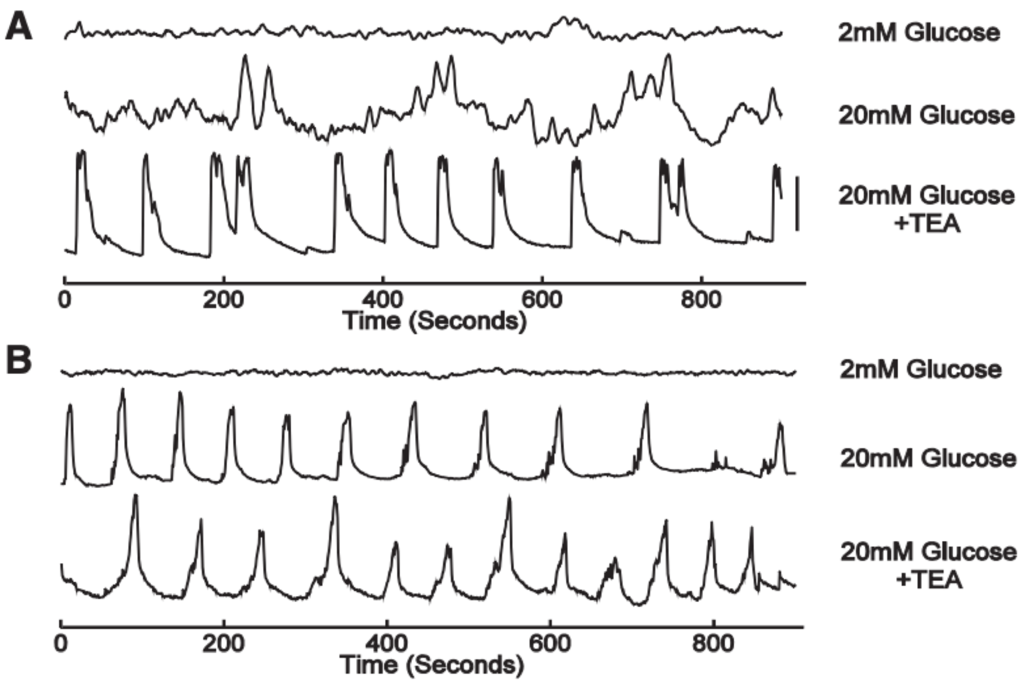
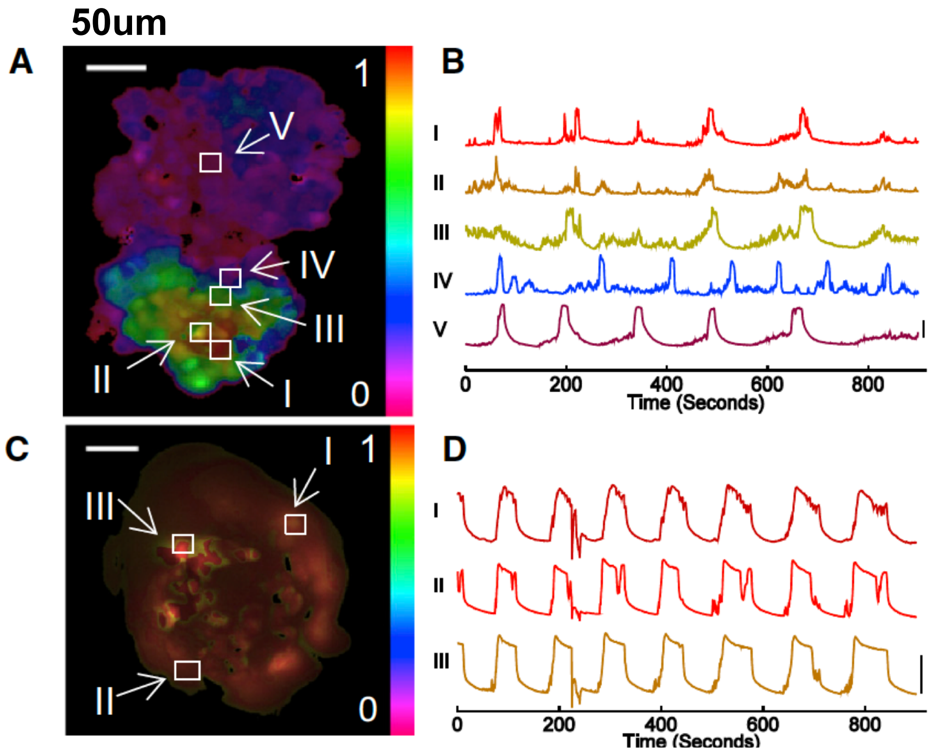
Dimension and size dependence of [Ca2+] synchronization

