

Quote of the Day

*“To deal with a 14-dimensional space, visualize a 3-D
space and say 'fourteen' to yourself very loudly.
Everyone does it.”*

Geoff Hinton

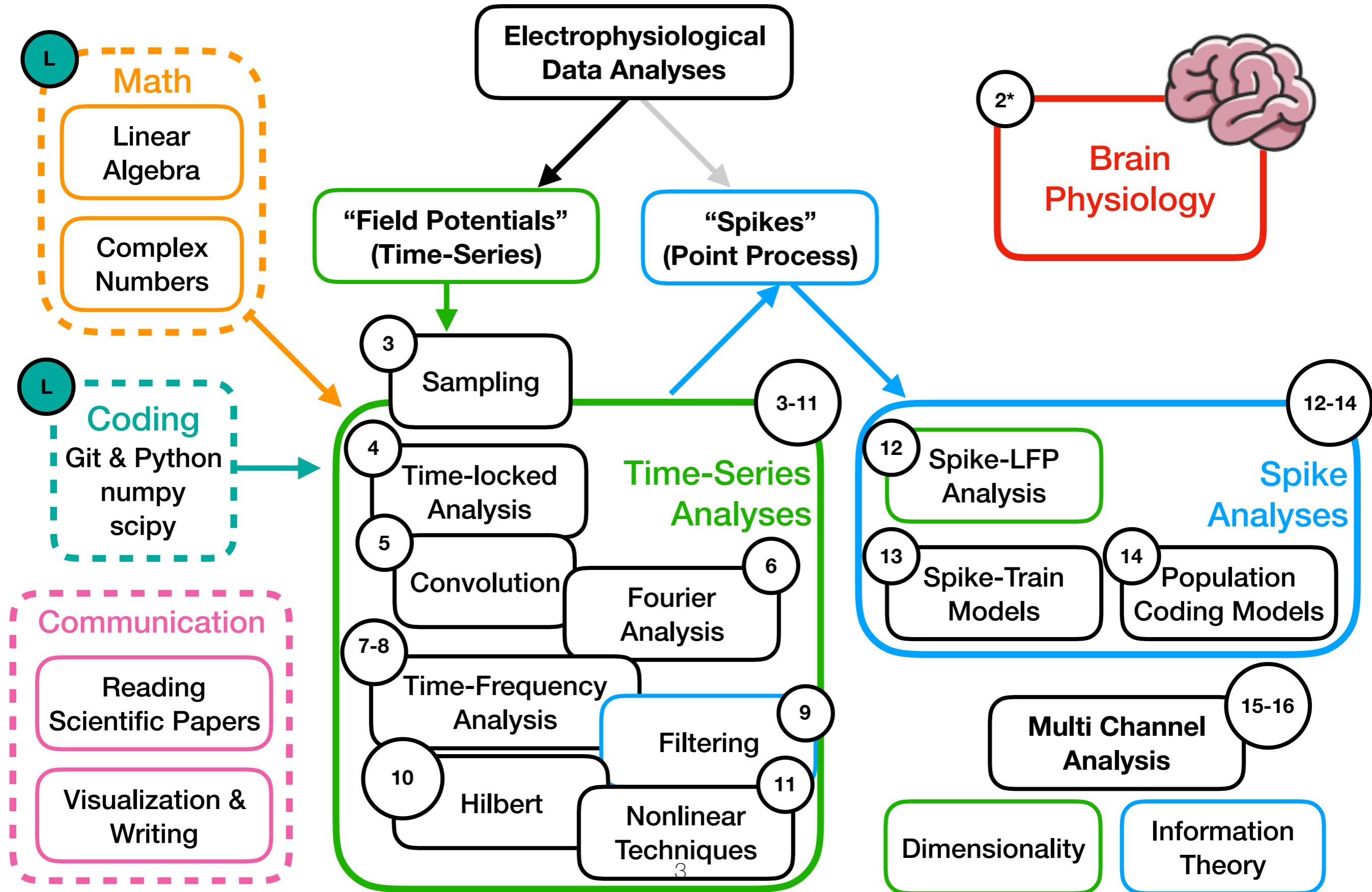


MultiDimensional Data Decomposition

Lecture 15
July 30, 2019



Course Outline: Road Map

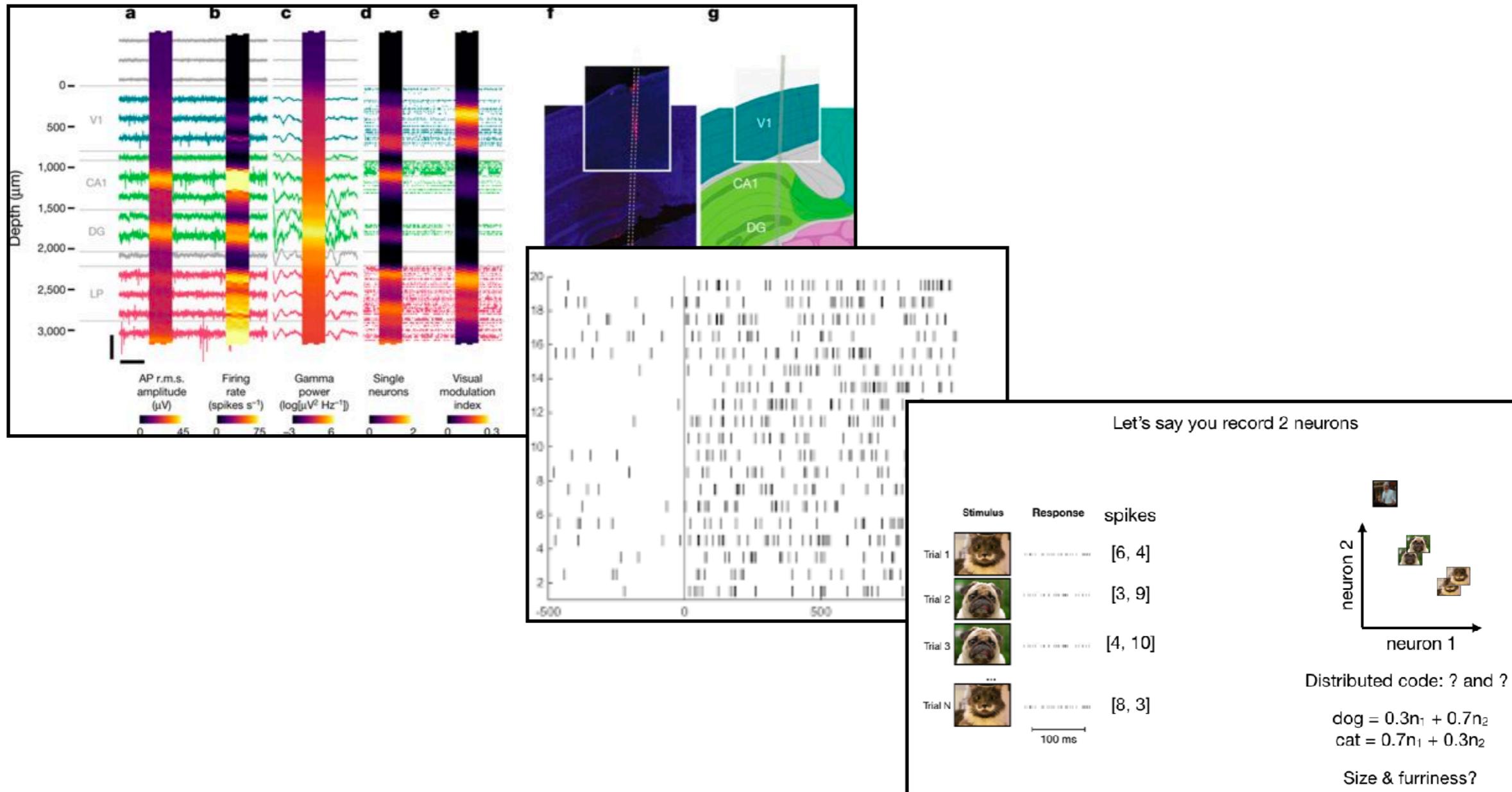


1. Introduce other types of (multichannel) neural data
2. Understand dimensionality
3. Motivate & introduce decomposition techniques



Multi-Channel Electrophysiology

Multi Single-Unit Decodings

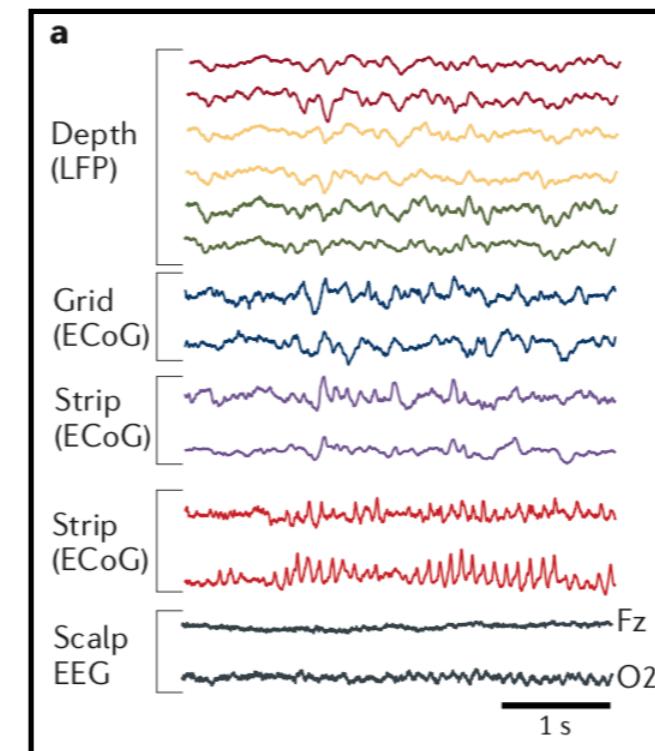
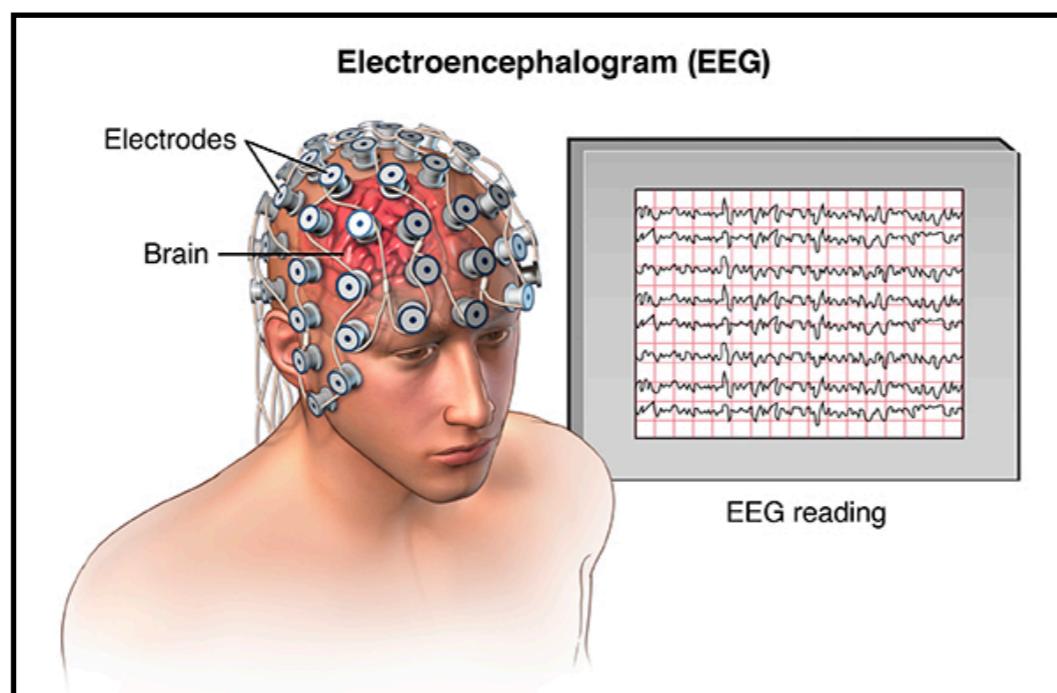


