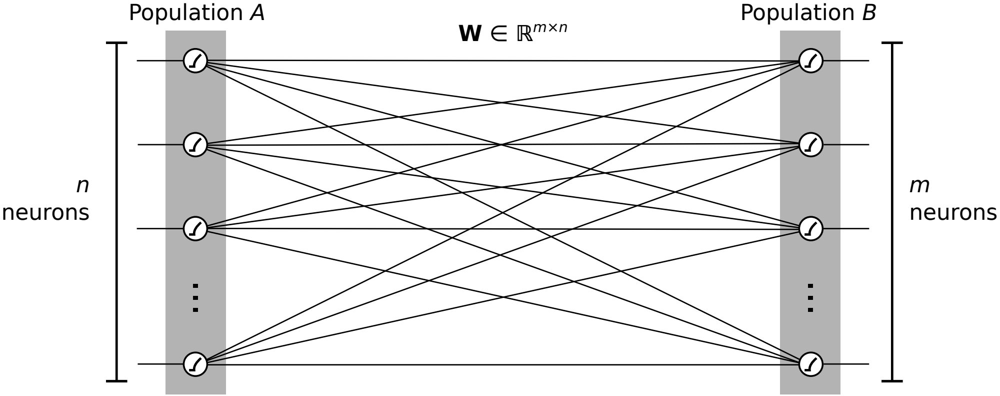
SYDE 556/750

Simulating Neurobiological Systems
Lecture 5: Feed-Forward Transformation

Andreas Stöckel

January 30, 2020

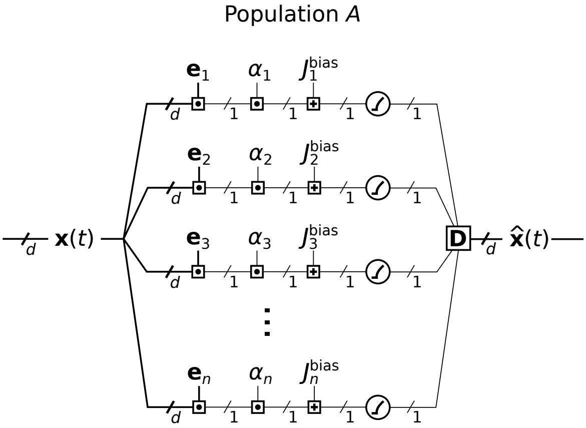
NEF Principle 2: Transformation



NEF Principle 2 – Transformation

Connections between populations describe *transformations* of neural representations. Transformations are functions of the variables represented by neural populations.

A Tale of Two Populations (I)



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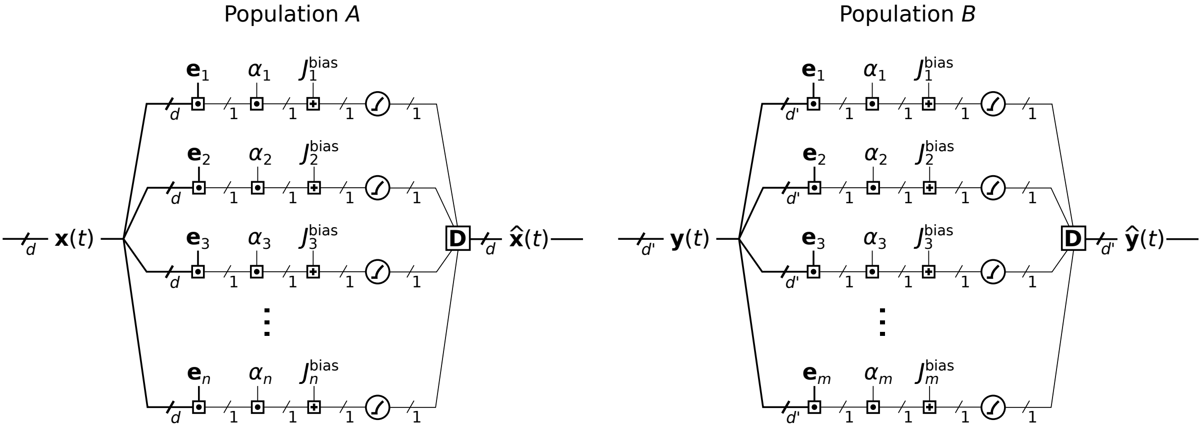
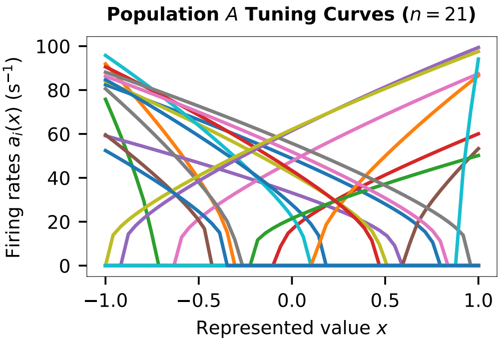
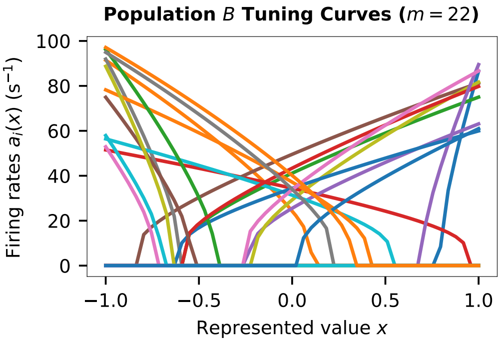
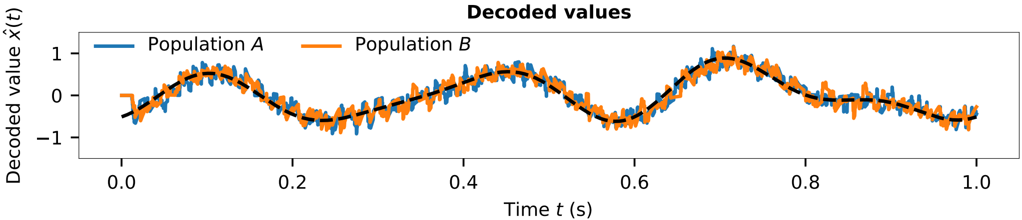


