



# What is Life? – The Free Energy Principle and Active Inference

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# Battleplan

- Premise
- NESS and Biology
- Relation to Bayes
- Markov Blankets
- Bayesian Brain Hypothesis
- Free Energy Revisited
- Sample Structures
- “This goes to 11!”

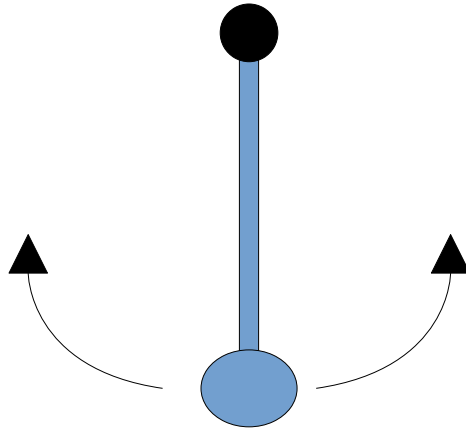




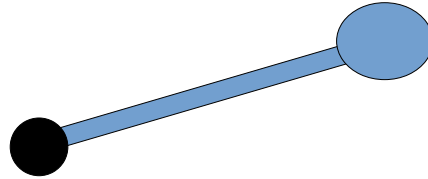
# Premise



# Equilibria



# Equilibria



# Equilibria



# Bayes?

# Bayes?

$$p(\text{🌡}) = (\text{Target}) \text{ Prior}$$