Decoding Analysis On Spike Trains

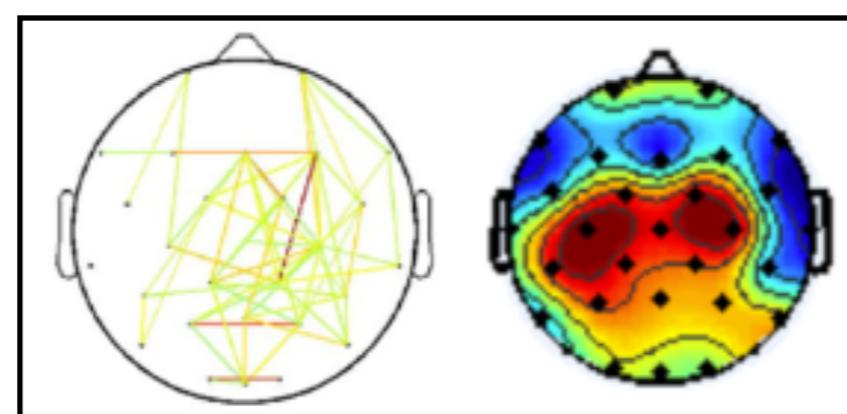


Multi-Channel Electrophysiology

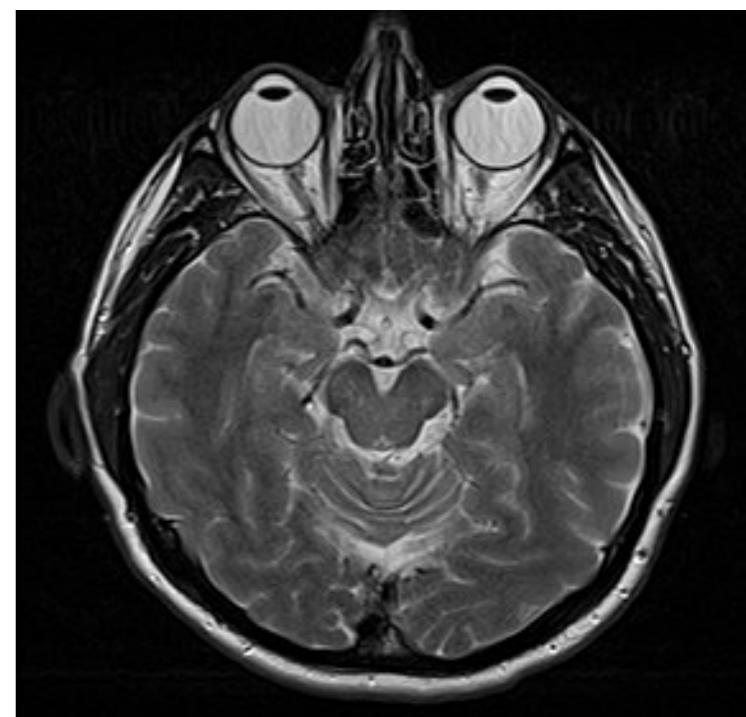
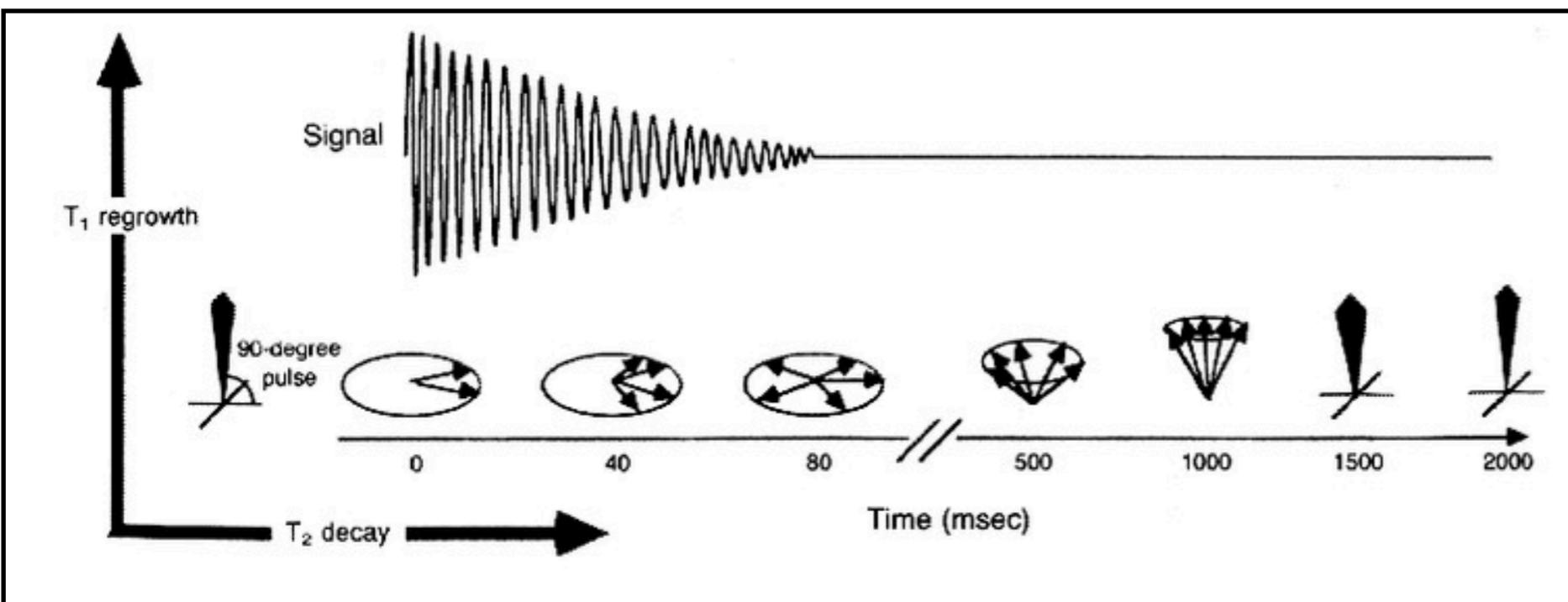
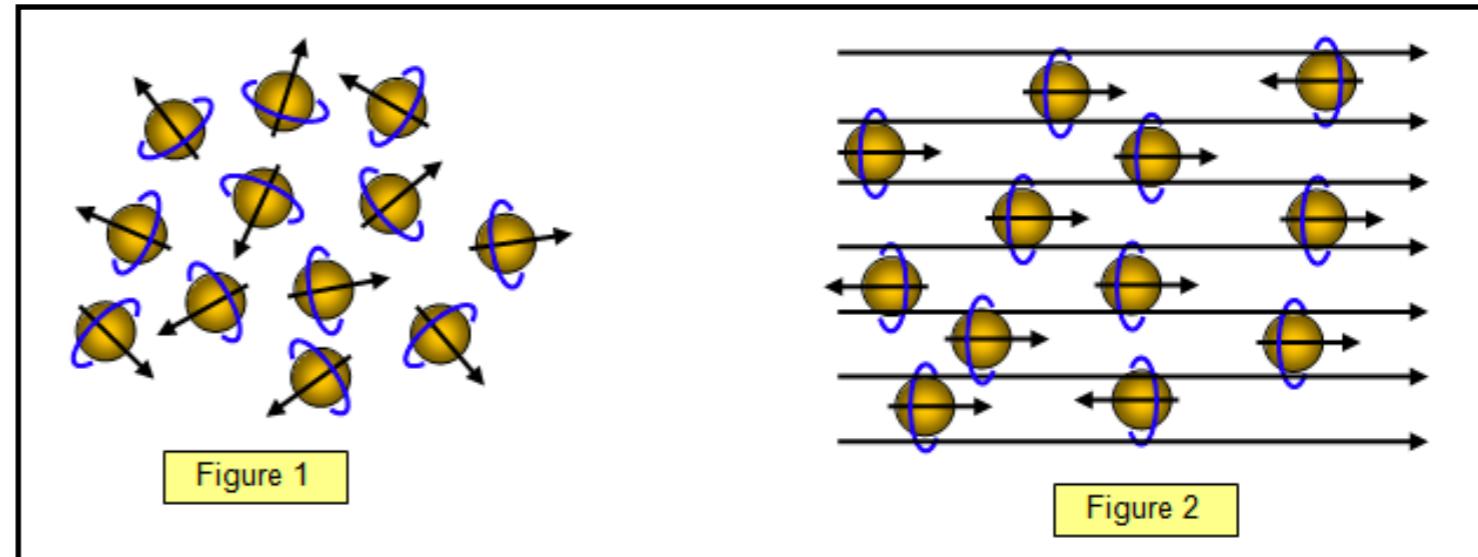
LFP / ECoG / EEG / MEG



Spatial Analysis: Cross Region/Layer & Connectivity



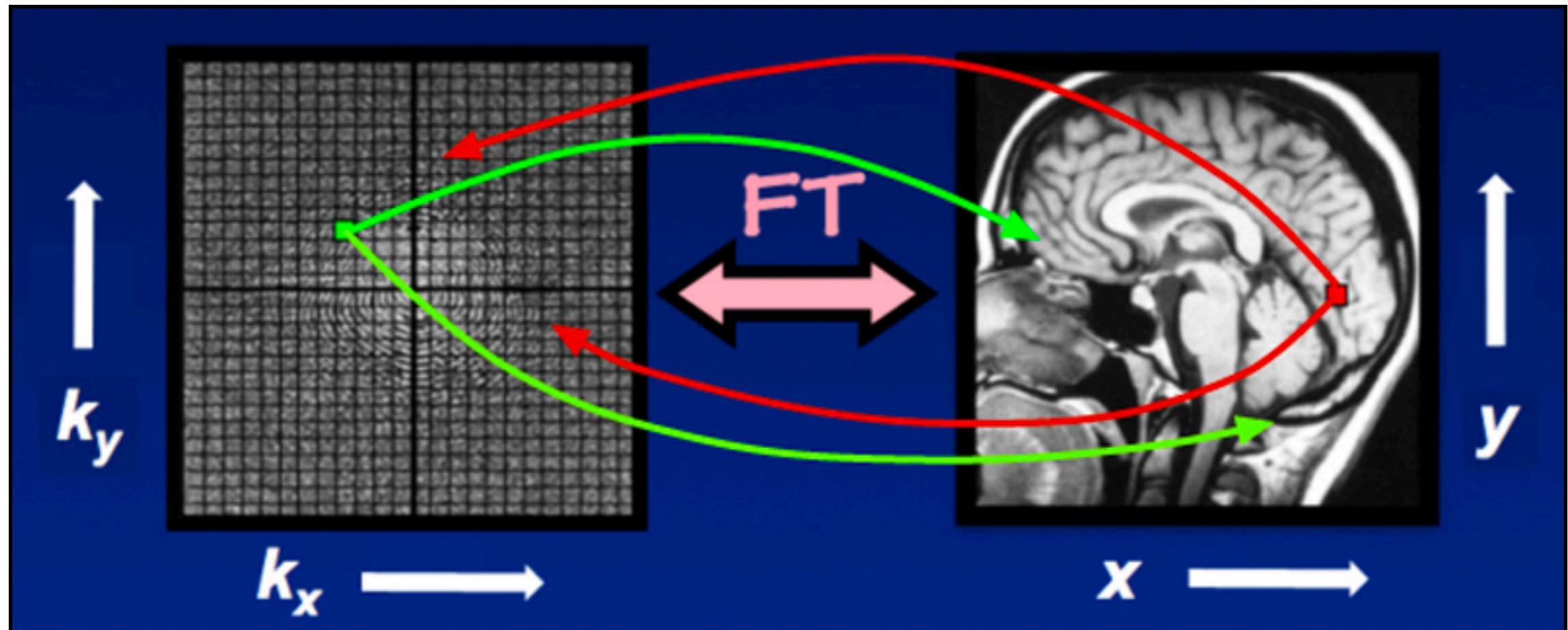
Magnetic Resonance Imaging



Applied magnetic field orients electron spin in hydrogen, and the contrast in decay of alignment is measured as the signal.



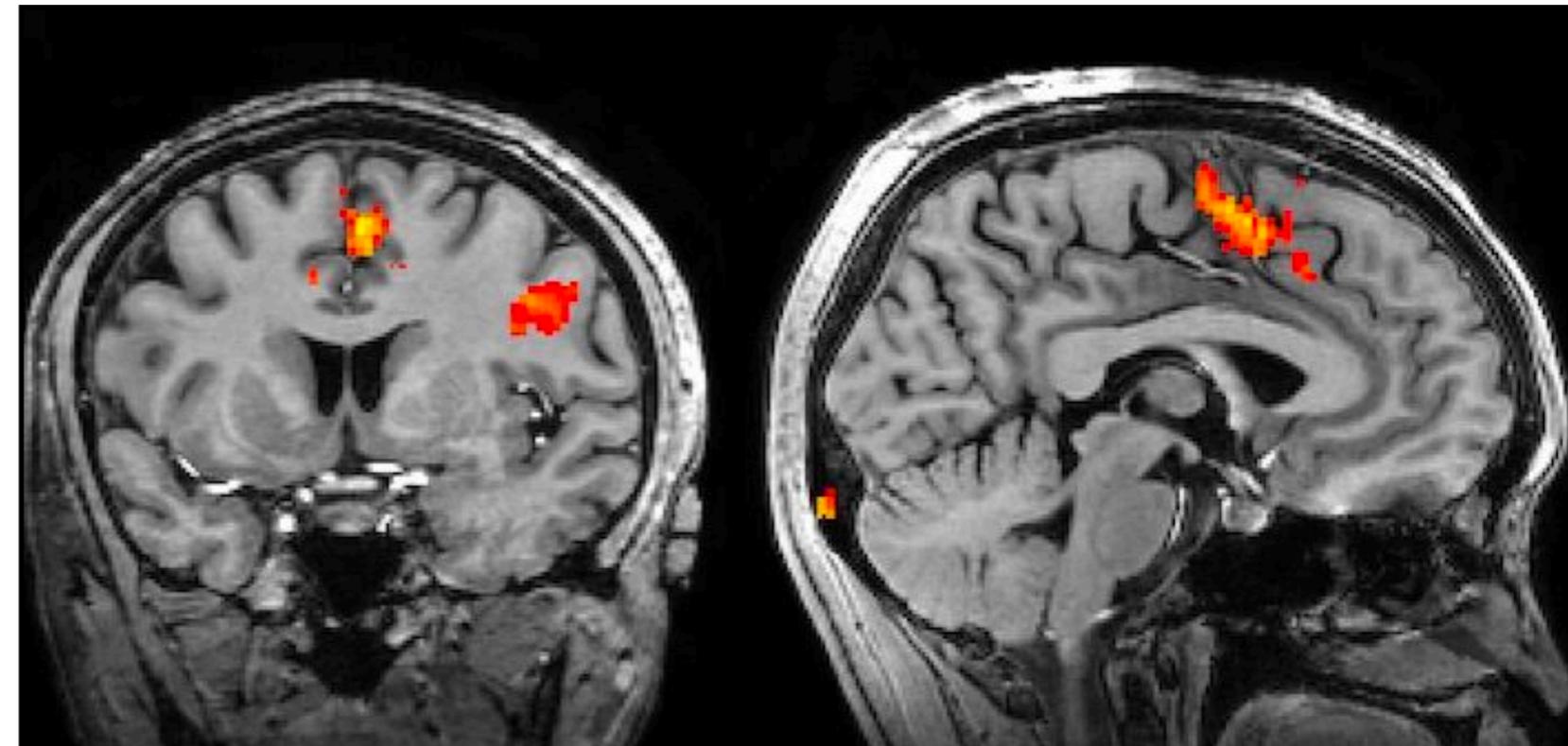
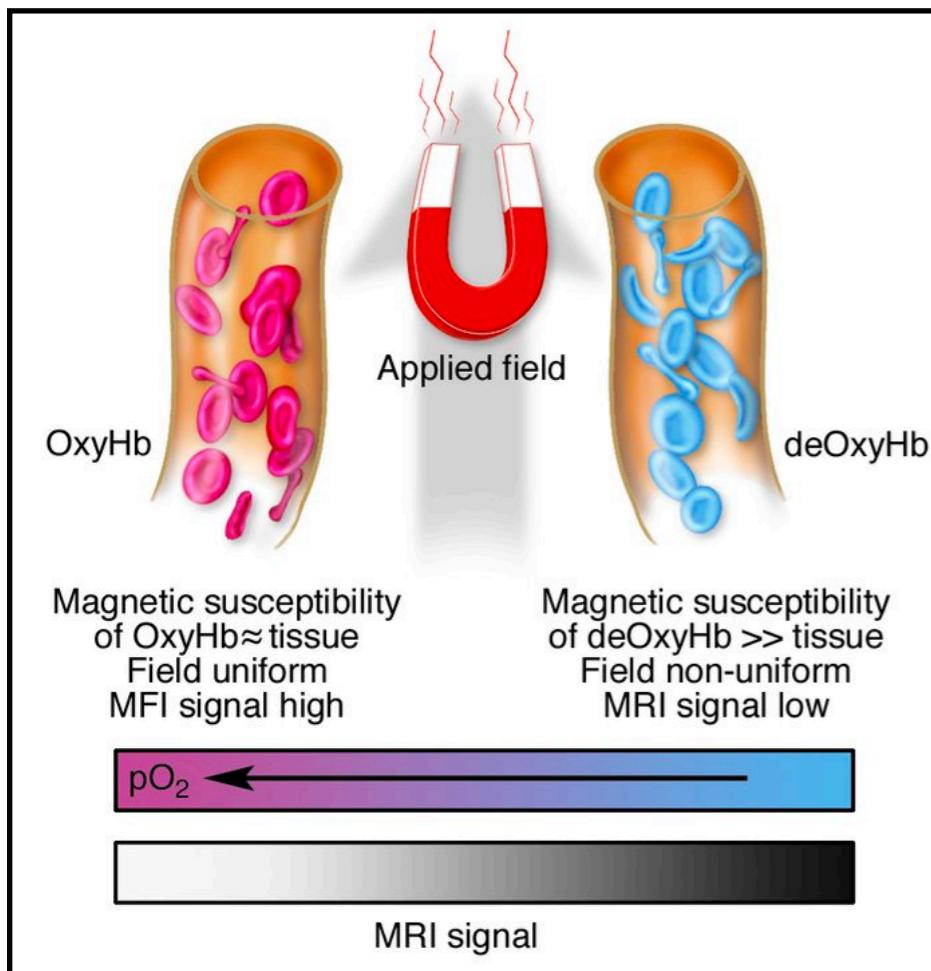
Magnetic Resonance Imaging



