Chapter 7: Mechanism of memory formation

Learning activity suggested answers

Learning Activity 7.1 (p. 288)

1. Draw a diagram of a neuron and label key structural features
   - Check for soma, axon and dendrites being labelled correctly.

2. What is the difference between a synapse and synaptic gap?
   - Synaptic gap is the tiny space between adjacent neurons, specifically the gap between the terminal buttons of the presynaptic neuron and the dendrites of the postsynaptic neuron. The synapse is where communication (via neurotransmitter) between adjacent neurons actually occurs and includes the synaptic gap (as well as the terminal buttons of the presynaptic neuron and the dendrites of the postsynaptic neuron).

3. What is synaptic growth?
   - Explanation should refer to the formation of additional synapses/synaptic connections (via dendritic spines) between adjacent neurons in a neural pathway (e.g. memory circuit).

4. What is a ‘memory circuit’?
   - Description should refer to a neural pathway comprising interconnected neurons involved in forming and storing a memory.

5. Describe the role each of the following has in memory formation:
   - a. the axon and its terminals
      - axon: carries neural information to buttons/sacs at the end of the axon terminals that secrete neurotransmitter which has one or more specific roles in memory formation and/or storage, depending on type; terminal buttons/sacs on the presynaptic neuron are one component of a synapse within a memory circuit
   - b. dendrites:
      - thin extensions of a neuron that receive neurotransmitter from adjacent neurons in a memory circuit and transmit it to the soma; dendrites on the postsynaptic neuron are one component of a synapse within a memory circuit
   - c. synapses:
      - sites where communication via neurotransmitter occurs between adjacent presynaptic and postsynaptic neurons in a memory circuit thereby making memory formation possible; may also be memory storage sites
d synaptic connections: enable communication between adjacent presynaptic and postsynaptic in a memory circuit thereby enabling memory formation and storage; may also be memory storage sites

e neurotransmitters

- Generally, enable communication of information to be encoded in memory and contribute to structural changes at the synapse are important in memory formation. Specific roles in memory have been associated with different neurotransmitters e.g.:
  - glutamate: enhances neuronal communication by contributing to synaptic growth and strengthening of synaptic connections.
  - dopamine: strengthening of synaptic connections
  - acetylcholine: specific role unclear but at an abnormally low level among people with Alzheimer’s disease
  - norepinephrine: contributes to encoding and storage of emotionally significant memories

6 Explain the mechanism of memory formation with reference to functional and structural changes at the neuronal level.
Explanation should refer to:

- functional neuronal change e.g. increase in secretion of specific neurotransmitter/s and/or greater effects of the neurotransmitter/s on postsynaptic neurons resulting in changes such as enhanced communication within the relevant memory circuit (incl. LTP), encoding of the memory, structural changes at the synapse and enhanced storage within the circuit (and possibly at the synapse)

- structural neuronal change e.g. synaptic formation/growth via dendritic growth enabling more and therefore stronger connections between adjacent neurons in a memory circuit, further strengthening of connections and establishment of the memory in long term storage through activation of the circuit and LTP

Learning Activity 7.4 (p. 291)

1 What is the hippocampus and where is it located?

- hippocampus: a brain structure in the medial temporal lobe of each hemisphere (i.e. inner surface area at the base of each temporal lobe) with crucial roles in the formation (and retrieval) of long-term declarative memories (and explicit memory processes)

2 Who is H.M. and why is he well known to memory researchers?

- A patient who experienced serious memory problems following surgical removal of most of the hippocampus and amygdala, as well as immediately surrounding tissue, within the medial temporal love areas.

- H.M.’s memory problems were studied and reported for over 50 years and led to an understanding of the role of the hippocampus in the formation and retrieval of certain types of memories (e.g. declarative) and in the distinction between different types of memory systems/subsystems and processes, including specific types of amnesia.
3 List the STM and LTM memory impairments experienced by H.M. after his surgery and what these indicate about the roles played and not played by the hippocampus in memory.

