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Limbic System
Lecture Outline

• Brief Review of Cortical Function

• Neuroanatomy of Limbic System
  – Cortex
    • Hippocampus
    • Parahippocampal gyrus
    • Amygdala
    • Cingulate gyrus
    • Olfactory cortex
  – Diencephalon
    • Thalamus – Anterior nucleus, Mediodorsal nucleus
    • Hypothalamus - Medial Hypothalamus, Mammillary bodies

• Connections
  – Amygdala
  – Hippocampus – Papez Circuit

• Blood Supply
Important Terms

• Brodman Areas 4, 3, 17, 41, 42
• Primary Sensory Cortex
• Primary Motor Cortex
• Unimodal Association Areas
• Multimodal Association Areas
• Limbic Association Areas
• Limbic Cortex
• Cingulate Gyrus
• Amygdala
  – Centromedial Division
  – Central Nucleus
  – Basolateral Division
• Hippocampal Formation
  – Parahippocampal gyrus
  – Dentate
  – Subiculum
  – CA1, CA2, CA3
• Uncus
• Entorhinal Cortex
• Olfactory Bulb
• Olfactory Tract
• Forix
• Mammillary body
• Mammillothalamic Tract
• Anterior Nucleus of the Thalamus
• Mediodorsal Nucleus of the Thalamus
• Papez Circuit
• Neocortex
• Paleocortex
• Archicortex
• Stria Termialis
The cerebral cortex is divided into:

Primary motor & sensory areas (M1, S1, A1, V1)
Brodman areas 4, 3, 41, 42, 17)

Unimodal association areas (MA, SA, AA, VA)

Multimodal association areas (Posterior and anterior)

Limbic association areas (Limbic lobe)

Limbic cortex (Hippocampus & Amygdala)
<table>
<thead>
<tr>
<th>LIMBIC LOBE (Cortical Areas)</th>
<th>Cortex Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cingulate gyrus &amp; Isthmus</td>
<td>Neocortex (six layers)</td>
</tr>
<tr>
<td>Subcallosal area</td>
<td></td>
</tr>
<tr>
<td>Parahippocampal Gyrus</td>
<td>Paleocortex (3-5 layers)</td>
</tr>
<tr>
<td>Uncus</td>
<td></td>
</tr>
<tr>
<td>Hippocampus</td>
<td>Archicortex (3 layers)</td>
</tr>
<tr>
<td>(Deep within parahippocampal gyrus)</td>
<td></td>
</tr>
</tbody>
</table>
The hippocampal formation and the amygdala are often described as being “inside” the telencephalon. The hippocampal formation can be viewed in the floor of the inferior horn of the lateral ventricle.
However, the amygdala and hippocampal formation are cortical areas that are continuous with surface cortical structures.
AMYGDALOID COMPLEX:

Located in temporal lobe, rostral (forward) of the hippocampal formation, in the anterior end of the temporal horn of the lateral ventricle.

Contains 3 groups of nuclei:

**Basolateral Group** – Connections to Cortical Structures

**Corticomedial Group** (smaller) – Receives large Olfactory Input

**Central Nucleus** – Connections to Reticular / Autonomic Regions of the Brain Stem

**Function** – General Limbic emotions & behaviors, fear, anger, satiety (eating), environmental context (reactions to environment)
The Amygdala

- A matrix of many nuclei
- Creates a bulge on the parahippocampal gyrus called the uncus
- Nuclei can be subdivided into:
  
  **Corticomedial division (CM)** with connections to the olfactory system and the hypothalamus (social behavior modulation)

  **Central nucleus (Ce)** with connections to the brain stem and hypothalamus (regulation of the autonomic nervous system)

  **Basolateral division (BL)** with connections to the cerebral cortex (emotional memory, e.g., fear)
The Olfactory Bulb is the major input to the Corticomedial Amygdala

- neocortical olfactory association area
- primary olfactory cortex
- entorhinal area
- uncus
- corticomedial amygdala
- olfactory bulb
- olfactory tract
Connections of the Corticomedial Nuclei:

- the Olfactory Bulb through the Lateral Olfactory Tract
- the Medial Hypothalamus through the Stria Terminalis
- through these connections odors influence sexual and other social behaviors in mammals

Modified From J.H. Martin, Neuroanatomy: Text and Atlas, 3rd ed Fig. 16-7
The Central Nucleus of the Amygdala

The Central Nucleus

connects to the hypothalamus and brain stem through the Ventral Amygdalofugal Pathway (VAFP)

Reticular Formation and Cranial Nerve Nuclei regulating the autonomic nervous system

lateral and medial hypothalamus

Central Nucleus

Modified From J.H. Martin, Neuroanatomy: Text and Atlas, 3rd ed Fig. 16-7
The Basolateral Amygdala

Nuclei of the Basolateral Amygdala are reciprocally connected to:

- frontal lobe multimodal association cortex (connections not shown)
- unimodal and multimodal sensory association cortex of the:
  temporal lobe
  occipital lobe

Sensory Association Cortex
Temporal Lobe
Hippocampus
A “triangular” circuit links the Amygdala to the Orbital & Prefrontal Cortex, Basal Ganglia and to the Mediodorsal Nucleus of the Thalamus. This circuit is involved with the experience and expression of emotional responses including anger, fear, pleasure and depression.
The Hippocampal Formation:
1. Dentate Gyrus
2. Hippocampus
3. Subiculum

Entorhinal Cortex

Dentate Gyrus

Hippocampus (CA1, CA2, CA3)

Fornix

Subiculum

Entorhinal Cortex of the Parahippocampal Gyrus

Source Undetermined
The hippocampus and the dentate gyrus are both archicortex with 3 layers.

There are multiple inputs to entorhinal cortex, including fibers from the cingulate gyrus, basolateral amygdala, olfactory cortex and cortical association areas.

The Perforant pathway goes from entorhinal cortex to dentate gyrus.

Granule cells (middle layer) of dentate gyrus project (mossy fibers) to the hippocampus.

Pyramidal cells (middle layer) of hippocampus give rise to the fornix, the output tract of the hippocampal complex. The fornix projects to mammillary bodies of hypothalamus and septal nuclei.
Basic neural circuits through the Hippocampal Formation

Multimodal Sensory Association Cortex: Parietal and Temporal Neocortex

Entorhinal Cortex (an area of the parahippocampal gyrus)

Dentate Gyrus → CA3 → CA1 → Subiculum

Hippocampus

Mammillary Bodies & Anterior Nuc. of thalamus

fornix

The Papez Circuit

Cingulate Gyrus

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The Papez Circuit
COMPONENTS OF HIPPOCAMPAL FORMATION:
Subiculum, Hippocampus, Dentate Gyrus

Efferents (Output): FORNIX
Cortical Network Subserving Memory

primary sensory areas
->
unimodal sensory association areas

(long term storage of explicit memories)

multimodal receptive association area: Posterior Parietal Cortex

(active working memory)

multimodal expressive association area: Dorsolateral Prefrontal Cortex

limbic association areas

(formation of explicit memory: semantic, episodic)

Hippocampal Formation

Basolateral Amygdala

(formation of emotional memory)

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Cerebral arteries supply the cortex and superficial white matter

- **middle cerebral artery**
- **anterior cerebral artery**
- **posterior cerebral artery**
- **border zones**

Modified From Haines, Fundamental Neuroscience for Basic and Clinical Applications, 3rd edition, 2005, Figs. 8-7, 8-9
Anterior Cerebral Artery includes leg and foot areas of the somatosensory and motor cortices.

Middle Cerebral Artery includes hand and face areas of the somatosensory and motor cortices.

Posterior Cerebral Artery includes visual cortex.

Territories of the Anterior, Middle, and Posterior Cerebral Arteries
Distribution of the Cerebral Arteries to Internal Structures of the Cerebral Hemispheres

Modified From J.H. Martin, Neuroanatomy: Text and Atlas, 3rd ed Fig. 4-5
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