

Forecast for 2009: Testing and Poking

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Worm Touch Meeting

1/14/2009

Overview

- What Needs to be Done
- Current Status
- Planned Experiments

The MEMS Fairy



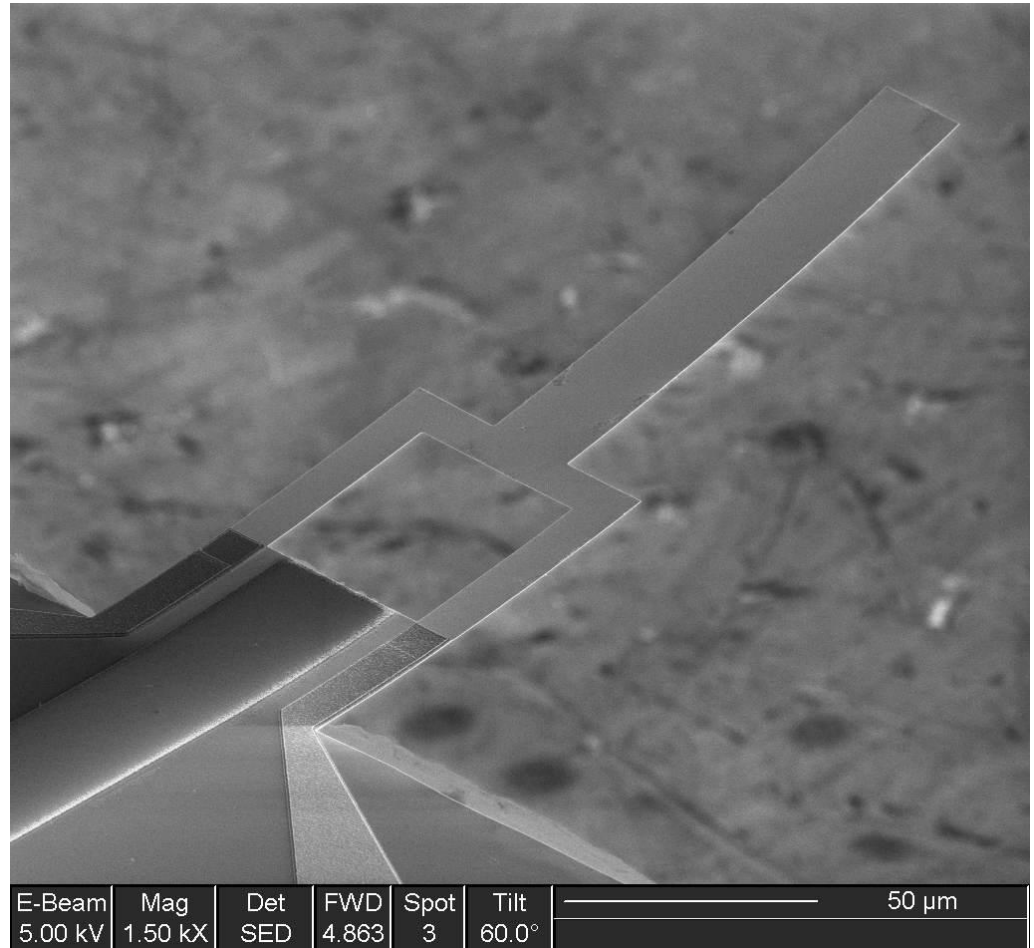
- What would the MEMS fairy do?
 - Piezoresistor noise, sensitivity and frequency response (electrical and mechanical) match design objectives.
 - Parylene passivation negligibly affects sensitivity and noise, allowing stable underwater performance for several hours.
 - Cross-talk between piezoresistor and piezoelectric is negligible or can be compensated.
 - Interface electronics include stable analog feedback control, auto-balancing Wheatstone bridge to compensate for DC noise.

Current Status

Fabrication is complete.
Have verified that PR and PE
work separately, still need
to test integrated device.