STM:
- short-term working memory was relatively normal so hippocampus does not appear to have a role in short-term memory storage or working memory (but information in STM disappeared/was permanently lost through inattention/non-rehearsal i.e. not transferred to LTM)

LTM:
- inability to form a new declarative, explicit memory, both semantic and episodic (but could form new procedural, implicit memories) suggesting crucial roles of the hippocampus in the formation of declarative memories but not procedural memories
- almost total loss of memory past events for about two years pre-surgery and
- partial loss of memory of past events for up to about 10 years pre-surgery (but it is believed that the hippocampus does not actually store long-term memories of any type)


5 Complete a version of the ‘Trace the Star’ task used by Brenda Milner to assess H.M.’s procedural memory. Go to the ‘Research Replication’ tab under ‘Brenda Milner’ at the following website devised by Milner: http://www.greatcanadianpsych.ca/Researchers.html

6 What does the H.M. case study suggest about where LTMs are stored in the brain? Explain with reference to the case study.

H.M. was unable to form new declarative memories for facts and personal events but was able to remember old ones i.e. pre-surgery. This suggests that the hippocampus, amygdala and immediately surrounding tissue do not store these memories long-term and that storage occurs in other cortical areas (following transfer from the hippocampus after formation and consolidation).

Learning Activity 7.5 (p. 294)

1 Where is the amygdala located?
Next to the hippocampus in the medial temporal lobe of each hemisphere (i.e. inner surface area at the base of each temporal lobe).

2 What role(s) does the amygdala play in:
   a implicit memory?
      Processing and storage of long-term memories of conditioned fear responses which involve implicit memory.
   b explicit memory?
Contributes to formation of explicit declarative memories (particularly episodic) by influencing the activity of the hippocampus i.e. attaches/‘tags’ significance to events that produce strong emotional reactions/emotionally significant facts and events then stimulating the hippocampus to encode and store the relevant emotional details.

3 Why are conditioned emotional responses said to involve implicit memory?
Explanation should refer to conditioned emotional responses:
- occurring involuntarily in the presence of a relevant stimulus (and therefore do not involve intentional conscious recall)
- observed through actions/behavioural responses

4 How does the hippocampus receive information about an emotional event from the amygdala?
Explanation should refer to:
- amygdala and hippocampus are neutrally connected
- presence of heightened level of norepinephrine/noradrenaline at the amygdala when emotionally aroused is detected by the hippocampus, thereby communicating details of the relevant experience

5 What role does the hippocampus play in the formation of emotional memories?
Ensuring encoding and long-term storage of emotional information/details tagged to a personal event.

6 Identify the independent and dependent variables in the study by Antoine Bechara and colleagues (1995).
IV: type of brain medial/medial temporal lobe damage (amygdala, hippocampus or both)
DV: skin conductance response/GSR (do not accept conditioned fear response)

7 Callie was badly bitten by her neighbour’s dog yesterday. Describe what would happen if Callie saw the dog today under each of the following conditions:
   a no amygdala or hippocampal damage
As a result of being bitten by her neighbour’s dog yesterday, the sight of the dog today is likely to cause Callie to experience a conditioned emotional response. She is likely to feel afraid and her autonomic nervous system will be activated (including secretion of NE/noradrenaline). She may ‘freeze’ or perhaps try to run away as quickly as possible. Her amygdala would have made a learned associated between the dog (CS) and the painful dog bite (UCS) and she would also be clearly able to verbalise this association.
   b bilateral amygdala damage
   - On seeing the dog, Callie would be able to recognize and verbalise that it was the same dog that had bitten her the day before. But she is unlikely to show a conditioned emotional response to seeing the dog (i.e. she would not be fearful of the dog, not would her autonomic nervous system be activated).
   c bilateral hippocampal damage.
   - On seeing the dog, Callie would experience a conditioned emotional response. She is likely to feel afraid and her autonomic nervous system will be activated. She may
‘freeze’ or perhaps try to run away as quickly as possible. But she is unlikely to be able to verbalise or explain why she had that response to that particular dog.

