

## Physio Psych 2200, Study Guide Section IV – How the Brain Works, Part II

\*\*\*\*\*

### Sleep

*Diurnal/Nocturnal* (active in the day vs night, respectively).

*Activity rhythm* (generally reflects sleep/wake patterns, with activity during wake).

*Entrainment* (to adjust an internal rhythm to an outside source such as sunlight).

*Free-running* (to experience a circadian rhythm driven internally, independent from any external cues)

*The circadian system:* Specialized **ganglion** cells in the retina (use melanopsin), project via **retinohypothalamic tract** to the **supra chiasmatic nucleus** (SCN) in the hypothalamus, which signals the **pineal gland** to secrete **melatonin**.

Severing the *optic tract* (visual pathway) does NOT eliminate input to the retinohypothalamic tract. Thus when blindness is caused by anomalies at the level of optic nerve or higher (with retina intact), the circadian system is still functional. However, about half of blind subjects (those with retinal anomalies) show a circadian disorder called “free running syndrome.”

**Time isolation experiment** – assessing sleep/wake patterns in humans under “free running” conditions. The human body adjusts to an “internal” day period slightly LONGER than 24 hr under these conditions.

Plasma **melatonin** levels (from the pineal) peak during sleep period (~4AM).

**Growth hormone** also surges at night, reflecting growth (in children) and cellular repair in adults, during sleep.

**EEG** = electroencephalograph, recording from multiple surface (skin) electrodes. Used in sleep labs to identify sleep states and diagnose sleep disorders.

#### Stages of sleep:

1 – SWS (slow wave sleep), light sleep, *alpha rhythm*

2 – SWS, light sleep, *sleep spindles*

3 and 4 – SWS, deep sleep, *delta waves*; **memory consolidation**

REM – *rapid eye movements*, follows stage 1 sleep (not 4), desynchronized, paralysis, dreaming

#### Neural mechanisms of sleep/wake:

•Inhibitory (sleep) **GABA** networks in cortex (driven by basal forebrain)

•Excitatory (wake) **Ach** networks in cortex (driven by “reticular activating system” including pons, raphe nucleus, locus coeruleus)

•REM driven by **pons**, cortical excitation (similar to wake) with motor paralysis (pons to spinal cord)

### Sleep Disorder Terminology

Somnambulism (sleep walking; stage 3+4 SWS)

Hypnagogic hallucination (partially in REM but feel awake, realistic possibly alien dreams; REM to wake)

Sleep paralysis (brief paralysis coming out of REM; REM to wake)

Narcolepsy (abnormal wake-to-REM transition)

Klein Levin (sleeping beauty)

Effects of **sleep deprivation** include: impaired working memory, impaired consolidation of memory, hallucinations, immune dysfunction, death.

**Mild alcohol** effects on sleep: initially increases SWS, but then has rebound effect and disrupts sleep (reduced GABA activity in sleep pathways), reducing memory consolidation.

**Caffeine** also disrupts sleep.

*Cetacean hemispheric desynchronization for sleep* (allows for ongoing breathing via surfacing – otherwise would die).

Despite entrainment to maternal melatonin, there is a **lack of organized circadian rhythm in newborns** (established by about 3 months). That is because the fetus can use the mothers melatonin surges *in utero* (fetus sleeps when mother sleeps), but after birth they have to use their own SCN/pineal circuitry -- takes time to mature.

\*\*\*\*\*

### **Emotions**

Dimension of emotion include: *intensity, valence, and self-reference*

The primary neural structures involved in emotional encoding = the **limbic system**

Although consistency in activation patterns varies across ages, genders and tasks there is good evidence of:

Often  
inversely  
related

← **Anterior Cingulate (+):** sadness, anger, love, pain, mystical, sex  
**Posterior Cingulate (+):** Happiness  
**Amygdala (+):** fear, humour, sex  
**Orbitofrontal (+):** mystical

Neural pathways involved in “good feelings” -- **mesocorticolimbic dopamine pathway** (involved in drug-addiction, particularly nucleus accumbens), **serotonin** pathways, and **opiate** (periaqueductal grey) pathways. These appear to be involved in “good feeling” aspects of *positive* emotions.

**Fear conditioning** is a type of learning studied in animal models, and is mediated by amygdala activity during memory formation for unpleasant events (mild foot-shock). The memory associates the unpleasant event with the place it happened, and the tone that signaled it happening.