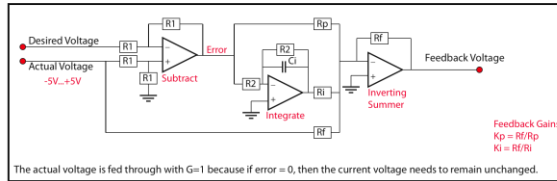
Getting trained on Auger
Electron Spectroscopy in
order to identify strange
etch byproducts.

Working on piezoresistor
characterization to look at
designed vs. actual
performance.



Current Status

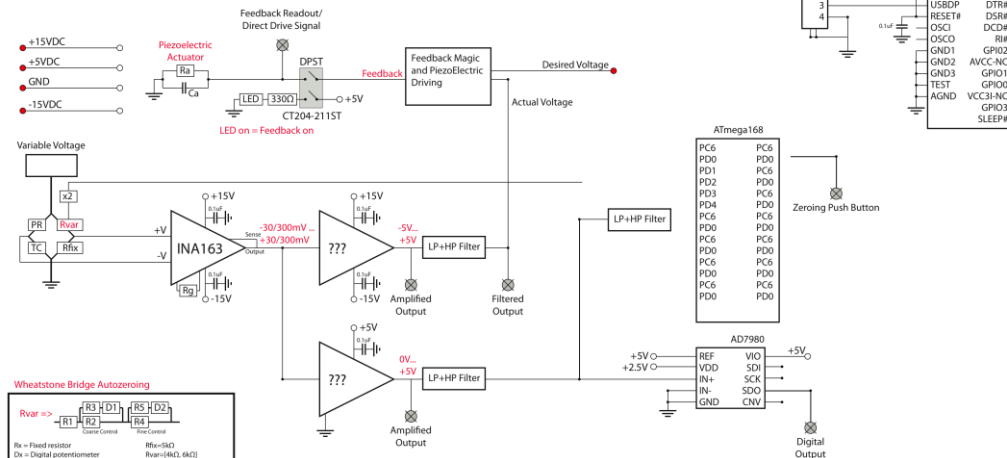
Piezoelectric Feedback Control



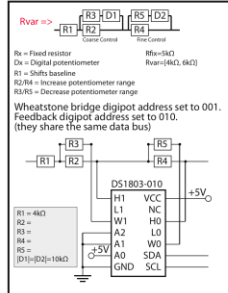
INTERFACE

Input:
 * 24V, 4mA DC power supply
 * Desired force OR direct force loop control
 * Target velocity or also again loop vs. closed loop control
 * Push button to zero Wheatstone bridge
 * I2C for microcontroller programming

Output:
 * Measured force (analog, approx. -5V to +5V, 800kHz)
 * Measured force (digital, approx. -5V to +5V, 50 kbit/s)



Wheatstone Bridge Autozeroing



DESCRIPTION

Wheatstone bridge that is set with two digital potentiometers while R6 is fixed in order to balance the bridge. R6 and TC are assumed to be within about 10% of each other, so bridge efficiency is optimal.

RA143: Free stage gain (G=100)
 AD7980: Low-power 18-bit ADC

Either analog or digital output can be sampled using an external DAC. On-board DAC can be added later once the massive data throughput is verified out.

