You reverse engineer how mammals may learn fear

- **Paper-pencil activity** to illustrate the process of 'reverse engineering the brain', one of the 14 grand challenges for the 21st century as identified by the National Academy of Engineering

- **What are we reverse engineering?** The rodent fear circuit as it learns Pavlovian fear conditioning with habituation, conditioning and extinction phases. **How is fear measured in a caged rodent?** Different levels of freezing
- Watch 1-minute video of rodent Pavlovian fear conditioning provided by Prof. Gregory J. Quirk of Univ of Puerto-Rico, San Juan

- **Did you know that fear is learned unconsciously? All living creatures have a specific circuit to learn fear …. can you sketch it?**

- To get you started, let's step back and build it up by step-by-step starting with how all living creatures may be hard-wired to learn two key biological traits. We will then provide you with some specifics related to what is known presently about the mammalian fear circuit, what is learning, etc. …and about what exactly you are supposed to sketch.

MOTIVATING EXAMPLE - Background

* What are two key traits seen in all animal species?

Survival and Reproduction
We are 'hard wired' to survive and to reproduce

* How are we 'hard wired' to survive?

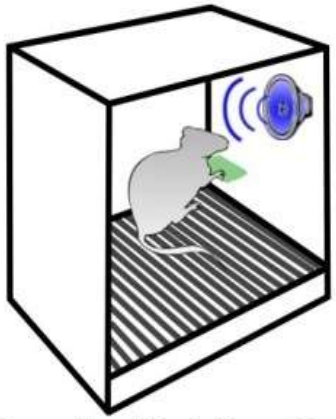
One way is to have innate fear
Another is to learn fear quickly, to avoid danger

– we are hard wired for fear. How?

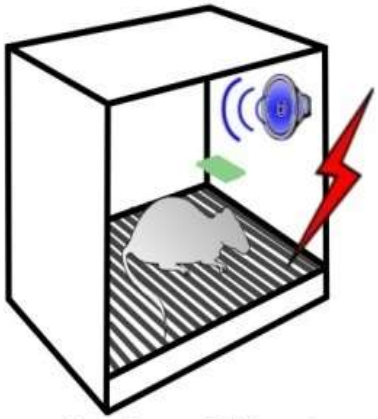
* Let's consider the case of a rat
First, how do we measure fear in a rat?

MOTIVATING EXAMPLE….contd.

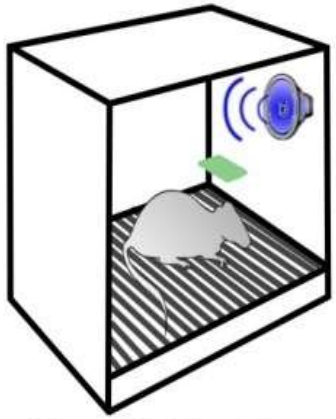
Pavlovian Fear Conditioning



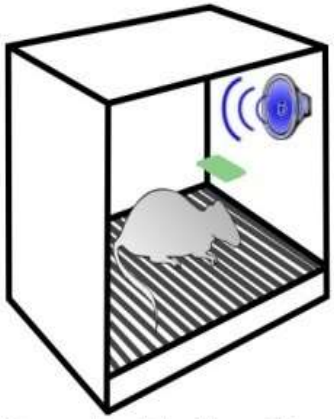
Day 1: Habituation
(5 trials, tone only)



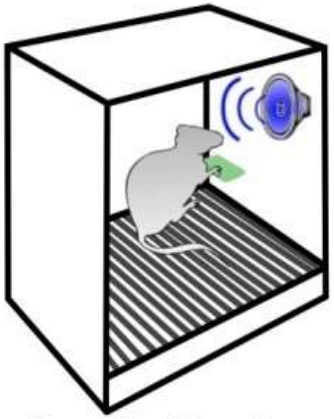
Day 1: Conditioning
(10 trials, tone + shock,
co-terminated)



Day 2: Testing
(5 trials of early-extinction,
tone only)



Day 2: Extinction
(20 trials, tone only)



Day 2: Testing
(5 trials of late-extinction,
tone only)

MOTIVATING EXAMPLE….contd.

* Fear is hard wired into our brains. Can you reverse engineer the circuit?

Let's look specifically for the neurons and neural pathways

First, fear is linked to the firing of neurons in the Ce of 'amygdala'

The amygdala in rats (and humans) is also the first site for learning fear

* What does learning mean?

Synapses are strengthened. How? What math rules? Remember that the brain has to follow all 'physical laws' – all you have learned in physics, chemistry, biology, etc. These laws are expressed in math terms. Can you list some of these?

LAWS: Nernst equation, chemical reaction equation, Ohm's law, electrical transmission,…..

Also, Hebb's law (Donald O Hebb, 1948) – 'cells that fire together wire together'

Many others too…..that you will learn in biology, bio-chemistry,…

MOTIVATING EXAMPLE….back to the rat

* What is a tone and how is it perceived in the rat brain?

Cochlea – sensory neurons – thalamus – amygdala

* What is a shock and how is it perceived in the rat brain?

