Memory, Sleep & Dreams

Sidarta Ribeiro, Ph.D.

Collège de France, 14 février 2025

Sonho (I see myself) by Kerexu Martin

INSTITUTO DO CÉREBRO

UFRN
UNIVERSIDADE FEDERAL DO RIO GRANDE DO NORTE

Yves Frégnac
(1951-2024)


The Sleep Cycle
REM
N1
N2
N3
Vivid Dreaming
Light sleep
Deep sleep

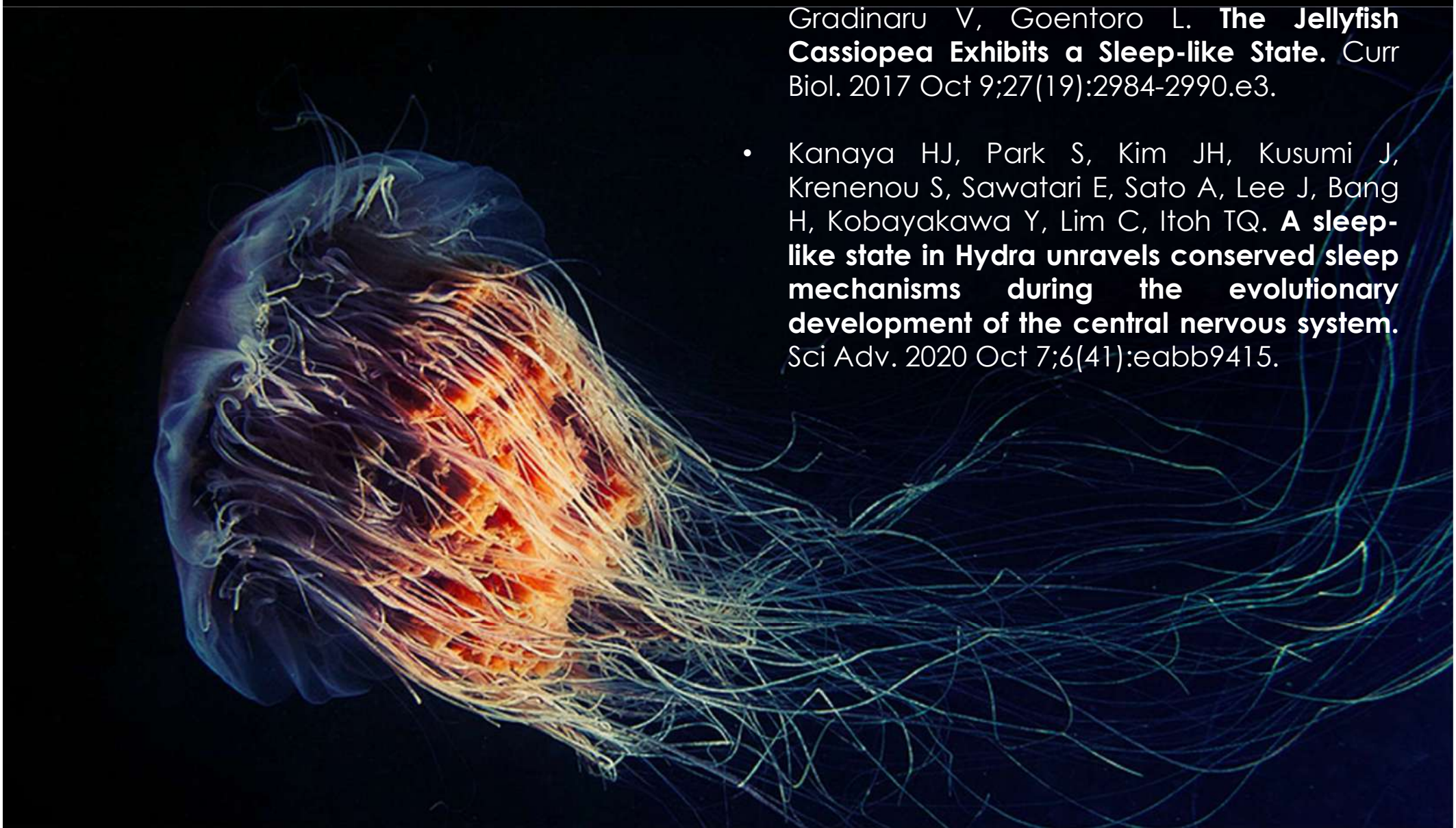
La Bohémienne Endormie, Henri Rousseau

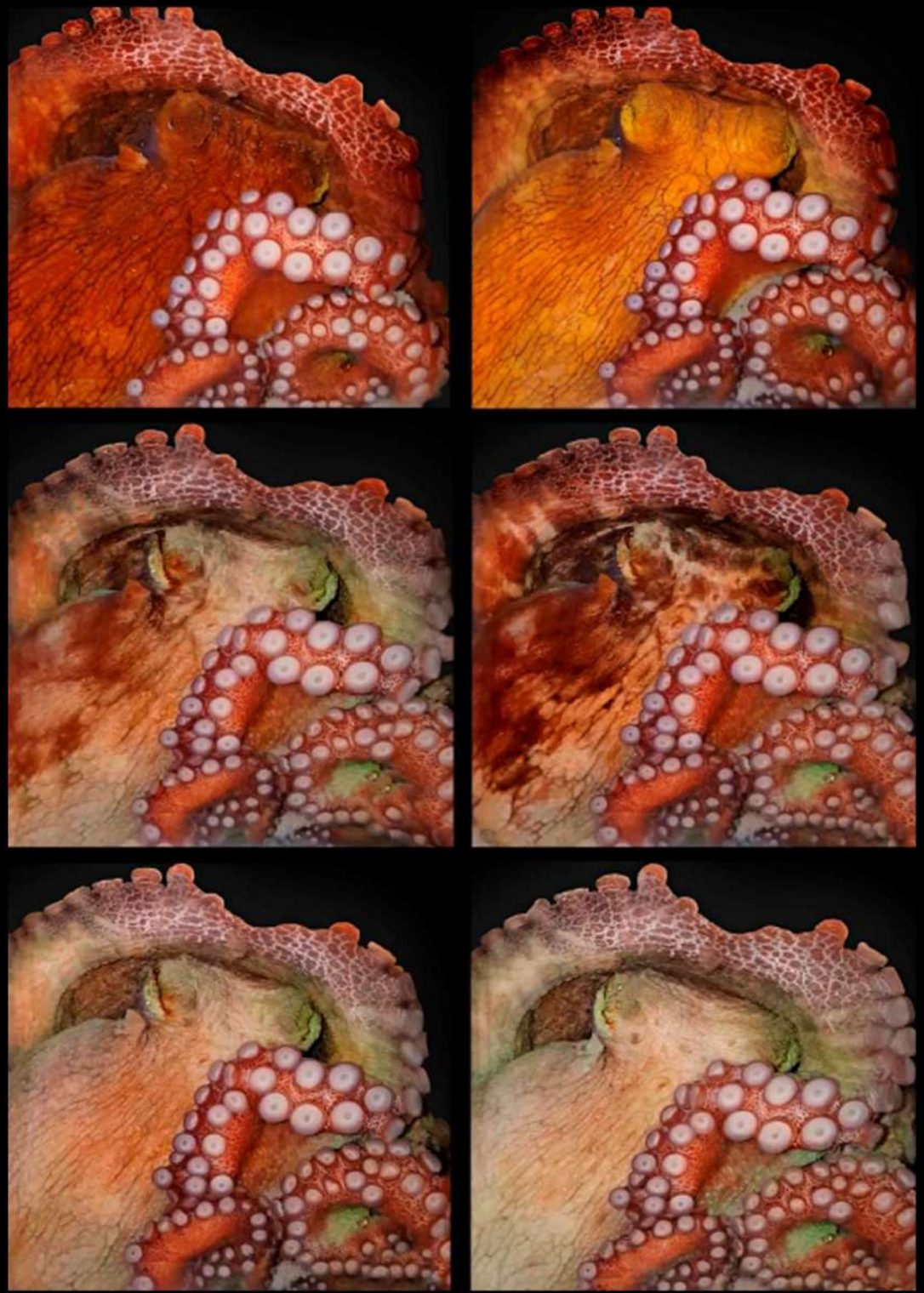
~560 million years
Earliest cnidarian ancestor

QUIET SLEEP

- Nath RD, Bedbrook CN, Abrams MJ, Basinger T, Bois JS, Prober DA, Sternberg PW, Gradinaru V, Goentoro L. **The Jellyfish Cassiopea Exhibits a Sleep-like State.** Curr Biol. 2017 Oct 9;27(19):2984-2990.e3.

- Kanaya HJ, Park S, Kim JH, Kusumi J, Krenenou S, Sawatari E, Sato A, Lee J, Bang H, Kobayakawa Y, Lim C, Itoh TQ. **A sleep-like state in Hydra unravels conserved sleep mechanisms during the evolutionary development of the central nervous system.** Sci Adv. 2020 Oct 7;6(41):eabb9415.





~490 million years
Earliest cephalopod ancestor

QUIET + ACTIVE SLEEP

- Brown ER, Piscopo S, De Stefano R, Giuditta A. **Brain and behavioural evidence for rest-activity cycles in Octopus vulgaris.** Behav Brain Res. 2006 Sep 25;172(2):355-9.

- Medeiros SLS, Paiva MMM, Lopes PH, Blanco W, Lima FD, Oliveira JBC, Medeiros IG, Sequerra EB, de Souza S, Leite TS, Ribeiro S. **Cyclic alternation of quiet and active sleep states in the octopus.** iScience. 2021 Mar 25;24(4):102223.

- Pophale A, Shimizu K, Mano T, Iglesias TL, Martin K, Hiroi M, Asada K, Andaluz PG, Van Dinh TT, Meshulam L, Reiter S. **Wake-like skin patterning and neural activity during octopus sleep.** Nature. 2023 Jul;619(7968):129-134.

~407 million years
Earliest insect ancestor

QUIET + ACTIVE SLEEP

- Shaw PJ, Cirelli C, Greenspan RJ, Tononi G. **Correlates of sleep and waking in Drosophila melanogaster.** Science. 2000 Mar 10;287(5459):1834-7.
- Hendricks JC, Finn SM, Panckeri KA, Chavkin J, Williams JA, Sehgal A, Pack AI. **Rest in Drosophila is a sleep-like state.** Neuron. 2000 Jan;25(1):129-38.
- Tainton-Heap LAL, Kirszenblat LC, Notaras ET, Grabowska MJ, Jeans R, Feng K, Shaw PJ, van Swinderen B. **A paradoxical kind of sleep in Drosophila melanogaster.** Curr Biol. 2021 Feb 8;31(3):578-590.e6.

315 million years
Earliest reptile ancestor

QUIET + ACTIVE SLEEP

- Shein-Idelson M, Ondracek JM, Liaw H-P, Reiter S, Laurent G. **Slow waves, sharp waves, ripples, and REM in sleeping dragons.** Science. 2016;352:590–595.

- Libourel PA, Barrillot B, Arthaud S, Massot B, Morel AL, Beuf O, Herrel A, Luppi PH. **Partial homologies between sleep states in lizards, mammals, and birds suggest a complex evolution of sleep states in amniotes.** PLoS Biol. 2018 Oct 11;16(10):e2005982.

- Albeck N, Udi DI, Eyal R, Shvartsman A, Shein-Idelson M. **Temperature-robust rapid eye movement and slow wave sleep in the lizard Laudakia vulgaris.** Commun Biol. 2022 Nov 29;5(1):1310.

~160 million years
Earliest bird ancestor

QUIET + ACTIVE SLEEP

- Dewasmes G, Cohen-Adad F, Koubi H, Le Maho Y. **Polygraphic and behavioral study of sleep in geese: existence of nuchal atonia during paradoxical sleep.** Physiol Behav. 1985 Jul;35(1):67-73.
- Low PS, Shank SS, Sejnowski TJ, Margoliash D. **Mammalian-like features of sleep structure in zebra finches**. Proc Natl Acad Sci U S A. 2008 Jul 1;105(26):9081-6.
- Libourel, P. A. et al. **Partial homologies between sleep states in lizards, mammals, and birds suggest a complex evolution of sleep states in amniotes.** PLoS Biol. 16 (2018).

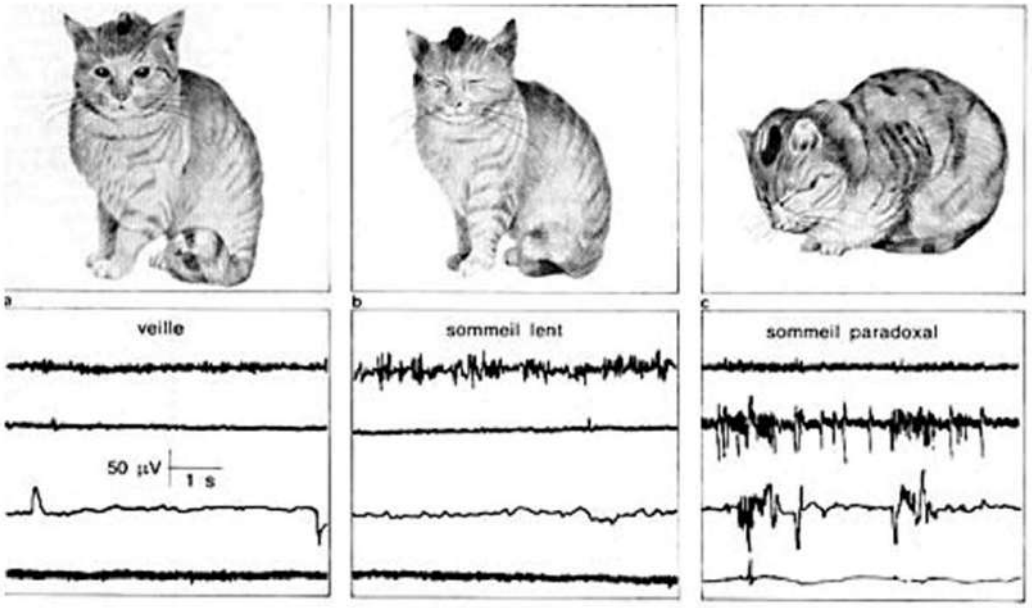
~220 million years
Earliest mammalian ancestor

QUIET + ACTIVE SLEEP

- Aserinsky E, Kleitman N. **Regularly occurring periods of eye motility, and concomitant phenomena, during sleep.** Science. 1953 Sep 4;118(3062):273-4.
- Jouvet M, Michel F, Courjon J. **L'activité électrique du rhinencéphale au cours du sommeil chez le chat.** C R Seances Soc Biol Fil. 1959;153(1):101-5.
- Vanderwolf CH. **Hippocampal electrical activity and voluntary movement in the rat.** Electroencephalogr Clin Neurophysiol. 1969 Apr;26(4):407-18.
- Timo-Iaria C, Negrão N, Schmidek WR, Hoshino K, Lobato de Menezes CE, Leme da Rocha T. **Phases and states of sleep in the rat.** Physiol Behav. 1970 Sep;5(9):1057-62.

Non-human mammals seem to **dream** during REM sleep

Michel Jouvet,
1925-2017



- Jouvet M, Michel F. **Corrélations électromyographique du sommeil chez le chat décortiqué et mésencéphalique chronique.** C R Seances Soc Biol Fil. 1959;153(3):422-5.
- Jouvet M, Michel F, Courjon J. **Sur la mise en jeu de deux mécanismes à expression électro-encéphalographique différente au cours du sommeil physiologique chez la chat.** C R Hebd Seances Acad Sci. 1959 May 25;248(21):3043-5.
- Jouvet M, Jouvet D, Valatx JL**. Etude du sommeil chez le chat pontique. Sa suppression automatique.** C R Seances Soc Biol Fil. 1963 Aug 31;157:845-9. French. PMID: 14081746.
- Jouvet M, Delorme F. **Locus coeruleus et sommeil paradoxal.** C R Séances Biol 1965; 159: 895-899.

Valli K, Revonsuo A, Pälkäs O, Ismail KH, Ali KJ, Punamäki RL. **The threat simulation theory of the evolutionary function of dreaming: Evidence from dreams of traumatized children.** Conscious Cogn. 2005 Mar;14(1):188-218.

The nightmare, Henry Fuseli

The nightmare as an ancestral dream type, capable of **warning** against possible dangers

Dream, Grete Stern

- Between 30% and 50% of reported dreams include some type of **negative emotion**, such as anxiety, fear or stress.
- **Nightmares** occur weekly in 4%-10% of the population.

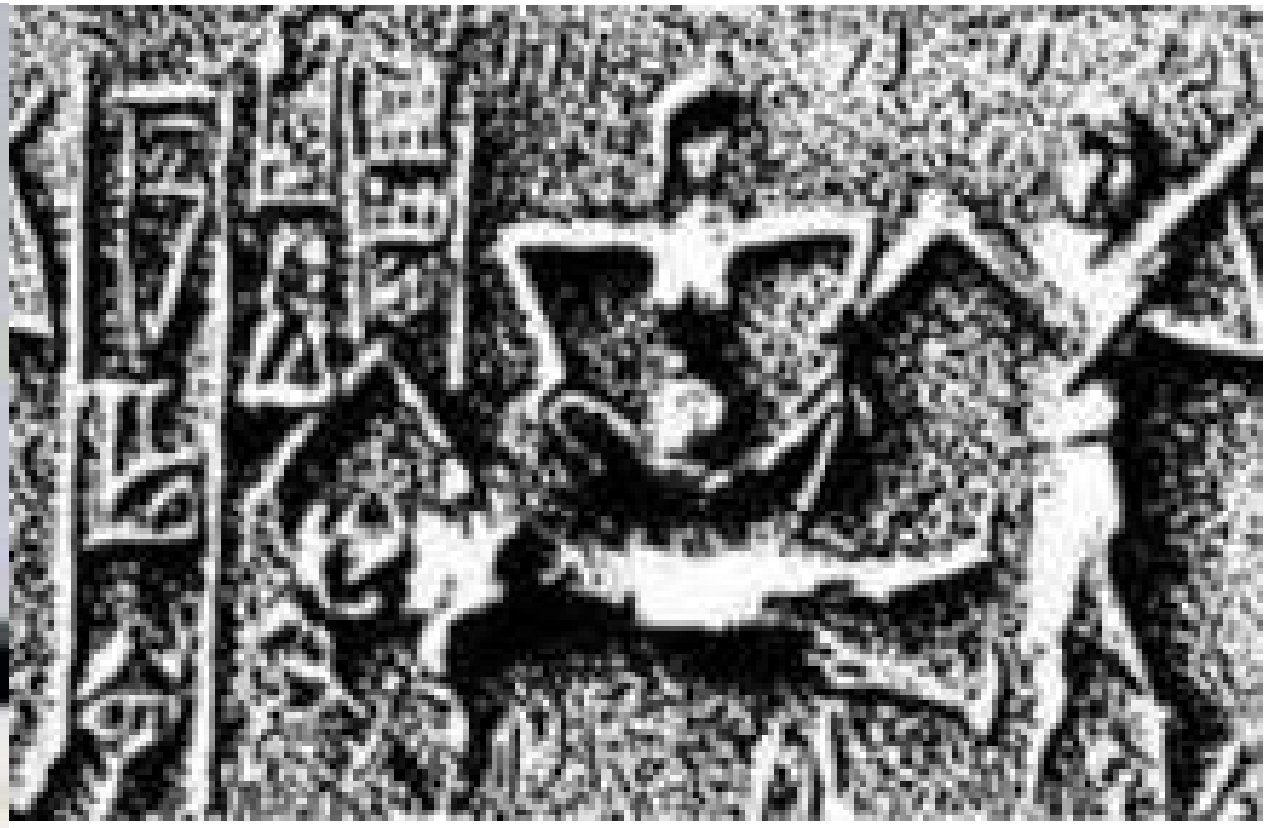
Merritt, J. M., Stickgold, R., Pace-Schott, E., Williams, J., & Hobson, J. A. (1994). **Emotion profiles in the dreams of men and women.** Consciousness and Cognition: An International Journal, 3(1), 46–60.

Schredl M, Doll E. **Emotions in diary dreams.** Conscious Cogn. 1998 Dec;7(4):634-46.

Levin R, Nielsen TA. **Disturbed dreaming, posttraumatic stress disorder, and affect distress: a review and neurocognitive model**. Psychol Bull. 2007 May;133(3):482-528.