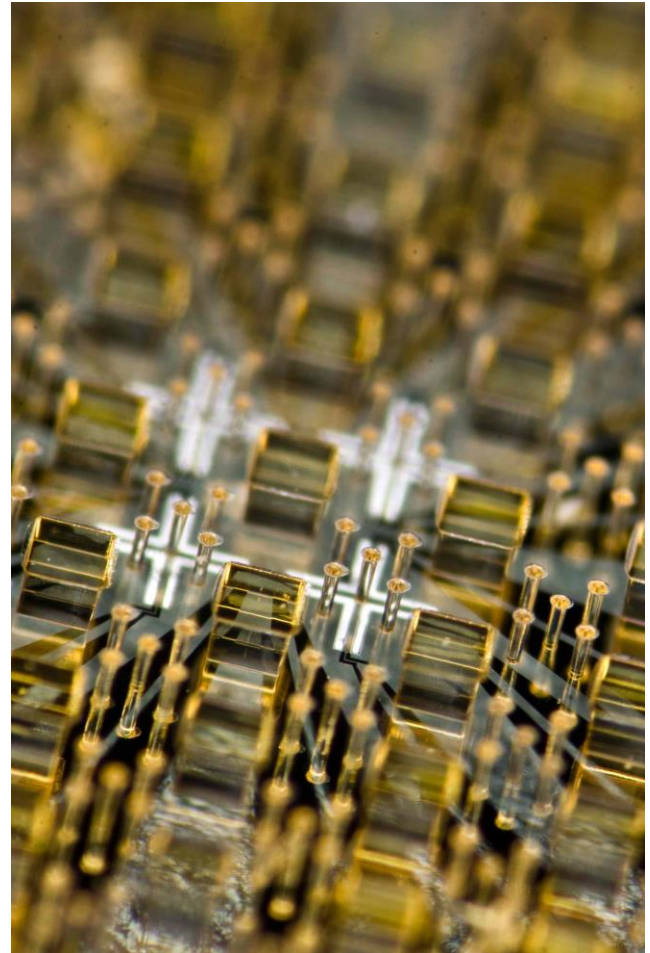
TODO

- * Measure PE and TC in order to extract resistance vs. base voltage calibration
- * Variable low-noise bridge bias (up to 15V)
- * Converting voltage to force on chip would be nice
- * Check the signs of the Wheatstone bridge and feedback to ensure they make sense
- * Digital potentiometer for setting R6 and TC
- * Push button or USB interface for setting bridge

