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

BMLIP, ¼ -2020

Magnus Koudahl

Battleplan

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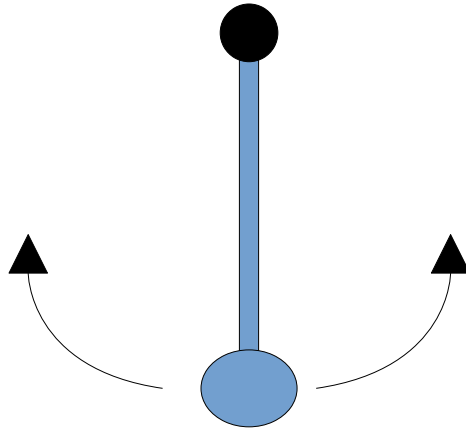- Relation to Bayes
- Markov Blankets

- Bayesian Brain Hypothesis
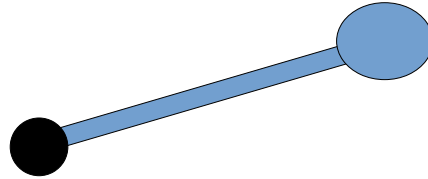- Free Energy Revisited
- Sample Structures
- "This goes to 11!"

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Premise

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Equilibria

Equilibria

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Equilibria

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Bayes?

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Bayes?

$$p(\;🌡\;) = \text{(Target) Prior}$$

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Bayes?

p(🌡) = (Target) Prior

q(🌡) = Posterior

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Markov Blankets

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Break time

What is Life? The Free Energy Principle and Active Inference
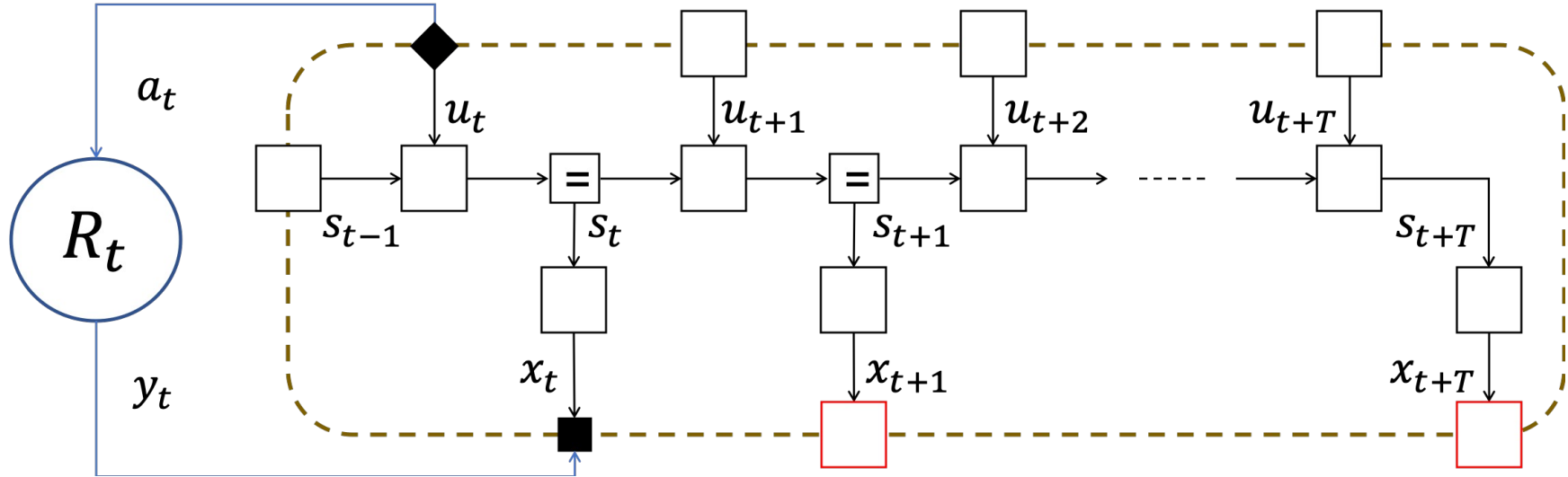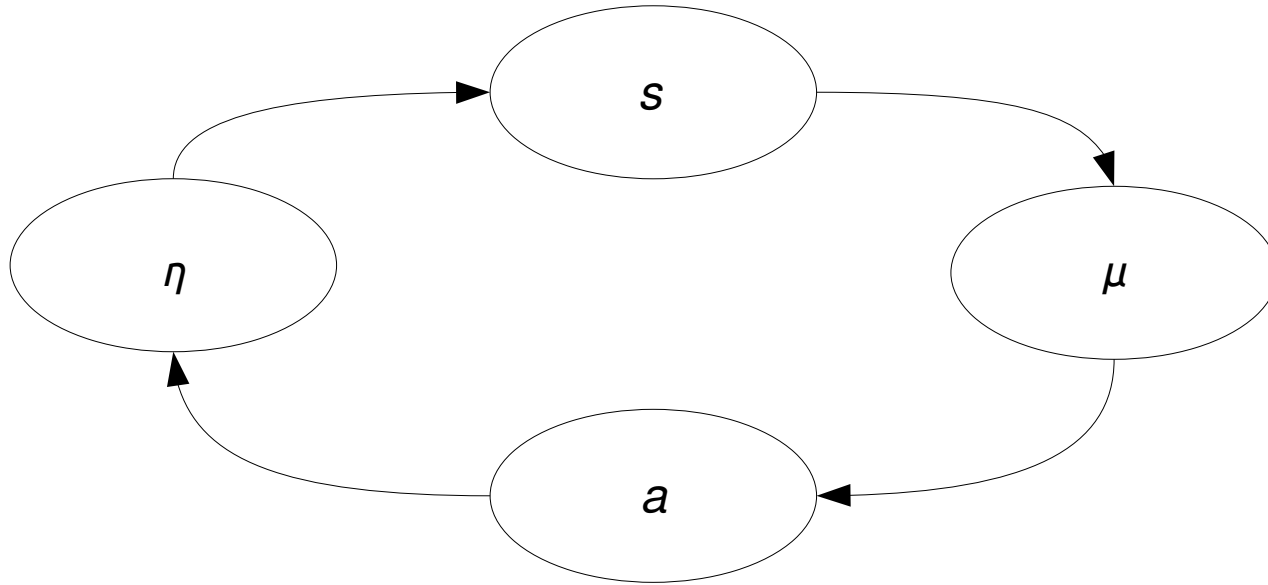
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Battleplan