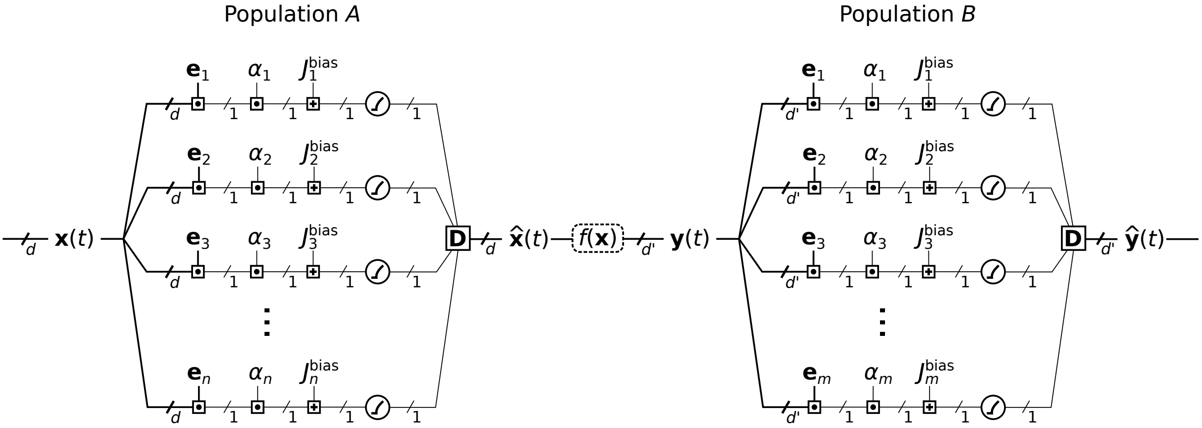
Communication Channel Experiment: Same input signal







A Tale of Two Populations (II)



