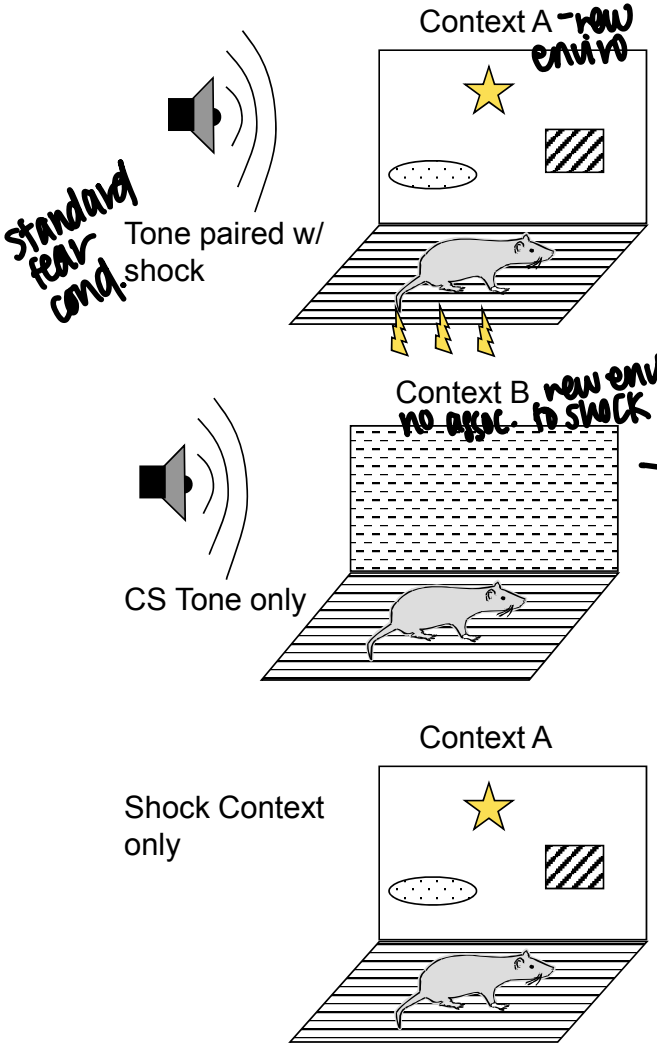
Learning & Memory (Ch.17) III

- The hippocampus and contextual memory
- A theory of how the hippocampus mediates episodic memory
- Multiple Memory Systems in the Brain
  - Dissociations, Interactions and Cooperation Among Systems
- Synaptic Plasticity
  - Synaptic changes that may be related to long term memory
  - **Long term potentiation**: A cellular model for long term memory

learning 2 things — when I hear tone I get shock; when I'm in this enviro I get shocked

Hippocampus and Contextual Memory



standard fear cond.

new enviro

new enviro - no assoc. to shock

- **Contextual** Fear Conditioning
  - Give CS tone-shock pairings in one distinct context (cued single tone)
- Give CS tone in ***separate*** context (B) =
  - Normal rats show fear freezing
  - Hipp. lesioned rats show ***normal fear to tone***
    - Implicit/procedural learning intact
- Put rat in ***shock context (A)*** with no CS tone =
  - Normal rats show fear freezing
  - Hippocampal lesioned rats ***do not*** show contextual fear conditioning
- Hippocampus involved in remembering **relations** between contexts and what events that occurred in those contexts
  - Note: **amygdala** lesions impair fear learning about ***both*** the tone ***and*** the context

Don't need hippoc. to learn 1 tone but need it to learn more (enviro/context)