MRI measures in “spatial frequency space” and does Fourier Transform to retrieve 2D image



Functional MRI

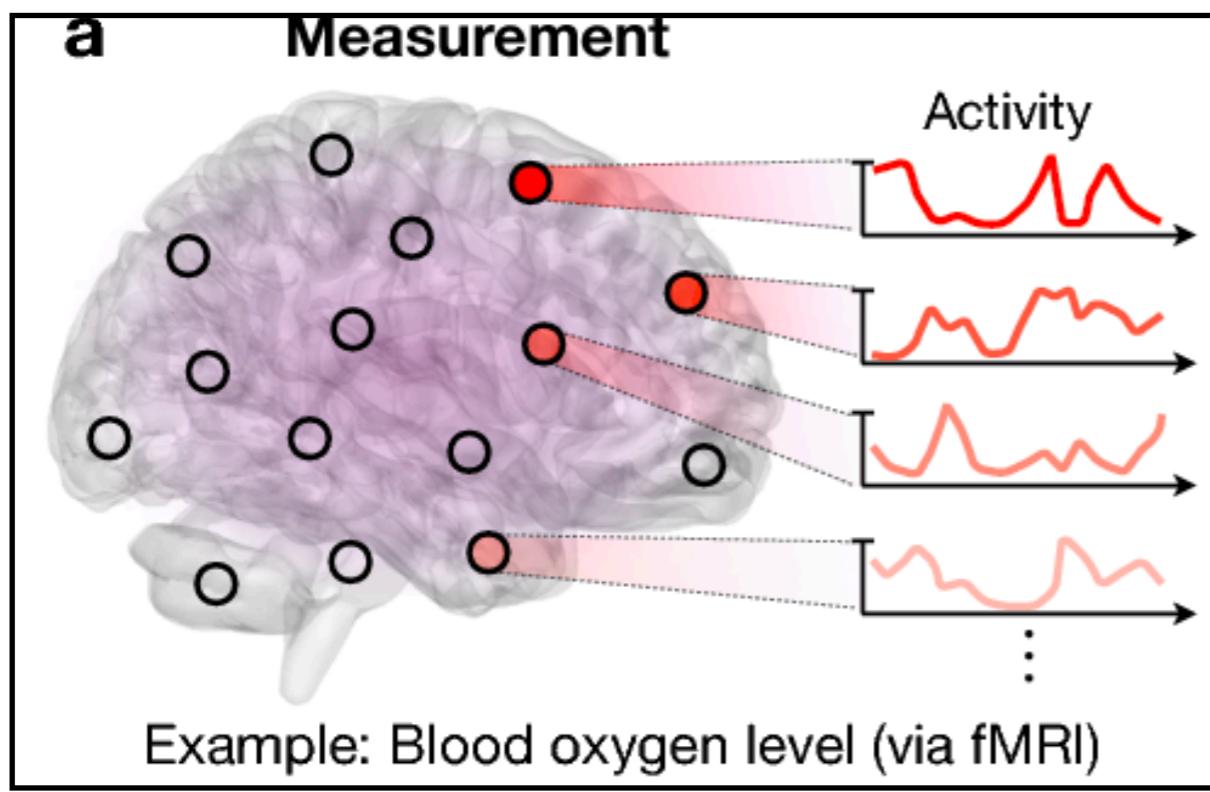
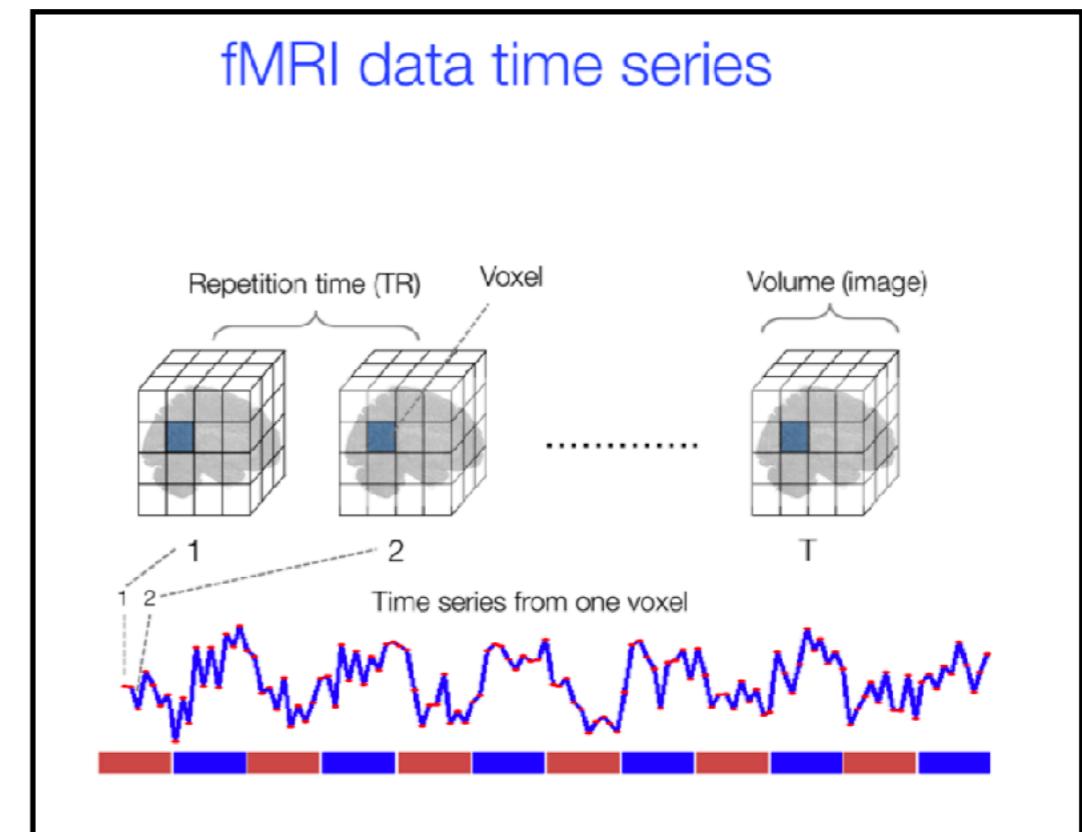
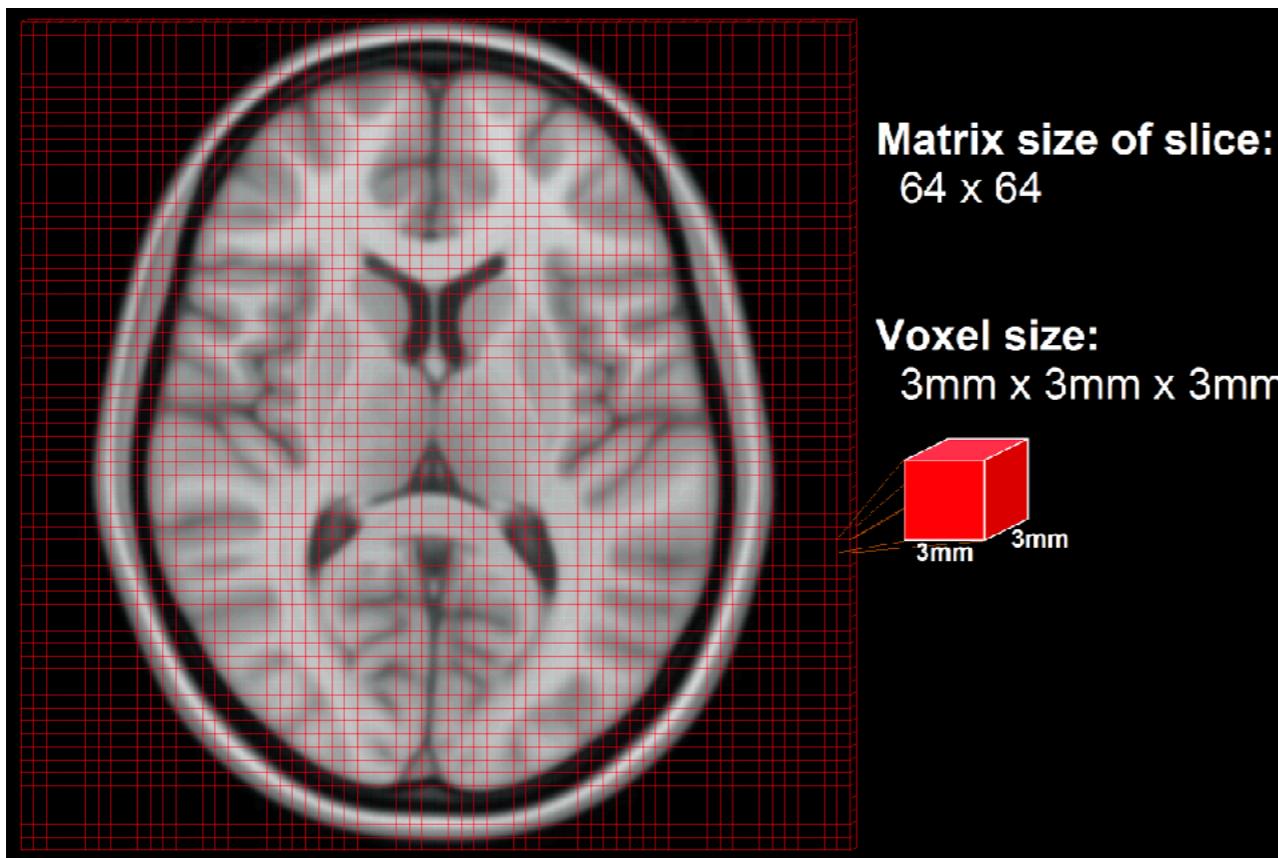


Neuronal activation increases metabolic (glucose) consumption,
bringing more oxygenated blood to an area

Oxygenated hemoglobin looks different from deoxygenated
hemoglobin -> infer neuronal activation.



Functional MRI



Very fine spatial resolution for non-invasive measurement ($\sim\text{mm}^3$).

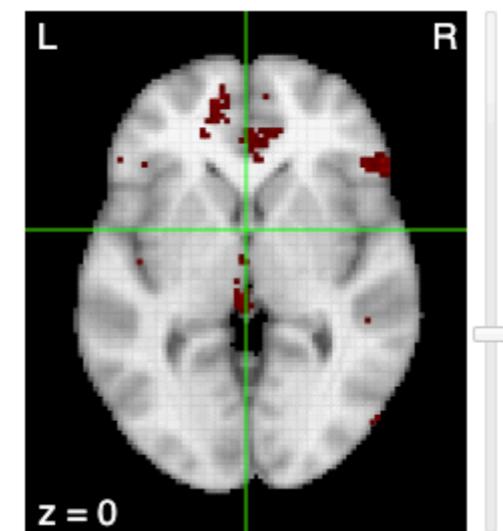
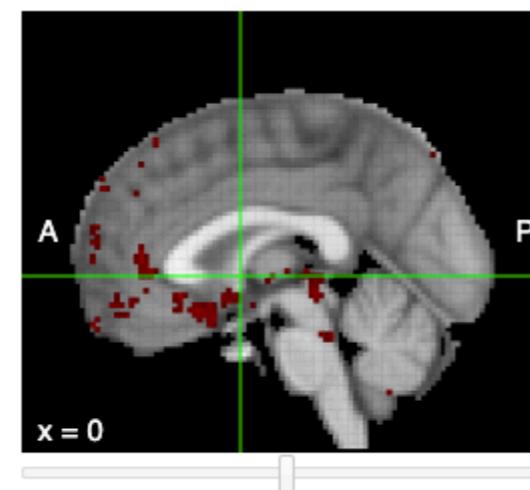
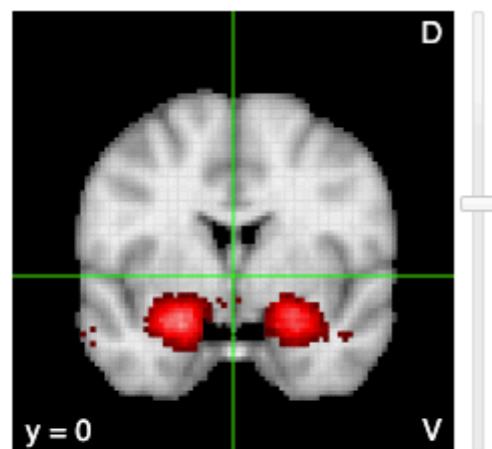
Very high-dimensional time series.



neurosynth.org

Neurosynth is a platform for large-scale, automated synthesis of functional magnetic resonance imaging (fMRI) data.