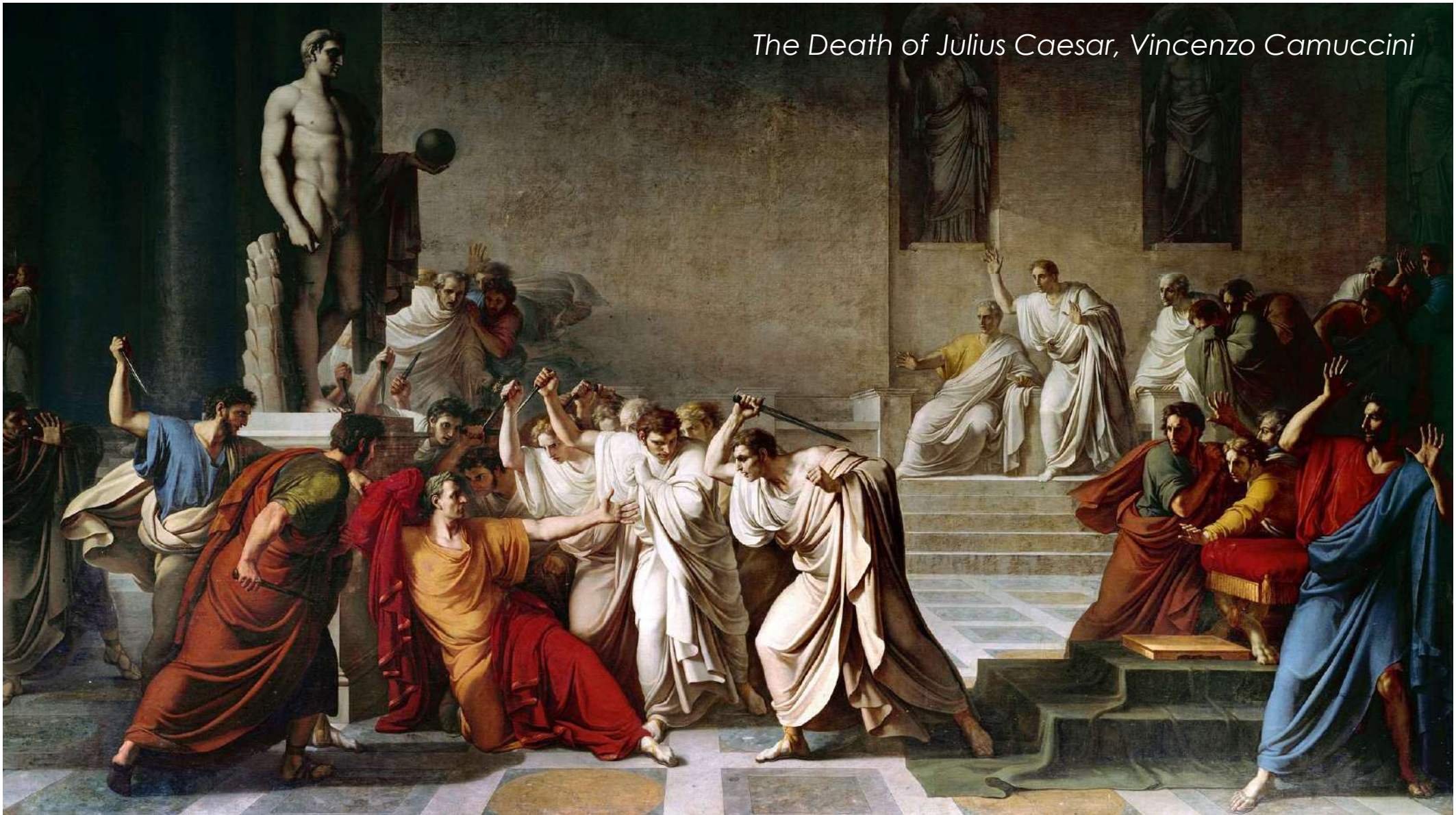
Premonitory dreams **warned** of impending threats

Dumuzid's ominous nightmare (~2100 BC)



Premonitory dreams could have either literal or allegorical **interpretations**

The dreams of Calpurnia and Julius Caesar on March 14th, 44 BC



The Death of Julius Caesar, Vincenzo Camuccini

Premonitory dreams played a key role in the **survival** of Indigenous populations

The dream of Sitting Bull and the battle of Little Bighorn (1876)

Stephen Standing Bear

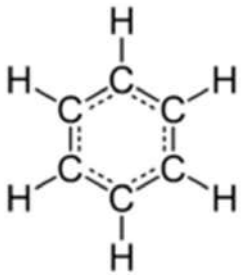
Dreams have revolutionized the **economy**

Elias Howe (1819-1867)

"Savages carrying spears with holes in the ends"

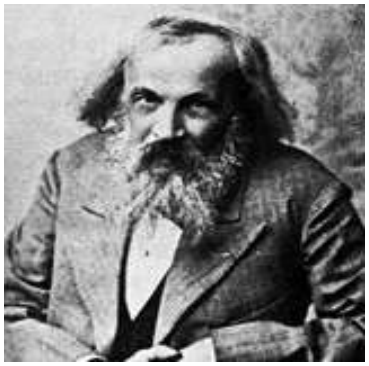
Howe lockstitch sewing machine

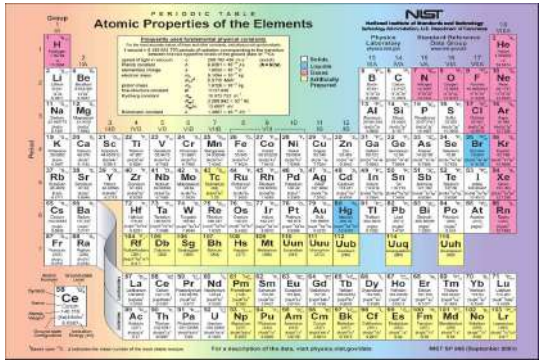
Dreams have revolutionized **science**



August Kekulé (1829-1896)

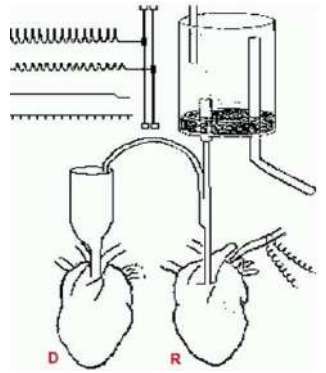
BENZENE





Dmitri Mendeleev (1834-1907)

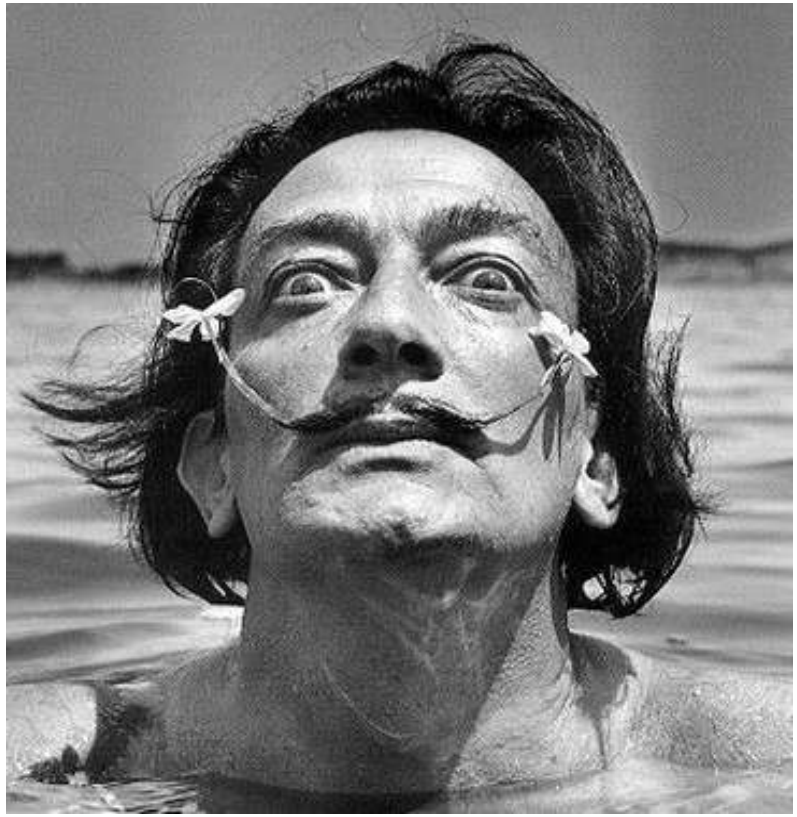
PERIODIC TABLE



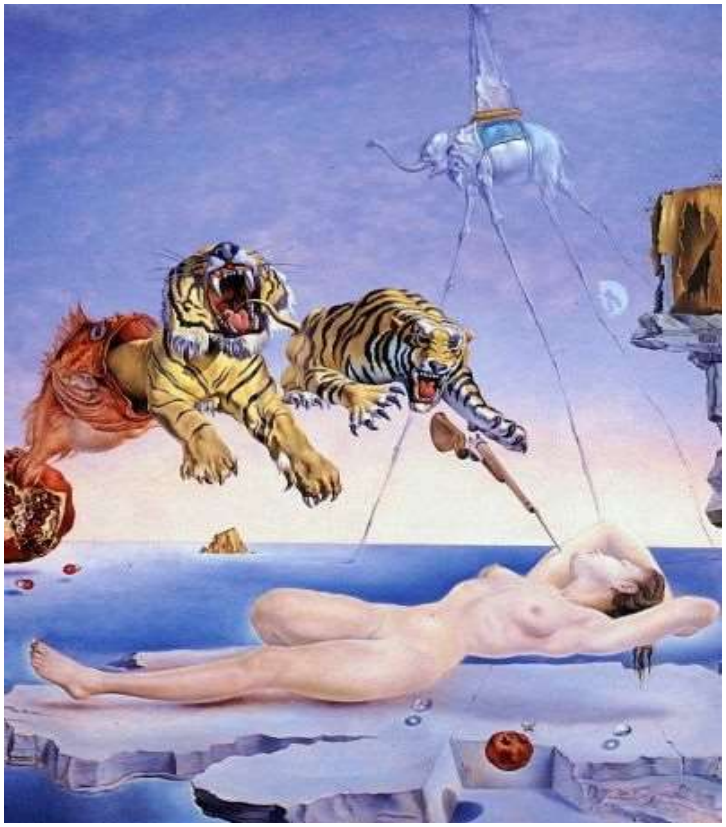
Otto Loewi (1873-1961)

ACETYLCHOLINE

Dreams have inspired the **arts**



Salvador Dalí
(1904-1989)

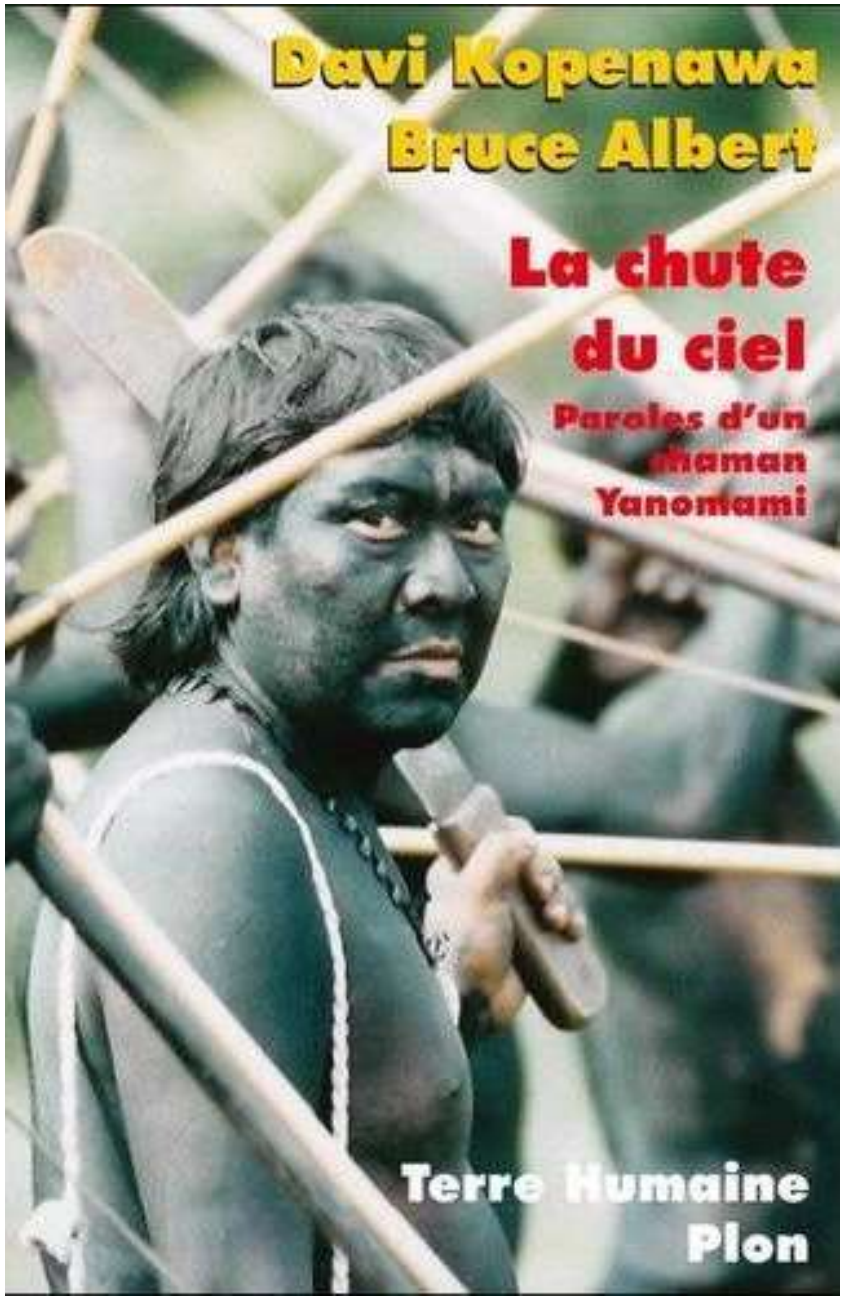


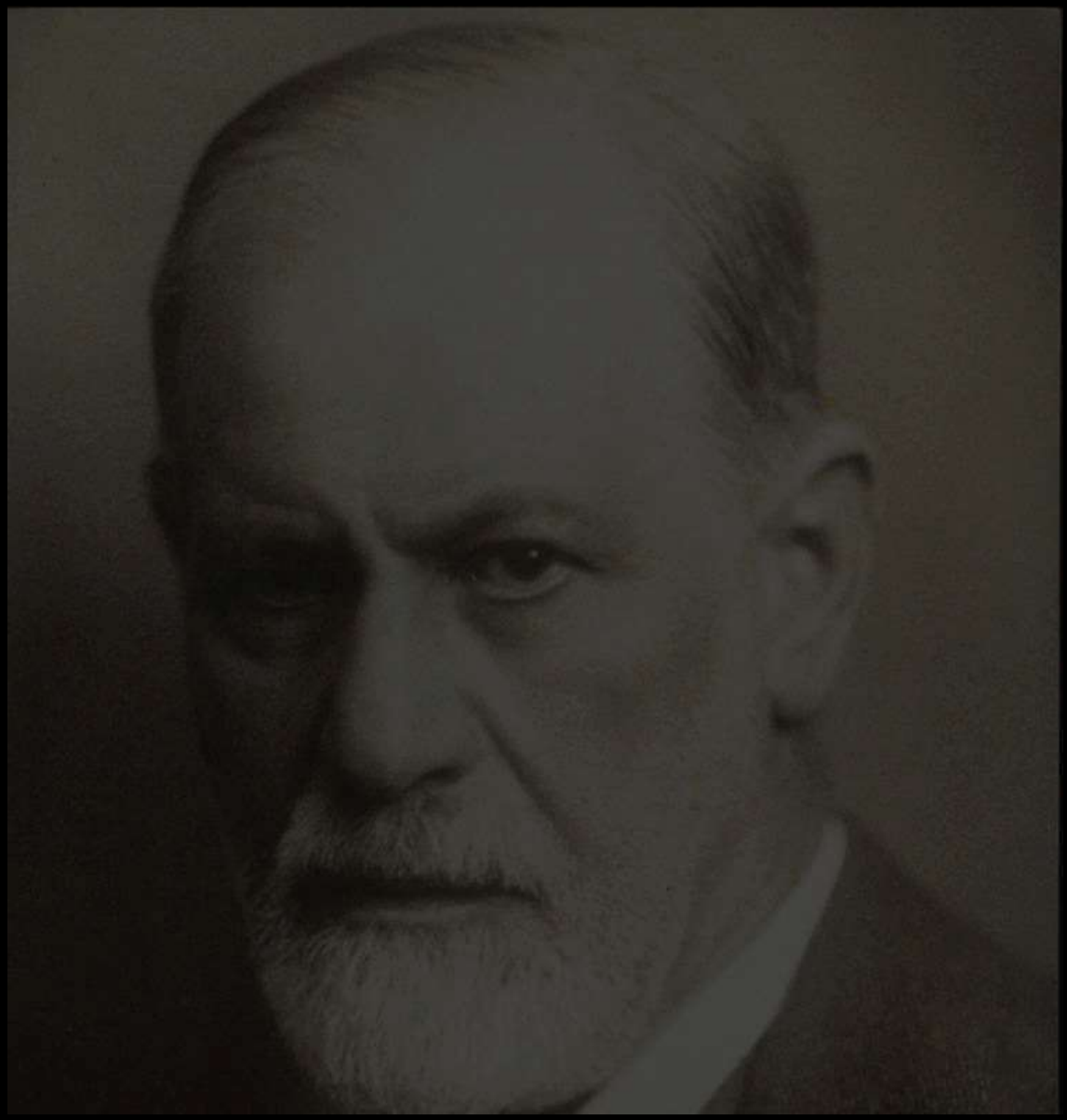
"Dream caused by the flight of a bee around a pomegranate a second before awakening"

Expert **dreamers** of South America

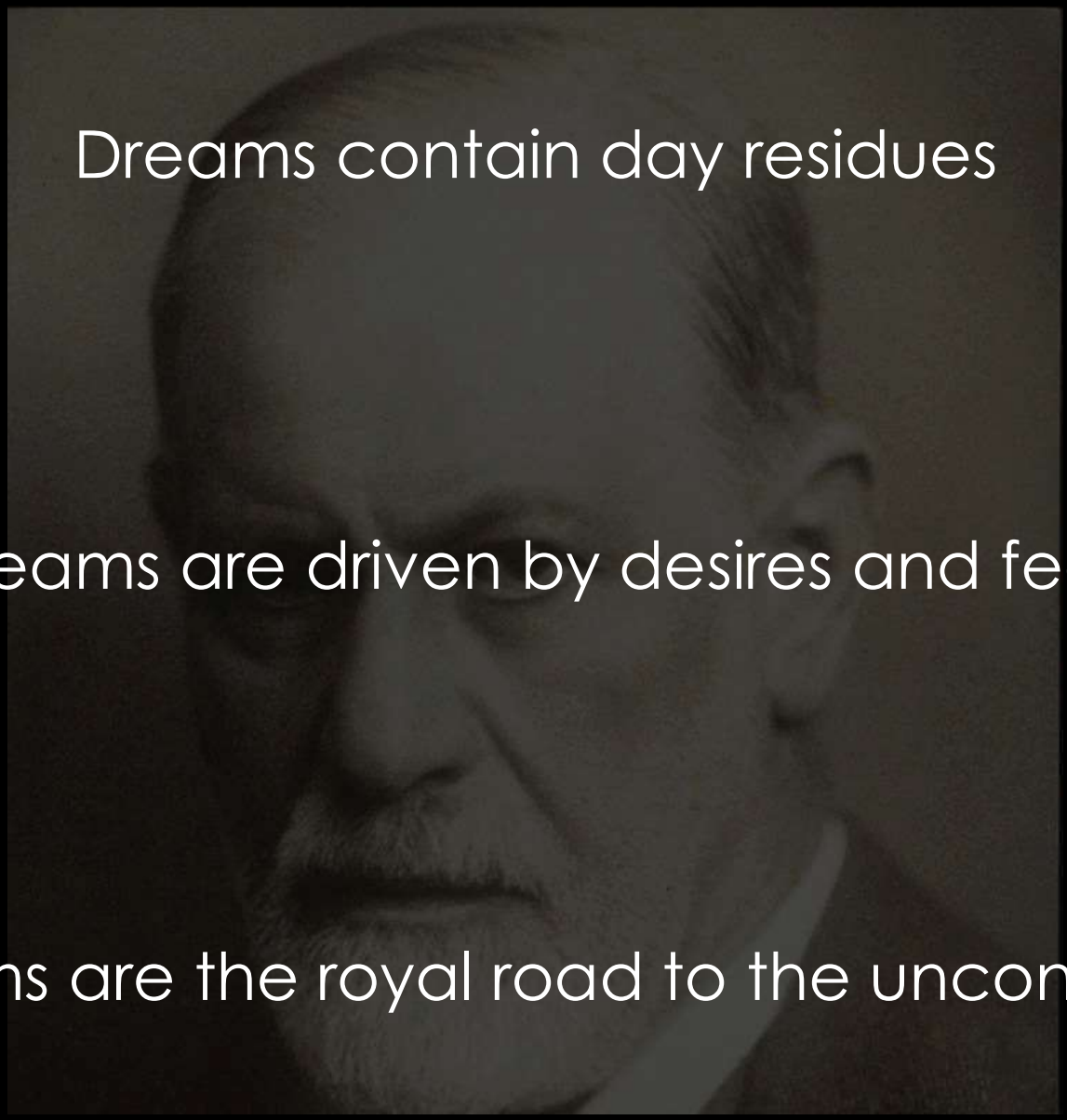
Xavante dance

Yanomami Dreams, Claudia Andujar





Sigmund Freud (1900) The Interpretation of Dreams



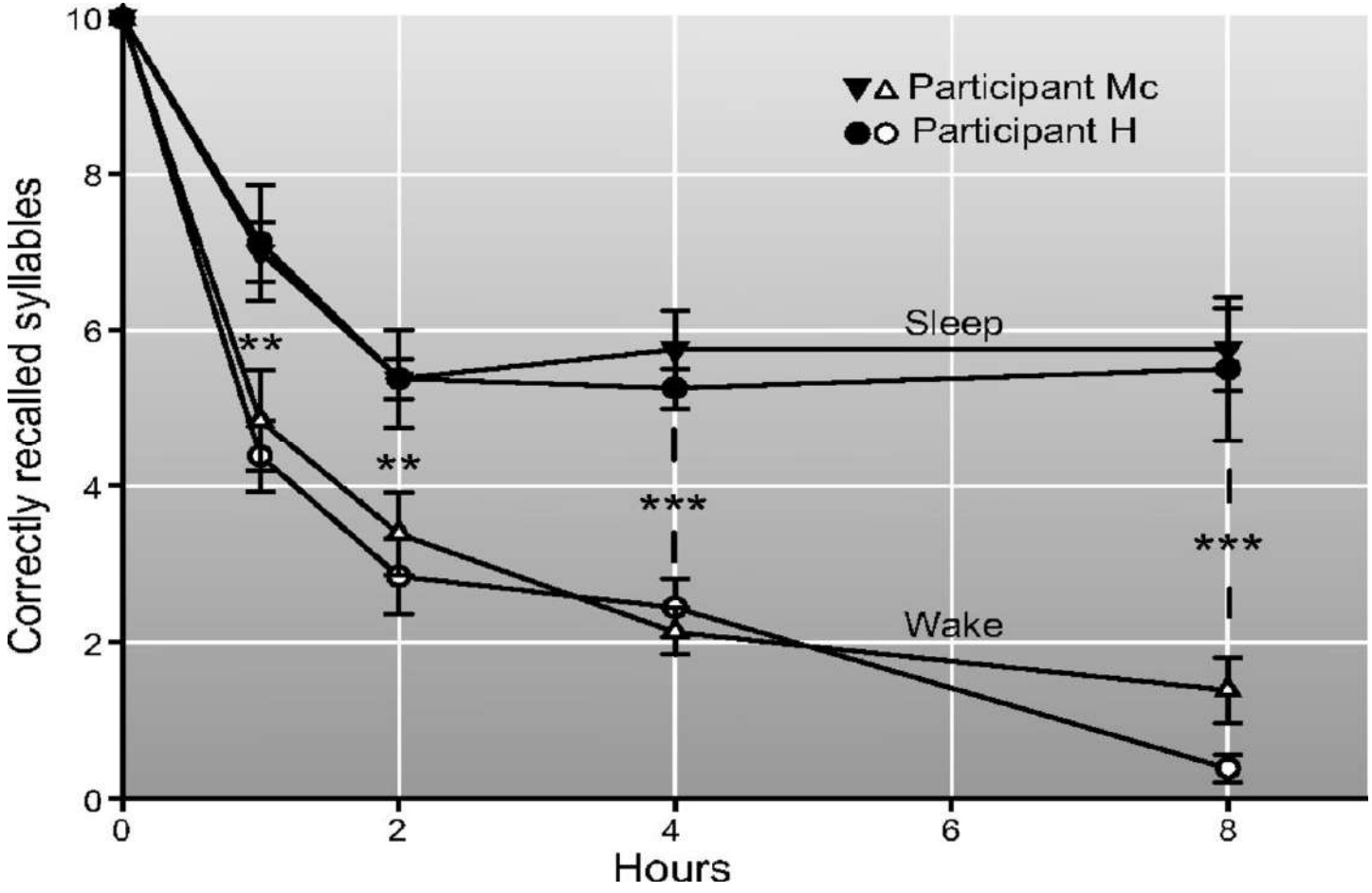
Dreams contain day residues

Dreams are driven by desires and fears

Dreams are the royal road to the unconscious

Sigmund Freud (1900) The Interpretation of Dreams

Post-training sleep **preserves** recent memories



Jenkins JB, Dallenbach KM (1924) **Oblivescence during sleep and waking**. Am J Psychol 35: 605–612.

