NEURO-ETHOLOGY

LEARNING & BEHAVIOUR

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Learning

relatively permanent change in behavior as a function of training, practice or experience

excludes behavioral changes resulting from sensory adaptation or fatigue

“relatively permanent” implies a lasting alteration of nervous system structure and/or function

Two fundamental questions

1. Neural mechanisms of learning? (cellular level)

2. What is learned? (where in the brain; organizational level)

Reasons for Learning……

SIMPLE LEARNING

a. habituation
b. Pavlovian learning
c. instrumental learning
d. biological mechanisms

HIGHER ORDER COGNITION

a. declarative vs. non-declarative memory
b. spatial learning
c. clinical cases

Types of Learning

- **Non-associative**
  - **Habituation, sensitization**
  - **perceptual in nature**
  - **recognition of objects and situations**
- **Associative**
  - **Classical conditioning**
    - **S-S learning**
  - **Operant Conditioning**
    - **R-S learning**

Contd….

- acquisition of new motor behaviors
- acquisition of associations between new stimuli and existing behaviors
- acquisition of new associations between familiar stimuli and existing responses

Non-associative learning

habituation

- repeated exposure to a stimulus results in reduced responding to that stimulus
- generally neutral, non-noxious stimuli

sensitization

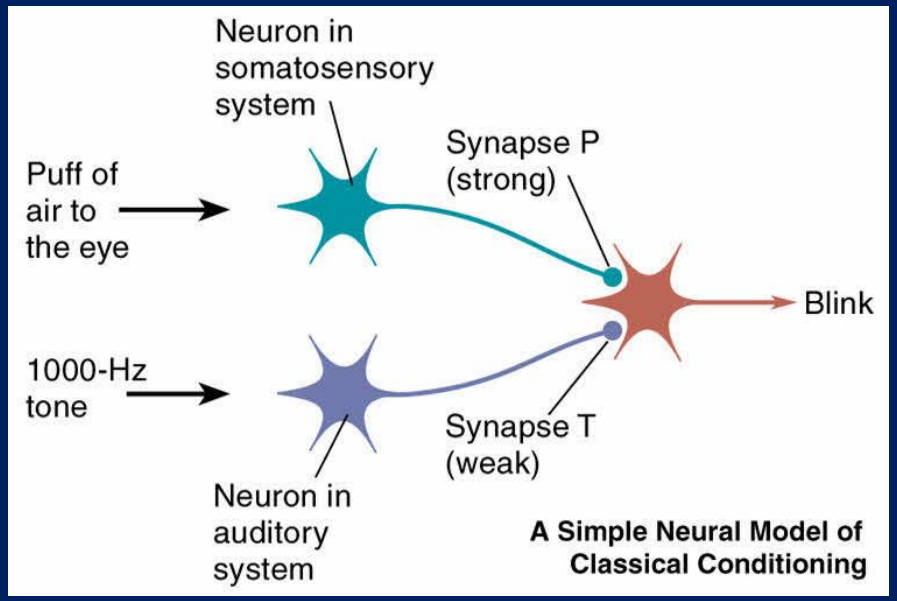
- repeated exposure to a stimulus results in increased responding to that stimulus
- generally biologically relevant, strong hedonic valence (+ or -)
- also refers to augmentation of responding following exposure to a second stimulus

Associative learning

classical conditioning; Pavlovian conditioning; respondent conditioning

•A neutral stimulus is paired with a stimulus that reliably elicits a response. Conditioning is indicated when the previously neutral stimulus elicits a response.

CS→US→UR



– Classical conditioning

- Unconditioned stimulus (US)
- Unconditioned response (UR)
- Conditioned stimulus (CS)
- Conditioned response (CR)

Associative learning

operant conditioning; instrumental learning

- repeated presentation of a stimulus after emission of a designated response increases (reinforces) or decreases (punishes) the likelihood of that response

