

SYDE 556/750

Simulating Neurobiological Systems
Lecture 5: Feed-Forward Transformation

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January 30, 2020

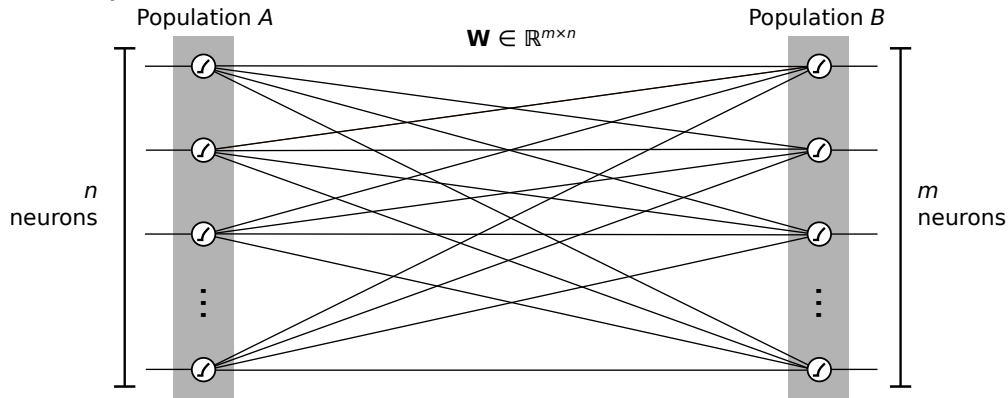


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NEF Principle 2: Transformation

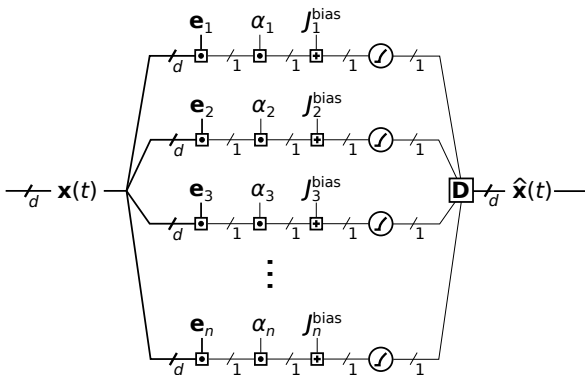


NEF Principle 2 – Transformation

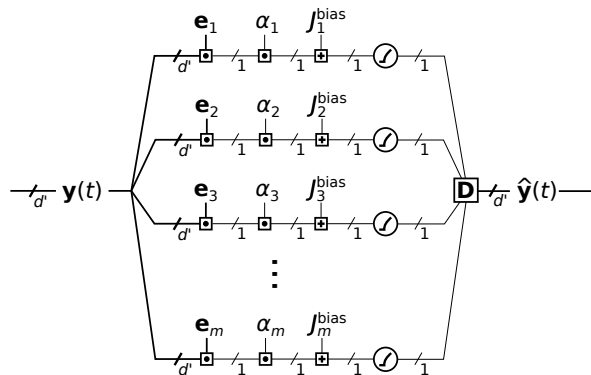
Connections between populations describe *transformations* of neural representations. Transformations are functions of the variables represented by neural populations.

A Tale of Two Populations (I)

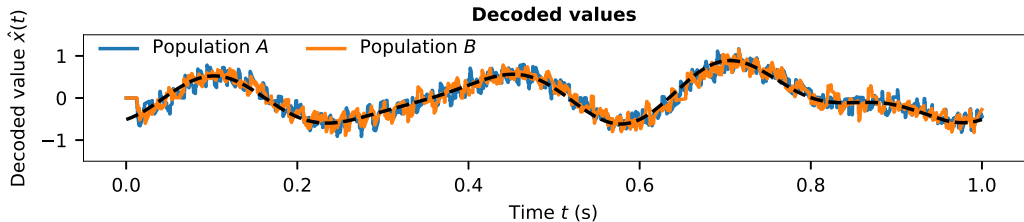
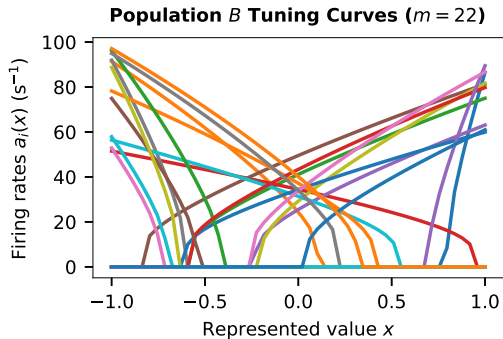
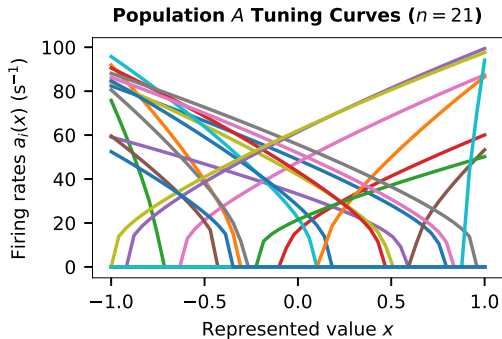
Population A