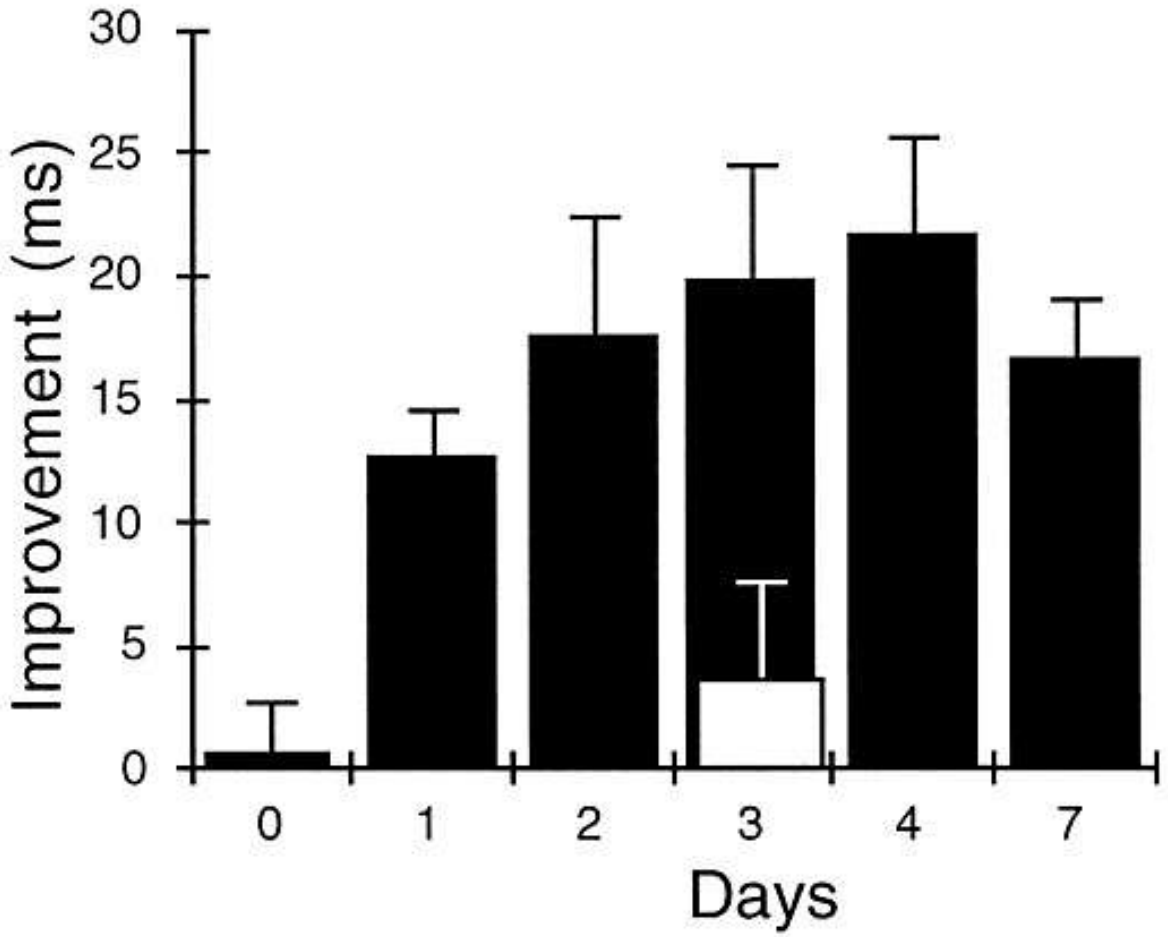
SLEEP DEPRIVATION IMPAIRS LEARNING

- *Pearlman, C.A. 1969.* ***Effect of rapid eye movement (dreaming) sleep deprivation on retention of avoidance learning in rats.*** *Rep. U.S. Naval Subm, Med. Center 22: 1–4.*
- *Leconte, P. and Bloch, V. 1970.* ***Déficit de la rétention d'um conditionnement après privation de sommeil paradoxal chez le rat.*** *Comptes Rendus de l' Académie des Sciences (Paris) 271D: 226–229.*
- *Fishbein, W. 1971.* ***Disruptive effects of rapid eye movement sleep deprivation on long-term memory.*** *Physiol. Behav. 6: 279–282.*
- *Pearlman, C.A. 1973.* ***REM sleep deprivation impairs latent extinction in rats.*** *Physiol. Behav. 11: 233–237.*
- *Pearlman, C. and Becker, M. 1974.* ***REM sleep deprivation impairs bar-press acquisition in rats.*** *Physiol. Behav. 13: 813–817.*

SLEEP INCREASES FOLLOWING MEMORY ACQUISITION

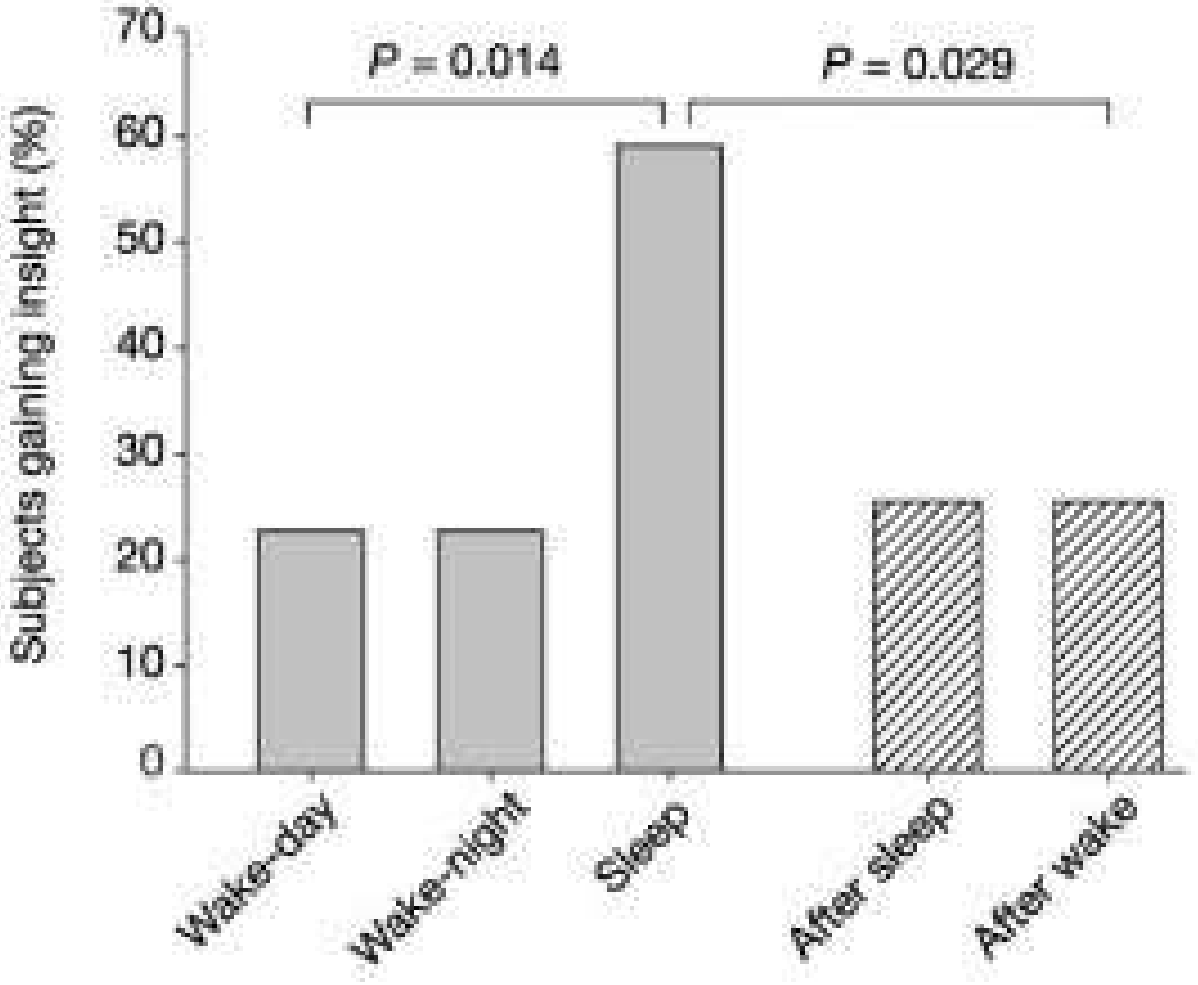
- *Lucero, M.A. 1970.* ***Lengthening of REM sleep duration consecutive to learning in the rat.*** *Brain Res. 20: 319–322.*
- *Leconte, P. and Hennevin, E. 1971.* ***Augmentation de la durée de sommeil paradoxal consécutive à un apprentissage chez le rat.*** *C.R. Acad. Sci. (Paris) 273: 86–88.*
- *Fishbein, W., Kastaniotis, C., and Chattman, D. 1974.* ***Paradoxical sleep: Prolonged augmentation following learning.*** *Brain Res. 79: 61–75.*
- *Smith, C., Kitahama, K., Valatx, J.L., and Jouvet, M. 1974.* ***Increased paradoxical sleep in mice during acquisition of a shock avoidance task.*** *Brain Res. 77: 221–230.*

The learning deficits caused by **sleep deprivation** cannot be explained away by stress



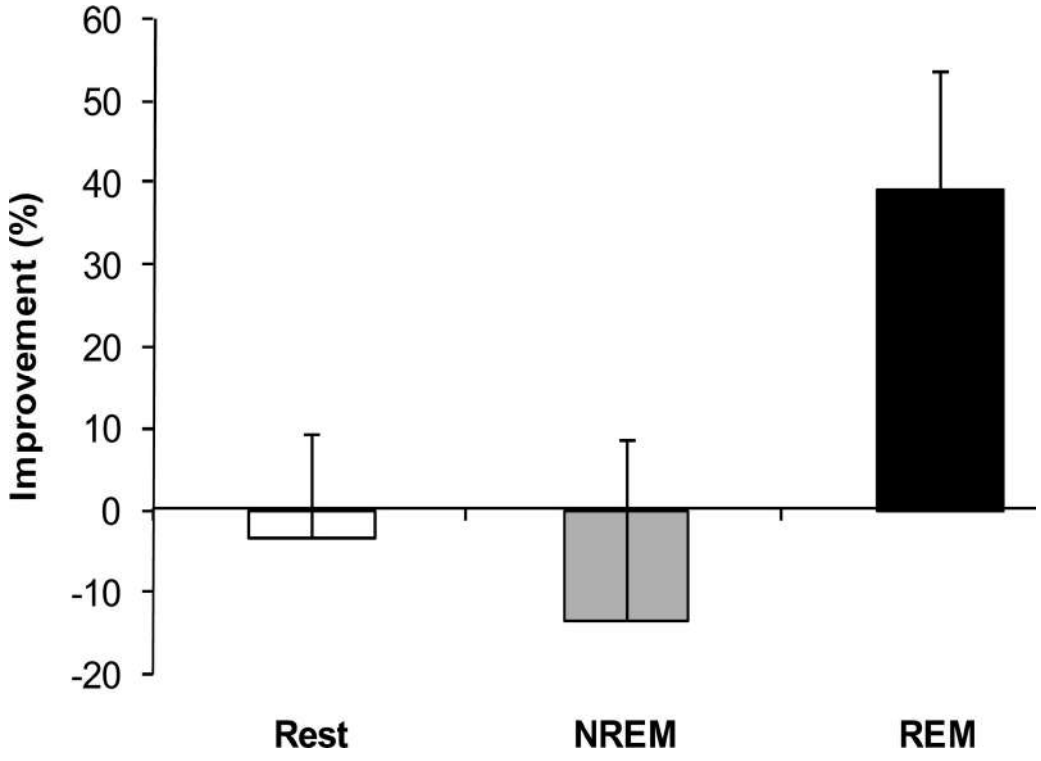
Stickgold R, James L, Hobson JA. **Visual discrimination learning requires sleep after training.** Nat Neurosci. 2000 Dec;3(12):1237-8.

Sleep inspires **insight**

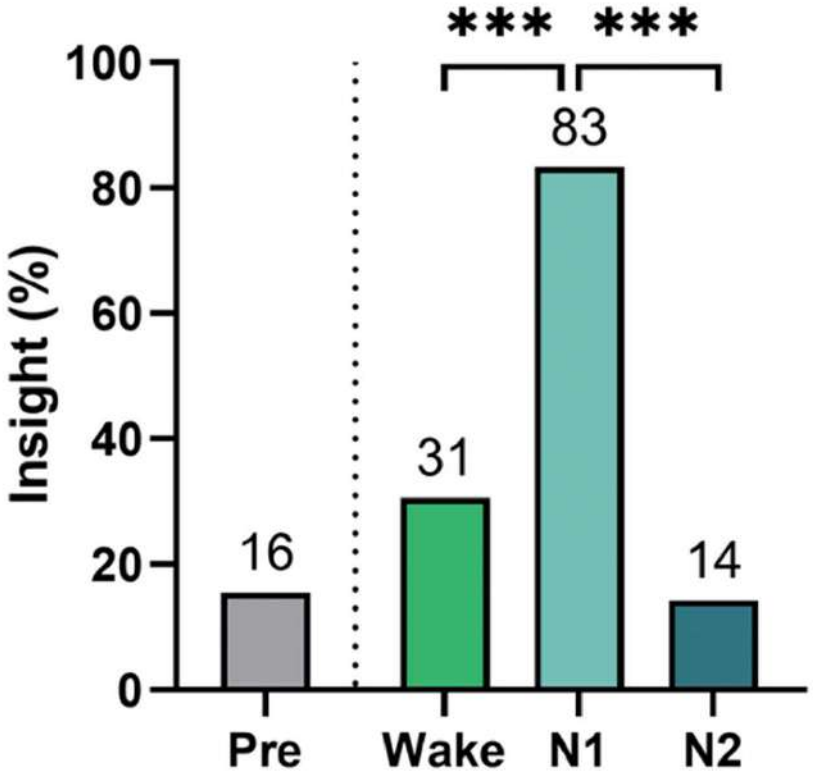


Wagner U, Gais S, Haider H, Verleger R, Born J. **Sleep inspires insight.** Nature. 2004 Jan 22;427(6972):352-5.

Dreaming sleep promotes **creativity**

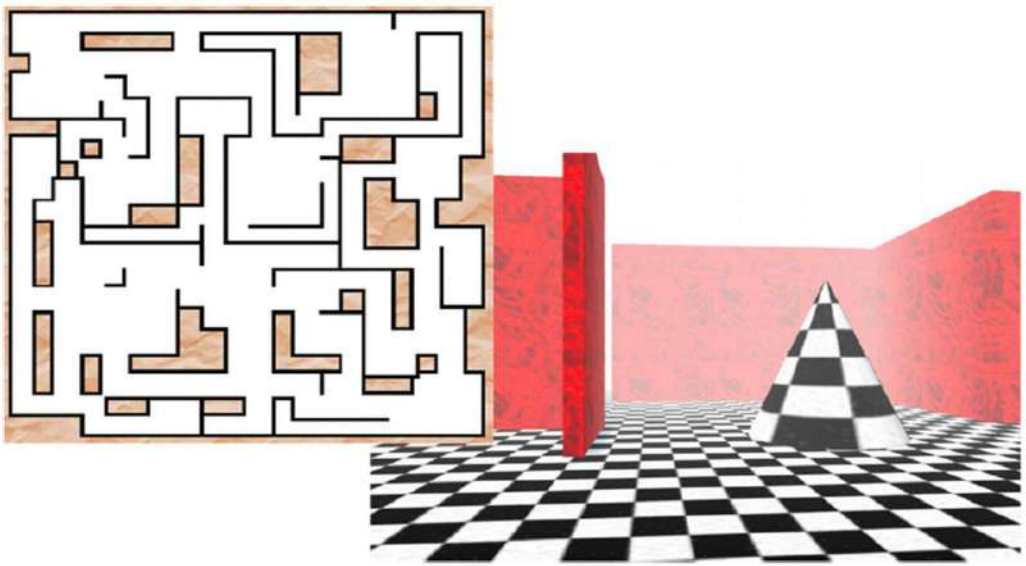


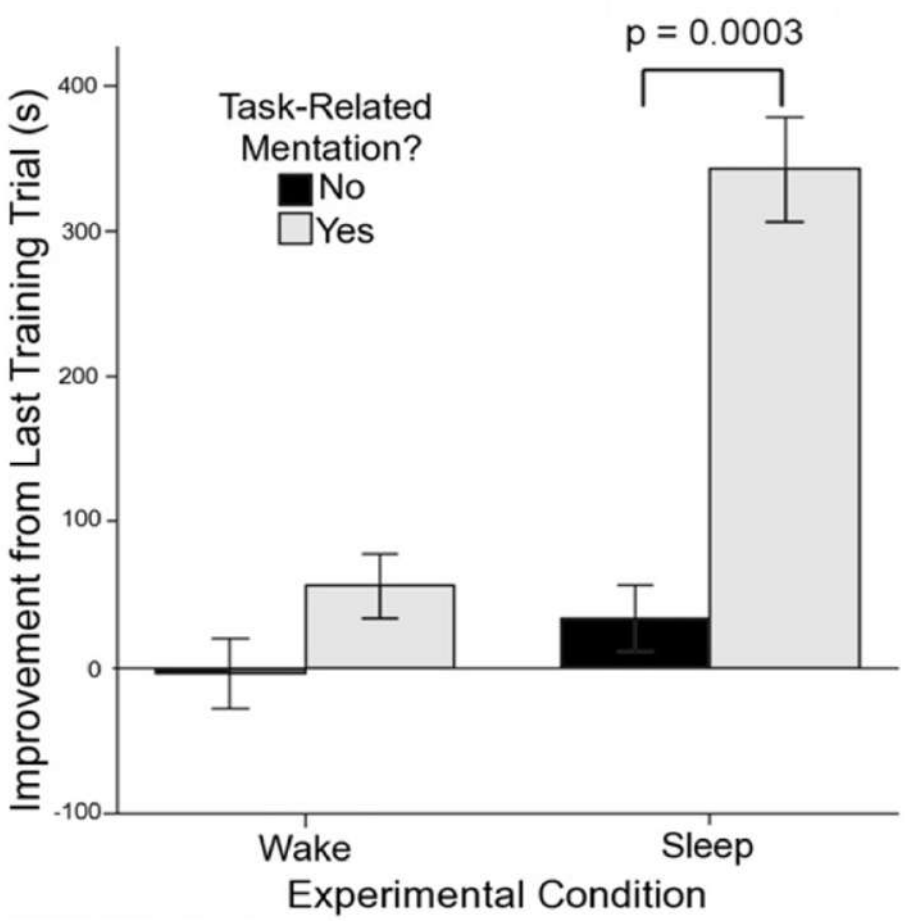
Cai DJ, Mednick SA, Harrison EM, Kanady JC, Mednick SC. **REM, not incubation, improves creativity by priming associative networks.** Proc Natl Acad Sci U S A. 2009 Jun 23;106(25):10130-4.



Lacaux C, Andrillon T, Bastoul C, Idir Y, Fonteix-Galet A, Arnulf I, Oudiette D. **Sleep onset is a creative sweet spot.** Sci Adv. 2021 Dec 10;7(50):eabj5866.