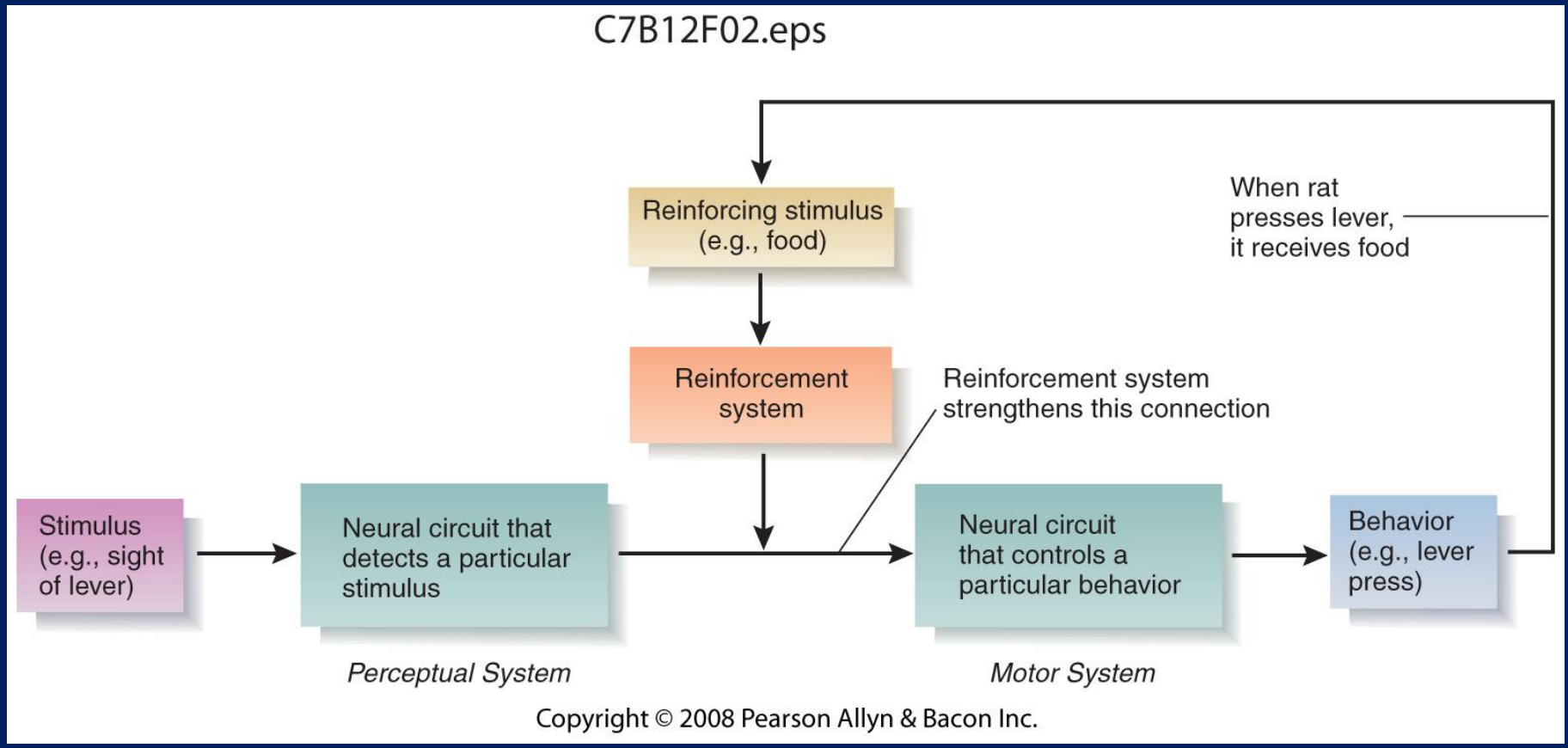
CR→US→UR

Modeling, latent learning

Usually defined as learning in the absence of a reinforcer (US or conditioned reinforcer such as money)

Problem: One can always posit a "hidden reinforcer," a negative hypothesis that cannot be disproven. The burden of proof therefore falls on those to make hidden reinforcers evident.

The existence of mirror neurons seems to provide a neurobiological basis for imitative learning.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Reinforcing stimulus (e.g., food)
When rat presses lever, it receives food
Reinforcement system
Reinforcement system strengthens this connection
Stimulus (e.g., sight of lever)
Neural circuit that detects a particular stimulus
Neural circuit that controls a particular behavior
Behavior (e.g., lever press)
Perceptual System
Motor System
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- Declarative memory
  - Memory that can be verbally expressed, such as memory for events in a person's past.

- Nondeclarative memory
  - Memory whose formation does not depend on the hippocampal formation; a collective term for perceptual, stimulus-response, and motor memory.

- Episodic memories
  - Memory of a collection of perceptions of events organized in time and identified by a particular context.
- Semantic memories
  - A memory of facts and general information.

– Spatial memories

- Functional imaging studies have shown that the right hippocampal formation becomes active when a person is remembering or performing a navigational task.

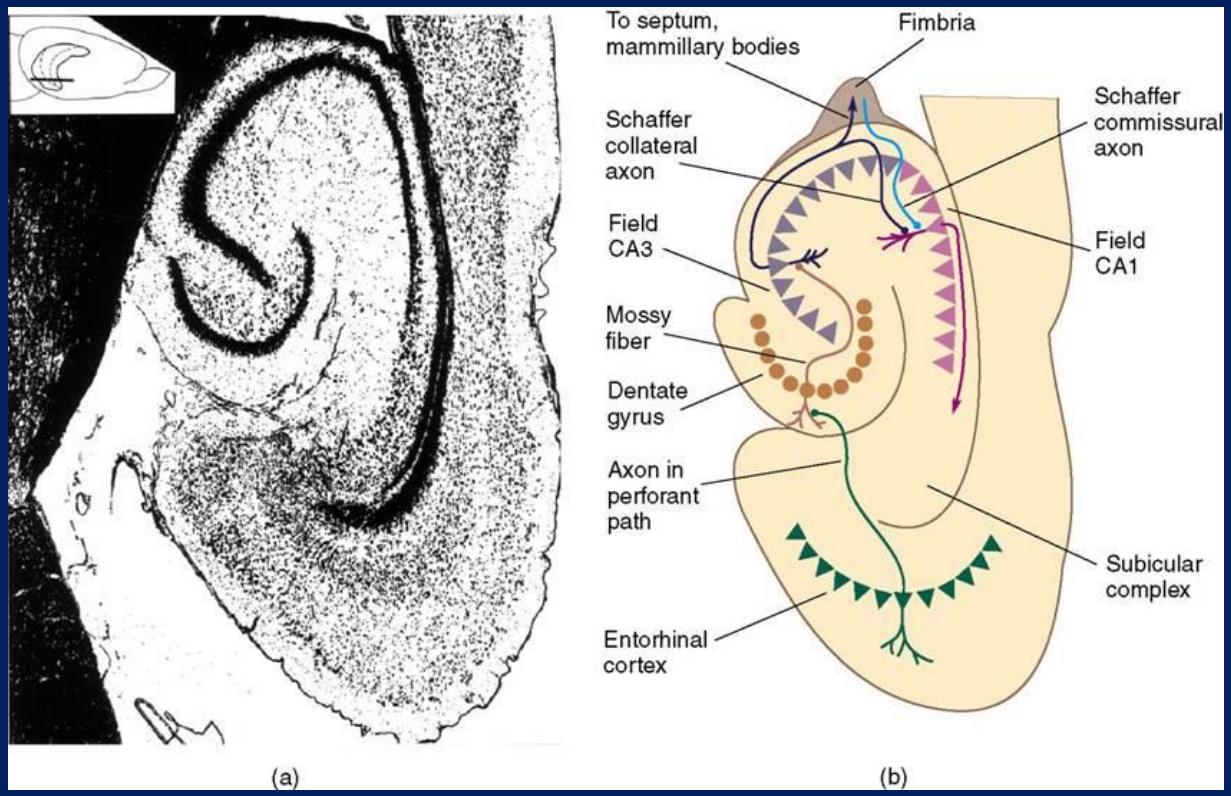
– Place cell

- A neuron that becomes active when the animal is in a particular location in the environment; most typically found in the hippocampal formation.