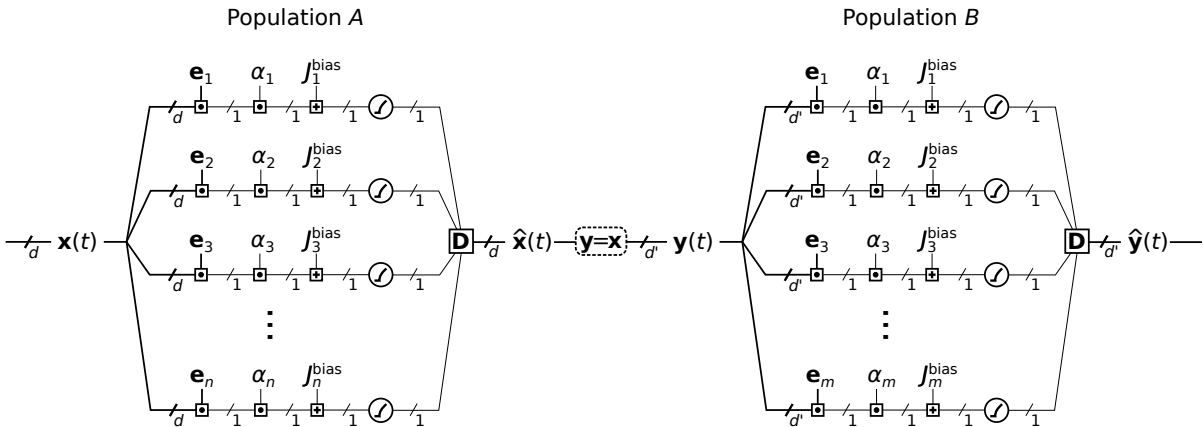
Population B



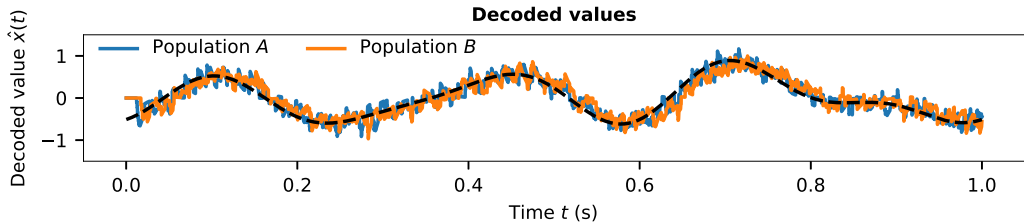
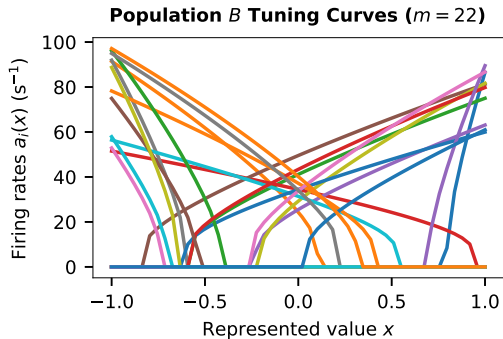
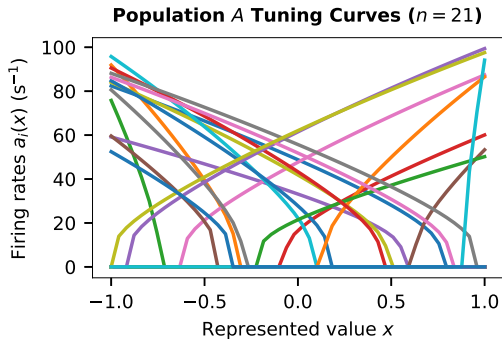
Communication Channel Experiment: Same input signal