Interface electronics are in progress

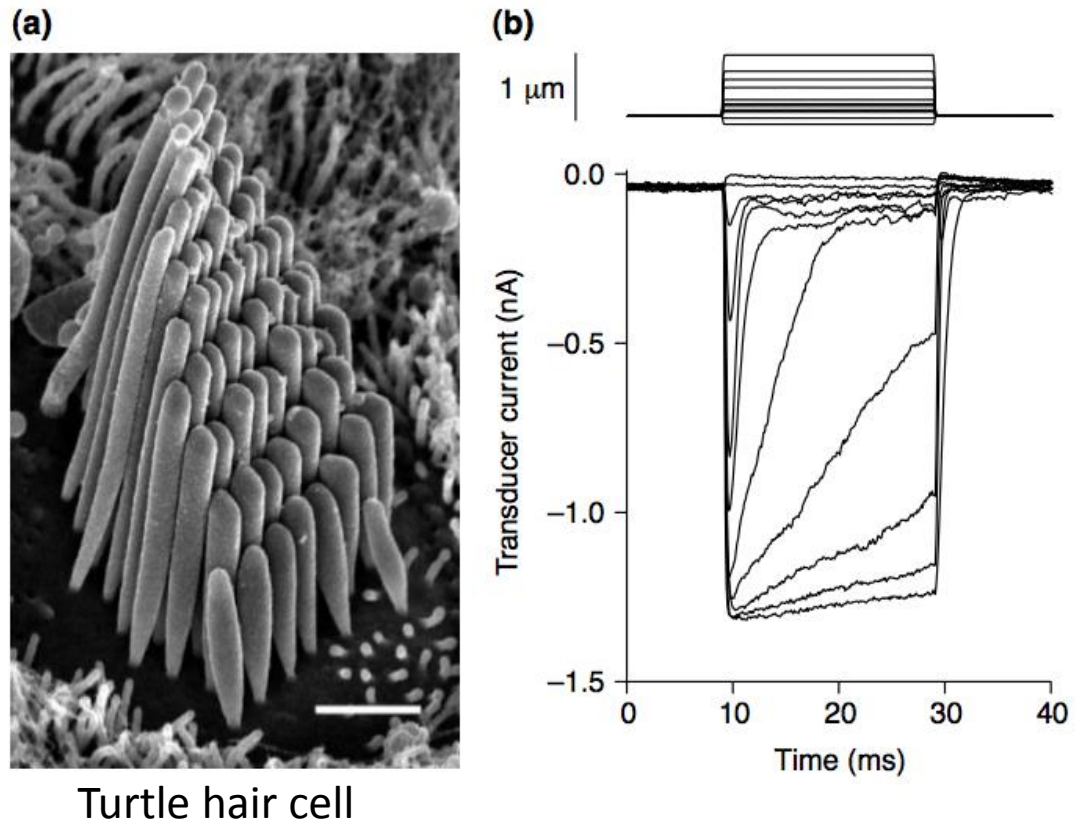
Current Status

Working on conference abstracts, papers
(cantilever design, AlN on Ti)