LTP in the hippocampus: A mammalian model for learning

Hippocampus most studied because of it's organization--

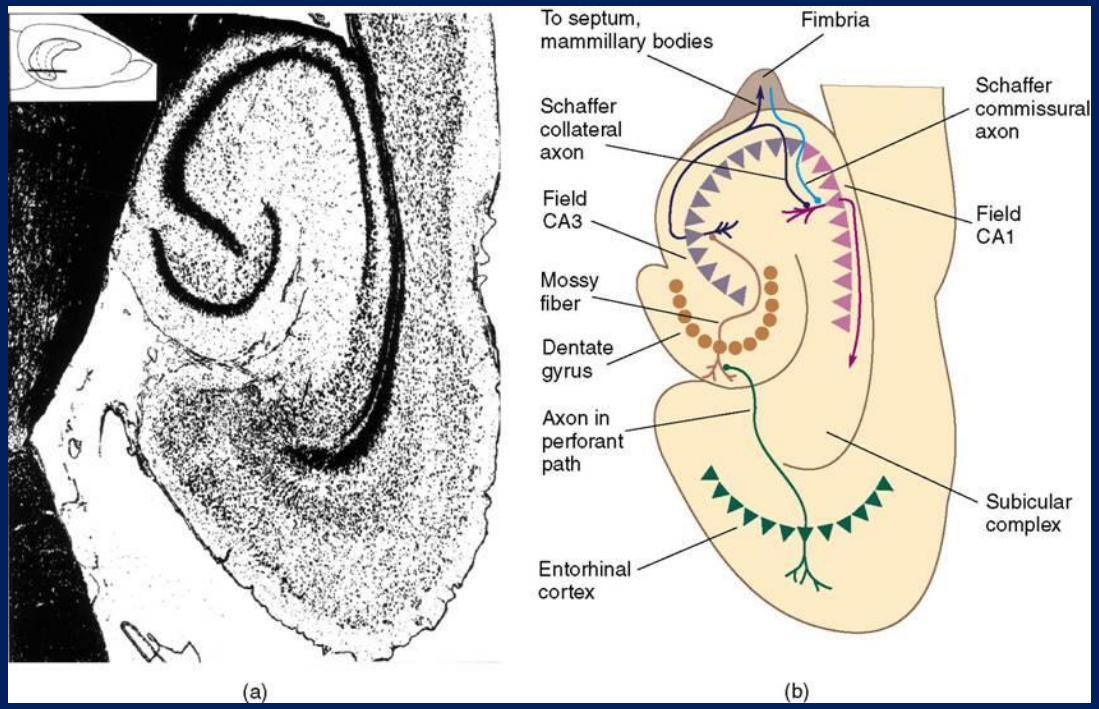
- complete circuitry represented in thin slices (100-400um thick)
- can be placed in a dish for *in vitro* electrophysiological experiments
- also thought to be important for memory consolidation *in vivo*



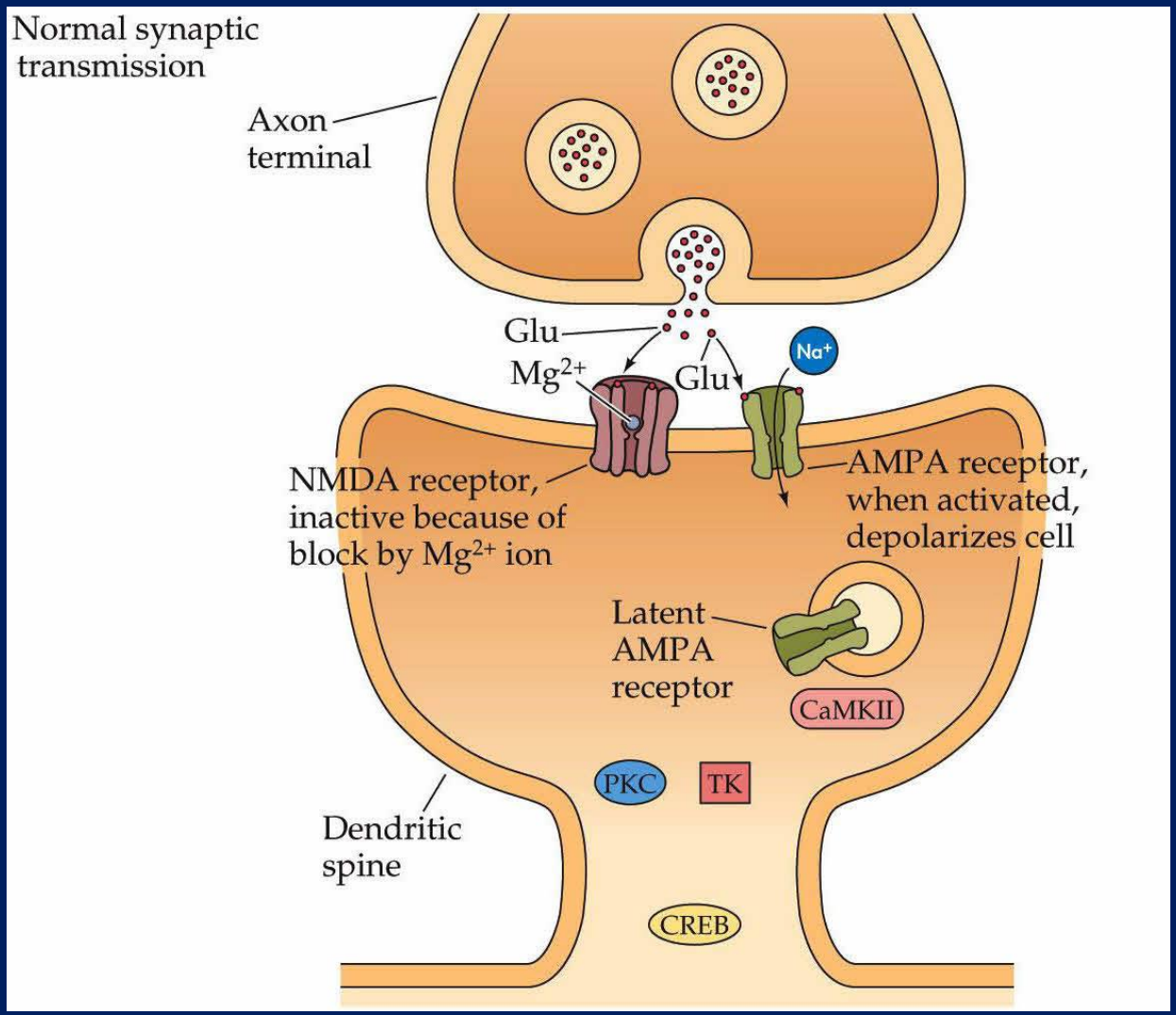
LTP in the hippocampus: A mammalian model for learning