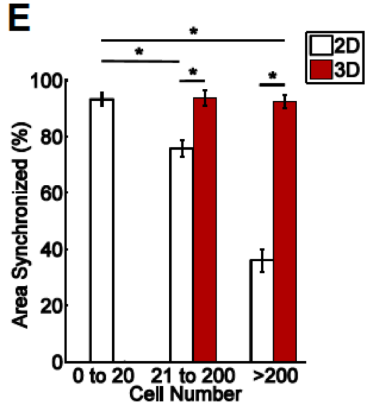
2D: ~4000 cells/mm^2 (MIN6)
3D: ~520,000 cells/cm^2 in hydrogel microwell arrays

[Ca2+] readout using Fluor4



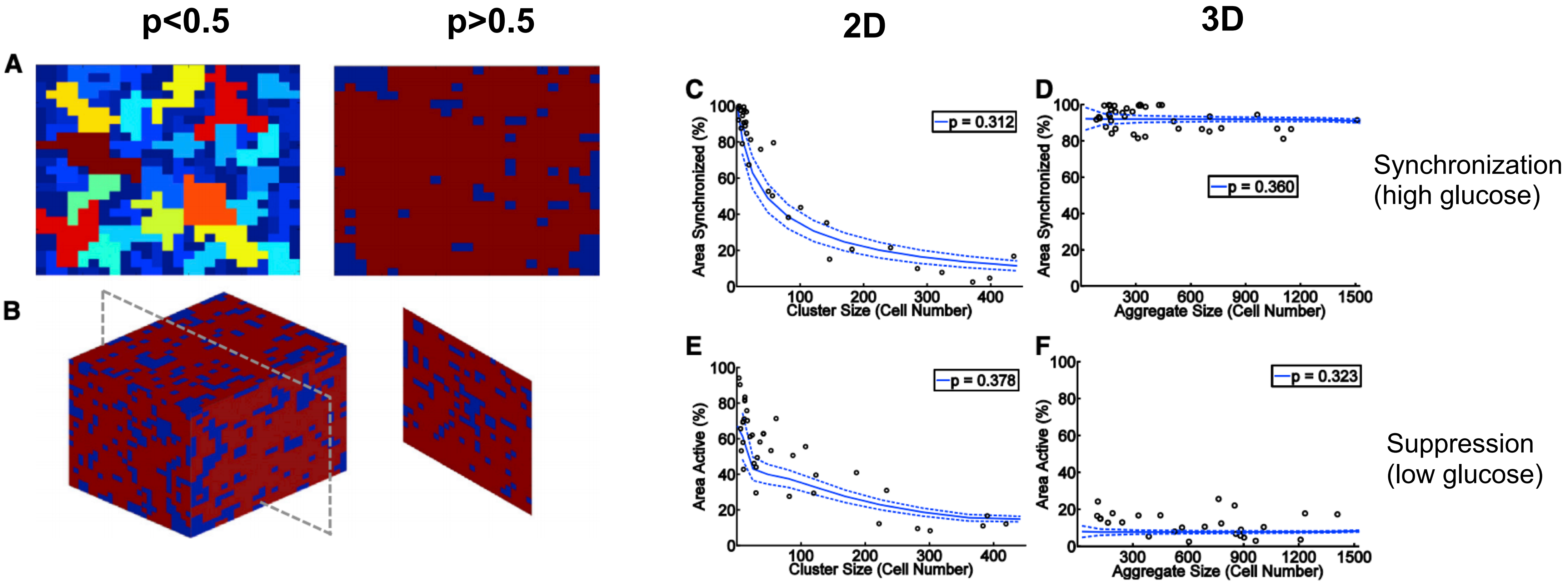


- High-glucose + TEA
- ~5 cell synchronization radius in 2D
- Synchronization is scale-dependent in 2D but not in 3D



