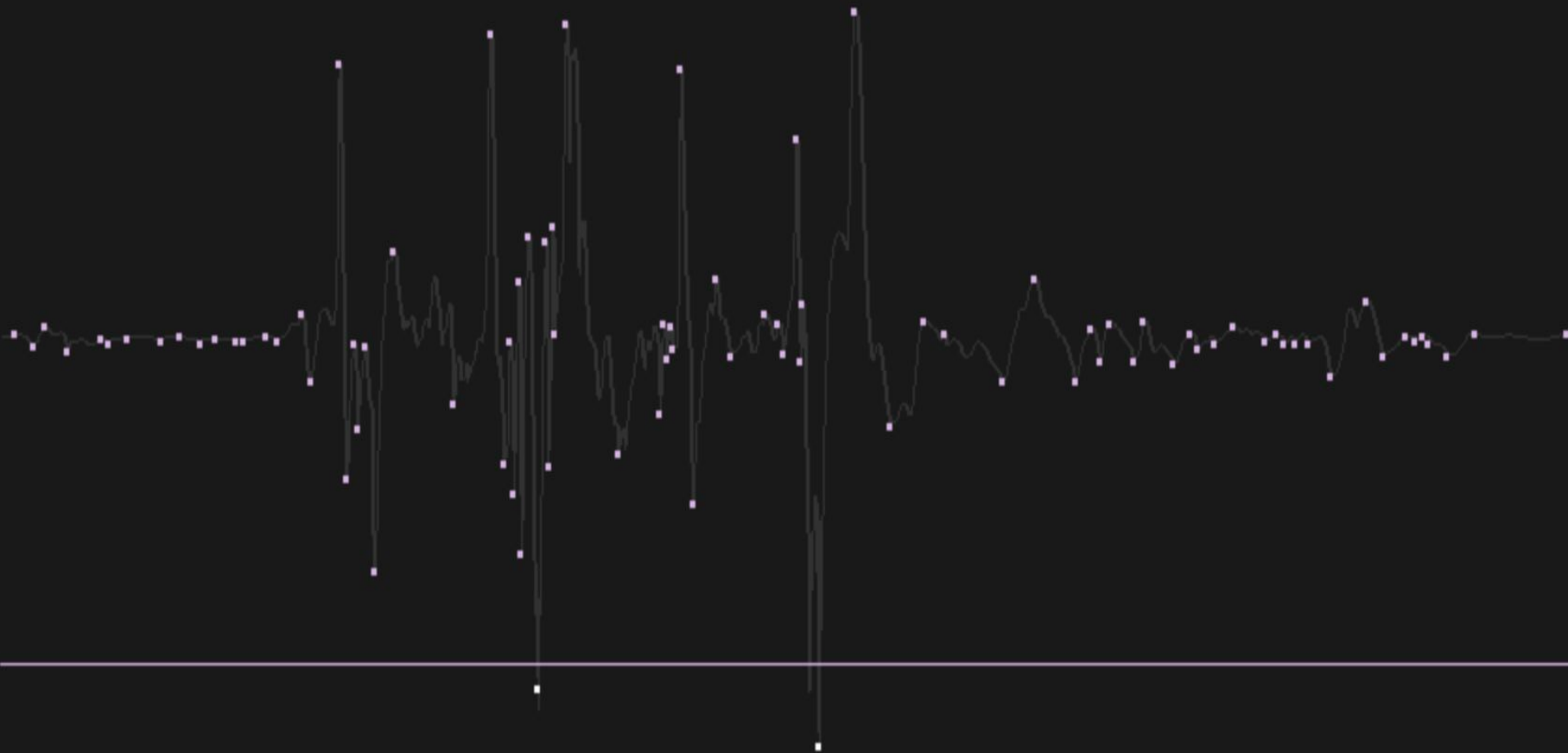


# CORAL NEURAL NETWORKS

## Analyzing Anthozoan Action Potentials



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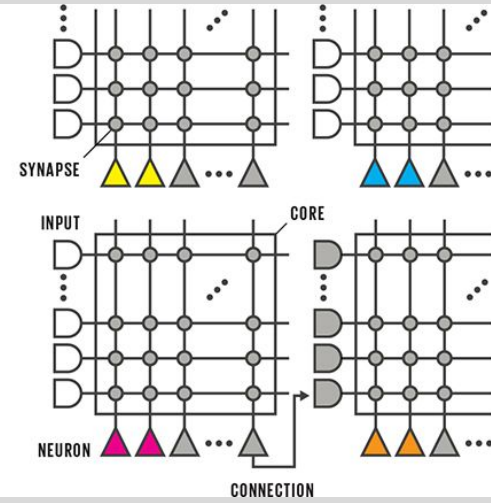
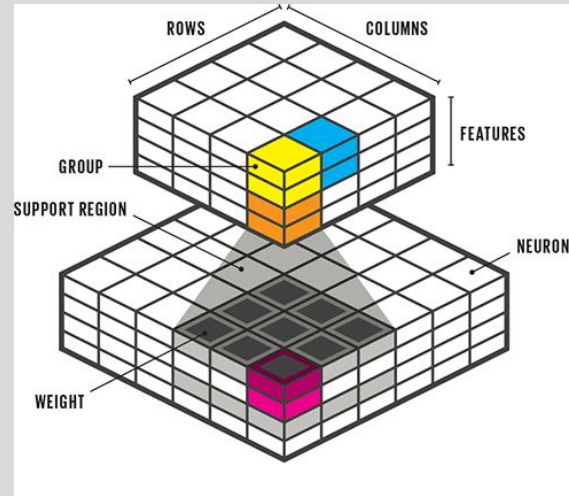
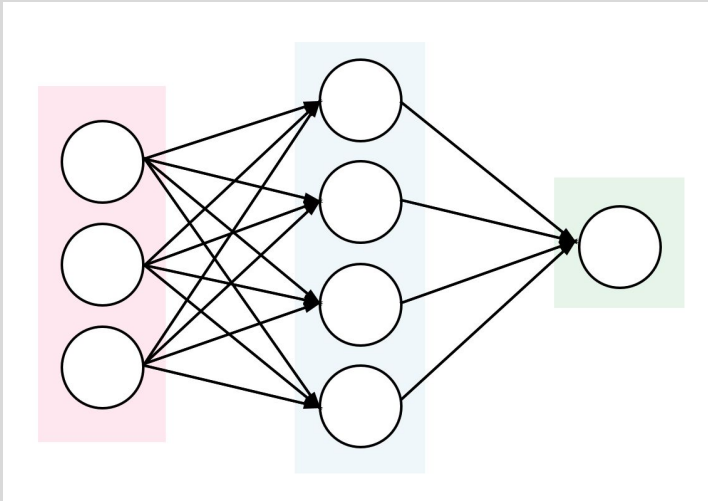
- Introduction
  - Motivation
  - Background/Theoretical Neuroscience
- Literature Review
- Experiment design
- Results
  - Baseline
  - Temperature, Electrical Stimulus
- Discussion and Implications
- Future work
  - Chaos, Fractal Phase Boundary



# INTRODUCTION

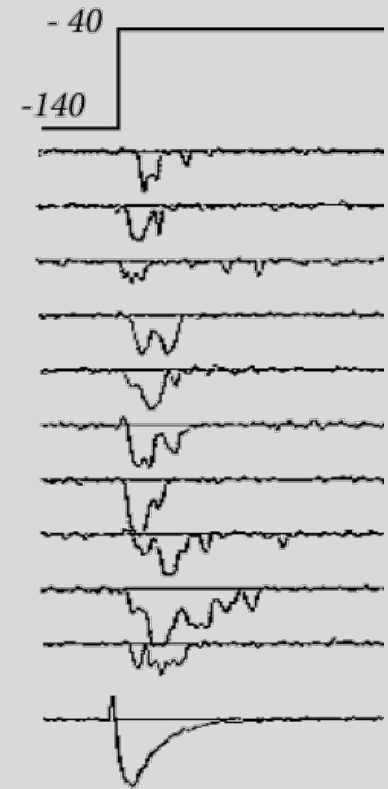
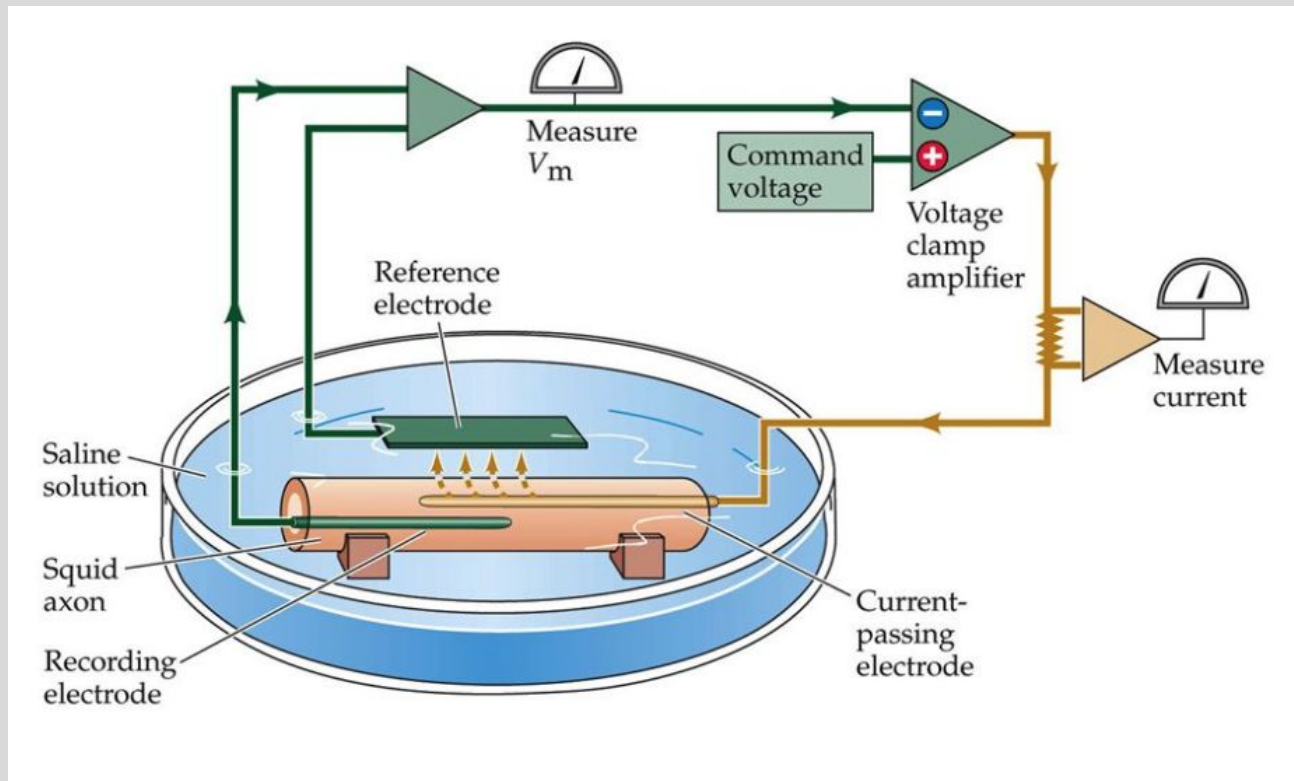
*Theoretical Neuroscience, Project Overview,  
Literature Review*