- Premise
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- Relation to Bayes
- Markov Blankets

- Bayesian Brain Hypothesis
- Free Energy Revisited
- Sample Structures
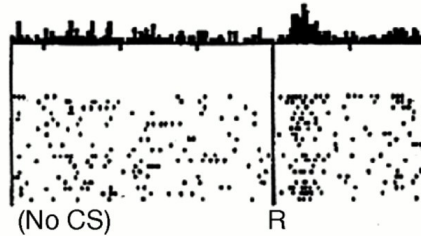- "This goes to 11!"

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The Bayesian Brain

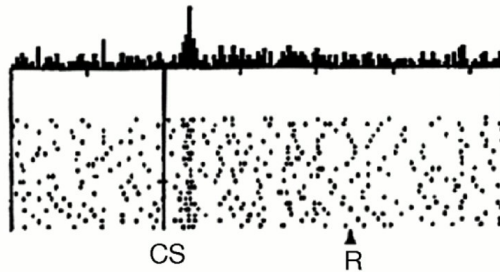*Perception is the inference of causes of observed impressions on our sensorium**

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*Loosely paraphrasing Helmholtz, 1866

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Predictive Coding

Do dopamine neurons report an error in the prediction of reward? *
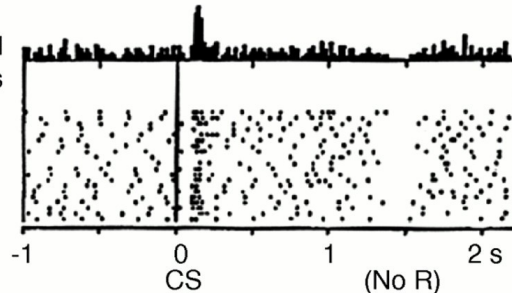
* Figure reproduced from Schultz, Dayan & Montague, 1997,
A Neural Substrate of Prediction and Reward
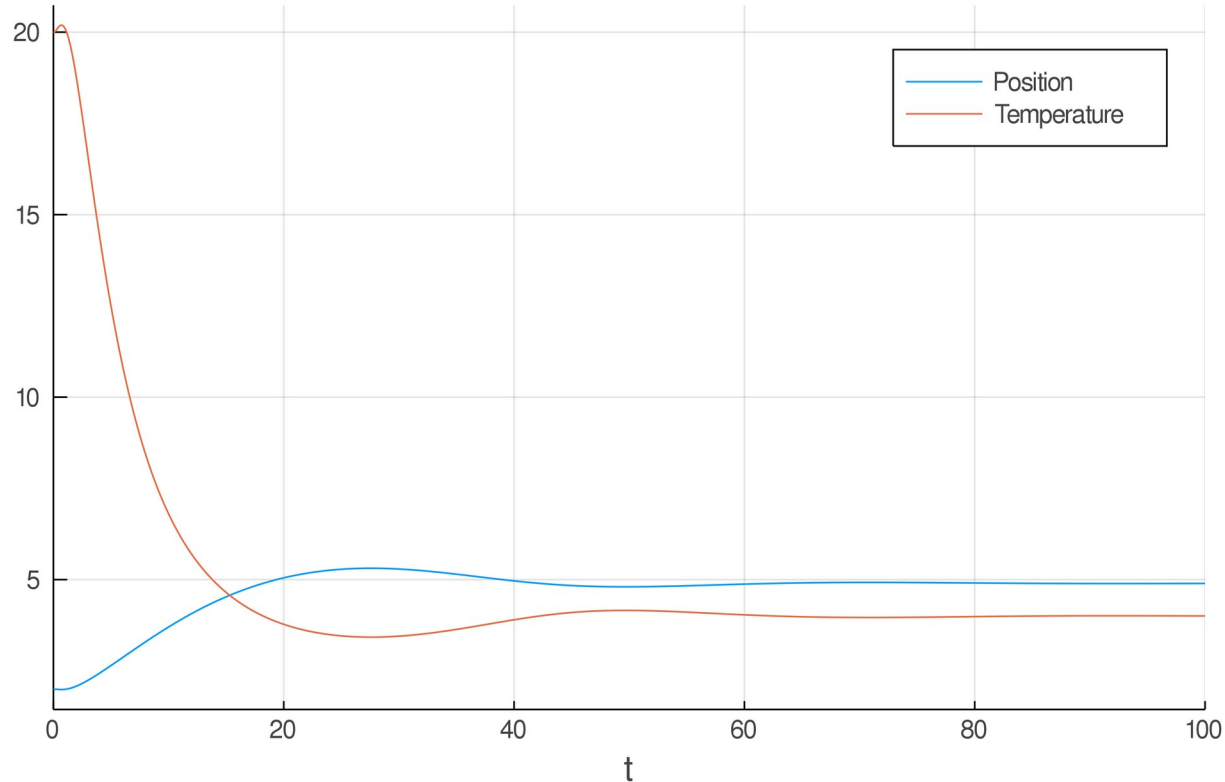
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Free Energy Revisited