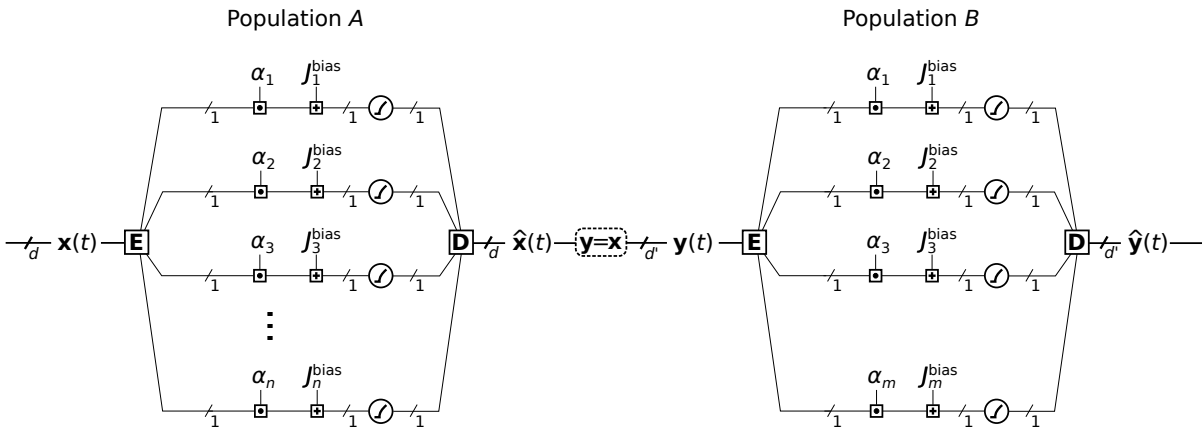
A Tale of Two Populations (II)



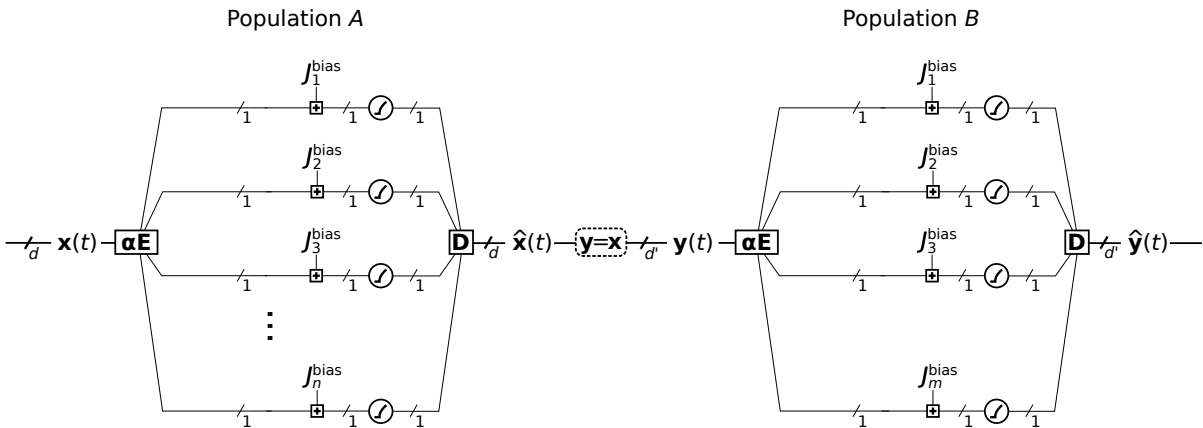
Communication Channel Experiment: Populations in series