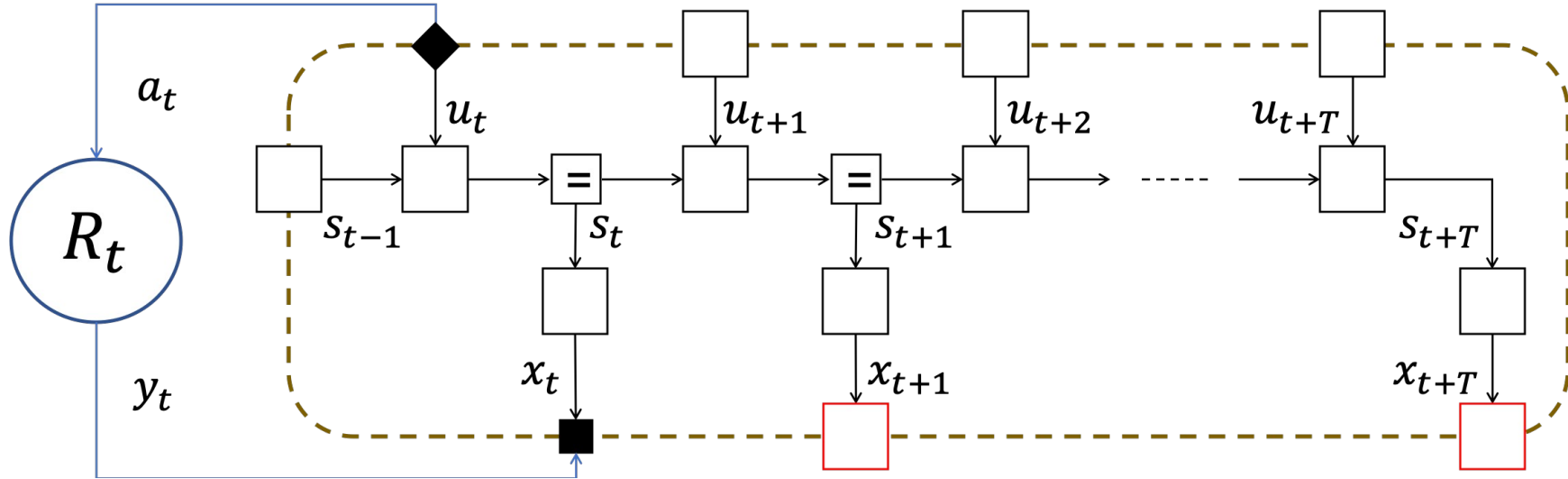


# Bayes?

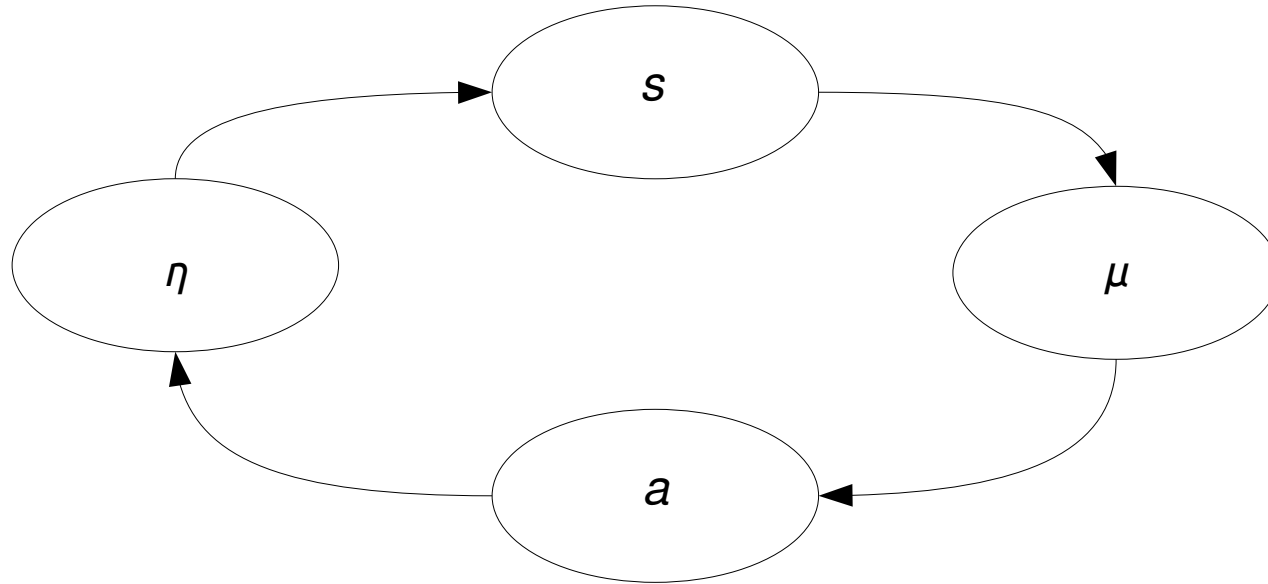
$p(\text{🌡️}) = (\text{Target}) \text{ Prior}$

$q(\text{🌡️}) = \text{Posterior}$

# Markov Blankets



# Markov Blankets



# Break time

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# The Bayesian Brain

*Perception is the inference of causes of observed impressions on our sensorium\**