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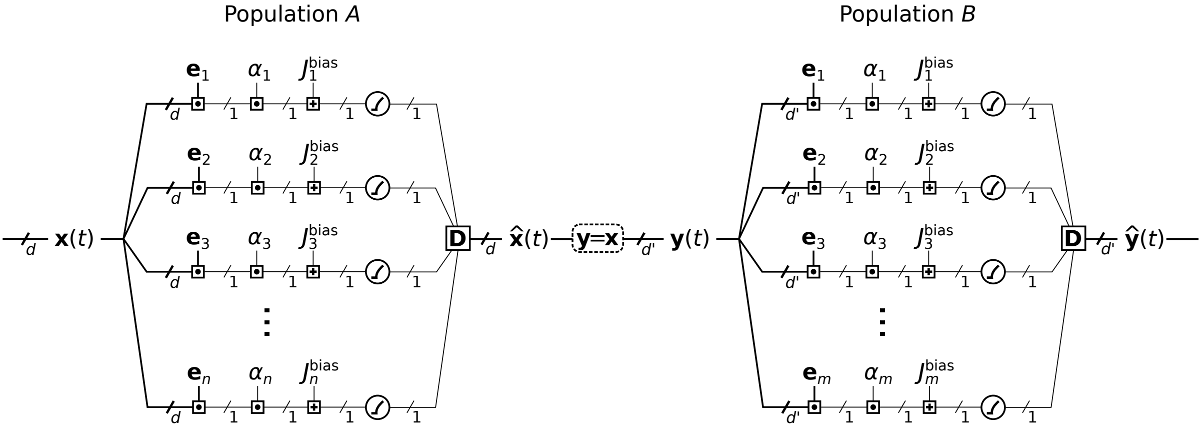
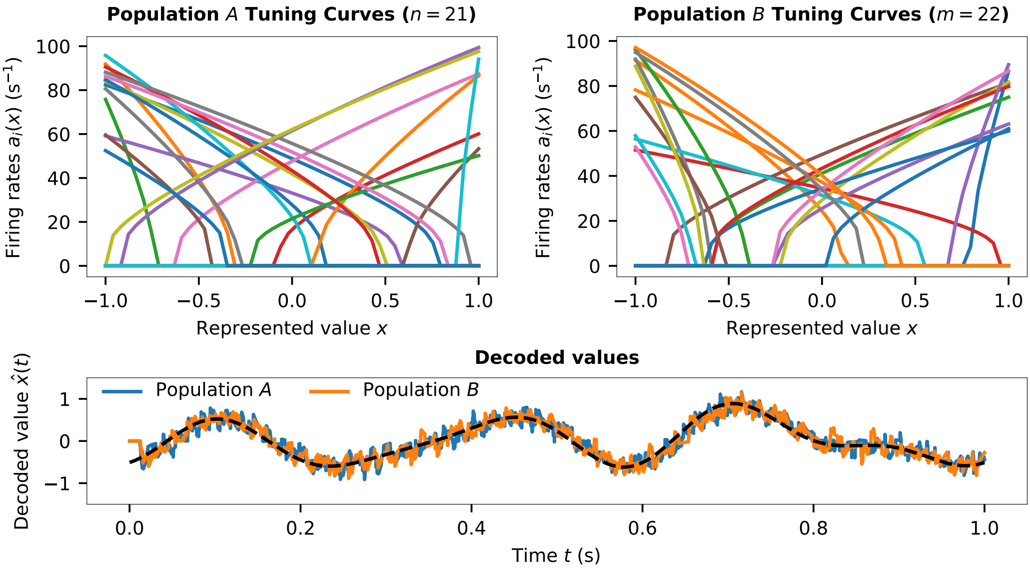
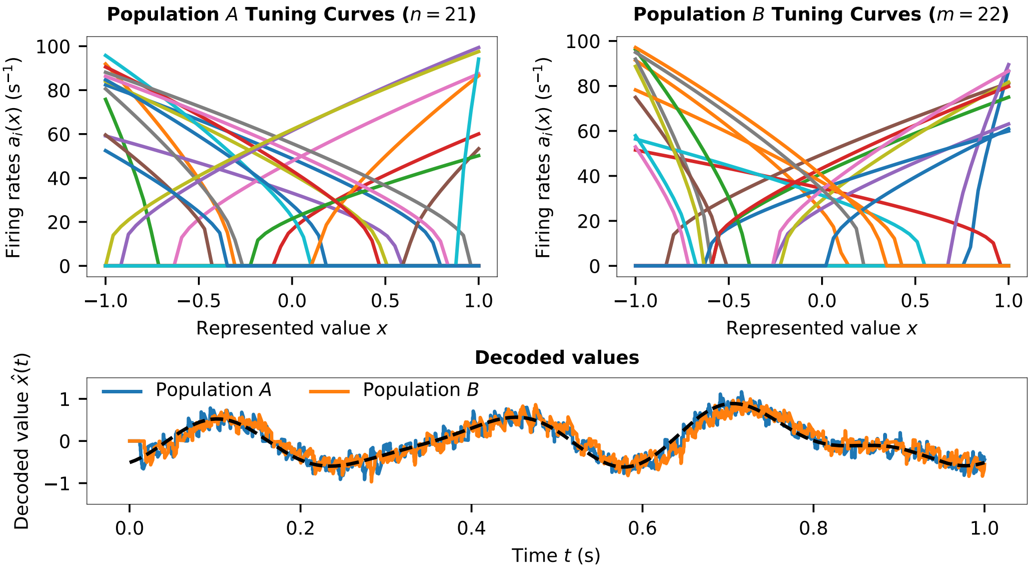


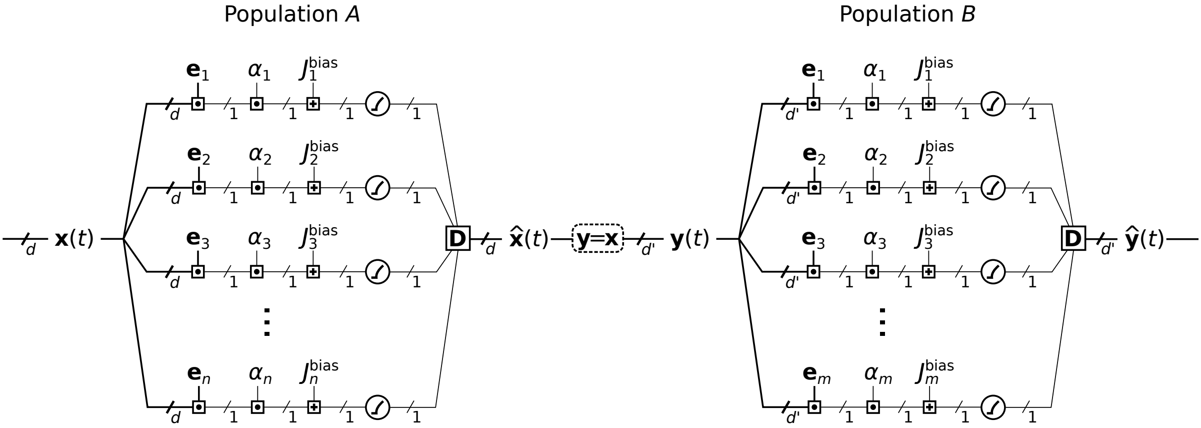
Communication Channel Experiment: Populations in series