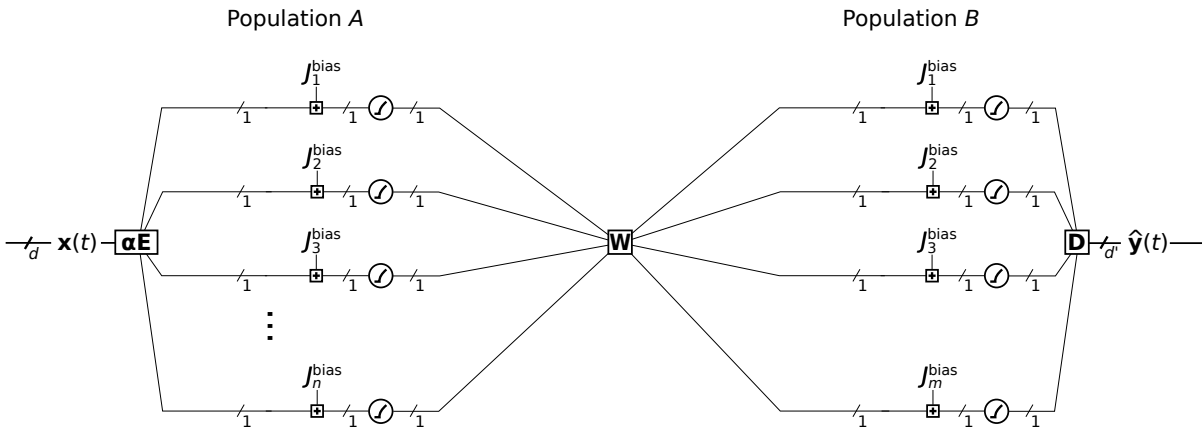
Computing Synaptic Weights: Step 1 – Encoding Matrix



Computing Synaptic Weights: Step 2 – Scaled Encoding Matrix

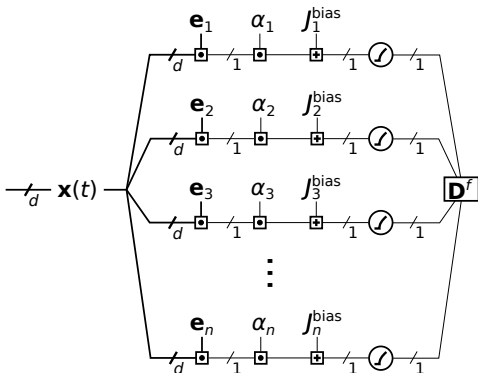


Computing Synaptic Weights: Step 3 – $\mathbf{W} = \mathbf{E}\mathbf{D}$

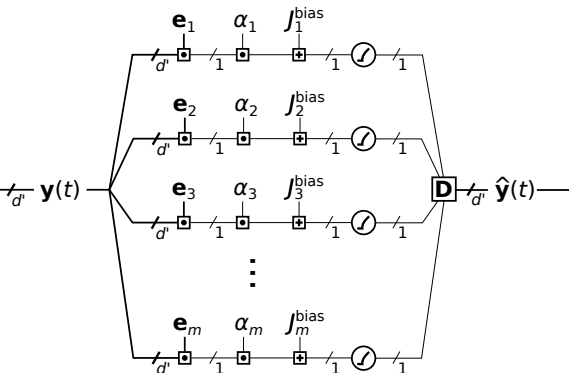


Computing Functions

Population A

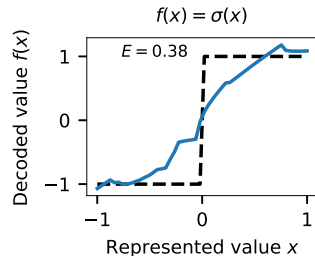
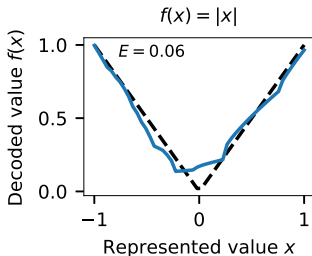
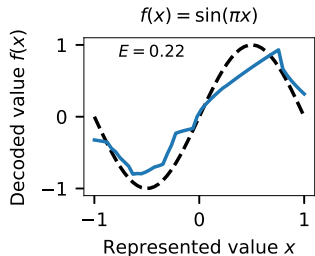
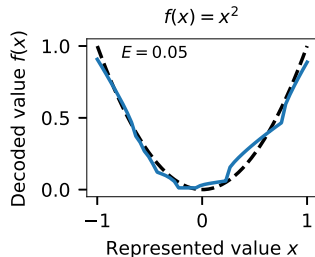
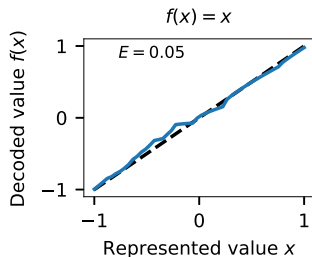
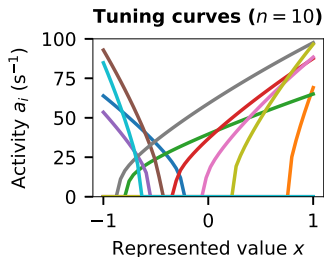