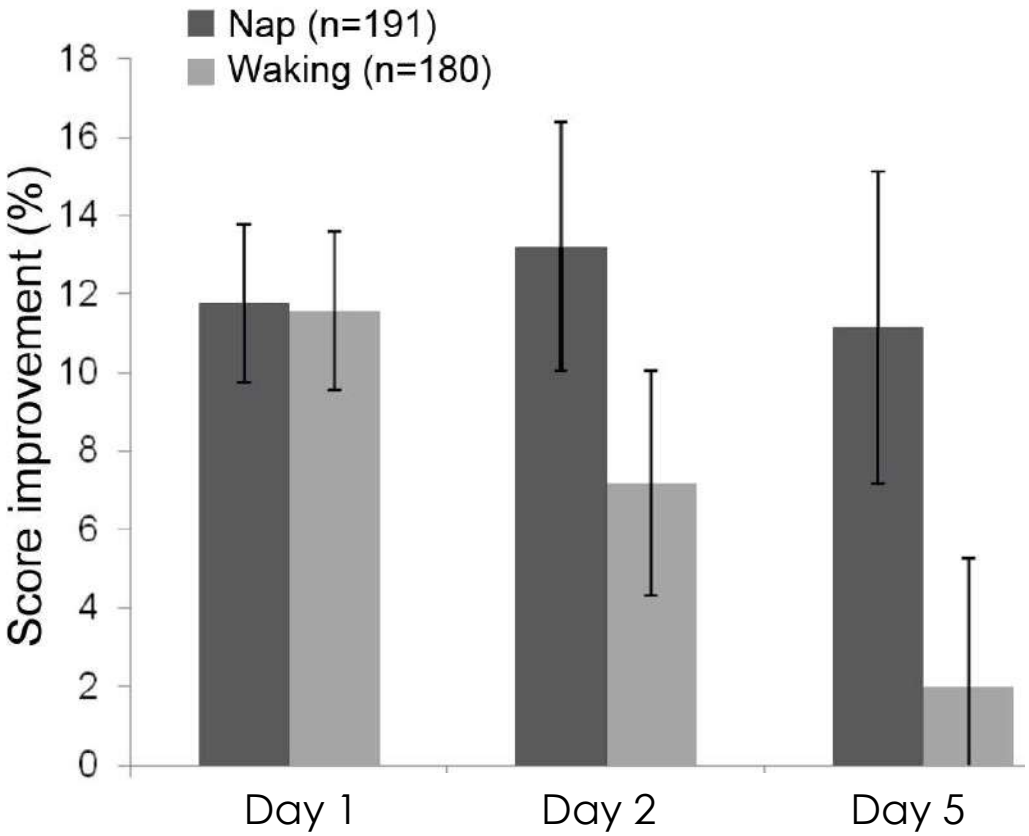
Dreaming improves **learning**

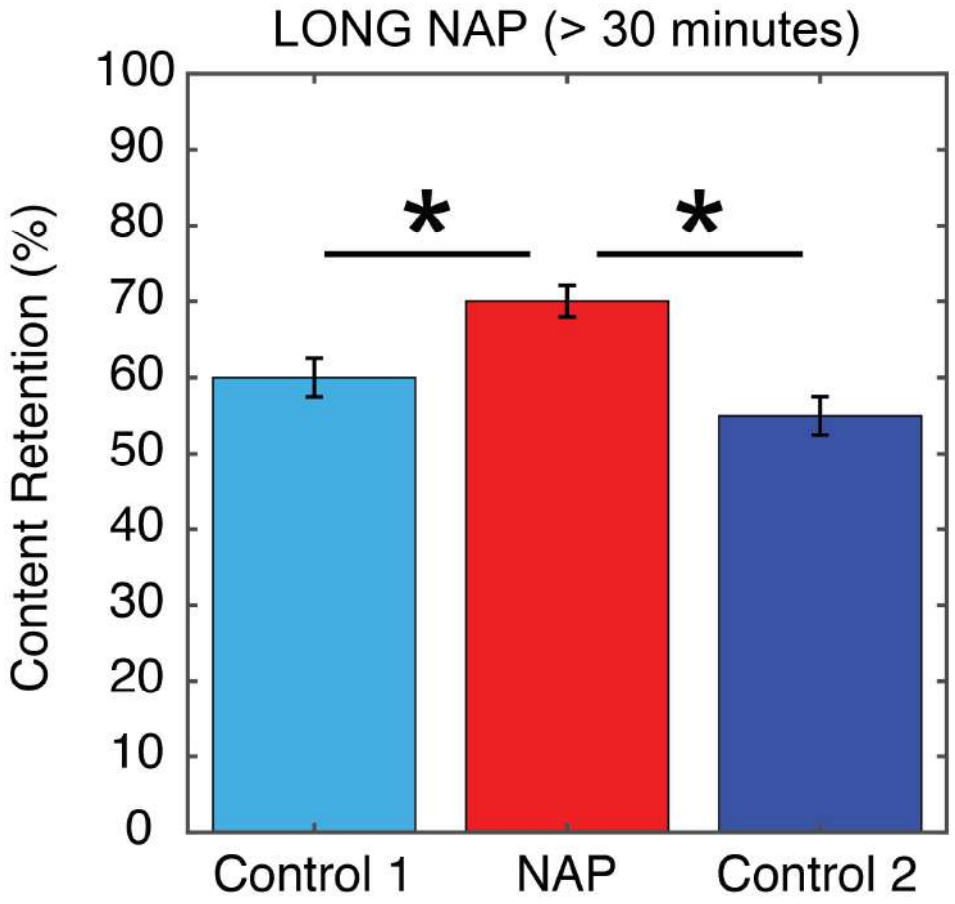




Wamsley EJ, Tucker M, Payne JD, Benavides JA, Stickgold R. **Dreaming of a learning task is associated with enhanced sleep-dependent memory consolidation.** Curr Biol. 2010 May 11;20(9):850-5.

Post-training school naps enhance **learning**



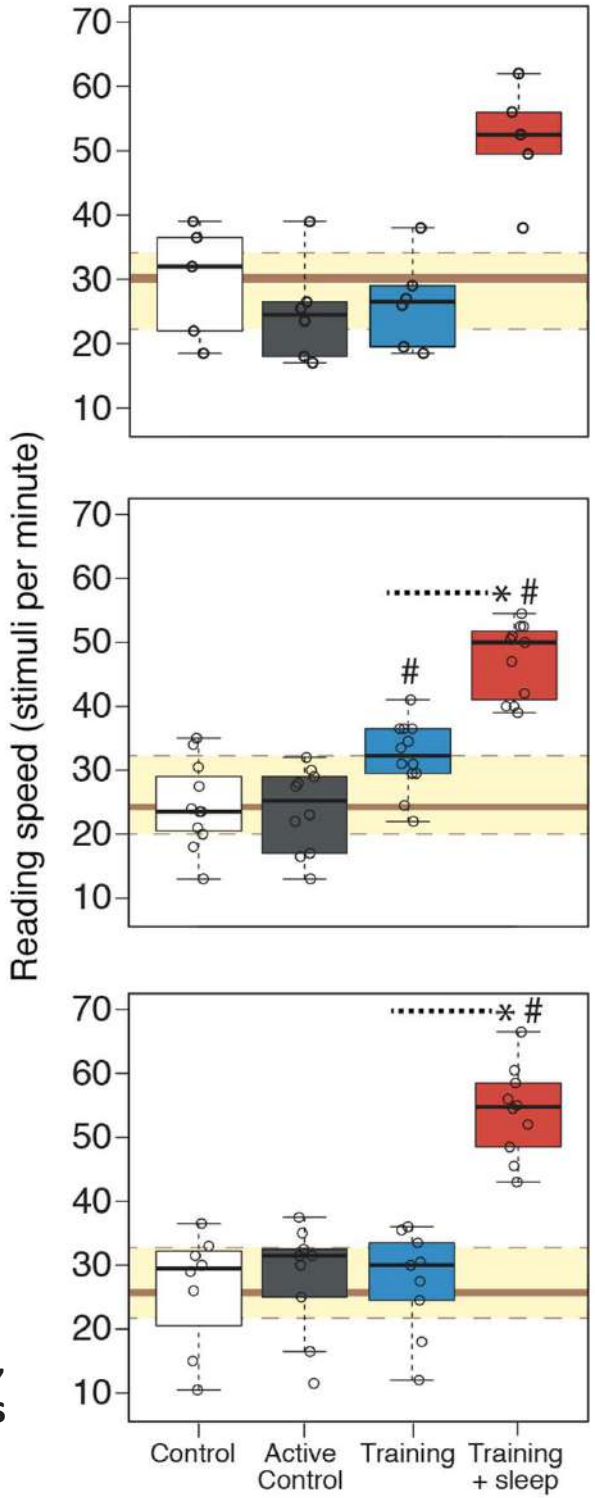


Lemos N, Weissheimer J, Ribeiro S. **Naps in school can enhance the duration of declarative memories learned by adolescents.** Front Syst Neurosci. 2014 Jun 3;8:103.

Cabral T, Mota NB, Fraga L, Copelli M, McDaniel MA, Ribeiro S. **Post-class naps boost declarative learning in a naturalistic school setting.** NPJ Sci Learn. 2018 Aug 21;3:14.

Post-training school naps **double** reading speed

Training sessions for 3 weeks (30 min/day)	Post training sleep for 3 weeks (up to 2h/day)	
		
✓	✓	**Training + Nap**
✓	✗	**Training**
✓ *but with symmetrical letters*	✗	**Active Control**
✗	✗	Negative Control

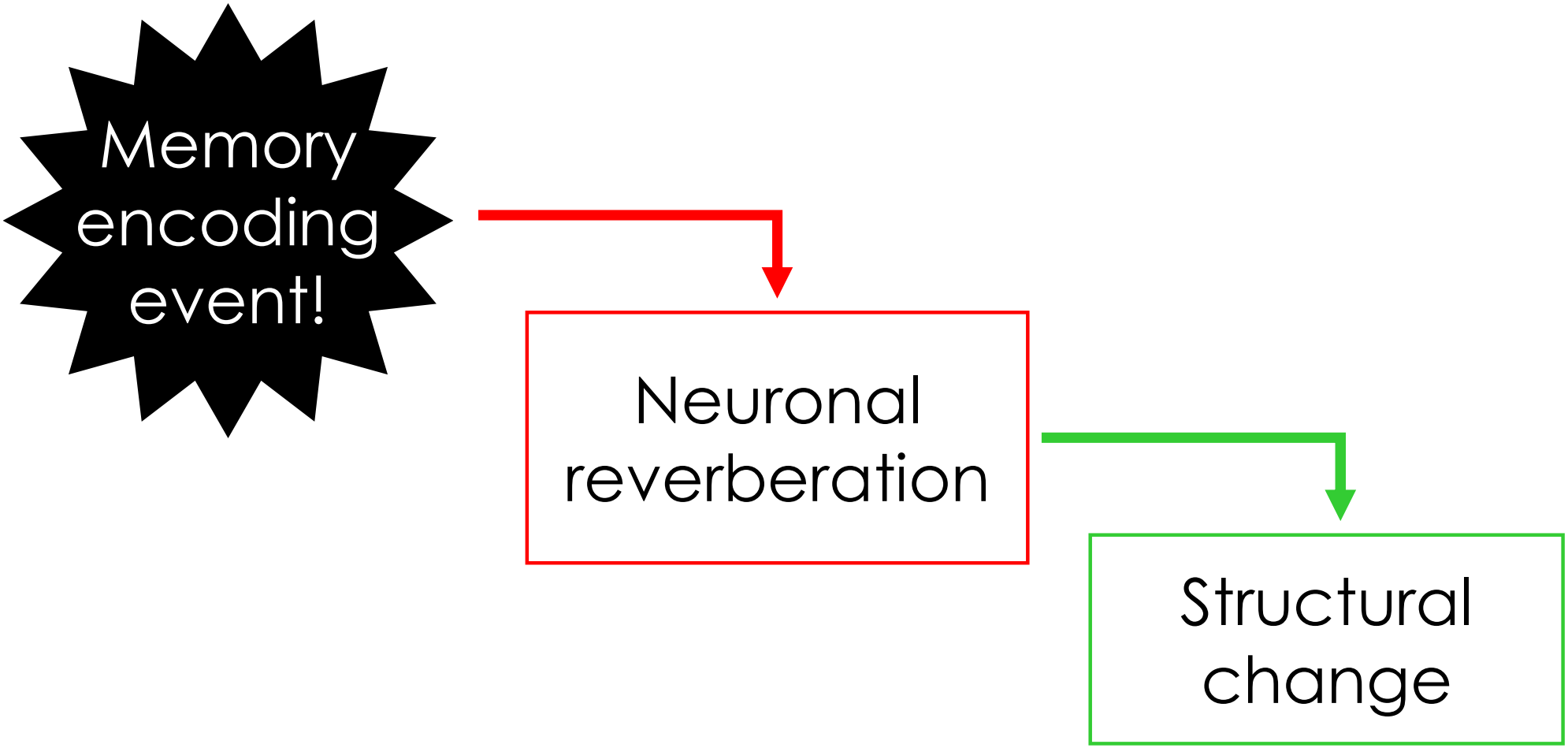


Torres AR, Mota NB, Adamy N, Naschold A, Lima TZ, Copelli M, Weissheimer J, Pegado F, Ribeiro S. **Selective Inhibition of Mirror Invariance for Letters Consolidated by Sleep Doubles Reading Fluency.** Curr Biol. 2021 Feb 22;31(4):909.

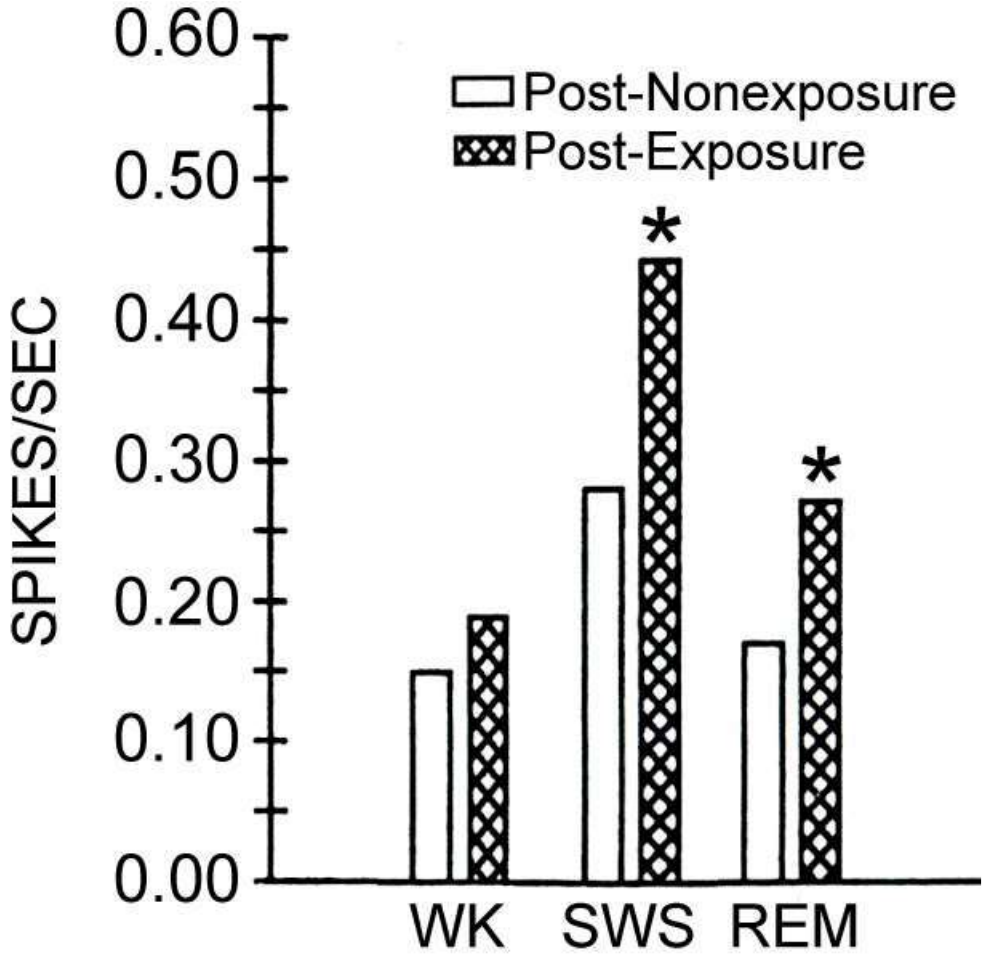
What are the
underlying
MECHANISMS?

The Dual Trace Theory of Memory Consolidation

Donald Hebb (The Organization of Behavior, 1949)

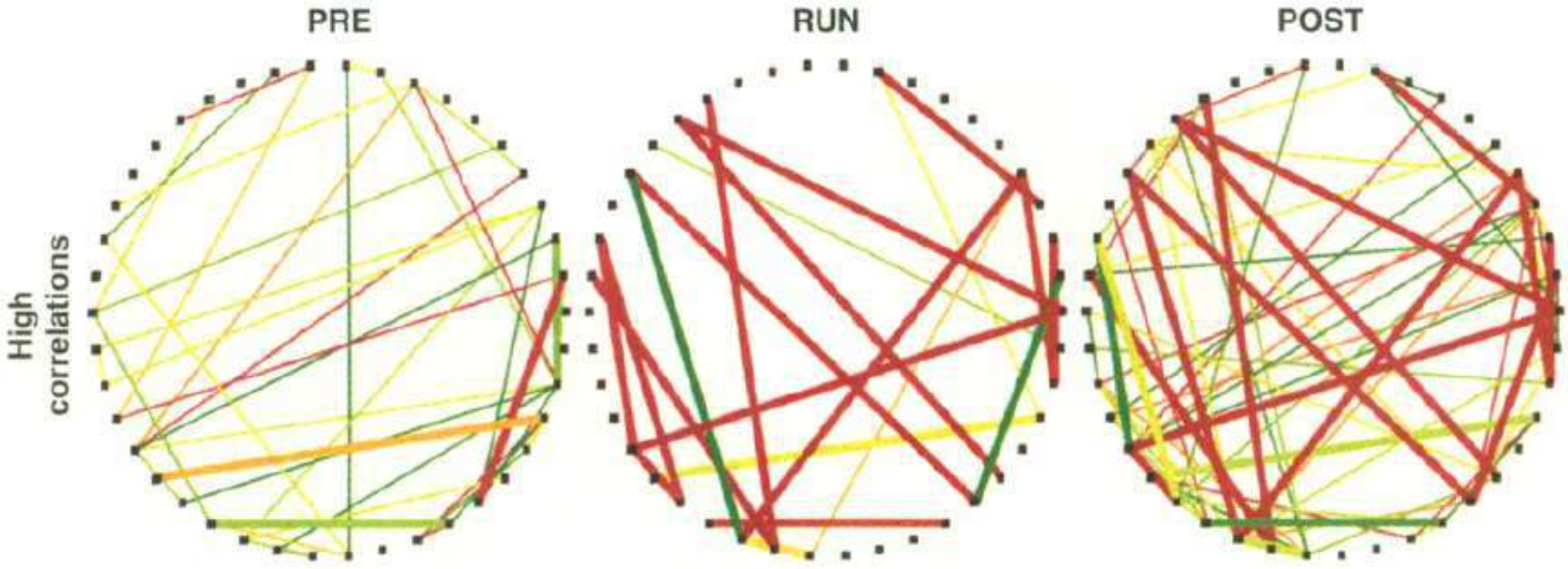


Electrophysiological day residues



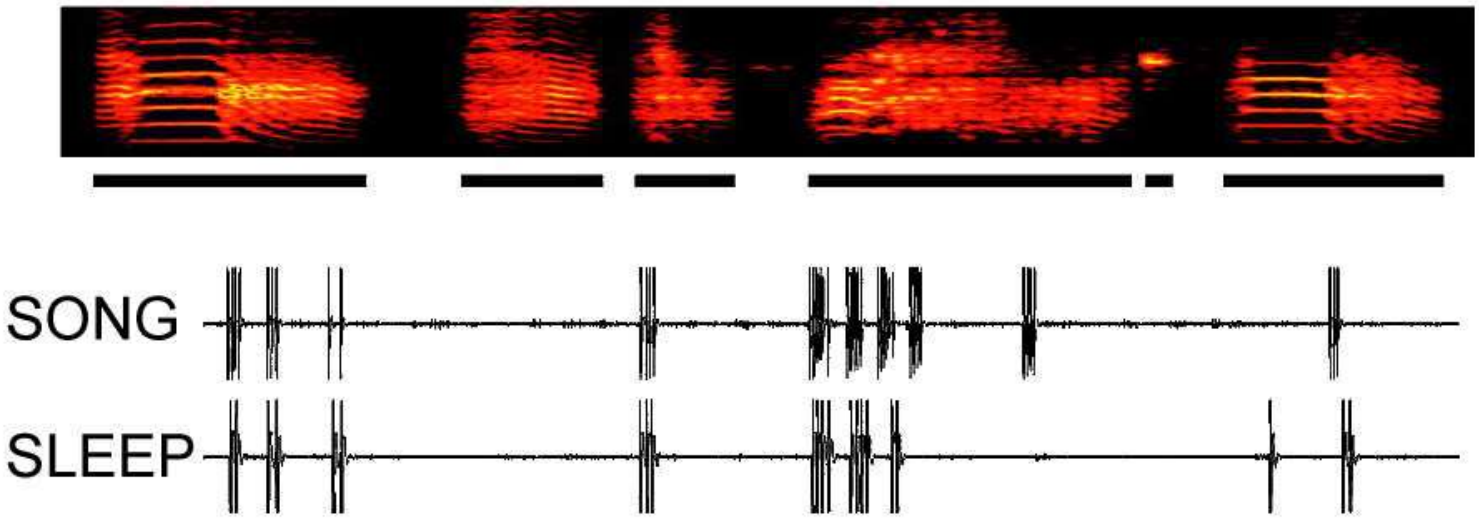
Pavlides C, Winson J. **Influences of hippocampal place cell firing in the awake state on the activity of these cells during subsequent sleep episodes.** J Neurosci. 1989 Aug;9(8):2907-18.