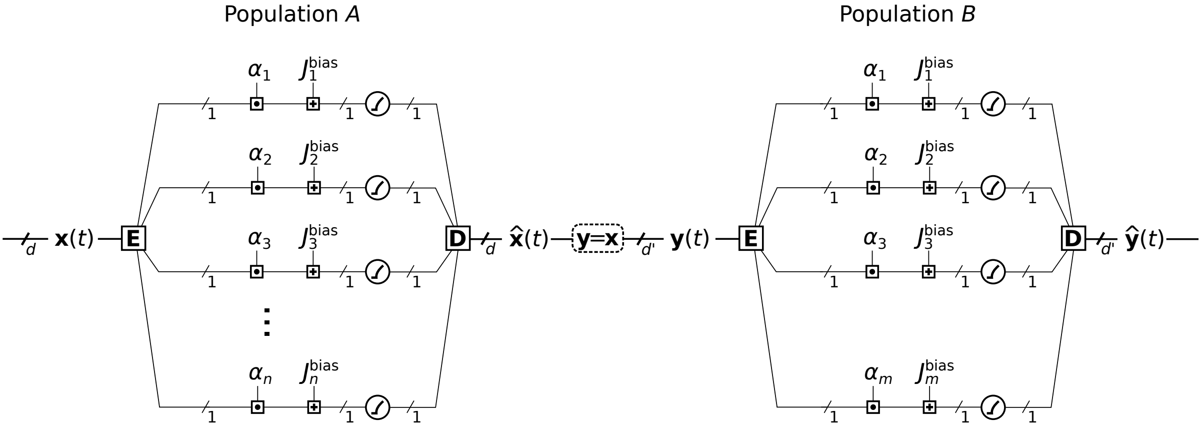
Communication Channel Experiment: Populations in series



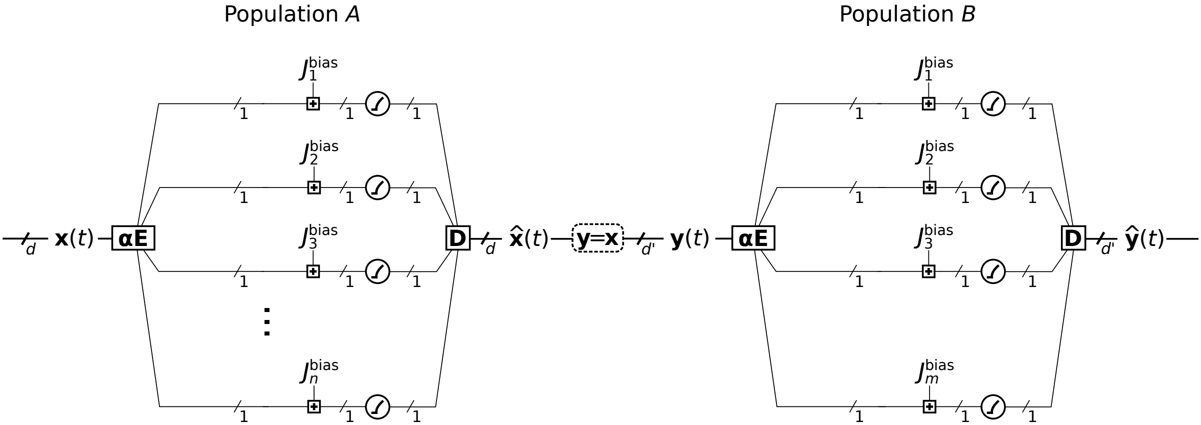
Computing Synaptic Weights: Step 1 – Encoding Matrix



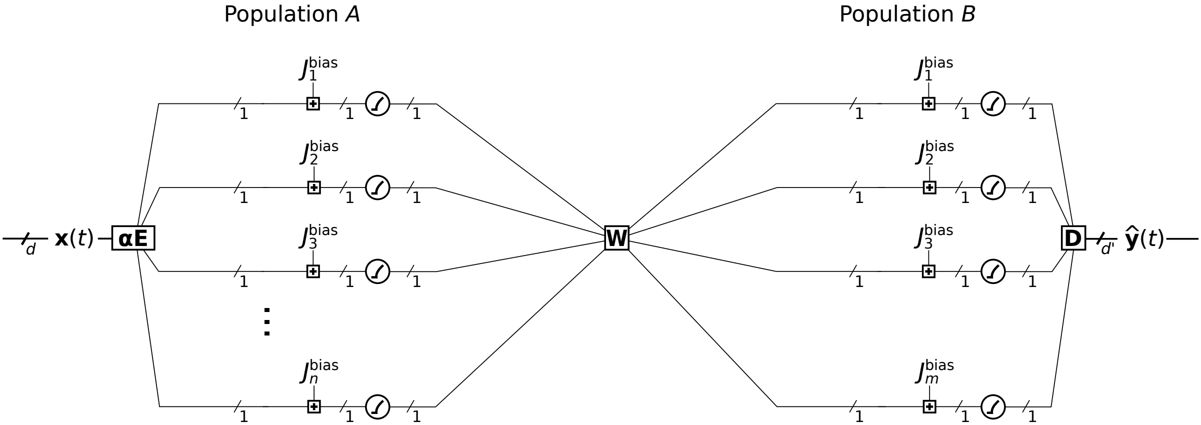
Computing Synaptic Weights: Step 1 – Encoding Matrix