# MOTIVATION



# INTRODUCTORY BIOPHYSICS

## The Hodgkin–Huxley experiment



# INTRODUCTORY BIOPHYSICS

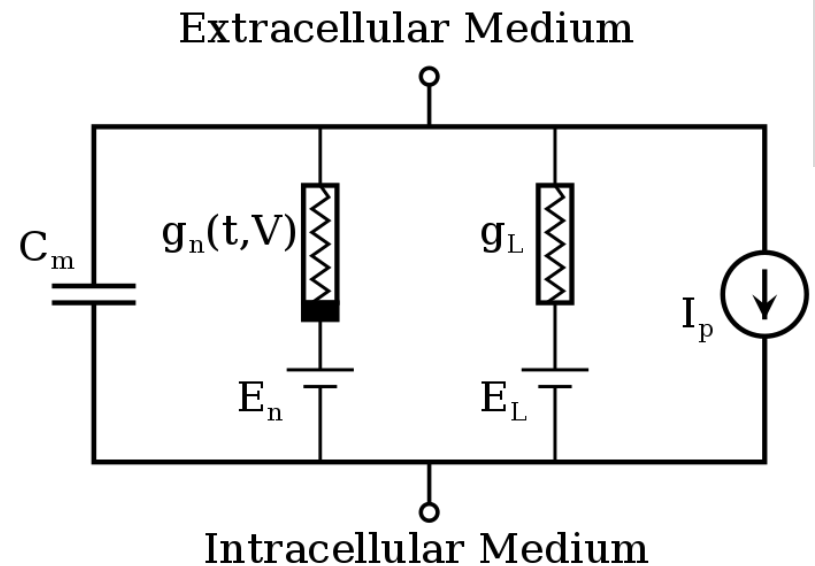
## The Hodgkin–Huxley model

$$I = C_m \frac{dV_m}{dt} + \bar{g}_K n^4 (V_m - V_K) + \bar{g}_{Na} m^3 h (V_m - V_{Na}) + \bar{g}_l (V_m - V_l),$$

$$\frac{dn}{dt} = \alpha_n(V_m)(1 - n) - \beta_n(V_m)n$$

$$\frac{dm}{dt} = \alpha_m(V_m)(1 - m) - \beta_m(V_m)m$$

$$\frac{dh}{dt} = \alpha_h(V_m)(1 - h) - \beta_h(V_m)h$$



# INTRODUCTORY BIOPHYSICS

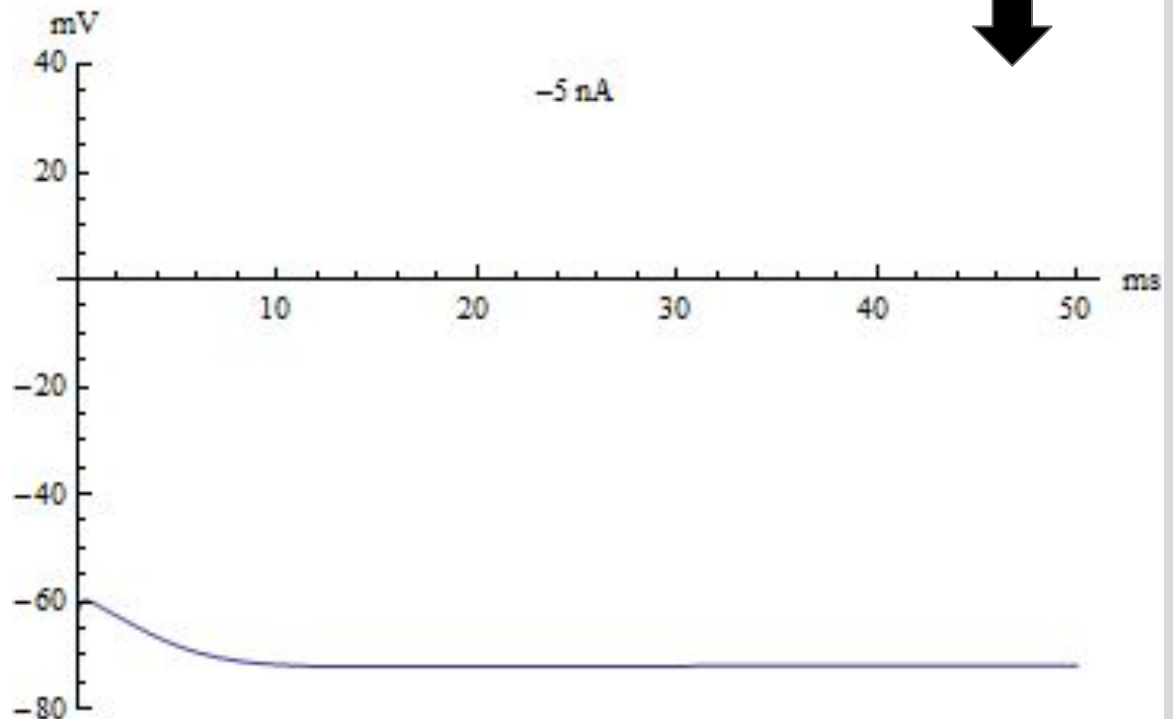
## The Hodgkin–Huxley model

$$I = C_m \frac{dV_m}{dt} + \bar{g}_K n^4 (V_m - V_K) + \bar{g}_{Na} m^3 h (V_m - V_{Na}) + \bar{g}_l (V_m - V_l),$$

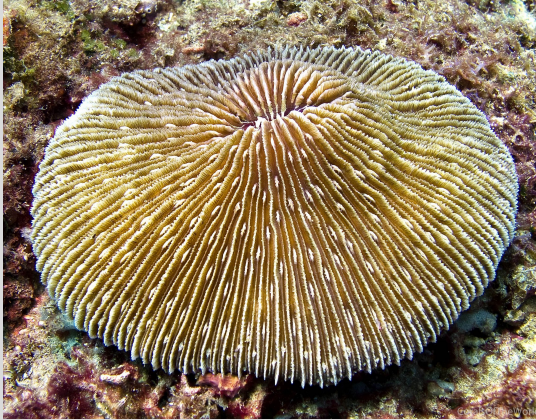
$$\frac{dn}{dt} = \alpha_n(V_m)(1 - n) - \beta_n(V_m)n$$

$$\frac{dm}{dt} = \alpha_m(V_m)(1 - m) - \beta_m(V_m)m$$

$$\frac{dh}{dt} = \alpha_h(V_m)(1 - h) - \beta_h(V_m)h$$



# CHOSEN CORALS AND RATIONALE



Fungia



Goniopora



Heteroxenia



Meandrina



Nephtheidae

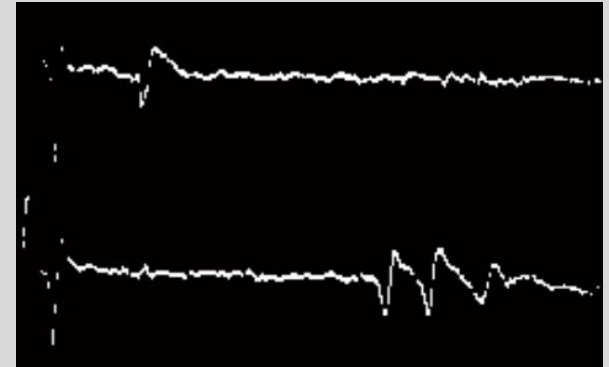
# LITERATURE REVIEW

## Multiple conducting systems and the control of behaviour in the brain coral *Meandrina meandrites* (L.)

BY I. D. MCFARLANE†

*Gatty Marine Laboratory and Department of Zoology,  
The University of St Andrews, Fife, Scotland*

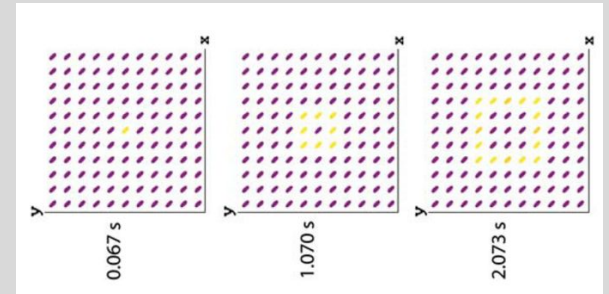
(Communicated by H. G. Callan, F.R.S. – Received 16 June 1977)



Published as: *J Comp Physiol A Neuroethol Sens Neural Behav Physiol.* 2008 February ; 194(2): 195–200

## Model of traveling waves in a coral nerve network

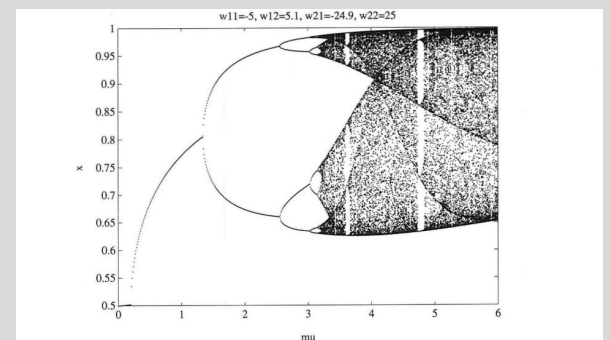
Eugenia Chen<sup>1</sup>, Klaus M. Stiefel<sup>1,2</sup>, Terrence J. Sejnowski<sup>1,3</sup>, and Theodore H. Bullock<sup>4</sup>



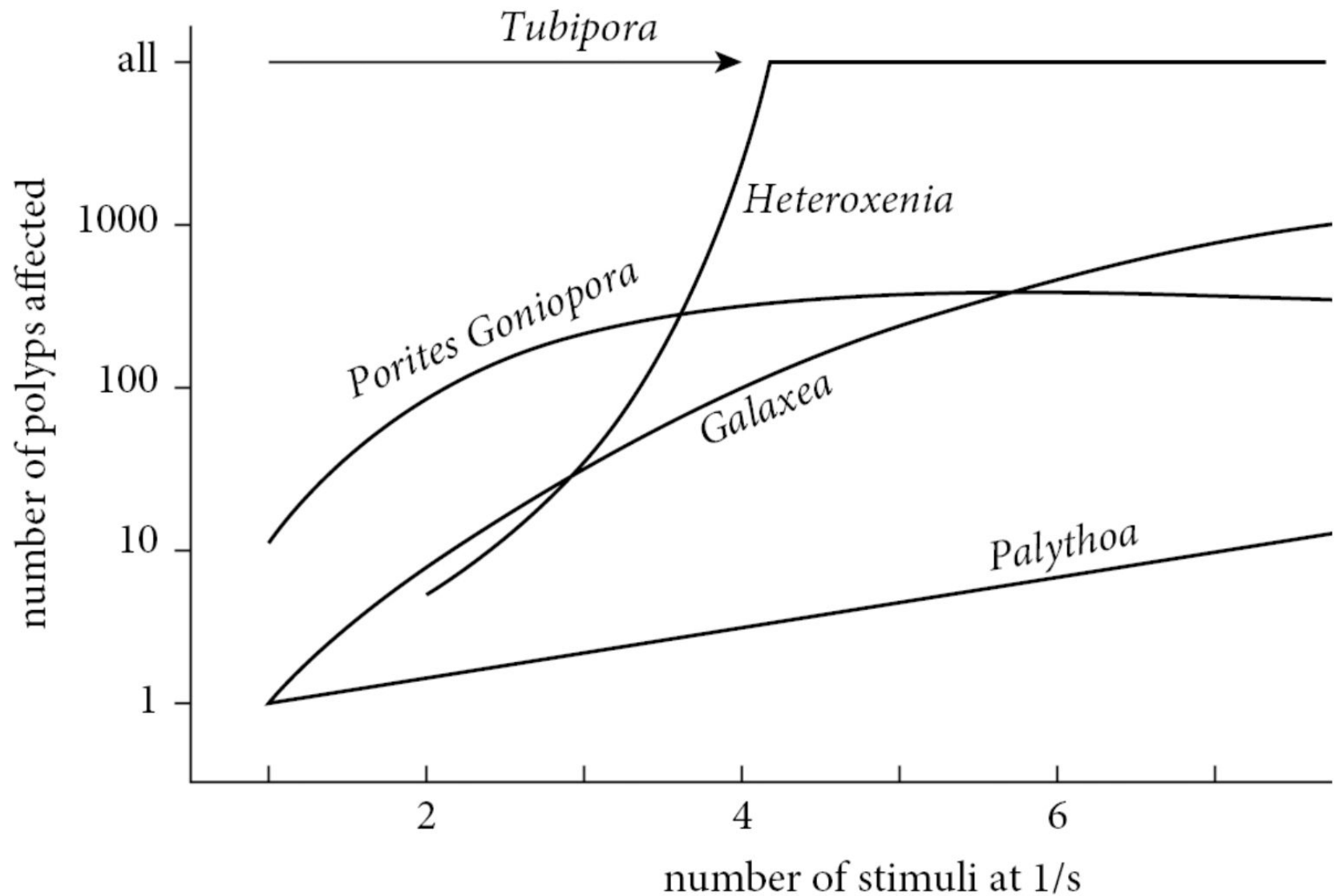
## Period-Doublings to Chaos in a Simple Neural Network: An Analytical Proof