Population B



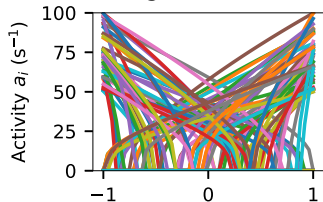
Function Decoder $\mathbf{D}^f = ((\mathbf{A}\mathbf{A}^\top + N\sigma^2\mathbf{I})^{-1}\mathbf{A}\mathbf{Y}^\top)^\top$, where $(\mathbf{Y})_{ik} = (f(\mathbf{x}_k))_i$

Decoding Functions – Using a Few Neurons



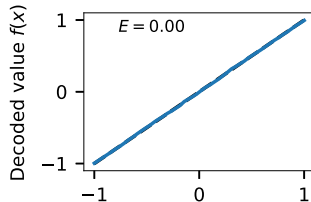
Decoding Functions – Using More Neurons

Tuning curves ($n = 100$)



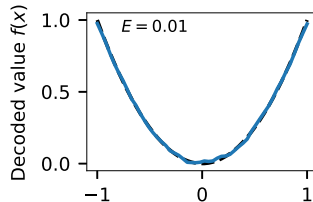
Represented value x

$$f(x) = x$$



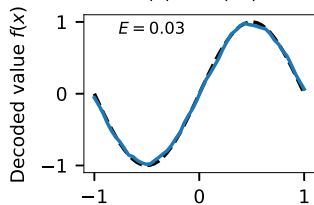
Represented value x

$$f(x) = x^2$$



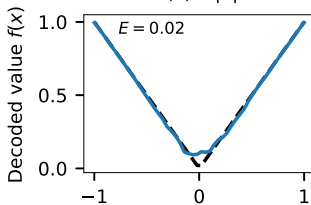
Represented value x

$$f(x) = \sin(\pi x)$$



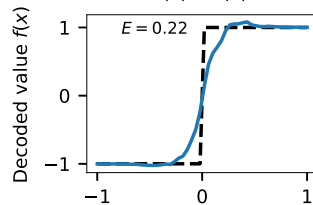
Represented value x

$$f(x) = |x|$$



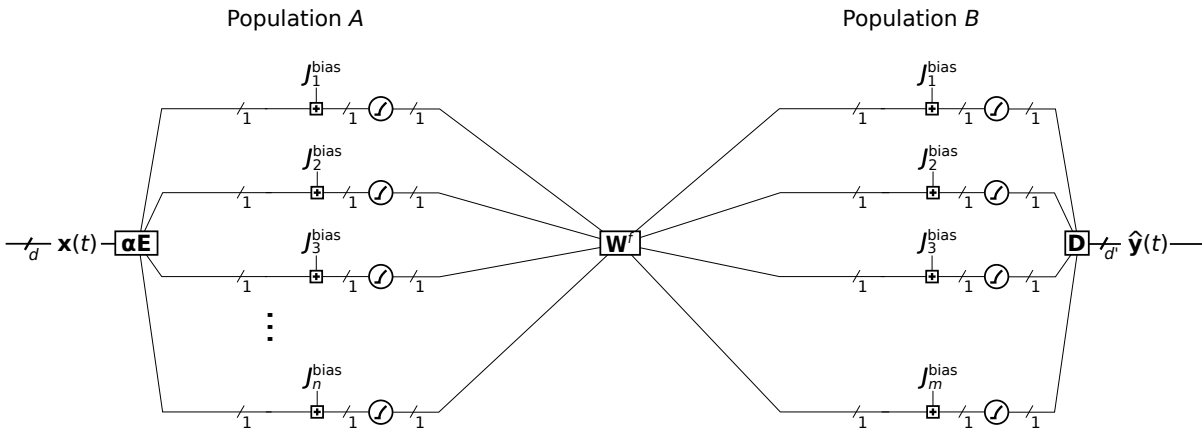
Represented value x

$$f(x) = \sigma(x)$$



Represented value x

Computing Functions – Weight Matrix



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

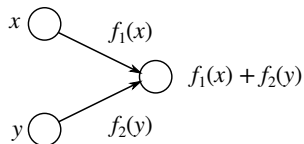
Computing Multivariate Functions