Waking firing patterns are **replayed** during sleep



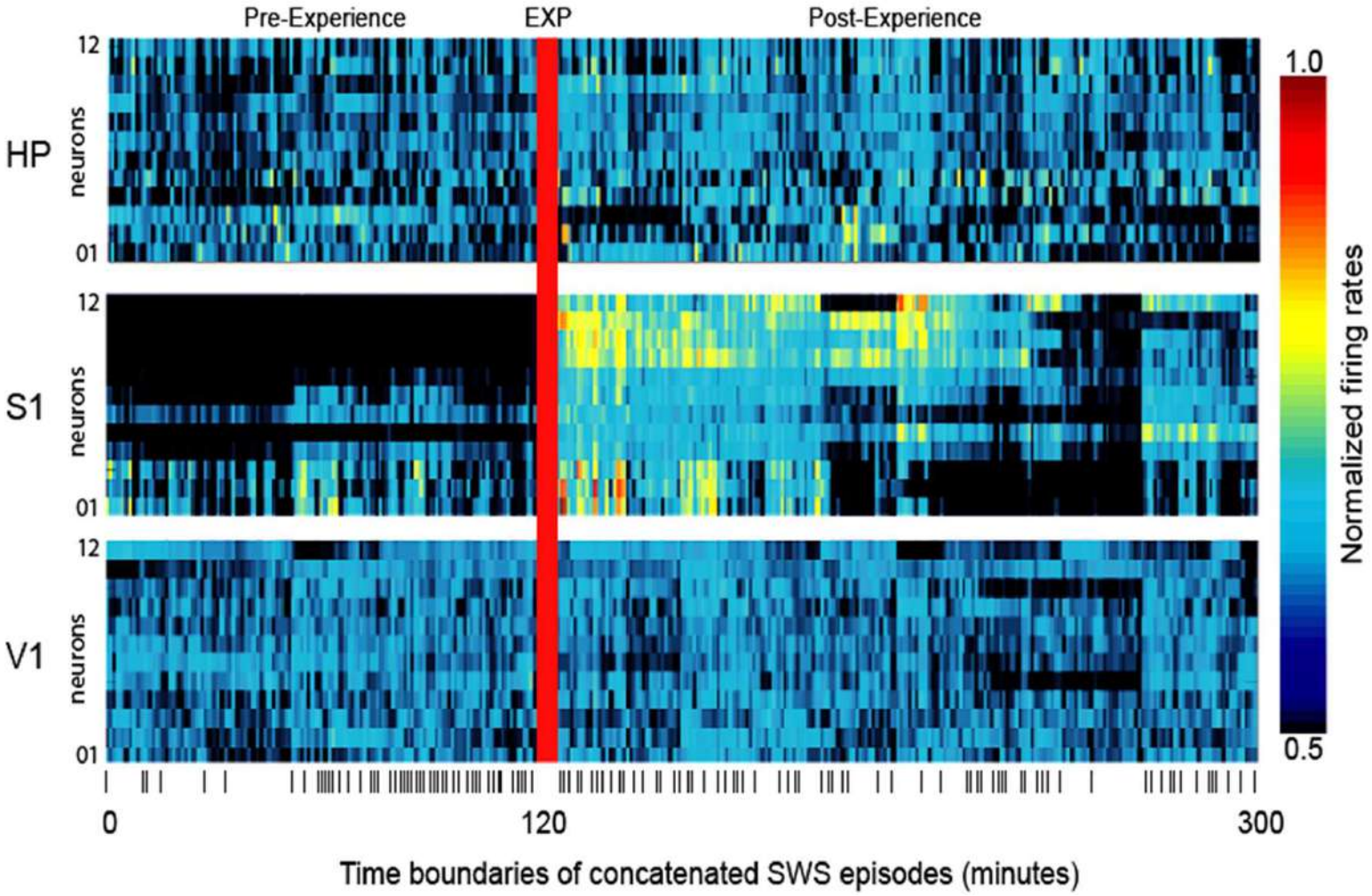
Wilson MA, McNaughton BL. **Reactivation of hippocampal ensemble memories during sleep.** Science. 1994 Jul 29;265(5172):676-9.

A case of **high-fidelity** replay



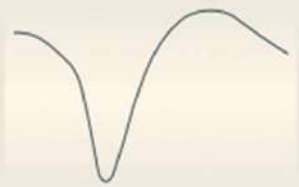
Dave AS, Margoliash D.**Song replay during sleep and computational rules for sensorimotor vocal learning.** Science 290: 812–816, 2000.

Cortical persistence and hippocampal **disengagement**



Ribeiro S, Shi X, Engelhard M, Zhou Y, Zhang H, Gervasoni D, Lin SC, Wada K, Lemos NA, Nicolelis MA. **Novel experience induces persistent sleep-dependent plasticity in the cortex but not in the hippocampus.** Front Neurosci. 2007 Oct 15;1(1):43-55.

Slow oscillation



Marshall L, Helgadóttir H, Mölle M, Born J. **Boosting slow oscillations during sleep potentiates memory.** Nature. 2006 Nov 30;444(7119):610-3.

Spindle

Strauss M, Griffon L, Van Beers P, Elbaz M, Bouziotis J, Sauvet F, Chennaoui M, Léger D, Peigneux P. **Order matters: sleep spindles contribute to memory consolidation only when followed by rapid-eye-movement sleep**. Sleep. 2022 Apr 11;45(4):zsac022.

Sharp wave-ripple

Maingret N, Girardeau G, Todorova R, Goutierre M, Zugaro M. **Hippocampo-cortical coupling mediates memory consolidation during sleep.** Nat Neurosci. 2016 Jul;19(7):959-64.

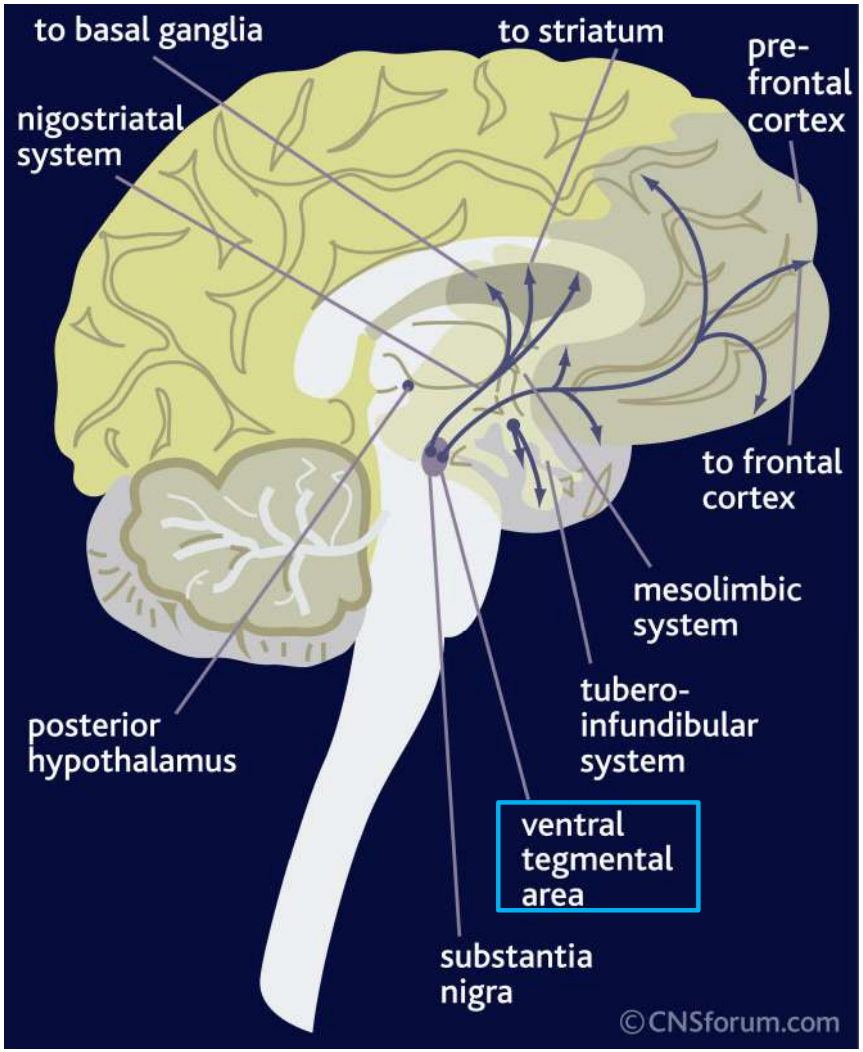
Girardeau G, Inema I, Buzsáki G. **Reactivations of emotional memory in the hippocampus-amygdala system during sleep.** Nat Neurosci. 2017 Nov;20(11):1634-1642.

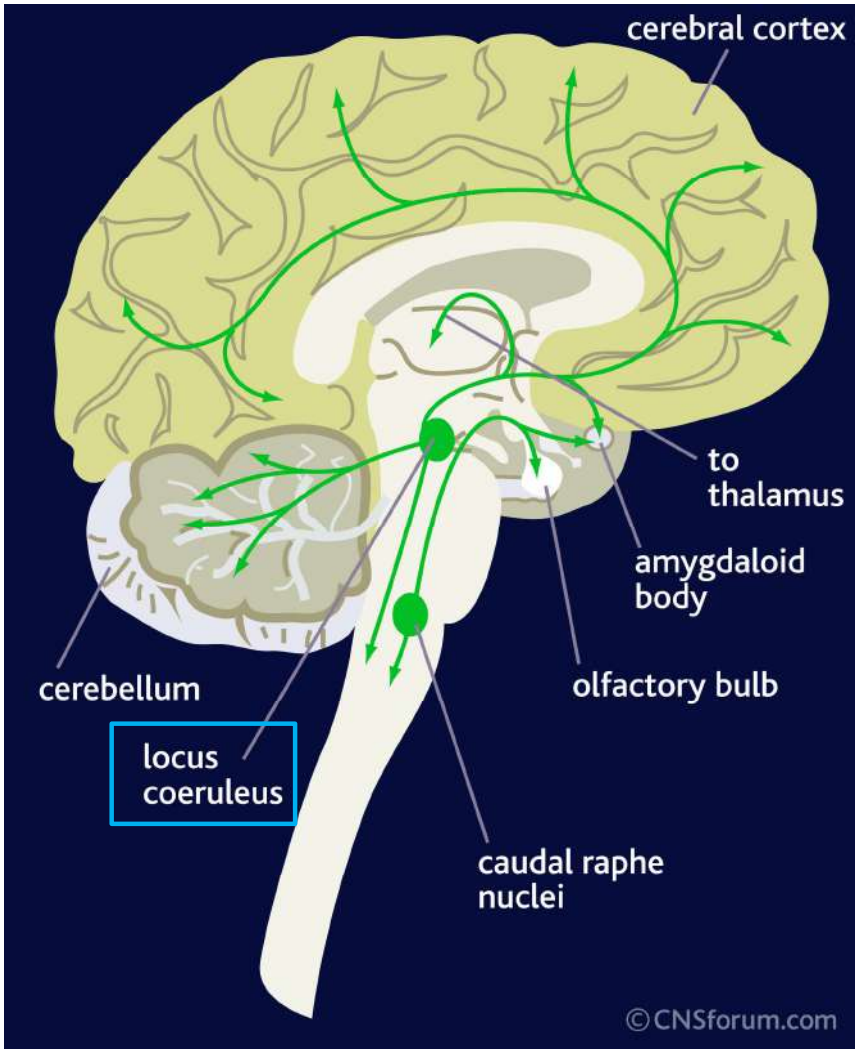
Theta activity

Boyce R, Glasgow SD, Williams S, Adamantidis A. **Causal evidence for the role of REM sleep theta rhythm in contextual memory consolidation.** Science. 2016 May 13;352(6287):812-6.

PGO wave

Datta S, O'Malley MW. **Fear extinction memory consolidation requires potentiation of pontine-wave activity during REM sleep.** J Neurosci. 2013 Mar 6;33(10):4561-9.





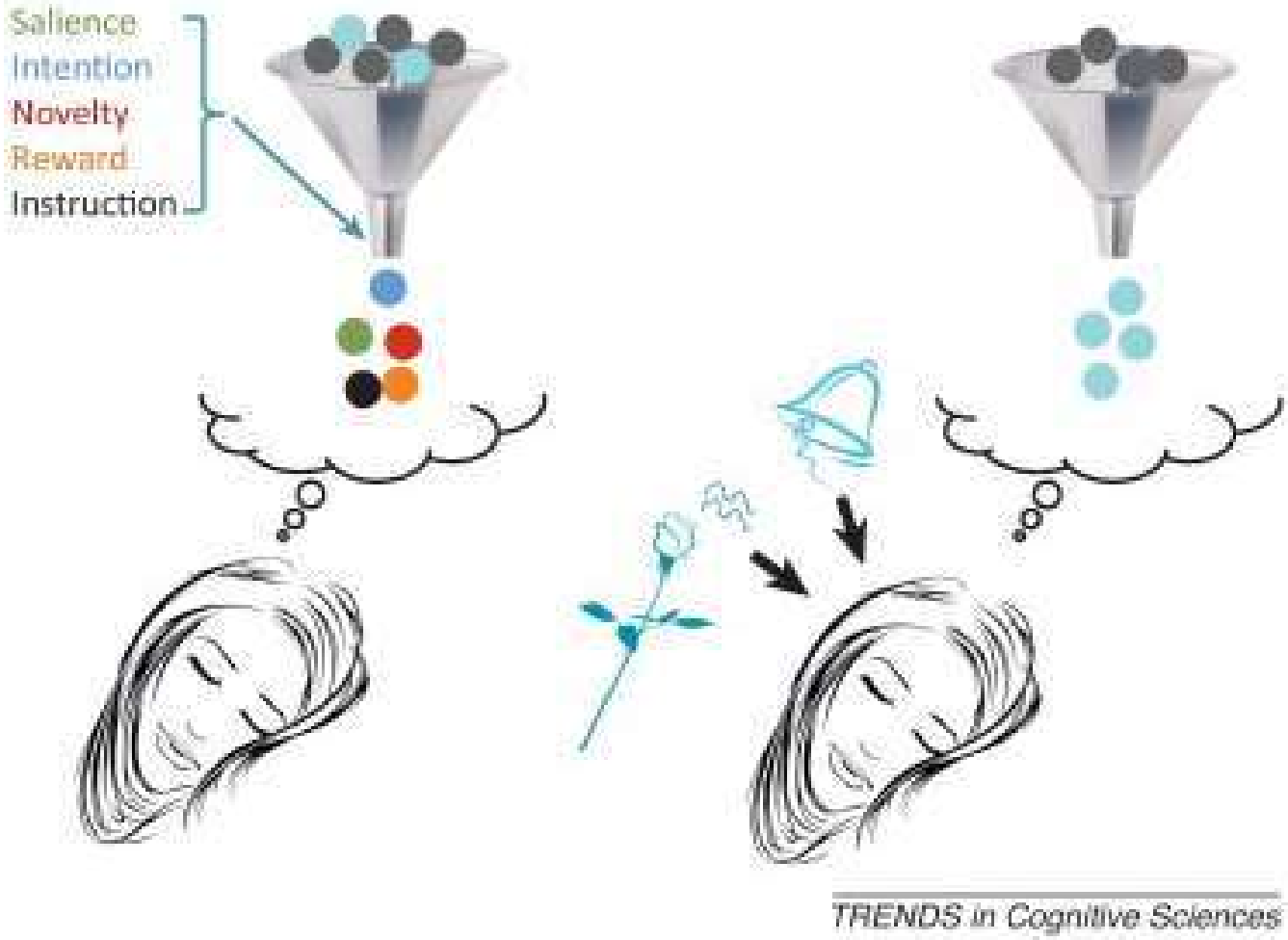
Gomperts SN, Kloosterman F, Wilson MA. **VTA neurons coordinate with the hippocampal reactivation of spatial experience.** Elife. 2015 Oct 14;4:e05360.

Harris JJ, Kollo M, Erskine A, Schaefer A, Burdakov D. **Natural VTA activity during NREM sleep influences future exploratory behavior.** iScience. 2022 May 13;25(6):104396.

Eschenko O, Sara SJ. **Learning-dependent, transient increase of activity in noradrenergic neurons of locus coeruleus during slow wave sleep in the rat: brain stem-cortex interplay for memory consolidation?** Cereb Cortex. 2008 Nov;18(11):2596-603.

Kjaerby C, Andersen M, Hauglund N, Untiet V, Dall C, Sigurdsson B, Ding F, Feng J, Li Y, Weikop P, Hirase H, Nedergaard M. **Memory-enhancing properties of sleep depend on the oscillatory amplitude of norepinephrine.** Nat Neurosci. 2022 Aug;25(8):1059-1070.

Targeted Memory Reactivation

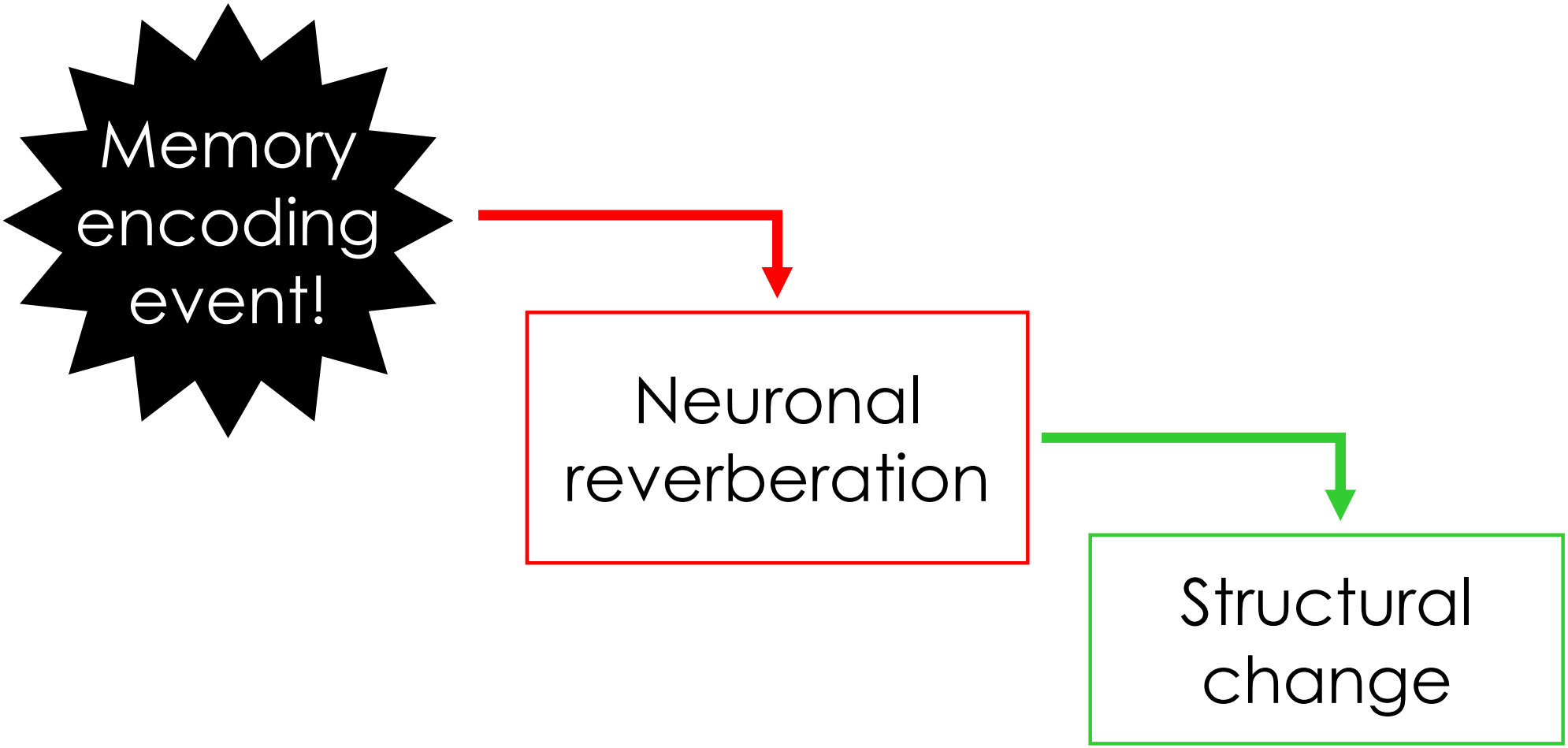


Rasch B, Büchel C, Gais S, Born J. **Odor cues during slow-wave sleep prompt declarative memory** consolidation. Science. 2007 Mar 9;315(5817):1426-9.

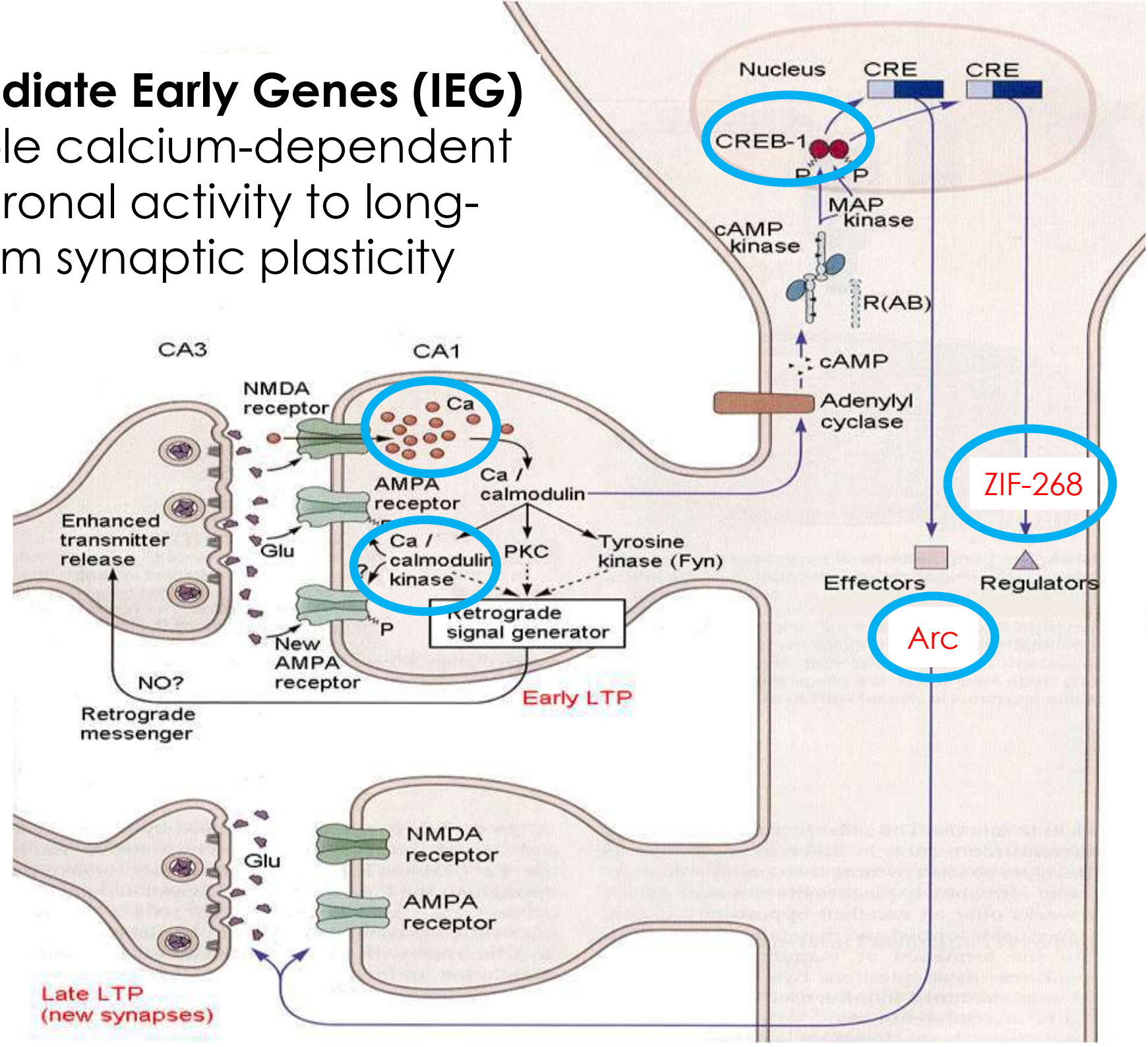
Rudoy JD, Voss JL, Westerberg CE, Paller KA. **Strengthening individual memories by reactivating them during sleep.** Science. 2009 Nov 20;326(5956):1079.