Learning Activity 7.6 (p. 296)

1 Briefly describe consolidation theory.
   consolidation theory: new information transferred from STM/working memory to LTM requires 30 minutes for encoding and storage as an LTM

2 What three conditions are necessary for memory to be consolidated and therefore permanently stored?
   Conditions are:
   • structural changes to the neurons occur during and immediately after the learning of new information
   • these neuronal changes require at least 30 minutes to consolidate/‘set’ and become stable and enduring – the resulting structural changes in the neurons form the LTM of what was learned
   • there must be no disruption during the consolidation period

3 Use consolidation theory to explain why a rugby player who is knocked unconscious during a game may be unable to remember how he was knocked unconscious.
   Explanation should refer to consolidation not occurring or being disrupted, i.e. because the player was knocked unconscious, the memory of how he was knocked unconscious, the information immediately preceding the event, did not form (or did not form properly) due to the prevention of or disruption to the consolidation process.

4 Give an example of research evidence for the hippocampus having a crucial role in consolidation.
   Example could refer to the H.M. case study, i.e. surgical removal has been used to explain his anterograde amnesia—why he was incapable of forming new long-term episodic or semantic memories—because consolidation was unable to occur.

5 Construct a research hypothesis for the experiment conducted by Hudspeth, McGaugh and Thomson (1964). Ensure you operationalise the variables.
   Example: rats given ECT immediately (20 or 30 minutes) after learning to successfully run through a maze will take significantly longer and make more errors when subsequently running through the maze than will rats that receive ECT 60 minutes after learning to run the maze.

6 a Briefly describe reconsolidation theory.
   Reconsolidation theory proposes that after a memory is activated and retrieved from LTM, it needs to be consolidated again in order to be stored back in LTM.

   b Explain how reconsolidation may account for retrieval of distorted memories.
   Memories for past events can be affected by new circumstances once they are retrieved. In reconsolidating a retrieved memory, it is vulnerable to all the distractions and disruptions
that affect any consolidation process. Therefore reconsolidated memories may differ from their original versions.

c Reconsolidation theory suggests that a drug could be developed to erase unwanted or inappropriate memories. Suggest how a drug might be used for memory erasure with reference to reconsolidation theory.

Example:

- An individual is asked to retrieve a ‘problematic’ memory and while the memory is in STM or being retold/reviewed a drug is administered to interfere with or to manipulate reconsolidation into LTM, so that a new, ‘non-problematic’ memory replaces the unwanted ‘problematic’ memory (or the unwanted memory is erased).

d Give an example of an ethical issue that may be relevant to intentional memory erasure.

Note that standard ethical guidelines for research do not all necessarily apply to this question unless interpreted to involve research on memory erasure. Answers will vary depending on the ethical guideline selected and the student’s interpretation of the question.

**Learning Activity 7.7 (p. 300)**

1. What is amnesia?

   Amnesia is loss of memory, either partial or complete, temporary or permanent.

2. Explain the meaning of the phrase ‘amnesia resulting from brain trauma and neurodegenerative disease’.

   Generally refers to brain-related causes of memory loss. Distinction is made between brain trauma (any type of brain damage) and neurodegenerative disease (characterised by a progressive decline in the structure, activity and function of brain tissue).

   Note that, unlike the study design, Brain Injury Australia (2010) classifies neurodegenerative disease as a brain trauma and prefers a conceptual distinction in terms of inflicted and acquired brain injury.

3. Why are Alzheimer’s disease and Korsakoff’s syndrome considered to be neurodegenerative diseases?

   Both Alzheimer’s disease and Korsakoff’s syndrome are characterised by a progressive decline in the structure, activity and function of brain tissue (especially in the medial temporal lobe area and in the hippocampus area).

4. Distinguish between amnesia that may result from an inflicted brain injury or from an acquired brain injury.

   - Amnesia caused by an inflicted brain injury: attributable to brain damage due to an intentional blow to the head or by violent shaking of the head sufficient to rupture veins or cause some other kind of injury.