○ Homogenous population ⊗ Heterogenous population

→ Linear connection —| Inh. connection —● Exc. connection

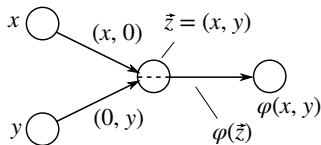
Linear Superposition

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



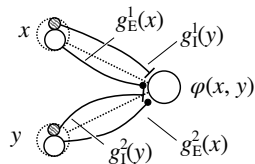
Nonlinear Functions

Multi-dimensional \mathbf{z}



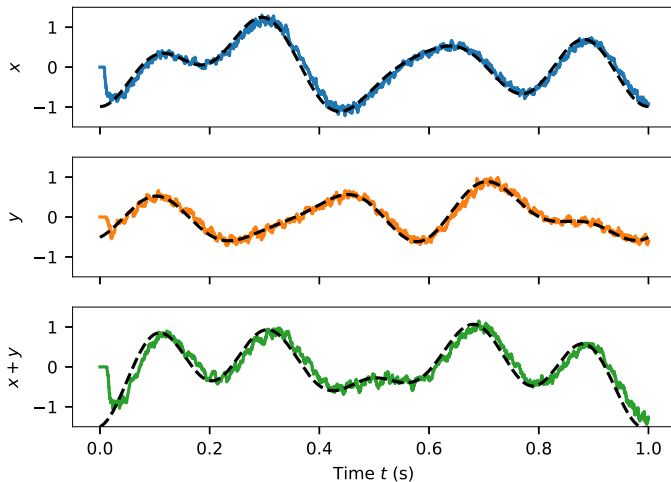
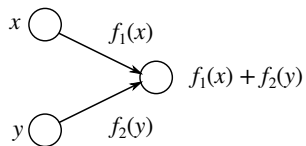
(Dendritic Computation)

Exploit dendritic nonlinearity



Computing Multivariate Functions – Linear Superposition

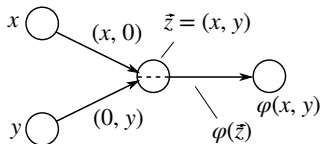
Linear Superposition



Computing Multivariate Functions – Multiplication

Nonlinear Functions

Multi-dimensional \mathbf{z}



Multiplication is useful...

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

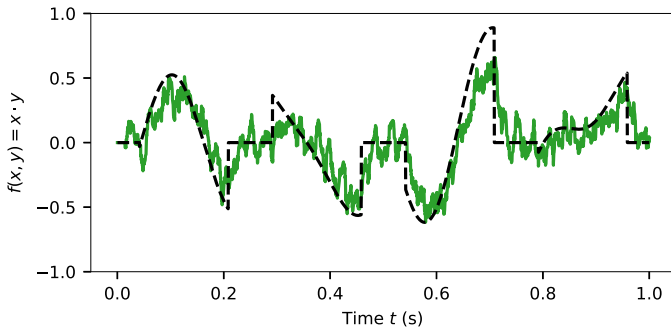
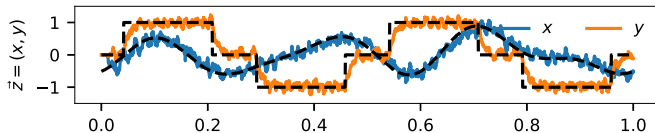


Image sources

Title slide

“Yellow Butterfly”

Author: Albert Bierstadt, circa 1890.

From Wikimedia.