The Dual Trace Theory of Memory Consolidation

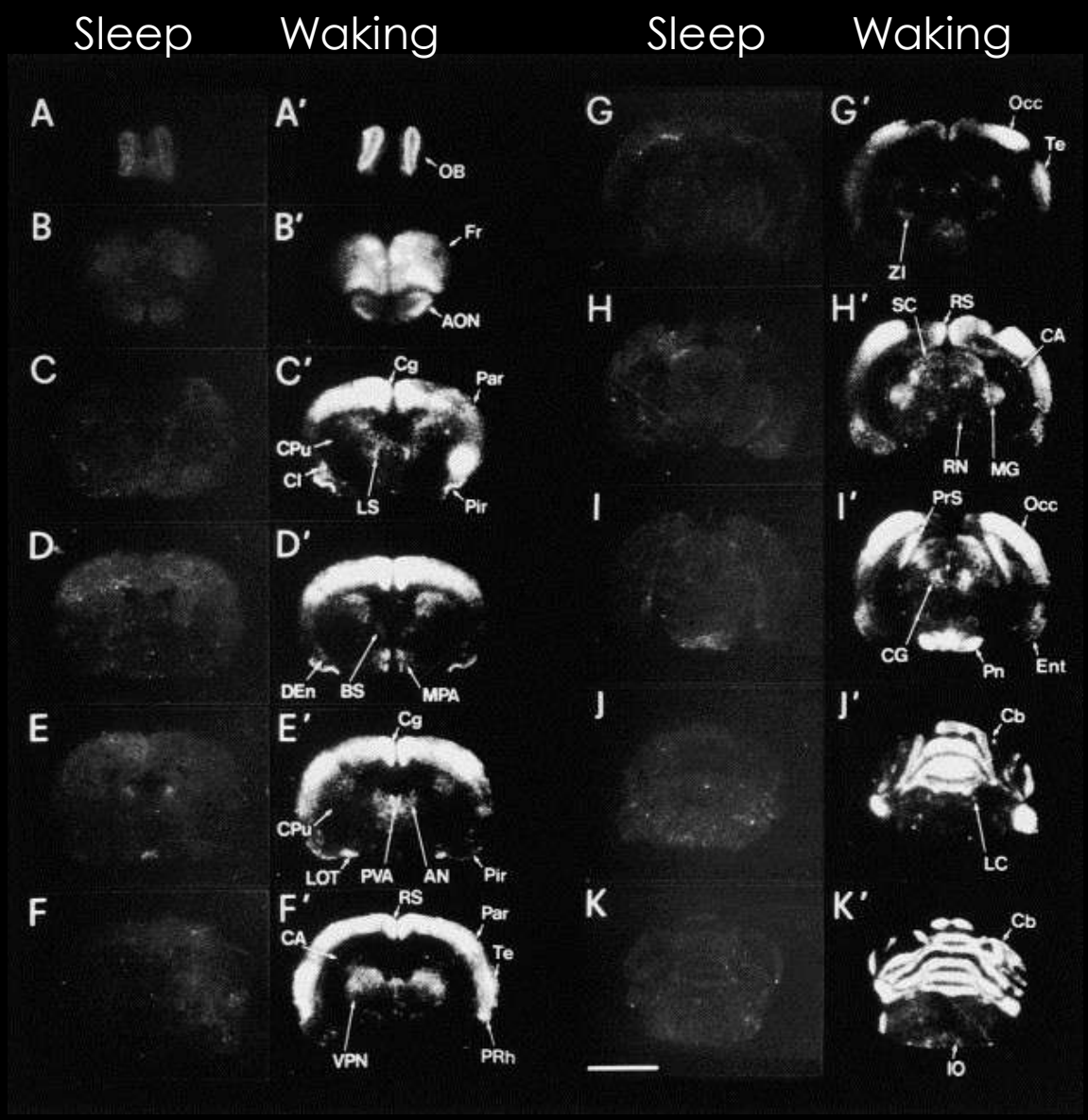
Donald Hebb (The Organization of Behavior, 1949)



Immediate Early Genes (IEG)
couple calcium-dependent neuronal activity to long-term synaptic plasticity

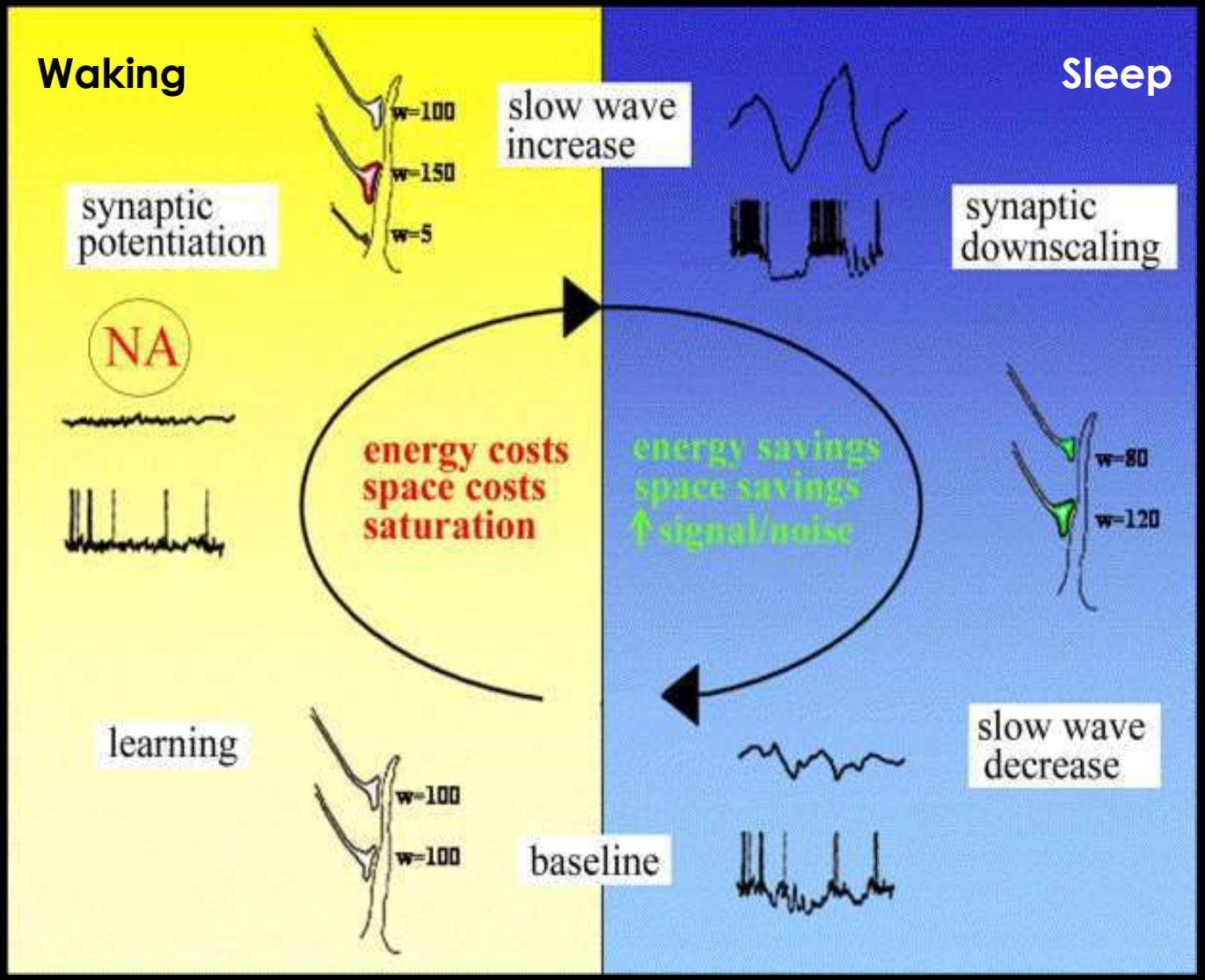


IEG expression is **downregulated** by long periods of sleep



Pompeiano M, Cirelli C, Tononi G. (1994): **Immediate-early genes in spontaneous wakefulness and sleep: Expression of c-fos and NGFI-A mRNA and protein.** J Sleep Res 3: 80–96

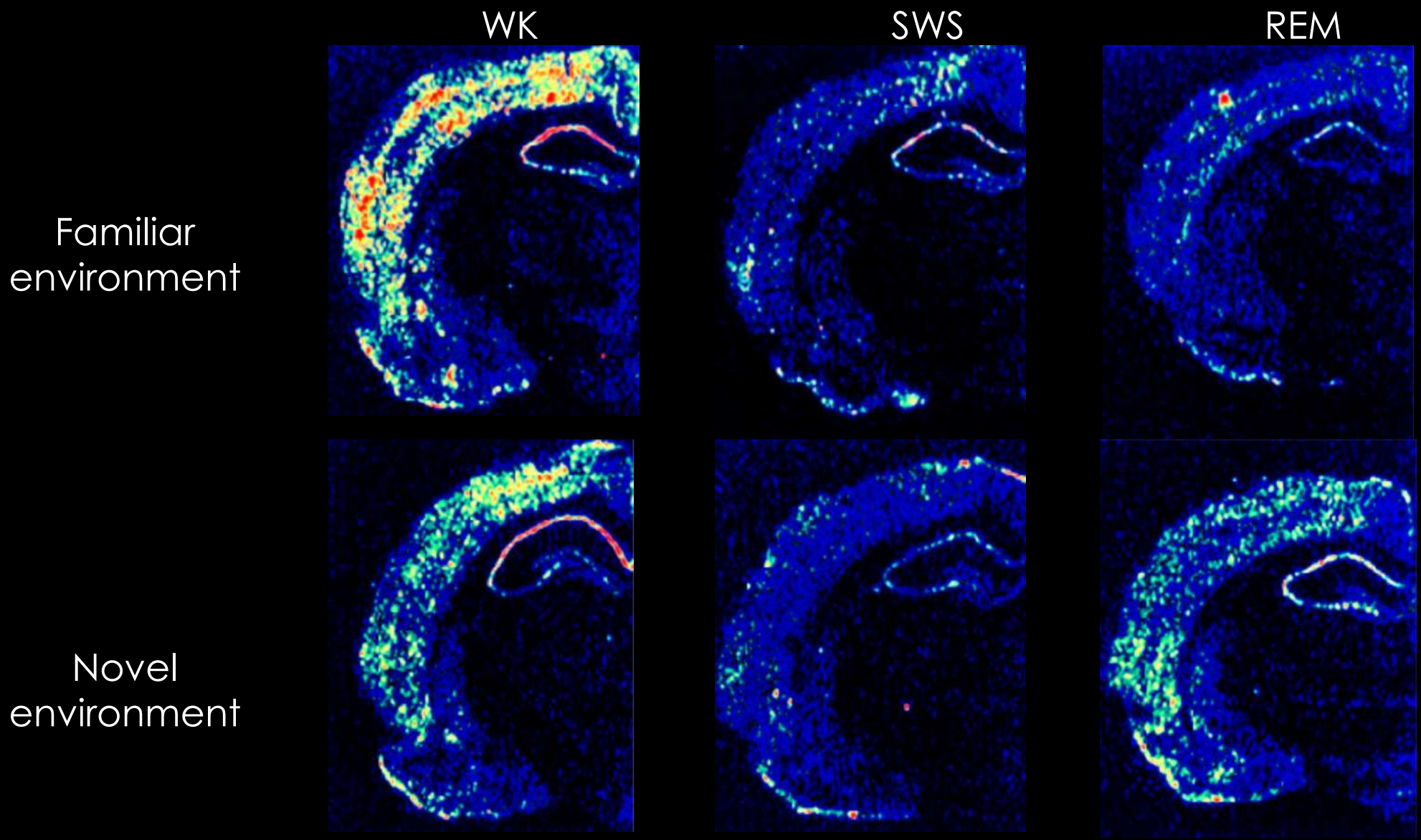
Synaptic Homeostasis Hypothesis (SHY)



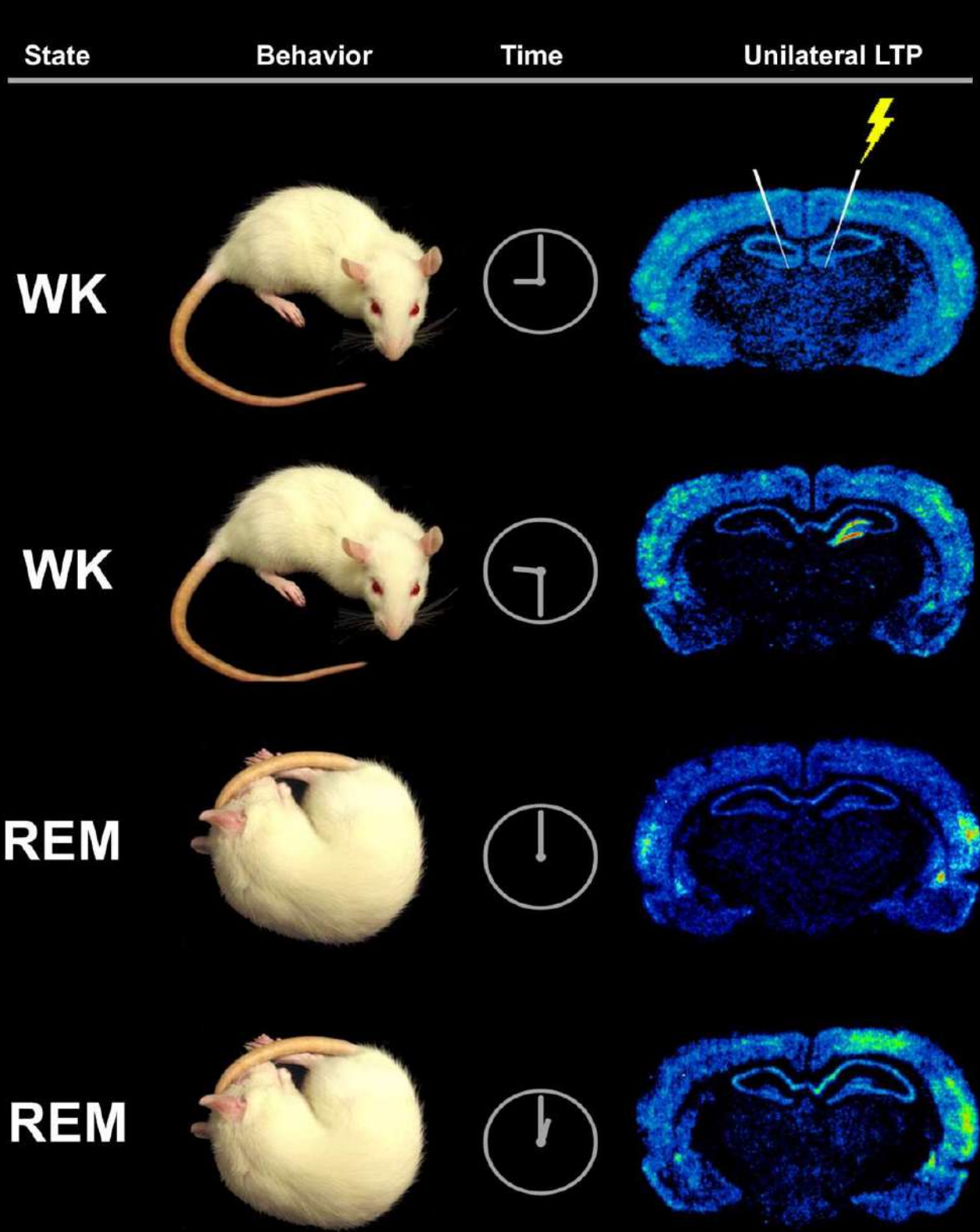
Tononi G, Cirelli C (2006) **Sleep function and synaptic homeostasis.** Sleep Med Rev 10: 49-62.

Molecular day residues:

IEG expression is upregulated during REM sleep



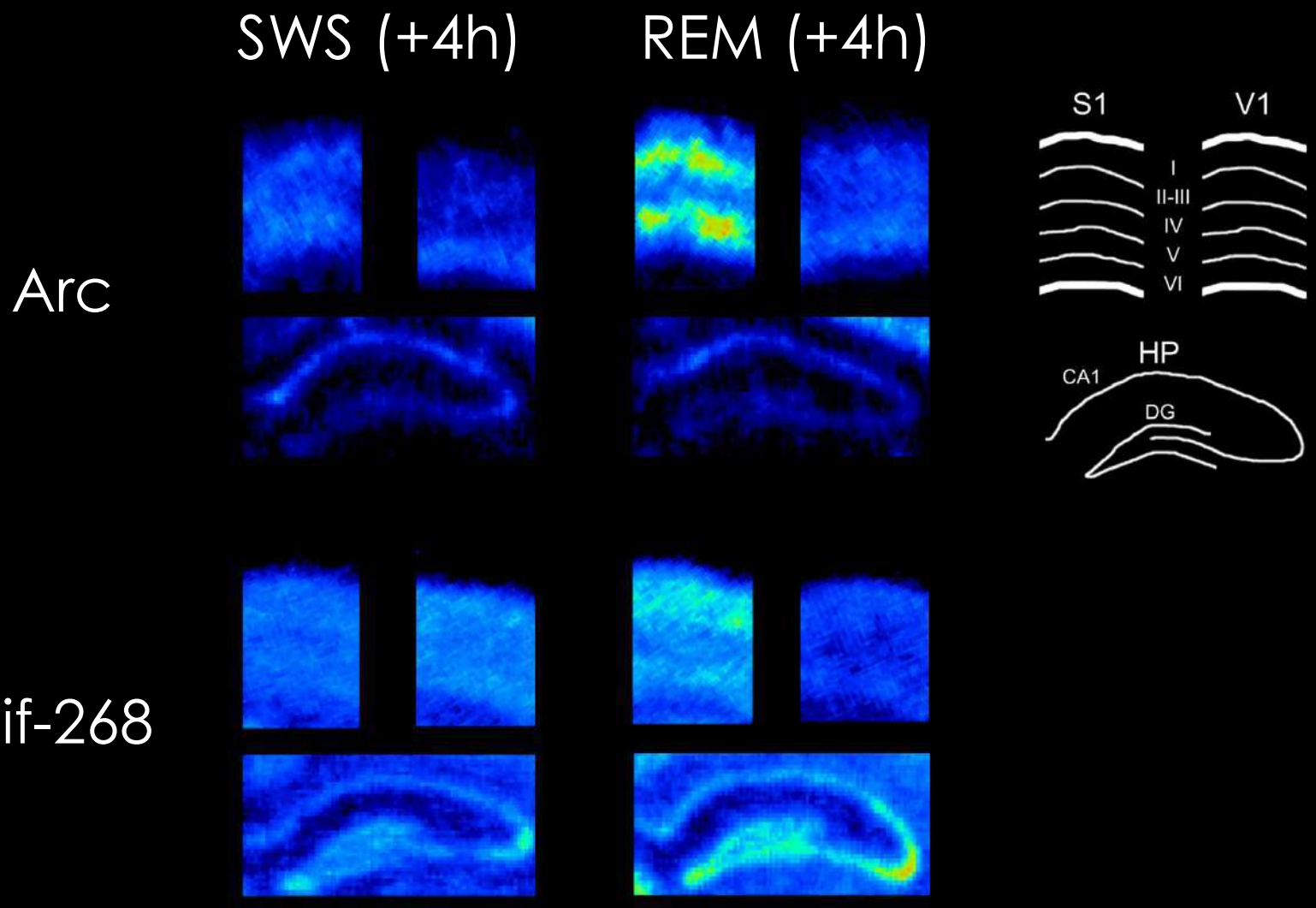
Ribeiro S, Goyal V, Mello CV, Pavlides C. **Brain gene expression during REM sleep depends on prior waking experience.** Learn Mem. 1999 Sep-Oct;6(5):500-8.



IEG reinduction during REM sleep **decreases** in the hippocampus and **increases** in the cerebral cortex and amygdala as the cycle recurs

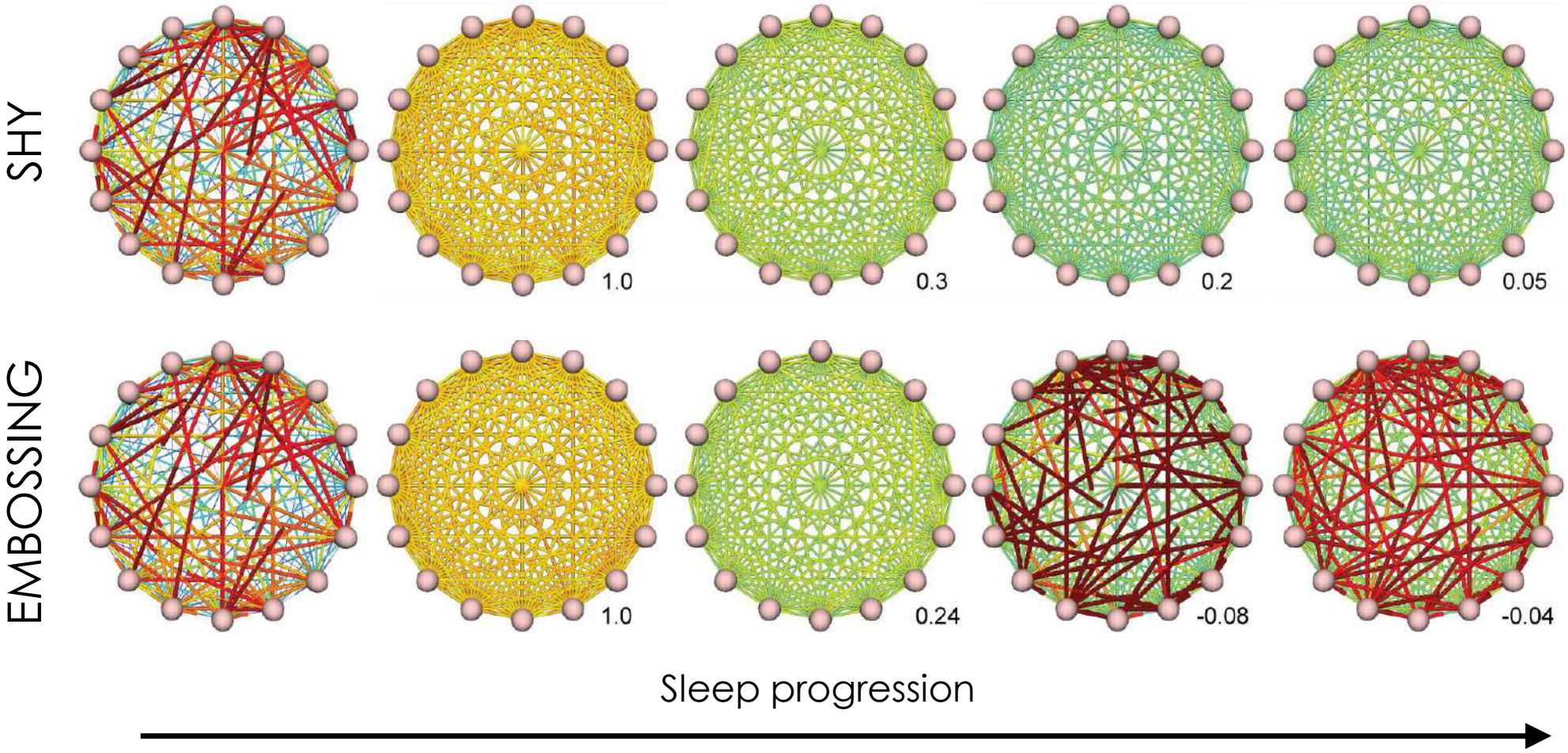
Ribeiro S, Mello CV, Velho T, Gardner TJ, Jarvis ED, Pavlides C.
Induction of hippocampal long-term potentiation during waking leads to increased extrahippocampal zif-268 expression during ensuing rapid-eye-movement sleep. J Neurosci. 2002 Dec 15;22(24):10914-23.