Dimensionality and size scaling of coordinated Ca2+ dynamics in MIN6 beta-cell clusters. **Biophysical Journal. 2014**

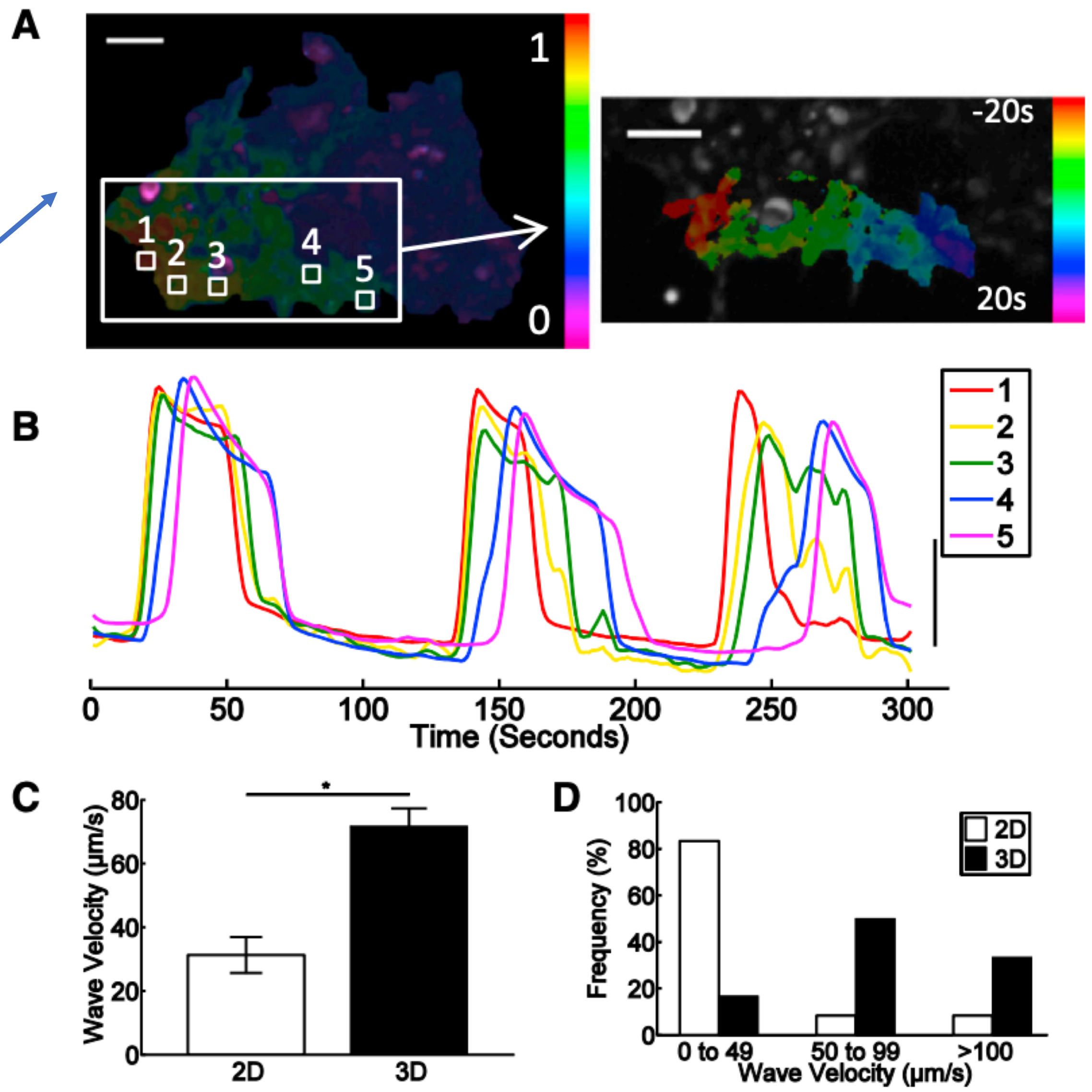
Coupled-resistor network model



Dimensionality and size scaling of coordinated Ca2+ dynamics in MIN6 beta-cell clusters. **Biophysical Journal. 2014**