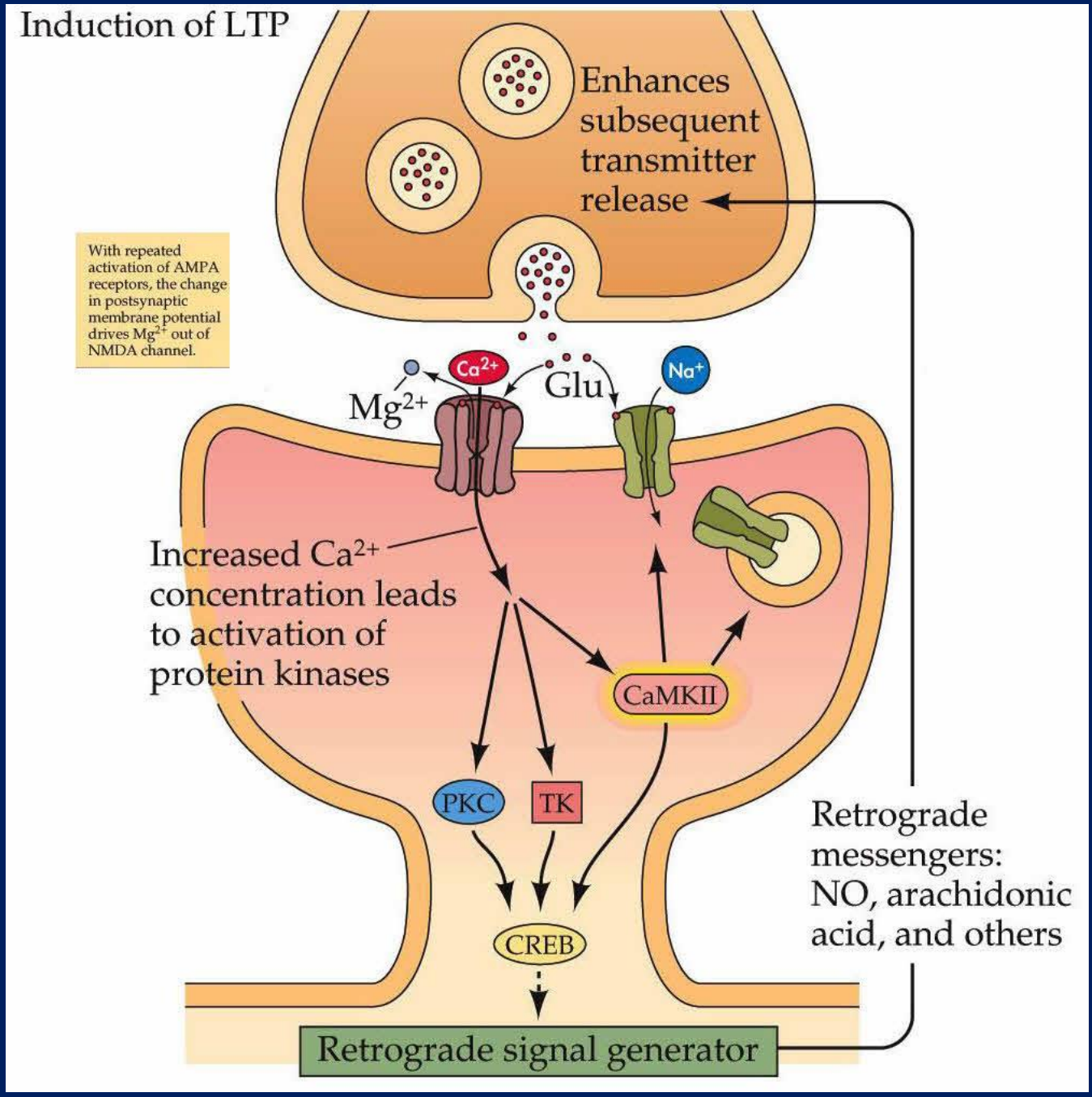
typical LTP experiment

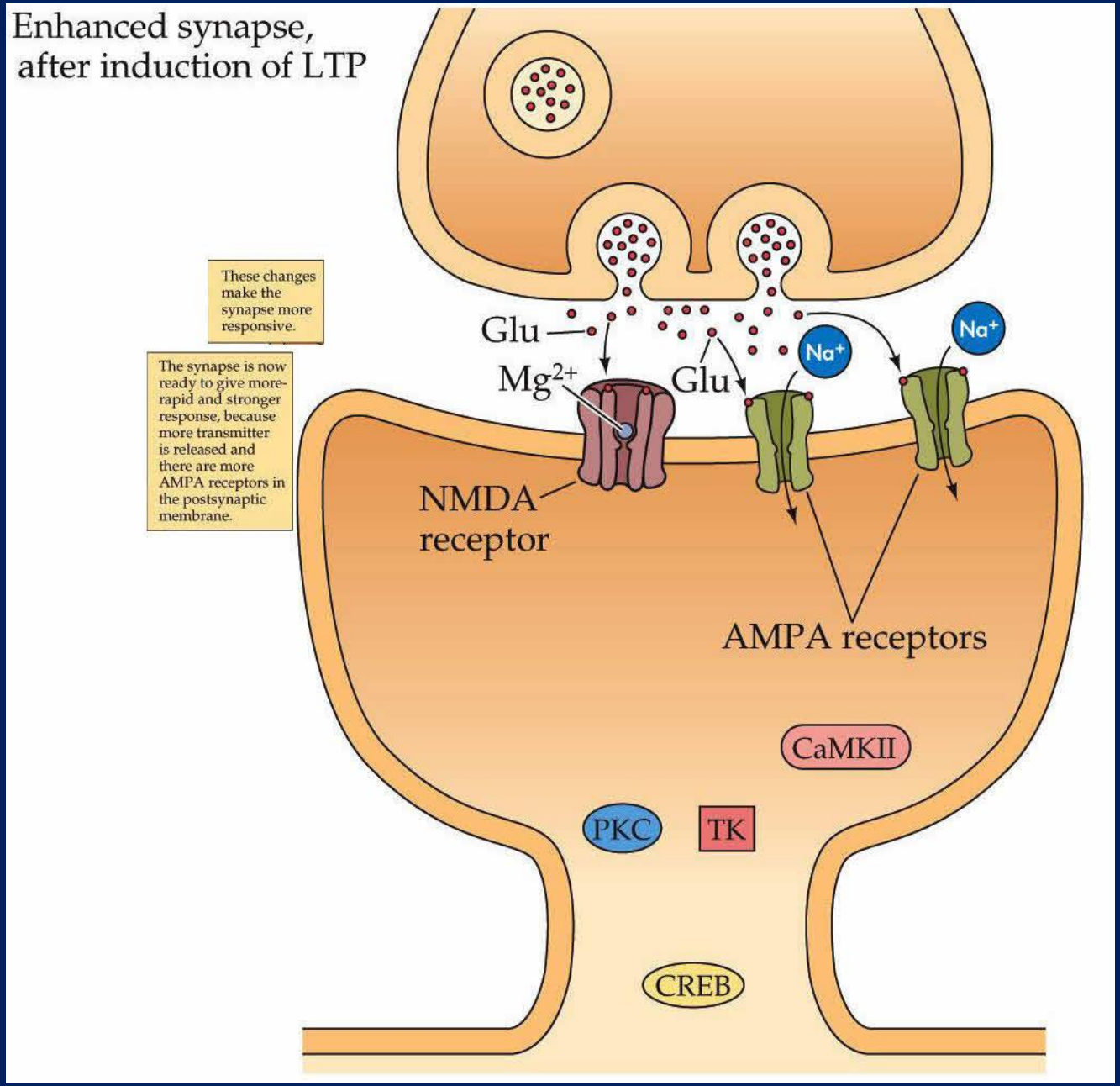
1. stimulate neuron A, record PSP from neuron B
2. stimulate neuron A tetanically (e.g. burst of stimuli @ 100 Hz)
3. record PSP from B w/test pulses at varying intervals
4. PSP augmented for several days or even up to months
5. this augmentation is what is called LTP



LTP in the hippocampus: A mammalian model for learning




Induction of LTP
Enhances subsequent transmitter release
With repeated activation of AMPA receptors, the change in postsynaptic membrane potential drives Mg^{2+} out of NMDA channel.
Ca^{2+}
Na^{+}
Mg^{2+}
Glu
Increased Ca^{2+} concentration leads to activation of protein kinases
CaMKII
PKC
TK
CREB
Retrograde signal generator
Retrograde messengers: NO, arachidonic acid, and others