Cortical IEG expression during late REM sleep



Ribeiro S, Shi X, Engelhard M, Zhou Y, Zhang H, Gervasoni D, Lin SC, Wada K, Lemos NA, Nicolelis MA. **Novel experience induces persistent sleep-dependent plasticity in the cortex but not in the hippocampus.** Front Neurosci. 2007 Oct 15;1(1):43-55.

Synaptic Embossing Hypothesis



Ribeiro S, Pereira CM, Faber J, Blanco W, Nicolelis MAL. **Downscale or emboss synapses during sleep.** Frontiers in Neuroscience 2009 Dec(Print) 3 (3): 420-421.

Blanco W, Pereira CM, Cota VR, Souza AC, Rennó-Costa C, Santos S, Dias G, Guerreiro AM, Tort AB, Neto AD, Ribeiro S. **Synaptic Homeostasis and Restructuring across the Sleep-Wake Cycle.** PLoS Comput Biol. 2015 May 28;11(5):e1004241.

SYNAPTIC HOMEOSTASIS HYPOTHESIS

Tononi G, Cirelli C (2003) **Sleep and synaptic homeostasis: a hypothesis.** Brain Res Bull 62: 143-150.

Cirelli C, Gutierrez CM, Tononi G (2004) **Extensive and divergent effects of sleep and wakefulness on brain gene expression.** Neuron 41: 35-43.

Tononi G, Cirelli C (2006) **Sleep function and synaptic homeostasis.** Sleep Med Rev 10: 49-62.

Vyazovskiy VV, Cirelli C, Tononi G, Tobler I (2008) **Cortical metabolic rates as measured by 2-deoxyglucose-uptake are increased after waking and decreased after sleep in mice.** Brain Res Bull 75: 591-597.

Olcese U, Esser SK, Tononi G (2010) **Sleep and synaptic renormalization: a computational study.** J Neurophysiol 104: 3476-3493.

Bushey D, Tononi G, Cirelli C (2011**) Sleep and synaptic homeostasis: structural evidence in Drosophila.** Science 332: 1576.

Nere A, Hashmi A, Cirelli C, Tononi G. **Sleep-dependent synaptic down-selection (I): modeling the benefits of sleep on memory consolidation and integration.** Front Neurol. 2013 Sep 30;4:143.

de Vivo L, Bellesi M, Marshall W, Bushong EA, Ellisman MH, Tononi G, Cirelli C. (2017) **Ultrastructural evidence for synaptic scaling across the wake/sleep cycle.** Science 355(6324):507-510.

X

SYNAPTIC EMBOSSING HYPOTHESIS

Ulloor J, Datta S (, Jaganath D, Havekes 2005) **Spatio-temporal activation of cyclic AMP response element-binding protein, activity-regulated cytoskeletal-associated protein and brain-derived nerve growth factor: a mechanism for pontine-wave generator activation-dependent two-way active-avoidance memory processing in the rat.** J Neurochem 95: 418-428.

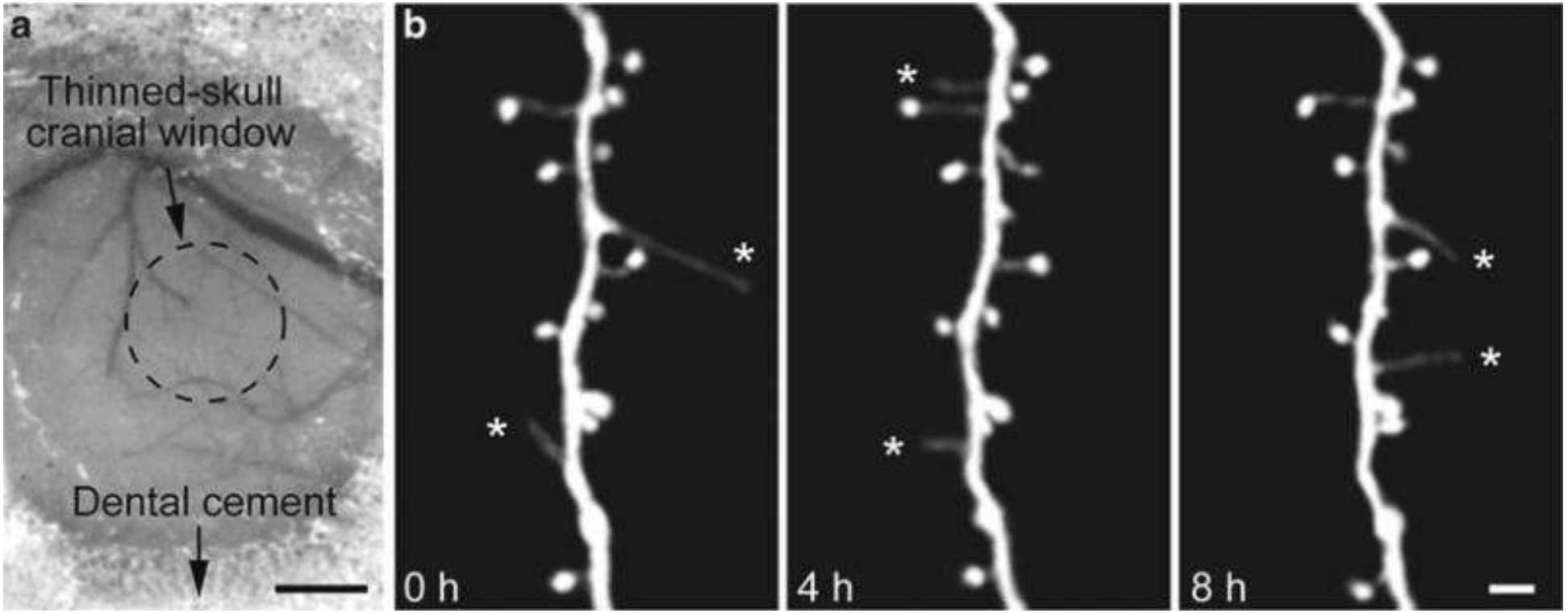
Vecsey CG, Baillie GSR, Daniels A, Wimmer M, Huang T, Brown KM, Li XY, Descalzi G, Kim SS, Chen T, Shang YZ, Zhuo M, Houslay MD, Abel T. **Sleep deprivation impairs cAMP signalling in the hippocampus.** Nature. 2009 Oct 22;461(7267):1122-5.

Aton SJ, Seibt J, Dumoulin M, Jha SK, Steinmetz N, Coleman T, Naidoo N, Frank MG. **Mechanisms of sleep-dependent consolidation of cortical plasticity.** Neuron. 2009 Feb 12;61(3):454-66

Seibt J, Dumoulin MC, Aton SJ, Coleman T, Watson A, Naidoo N, Frank MG. **Protein synthesis during sleep consolidates cortical plasticity in vivo.** Curr Biol. 2012 Apr 24;22(8):676-82.

Yang G, Lai CS, Cichon J, Ma L, Li W, Gan WB. **Sleep promotes branch-specific formation of dendritic spines after learning**. Science. 2014 Jun 6;344(6188):1173-8.

Calais JB, Ojopi EB, Morya E, Sameshima K, Ribeiro S. **Experience-dependent upregulation of multiple plasticity factors in the hippocampus during early REM sleep.** Neurobiol Learn Mem. 2015 Jul;122:19-27.

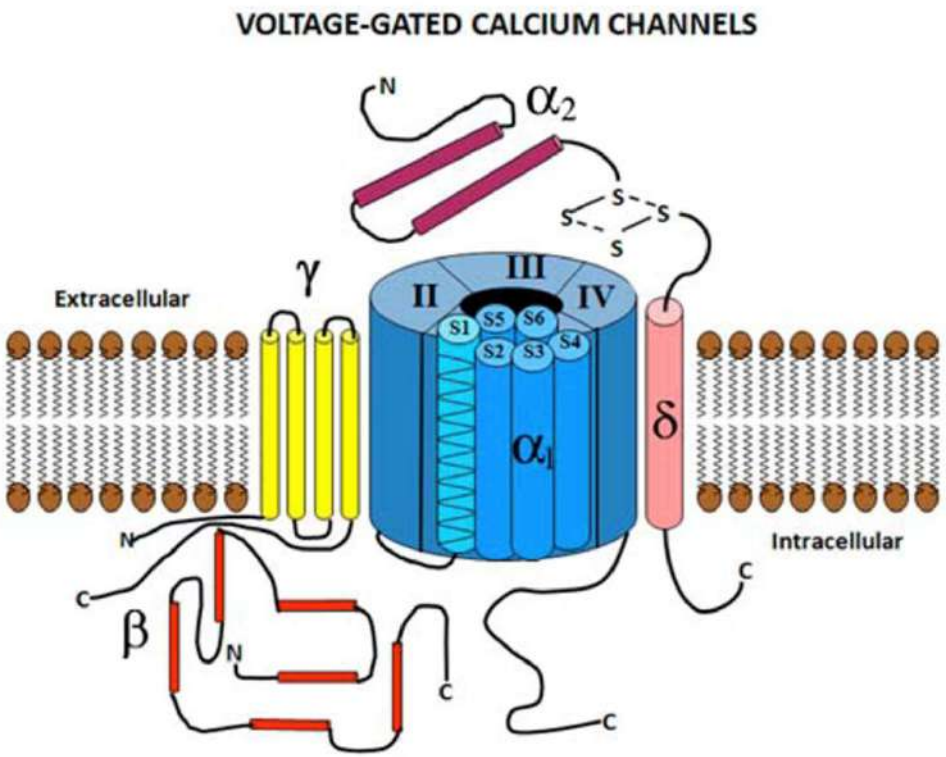


- REM sleep **prunes** newly formed spines after learning
- REM sleep **strengthens** a fraction of new spines after learning
- REM sleep facilitates the long-term survival of **new spines** after learning

Li W, Ma L, Yang G, Gan WB. **REM sleep selectively prunes and maintains new synapses in development and learning.** Nat Neurosci. 2017 Mar;20(3):427-437. doi: 10.1038/nn.4479.

Waking experience and sleep states modulate the levels of **phosphorylated proteins**

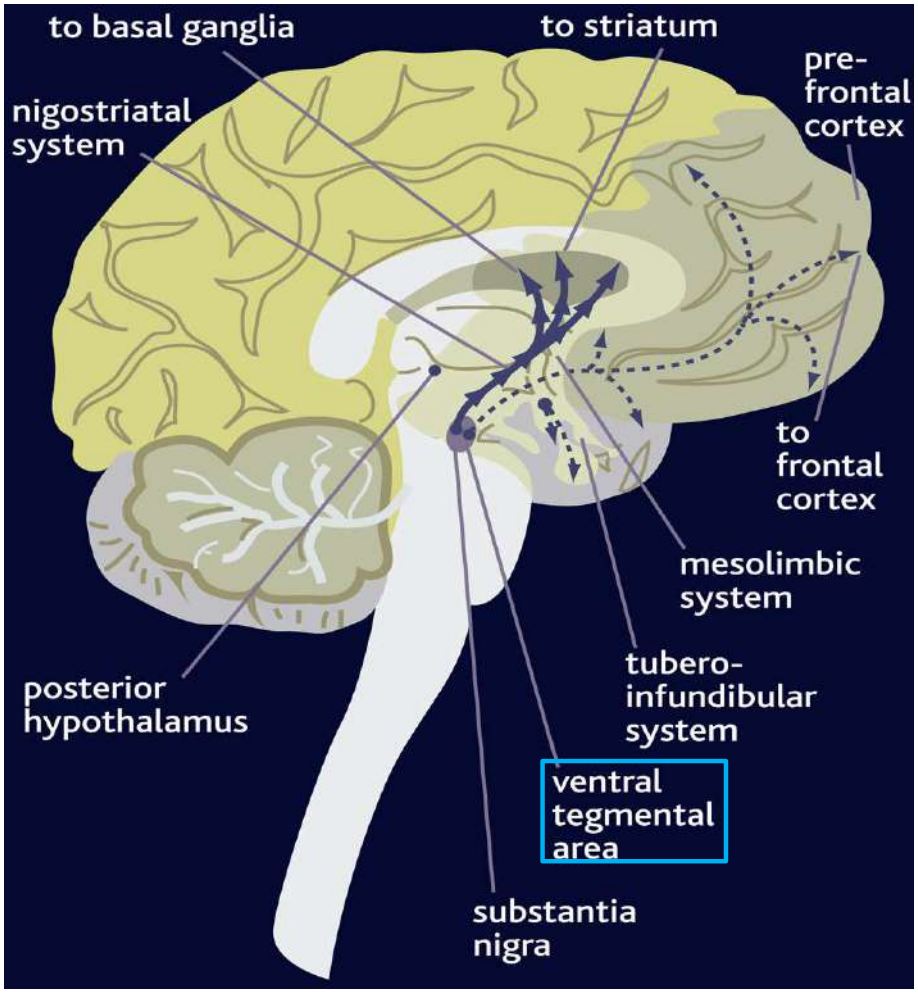
- The levels of several phosphoproteins were correlated with the abundance of **sleep spindles** at the SWS/REM transition.
- In particular, the voltage-dependent calcium channel subunit alpha-2/delta-1 is significantly **down-regulated** from SWS to REM in the hippocampus, but not in the cerebral cortex.



AC Souza, DCF Golbert, JS Cassoli, I Sánchez-Gendriz, VVF Lima, FA Cini, D Martins-de-Souza, S Ribeiro. **Experience-dependent phosphoproteomic changes in hippocampus and neocortex correlate with the abundance of spindle oscillations during the transition between SWS and REM sleep.** Preprint Research Square 2022 doi: 10.21203/rs.3.rs-1842393/v2

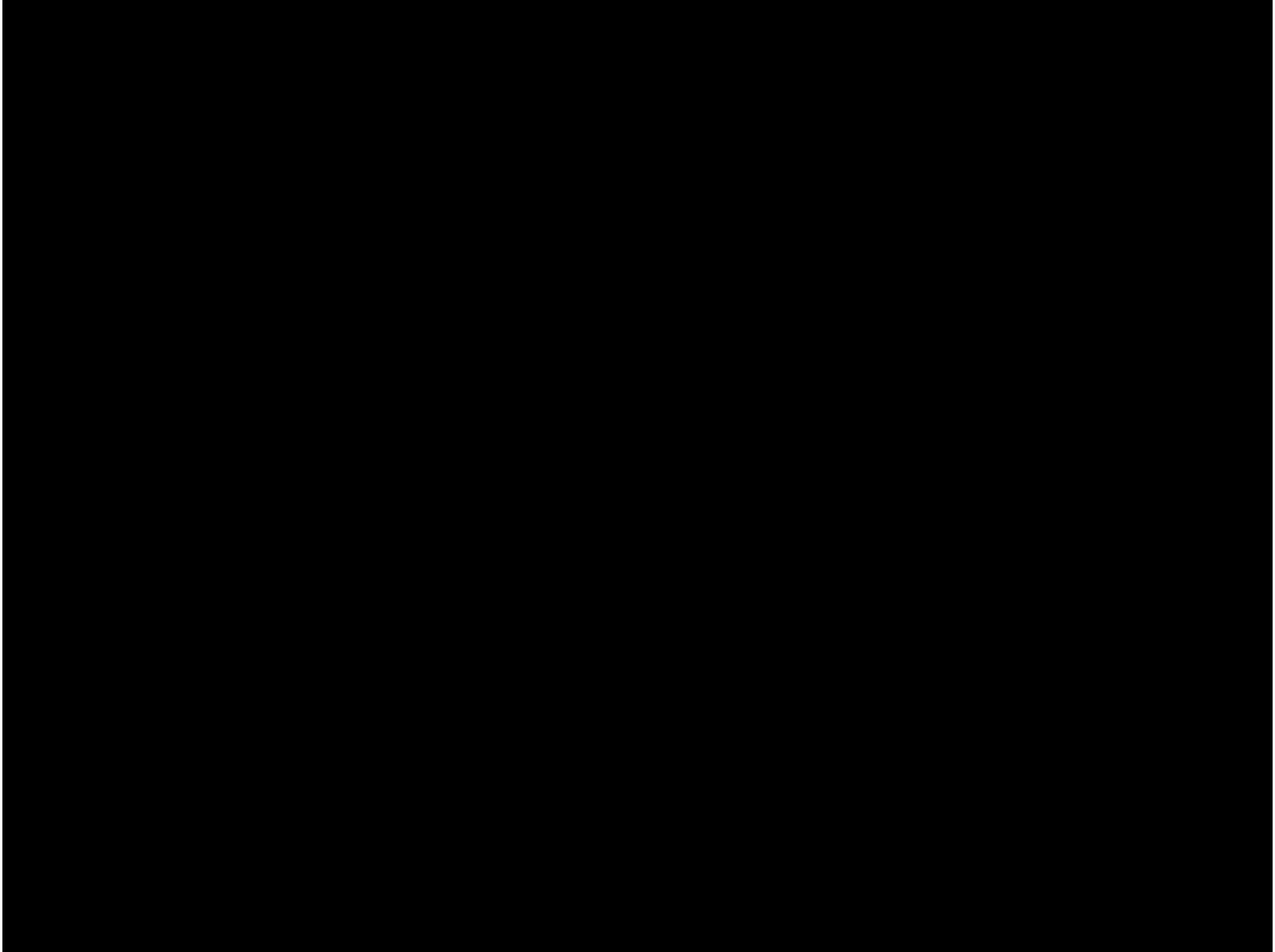
Dream, Grete Stern

Damage to **dopaminergic** reward circuits preserves REM sleep but eliminates dreaming



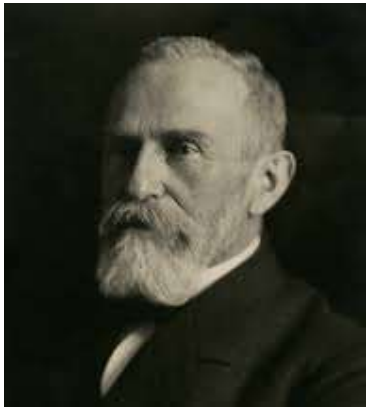
Solms M. **Dreaming and REM sleep are controlled by different brain mechanisms.** Behav Brain Sci. 2000 Dec;23(6):843-50; discussion 904-1121.