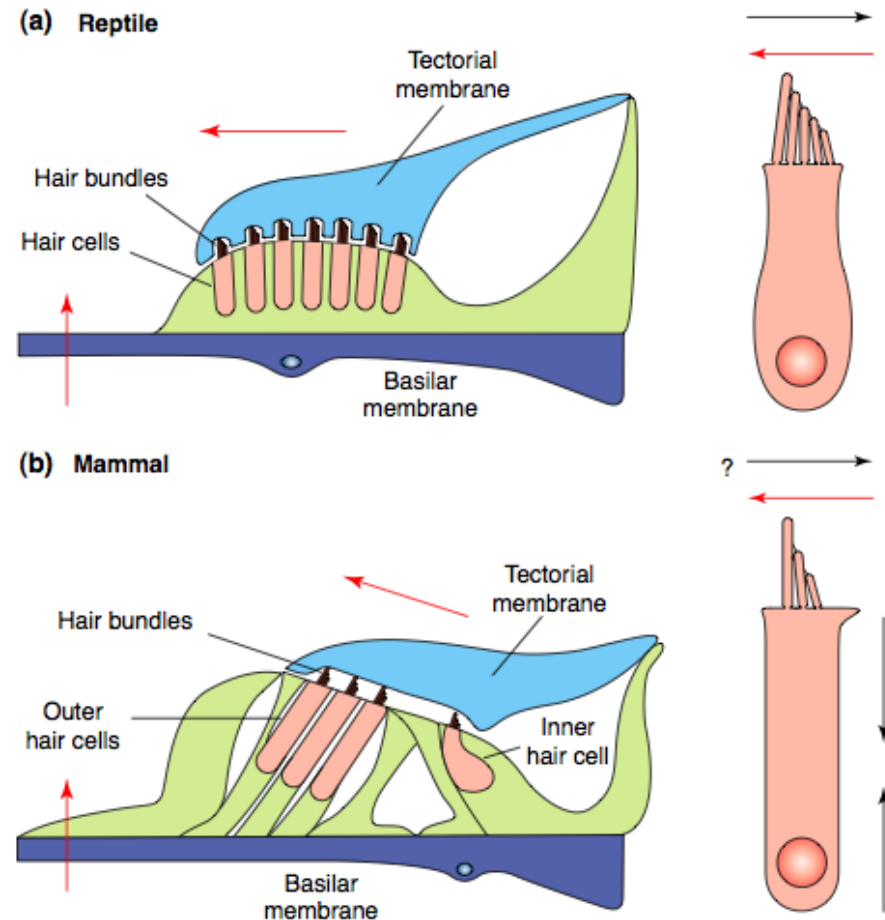
Planned Biological Experiments

- Hair Cells
- TRNs



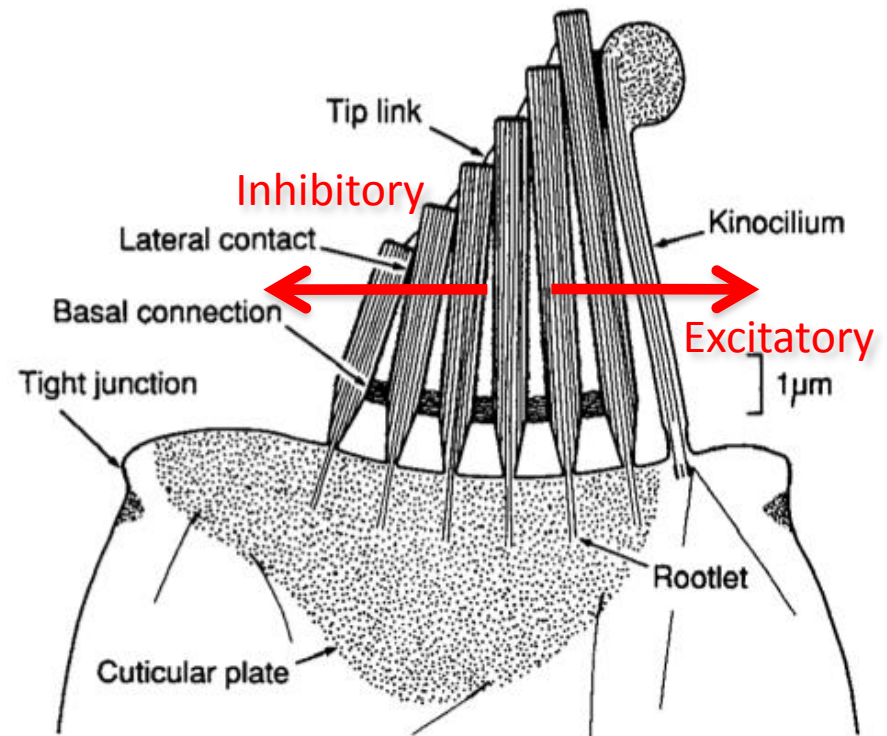
Hair Cells

- **Goal:** direct application of force to hair cell stereocilia
- Frequency response of actuators to date $\sim 6\text{kHz}$ (60us rise time)
- Glass probe used, acid cleaned to adhere to hair cells



Hair Cells

- Hearing threshold = 0.1-1nm of tip deflection
- Sensitive over 100nm range
20kHz in humans, 100kHz in bats and whales
- Small number of channels (5-50) per stereocilium, 100k/ear -> hard to purify
- <25usec delay between deflection and opening
- 0.6pN to directly open channel



Hair Cells

- Active tuning and hair cell actuation, another force measurement?
- $k \sim 1\text{mN/m}$
- Adaptation mediated by Ca^{2+}
- Both electrical and mechanical tuning mechanisms