Wave velocity under 2D/3D coupling

2D



P<0.001

Dimensionality and size scaling of coordinated Ca2+ dynamics in MIN6 beta-cell clusters. **Biophysical Journal. 2014**

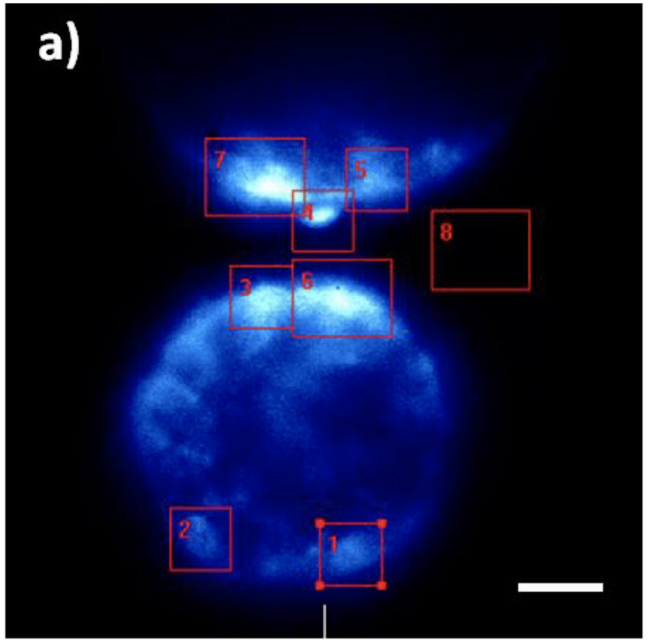
Interesting points

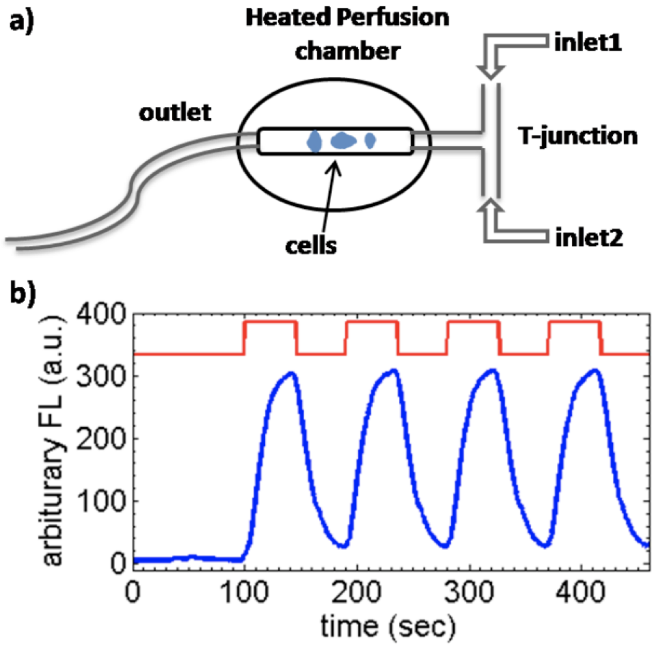
1. Low-pass frequency response of beta cells