Xin Wang

Department of Mathematics, University of Southern California,  
Los Angeles, CA 90089-1113, USA



# LITERATURE REVIEW

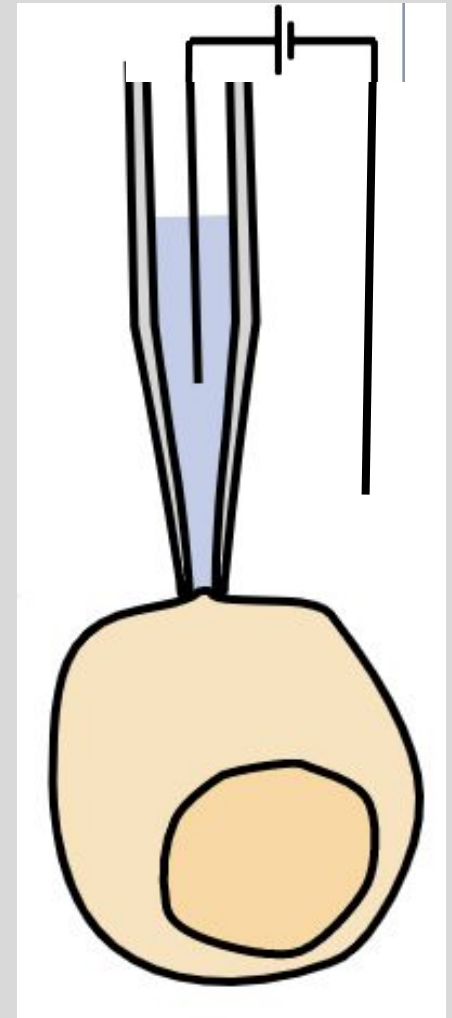
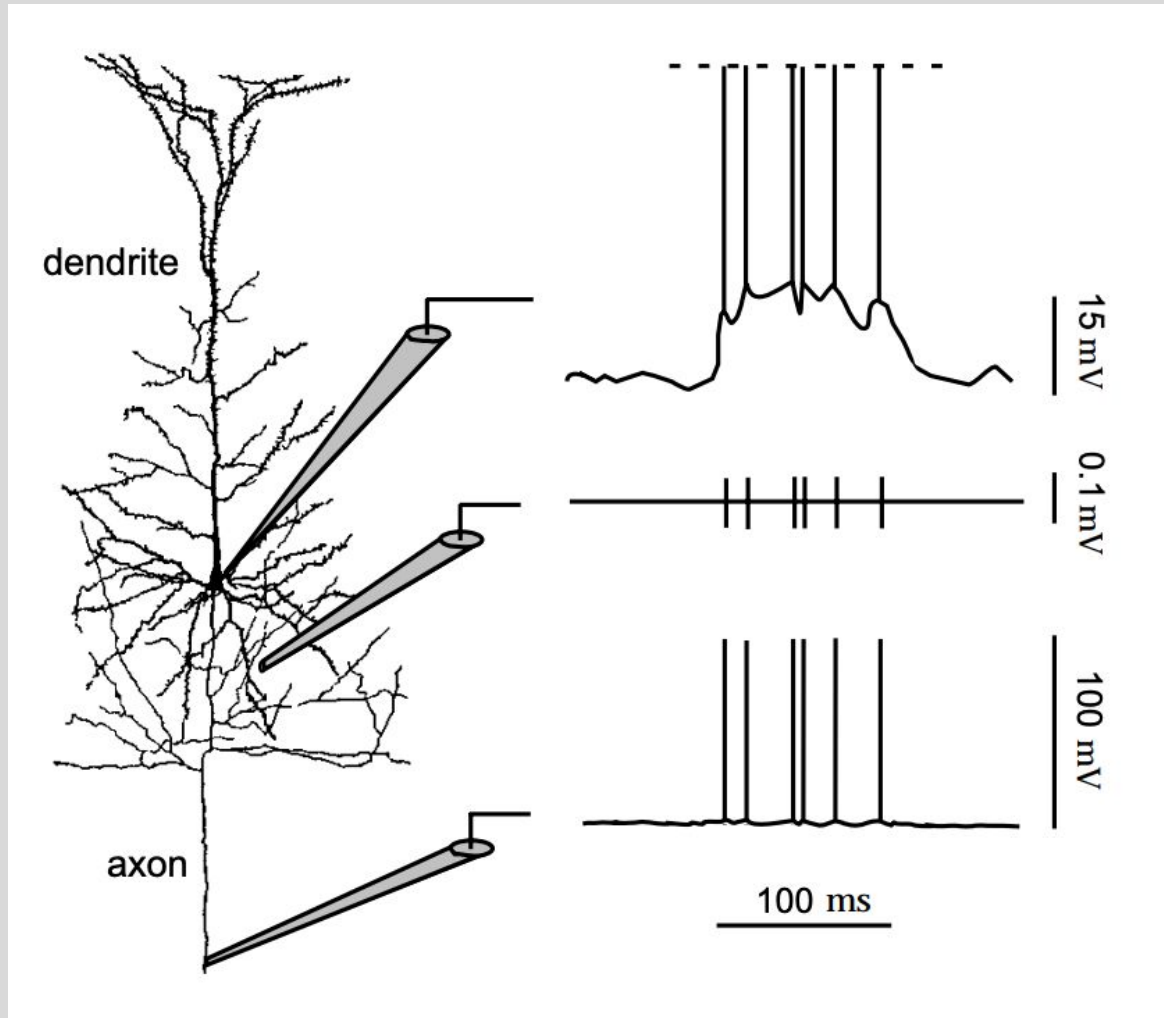




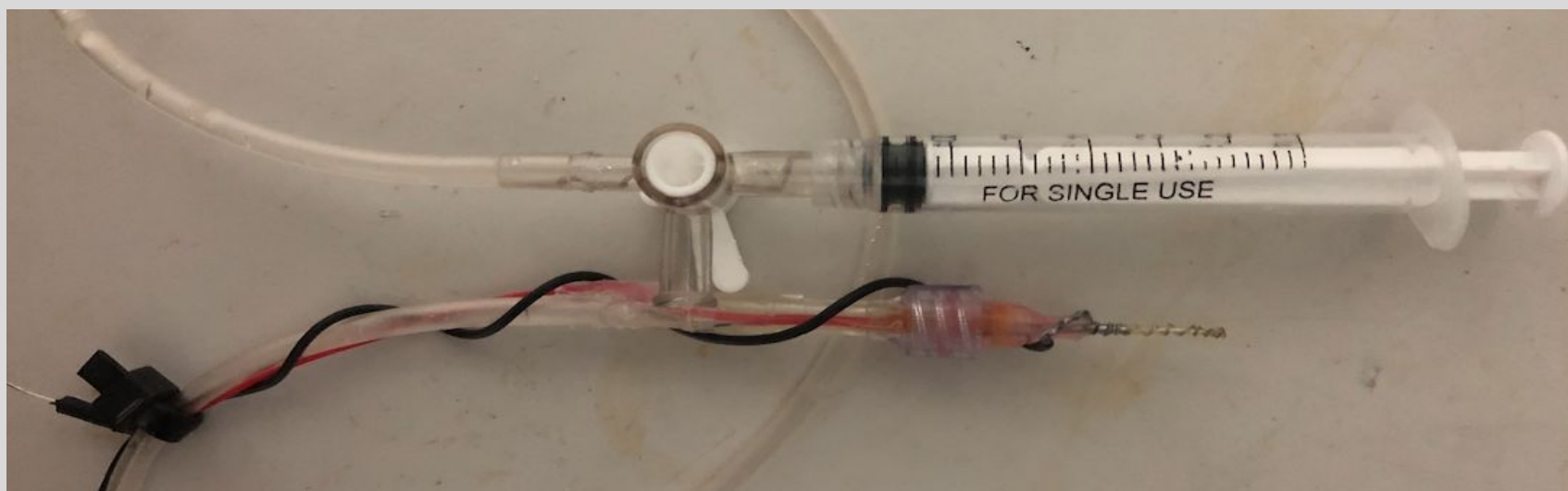
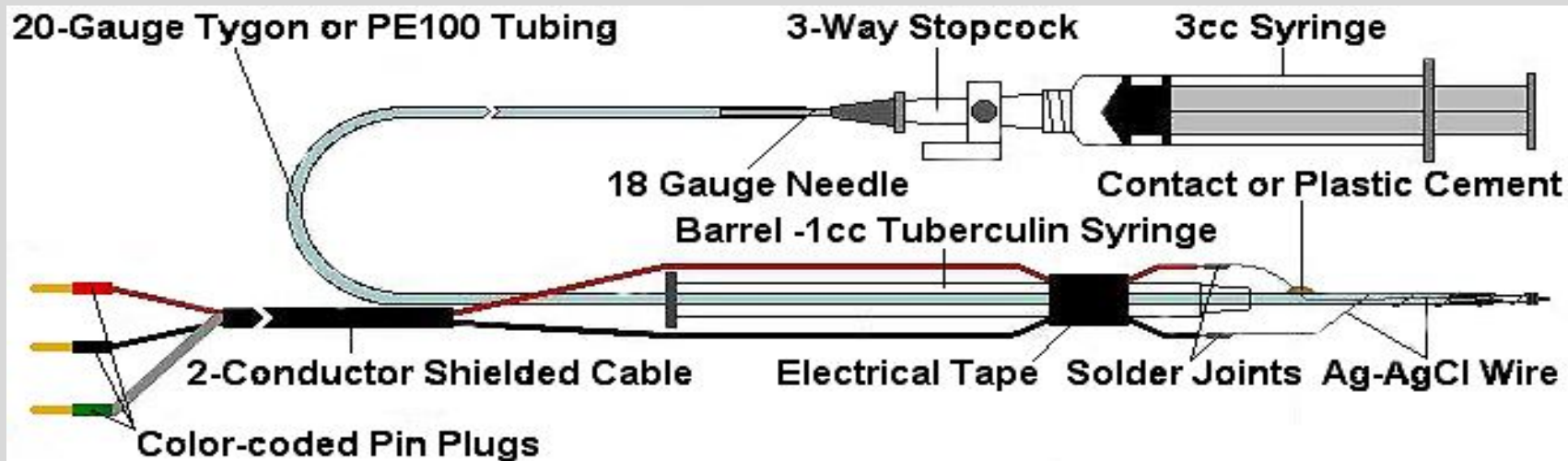
# METHODOLOGY