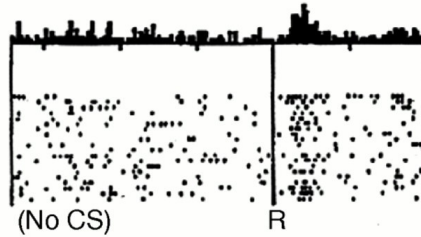




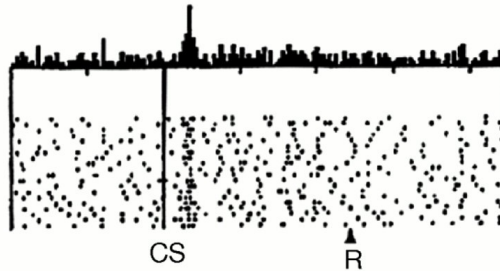
# Predictive Coding

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

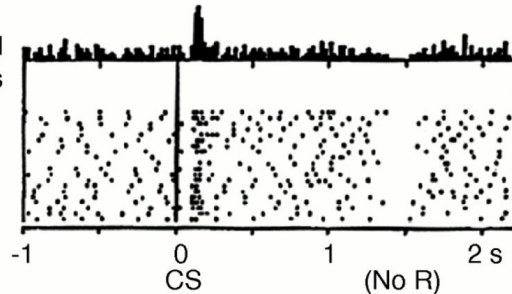
No prediction  
Reward occurs



Reward predicted  
Reward occurs



Reward predicted  
No reward occurs



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

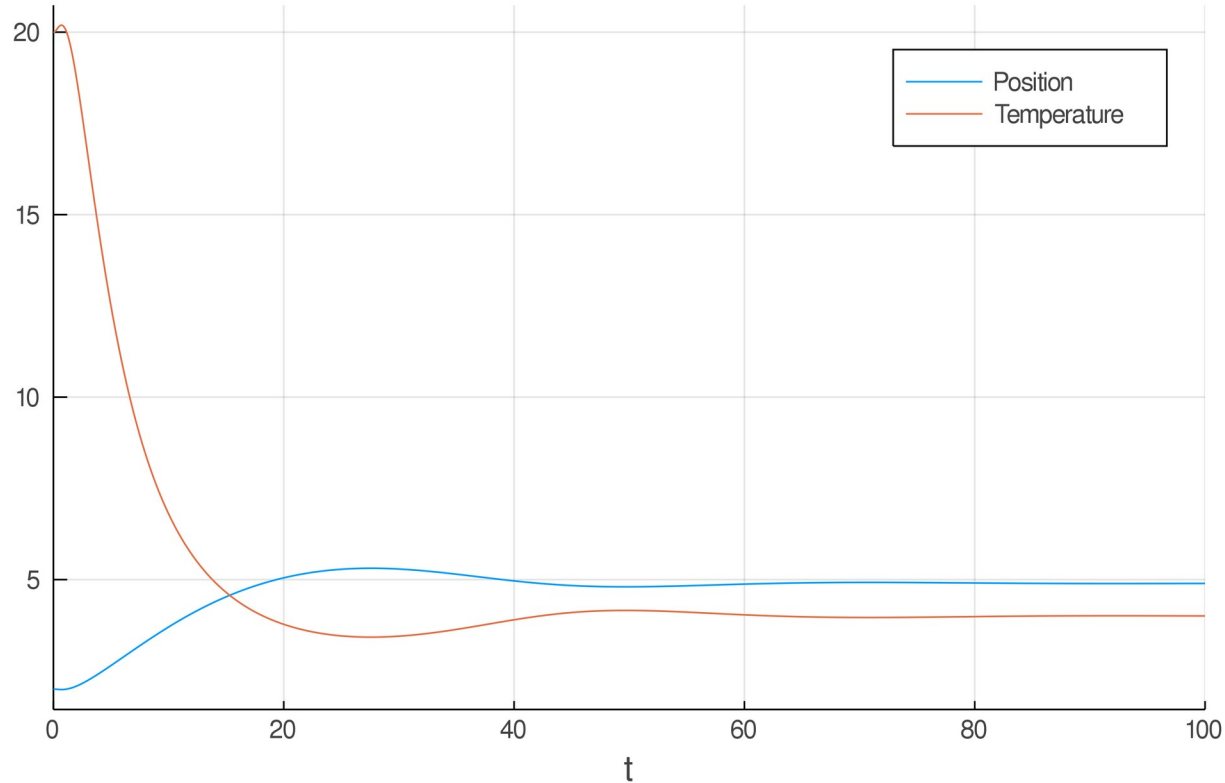
# Free Energy Revisited

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

