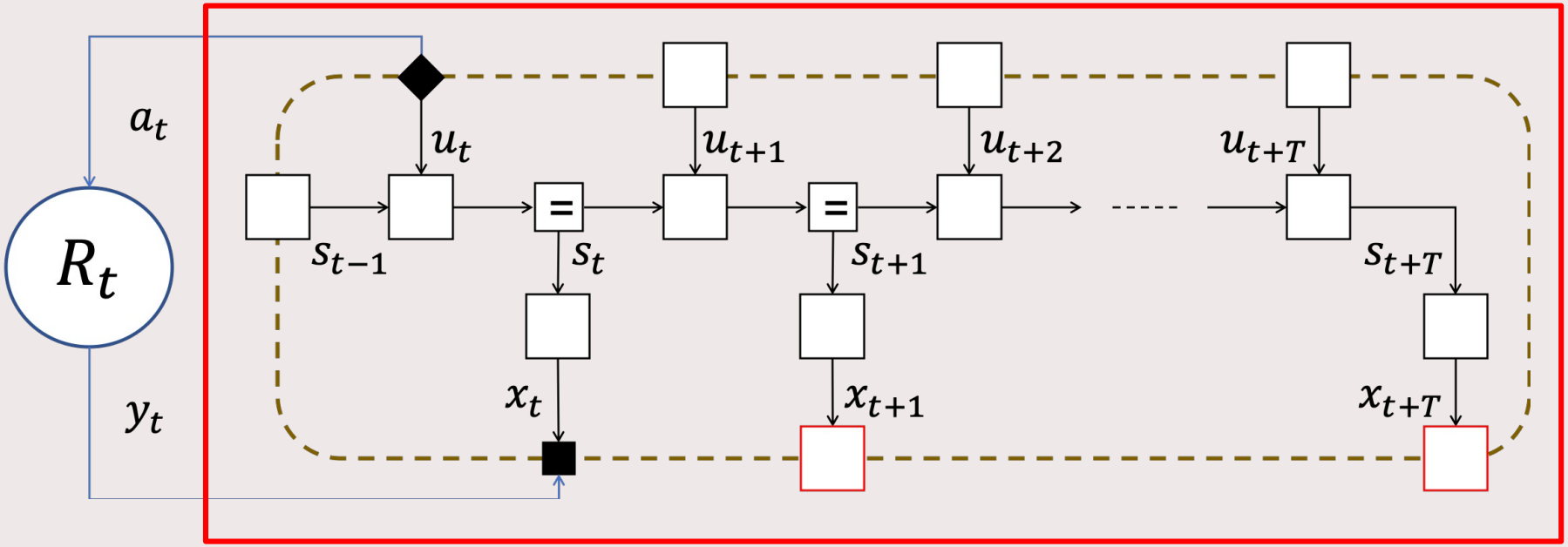
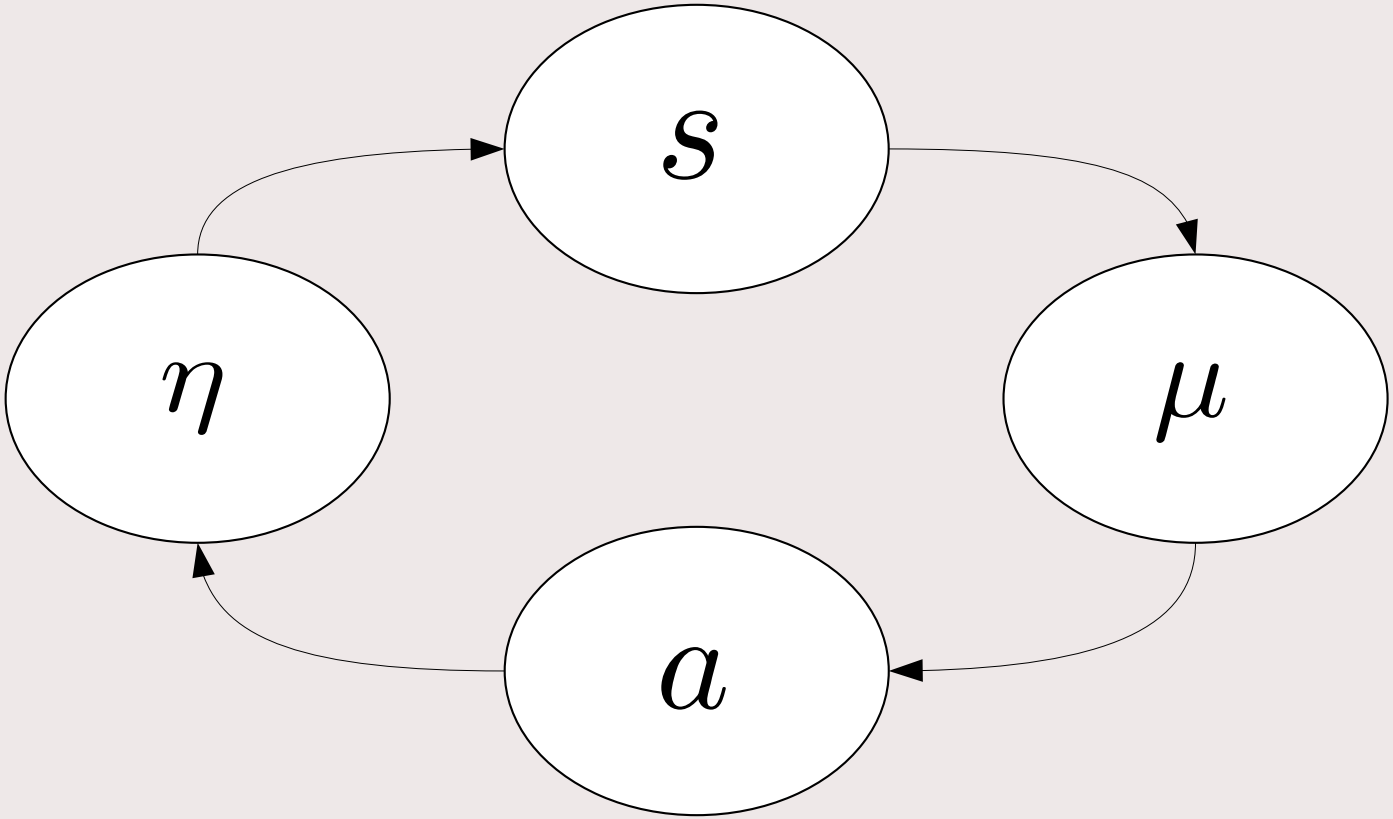
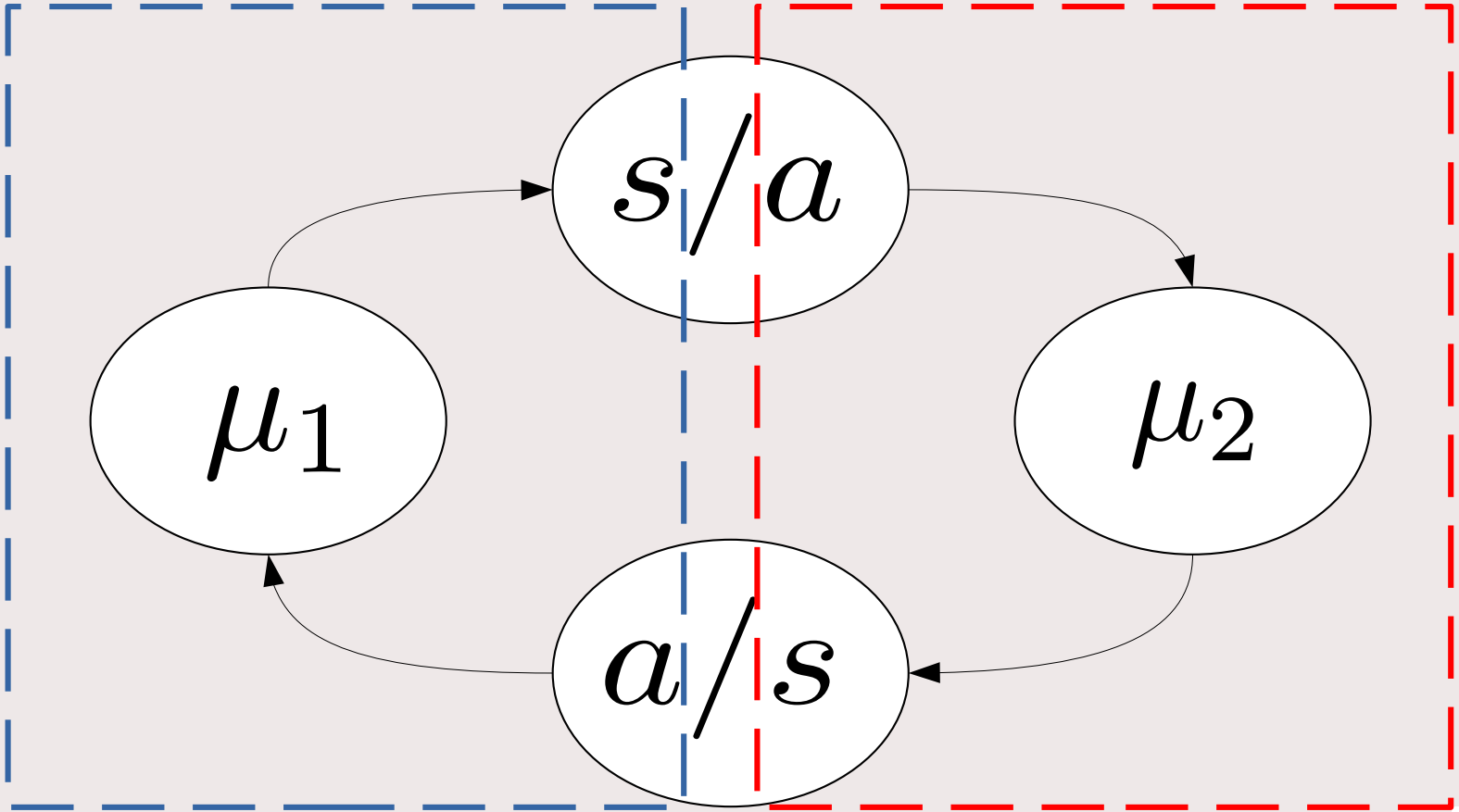
This one goes to 11!







Further Reading

Lighthearted:
Sean Carroll – What is the purpose of life? (YT)
Kai Ueltzhoffer – Life and the Second Law (Blog)
Maxwell Ramstead – A Tutorial on Active Inference (YT)

Research Papers:
Christopher Buckley – A Mathematical Review
Karl Friston – A Rough guide to the brain
Karl Friston – Knowing one's place
Karl Friston – Free Energy, Value and Attractors

Here be dragons…
Karl Friston – A Free Energy Principle for a Particular Physics