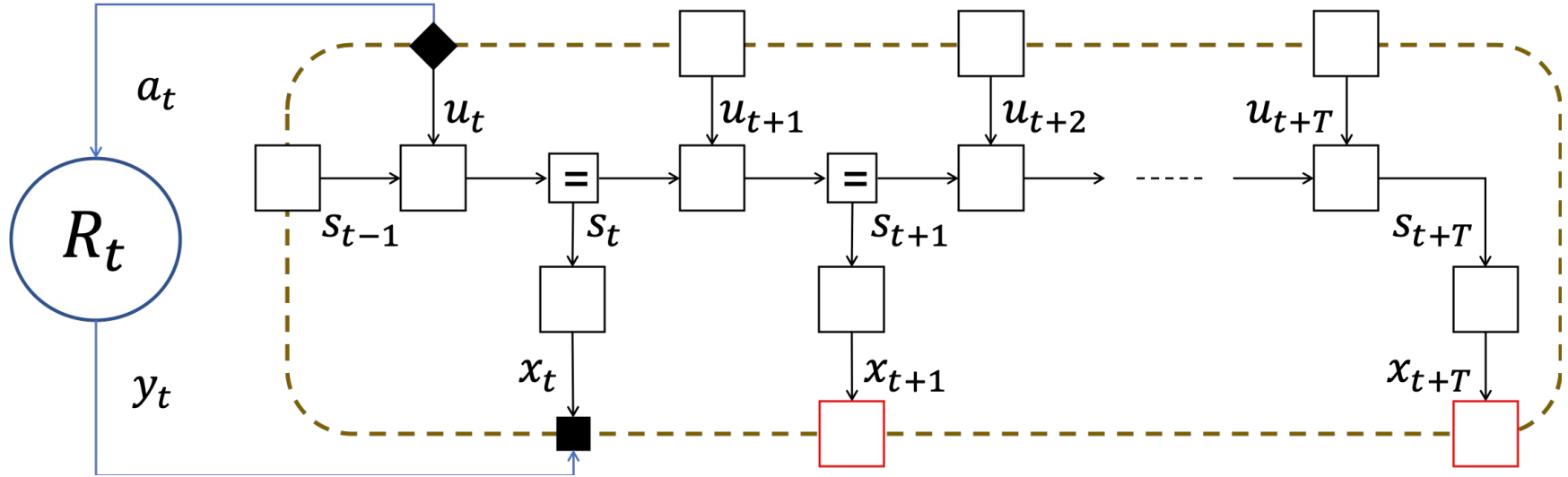$$F = - \int q(s|u) \log \frac{p(x, s|u)}{q(s|u)} \mathrm{d}s$$

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Free Energy Revisited

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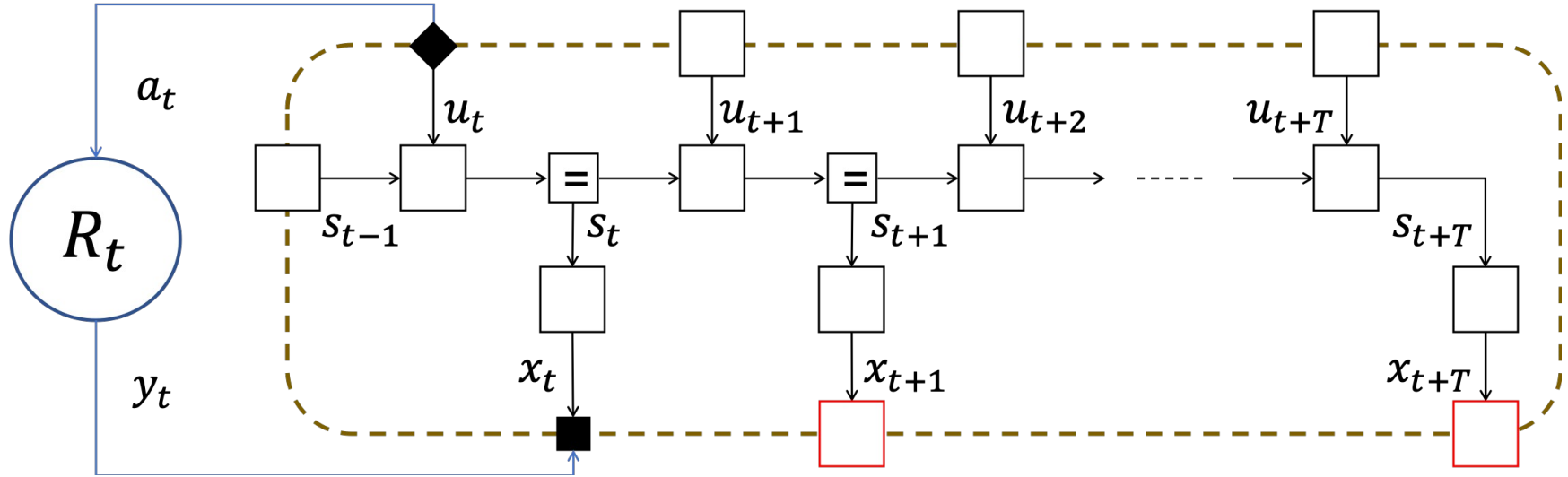
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The Bayesian Thermostat

