# The Neurobiology of Dreaming

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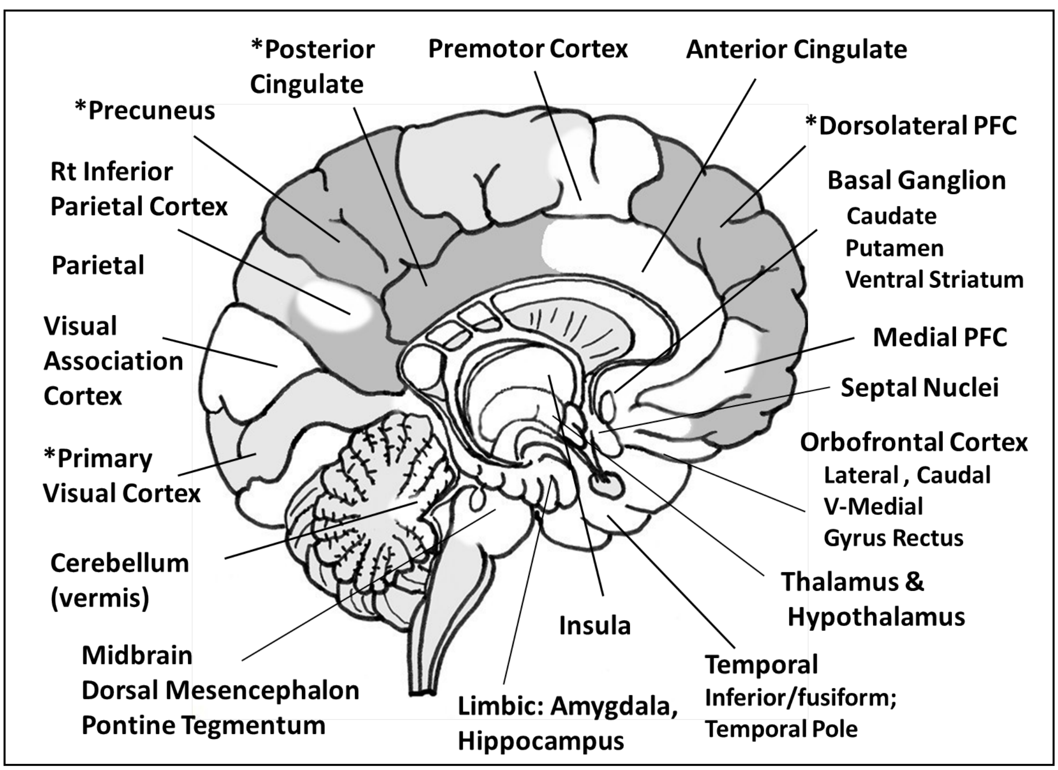
The unique state of the brain in REM sleep, when our more vivid dreams occur, appears to be involved in emotional processing and connecting new material with existing memories, often revealing these connections in the form of personally 'meaningful' picture-metaphors. The complex of active centres in the frontal regions appears to provide the cognitive capability for managing emotion, psychological restoral, conflict resolution and adaptive learning.

## The Diverse Nature of Dreaming

Dreaming occurs in many stages of sleep: hypnagogic images at sleep onset (Stage 1), NREM dreams in deeper sleep (Stages 2 and 3), and the more vivid dreams during lighter REM or paradoxical sleep. Dreams differ between REM and NREM. REM (for rapid eye movement) stages begin at roughly 90-minute intervals and are of short duration at the beginning of sleep. REM stages become more frequent and lengthy as sleep continues, REM occupies on average about 20 to 25% of our sleep time. When subjects are woken from REM sleep in laboratory studies, dreams are reported over 80% of the time. These tend to be the more vivid, highly visual, story-like dreams. During NREM periods the dreams are less frequent, often more thought-like and more like a replay or practice of prior day events. Although the function of each state is not fully understood, studies have suggested the REM stage is involved in brain development and psychological restoral and adaption as well as consolidation of procedural memories by linking distant but related emotional memories and consolidating them into a smooth narrative. The NREM state is thought to be more involved in physiological restoral and consolidation of episodic and declarative memory. Researcher Alan Hobson (Hobson et al. 2003) theorises that dreaming is a parallel state of consciousness, which is continually running but normally suppressed during waking. Ernest Hartmann (2011) contends that waking, day dreaming and the various stages of dreaming are a conscious continuum. Lucid dreaming (being aware in the dream that you are dreaming) for example appears to be a hybrid state between REM sleep and waking.