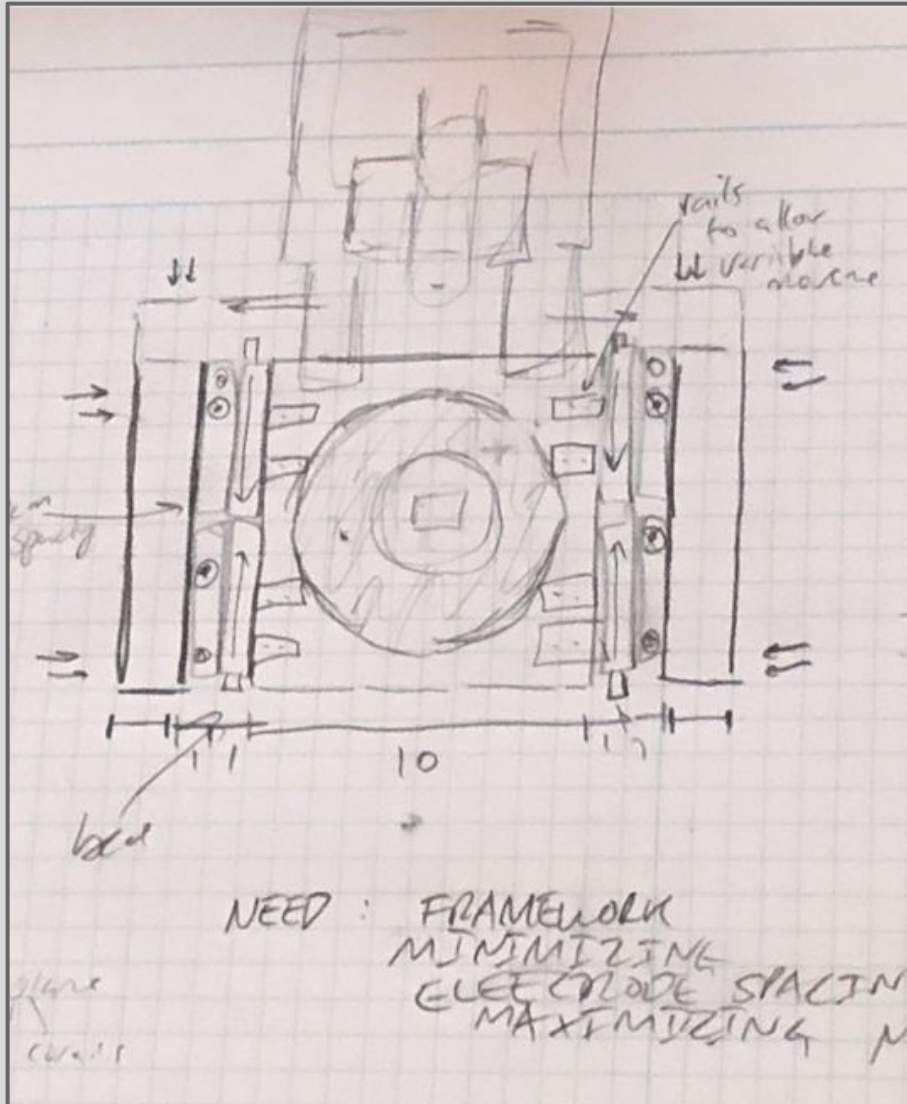
# RECORDING DEVICES



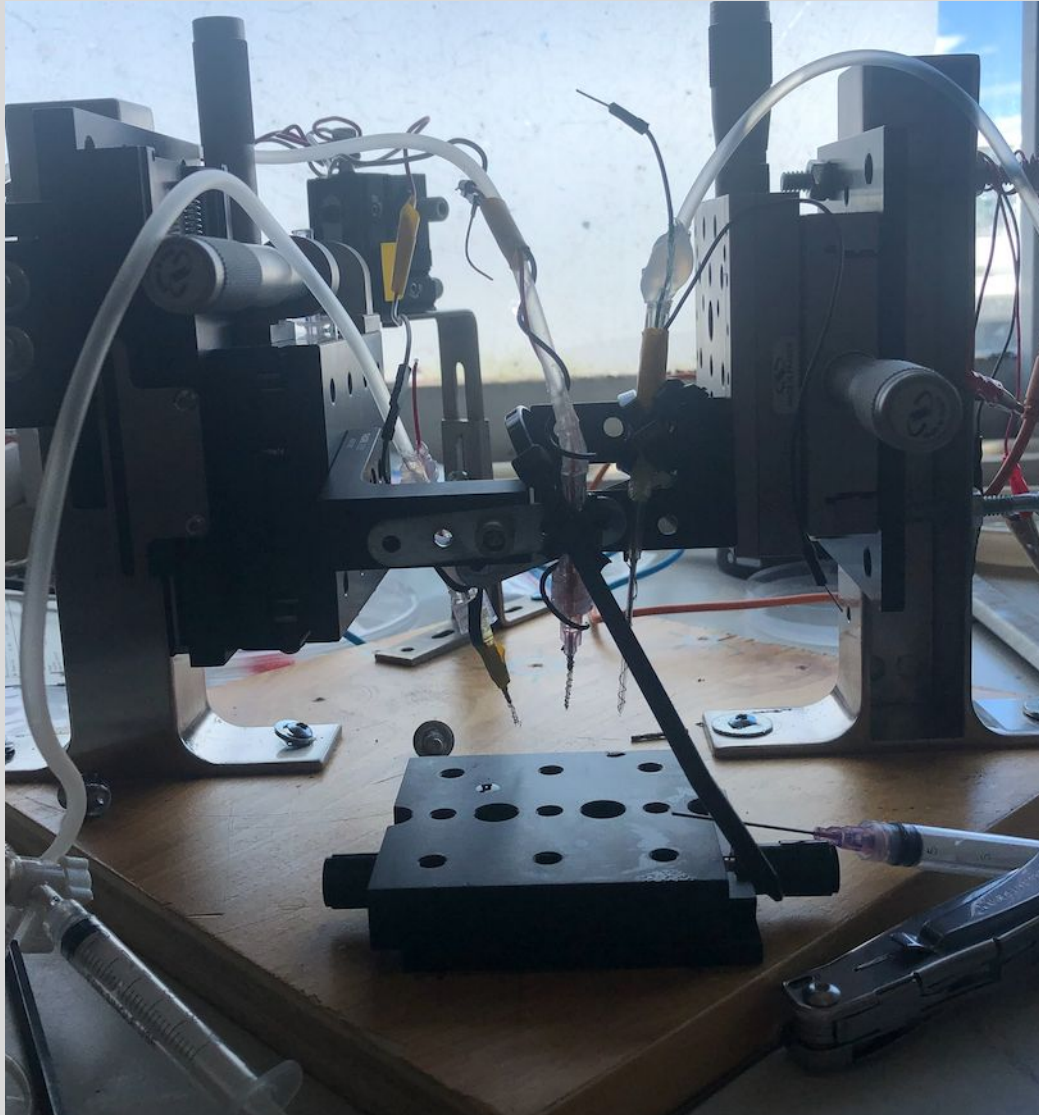
# SUCTION ELECTRODES



# MICROMANIPS AND ORGANISATION



# SYSTEM SETUP



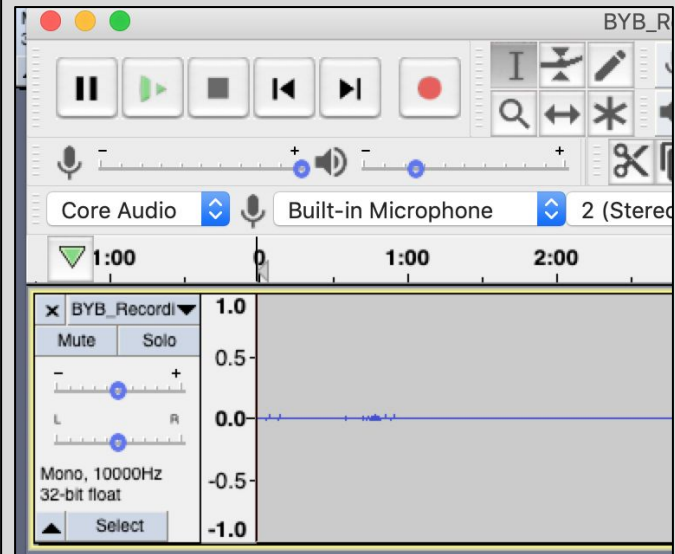
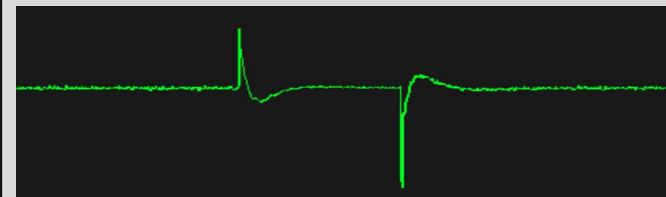
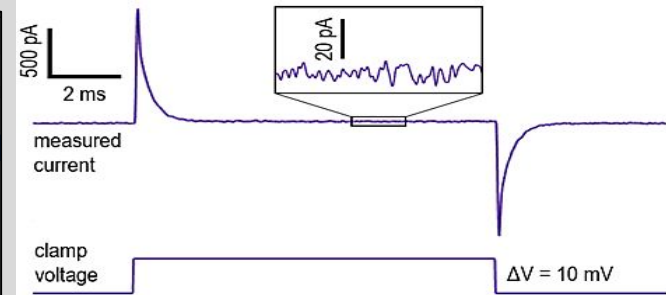


# RESULTS

*First recordings of solitary polyp and octocorallia action potentials, hints at periodicity,*

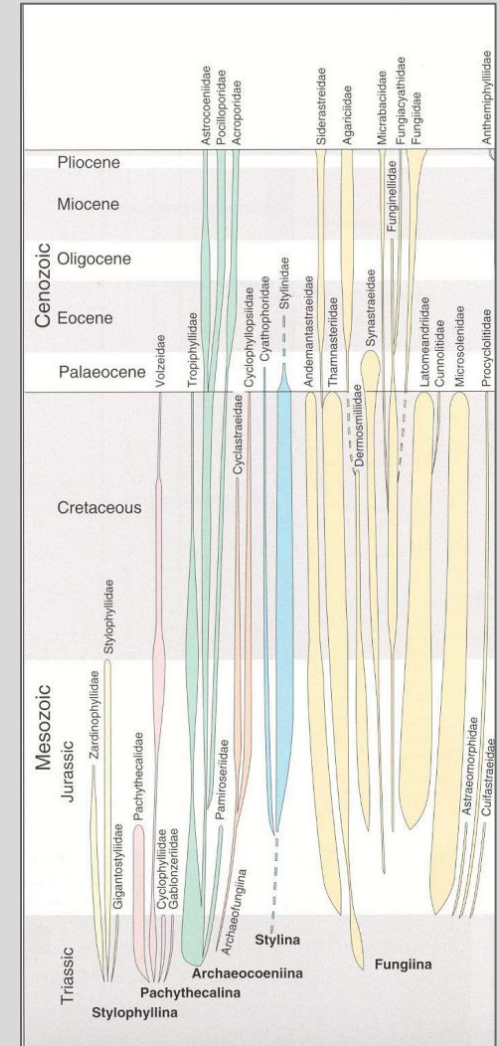
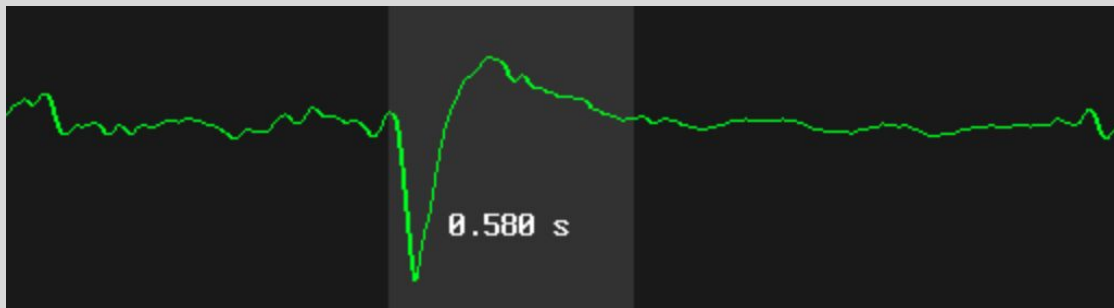
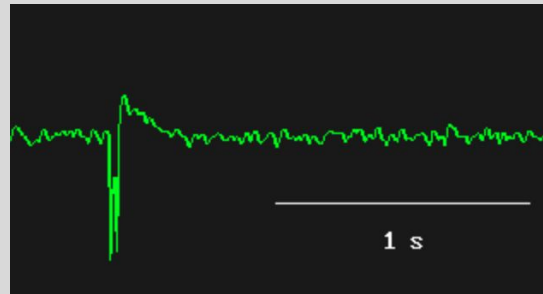
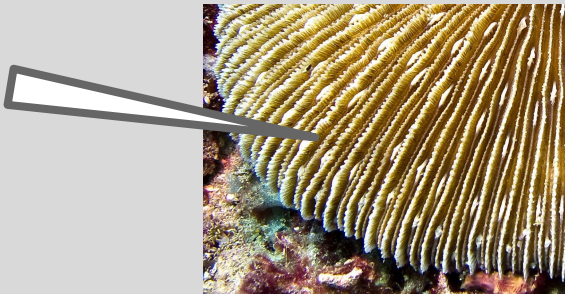
# Raw Data Formatting, Parsing, Challenges