   - Amnesia caused by an acquired brain injury: attributable to brain damage at some time after birth due to an accident, a stroke, brain infection, long-term alcoholism, drug abuse, brain surgery, or by a neurodegenerative disease of the brain such as Alzheimer’s disease.
5 Distinguish between anterograde amnesia and retrograde amnesia, with reference to an example.

- anterograde amnesia: loss of memory only for information or events occurring after the trauma causing amnesia, e.g. Gerald’s life seems to be stuck in 1975, since experiencing considerable damage to his medial temporal lobes and hippocampus as a result of Korsakoff’s syndrome. He recognises some family members, can relate past memories from different time periods, but doesn’t understand why he is in a hospital, and when this is repeatedly explained to him, he can only hold onto that knowledge for moments before it vanishes.

- retrograde amnesia: loss of memory only for information or events occurring before the trauma causing amnesia, e.g. Megumi, a visiting Japanese exchange teacher, had a severe and extensive stroke while on a working holiday to Australia. When she regained consciousness, she had no recollection of where she was, and as she woke up in hospital, she was surprised to hear English being spoken by the nurses and doctors. Loss of memory seems to include events occurring in the year preceding the stroke.

6 Voula was involved in a car accident as a passenger. She was not wearing a seatbelt and hit her head on the front windscreen when the two cars collided. She was unconscious for a short time. Brain scans showed there was no permanent brain damage; however, Voula experienced memory problems for some time after the accident.

a If Voula suffered anterograde amnesia, what memory problems is she likely to experience?
- Problems should involve memory of new information or events experienced after the accident.

b If Voula suffered retrograde amnesia, what memory problems is she likely to experience?
- Problems should involve memory of new information or events experienced before the accident. Memory loss may extend back a just few moments before the accident, or days, or weeks or sometimes years. Retrograde amnesias are usually of a temporary nature and are often caused by a blow to the head, such as the one Voula received in her car accident. It would be expected that Voula finds that her inability to remember information and events leading up to the accident gradually disappears. The period of time for which Voula’s memory is lost will shrink as she gradually recovers her memory, but it is unlikely that she will ever recover a full picture of events leading up to the accident.

Learning Activity 7.8 (p. 304)

1 Explain what dementia is with reference to commonly described early and latter stage symptoms.

Explanation should refer to:

- Dementia as an umbrella term for a variety of symptoms of a large group of neurodegenerative diseases and other disorders that cause a progressive decline in mental functioning, behaviour and the ability to perform everyday tasks.

- Early symptoms include: occasional memory loss, decline in mental abilities and mild behavior and personality changes.
• Latter symptoms: Persistent memory loss, impaired ability to function independently and meet basic needs.

2

a What is Alzheimer’s disease?
Alzheimer’s disease: a type of dementia characterised by the gradual widespread degeneration of brain neurons, causing memory loss, a decline in cognitive and social skills, and personality changes.

b Why is Alzheimer’s disease irreversible?
Explanation should refer to the neurodegenerative nature of the disease i.e. neurological degradation, including neuronal loss, neurons cannot be recovered (but in some cases may be slowed).

c Why is Alzheimer’s disease attributable to neurological factors?
Explanation should refer to presence of specific neurological abnormalities, commonly found in brain scans and post-mortem brain tissue analyses (compared with people who do not have the disease) e.g. abnormally high levels of amyloid plaques, neurofibrially tangles and abnormally low levels of Ach that adversely effect with – and between – neuron communication.

d Why does Alzheimer’s disease ultimately lead to an earlier death?
Explanation should refer to the role of the brain in survival and to the impact of progressive degeneration of significant bands of neural tissue.

3 Consider the list on page 302 outlining memory loss that can be experienced in the latter stages of Alzheimer’s disease. For each item in the list, identify the

a specific type of LTM (e.g. semantic, episodic, procedural)

b LTM process (e.g. explicit or implicit memory)

c type of amnesia (e.g. retrograde or anterograde).