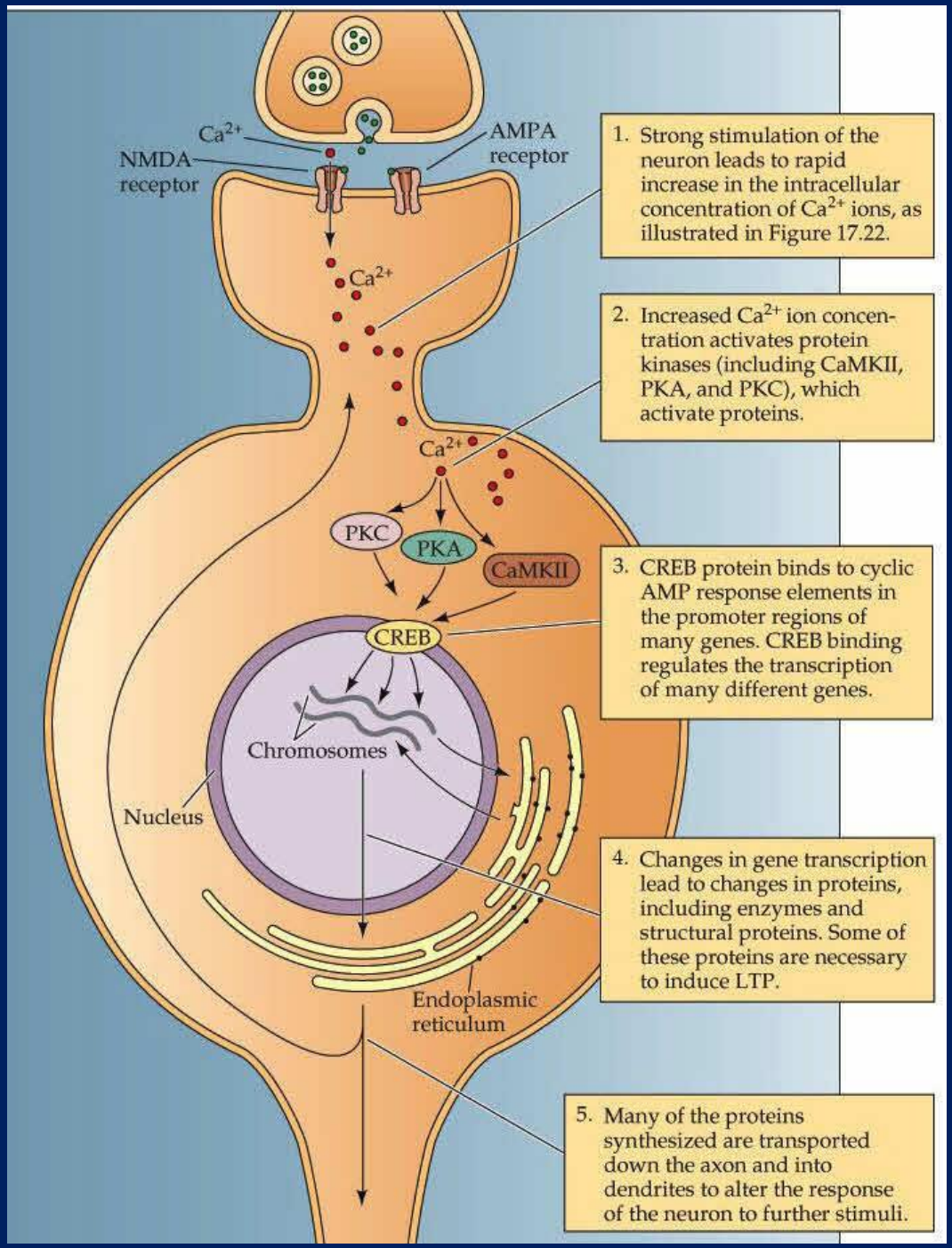

Enhanced synapse, after induction of LTP
These changes make the synapse more responsive.
The synapse is now ready to give more-rapid and stronger response, because more transmitter is released and there are more AMPA receptors in the postsynaptic membrane.
Glu
Mg2+
Glu
Na+
Na+
NMDA receptor
AMPA receptors
CaMKII
PKC
TK
CREB

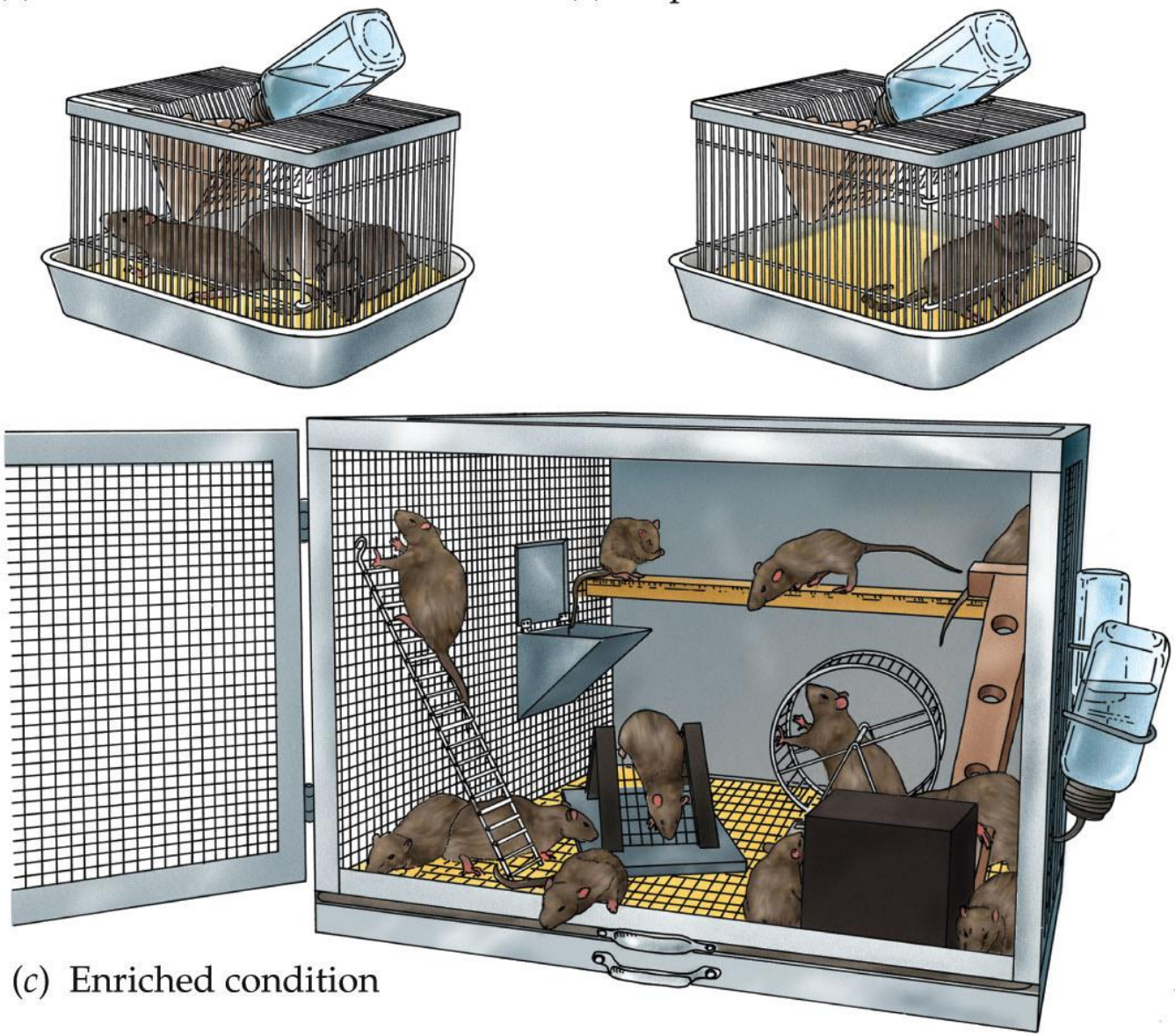
CaMKII: Calcium/calmodulin dependent kinase II