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BEST RECORDING YET STIMULUS AND PULSE AFTER .wav	Yesterday at 12:52 PM	10.7 MB	Waveform audio
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BYB_Recording_2019-07-07_21.30.39.wav	Jul 7, 2019 at 9:34 PM	4.1 MB	Waveform audio
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BYB_Recording_2019-07-04_12.55.22.wav	Jul 4, 2019 at 1:04 PM	10.4 MB	Waveform audio
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repeated 12V stimulation ion exha...ith just one tentacle in eletrode.wav	Jul 4, 2019 at 11:56 AM	2 MB	Waveform audio
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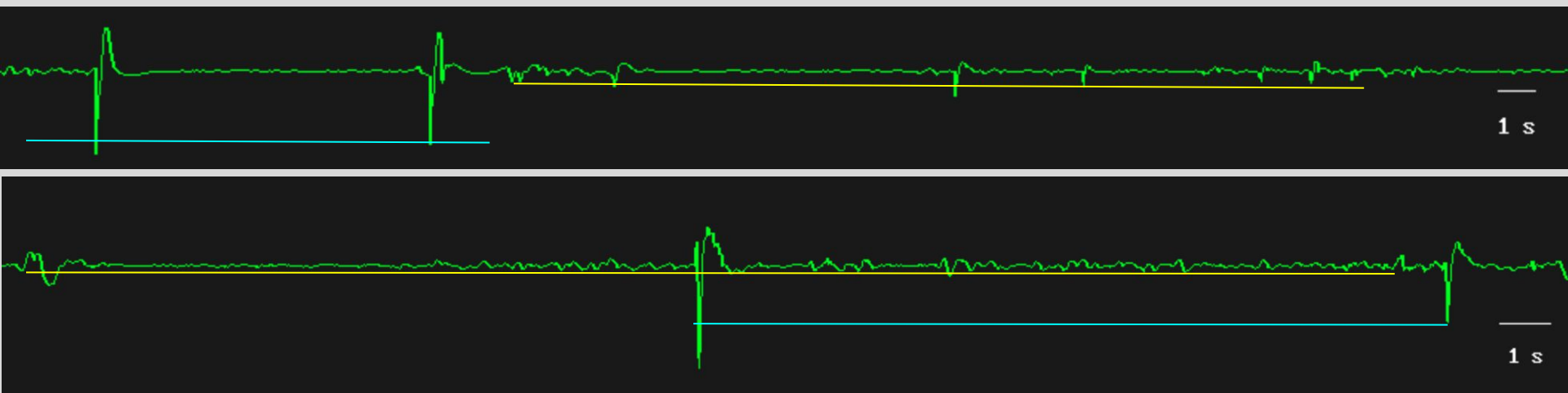
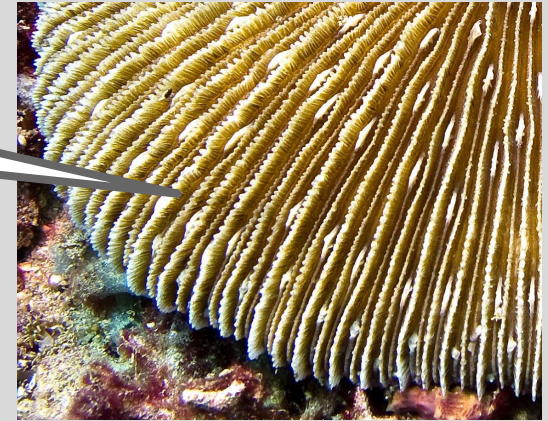
# FUNGIA ACTION POTENTIAL TRACE

- Only 1 AP waveform type recorded
- 550ms action potential
- Evolutionary implications
  - Oldest scleractinian corals likely solitary organisms (Early Triassic)



# MULTIPLE FIRING CELLS PER TENTACLE

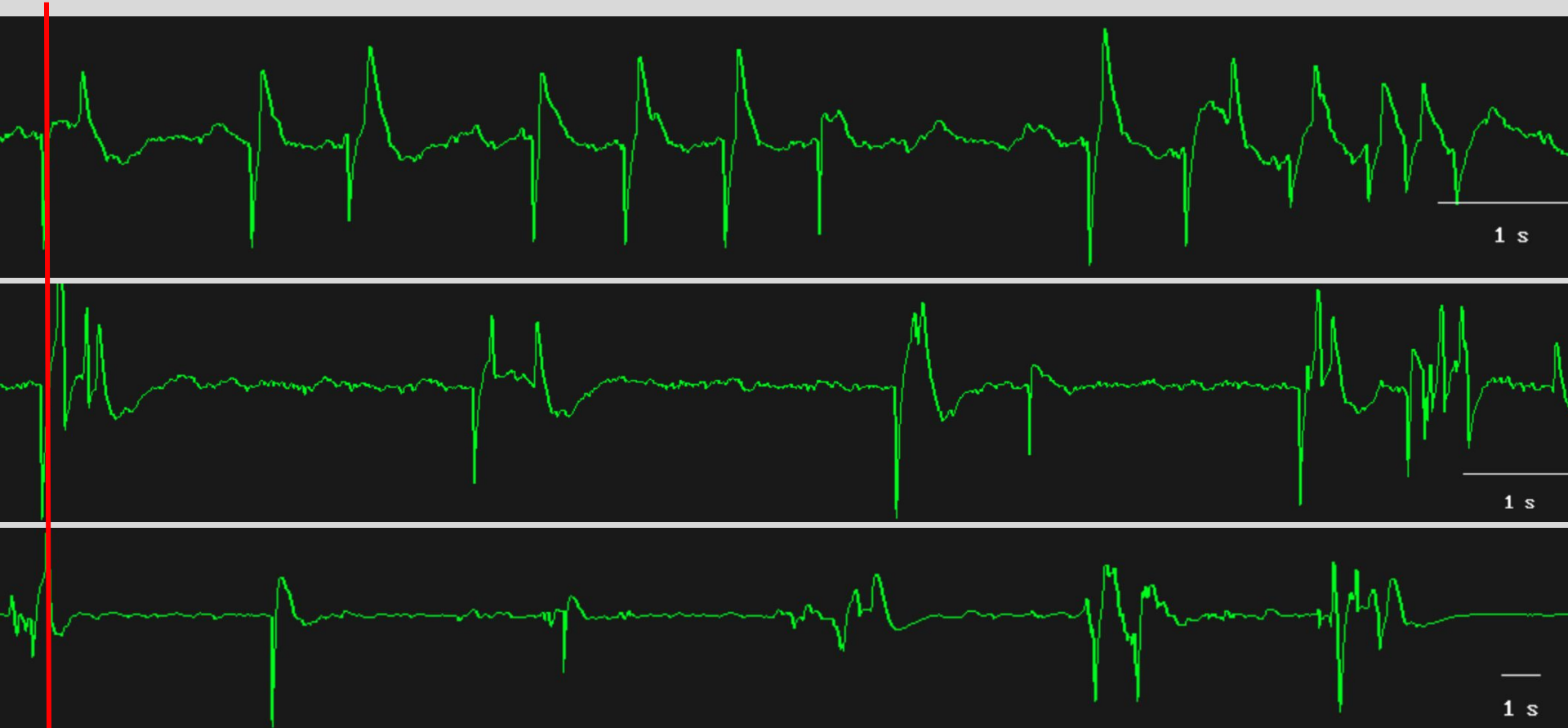
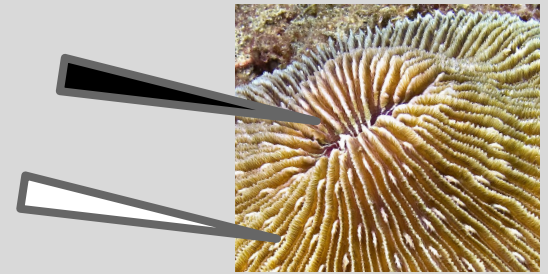
- Activity Baseline/ Mechanical Stimulation from SE
- Amplitude variation in the signal
  - APs as an all or nothing event
  - One mic, multiple speakers



# FUNGIA PERIODIC ELECTRICAL STIMULATION

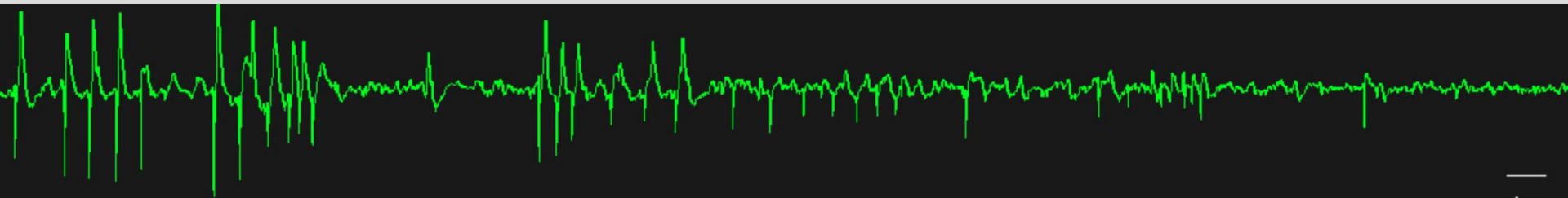
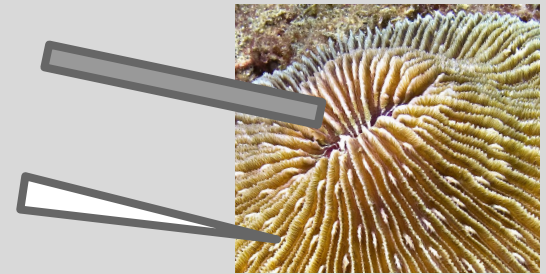
Oral Disk 1ms 9V pulse @ 1Hz, 0.33Hz, 0.2Hz