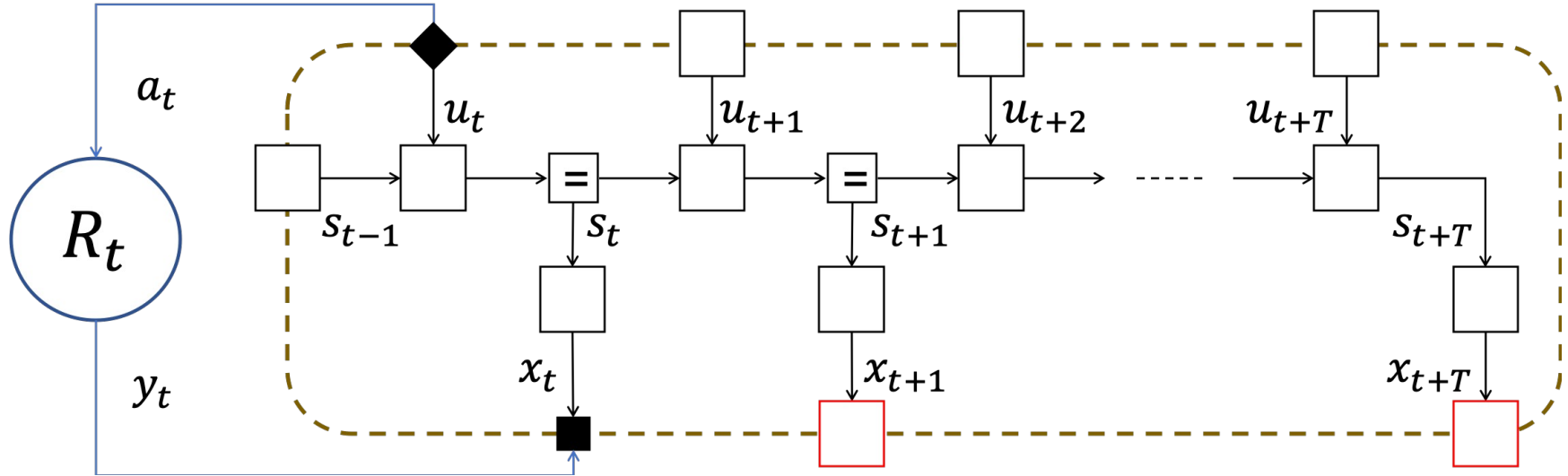
# Free Energy Revisited

$$F = \underbrace{\int q(s|u) \log \frac{q(s|u)}{p(s|x, u)} ds}_{\text{Epistemic Value}} - \underbrace{\int q(s|u) \log p(x|u) ds}_{\text{Instrumental Value}}$$

# The Bayesian Thermostat



# The Discrete Time SSM



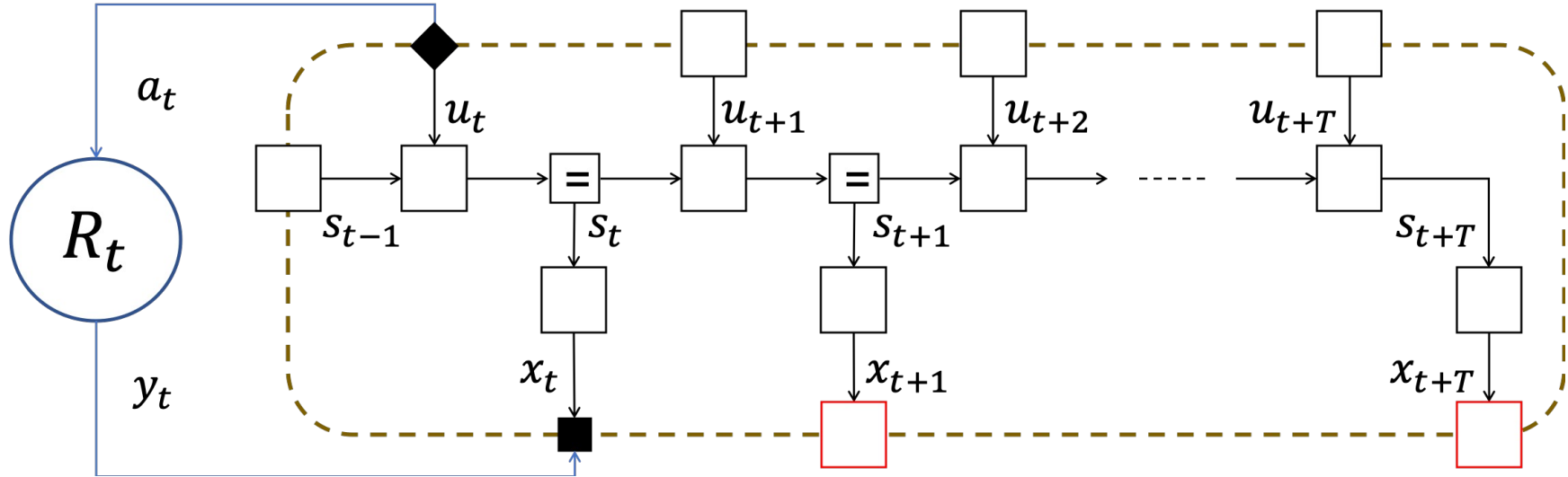
# Free Energy Revisited

$$\begin{aligned} EF &= - \iint p(x|s)q(s|u) \log \frac{p(x, s|u)}{q(s|u)} dx ds \\ &= \mathbf{E}_{p(x|s)} [F] \end{aligned}$$

