A Chemical "Interpretation of Dreams"

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Summary. Dreams could be considered as snippets of memory processed during sleep, to optimize conscious behavior. To comprehend the process of dreaming, one needs to clarify how memory is enabled. We discuss various proposals that were forwarded to clarify the physiologic basis of dreaming. Curiously in an age when mood altering drugs are the rage, psychoanalytic discussions of dreams, a la Freud, have avoided grappling with the neurochemical processes underlying the recall of dreams. We propose that dreams are derived from memory based on a chemically-based coding mechanism. The *tripartite* mechanism of memory involves the dynamic interactions of neurons with their surrounding extracellular matrix (nECM). Dopants (metal cations and neurotransmitters (NTs)) enable a chemical code, comprising metal-centered complexes representing cognitive units of information (*cuinfo*), with emotive states encoded by neurotransmitters (NTs). The neuron can decode the *cuinfo* as the basis of the memory that fuels dreams. Such a chemodynamic process is physiologically credible in that it involves materials and processes available to the neural net. During sleep dreaming, the chemodynamic "reading" of memory units (i.e. *cuinfo*) is disordered, scrambled and distorted. Sets of memory units (*cuinfo*) are decorated with NTs, to encode emotive states. Like a deck of randomly dealt cards, the neural "reading" of the *cuinfo* occurs without reference to temporal sequence or logical order. Rather, the integrated "emotive weight" of the *cuinfo* complexes determines their existential import during the dreaming process. Similarly, those with greater "emotive weight" are more likely to exert greater import in recall. Ultimately, the brain's "affective calculus" during subsequent consciousness determines the dream's impact and interpretation.

Keywords: Metal complexes, neurotransmitters, extracellular matrix, emotions, memory

"... each of us remembers and forgets in a pattern whose labyrinthing windings are an identification mark no less distinctive than a fingerprint".

Philip Roth - American Pastoral

"The pendulum of the mind oscillates between sense and nonsense, not between right and wrong."

C.G. Jung, Memories, Dreams, Reflections

"What takes us back to the past, are the memories. What brings us forward, is our dreams."

Jeremy Irons, actor

"Memories makes us who we are, and dreams makes us who we will become.

unknown

1. Background

Historically in many societies, dreams were considered to be revelations, harbingers of the future, messages from a higher being. For example, the Bible describes the dream of Jacob as he was fleeing from the wrath of his brother Esau. He dreamt of a pair of ladders with Angels ascending and descending from the earth to heaven.

Years later, Pharoh dreamt of 7 healthy cows being swallowed whole by 7 lean cows. Joseph, the young son of Jacob, interpreted this dream as predicting that Egypt would be visited by 7 years of plenty, followed by 7 years of famine and want (Bible Genesis).

The book of Daniel also describes the dreams of 4 (sequential) rulers of Babylon, Nebuchadnezer, Belshazzar, Darius the Mede and Cyrus (Xerxes) of Persia. Daniel's interpretations of their dreams were considered as prophesies of the future, which some consider as setting the stage for the Christian revelations of the New Testament (Bible Daniel).

Greek Oracles had dreams, on which they based prophesies and guidance. It was recently found that the oracular dreams may have been instigated by petrochemical fumes (i.e. ethylene, butanes, etc.) emanating from underground petrochemical pools (Broad 2002; Spiller et al, 2008).

Sigmund Freud amplified on the dream state and infused it with motivational drives such as wishes, sibling rivalry, sexual fantasies, angst toward parents and tabooed desires. His concept of the dream inspired many followers who termed themselves "psychoanalysts" (Freud,1900; Crew, 1995; Solms, 2004). But Freudian analyses did little to establish the physiologic or neurochemical basis of dreams.

Dreams could be considered as snippets of memory processed to optimize conscious behavior. A function of dreaming could be to simulate (imagine) threatening events, to aid in planning threat-avoidance strategies (Revonsuo, 2000). In that context, nightmares might be considered as imagining situations to avoid (Robson & MacCarley 1977; Leung, & Robson, 1993). Possibly, REM-dreaming might have a function in memory processing. Dreaming could be considered to be a psychic process in which memories acquired during conscious awareness are reviewed during sleep.

Others have explained how the dream state is enabled in specific anatomic compartments of the brain (i.e. amygdala,

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thalamus, visual cortex) (LeDou, 2002). But an anatomic scale seems too gross to capture the encoding of emotive mental states and memory.

2. Dream Traits

In a related topic, do animals dream? Work with rats, flies and bees (Broadie et al, 2011; Melnattur et al, 2015; Blumberg et al, 2018) suggest that dreams are a phylogenetic inheritance of neural creatures. Our dog seems to dream… makes noises and moves his paws while sleeping…seeming to chase cats. In any case, it seems reasonable to suppose that animals do dream. Thus, a mechanism of dreaming of non-verbal creatures could credibly have evolved to humans.