2. Only small populations of cells (pacemakers) sense glucose stimulus

3. Unknown degree of randomness and strength of coupling

4. Entrainment of cells to glucose stimulus





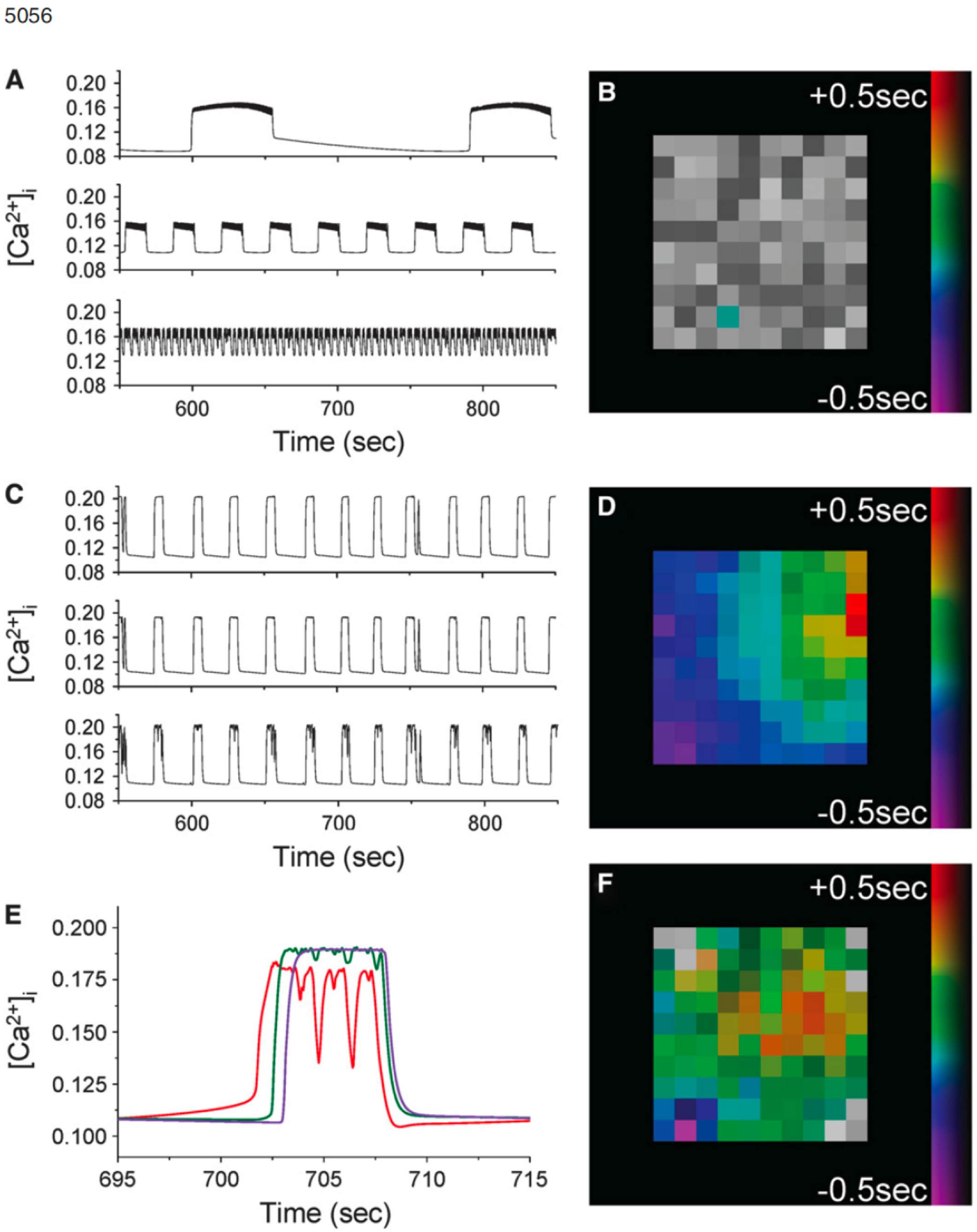
Quantifying granule transport and controlling calcium oscillations in insulin-secreting beta cells. **2010**

Coupled phantom burster model

$$C_m \frac{dV_j}{dt} = -(I_{K(Ca)} + I_{K(ATP)} + I_{Ca} + I_K + I_{coupl,j})$$

$$I_{coupl,j} = g_c \sum_{i}^{neighbor_j} (V_j - V_i).$$

How is this distributed?