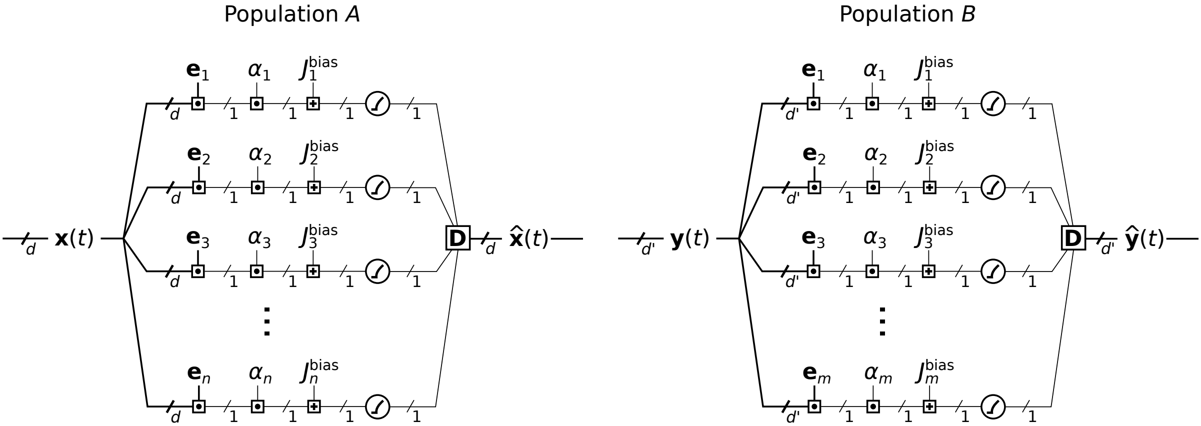
Computing Synaptic Weights: Step 2 – Scaled Encoding Matrix



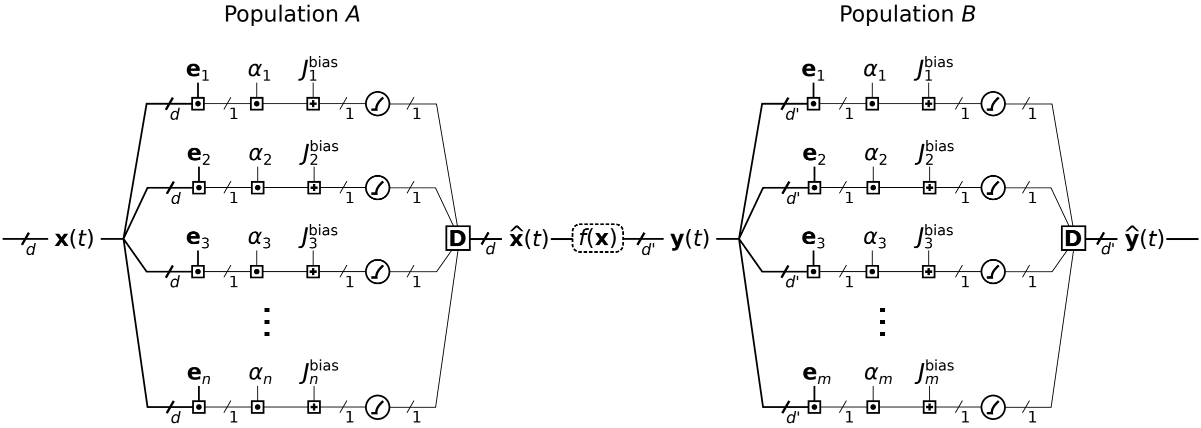
Computing Synaptic Weights: Step 3 – $\mathbf{W} = \mathbf{E}\mathbf{D}$