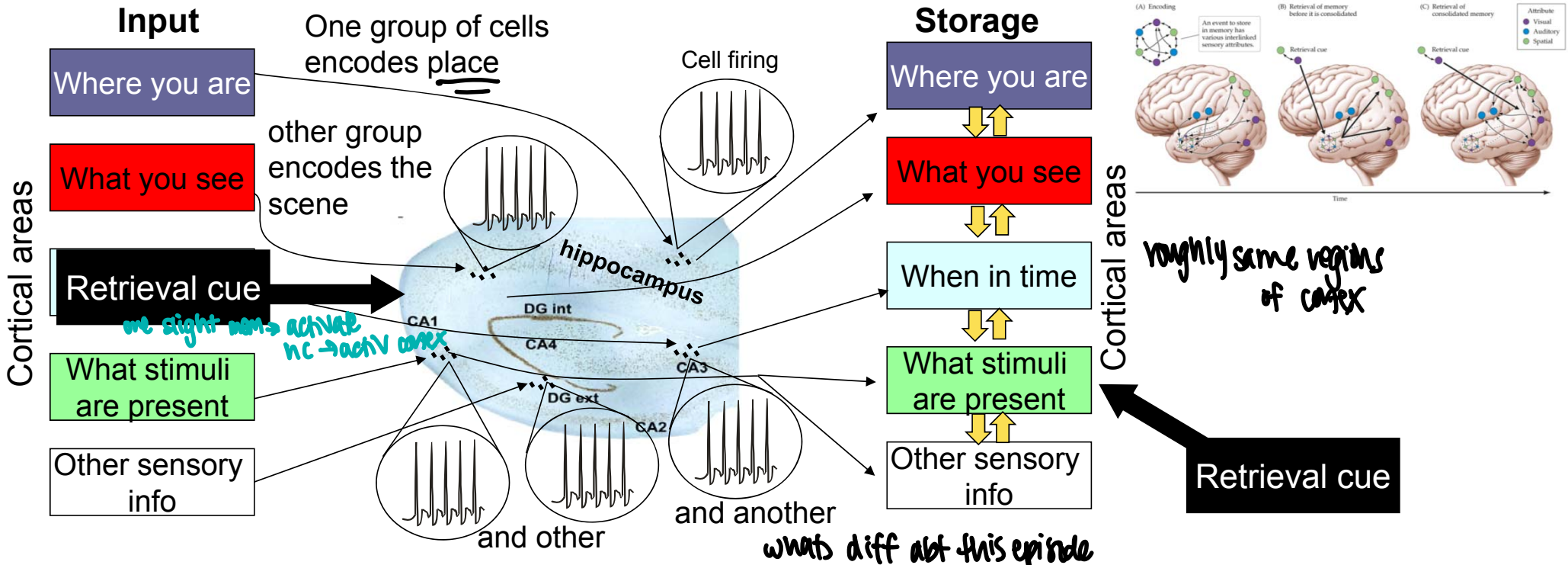
just walking around & recognizing

doesn't remember the context

important 4 both

unlikely to test on details of this

The Hippocampus and Episodic Memory



-Hippocampus records multiple bits of info about episode and relation to each other: encodes as distinct patterns of activity

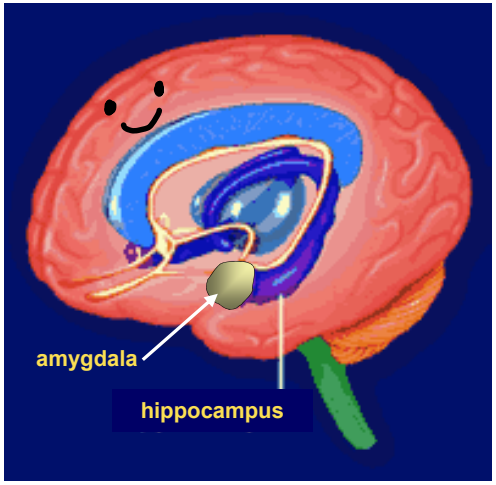
-Helps consolidate different bits of information linked to a particular memory in the same cortical regions that originally processed that aspect of the memory

-When you remember an episode, similar pattern of activation in hippocampus can activate similar regions of cortex to trigger recall

-Over time, a retrieval cue may be able to activate cortex to retrieve the memory without the hippocampus

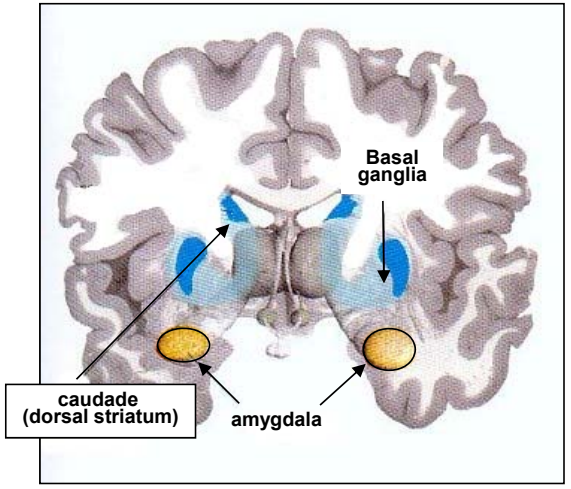
Summary of Some Anatomically-Dissociable Memory Systems

- **Hippocampus**
  - Declarative Memory (**Humans**), Spatial/ Relational Memory (**Rats**)
- **Striatum** (a.k.a. Caudate Nucleus, Basal Ganglia)
  - Procedural memory/skill/habit learning (**Humans**); Instrumental conditioning (**Rats**) if I move in this way, smth happens
- **Amygdala**
  - Pavlovian conditioning for appetitive or aversive events (**Humans and Rats)**