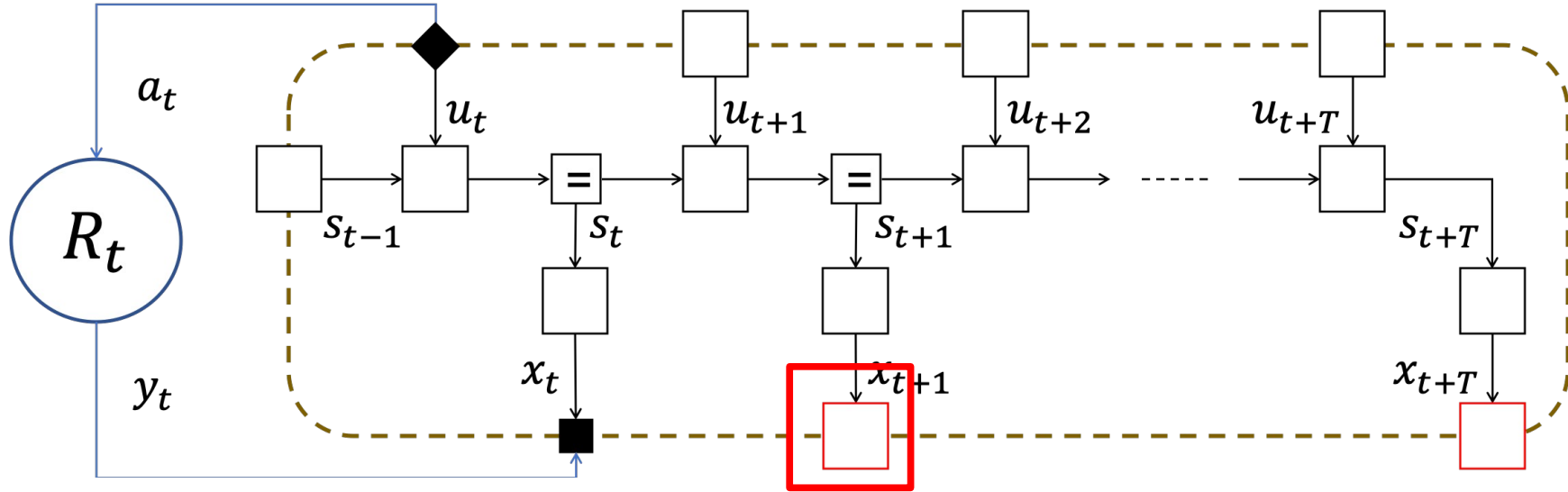


# How far can we push this?

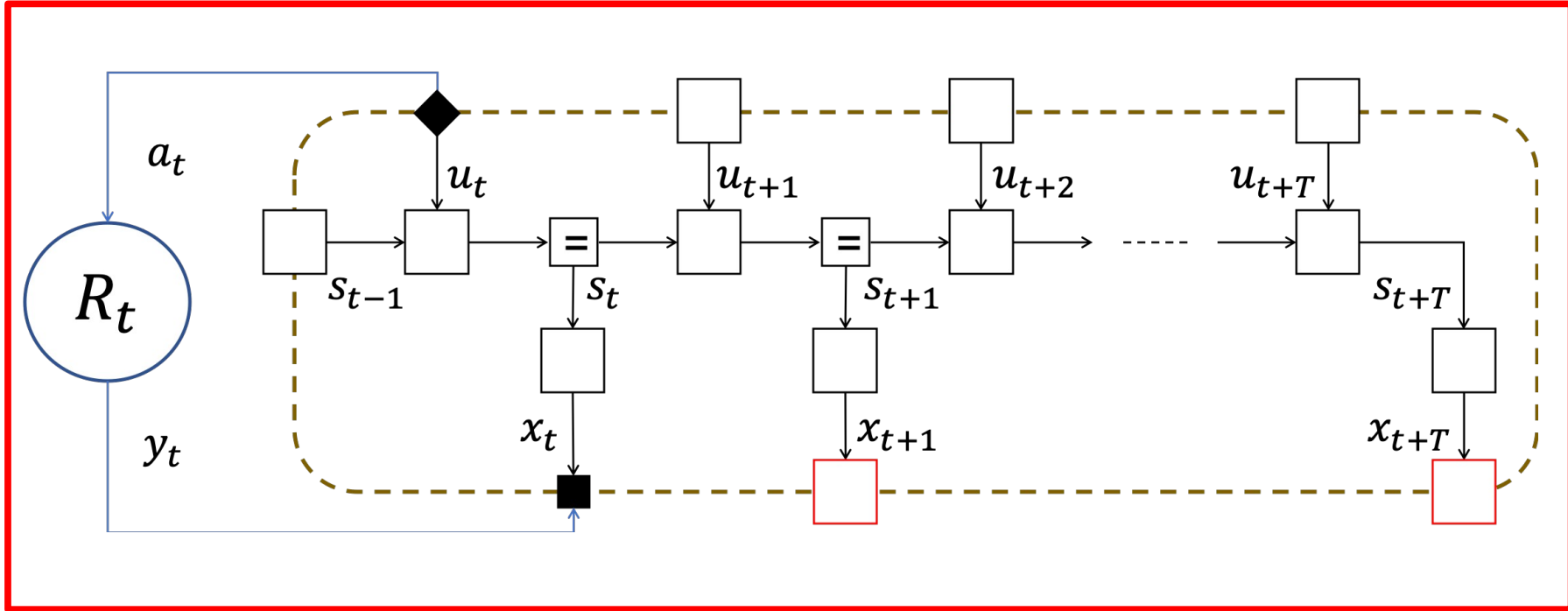
# How far can we push this?