Periodicity with skips, multiple firing



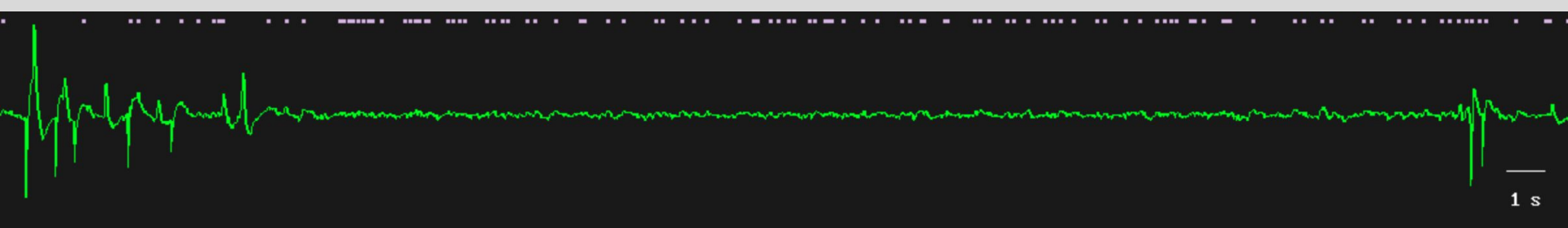
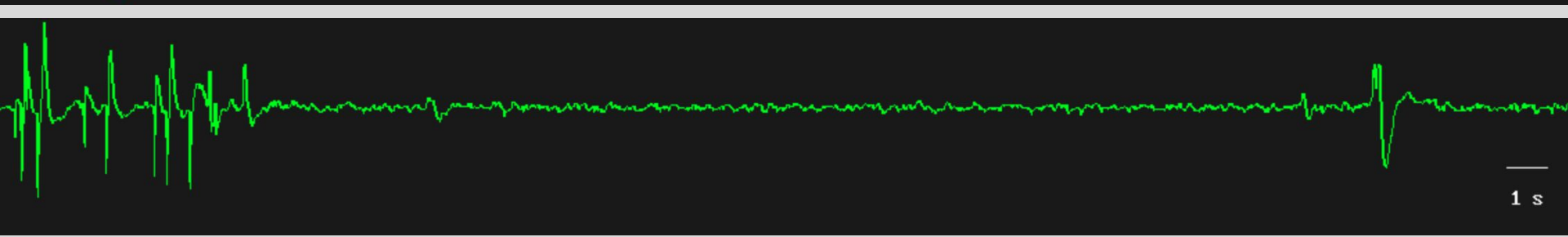
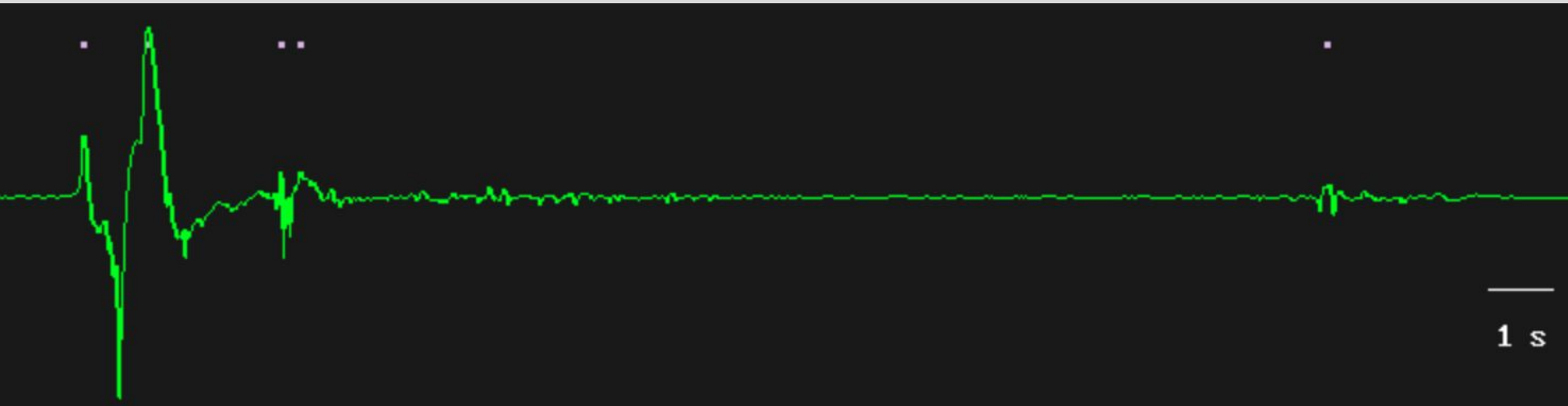
# FUNGIA ION DEPLETION

- Repeated mechanical stimulation evokes same waveform each time
  - Event duration, shape constant
- APs have decreasing amplitude
  - Ion depletion (muscles)
  - Sensory numbing (wearing a watch)



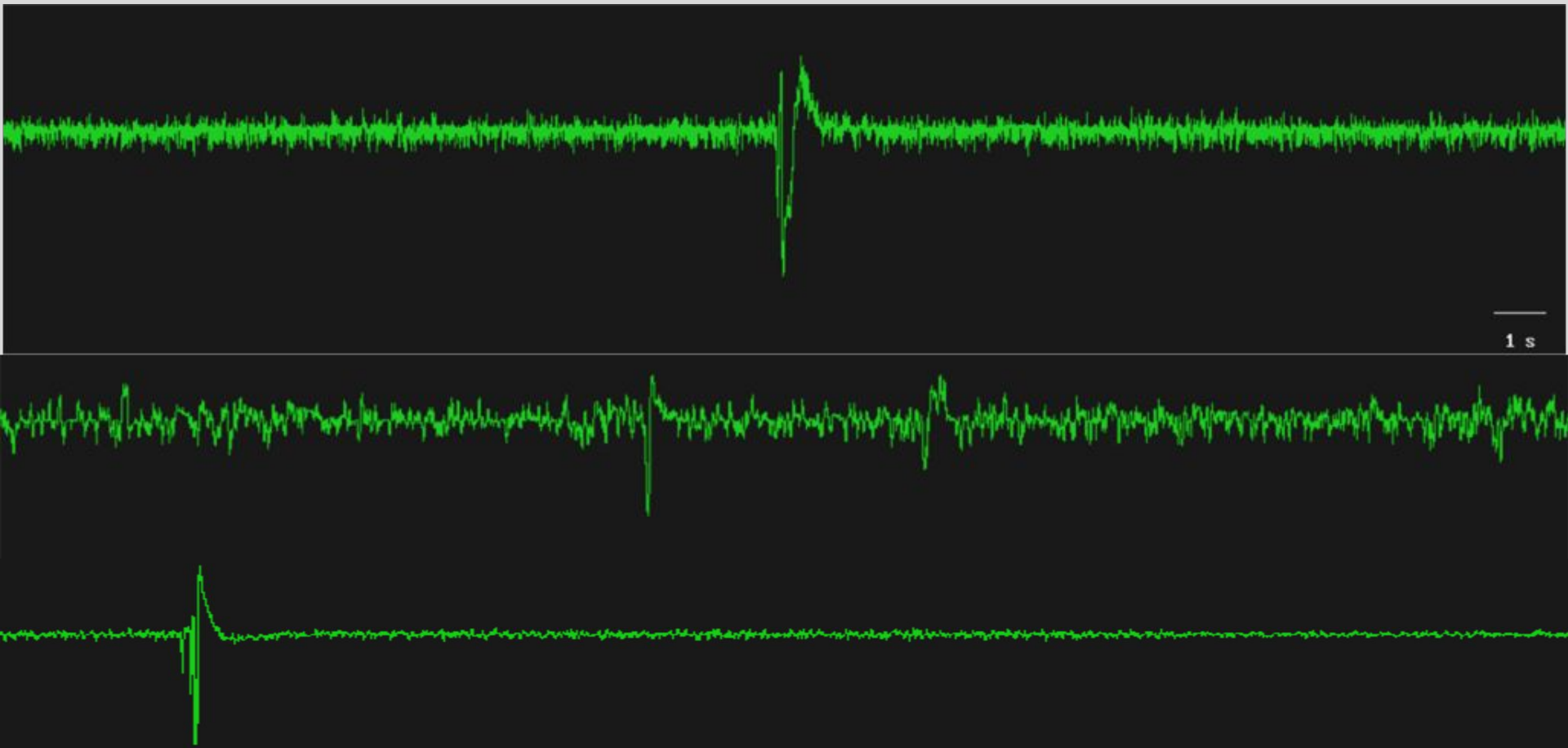
1 s

# FUNGINA PREVIOUSLY UNRECORDED SECONDARY PULSE



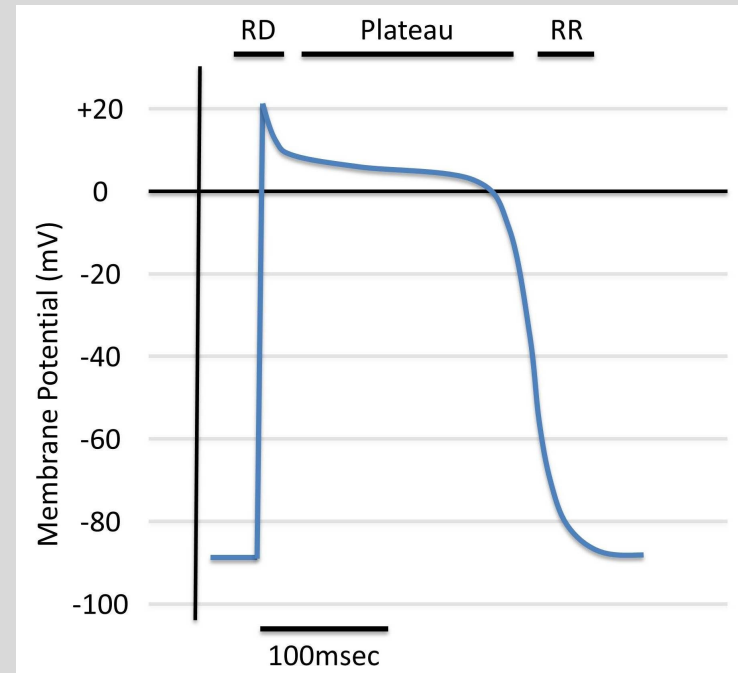
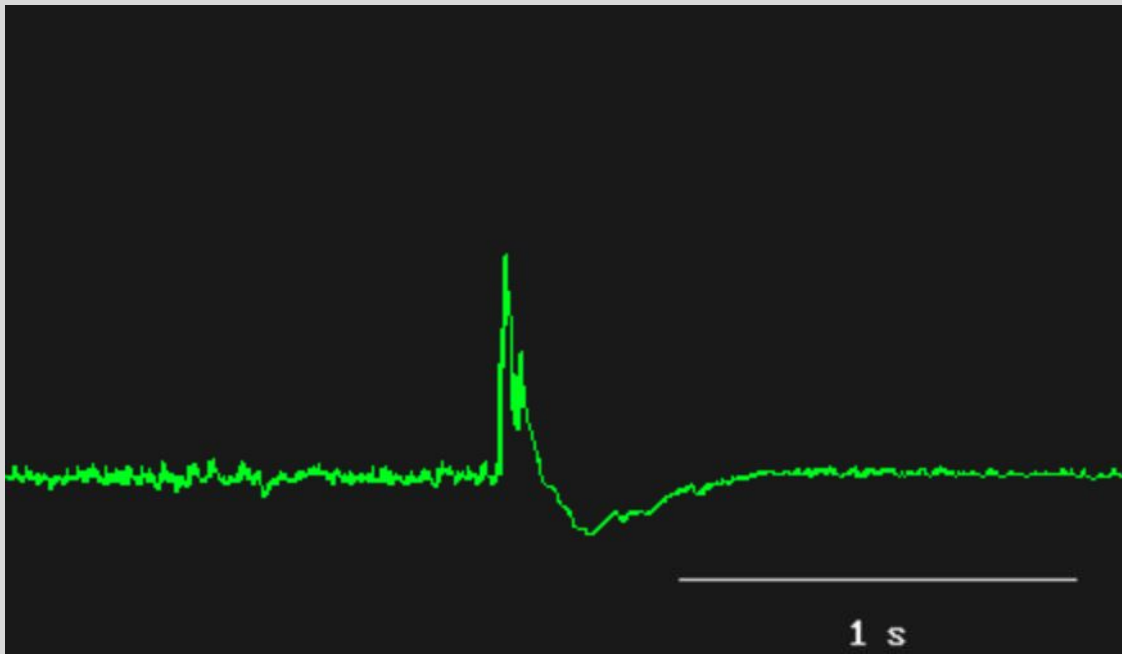
# Goniopora Action Potential