The Discrete Time SSM

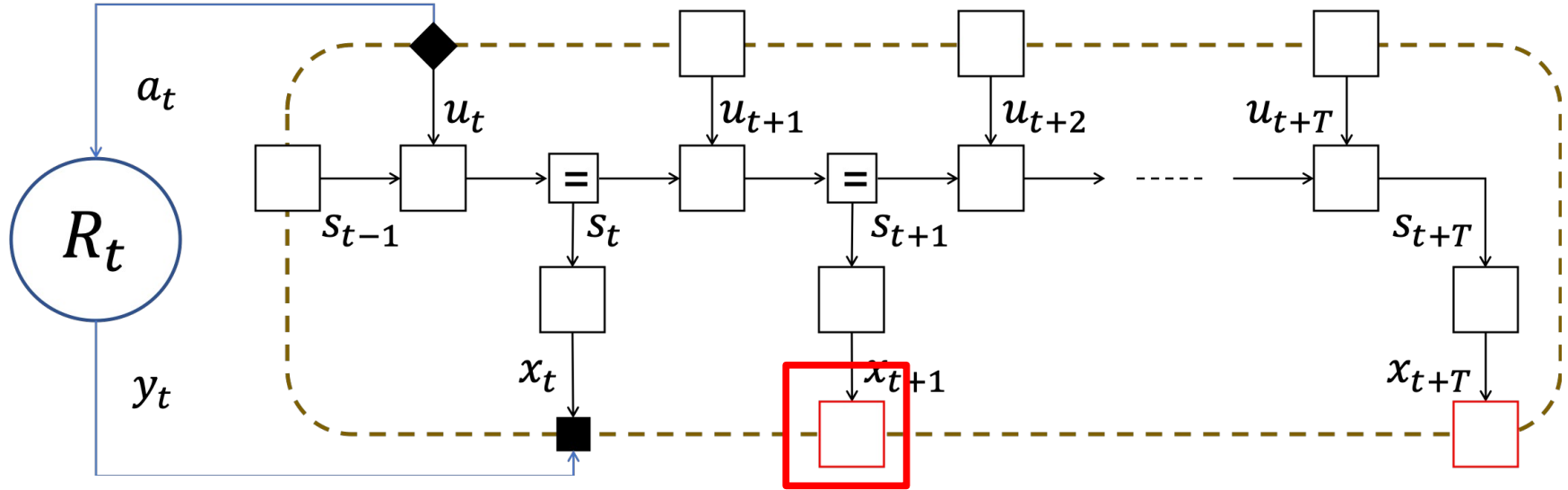What is Life? The Free Energy Principle and Active Inference

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Free Energy Revisited

$$EF = -\iint p(x|s)q(s|u)\log\frac{p(x,s|u)}{q(s|u)}\mathrm{d}x\mathrm{d}s$$

$$= \mathbf{E}_{p(x|s)}\left[F\right]$$

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How far can we push this?

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How far can we push this?

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How far can we push this?

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How far can we push this?