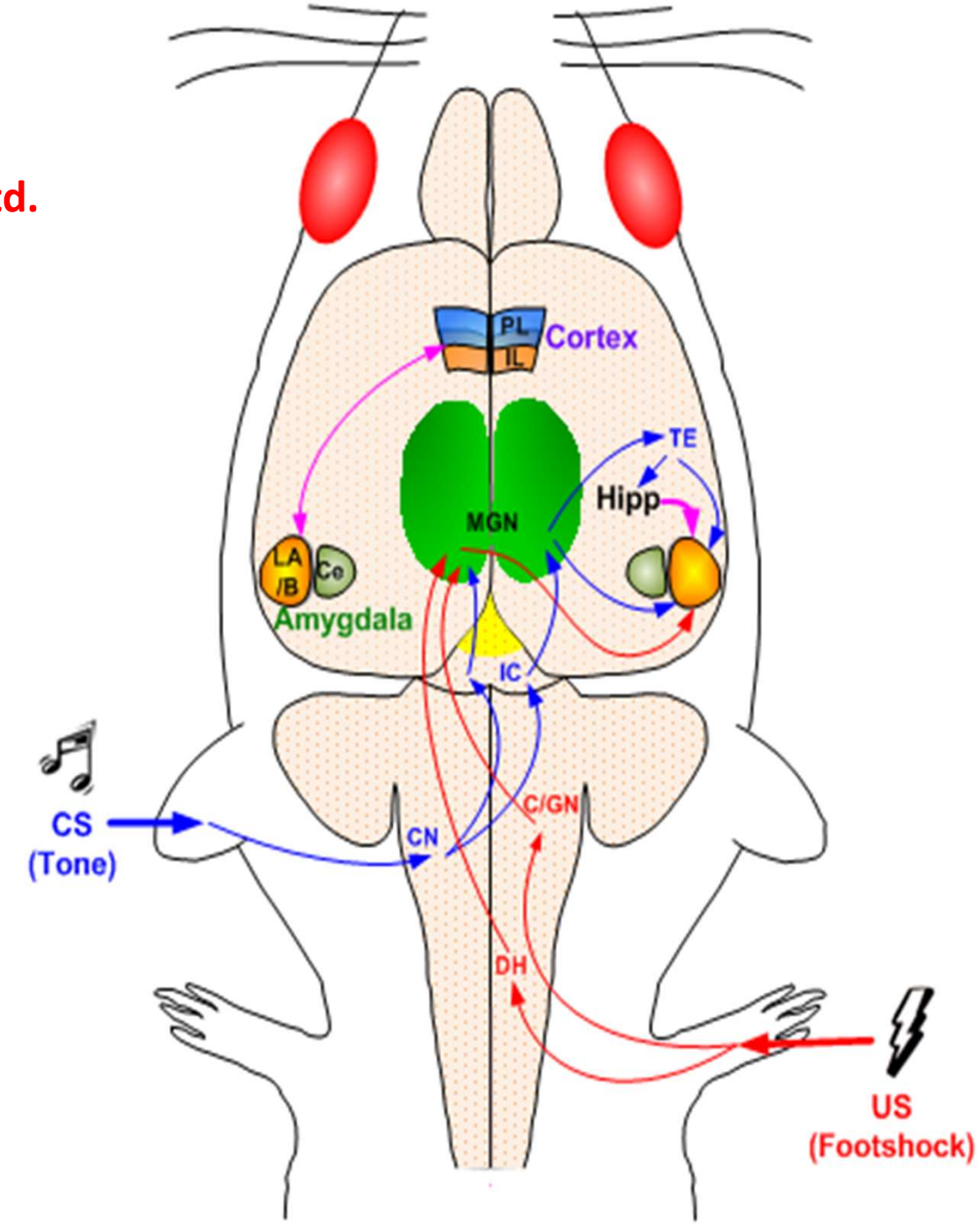
Foot – sensory neurons – thalamus – amygdala

* How are tone and shock paired in the rat brain?

Use Hebb's Law – Cells that fire together, wire together

Can you explain how this might be applied in the rat's case?

MOTIVATING EXAMPLE….contd.



MOTIVATING EXAMPLE….

Hebb Rule: Neurons that fire together, wire together!

Sketch the rat fear circuit: tone and shock pathways to amygdala, via thalamus

- View the video of the activity. Then make a sketch of the fear circuit with 5 neurons and connect them via synapses. What synapses are plastic, what are non-plastic, and why?
- BASELINE FIRING RATES: Assume the following firing rates: Assume sensory tone neuron in ear and shock neuron in the foot both fire at 12 Hz. Also, assume that neurons in the corresponding thalamic areas for the tone and pain pathways fire at 20 Hz each. And that the amygdala neuron fires at 0.5 Hz, i.e., once in two seconds.
- FEAR STATE: Assume that the amygdala neuron fires at 7 Hz after Pavlovian fear conditioning. What is your best guess on firing rates of the other 4 neurons?

List the firing rates of all 5 neurons for the following cases: BEFORE CONDITIONING – Tone only and Shock only cases, and AFTER CONDITONIING – Tone only case (no need for shock only case). Then explain how Hebb's law causes certain synapses (which ones?) to grow. Provide two sketches, one prior to conditioning and one after conditioning.