It takes thousands of published articles reporting the results of fMRI studies, chews on them for a bit, and then spits out images that look like this:



An automated meta-analysis of 1037 studies of [emotion](#)

Database Status

507891 activations reported in [14371 studies](#)

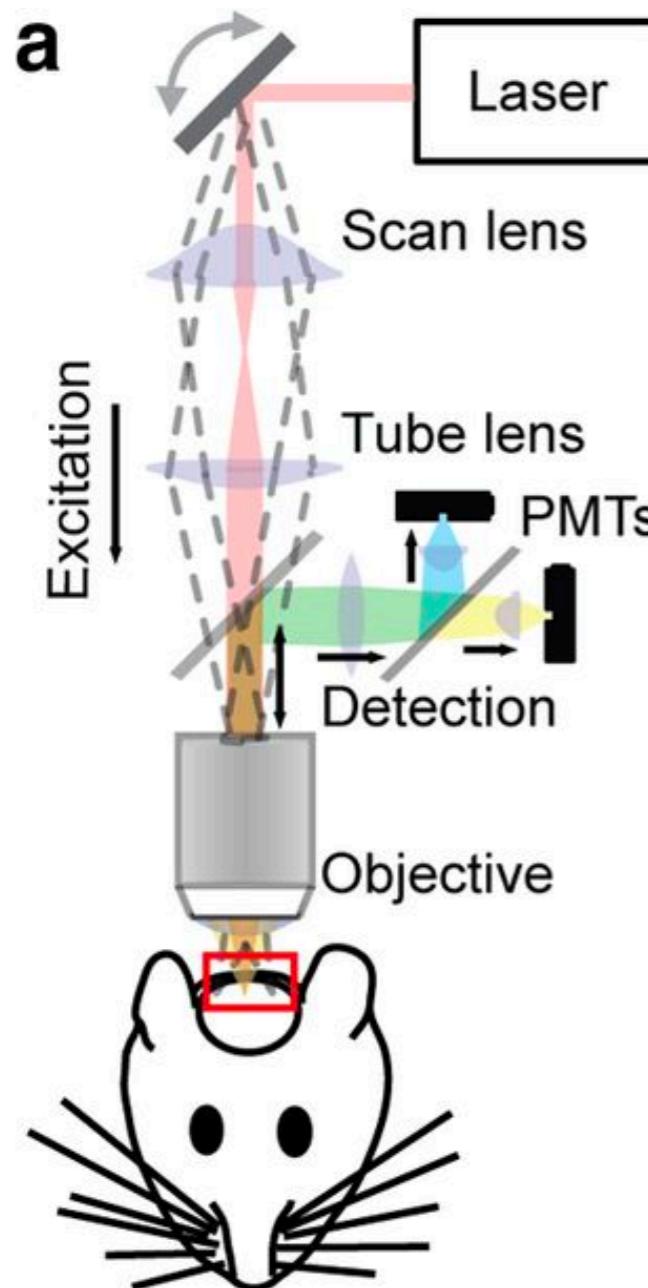
Interactive, downloadable meta-analyses of [1335 terms](#)

Functional connectivity and coactivation maps for over [150,000 brain locations](#)

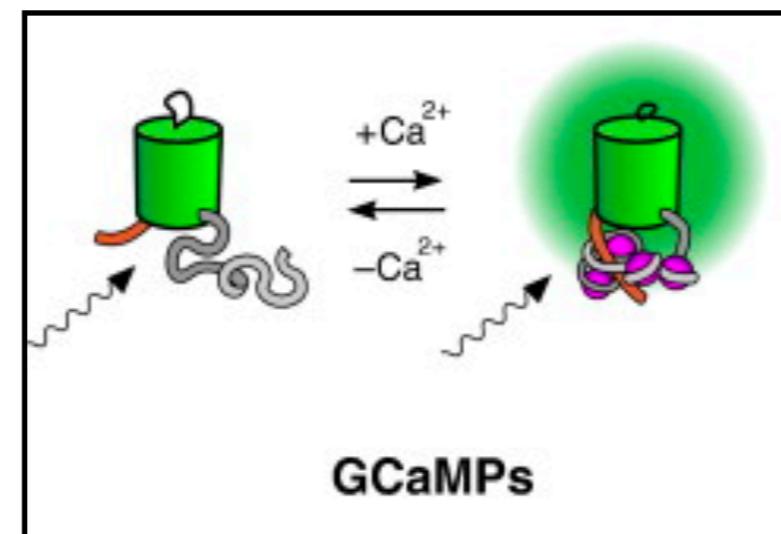


(Single Neuron) Optical Imaging

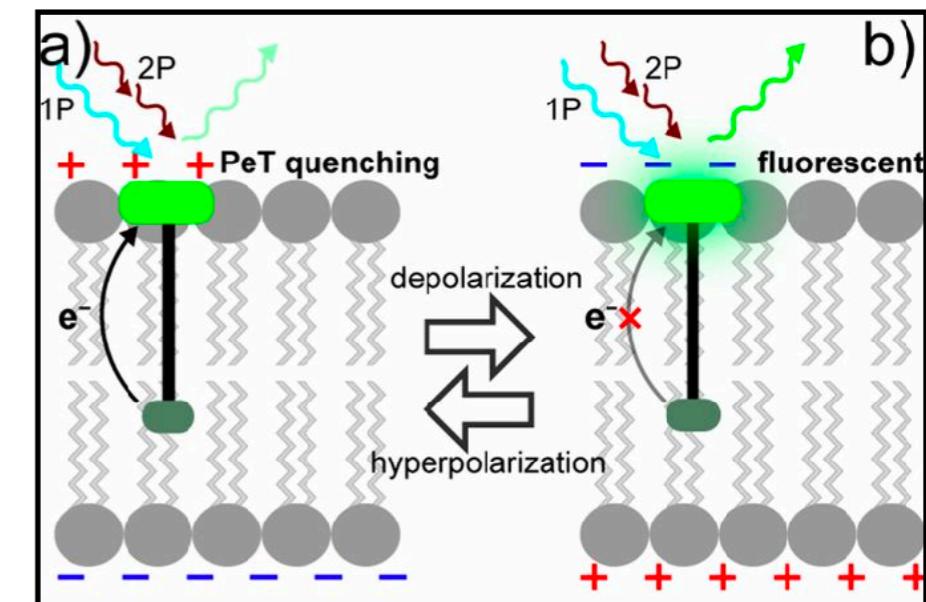
Optical Imaging



Genetically Encoded Calcium Indicator



Voltage Sensitive Dye



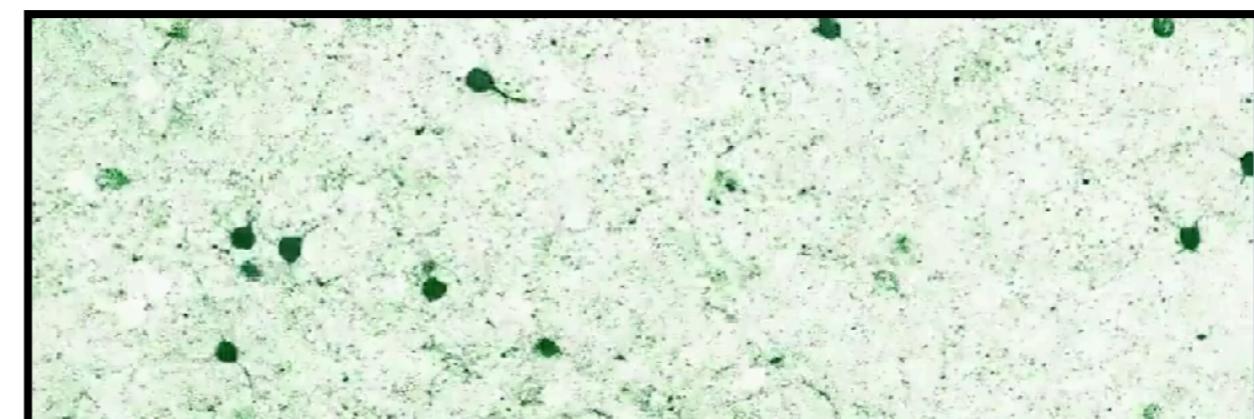
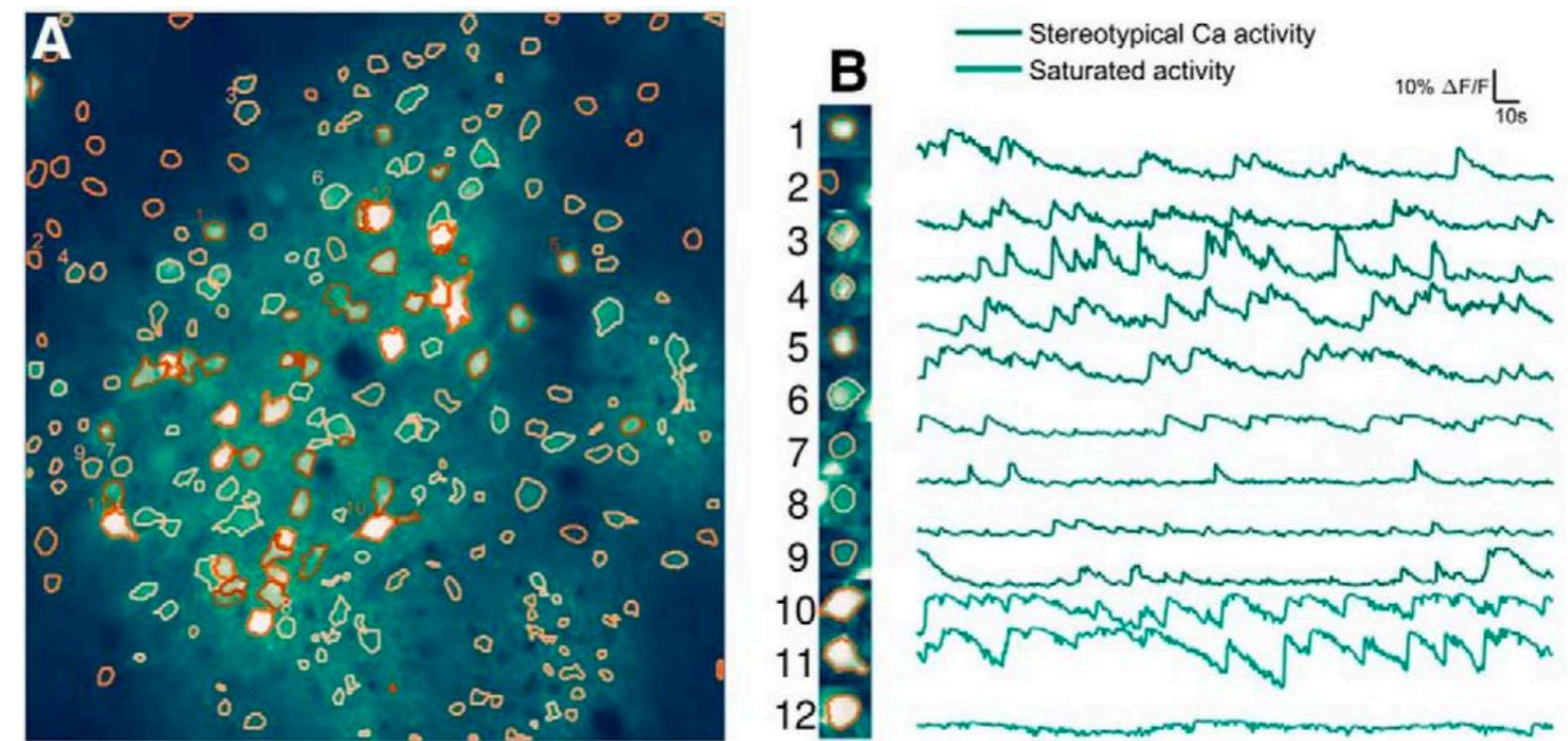
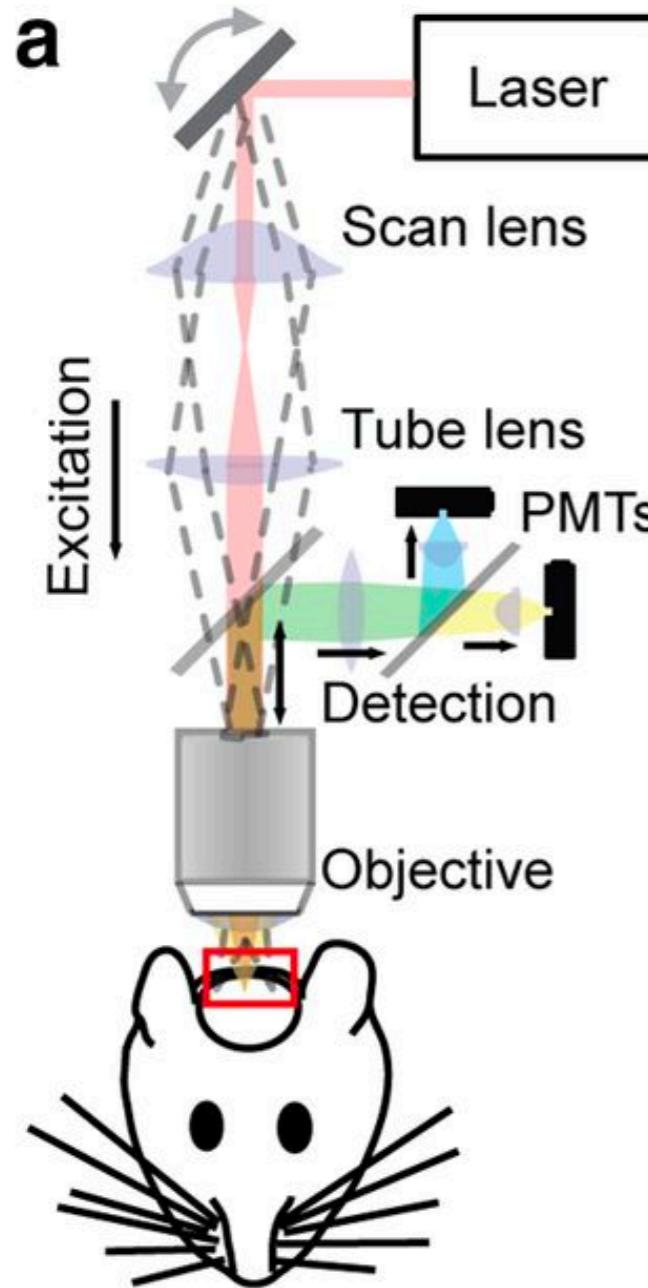
Change in ion concentration or membrane potential activates dye