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Markov Blankets

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Markov Blankets

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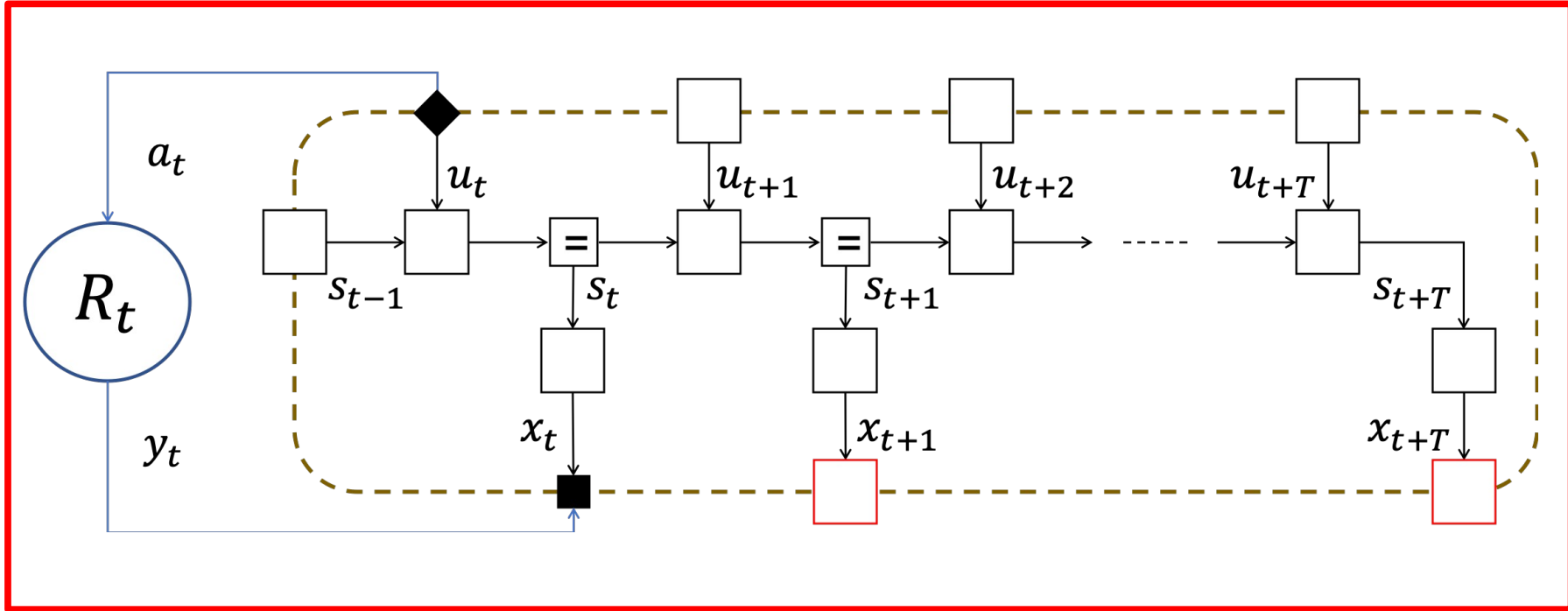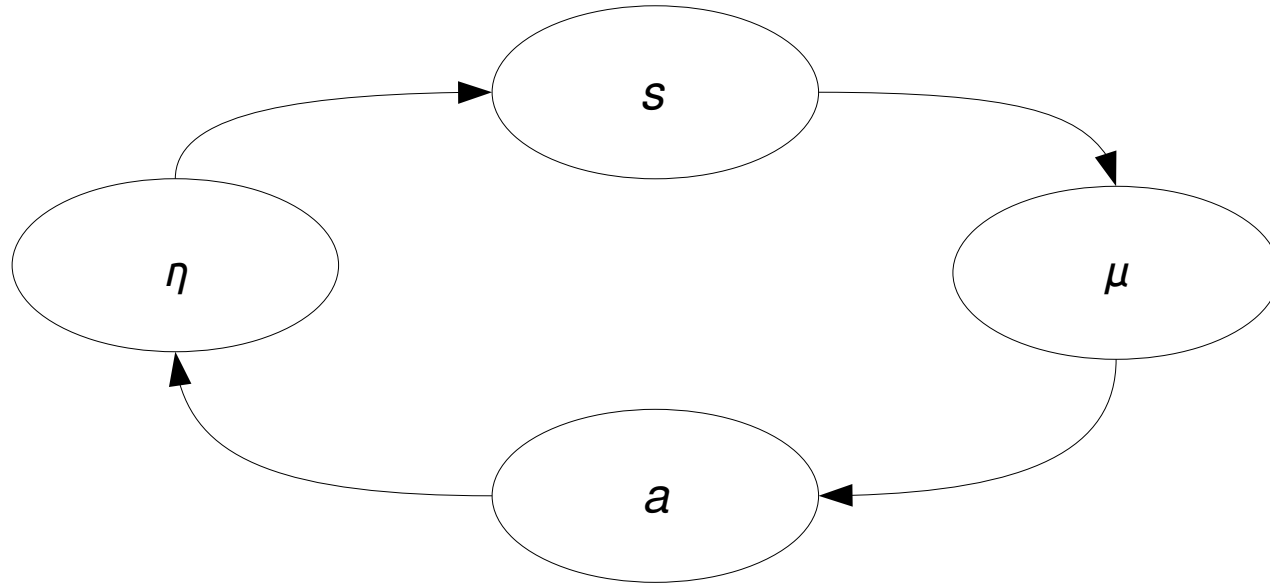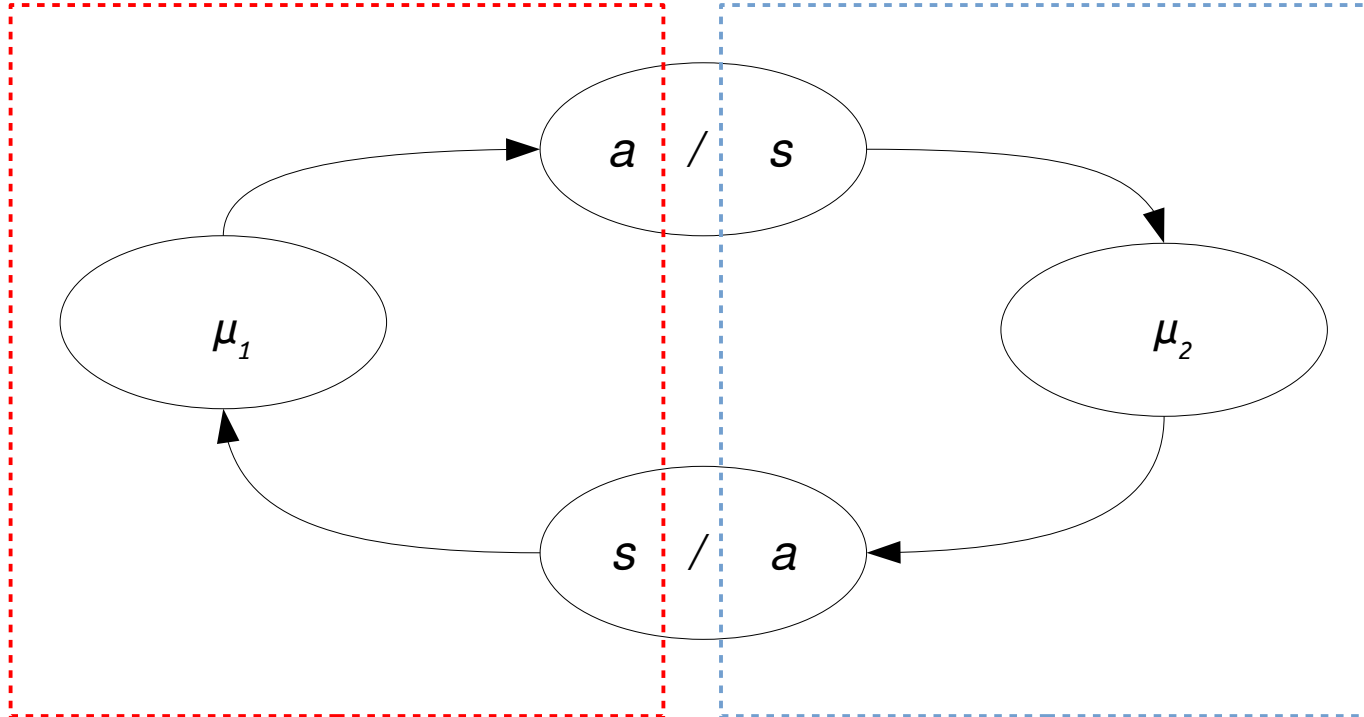
Further Reading