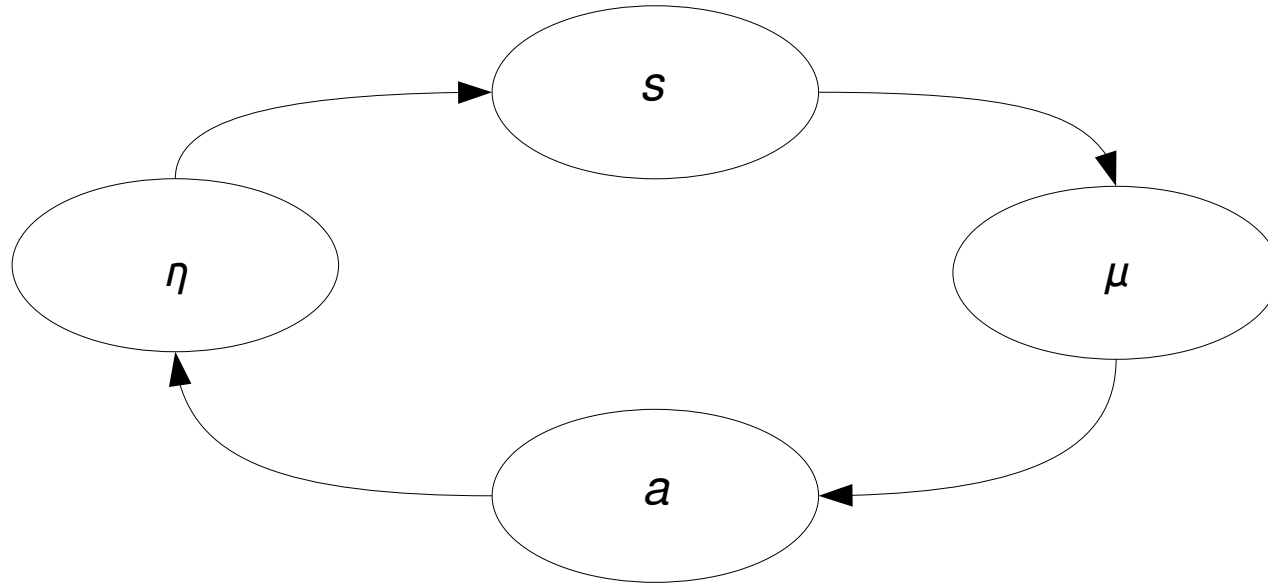
# How far can we push this?