-> Changes brightness or emission wavelength



(Single Neuron) Optical Imaging

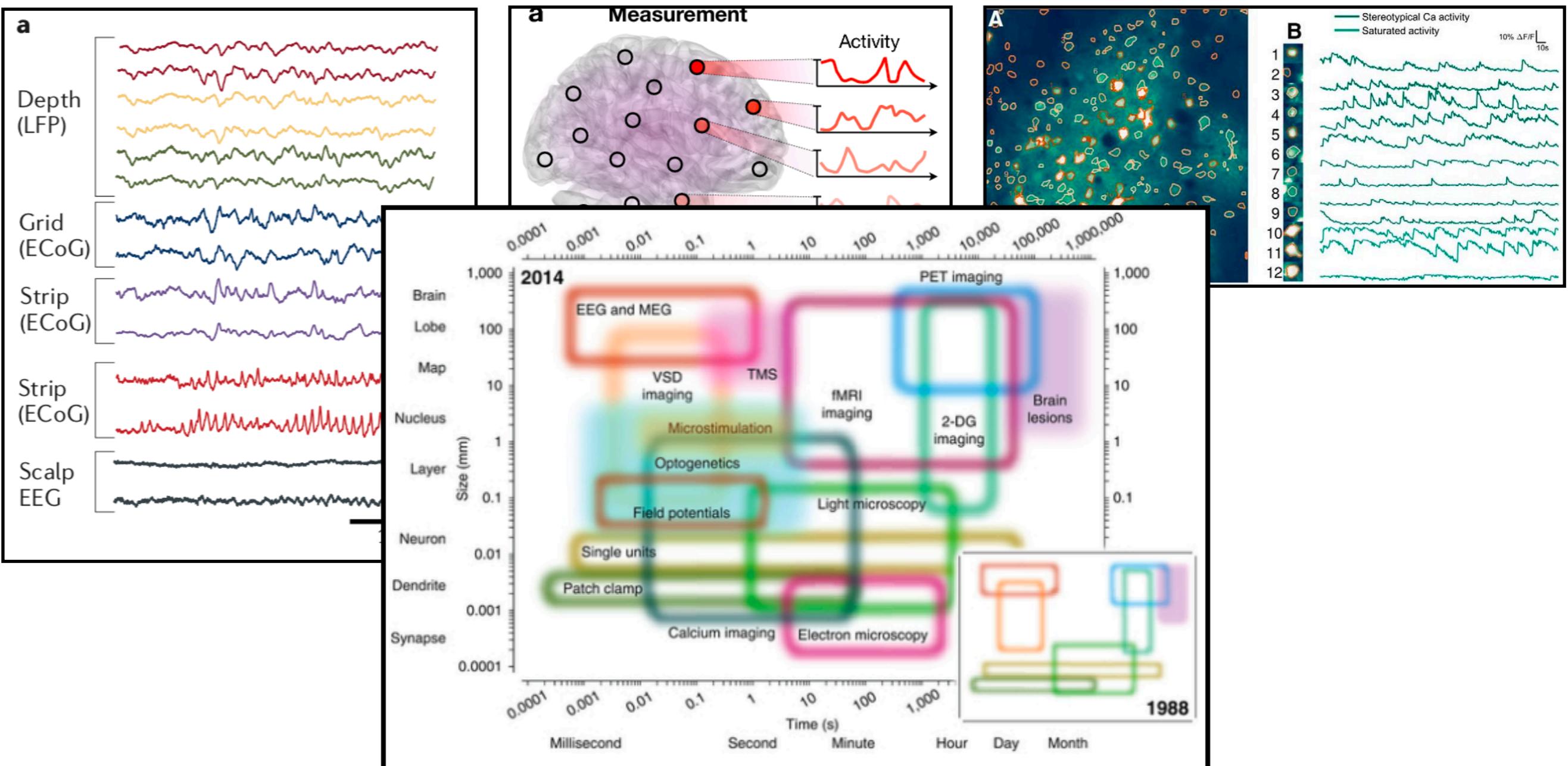
Can isolate single cell activity



Produces a “movie”



Multi-Dimensional Time Series

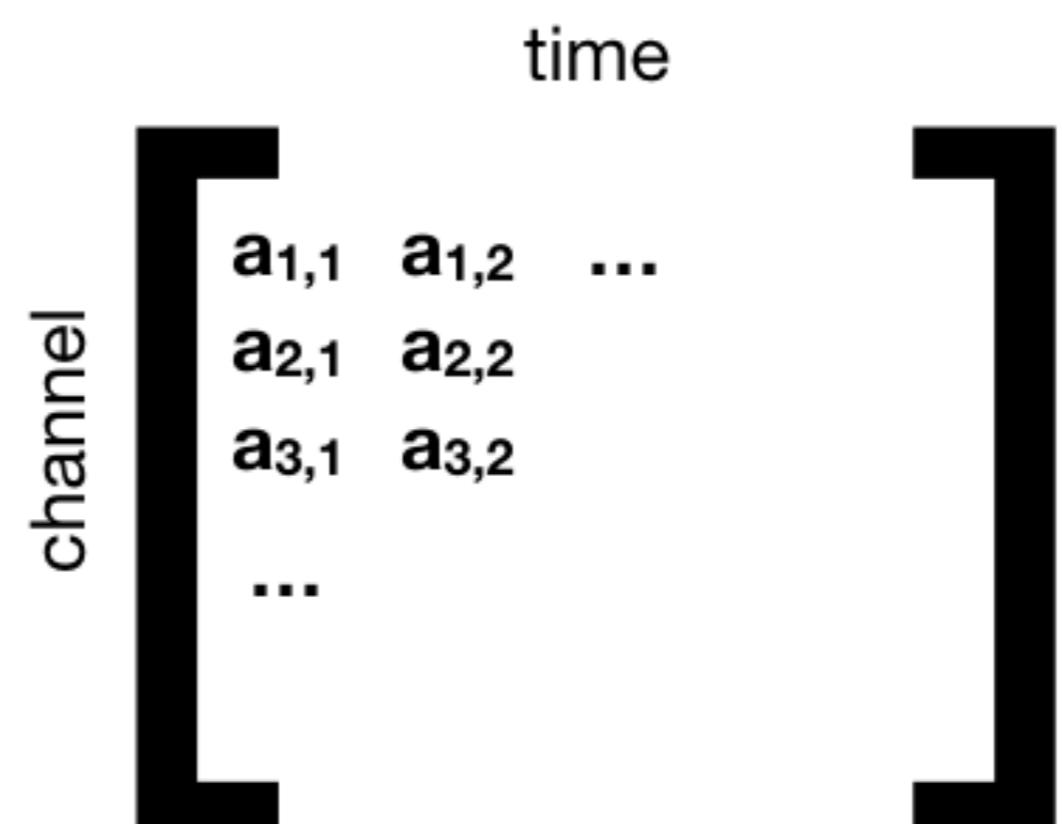
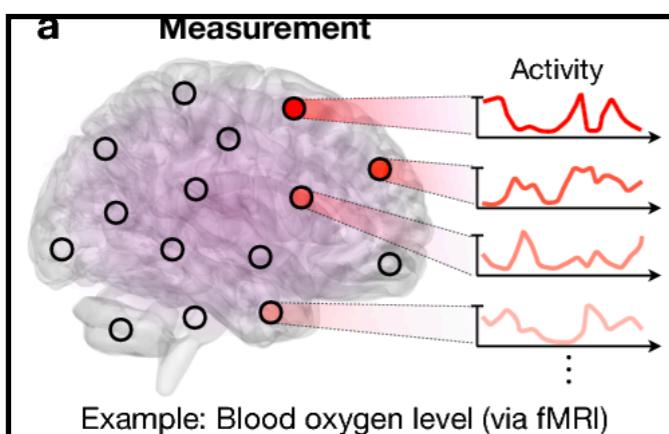
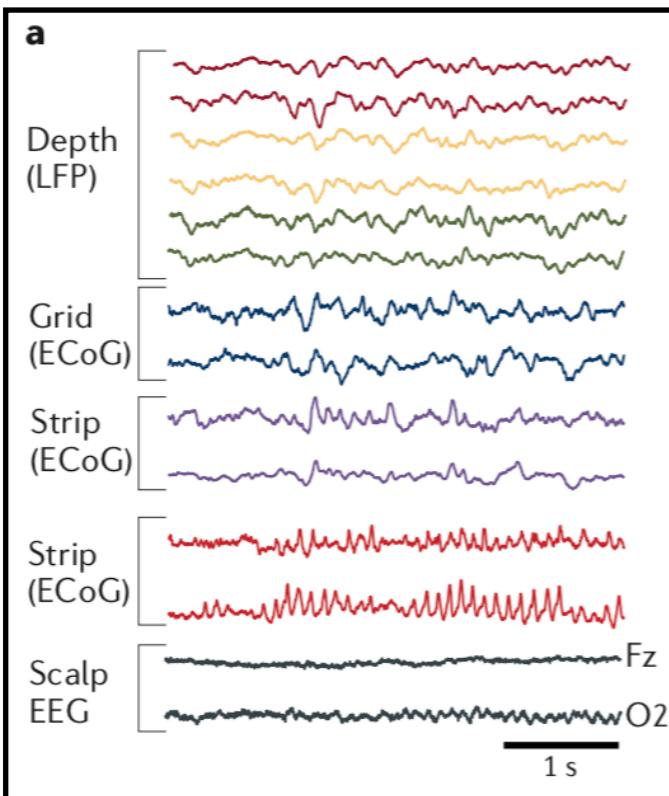


We've been learning (mostly) univariate (1-dimensional) analysis tools.

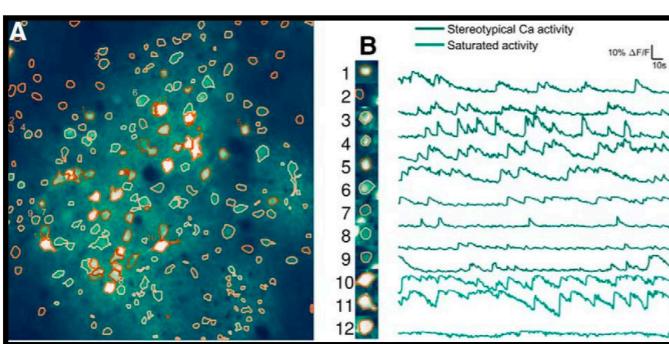
Multi-dimensional data are ubiquitous, though.