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
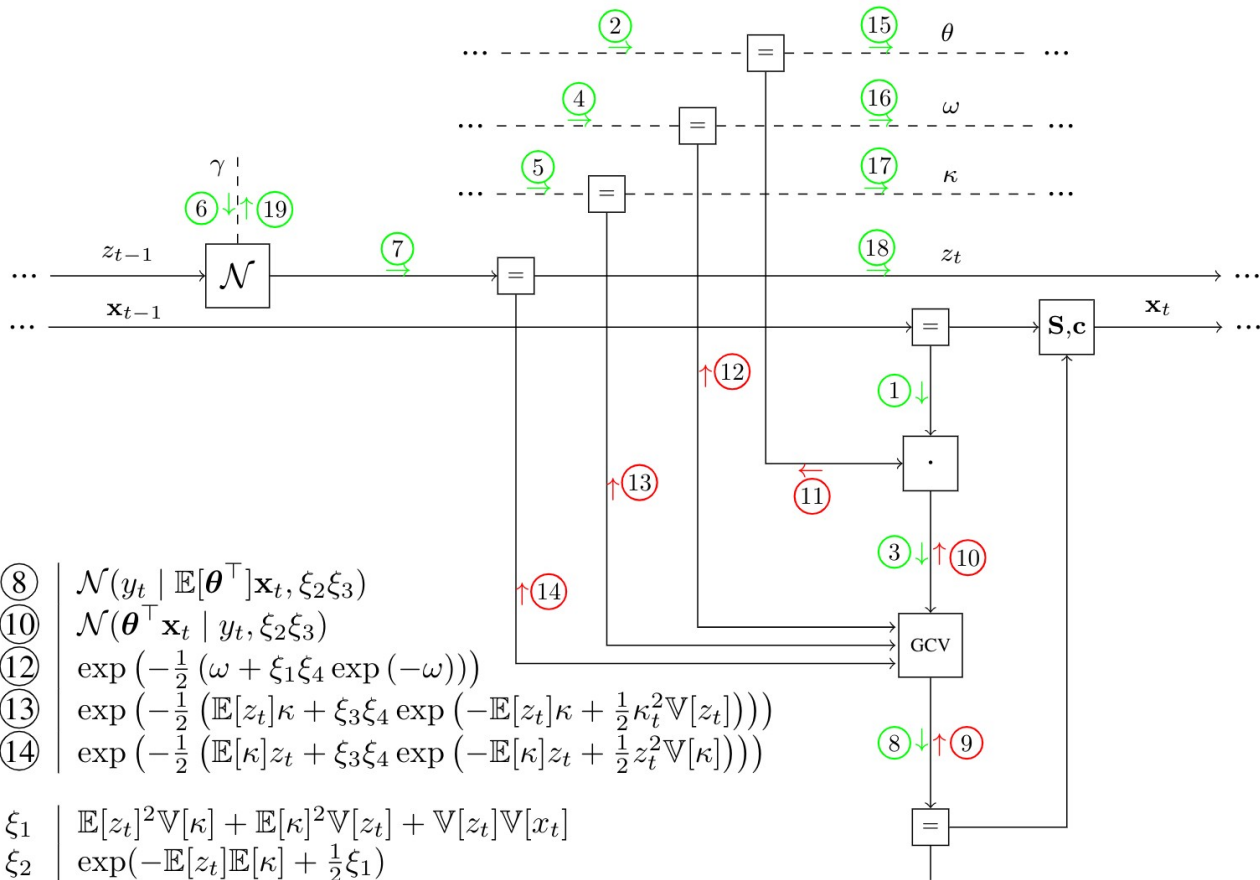Karl Friston – Knowing one's place
Christopher Buckley – A Mathematical Review
Karl Friston – Free Energy, Value and Attractors