PKA, PKC: Protein kinase A, C

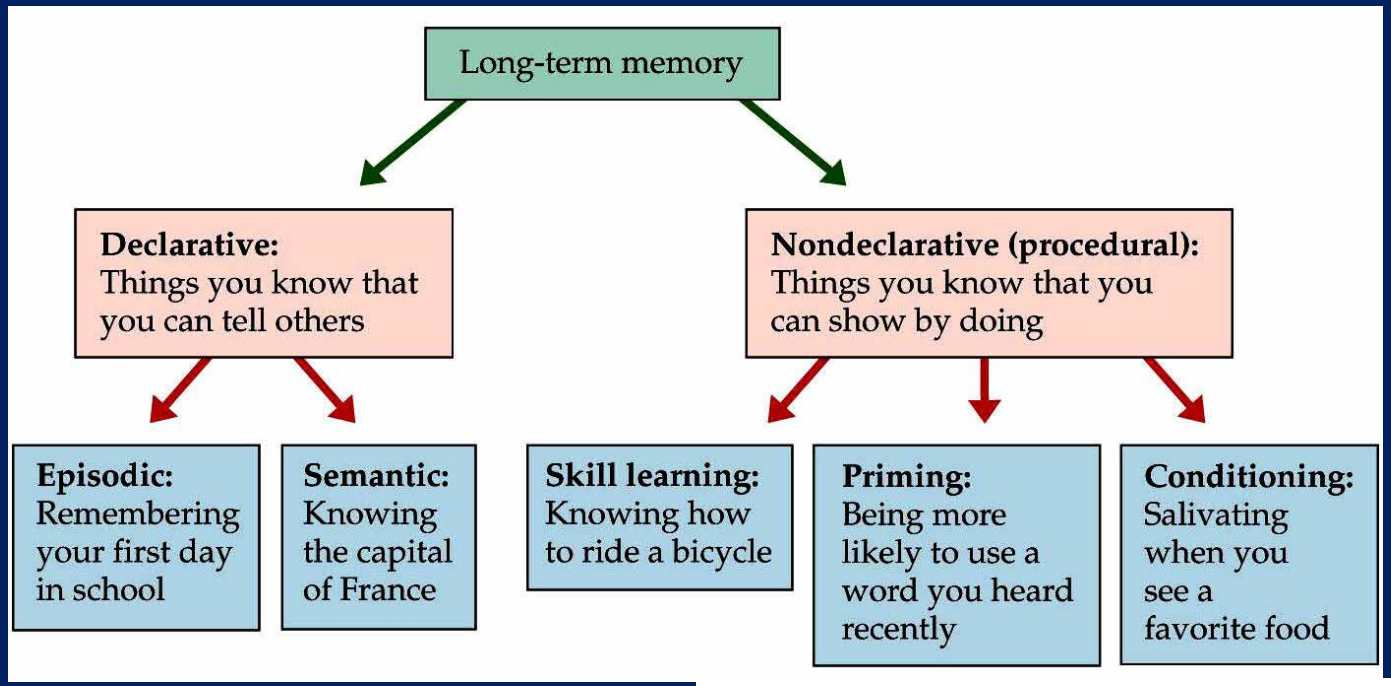
CREB: cAMP-responsive element-binding protein

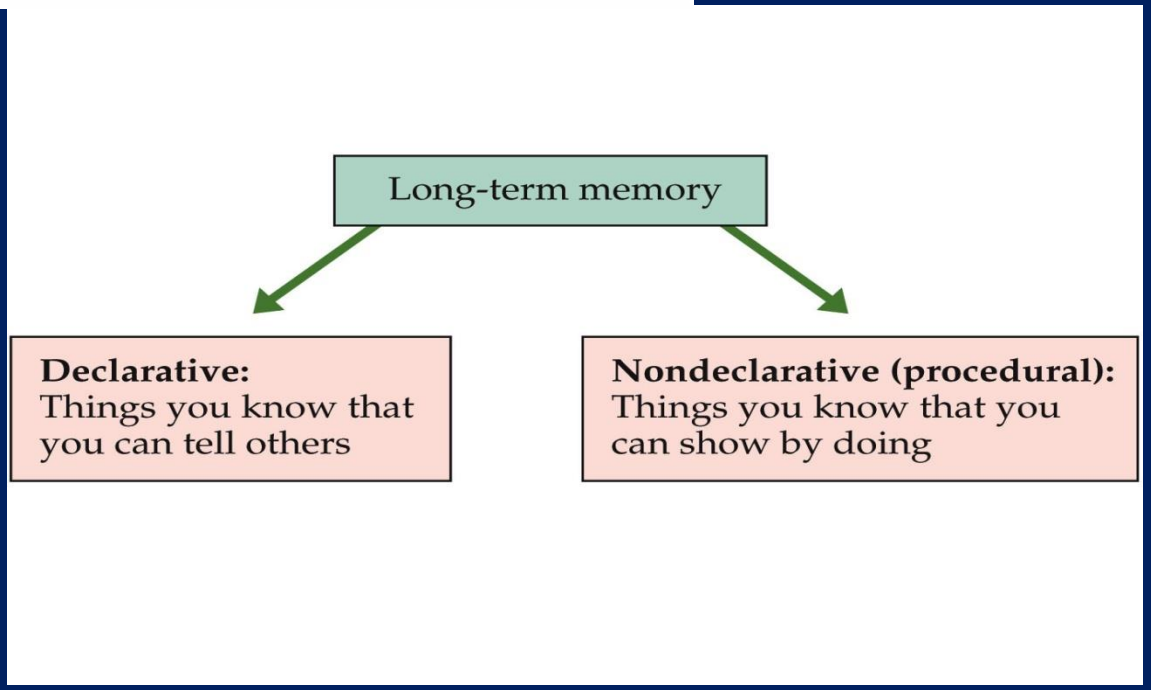
Low-frequency stimulation results in small increases in [Ca^{2+}] in the postsynaptic cell, which in turn results in *fewer* AMPA channels opening in response to glutamate. This is called low-frequency depression and is a mechanism for weakening synaptic strength.