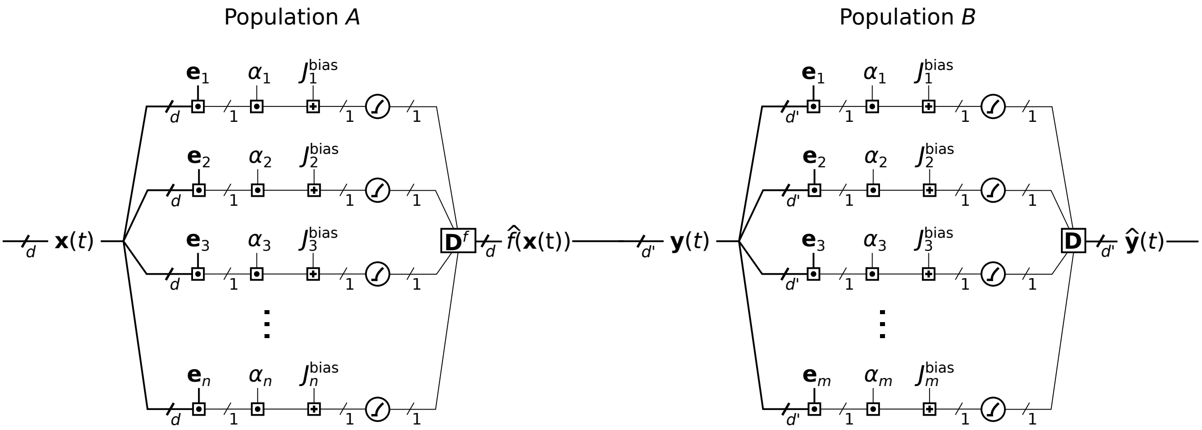
Computing Functions



Computing Functions

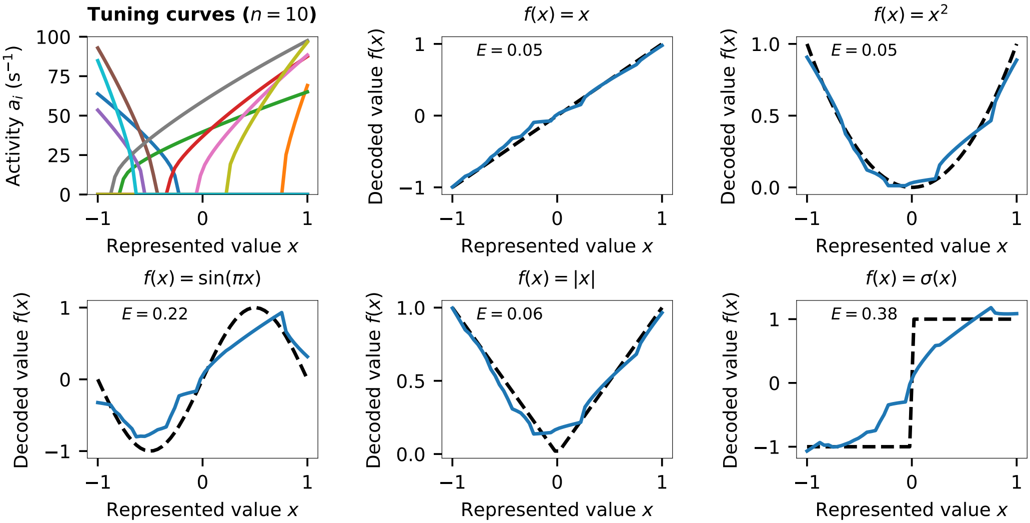


Computing Functions

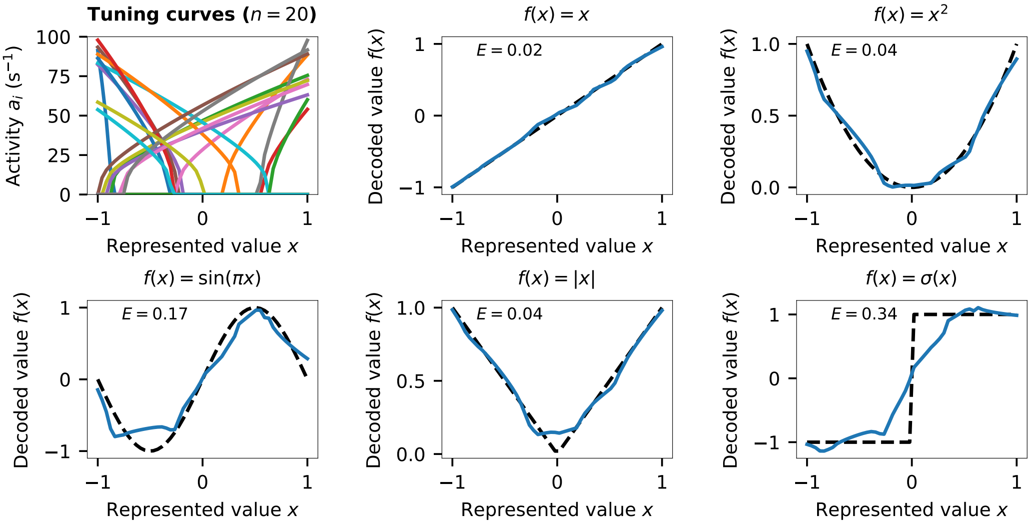


Function Decoder $\mathbf{D}^f = \left((\mathbf{A}\mathbf{A}^\top + N\sigma^2\mathbf{I})^{-1}\mathbf{A}\mathbf{Y}^\top\right)^\top$, where $\left(\mathbf{Y}\right)_{ik} = \left(f(\mathbf{x}_k)\right)_i$

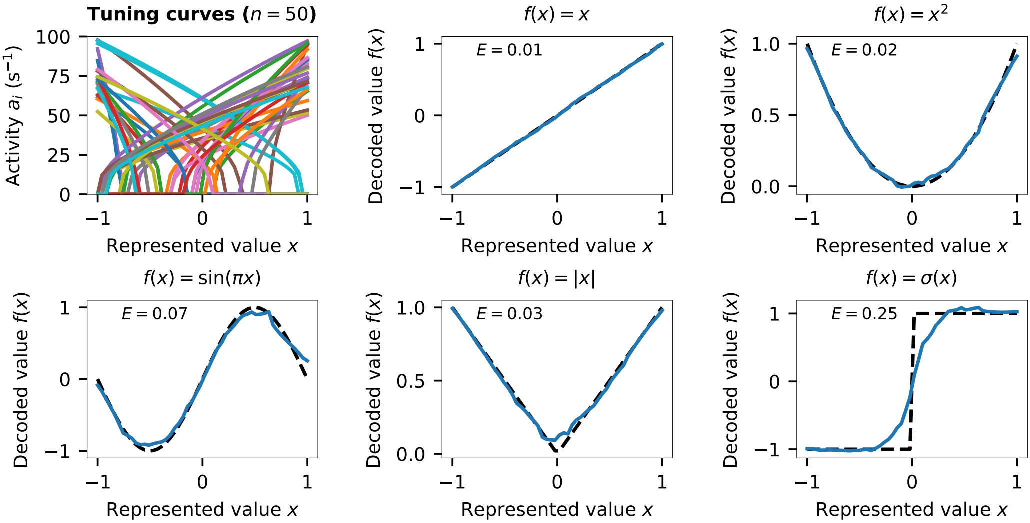
Decoding Functions – Using a Few Neurons