- Multiple brain regions can interact to regulate a particular type of memory
- However, different brain regions can participate in separate forms of learning & memory, independent of each other
  - Different learning systems can encode different aspects of the environment in parallel, i.e.: each system learning something different
- When 2 or more brain regions are independently involved in separate forms of learning (i.e.: lesions to one area impair on one task but not others) this is referred to as a ***dissociation*** of memory systems

diff types of systems designed to solve specif problem

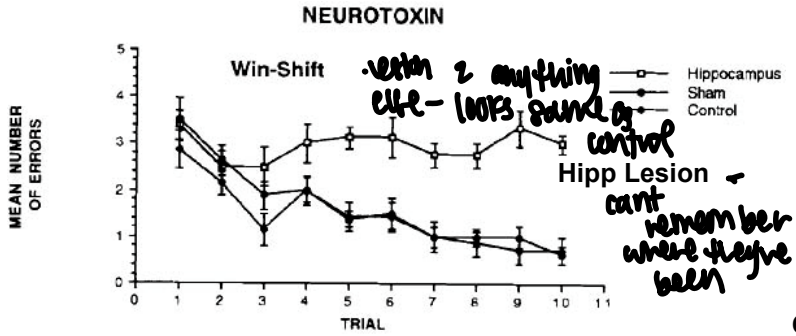


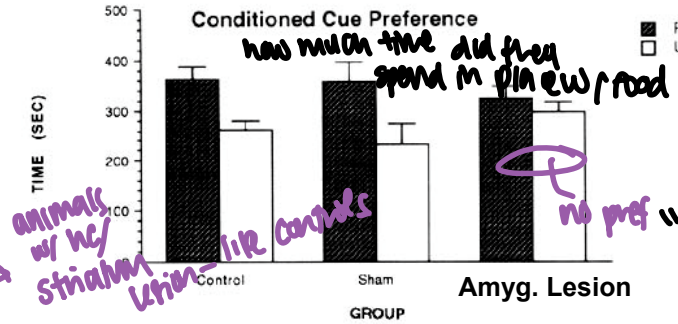
A Triple Dissociation of Memory Systems

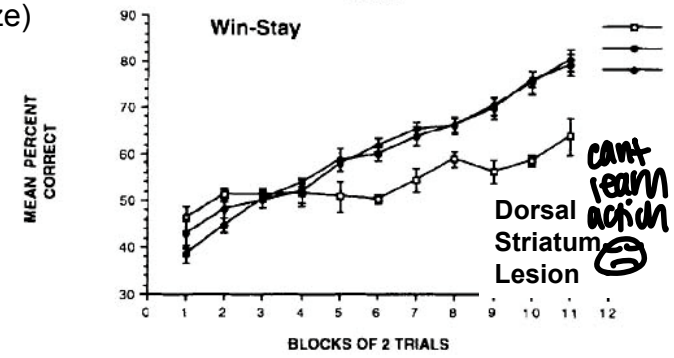
Three radial arm maze tasks:

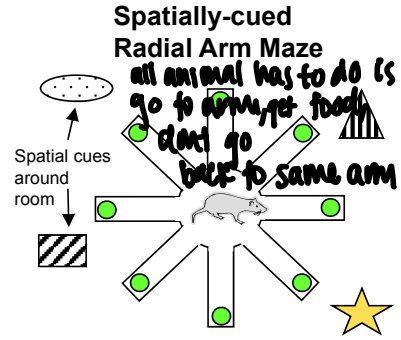
- **Spatial Radial Maze**
  - Don't go back to previously entered arm (spatial/relational learning)
  - **Hippocampal lesion = Impairment**
  - Amygdala lesion = no impairment
  - Dorsal Striatum lesion =no impairment
- **Conditioned Place Preference**
  - Go back to arm where you got food before (Pavlovian Learning)
  - Hippocampal lesion = no impairment
  - **Amygdala lesion = Impairment**
  - Dorsal Striatum lesion =no impairment
- **Locally Cued-Radial Arm Maze**
  - NO SPATIAL CUES (curtains around the maze)
  - Go to arms where a light is on (Stimulus-Response)
    - Once rat eats food from arm, light turns off
  - Hippocampal lesion = no impairment
  - Amygdala lesion = no impairment
  - **Dorsal Striatum lesion =Impairment**

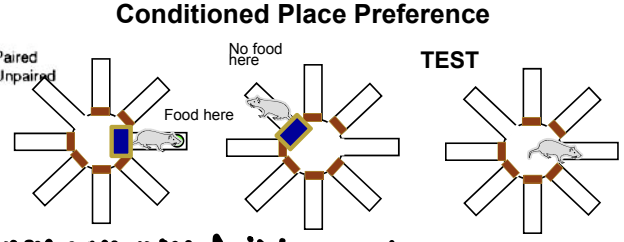
McDonald and White (1993)