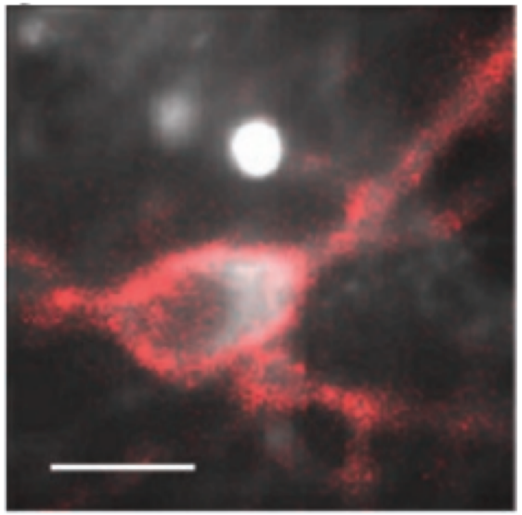
Gap junction coupling and calcium waves in the pancreatic islet. **Biophysical Journal**

Estimating membrane potentials

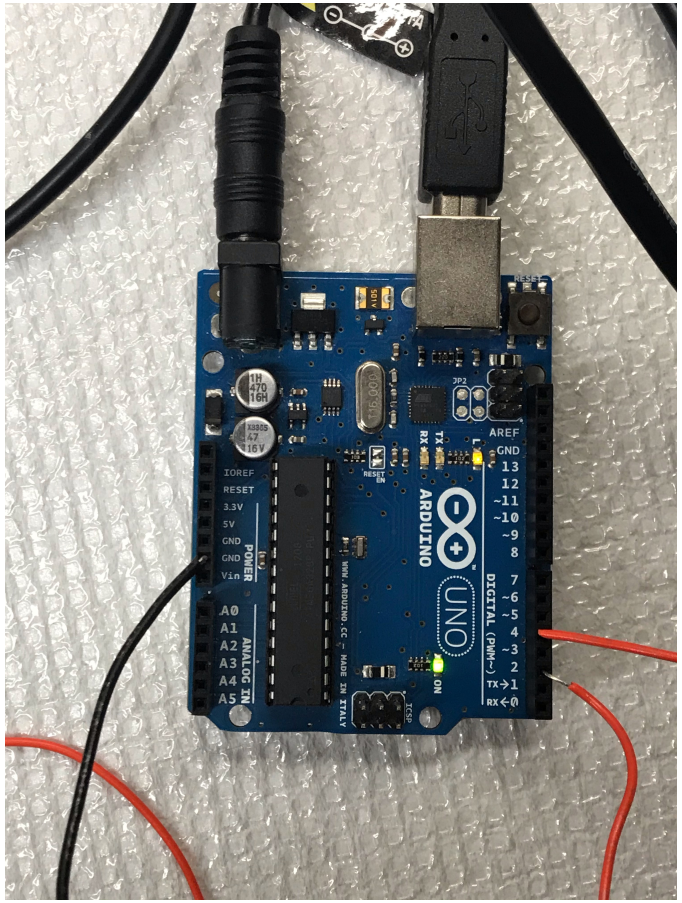
$$S_i(t) = a_i + b_i V(t) + \varepsilon_i(t)$$

$$\left\langle \varepsilon_i(t_1)\varepsilon_j(t_2) \right\rangle = \sigma_i^2 \delta_{i,j} \delta(t_1 - t_2)$$

$$\varsigma_i^2 = \left\langle \left(\hat{V}_i(t) - V(t) \right)^2 \right\rangle \quad w_i \equiv \frac{1/\varsigma_i^2}{\sum_i 1/\varsigma_i^2}$$



Optical recording of action potentials in mammalian neurons using a microbial rhodopsin. **Nature Methods**



Analog Input
Onboard 10-bit ADC (6 channels)
16 MHz Arduino has ADC clock set to 16 MHz/128 = 125 kHz. Each conversion in AVR takes 13 ADC clocks so 125 kHz/13 ~ 10 kHz

Digital Input
12 digital I/O pins. No analog to digital conversion but input has to be 0 or 5V