Multi-Dimensional Time Series



the general/abstract view

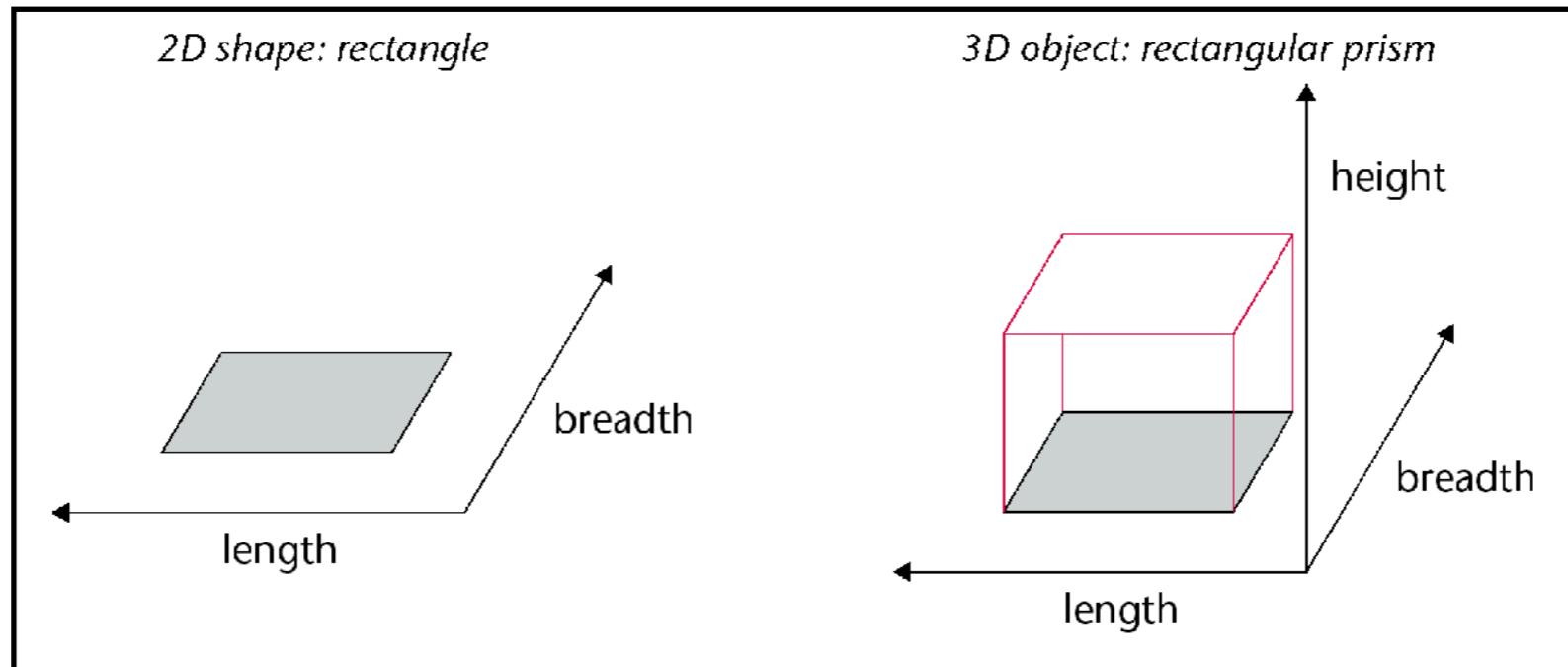


1. Introduce other types of neural data
2. Understand dimensionality
3. Motivate & introduce decomposition techniques

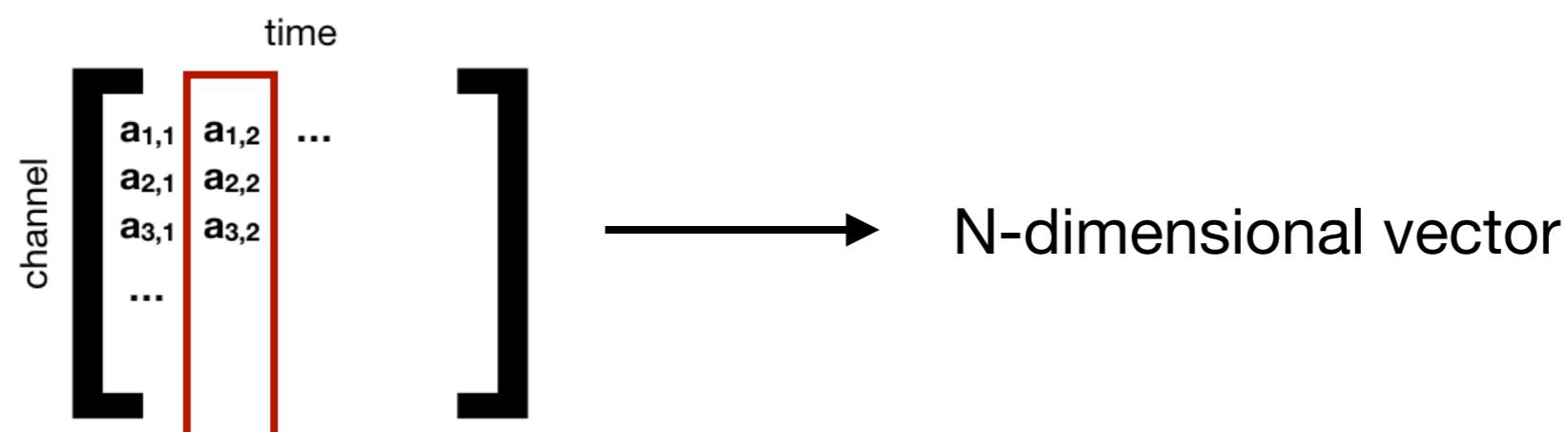


Dimensionality

In physical space, we have 3 dimensions
(4 if you count time).

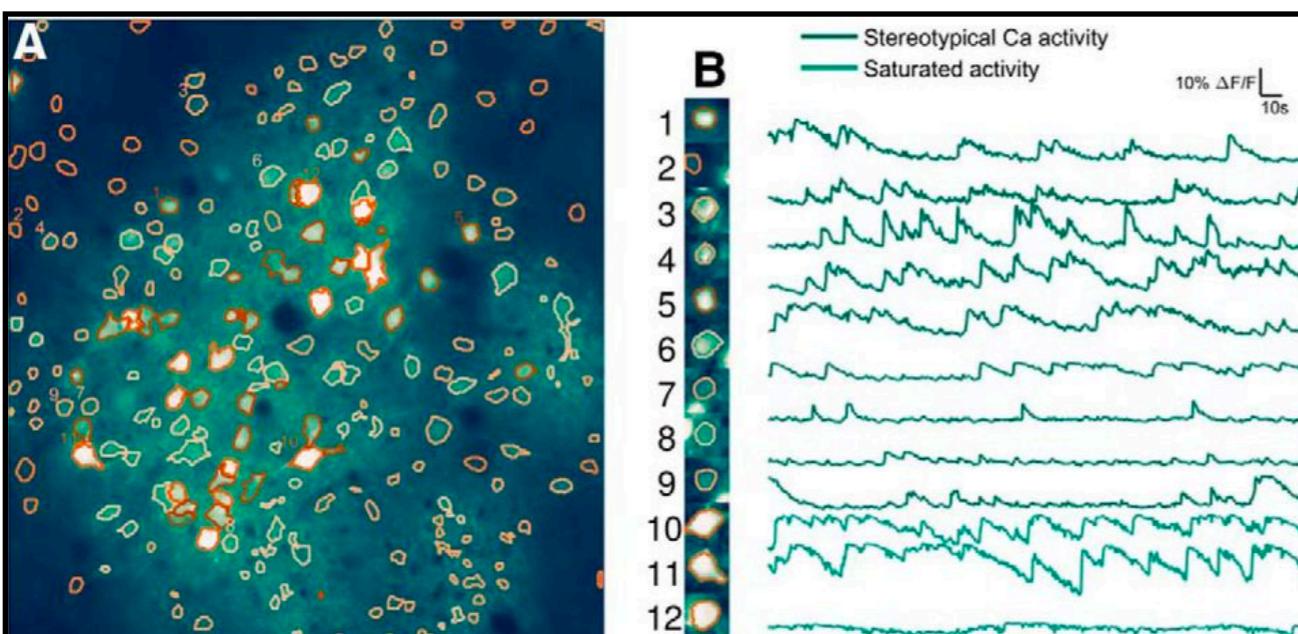
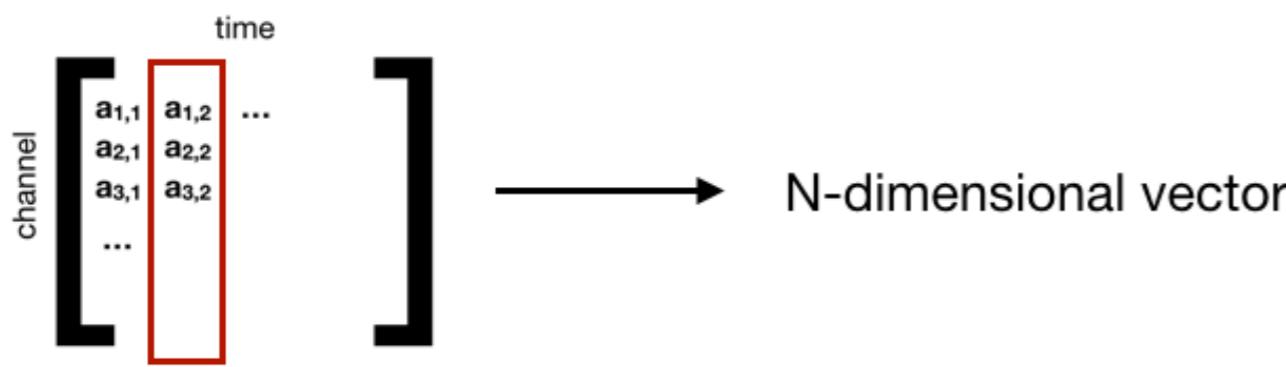


Mathematically, any variable can be casted as a dimension of a vector (state) space.

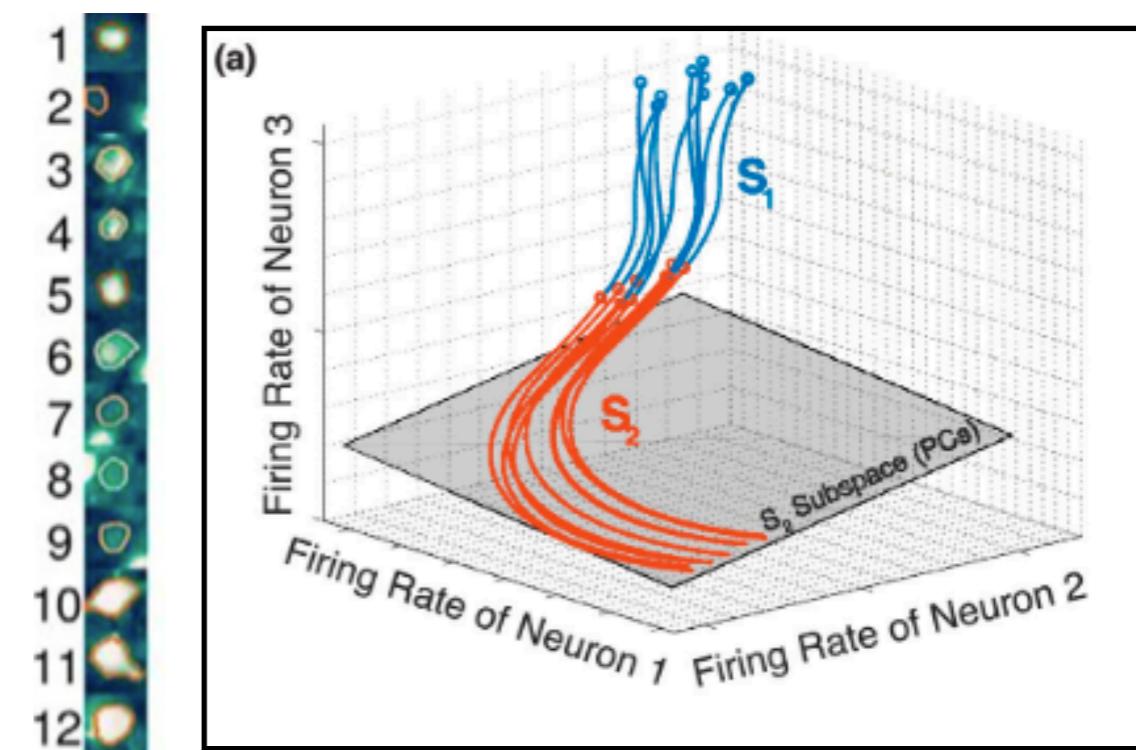


Dimensionality in Neural Recordings

Mathematically, any variable can be casted as a dimension of a vector space.



Activity of all cells at a single time point is a 12-dimensional vector



Activity over time traces out a trajectory in “state space”.

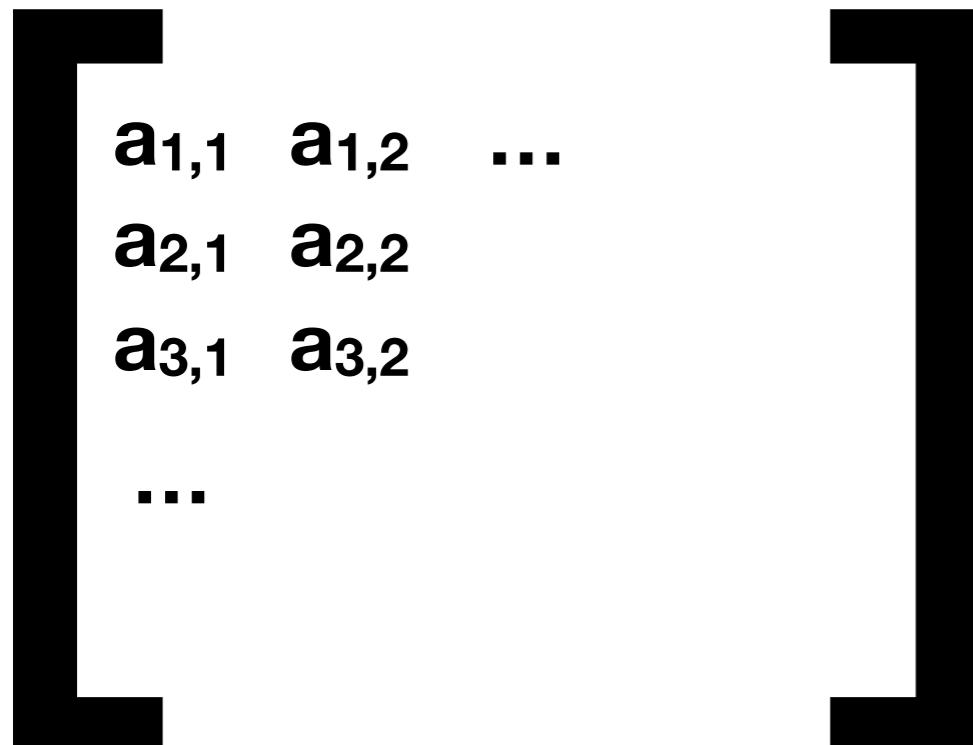


Dimensionality in General

Examples of multi-dimensional data

M features

N samples



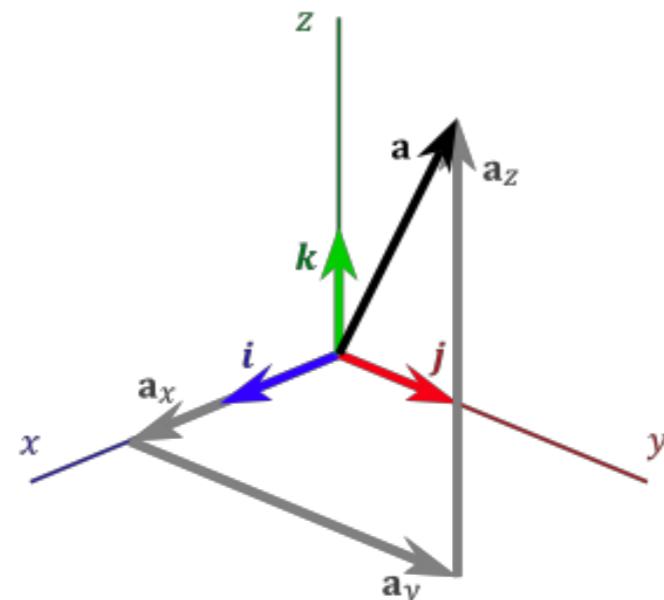
Samples	Features	Dim
person	height, weight, eye color	3
game	pixel values, audio	5000
coffee	roast, bean, acidity, region, bitterness, aroma	6
smart phones	color, size, GB, camera res, sound frequency	5
happiness	income, health (BMI, HR, etc), # of children, drug intake, subj wellbeing	6
car	make, model, year, color	4