Biological Psychology 6e, Figure 17.17


Long-term memory
Declarative:
Things you know that you can tell others
Nondeclarative (procedural):
Things you know that you can show by doing
Episodic:
Remembering your first day in school
Semantic:
Knowing the capital of France
Skill learning:
Knowing how to ride a bicycle
Priming:
Being more likely to use a word you heard recently
Conditioning:
Salivating when you see a favorite food


Long-term memory
Declarative:
Things you know that you can tell others
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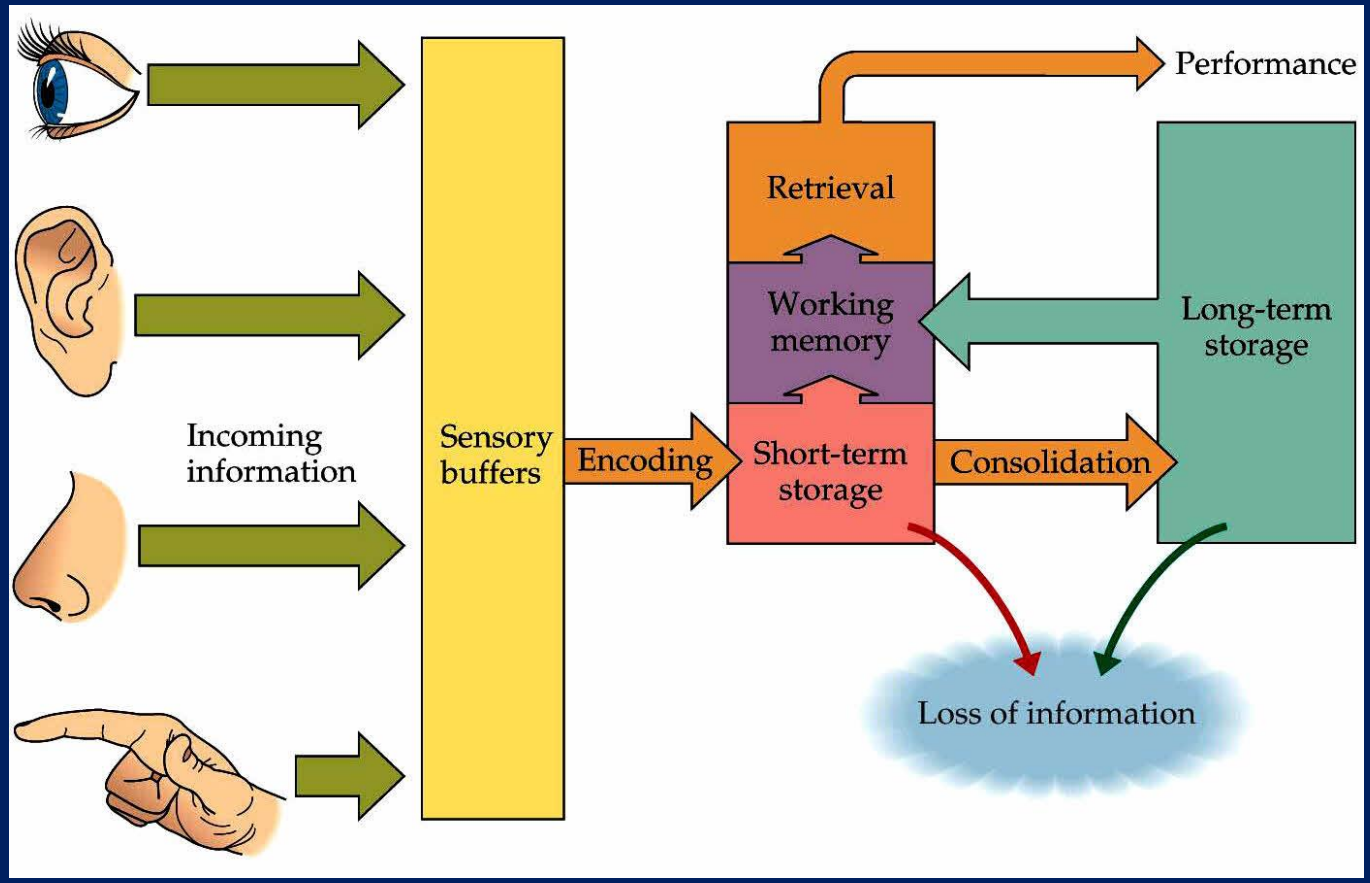
Organizational Aspects of Learning and Memory

Acquisition
Storage
Retrieval



Organizational Aspects of Learning and Memory

Memory can be categorized according to its duration or persistence

- Sensory traces
  - e.g. iconic (visual) and echoic (auditory)
    - at most a few seconds in duration

Organizational Aspects of Learning and Memory

Memory can be categorized according to its duration or persistence

- Sensory traces
- Short-term memory (STM) or working memory
  - information held in "consciousness"
    - phonological loop (sub-vocal rehearsal)
    - visual imagery
    - episodic buffer
  - can be initiated by current event or by recall from LTM
  - controlled by "central executive"

Organizational Aspects of Learning and Memory

Memory can be categorized according to its duration or persistence

- Sensory traces
- Short-term memory (STM) or working memory
- Intermediate-term memory
  - distinguishable from STM and LTM?
  - up to a few days in duration

Organizational Aspects of Learning and Memory

Memory can be categorized according to its duration or persistence

- Sensory traces
- Short-term memory (STM) or working memory
- Intermediate term memory
- Long-term memory
  - indefinite duration, up to days

Memory can be characterized by its underlying physical bases

- Sensory traces
  - persistent activity in sensory pathways
- Short-term memory (STM) or working memory
  - reverberating circuits, electrical basis
  - limited capacity, can be disrupted by intrusion of other activity, displays both primacy and recency effects
- Intermediate term memory
  - biochemical basis?, accessible by working memory
  - eventually irretrievable (storage or retrieval failure?)
- Long-term memory
  - structural or anatomical basis
  - protein synthesis essential
  - unlimited(?) capacity

Concluding Remarks

- Learning and memory
  - Occur at synapses
- Unique features of Ca^{2+}
  - Critical for neurotransmitter secretion and muscle contraction, every form of synaptic plasticity
  - Charge-carrying ion plus a potent second messenger
    - Can couple electrical activity with long-term changes in brain