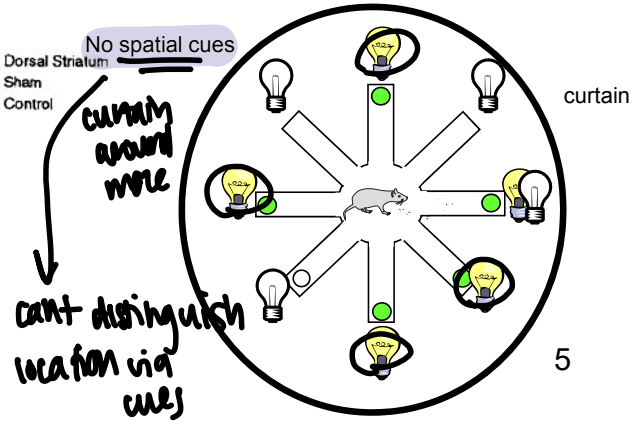












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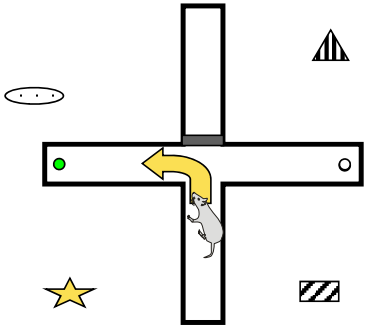
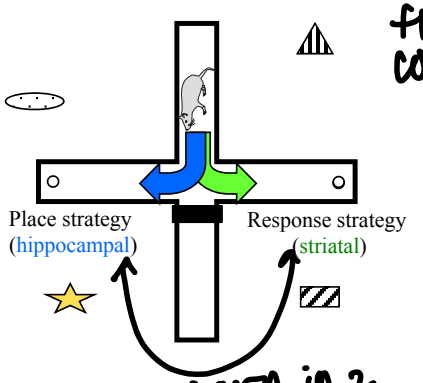
Parallel and independent processing by different memory systems

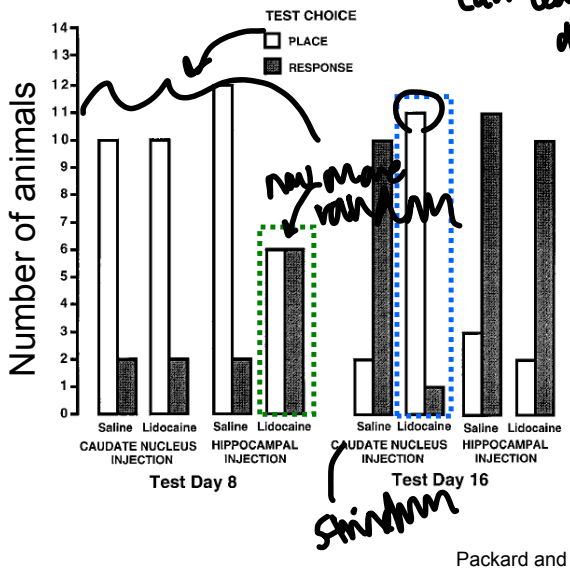
- Train to always enter one maze arm
  - Rats can use either a place (hippocampal) or response (striatal) strategy
- On probes, release from new start point, see where rats go
- **Early in training:** Most control rats use hippocampal strategy
  - **Inactivate hippocampus = many rats shift to using striatal strategy**
- **Late in training:** Most rats use striatal strategy
  - **Inactivate striatum = most rats shift to using hippocampal strategy**