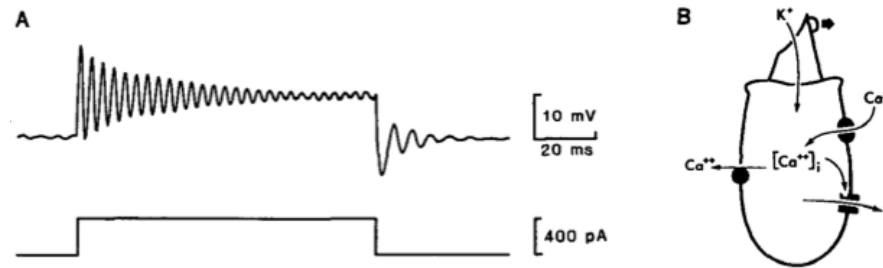
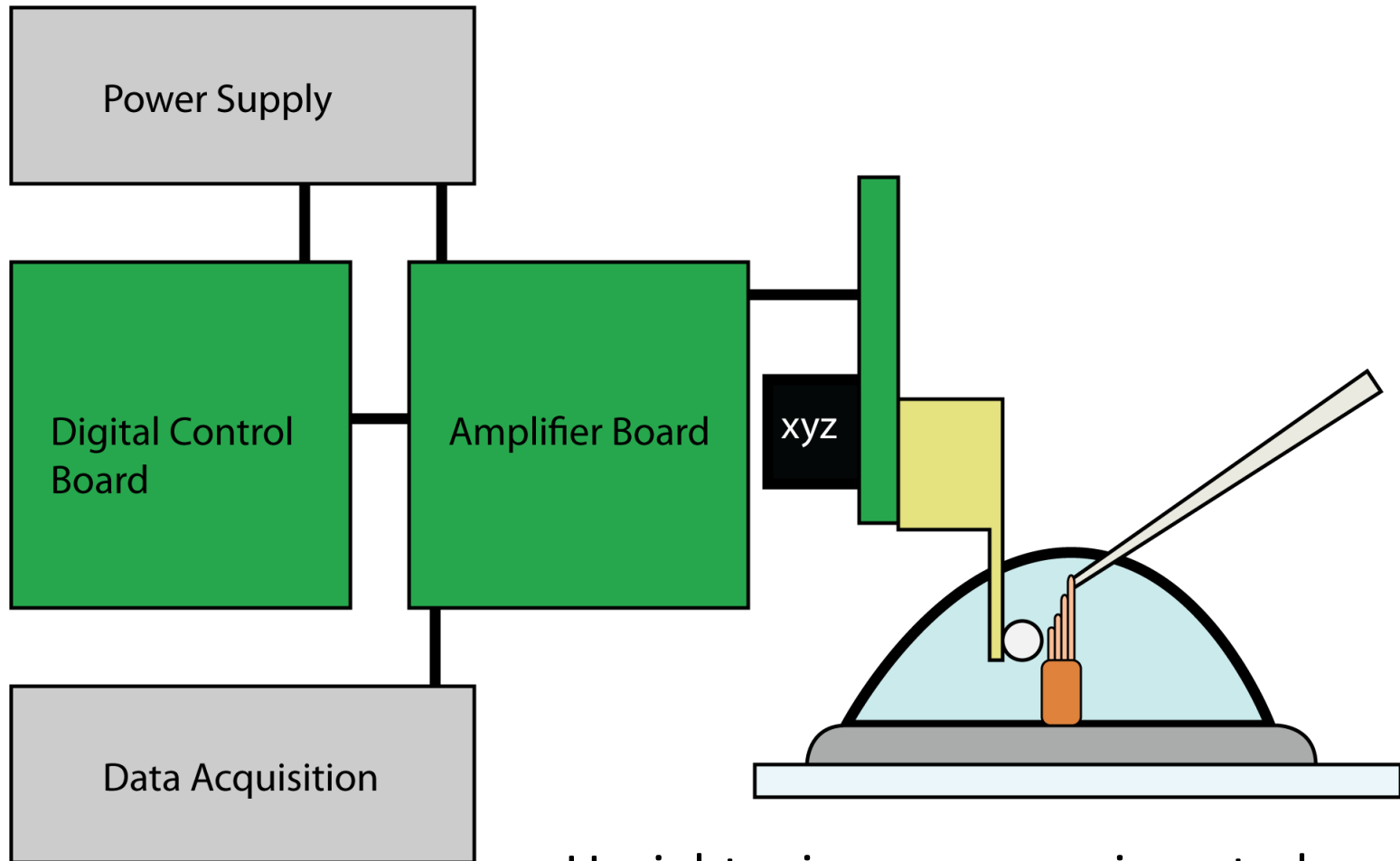