**Mirror neuron system** – activation in the brain consistent with doing/experiencing an event, but *caused by watching someone else experience the event*. This also applies to emotional activation (watching someone else experience an emotion). This causes “empathy” -- the ability to feel what others are feeling. *Mirror neurons are sub-sets of neurons distributed within relevant brain structures* (there is no single “mirror neuron” structure).

**Autistic children** fail to show mirror activation of emotion areas when viewing emotional faces – they *may* lack mirror neurons.

There is evidence of **sex differences** in neural activation for emotion, including for fear-modulated memory (left versus right amygdala) and sexual arousal.

**Oxytocin** levels rise during “bonding” events such as nursing a new baby, and sex. The hormone *rises* when people feel *affection and trust*, and the presence of oxytocin inhibits (*reduces*) activation of negative emotions (*fear and anger*).

**Testosterone** levels are highly correlated with aggressive behaviors, modulation of testosterone in rodents can directly change their aggressive behavior.

Positive-excitement activities (sky-diving) involve initial stress response (rise in cortisol), as well as a large rise in **epinephrine (E) and norepinephrine (NE)**. With experience, the fear component (cortisol) minimizes, but the *epinephrine and norepinephrine peak continue to be seen*. E/NE may be the cause of positive “addictive” feelings for high-risk exciting activities (adrenaline junkie). The overall effect is probably *not* positive for those unable to overcome a fear response (cortisol spike).

There is a *fine line* between positive/negative excitement effects of epinephrine & norepinephrine – E/NE are *also* elevated during unpleasant events such as being on an overcrowded train, or taking an exam. What is “fun-exciting” for you may be “fear & horror inducing” to another. (Think of the variety of reactions to roller-coasters).

**Stress hormones/amygdala activation** modulate memories, making some memories more powerful (harder to forget) than others. Recall that the olfactory system projects directly to amygdala and hippocampus, making *smell-related memories* very powerful. In a similar way, *fear related memories* are also powerful (we will later discuss PTSD).

Many aspects of emotion are *biologically mediated* since emotional recognition is seen across cultures, in newborn babies and non-human animals. Also, similar brain areas are consistently activated across people. But *some* components of emotion are *learned* such

as what events/people trigger what feelings. **Abused children show elevated fear responses to angry faces**, because this what they have learned.

\*\*\*\*\*

## **Learning and Memory**

**Define learning (acquisition), memory (storage and retrieval), forgetting (normal loss), amnesia (pathological loss).**

**Retrograde amnesia** – loss of older memories

**Anterograde amnesia** – inability to form new memories

*Short vs long term memory* = info held for *min/hours* versus *days/years*

*Working memory* == info held “on-line” for current task, and may come from both short and/or long term memories

Define *consolidation* -- transfer from short to permanent long-term memory (**mainly during SWS**).

Define *declarative (episodic, semantic)* versus *procedural (skill, priming, conditioning)* memory. **Declarative = you can explain it, procedural = you can do it.**

**Declarative short-term** memories are processed in medial temporal lobe structures (MTL; **hippocampus, parahippocampus, entorhinal cortex, perirhinal cortex**), and **thalamus**. This includes:

- 1) formation/encoding,**
- 2) short-term retrieval, &**
- 3) consolidation.**

During consolidation, declarative memories are transferred via the hippocampus to a **distributed network in cortex**, which is organized to some degree by sensory modalities (language memories in language areas, etc.).

**Long-term declarative memories** are then stored in cortical networks, where they can be retrieved directly.

**HM** – the subject of medial temporal lobectomy, showed resulting declarative *anterograde amnesia* (famous case study). Lost hippocampus, entorhinal and parahippocampus. He retained skill learning (procedural memory).

Widespread cortical damage in **Korsakoff’s** syndrome (vitamin deficiency in alcoholics) causes memory loss (mainly *declarative* - informational memories, not procedural, which are stored elsewhere). Amnesias are also seen in other cortical degenerative diseases (dementia, spongiform encephalopathy).

**Amygdala** plays a role in coding “emotional” memories, which are more resistant to forgetting

**Procedural memories** are mediated, apparently both during short and long term, in structures including the **basal ganglia, motor cortex, amygdala and cerebellum.**

These different circuits explain why some individuals with brain damage (e.g., HM) can *retain* the ability to form **procedural** but *lose* the ability to form **declarative** memories.

**Alzheimers** damage to basal forebrain leads to memory loss (plaques and tangles kill neurons), for both *declarative and procedural* memories (information and also ability to do everyday tasks is gradually lost).