➢ ***Training:*** Always turn left/west

➢ ***Probe:*** *Release from different start point*





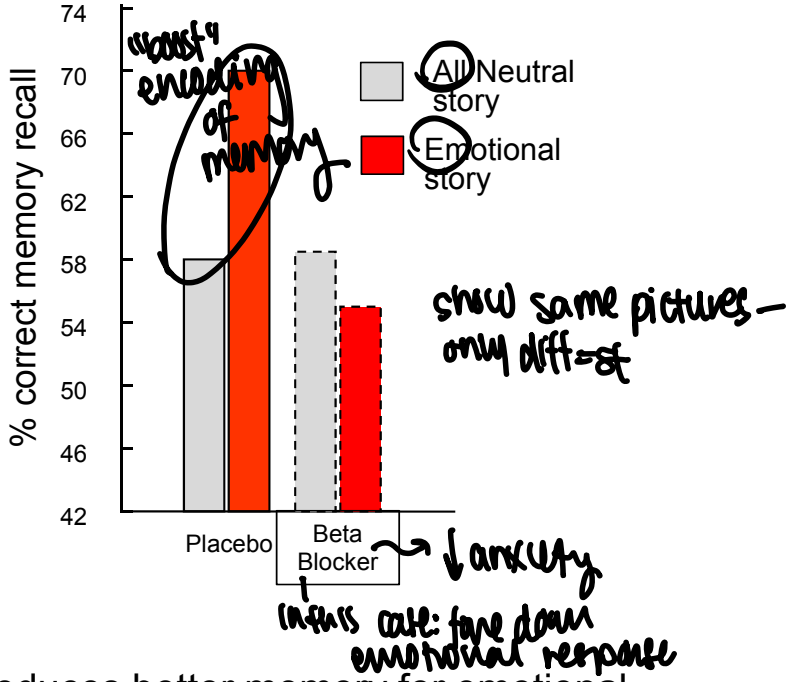


- **This shows:**
- **1) different memory systems can learn independently and in parallel to each other**
- **2) Suppression of one system allows behaviours driven by another to emerge**
- **3) Different systems learn at different rates (hippocampal = rapid, striatal = more gradual)**

Packard and McGaugh, 1996

Emotions and Memory Consolidation (I)

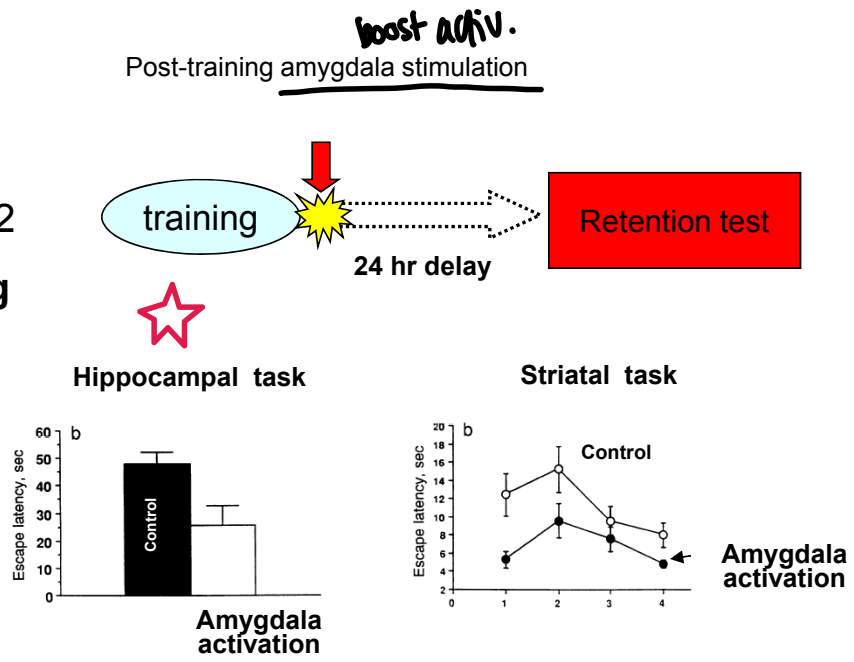
- Strong emotional states can enhance memory consolidation; may be mediated in part by noradrenaline
  - Normal subjects show better memory for "emotional" vs neutral stories attributed to the same pictures



  - **Noradrenaline Beta-receptor antagonists** = selectively reduces better memory for emotional part of story (not other parts) even though they still report emotional response to story
  - An exaggerated type of memory modulation like this may underlie Post-Traumatic Stress Disorder

Emotions and Memory Consolidation (II)

- Emotional enhancement of memory consolidation is mediated by the amygdala
  - Train rats on memory task on Day 1, test memory on Day 2
  - Stimulate amygdala with drugs **immediately post-training** on Day 1 = improved memory consolidation tested on Day 2 on tasks such as:
    - Spatial (hippocampal) learning
    - Instrumental (striatal) learning
    - Aversive (amygdala) learning

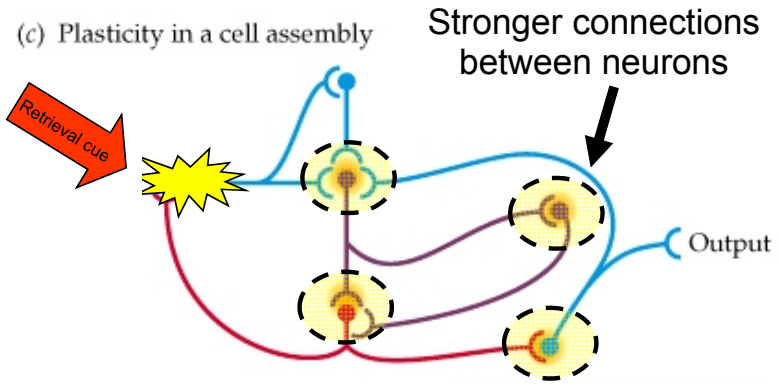


hey guys this mem is extra important!