- Low responsivity, volatile seal
- 1200ms action potential - longest measured
  - Corresponds to slowest tentacle contraction



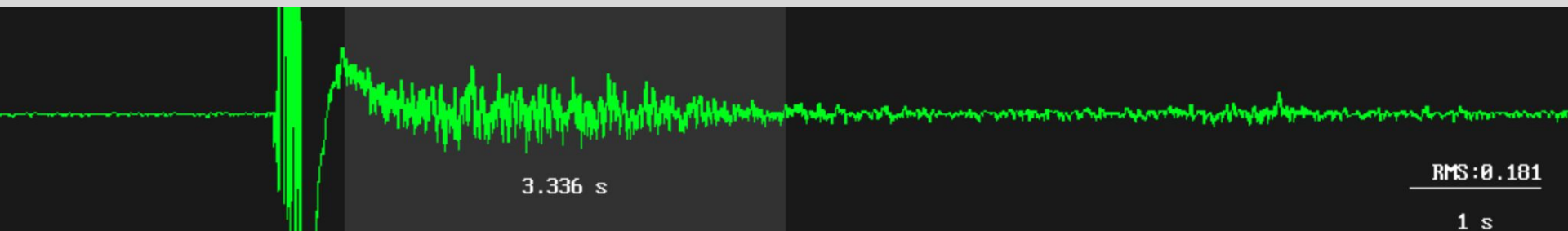
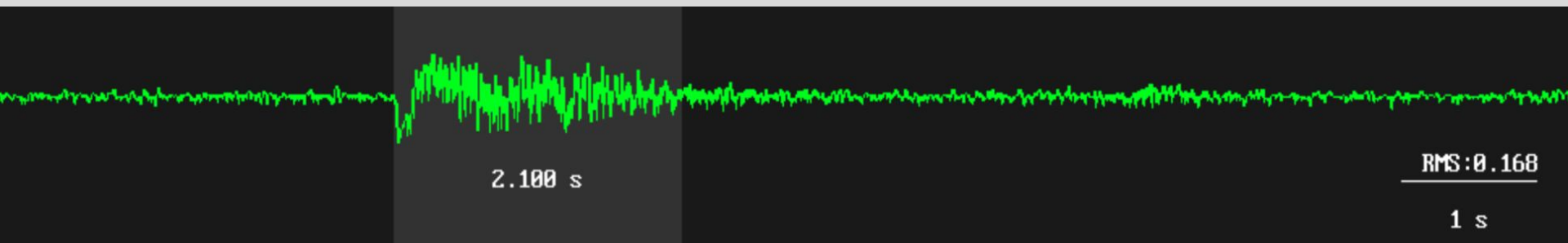
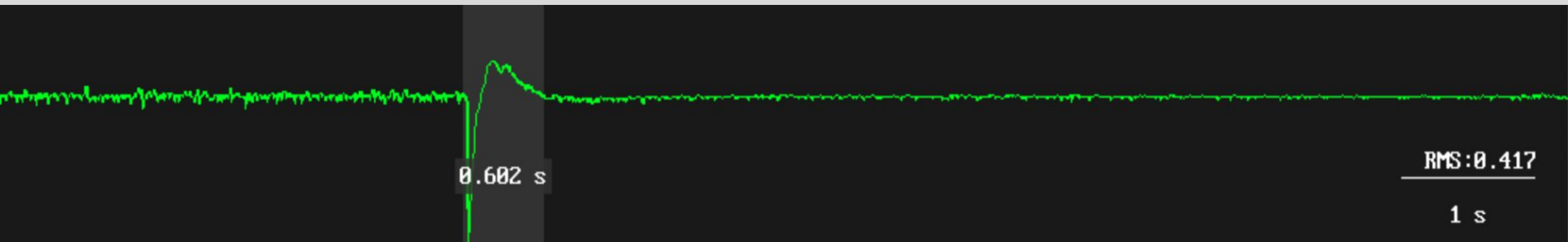
# Heteroxenia Action Potential First Trace (Passive Waveform)

- Plateau feature suggests cardiomyocyte AP similar (potentially periodicity artifact)
- >1s duration - periodicity timescale (not SSc/SSo)
  - Unusually slow > suggestive of relation to tentacle contraction



# Heteroxenia - Three Action Potential Waveform

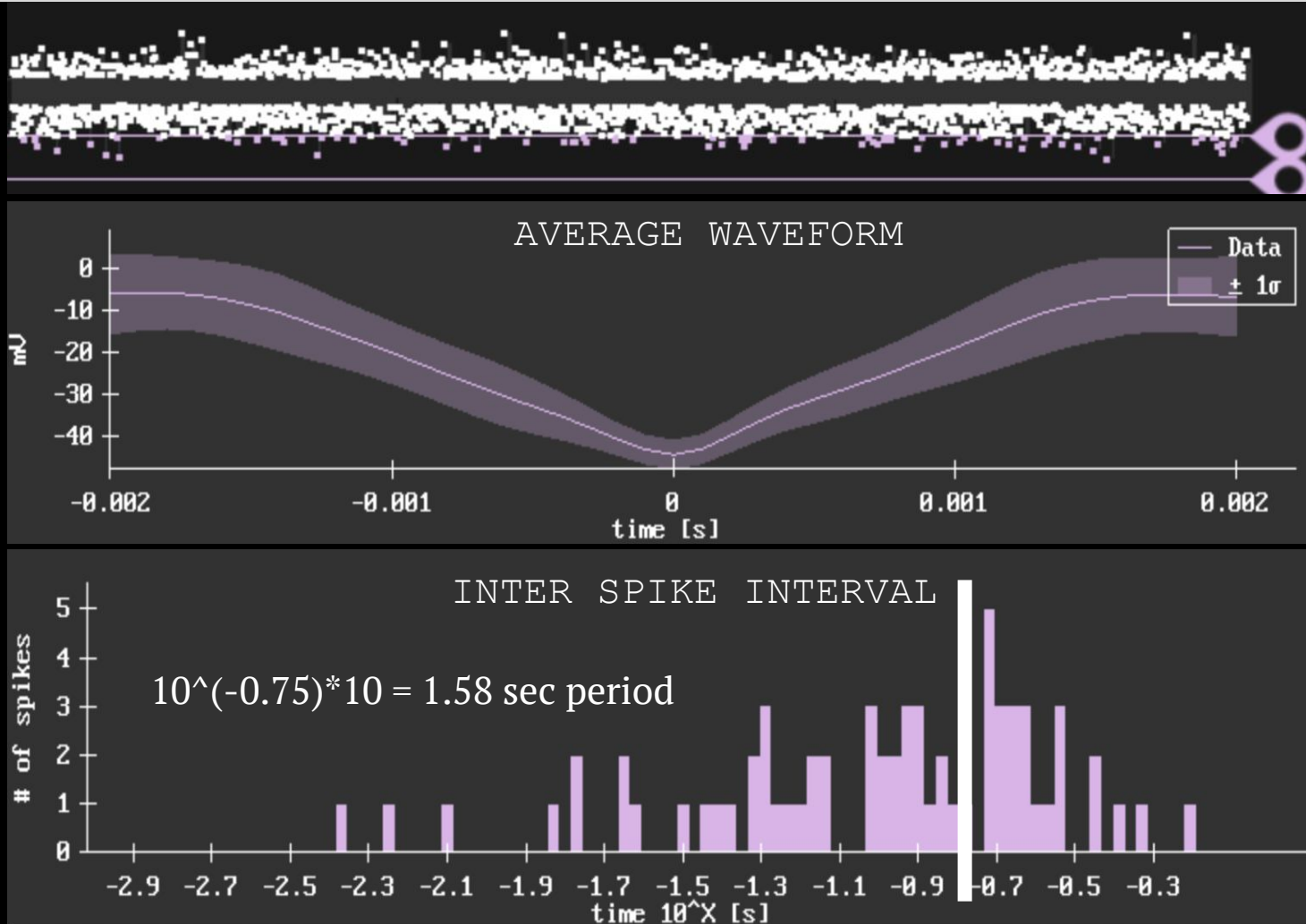
- Similarity to SSo, SSc in McFarlane 1975
- Not present without stimulation--sensory burst/cascade



# HETEROXENIA PERIODICITY ABOVE THE NOISE



Preliminary indication for neurophysiological origin of 40 BMP (T = ~1.5s)

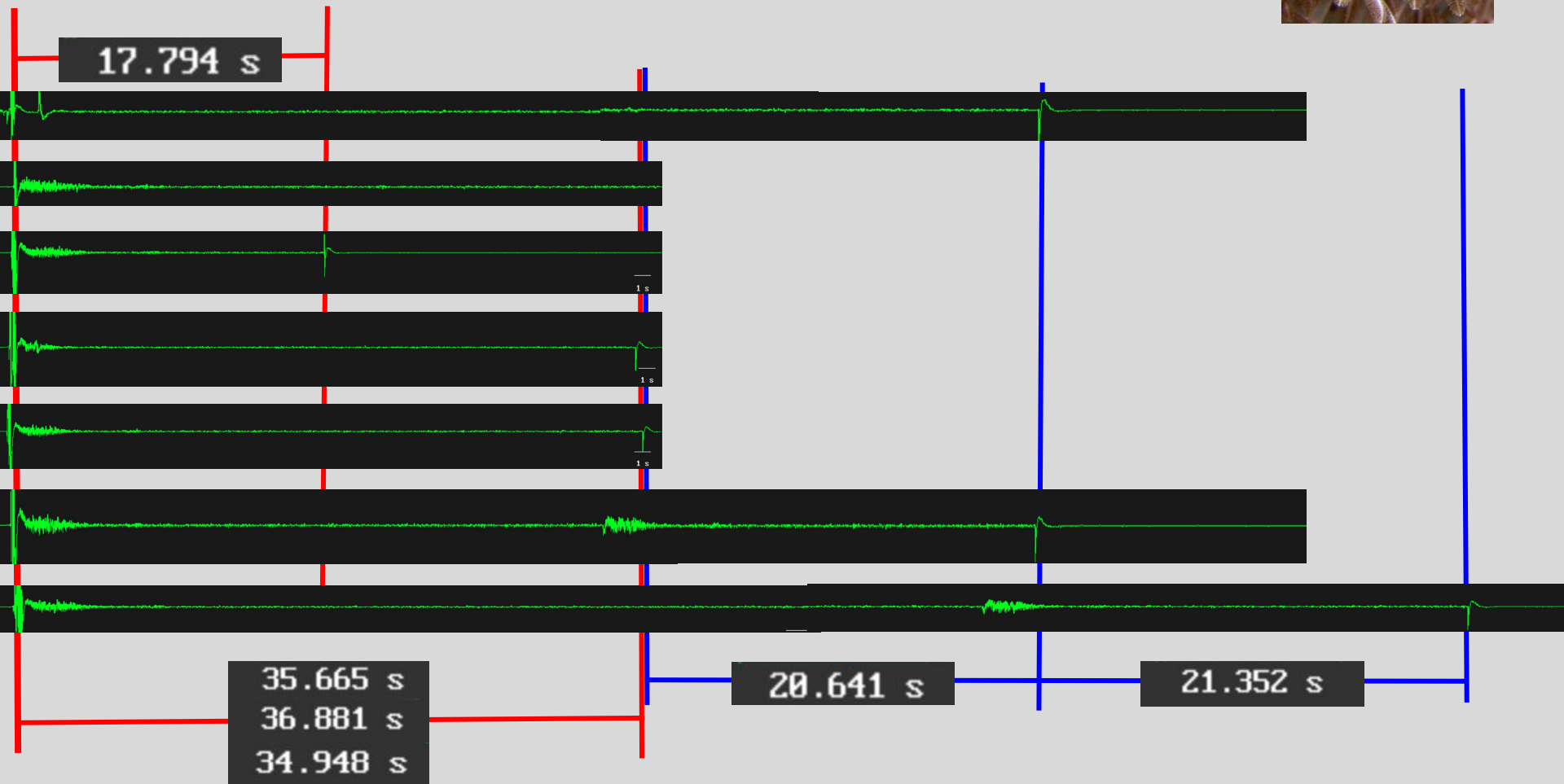


# Inhibition Periods Controlled by APs

Recording and stimulating at the same pulse (1ms 9V)