**Amygdala** mediates emotional memories; *amygdala damage* impairs formation and retrieval of these memories.

Define **learning and memory tasks used in animals:**

- Delayed match to sample (or non-match to sample)
- Spatial location recognition memory
- Response recognition memory
- Object recognition memory

In addition to consolidation, the **hippocampus** plays a unique role in spatial navigation and learning. Cabbies in London have a *larger hippocampus* than regular drivers.

Define **long term potentiation (LTP).**

In addition to various degrees of retrograde memory disruption caused by brain injury and/or hippocampal trauma, the *retrieval* of existing memories can also be psychologically “blocked” under certain conditions of repression (e.g., hypnotic suggestion). This can probably be mediated in some cases by amygdala-based disruption of hippocampal retrieval, relating to emotional content (i.e., repression of horrifying memories).

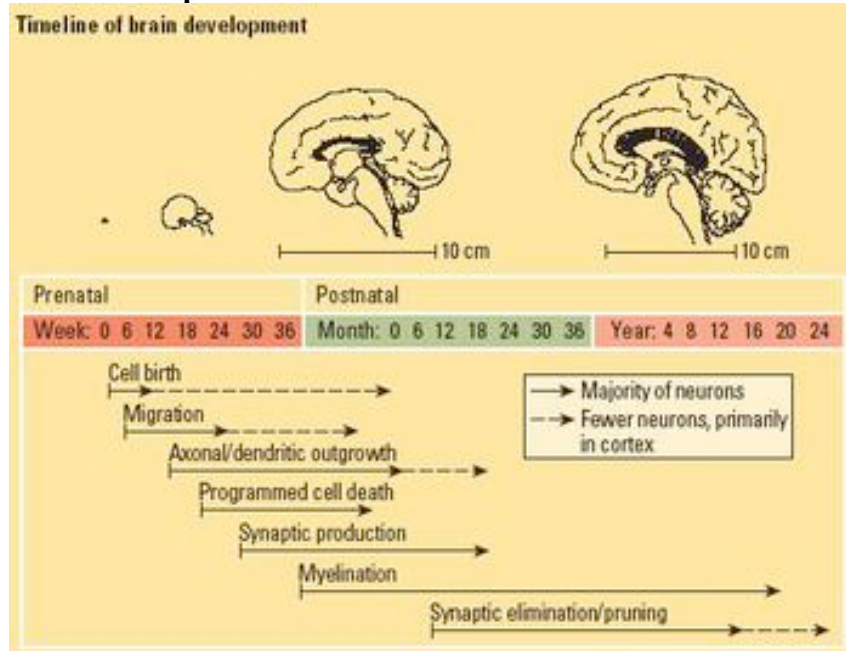
\*\*\*\*\*

## **Cognitive Neurodevelopment**

**Postnatal Behavioral Developmental domains:**

- Gross motor
- Fine motor
- Language
- Cognitive
- Social

## Brain development timeframes:



Neurogenesis (cell birth) – prenatal 0-38 weeks

Neuromigration – prenatal 4 weeks to postnatal month

Dendritic growth – prenatal week 12 to postnatal 2 years

Apoptosis – prenatal week 16 to postnatal 2-4 months

Synaptogenesis – prenatal week 24 to postnatal 2 years

Myelination – birth to 20 years

Pruning – postnatal 6 months to 20 years+

## Developmental Milestones:

1 month – poor motor development, hearing intact but vision not fully developed, rudimentary recognition of familiar sounds (parents voices) and faces

3 months – Some motor skills (grasping), social awareness of familiar figures increases

6 months – Improved motor skills (sitting, holding, rolling), improved social communication (babble, laugh, scream)

1 year – first steps, first words, increased cognitive awareness (e.g., looks for missing objects), increased social awareness (recognizes names, copies/imitates and/or responds to emotions)

## Fetal learning:

Neuronal apoptosis and synaptogenesis (i.e., circuit formation) is ongoing between 24-26 weeks through birth (last trimester). Accordingly, newborn infants can show familiarity to sounds (voices, stories) heard during this prenatal time.

**Methods for testing infants:**

- Emotional response to stimuli (likes/dislikes)
- Recognition-memory testing (memory)
- Operant head-turn and sucking paradigms – can show infants ability to discriminate stimuli based on responses, as well as likes/dislikes
- Bayley scales – developmental “tasks” normed to population
- EEG – brain wave patterns in response to stimuli

**Language re-organization in right hemisphere:**

- Major “explosion” in vocabulary between age 2-3 years
- By age 4-5, children use adult like grammar and full sentences
- Left temporal lesions (left hemispherectomy) *prior* to full language development can trigger language re-organization in the right hemisphere
- The sooner the better – adult lesions produce aphasia with minimal language recovery.