<table>
<thead>
<tr>
<th>Memory loss typically involved in Alzheimer’s disease</th>
<th>Type of LTM</th>
<th>LTM process</th>
<th>Type of amnesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Events—the person may forget part or all of an event.</td>
<td>episodic</td>
<td>explicit</td>
<td>retrograde</td>
</tr>
<tr>
<td>Words or names—the person progressively forgets words and names of people and things.</td>
<td>declarative: semantic</td>
<td>explicit</td>
<td>retrograde</td>
</tr>
<tr>
<td>Written and verbal</td>
<td>new information</td>
<td>explicit</td>
<td>anterograde for directions to</td>
</tr>
</tbody>
</table>
directions— the person progressively loses the ability to follow directions.  

<table>
<thead>
<tr>
<th>Type of memory</th>
<th>Type of decline</th>
<th>Effects of decline</th>
</tr>
</thead>
</table>
| STM—working memory | • difficulties with more complex tasks  
| | • efficiency of an aged nervous system | • simple STM tasks are unaffected, but complicated tasks, requiring simultaneous storage and manipulation of information in working memory, or when attention must be divided between tasks, show that age-related factors may impact on effective STM functioning  
| | | • decline in visuo-spatial sketchpad— progressive loss of ability to follow directions  
| | | • Nervous systems of older people are less efficient at receiving and transmitting information, and therefore the rate or speed at which information is processed in short-term memory is slower. The ability to process both numbers and words in short-term memory declines as we age.  

Stories on TV, in movies or books— the person progressively loses the ability to follow stories.  

<table>
<thead>
<tr>
<th>Type of memory</th>
<th>Type of decline</th>
<th>Effects of decline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored knowledge— over time, the person loses known information such as historical or political information.</td>
<td>semantic</td>
<td>explicit</td>
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</table>

<table>
<thead>
<tr>
<th>Type of memory</th>
<th>Type of decline</th>
<th>Effects of decline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Everyday skills— the person may progressively lose the capacity to perform tasks such as dressing and cooking</td>
<td>procedural and semantic</td>
<td>implicit &amp; explicit</td>
</tr>
</tbody>
</table>

Learning Activity 7.9 (p. 307)

1. Construct a table to summarise memory decline associated with age in STM (working memory) and in the different types of LTM.
Procedural LTM
- stability in LTM procedural memories
- Nilsson found hardly any decline in the retrieval of information from procedural memory. Procedural memories seemed to remain intact over time. However, memory loss can involve everyday skills—the person may progressively lose the capacity to perform tasks such as dressing and cooking.

Declarative—episodic LTM
- decline in memory for people and events in our lives
- Studies of episodic memory have found a steady decline for memories of personal experiences as people age, from as early as age 30 or as late as age 50. Nilsson’s study revealed older participants performed worse than younger participants on 26 different measures of episodic memory.

Declarative—semantic LTM
- stability in semantic memories
- Semantic memory tests used by Nilsson tapped into general knowledge that most people would know regardless of their education. He concluded that semantic memory appeared to be fairly resistant to ageing. However, loss of stored knowledge, and words or names may still occur.

2 Use your table to write a one-paragraph description on age and memory decline.
Ensure responses include at least three key age-related memory declines.

3 What are four explanations of age-related decline in memory?
Explanations may refer to:
- lack of motivation by elderly participants in experiments and other studies on age-related decline in memory, e.g. poor performance of some tasks could be explained by lack of interest in participating in traditional psychological experiments involving memorising meaningless material such as nonsense syllables, word lists and number series
- lack of confidence in one’s memory may exacerbate a memory problem or a bad memory performance in a research study
- type of retrieval method used: information may not actually be lost and is not retrieved due to use of inappropriate retrieval method, e.g. relying on recall rather than recognition
- age-related slowing of CNS functioning, i.e. cognitive slowing—slower and less efficient mental