Many words have been expended in trying to "psycho-analyze" the meaning of the dreams experienced by humans during sleep. Emotive states are considered to be central to dreams, modulated ("repressed" or "inhibited") by memories (Freud, Jung, etc). But Freud's psycho-analytic approach has been undercut by doubts about this pseudo-scientific methods and of the self-interest of its founder and his followers (Freud,1900; Crew, 1995). Curiously in an age when mood-altering drugs are the rage, "psycho-analytic" discussions have avoided grappling with the neurochemical processes underlying neural recall and dreams (Hobson, 1994).

Experiments in Robotics seems to confirm such an idea. Robots equipped with an algorithm that inferred their own physical structure from their memory of prior actions were considered to be capable of "dreaming " (Adami, 2006; Bongard et al., 2006). Such robots performed better at adjusting their gait to compensate for changed circumstances, such as losing one of four limbs. They could diagnose and recover from damage to perform better.

Possibly, the dreams of humans could be considered in that light. Of course, one cannot overlook the emotive aspect of dreams. Indeed, dreams may turn logic around, mixing up the timing of events and transposing places and characters. But their emotive qualities ring true. Regardless of logical inconsistency, the emotive quality of a dream make it seem real and credible.

Characteristic traits of dreams:

Distortions of shape
Forced perspectives
Juxtapositions of logically unrelated elements
Temporal disordering
Emotive states (fear, anxiety, love, hate)
Wishes/desires

3. Memory and Dreams

It has been said that "*biology is chemistry*". Indeed, chemical terms and concepts are used to describe many biological processes (such as metabolism, photosynthesis, blood coagulation, reproduction, etc.); they are the basis for modern medical practice and at the core of biological considerations of life processes. The sole exception has been the realm of memory. In spite of the panoply of drugs that affect mental states and moods, there is great denial that chemical processes underlie mental talents.

For example, engrams, the physical traces of neural memory, were first conceptualized by Semon ~1900 (Semon,1923; Lashley,1950; Schacter, 2001; Bruce, 2001; Kwon & Choi, 2009; Josselyn et al, 2015; Kim et al, 2018). But their physicality was elusive. Lashley looked for the engram in different brain compartments for 30 years, but concluded that it was dispersed within the brain. A later generation of neurobiologists identified "engram neurons" (Hsiang et al, 2014; Tonegawa, 2015; Kitamura et al, 2017). The underlying premise was that cognitive information could be encoded and stored as synaptic connections between sets of such neurons. Better "connections" were presumed to equate with increased synaptic functionality, manifest as recall.

But such presumption is fanciful, not grounded in the practice of synthetic memory chips. For example, there is no model for binary information storage as synaptic contacts between processors in memory chips. Rather, chip memory is stored within the matrix (i.e. Si) comprising the chip, encoded by the distribution of dopant metals, readable as 0 or 1 (Di Ventra & Pershin, 2011; Chua, 2011; Zhou et al, 2014).

Where does this leave "cognitive information" (cog-info) as distinct from "information"? Descriptions of neural memory mechanisms must diverge from those of computer memory in that they need to account for the emotive states achieved by neural nets. "Information Theory" based on binary coding is inadequate. The point has been made that unlike "information" which is "demotive", the cognitive information" (cog-info) of the neural net is laden with emotive content for which one must account, to achieve a satisfactory rationalization of neural memory and related expressions, such as dreams.

4. Mechanism

In that we are interested in the physiologic mechanism of neural memory, the term "mechanism" also requires clarification. The word conjures up *mechanical constructs* like gears, pulleys, springs, planes and levers. But Robert Boyle, one of the fathers of chemistry, used this term to focus on essential qualities of "matter and motion". He viewed gases as kinetic atoms, whose "mechanical" collisions were the basis for gas pressure, formulated today as Boyle's Ideal Gas Law.

Boyle entitled his writings on corposcular matter (*prima naturalia or minus naturalia*), as a "Mechanical Philosophy" (Klaas, 2013; Roux & Garber, 2013). But there are no visible moving mechanical parts in chemical transformations. Modern chemists employ the word "mechanism" to describe the stages of a molecular process, such as the synthesis of a "product" from known "reactants", or the redistribution of electrons from one local orbit to a resonant larger area, to form various types of bonds (single, double and triple bonds, resonance, aromaticity).