- Amygdala can modulate consolidation of memories by other memory systems
- Emotional events activate amygdala, which in turn can enhance consolidation of memories (possibly via stress response mechanisms)

Synaptic Plasticity

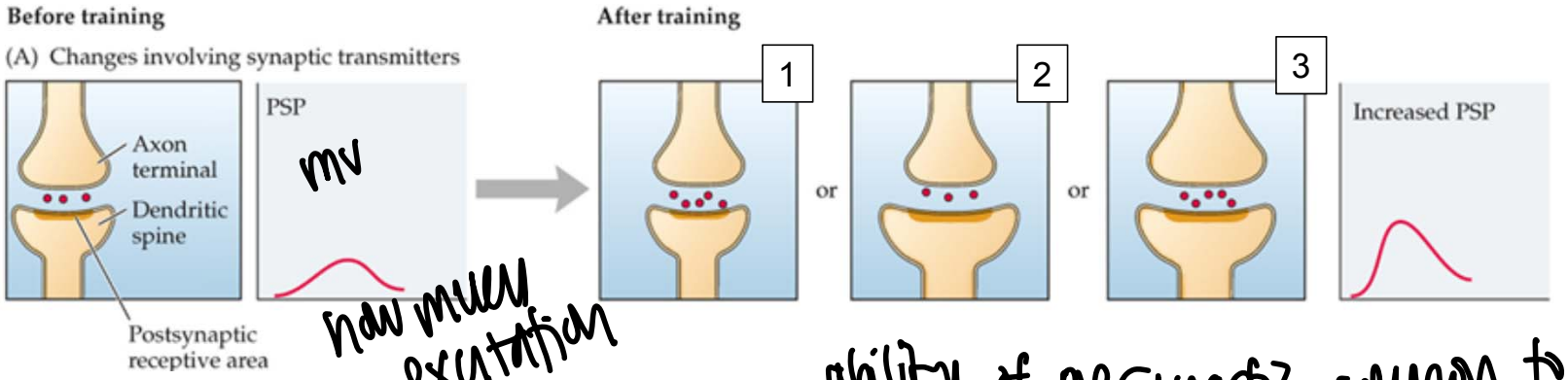
- The brain is plastic (i.e.: it changes); every time you learn/encode a memory changes occur in neurons in brain
  - Short term memory can be carried out by **cell assemblies,** groups of interconnected neurons
  - Activity driven by an input can start a chain of activation that can continue for some time (**reverberatory circuit)** that encodes a particular memory



  - If activity in circuit is **strong enough/last long enough**, long term alterations can occur at synapses to make memories more permanent (i.e. same neurons can be activated in the same pattern at later time)
  - These alterations are referred to changes in **synaptic strength**

Mechanisms of Changes in Synaptic Strength

- **Synaptic strength** are typically measured by changes in excitatory post synaptic potential (EPSP) evoked by an input
  - ↑ strength = larger EPSPs evoked in postsynaptic neuron