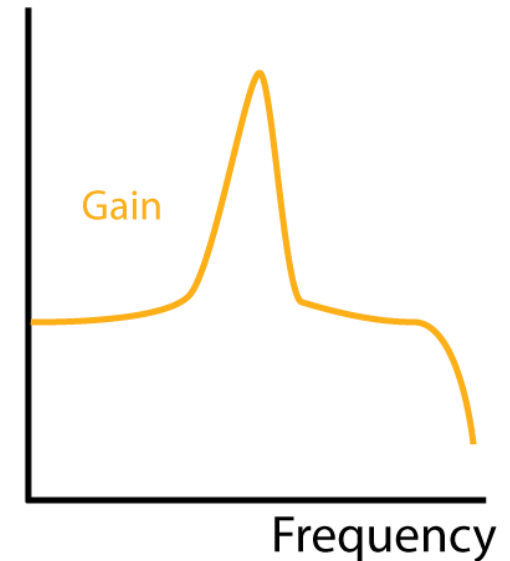
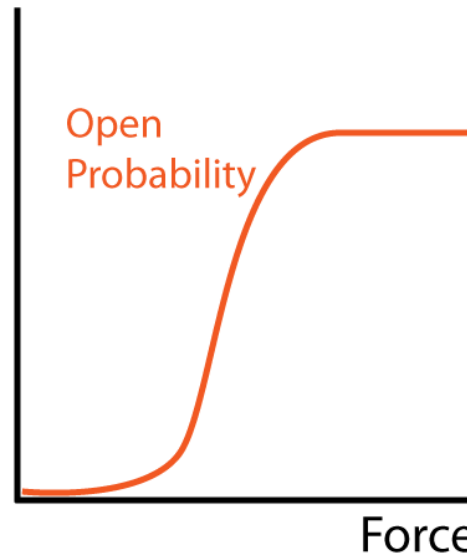
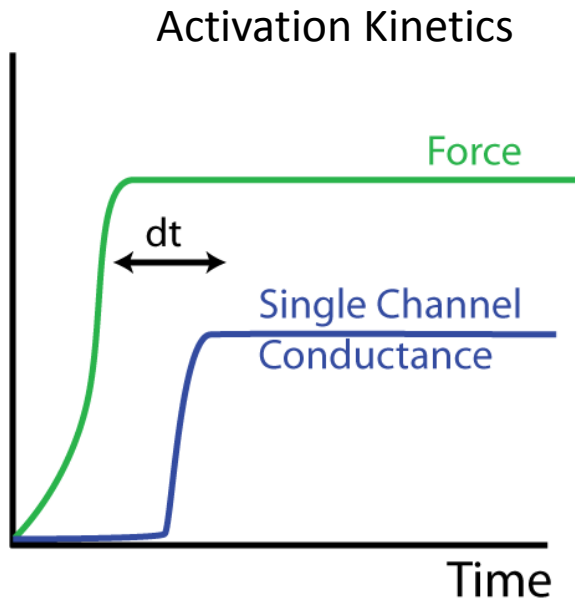
Figure 5 Electrical resonance and its ionic basis. (A) When a hair cell of the bullfrog's sacculus was depolarized by a square current pulse, the membrane potential exhibited damped, sinusoidal oscillation at a frequency of 270 Hz. Oscillation at a lower frequency also occurred at the termination of the pulse. (B) Positive deflection of a hair bundle allows K^+ , the principal cation in the endolymph that bathes the bundles, to enter through transduction channels and to depolarize the cell; the injection of current through a micro-electrode has a similar effect. As depolarization activates voltage-sensitive Ca^{2+} channels, the influx of Ca^{2+} further depolarizes the cell. As Ca^{2+} accumulates in the cytoplasm near the plasma membrane, however, it opens Ca^{2+} -sensitive K^+ channels; the efflux of K^+ through these channels repolarizes the membrane and the next cycle of oscillation commences.