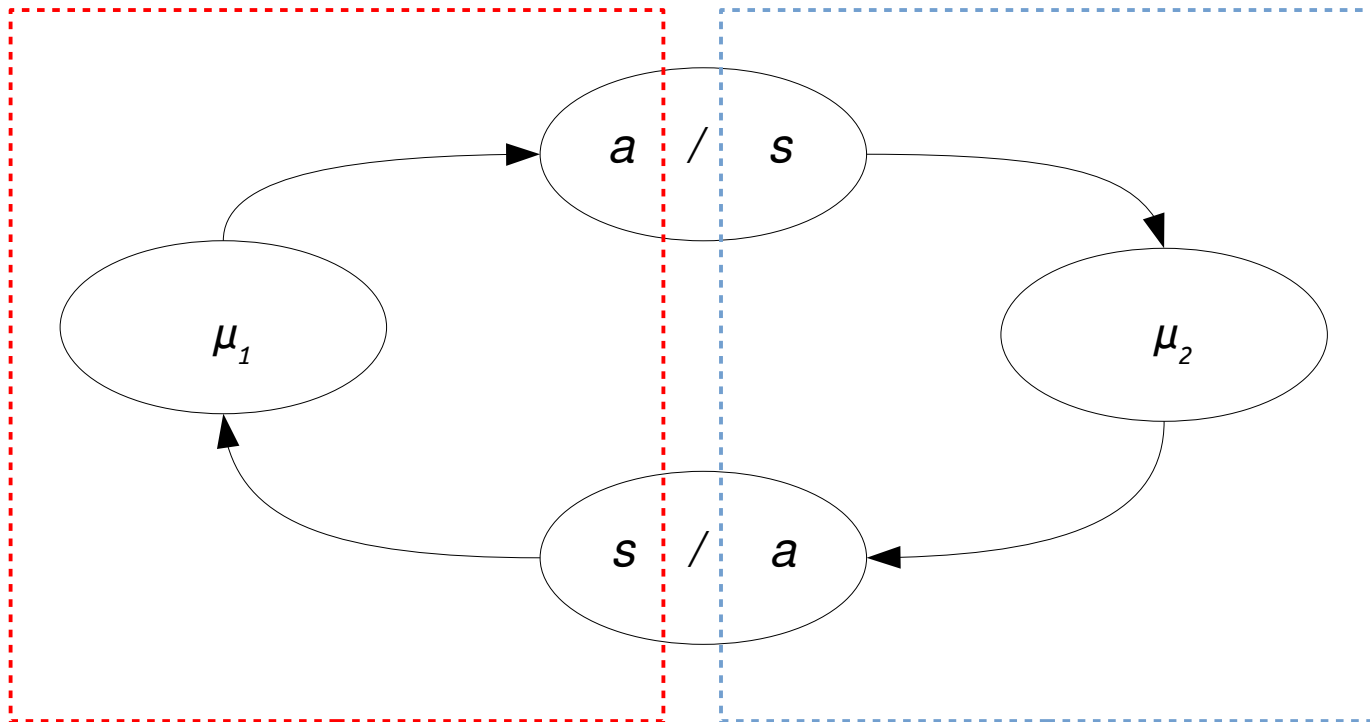
# How far can we push this?



# Markov Blankets



# Markov Blankets





# Further Reading

## Lighthearted

Sean Carroll – [What is the purpose of Life?](#)

Kai Ueltzhoffer – [Life and the Second Law](#)

Maxwell Ramstead – [A Tutorial on Active Inference](#)

## Research Papers

Karl Friston - [A rough guide to the brain](#)