**Figure 1**: *Relatively active (white) and inactive (dark grey) centres in the brain during REM sleep derived from PET scan data (Maquet, Braun, Nofzinger and Hofle in Hobson et al. 2003).*



## Physical Manifestations of Dreams in the Brain

Researcher Alan Hobson (Hobson et al. 2003) indicates that the unique state of the brain, the combination of active and inactive regions, accounts for the unusual characteristics of dreams as well as some of the functions that psychologists have attributed to dreaming. His conclusions came from compiling neuro-imaging PET scan data from studies performed in 1996 and 1997 by four teams led, respectively, by Pierre Maquet, Allen Braun, Eric Nofzinger and Nina Hofle. These studies revealed that a great deal of our brain is active during REM sleep and dreaming. As expected, areas that regulate sleep, consciousness, alertness and metabolic function are activated (i.e., pons and midbrain, hypothalamus, and thalamus—which also provides a central relay function). High activity was seen in the limbic regions involved in emotional processing (amygdala and hypothalamus) and short- to long-term memory consolidation (hippocampal regions). Adjacent regions involved in emotional control, fear extinction and reward-based adaptive action planning and learning functions (basal ganglia, medial prefrontal, anterior cingulate, lateral, medial and caudal orbital, and infralimbic) were also activated (to be discussed later). Regions involved in perception of the dream were active. Although the primary visual cortex and much of the parietal cortex remains inactive, activity is heightened in the visual association cortex, which processes imagery associations, and the right inferior parietal cortex, which organises the imagery into a visual space. Other fictive sensory dream experiences may be due to internally stimulated activity in the vermis cerebellum and other motor and sensory regions as well as activity in the temporal areas involved in facial recognition, auditory processing and episodic recall. Areas that are deactivated include functions such as rational thought and linear logic (the dorsolateral prefrontal cortex) and episodic memory (precuneus and posterior cingulate). As Braun (Braun et al. 1997) puts it, dreaming is a "state of generalised brain activity with the specific exclusion of executive systems".

In NREM sleep these same studies indicate that executive activity remains diminished in the dorsolateral prefrontal cortex as in REM. As opposed to REM, however, there is a decrease in activity in the midbrain, thalamus and cerebellum as well as areas involved in emotional processing and analogical decision-making and learning (amygdala, hypothalamus, basal ganglia, anterior insula, medial prefrontal cortex, orbitofrontal regions, right temporal lobe and pole, and basal forebrain). While activity in NREM decreases in one area of imagery formation (the right inferior parietal cortex), it increases in the visual association and primary visual cortices. Brain activity also increases in the left parietal region and left temporal lobe, both of which are involved in activities such as contemplating distance, recognition of known faces and accessing word meaning.

During lucid dreaming, the normally REM inactive regions of the prefrontal cortex, which control logical reasoning and executive decision-making, become activated, and EEG tracings become similar to those of the waking state. PET scans indicate a greater sense of control over the dream (lucidity) when the medial frontal cortex (involved in consciousness) is active and the amygdala (involved in emotion) is dampened. Conscious control is real, as shown in studies by Stephen LaBerge (1981) who discovered that lucid dreamers could communicate with researchers in the outside world by moving their eyes or flexing their muscles in predetermined patterns.

## The Theoretical Functions of Dreaming

Whether the dream itself has a function, or is simply a reflection of processing taking place within active centres of the brain during REM, remains controversial. What is becoming apparent, however, is that the known processing capabilities of those centers that activate during REM sleep can be observed to a degree in the content of the dreams.

### *Dreams as an Expression of the Unconscious*

The majority of the centres of the brain that are active during REM are those which process material unconsciously or prior to their output becoming conscious. This supports Sigmund Freud's (1900) and Carl Jung's (1971) claims, respectively, that dreams are the "royal road to the unconscious" and "the most readily accessible expression of the unconscious". Jung (1973) observed the language of the unconscious to be symbolic, an "emotionally charged pictorial language" where a conscious event can express its unconscious meaning. This non-rational, figurative nature of dream imagery is due in part to the lack of a rational reference (deactivated dorsolateral prefrontal cortex) and the visual activity taking place in the visual association cortex and right inferior parietal cortex. These regions form picture associations with the emotions, memories and conceptualisations processed within and organise them into a dream space. Hartmann (2011), states that the dream, especially the "central image", pictures the emotion of the dreamer—the intensity of the image being a measure of the strength of the emotion. The meaning of the dream, therefore, may lie in the personal associations each visual construction represents. Fritz Perls (1976), a founder of Gestalt Therapy, understood this well and asked clients to role-play or "become" the images in their dreams, urging them to experience that "thing" in the dream and express the emotions it contains.

### *Emotional Processing*

High limbic activity has lead researchers to conclude that dreams selectively process emotionally relevant memories via interplay between the cortex and the limbic system (Seligman & Yellin 1987) and that the amygdala "orchestrates" the dream activity, integrating dream emotion with dream action (Dang-Vu et al. 2007). The effect of dreams on managing emotion has long been suspected. Freud suggested that bad dreams let the brain learn to gain control over emotions resulting from distressing experiences. This emotional regulation may result from an activity in REM described by Els Van der Helm et al. (2011) who proposes that adrenergic neurotransmitters coupled with activation of the amygdala-hippocampal networks, (re)process and depotentiate previous emotional experiences, decreasing their emotional intensity.