Experimental Setup



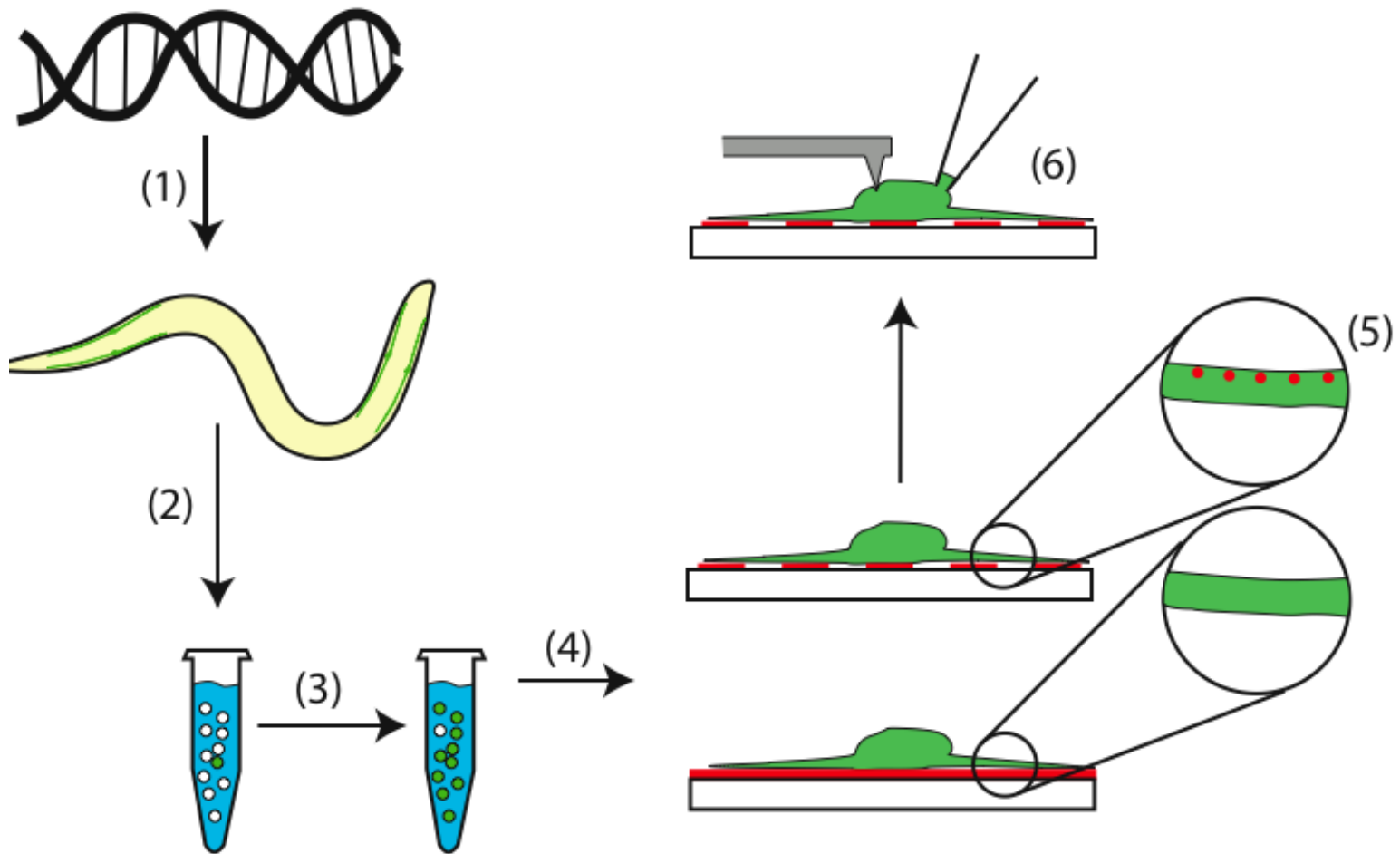
Upright microscope vs. inverted....

Things to Measure?



Need to learn more about what is unknown, where limitations of current force application systems limit the experiments

Touch Receptor Neurons



Timeline

- **Jan-Feb:** Device characterization
- **Feb-Mar:** System integration
- **Apr-May:** System characterization
- **June:** Start experiments