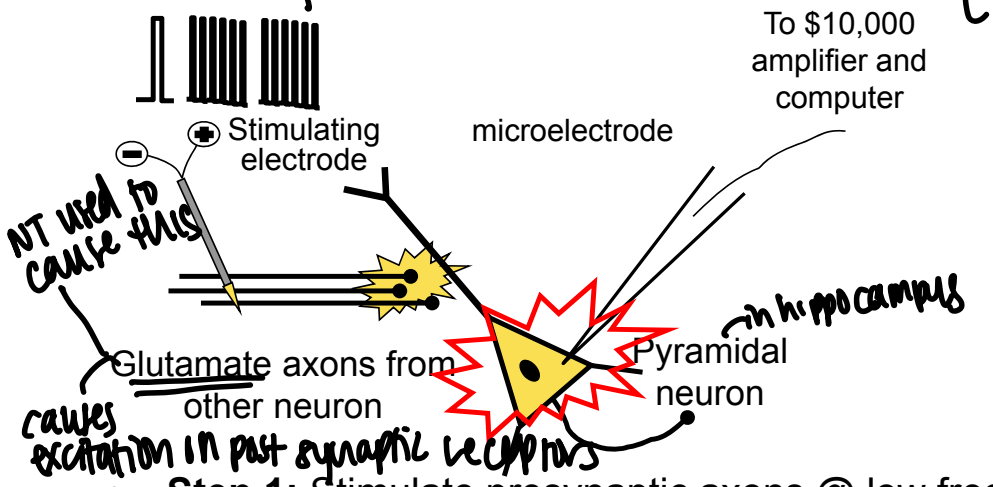


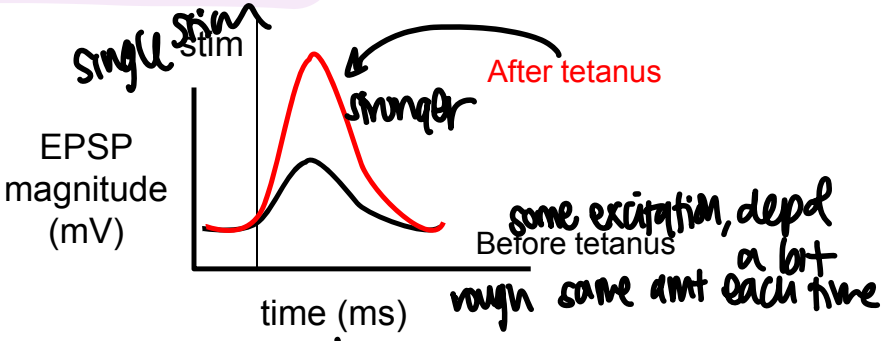
1) Increase in presynaptic transmitter release
2) Increase # of postsynaptic receptors or their sensitivity -or-
3) Both 1 and 2

Other types of physical changes in neurons can also occur (change in shape, # of dendrites etc) that can affect the way the post-synaptic neuron responds to input

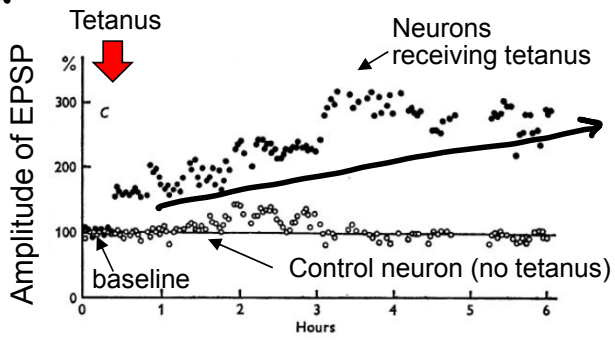
- **Note:** opposite changes can occur too, decreasing synaptic strength

Long Term Potentiation (I)





Long lasting increase



- **Step 1:** Stimulate presynaptic axons @ low frequency (1/15 sec) to get subthreshold EPSP (no action potentials), establish baseline
- **Step 2:** Stimulate axons at **high frequency** (i.e.: *tetanus*, e.g. 100 Hz) and get lots of action potentials in postsynaptic neuron
- **Step 3:** axons at low frequency again, same subthreshold current =

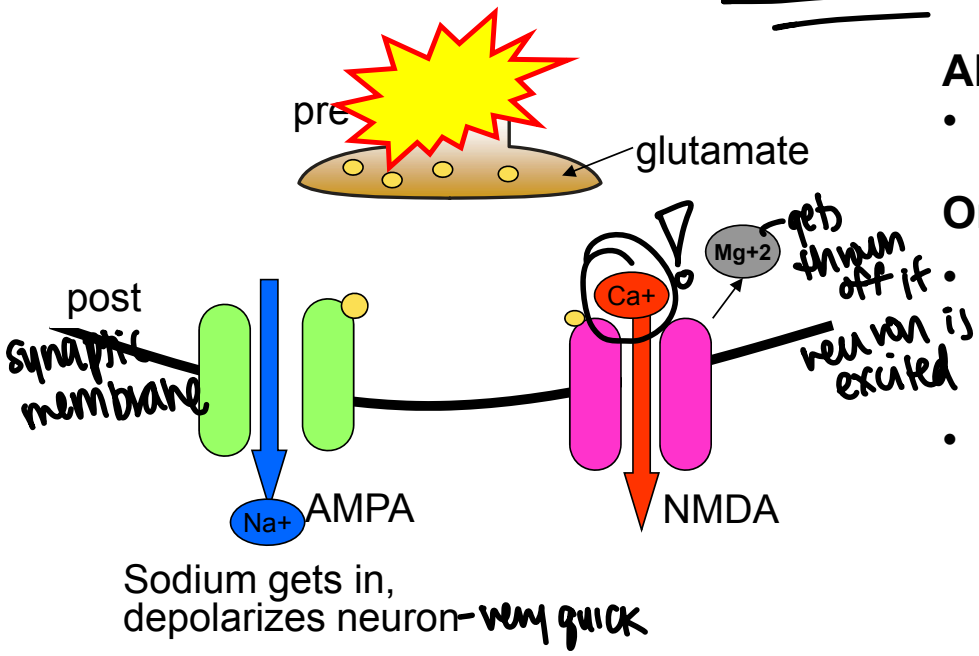
➢ **MUCH BIGGER EPSP than before**

- **Input has become stronger (potentiated), larger EPSP, more likely to evoke action potential**

he will re-explain this at the start of next class :)