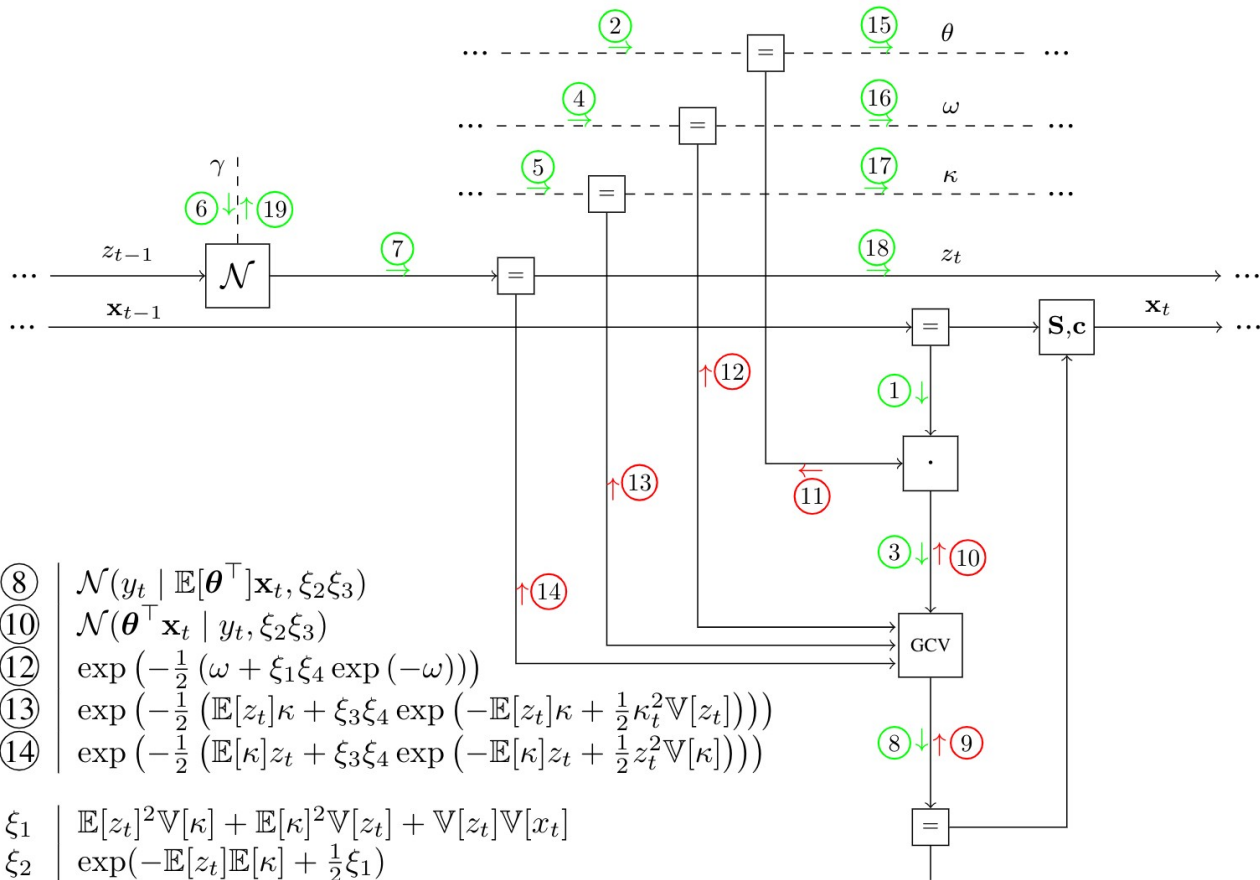
Karl Friston – [Knowing one's place](#)

Christopher Buckley – [A Mathematical Review](#)

Karl Friston – [Free Energy, Value and Attractors](#)

## Here be dragons...

Karl Friston – [A Free Energy Principle for a Particular Physics](#)



$$\begin{aligned}
 \textcircled{8} & \quad \mathcal{N}(y_t \mid \mathbb{E}[\boldsymbol{\theta}^\top] \mathbf{x}_t, \xi_2 \xi_3) \\
 \textcircled{10} & \quad \mathcal{N}(\boldsymbol{\theta}^\top \mathbf{x}_t \mid y_t, \xi_2 \xi_3) \\
 \textcircled{12} & \quad \exp\left(-\frac{1}{2}(\omega + \xi_1 \xi_4 \exp(-\omega))\right) \\
 \textcircled{13} & \quad \exp\left(-\frac{1}{2}\left(\mathbb{E}[z_t] \kappa + \xi_3 \xi_4 \exp\left(-\mathbb{E}[z_t] \kappa + \frac{1}{2} \kappa_t^2 \mathbb{V}[z_t]\right)\right)\right) \\
 \textcircled{14} & \quad \exp\left(-\frac{1}{2}\left(\mathbb{E}[\kappa] z_t + \xi_3 \xi_4 \exp\left(-\mathbb{E}[\kappa] z_t + \frac{1}{2} z_t^2 \mathbb{V}[\kappa]\right)\right)\right)
 \end{aligned}$$

$$\begin{aligned}
 \xi_1 & \quad \mathbb{E}[z_t]^2 \mathbb{V}[\kappa] + \mathbb{E}[\kappa]^2 \mathbb{V}[z_t] + \mathbb{V}[z_t] \mathbb{V}[x_t] \\
 \xi_2 & \quad \exp(-\mathbb{E}[z_t] \mathbb{E}[\kappa] + \frac{1}{2} \xi_1) \\
 \xi_3 & \quad \exp(-\mathbb{E}[\omega] + \frac{1}{2} \mathbb{V}[\omega]) \\
 \xi_4 & \quad (y_t - \mathbb{E}[\boldsymbol{\theta}^\top] \mathbf{x}_t)^2
 \end{aligned}$$