1. Introduce other types of neural data
2. Understand dimensionality
3. Motivate & introduce decomposition techniques

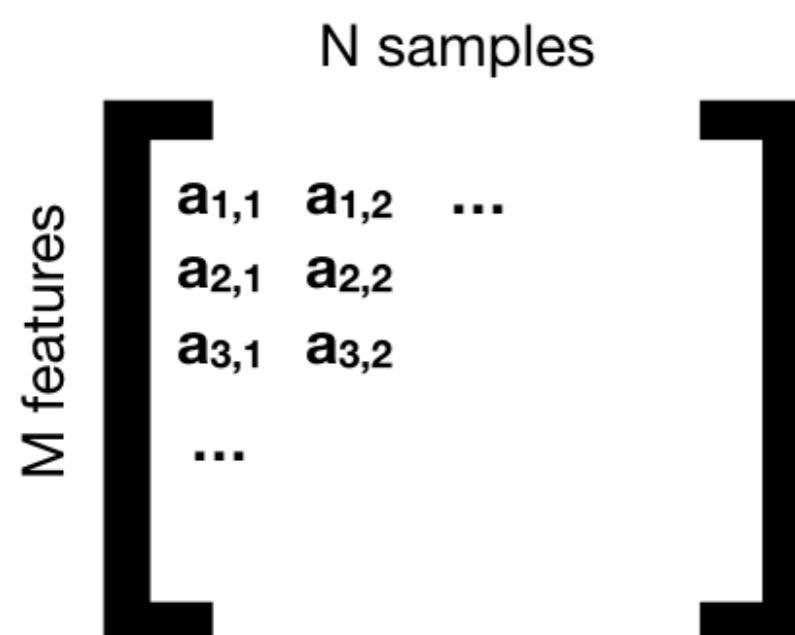


Basis & Dot Product



A basis set is a set of vectors that **spans** the entirety of the vector (or state) space.

Typically, a N-dimensional space has N basis vectors, e.g., 3D Euclidean bases.

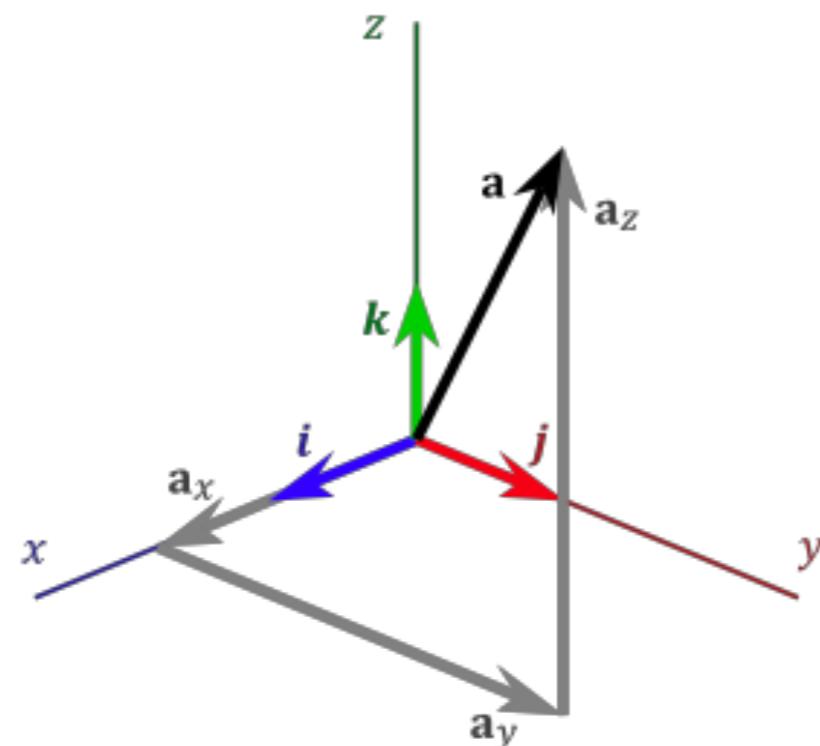


Can write every vector as a **linear combination** of the basis vectors...

...via dot product.



Basis & Dot Product



$$\mathbf{i} = [1, 0, 0]$$

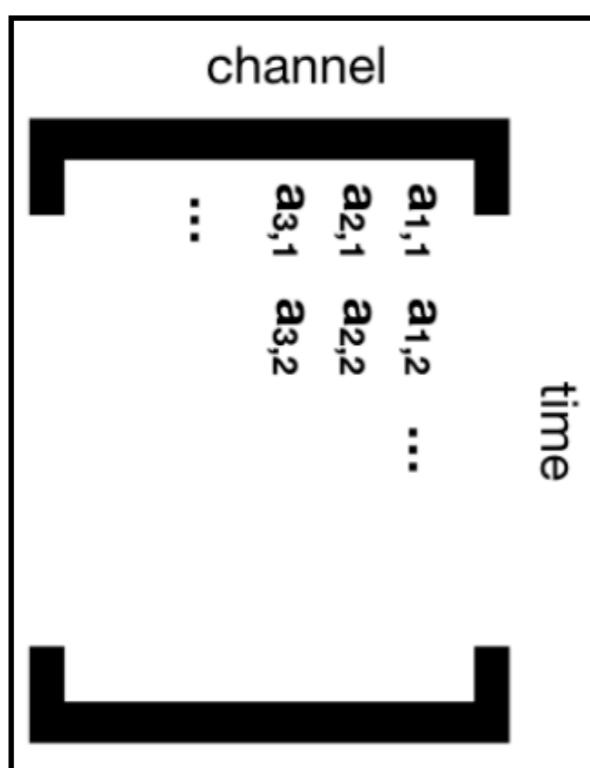
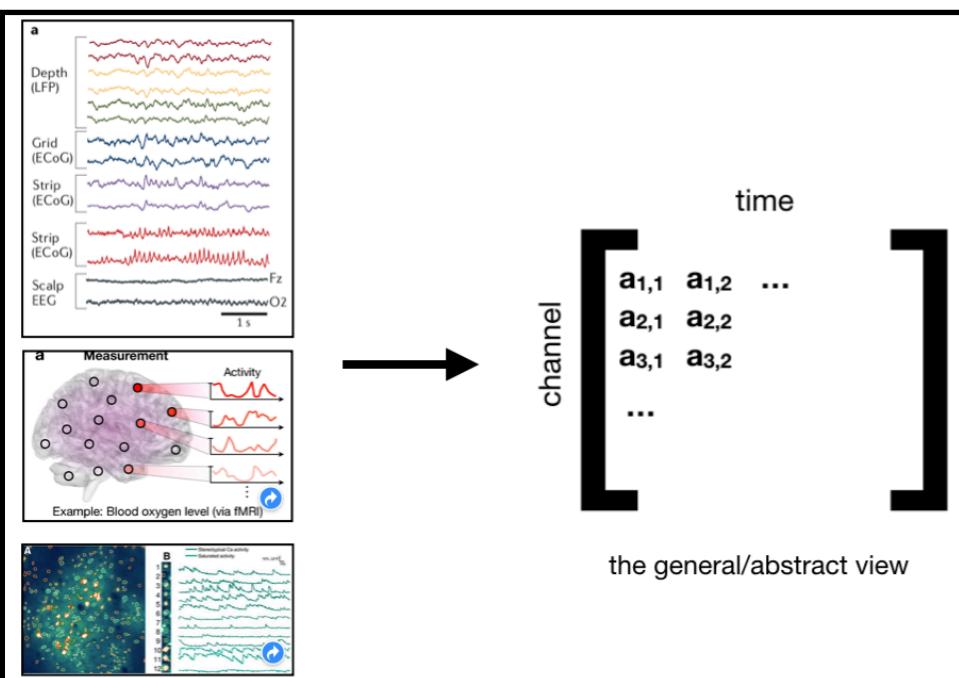
$$\mathbf{j} = [0, 1, 0]$$

$$\mathbf{k} = [0, 0, 1]$$

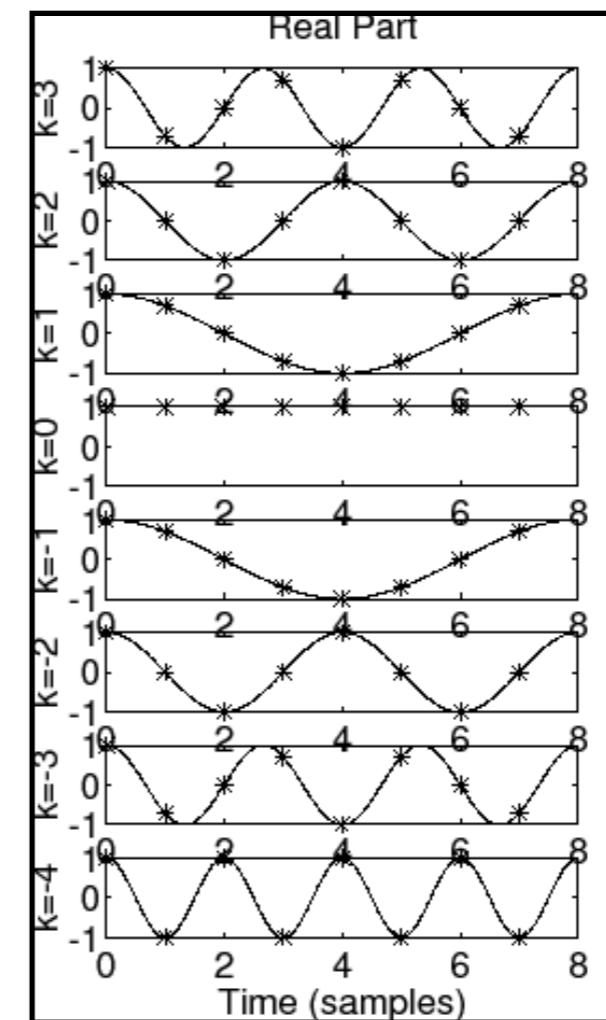
$$\mathbf{u} = [2, 7, -3] = 2\mathbf{i} + 7\mathbf{j} + (-3)\mathbf{k}$$

Linear combination

Fourier Basis

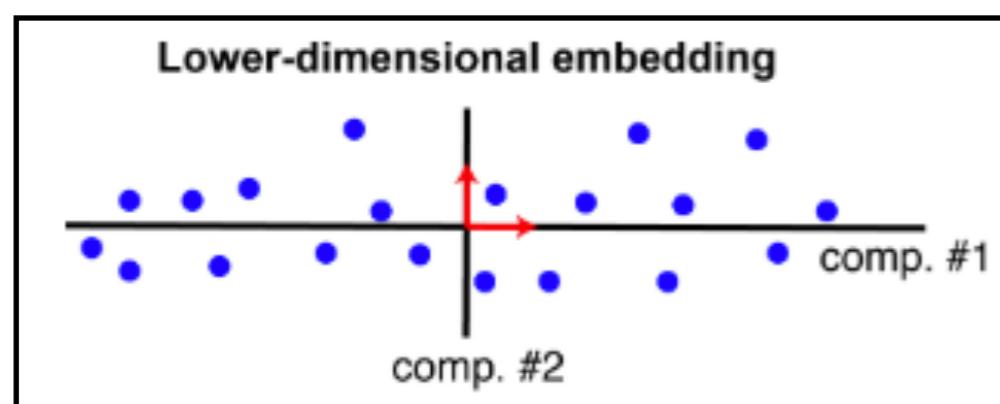
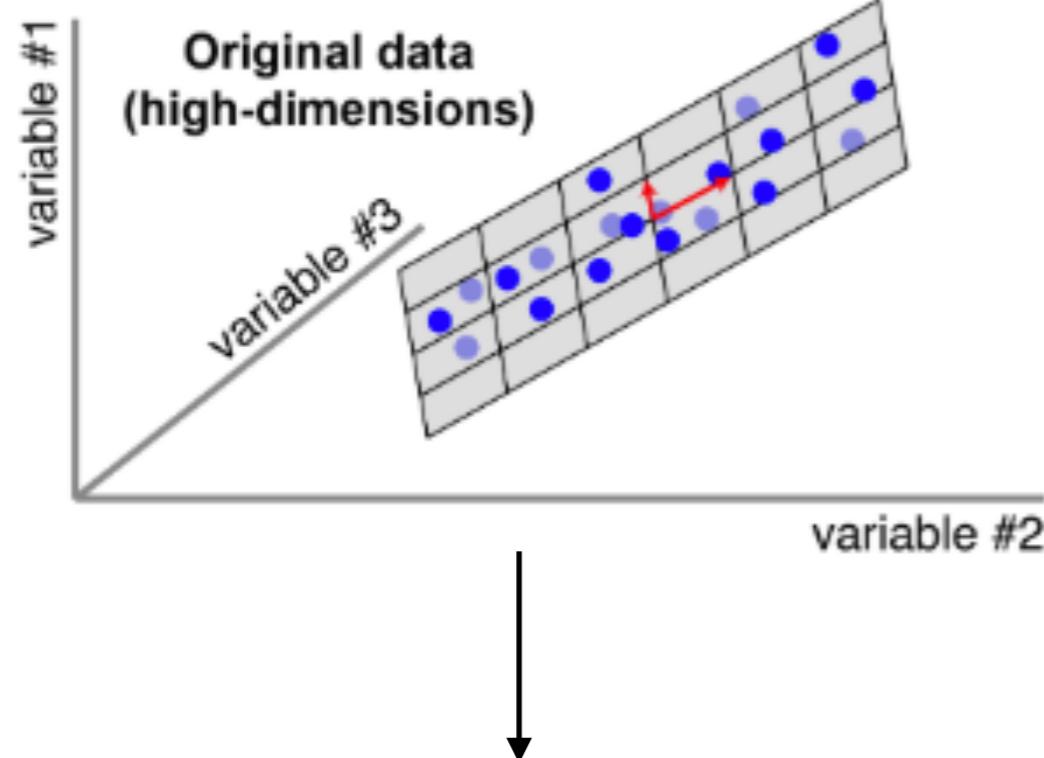


If the number of time points is the dimensionality, then the N complex sinusoids in DFT are an orthogonal basis set for an N-dimensional vector space.

