Evolution of Neural Excitability
5/01/13

Arguments for Evolution
1. Biogeography- similar animals in same regions
2. Fossil Record- older forms in older rocks, transitional fossils
3. Classification- organisms organized in nested patterns
4. Comparative Anatomy- “our inner fish”
5. Recent Evolution- Bacteria, Birds, Fish
6. Genetics- Shared important genes- humans 47% genetic similarity with fruit fly; 99% with chimpanzees

“Never the less, all living things are about the same” C. Darwin

Announcements:
Final presentations: Monday, May 13, 9:00 to 11:30 AM
Location: TBA, ~ 10 min power point group presentation
30% Final Paper (25%) and Class Presentation (5%)
Send in final paper draft
paper due Monday, May 13 by midnight
Individual papers, but collaboration encouraged
Excitability mechanisms have changed little in the half-billion years since the chordates, mollusks and arthropods last had a common ancestor.

Early Beginnings of Behavior

Where do we see behavior that might require a nervous system?
Sponges! 

Sponges can control direction and speed of water flow 

3mm/s “conduction” 
Blocked by Ca2+ channel blockers 

Sponges show that it is possible to be a multicellular animal responding, behaving and maintaining a well regulated body form without having a nervous system of any apparent kind! 

Sponges (and plants) show that multicellularity and coordinated behavior is not linked to having a nervous system! 

What happened next???

The early evolution of distinct conducting and contractile tissues allowed the rapid and coordinated movements that most animals make. 

Where do we see this?

A PSEUDOCELLM TISSUE OF LIFE
Early nervous systems

Coordinated “swimming”

Shell mounting

Clone Wars
Chideria: Starting point for neural evolution.
1. evolution of axons (giant axons),
2. chemical and electrical synapses,
3. neuroepithelial cells and myoepithelial cells.
4. pacemaker neurons

First “brains”??

Next big event - modern NS blueprint
**Platyhelminths**

Neurons in distinct ganglia
Distinct muscle fibers
Nervous and Motor systems separated

**Platyhelminths**: Basic plan for future nervous systems laid out here. First clear brains in flatworms: Then: continuing centralization and cephalization.

**Nervous systems (and behavior) become more complex**

Abstract categorization?
Map learning

**Forebrain evolution in vertebrates**

Lamprey
Cerebrum
Reticulum
Corpora mammillaria

Honorary Verts in UK
Nervous systems have great differences in the degrees of complexity and organization.

The ionic currents and mechanisms underlying excitability and synaptic communication are very similar across diverse neural organizations.

What are the requirements for excitability?

All cells have the requirements for excitability
1. Cell membrane
2. Ionic gradients (Na⁺-K⁺ ATPase), high [Na⁺]o
3. Gated permeability changes
4. Effector system responding to signals (RP or changes in [Ca^{2+}])

Neurons specialized in making electricity a messenger
Channels driving behavior

AVOIDANCE RESPONSE OF PARAMECION

Swimming Neurons!
Two Types: ICa, ICa(V)
ICa(Ca), ICa(A)
Mechano ICa
Spatial distribution of channels!!
Channels in bacteria

**Why TTX sensitive Na\(^+\) channels?????**

Ca\(^{++}\) AP = 100 μA/cm\(^2\) current density= 10μM [Ca\(^{++}\)]

Cells made an irreversible investment in Ca as an internal messenger

Bad things happen when Ca stays too high in a cell (Duchene’s Dystrophy)

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Channels in viruses???

**A Potassium Channel Protein Encoded by Chlorella Virus PBCV-1**

B. Plogge, T. S. Gazzarrini, H. Nelson, S. Cerana, J. L. Van Etten, C. Darst, D. DiFrancesco, A. Moroni, G. Thrall:

The large chlorella virus PBCV-1, which contains double-stranded DNA (dsDNA), encodes a 94-codon open reading frame (ORF) that contains a motif resembling the signature sequence of the pore domain of potassium channel proteins. Phylogenetic analyses of the encoded protein, Koc, indicate a previously unidentified type of potassium channel. The messenger RNA encoded by the ORF leads to functional expression of a potassium-selective conductance in Xenopus laevis oocytes. The channel blocks potassium and bicarbonate, but not chloride, inhibits this conductance in addition to virus plaque formation. Thus, PBCV-1 encodes the first known viral protein that functions as a potassium-selective channel and is essential in the virus life cycle.

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**Why TTX sensitive Na\(^+\) channels?????**

Ca\(^{++}\) AP = 100 μA/cm\(^2\) current density= 10μM [Ca\(^{++}\)]

Cells made an irreversible investment in Ca as an internal messenger

Greater current density for Na

Na\(^{+}\) AP = 4 mA/cm\(^2\) = 10 mM [Na\(^{+}\)]
Na⁺ channels are a specialization for making powerful currents without a flood of internal messengers.

They allow specialization of conducting tissue separate from contractile and secretory tissue.

What were the first channels?

K⁺ and/or Cl⁻ needed for osmotic balance

Or/also:

Ca²⁺ channels—response to external stimuli, control of cellular functions, including AP generation. K channels for recovery

Na channels evolved from Ca channels

Voltage-gated and transmitter receptor channels arise from gene families

Ca, K and Na channels a family

Fast ACh, Gly, GABA, 5HT3 a family

Modulatory ACh, Gly, GABA, amine receptors a family (rhodopsin too)