Glutamate Mechanisms of LTP

- LTP can occur anywhere in the brain where there are **glutamate synapses**
  - Hippocampus, Cortex, Amygdala, Striatum etc
- Two main types of ionotropic glutamate receptors: activation



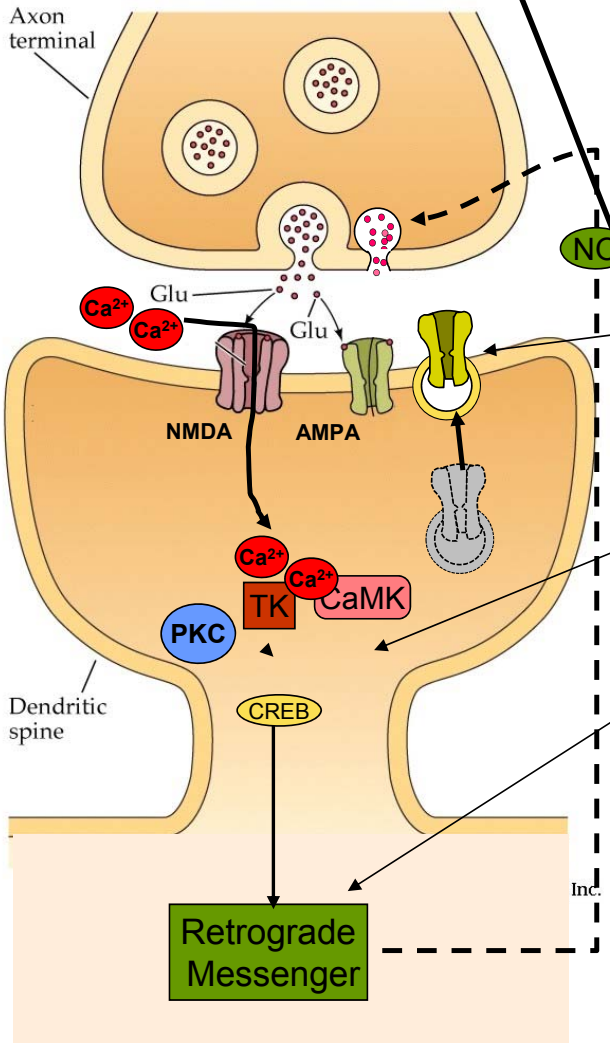
Sodium gets in, depolarizes neuron - very quick

AMPA and NMDA receptors
- Both allow Na+ to pass thru and depolarize neuron

Only NMDA receptor allows Ca2+ to get into neuron
- If neuron is hyperpolarized, NMDA receptor blocked by Mg2+ ions cannot be activated by glutamate
- AMPA receptors are not blocked; can always be activated by glutamate

- If AMPA receptors depolarize neuron enough, Mg2+ block of NMDA receptor is removed (**voltage dependent Mg2+ block**)
- Glutamate can now activate NMDA receptor, allows Ca2+ to get into cell

Cellular Mechanisms of LTP (I)



- Once Ca2+ enter cell, it activates multiple enzyme pathways (**kinases = phosphorylate other proteins)**
- Ca2+ activates **Ca**lcium-Cal**m**odulin which in turn activates other kinases
- CaM Kinase hits latent AMPA receptor (floating inside cell) and inserts in membrane = more receptors

- **P**rotein **K**inase **C** and **T**yrosine **K**inase can activate CREB = short term and long term effects
- CREB can lead to formation of retrograde messenger (molecule that goes from postsynaptic neuron to presynaptic terminal (e.g., Nitric Oxide)
  - These messengers promote more transmitter release
- ↑ synaptic strength by both pre and postsynaptic mechanisms

Cellular Mechanisms of LTP (II)

- LTP comes in two phases.
- **1st phase:** ↑ in receptors/glutamate release occur quickly (<1 hr)
  - ➢ These changes blocked by NMDA antagonists
- **2nd phase:** CREB activates **protein synthesis**, that causes longer lasting changes (>3 Hrs)
  - — Dendrite shape and size, more ion channels, more dendrites, etc
  - — These changes are processed for hours after initial memory was encoded
  - ➢ These latter of LTP phases also blocked by **protein synthesis inhibitors**
- **Both phases blocked by prevention of Ca2+ entry into the cell**
  - Ca2+ entry is localized, so only certain synapses/ dendrites on a neuron will change synaptic strength