***Tripartite* mechanism of neural memory** (Marx & Gilon, 2018-2020). We enlist the concepts and iconographies of chemistry to describe the encoding of cognitive information (cog-info) which engender units of emotive memory and dreams. The tripartite mechanism of memory describes the dynamic interactions of 3 physiologic compartments comprising:

- neurons – arborized cells with much exposed, surface which perform as "microprocessors". They are organized as circuits which can synaptically transfer dynamic electrodynamic signals to organs and tissues far from the brain.

- neural extracellular matrix (nECM) – a heterogeneous poly-anionic hydrogel lattice of polysaccharides and proteins embedding the neurons (Bandtlow & Zimmermann, 2000). It serves as the neuron's "library".
- dopants – metals and neurotransmitters (NTs) released from neural vesicles, to form metal-centered complexes within the nECM, the neural memory code.

The entities formed by the complexation of the nECM with metals and NTs (dopants), which encode cognitive units of information (*cuinfo*), are chemo-graphically represented below (Figure 1).

The *cuinfo*, analogous to a binary bit, can be considered as the quantal physical trace of memory. Like a pixilated TV image or an algorithm comprised of 0 & 1, neural memory is due to the integration/consolidation of many such sets of *cuinfo* to form a comprehensible pattern of recall.

A dream could be considered as a collage, an arbitrarily ordered sequence of memories that don't necessarily replay the temporal sequence. The logic of the dreamt sequences is irrational. Rather, their affective import is established by the cumulative weight of emotive signals associated NTs complexed to the *cuinfo* sets (Figure 1). During conscious recall of the dream, it is interpreted in conformance to the "affective logic" of the awakened dreamer.

Most dreams are visual replays, though there may be auditory and gustatory recalls, overlayed with as emotive associations (fear, love, anxiety, hate, etc.). These all may also be subject to distortions (magnification, diminution, skewing, forced perspectives) as well as odd juxtapositioning, resulting in "surrealistic" memory experiences.

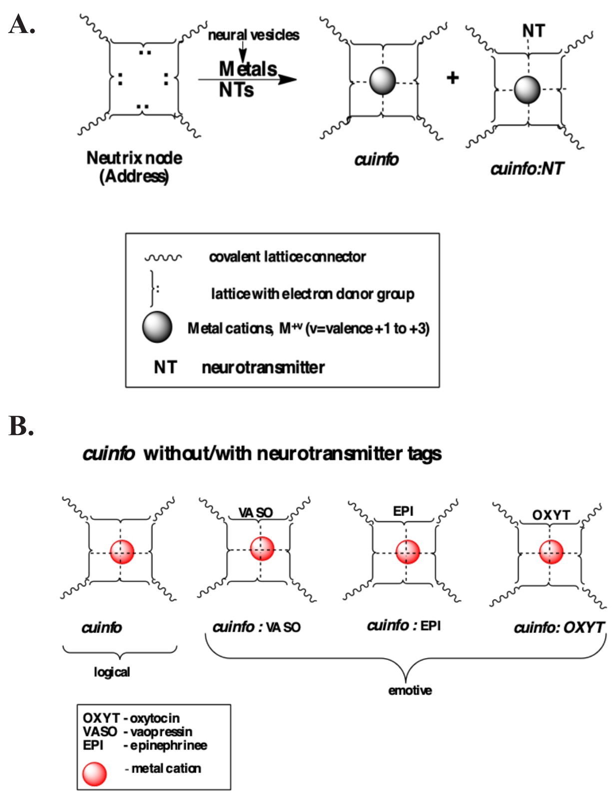

Figure 1. A,B. Chemographic representations provides a shorthand for considering the chemical types of cuinfo that can be formed through metal binding with neurotransmitters (NTs), the molecular conveyors (encoders) of emotions.

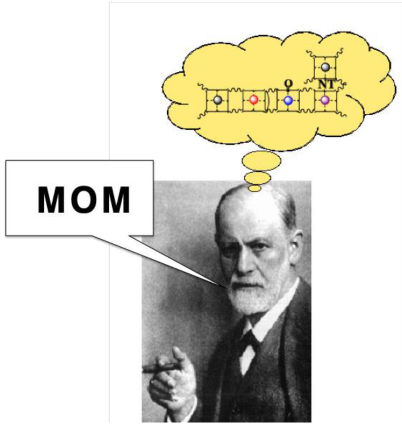

Figure 2. A schematic portrait of Freud, illustrating that his anecdotal ideas of dreams are caused by the chemo-dynamic (tripartite) mechanism of memory occurring in his own brain.

5. Forgetting (Freud)

In the absence of a mechanistic explanation, the process that governs dreams has remained obscure, the purvue of psychoanalysts, though there have been attempts to reconcile psychiatry with neurochemistry and neurobiology (Loftus & Loftus, 1980; Payne & Nadel 2004; Kandel et al, 2014; Asok et al, 2019).