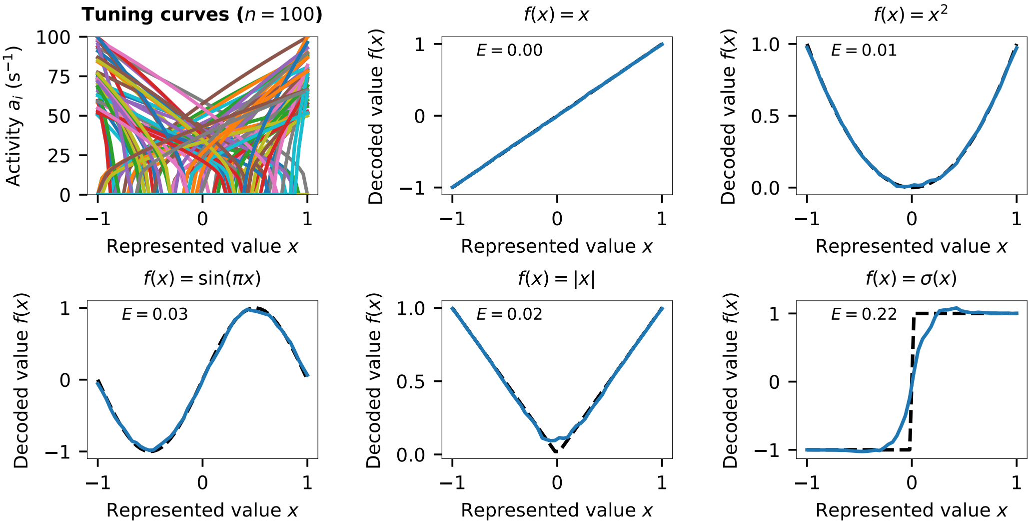
Decoding Functions – Using More Neurons



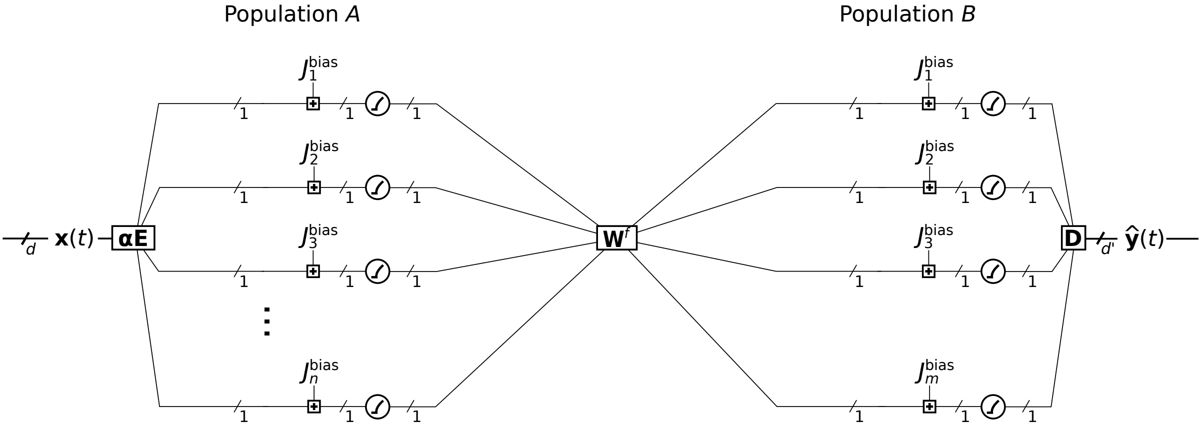
Decoding Functions – Using More Neurons



Decoding Functions – Using More Neurons



Computing Functions – Weight Matrix



$$\mathbf{W}^f = \mathbf{E}\mathbf{D}^f$$

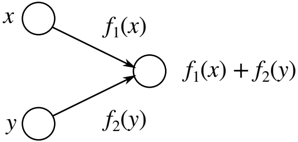
Computing Multivariate Functions

Homogenous population Heterogenous population

Linear connection Inh. connection Exc. connection

Linear Superposition

$$W^{f_1}\mathbf{a}_1(\mathbf{x}) + W^{f_2}\mathbf{a}_2(\mathbf{y})$$



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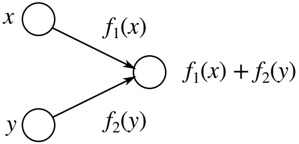
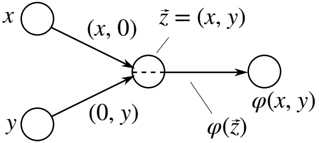
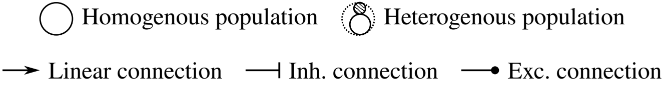