Nightmares are the extreme. Although negative emotion appears more frequently than positive emotion (likely due to high limbic activity), we do not usually report the dream as a nightmare unless it is extremely upsetting, contains overwhelming anxiety, apprehension or fear. Nightmares have a number of causes including:

- heavy emotional stress
- severe threat to self or self image
- unresolved or extreme trauma (PTSD)
- long-term psychological problems
- the influence of certain drugs
- emerging medical problem requiring attention, or
- sleep disorders affecting REM/NREM balance

Stanley Krippner et al. (2012) states that PTSD-related nightmares are not characterised by metaphor but are instead life-like replays of the event and are, therefore, not treated by interpreting the narrative or imagery. Therapy involves "modifying the nightmare (imagery rehearsal therapy) and resolving the issues it presents". Alan Siegel (2012) indicates that recovery (mastery) can be seen as the nightmares begin to incorporate images from the present and the pre-trauma past and include more figurative imagery and metaphors.

### *Problem Resolution and Psychological Restoration*

As indicated previously, a number of cognitive frontal regions of the brain are highly active in REM. This suggests that the dreaming brain may be capable of problem resolution, psychological restoration and learning. Ernest Hartmann (2011) finds that the "broad, loose connections of dreaming can provide a different perspective and can help us make important decisions and discoveries". The creative, problem-solving history of dreams is also well documented by Deirdre Barrett (2001) who researched the many inventions and artistic creations that have originated within dreams.

Jung (1973) indicated that dreams restore psychological balance by recognising and compensating for misconceptions in order to bring our awareness back to reality and/or to warn of the dangers of our present course. Alfred Adler suggested that dreams solve problems by diverging from rational logic towards an inner logic, driven by emotion, that either reinforces or inhibits the contemplated action. Coutts (2008) agrees, stating that dreams improve the mind's ability to meet waking human needs by testing dream scenarios and adapting or rejecting them, depending on their outcome. A study by McNamara et al. (2002) demonstrated that the cognitive operations in dreams may function to identify norm violations and generate counterfactuals ('what-if' scenarios that, in effect, compensate for the violation). Many psychologists believe dreams serve an adaptive function such as adapting to emotional stress (Stewart & Koulack 1993), threat rehearsal for purposes of survival (Revonsuo 2000), or practicing physical, intellectual and social skills needed in waking life (Blackmore 2004).

Dreams may also help bring about our psychological growth and maturation. Jung (1971) claimed that dreams provide a 'transcendent' function, which brings about new awareness and a more integrated personality (a process he called "individuation") whereby gradually a wider and more mature personality emerges. Others agree that dreams help develop the ego (Jones 1962) and integrate our fragmented personalities (Perls 1976). David Feinstein (1990) describes how dreams either find a way to accommodate new material into our internal model ('old myth'), strengthen an unconscious 'counter myth', or creatively develop a 'new myth' (new model) that better accommodates internal and external reality. Hartmann (2011) characterises dreams as an emotionally guided, hyper-connective mental function—which is "in part how the brain learns"—organizing memory based on what is emotionally important to us, creating new connections, and weaving new material into established memory to arrive at new insights.

### *Neurobiological Basis for Dream Cognition*

A compilation of neurological studies (Hoss 2013) suggests that a networking between REM-active frontal regions might provide many of the cognitive functions referenced above. For example, the anterior cingulate is found to be involved in:

- monitoring anomalies and initiating action to resolve conflicting perceptions
- mediating resolution by anticipating consequences based on experience or imagined outcomes (dream scenarios)
- selecting a response based on valuing the reward
- monitoring the outcome, and
- adapting behaviour based on that outcome.

The anterior cingulate also networks to perform these activities with other adjacent structures including:

- the basal ganglion, which is involved in novelty detection, motivation, deciding which of several possible behaviours to execute, and reward-based adaptive action planning and learning
- the lateral and caudal orbitofrontal cortex, which are involved in emotion control, regulating planning behaviour based on reward, cognitive empathy, and personal social behaviour and decision making)
- the medial prefrontal cortex, which is involved in goal-directed behaviour, social and self referential activities, self monitoring of learning, and our 'sense of knowing'
- the infralimbic region which is involved in fear extinction, and
- the hippocampal and entorhinal structures, which provide memory consolidation, optimisation, encoding and retrieval functions, as well as extinction learning, are active.

## Conclusion

In summary, the capability may exist for our dreaming mind to not only make new connections and reveal them in personally 'meaningful' picture-metaphors, but also to dampen emotional response and bring about conflict resolution or adaption to external threats by: recognising anomalies, conflicting perceptions and threats to our inner sense of self; mediating a resolution by creating and testing imagined outcomes in the form of dream scenarios; selecting a scenario based on achieving the anticipated rewards; and emotionally reinforcing certain scenarios, thus encoding the result in memory as new learning.

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