The Freudian "psycho-analytic" approach to memory recall and loss is incomplete. It only relates to verbal humans and ignores all other sentient creatures that also remember, learn, forget and possibly dream (Figure 2, Freud, 1900). It contributes little to the comprehension of memory processes of all animals.

6. Forgetting (tripartite)

The tripartite mechanism of memory formation, retention and loss focuses on biochemical processes, particularly complexation, dissociation and crosslinking.The stability of the *cuinfo* is dictated by the composition of the "address". Monovalent metal (Na^+, K^+ , Li^+) complexes are unstable and readily dissociate. Divalent metal complexes are much more stable but their stability varies with the composition of the "address". For example, work with impedimetric electrodes coated with tetrasaccharide analogues of the nECM showed variable selectivity for different metal cations (i.e. Pb^{+2}, Cd^{+2}, Hg^{+2}) depending on the specifics of the sulfation pattern (Alishensky et al, 2019).

As the formation of metal complexes are inherently reversible reactions, unstable monovalent metal complexes could be relevant to short-term memory (STM) whereas more stable divalent metal complexes could be relevant to long-term memory (LTM).

Other factors also impinge on these reactions. For example, complexation with a NT would render the [*cuinfo*:metal:NT] complex more stable, but still not persistent as it could eventually dissociate with resultant memory loss. There are cross-linking reactions induced by enzymes (transglutaminases) or free radical reactions, which render the *cuinfo* complexes persistent and less susceptible to degradative processes, thus capable of retaining LTM. In short, forgetting could be ascribed to chemical dissociation or the degradation of the nECM in which the memory units are encoded.

While the proposed *tripartite* mechanisms does not constitute proof, it has great explanatory power, as it is consonant with the perspective of biologic evolution (Roshchin, 2010) and neurophysiology. Moreover, it identifies NTs as capable of eliciting physiologic reactions as well as encoding mental states recalled as “emotions”.

7. Conclusion

Dreams may be assemblages of thought elements that convey no information; they may be just noise.

Medawar (Medawar, 1967, p 88).

Medawar’s comment may help focus on the phenomenon of dreams through the lens of the *tripartite* mechanism, as follows: When one sleeps, the neural net continuously reviews the library of *cuinfo* surrounding the neurons, but without the intervention of the logical processes that confer causality and temporal order to experience during consciousness.

We are not ferro-silico robots operating in a mechano-electric sense. Rather, we are chemo-dynamic “golems” of flesh and blood, imbued with emotions that render value and meaning to our experiences. Recall that the original “golem of Prague” was made of clay, and had the word TRUTH inscribed in his mouth, instructed to save the Jews of Prague from pogroms. We too have been constructed from earthly clay, imbued by the elemental truth of the periodic alphabet that has been inserted into the very fabric of our material being.

Memory is a key talent that impacts on our ability to remember to survive. Here, we attempt to untangle some aspects of memory, as during conscious awareness or as a result of dreaming. While the proposed *tripartite* mechanism of neural memory and its heuristic implications does not constitute proof, it permits one to characterize the “engram”, the physical trace of memory first hypothesized by Richard Semon as a metal-centered complex (Figure 1).

Like the “bit” of computer memory or a pixtel of a video image, the *cuinfo* has no meaning on its own…it must be read as part of a set that is recognized as a meaningful pattern. The collective “weight” (meaning) of a particular set of *cuinfo* is established by the NTs which confer the emotive import, though we have no clue as to how molecular weighting is achieved. Consider that during the conscious (awake) state, the neural creature is presented by a variety of affective stimuli. It remains a puzzle how different emotive states (pain, love, hunger, fear, etc.) become integrated in memory resulting in definitive action and dreams.

Ultimately, solving the NT “affective calculus” during consciousness determines the survival of all neural creatures. The *tripartite* mechanism achieves a unitary view of psychology and physiology, as it pertains to memory and dreams.

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By GM: In memorium to my late wife, the artist Georgette Batlle (1940-2009), my muse. Thanks to my companion Karine Ahouva Leopold (Jerusalem, Paris) for bringing me to Tango and introductions to people and places.

GM CG: We note that Professor Gallistel’s (Rutgers University) remarks on our early manuscripts drew our attention to “memory” as the proper focus of our speculations.

Conflict of Interest

GM is a founder of MX Biotech Ltd., with the commercial goal to develop new “memory materials” and devices.

CG is an emeritus professor at the Institute of Chemistry, The Hebrew University of Jerusalem. He is active in developing technologies for the conversion of peptides and active regions of proteins into orally available drugs.

Notwithstanding, the ideas forwarded here are scientifically genuine and presented in good faith, without commercial clouding of the concepts expressed therein.

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