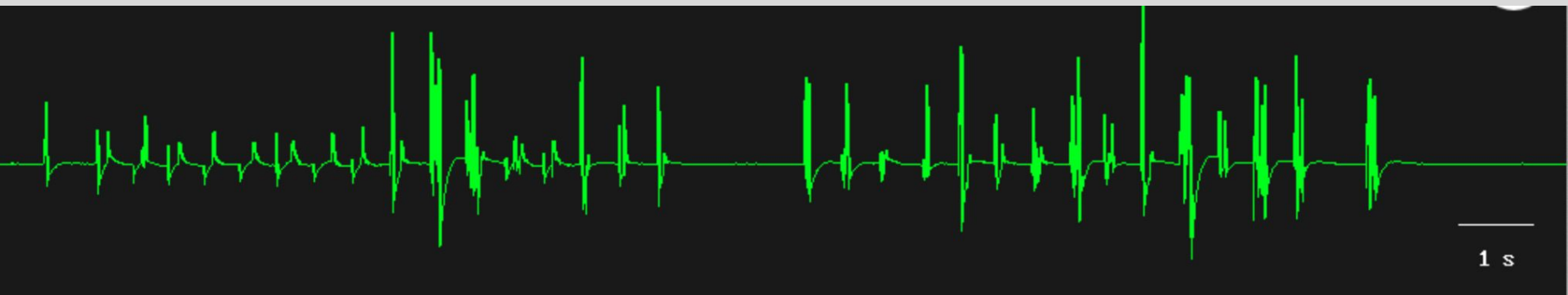
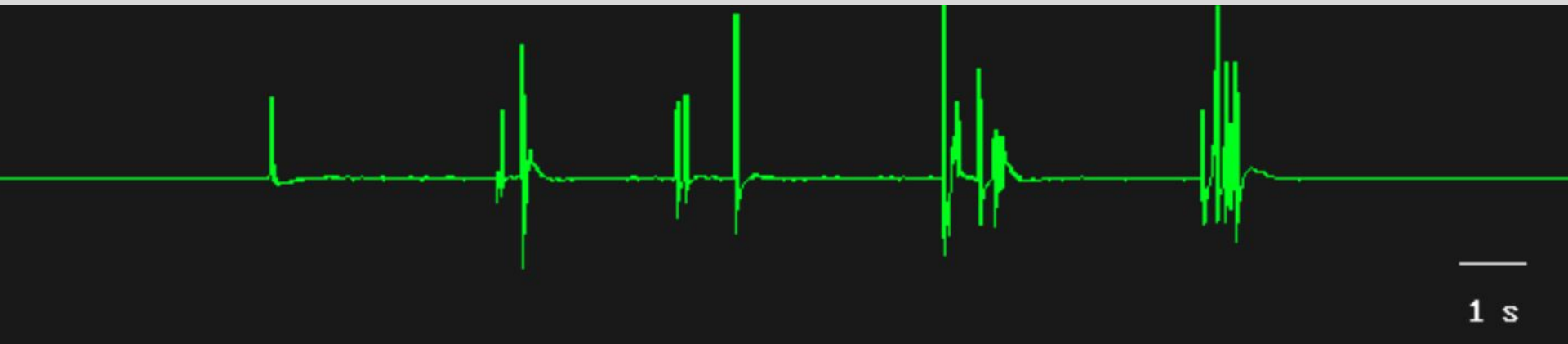
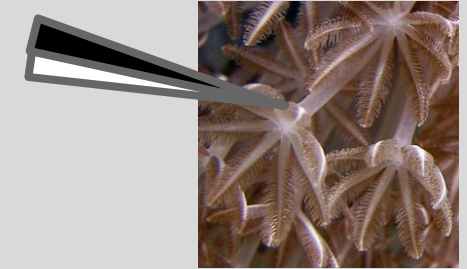
Musculature contraction inhibitory action potential & burst event

Inhibition matches known “half minute” contraction duration



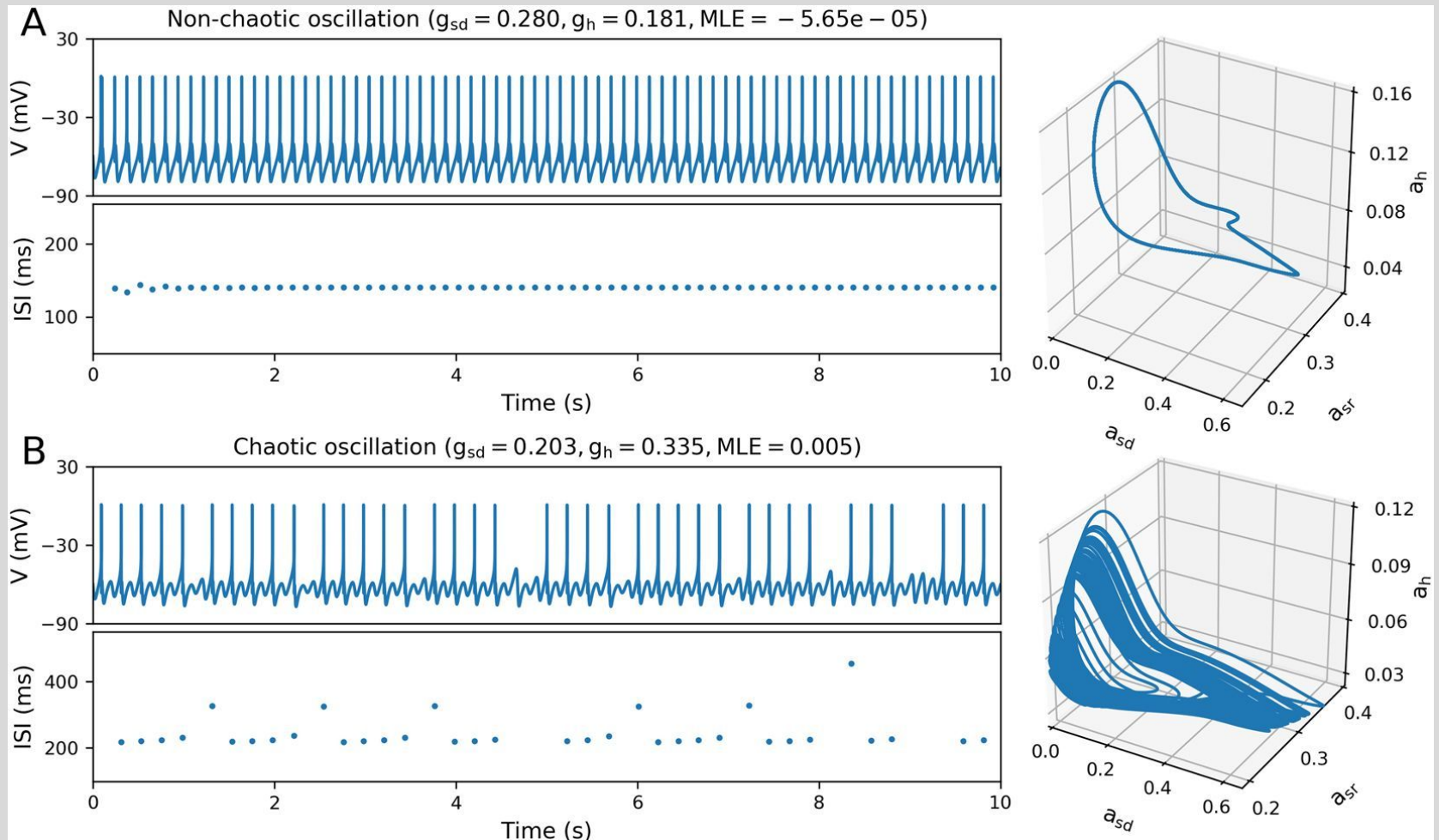
# SPONTANEOUS SPIKING DURING VOLTAGE STEP

- 9V constant potential difference applied
- periodicity with skips, multiple firing



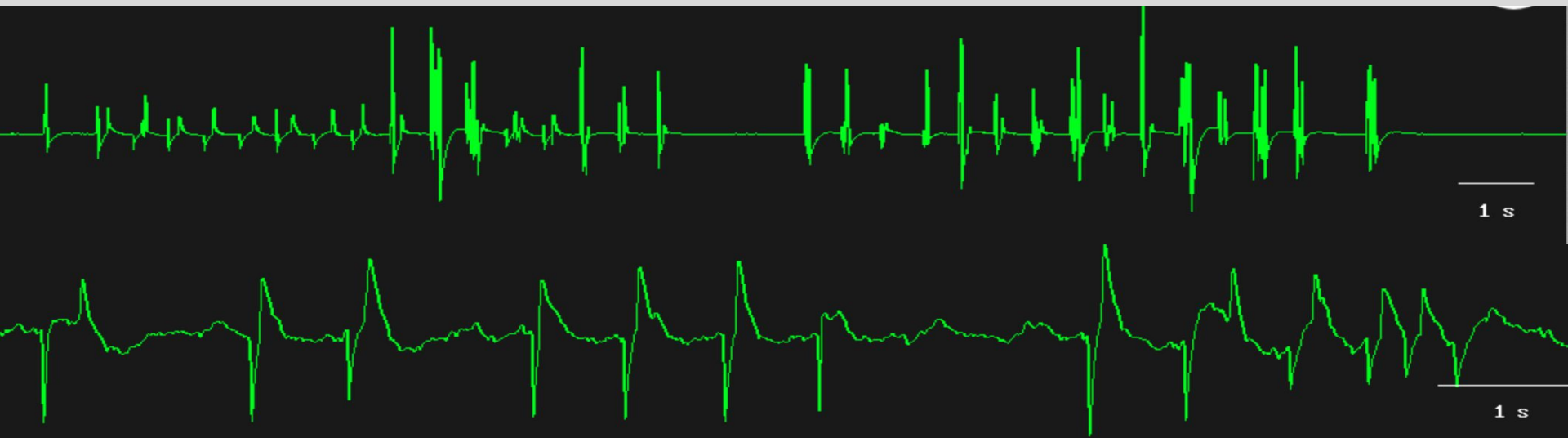
# SIMILARITY TO CHAOS!

## Distinctly non Hodgkin Huxley doubling behavior



# Conclusion

- First recorded action potentials of three coral species
  - Action potential detection characteristic of multiple systems in higher organisms
- Periodicity extant
- Chaotic behavior extant
  - Hints at period doubling



# FUTURE WORK

- **\*\*\*Further heteroxenia chaos/period doubling experiments**
- Selectively iron deficient solution
- Further methylene blue dying
  - Map conductivity and identify AP location
- **\*\*\*Patch clamp experiments**

