Memory Part 2

Reinforcement learning (12.2)

- Involves a reinforcing or pushing “signals” – context dependent
- Reinforcement signal is information poor but motivation rich
- Involves “basic” brain structures that do not “process” information
  - E.g. drug addiction: deficit in the control of the reinforcing value

**Reinforcement: the ventral tegmental area**
- Midbrain → basal forebrain (dopamine: VTA)
- Self-stimulation studies: rats will work to exhaustion
- Self-stimulation is a form of instrumental conditioning (no perceived reward)

**Meso-limbic system**
- VTA: → amygdala, nucleus accumbens, and hippocampus
- Nucleus accumbens: neural substrate of drug addiction?

Dopamine in nucleus accumbens: stimulations (12.19)

- Both stimulation of VTA and natural rewards (sugar, food, sex….) increase dopamine in nucleus accumbens
- Sex chamber
  - Hedonic value of dopamine: natural stimulation (makes you feel good)
  - Dopamine also released in anticipation rewards

Reinforcement learning

**Meso-cortical system**
- VTA → primary/secondary association cortex, hippocampus, and frontal cortex
- Frontal cortex: working memory, reinforcement of current plans and strategies

- So what controls the VTA?
  - Lateral hypothalamus, amygdala, and prefrontal cortex → VTA
  - LH: hunger
  - Amygdala: emotional stimuli
  - Prefrontal cortex: planning and strategies

Motor learning (12.3)

- Motor learning: learning within the motor system (little perceptual input required)
  - e.g. ride a bike, play tennis, tie a shoe

Relational learning

- Learning relationships between stimuli or previous phenomes
  - Memory without meaning ~30 minutes (Ebbinghaus)
- Use of contextual information (schema) to store or retrieve new memories
Schemas: set of interconnected concepts/memories
- Schemas are continuously updated
- Memories can be “manipulated” by manipulating (consciously or not) their relationship to other memories – false memories. Eye witness testimony. Implanted memories

Memory: neural mechanisms

- Neural substrate of memory: what is memory?
  - Neural activity done cannot account for memories that last more than a few seconds
  - Synapses are the primary encoding mechanism
  - Memory items: a pattern of synapses (between excitatory cells)
  - Different kinds of memory, different kinds of learning → different brain structures
- The hippocampus: short term memory
  - Basic anatomy: the tri-synaptic circuit
  - Long-term potentiation
  - Long-term depression
  - Rat hippocampus (12.4)
    - Entorhinal cortex (inputs) → dentate gyrus → CA3 → CA1

Long-term potentiation (12.5)

- Electrical test stimulus = “recall”
- LTP induction = “learning”
- Memory = “size of the EPSP”
- LTP: synapse specific (12.7)
The Hebb learning rule: if presynaptic and postsynaptic sites are repeatedly active at the same time the synapse is strengthened

Hippocampus (12.6)

- Memory is associative – so is long term potentiation
- If two synapses, weak and strong, are stimulated at the same time (i.e. association), the weak synapse becomes stronger
- Associative LTP (12.9)
  - Many (almost simultaneous) inputs can be associated: “dendritic spike”
  - Memories are represented by patterns of synapses

Memory: LTP and NMDA receptors

- If classical conditioning is implemented by neurons there should be a neuronal mechanism that mimics it
- Fact 1: synaptic modification occurs only if there is Ca2+ entry in a synapse (second messenger including CaM-KII)
- Fact 2: LTP occurs only when Ca2+ enters through NMDA receptors
  - NMDA receptors are permeable to Na+ and Ca2+ but are normally blocked by Mg2+
  - NMDA receptors are unblocked only if there is postsynaptic depolarization:
    - Action potential
    - Depolarization through an electrode → i.e. NMDA unblocked only if there is postsynaptic activity
  - Unblocked NMDA receptors let Ca2+ through only if there is glutamate bound → i.e. Ca2+ enters only if there is presynaptic activity
- So… Ca2+ enters through pre and post synaptic activity (Hebb rule again)
- NMDA, depolarization, and calcium (12.8)

LTD

- Long term depression: decrease in synaptic strength
- Induction (i.e. learning)
  - High frequency stimulation → LTP
  - Low frequency stimulation → LTD
- Result in a decrease in AMPA receptors
- Also associative and selective
- Goal: prevent overly strong synapses