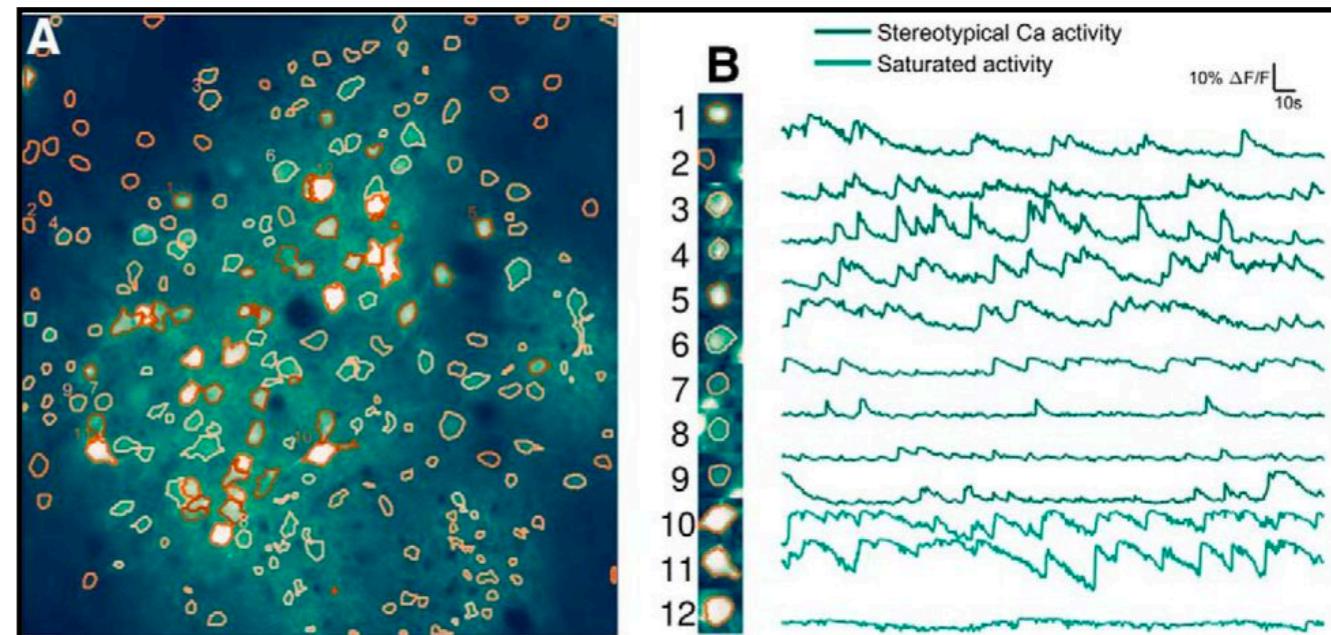


Principle Component Analysis

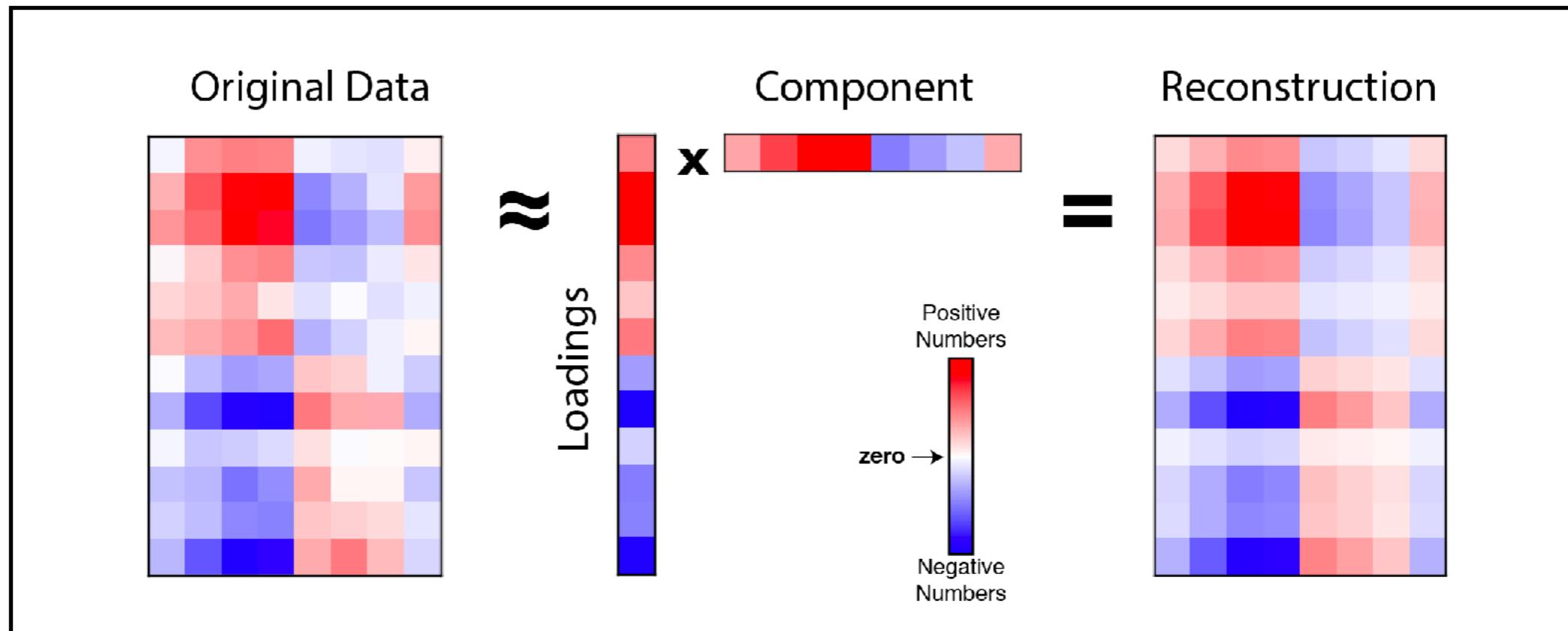
Correlated Dimensions



Find a smaller number of
(empirical) basis vectors



Principle Component Analysis

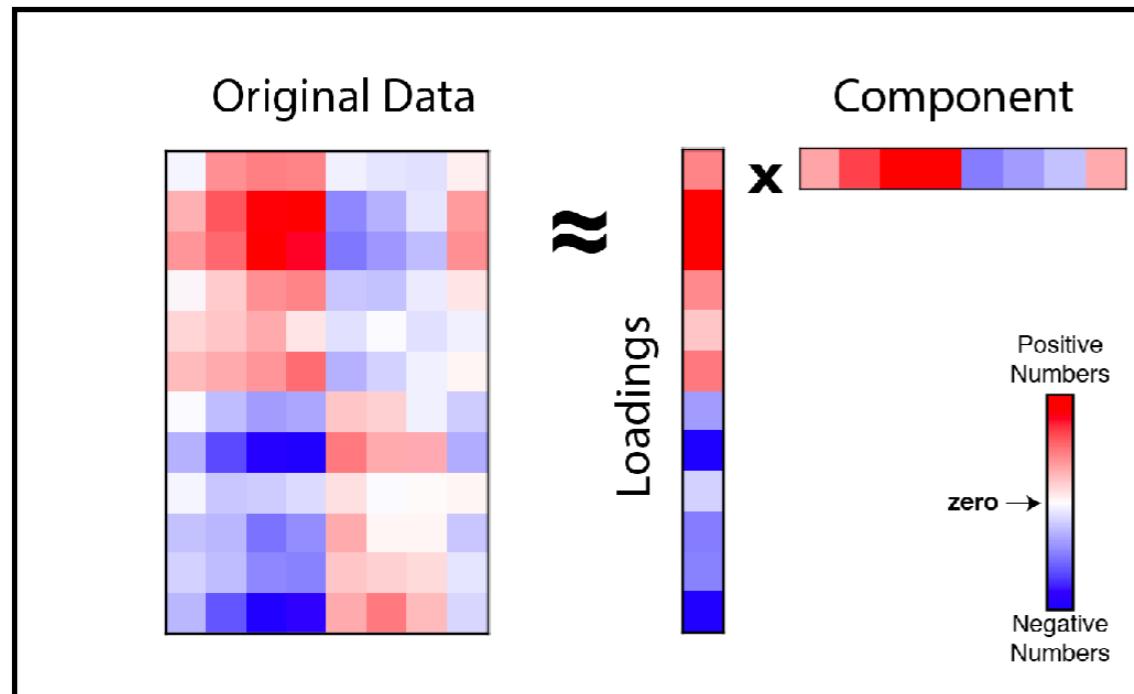


“Component” ~ basis

“Loadings” ~ weights



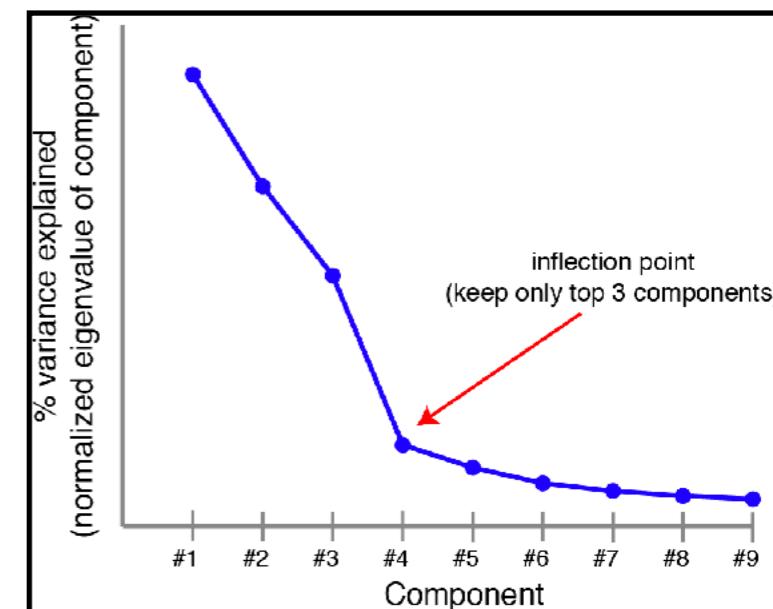
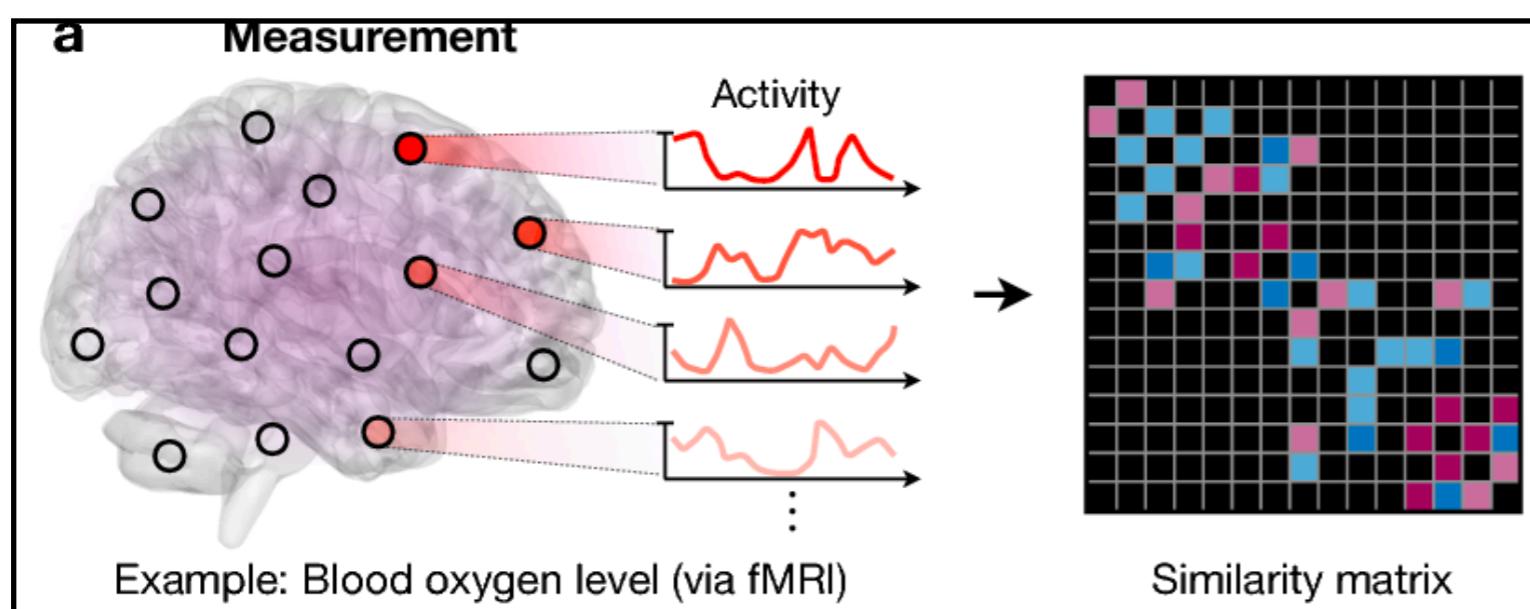
Principle Component Analysis



PCA decomposes correlated brain activity into a “smaller” set of orthogonal bases.

Bases are the eigenvectors of the correlation matrix

Eigenvalues represent how much variance is explained by each basis



Principle Component Analysis

sklearn.decomposition.PCA

```
class sklearn.decomposition. PCA (n_components=None, copy=True, whiten=False, svd_solver='auto', tol=0.0,  
iterated_power='auto', random_state=None) [source]
```



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<https://tinyurl.com/cogs118c-att>