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

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$\circled{8} \quad \mathcal{N}(y_t \mid \mathbb{E}[\boldsymbol{\theta}^\top]\mathbf{x}_t, \xi_2\xi_3)$

$\circled{10} \quad \mathcal{N}(\boldsymbol{\theta}^\top\mathbf{x}_t \mid y_t, \xi_2\xi_3)$

$\circled{12} \quad \exp\left(-\frac{1}{2}\left(\omega + \xi_1\xi_4\exp\left(-\omega\right)\right)\right)$

$\circled{13} \quad \exp\left(-\frac{1}{2}\left(\mathbb{E}[z_t]\kappa + \xi_3\xi_4\exp\left(-\mathbb{E}[z_t]\kappa + \frac{1}{2}\kappa_t^2\mathbb{V}[z_t]\right)\right)\right)$

$\circled{14} \quad \exp\left(-\frac{1}{2}\left(\mathbb{E}[\kappa]z_t + \xi_3\xi_4\exp\left(-\mathbb{E}[\kappa]z_t + \frac{1}{2}z_t^2\mathbb{V}[\kappa]\right)\right)\right)$

$\xi_1 \quad \mathbb{E}[z_t]^2\mathbb{V}[\kappa] + \mathbb{E}[\kappa]^2\mathbb{V}[z_t] + \mathbb{V}[z_t]\mathbb{V}[x_t]$

$\xi_2 \quad \exp(-\mathbb{E}[z_t]\mathbb{E}[\kappa] + \frac{1}{2}\xi_1)$

$\xi_3 \quad \exp(-\mathbb{E}[\omega] + \frac{1}{2}\mathbb{V}[\omega])$

$\xi_4 \quad (y_t - \mathbb{E}[\boldsymbol{\theta}^\top]\mathbf{x}_t)^2$