Nonlinear Functions

Multi-dimensional $\mathbf{z}$



Computing Multivariate Functions



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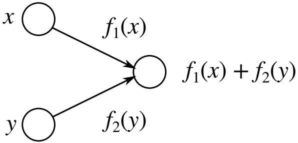
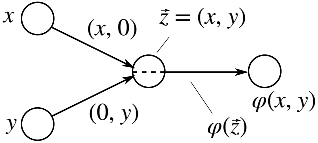


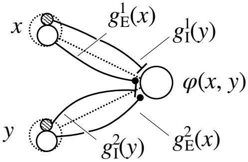
Nonlinear Functions

Multi-dimensional $\mathbf{z}$



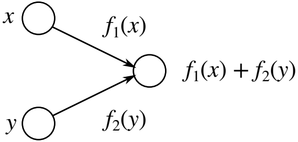
(Dendritic Computation)

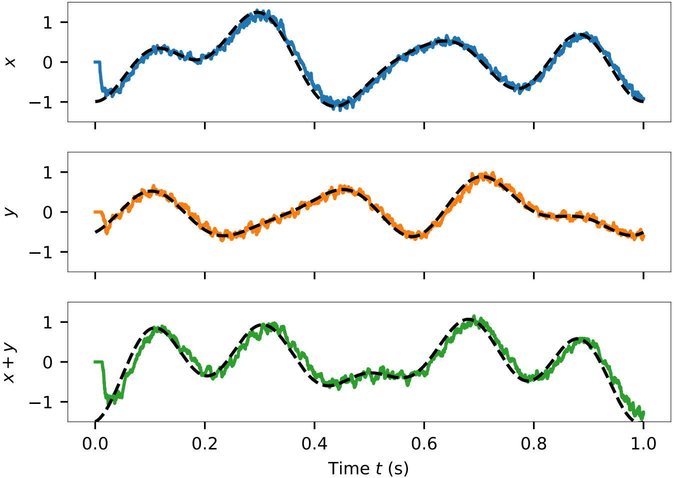
Exploit dendritic nonlinearity



Computing Multivariate Functions – Linear Superposition

Linear Superposition

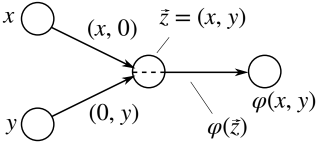


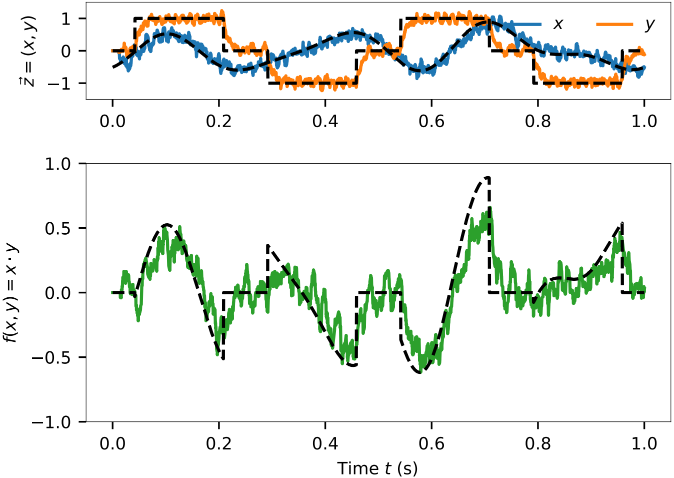


Computing Multivariate Functions – Multiplication

Nonlinear Functions

Multi-dimensional $\mathbf{z}$

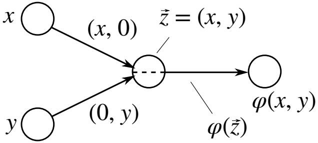




Computing Multivariate Functions – Multiplication

Nonlinear Functions

Multi-dimensional $\mathbf{z}$



Multiplication is useful...

- Gating of signals
- Attention effects
- Binding
- Statistical inference

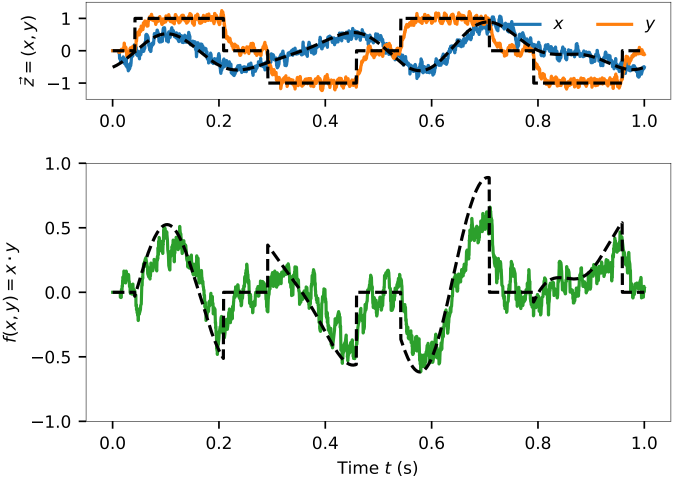


Image sources

Title slide
"Yellow Butterfly"
Author: Albert Bierstadt, circa 1890.
From Wikimedia.