Le Rêve, Henri Rousseau

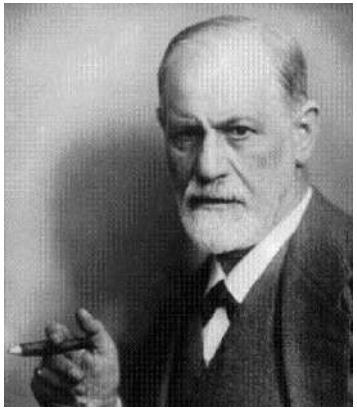


Psychosis resembles dreaming

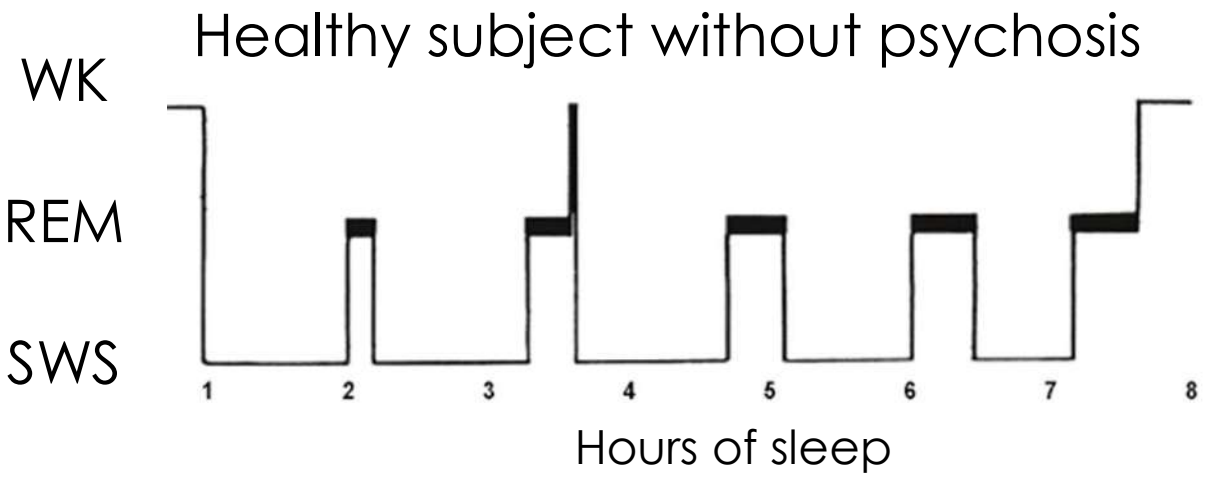
Emil Kraepelin

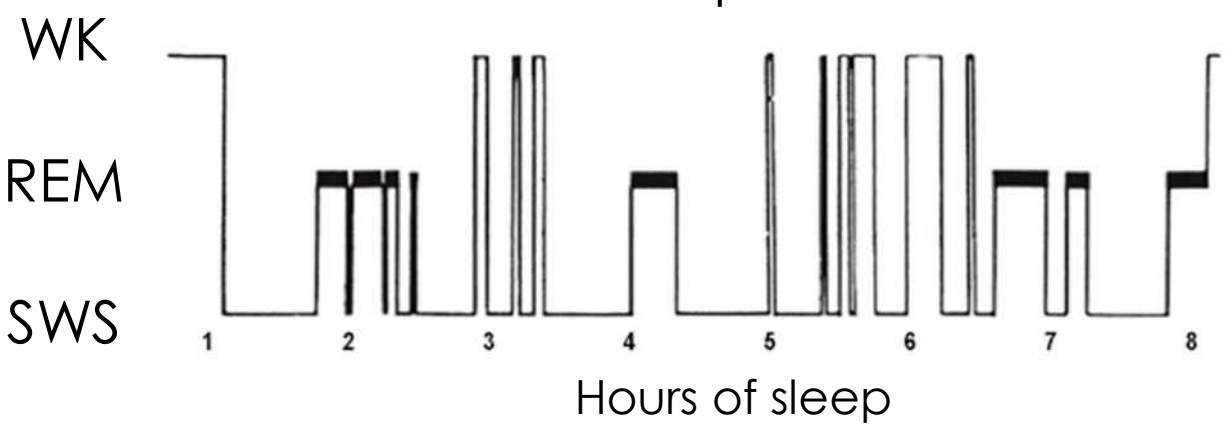


Eugen Bleuler



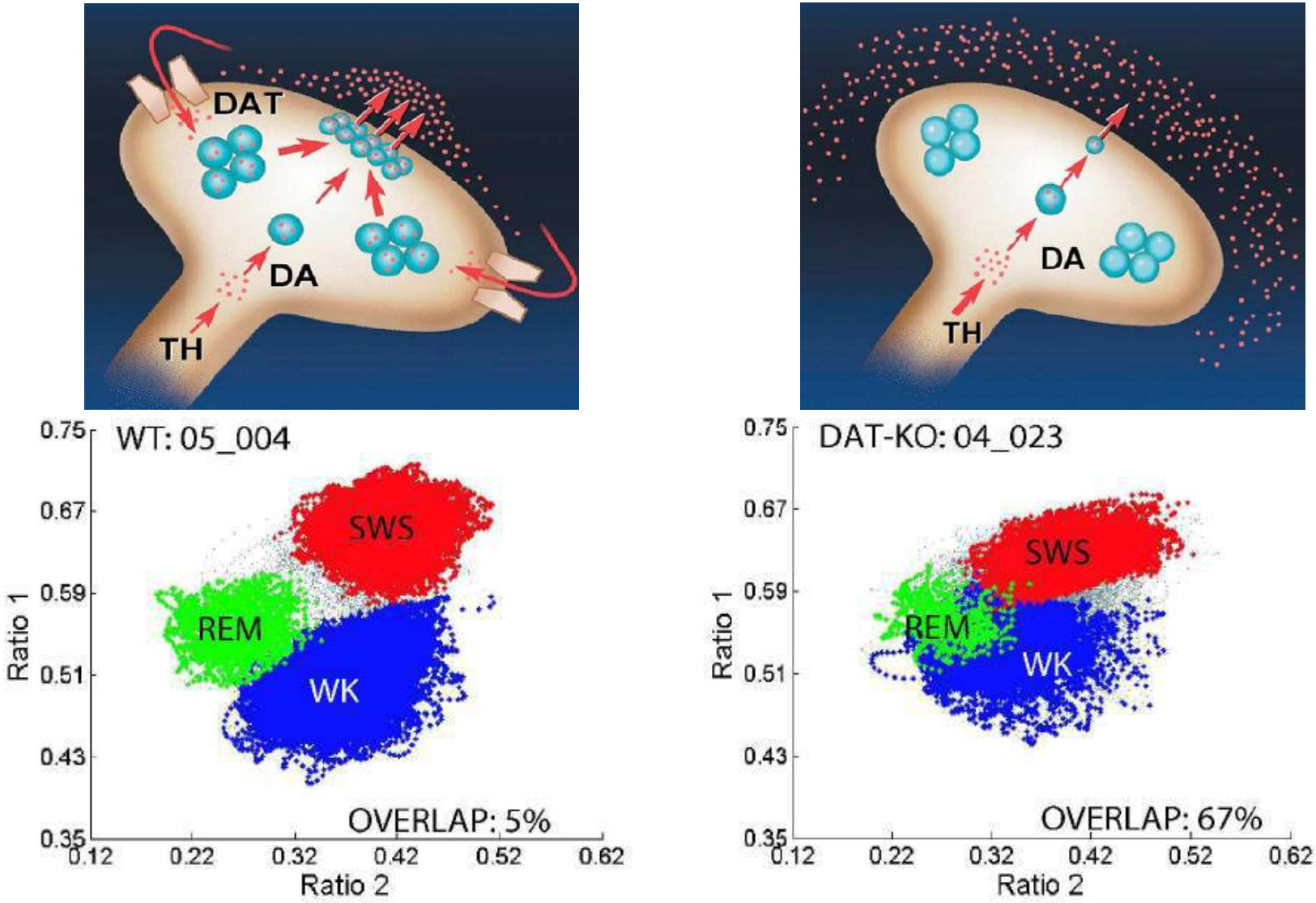
Sigmund Freud





Ernest Hartmann (1967) The Biology of Dreams

Dopamine increases WK/REM spectral overlap

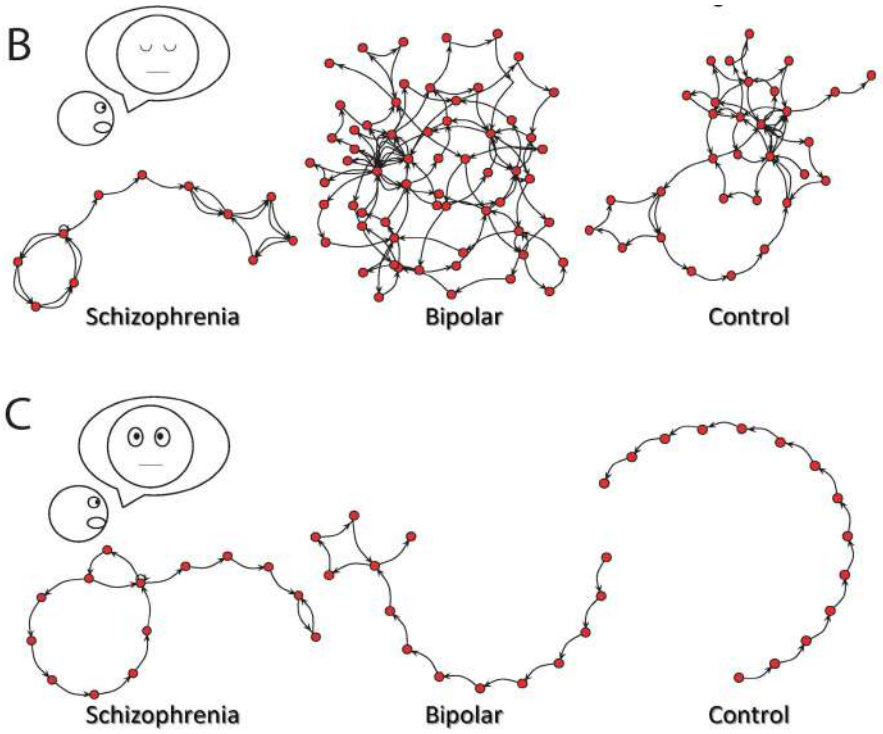


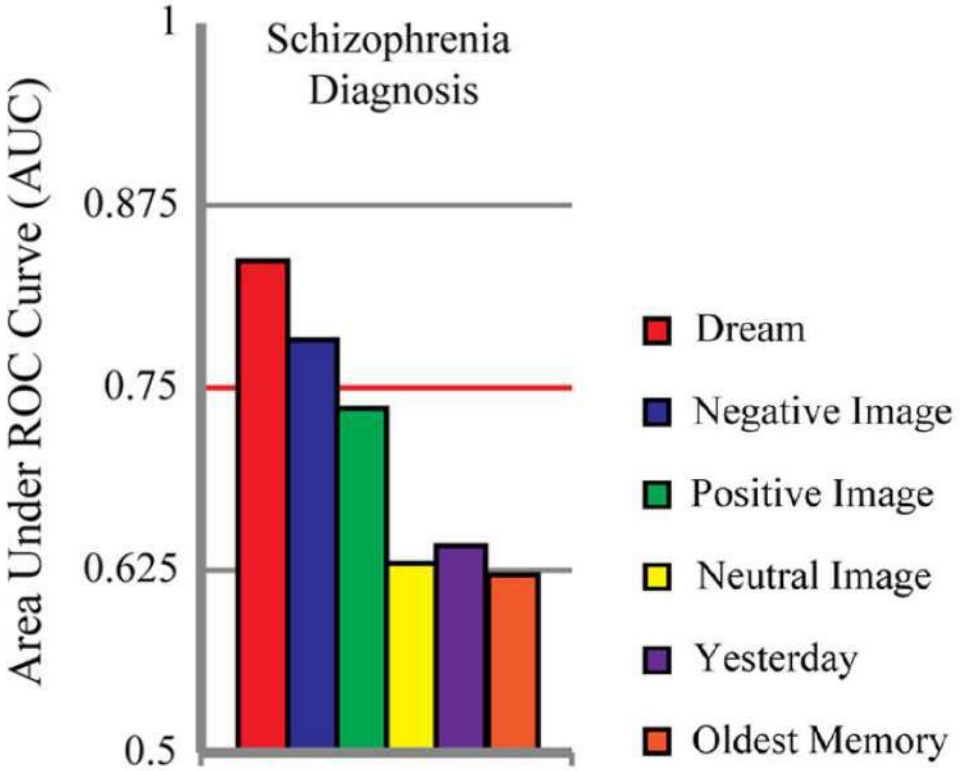
Dzirasa K, Ribeiro S, Costa R, Santos LM, Lin SC, Grosmark A, Sotnikova TD, Gainetdinov RR, Caron MG, Nicolelis MA**. Dopaminergic control of sleep-wake states.** J Neurosci. 2006 Oct 11;26(41):10577-89.

Dream reports are especially informative about **schizophrenia**

Dream Report

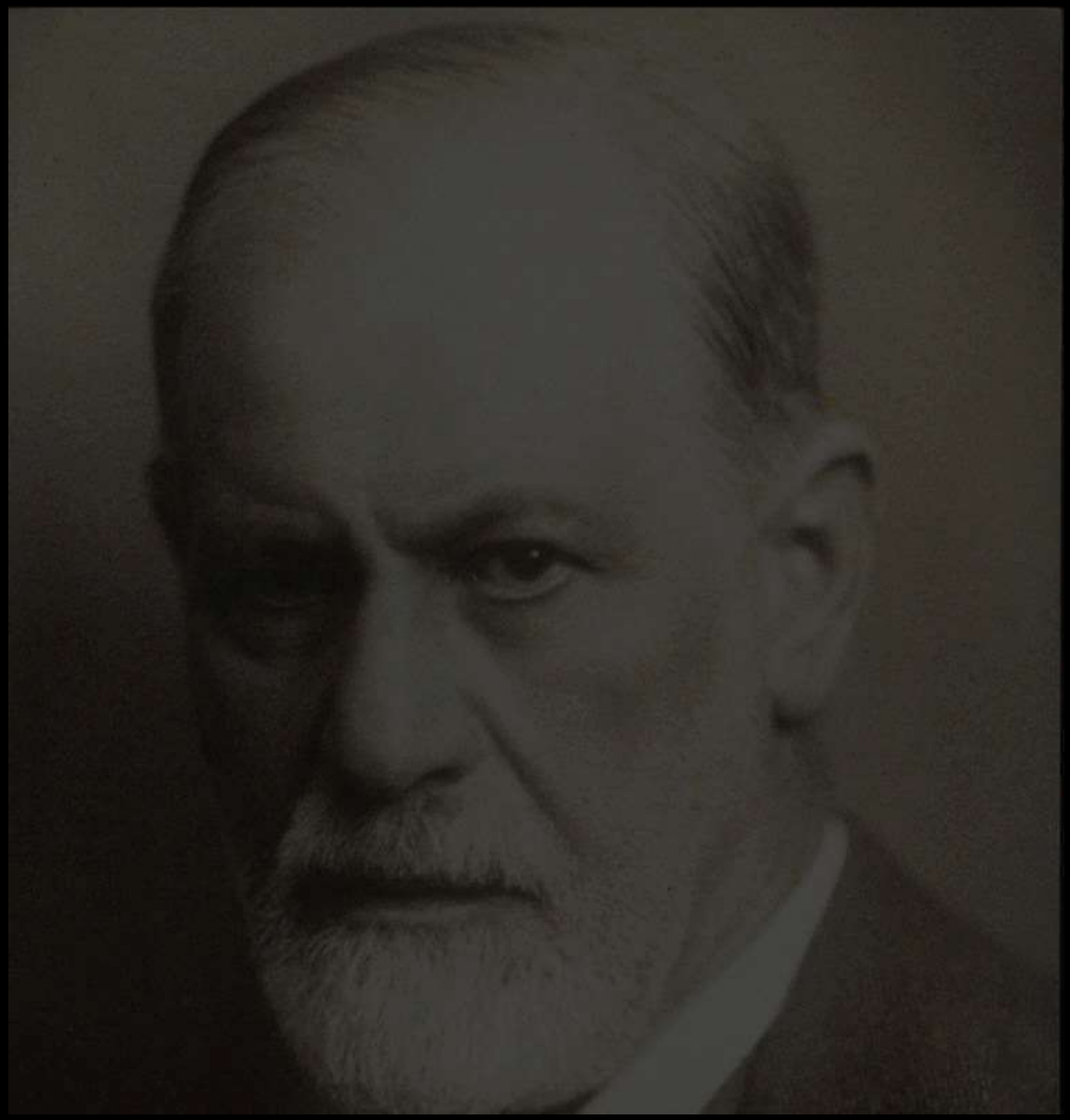
Waking Report





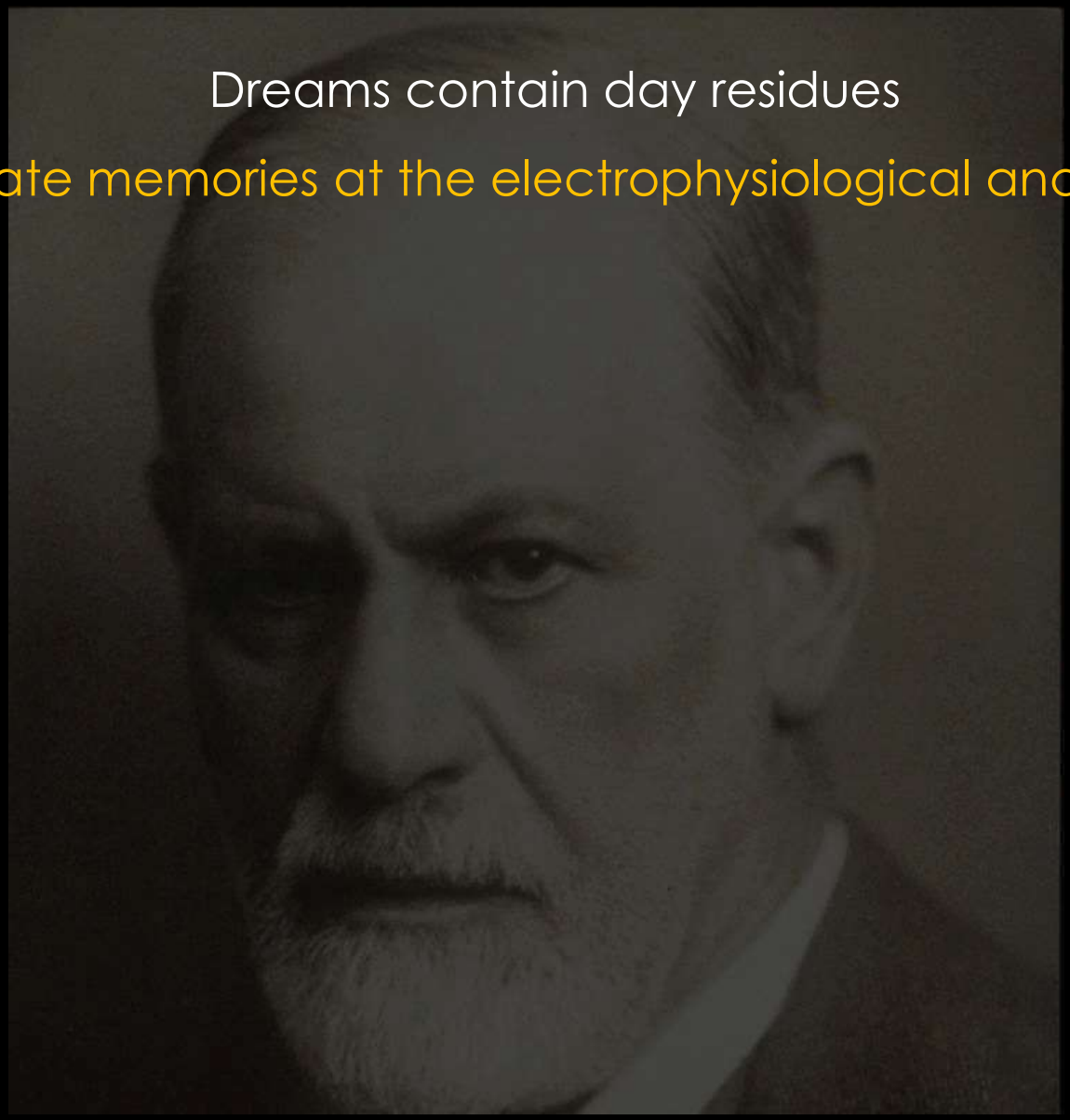
Mota NB, Furtado R, Maia PP, Copelli M, Ribeiro S. **Graph analysis of dream reports is especially informative about psychosis.** Sci Rep. 2014 Jan 15;4:3691.

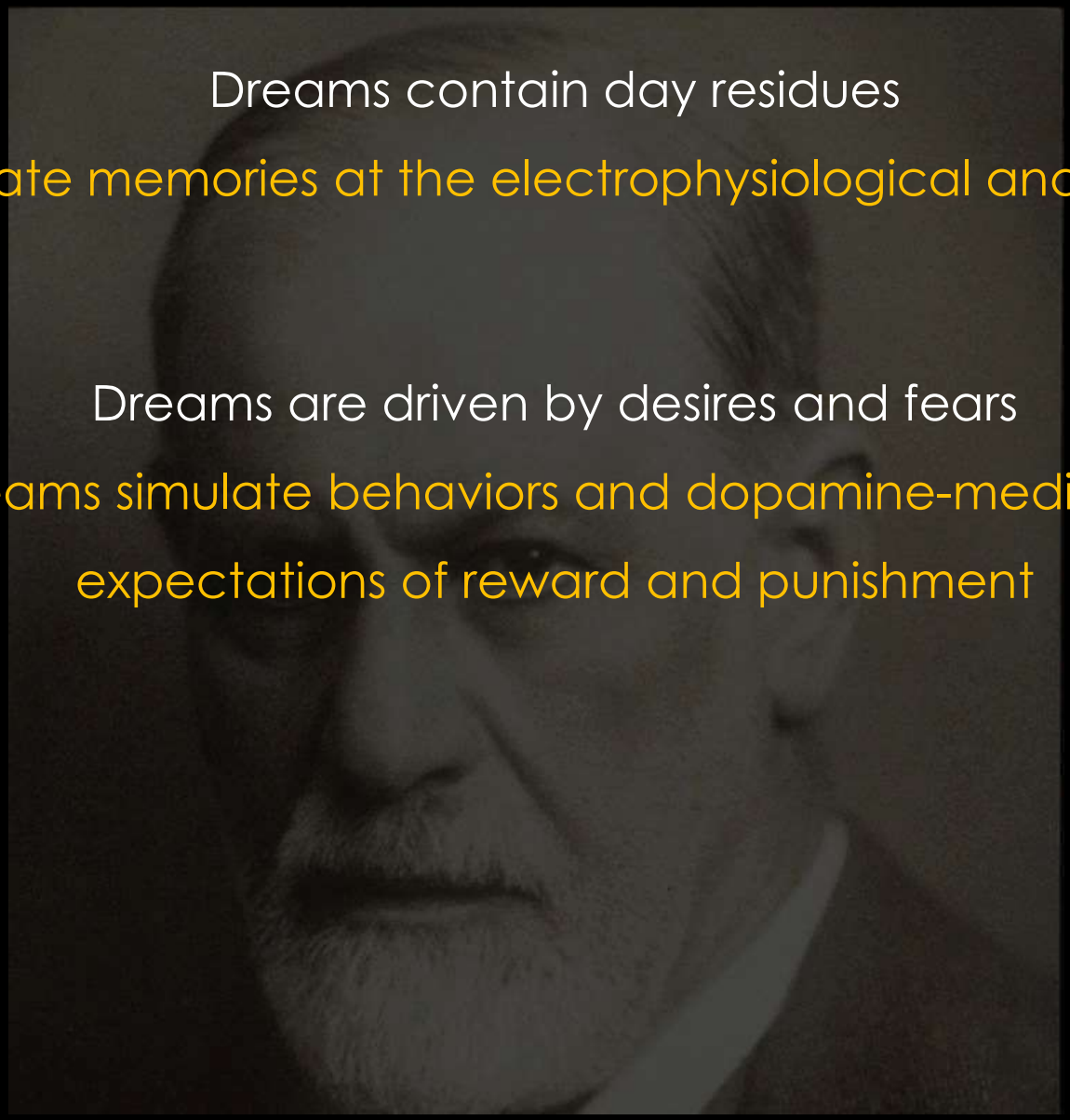
Mota NB, Copelli M, Ribeiro S. **Thought disorder measured as random speech structure classifies negative symptoms and schizophrenia diagnosis 6 months in advance.** NPJ Schizophr. 2017 Apr 13;3:18.



Dreams contain day residues

Dreams reactivate memories at the electrophysiological and molecular levels



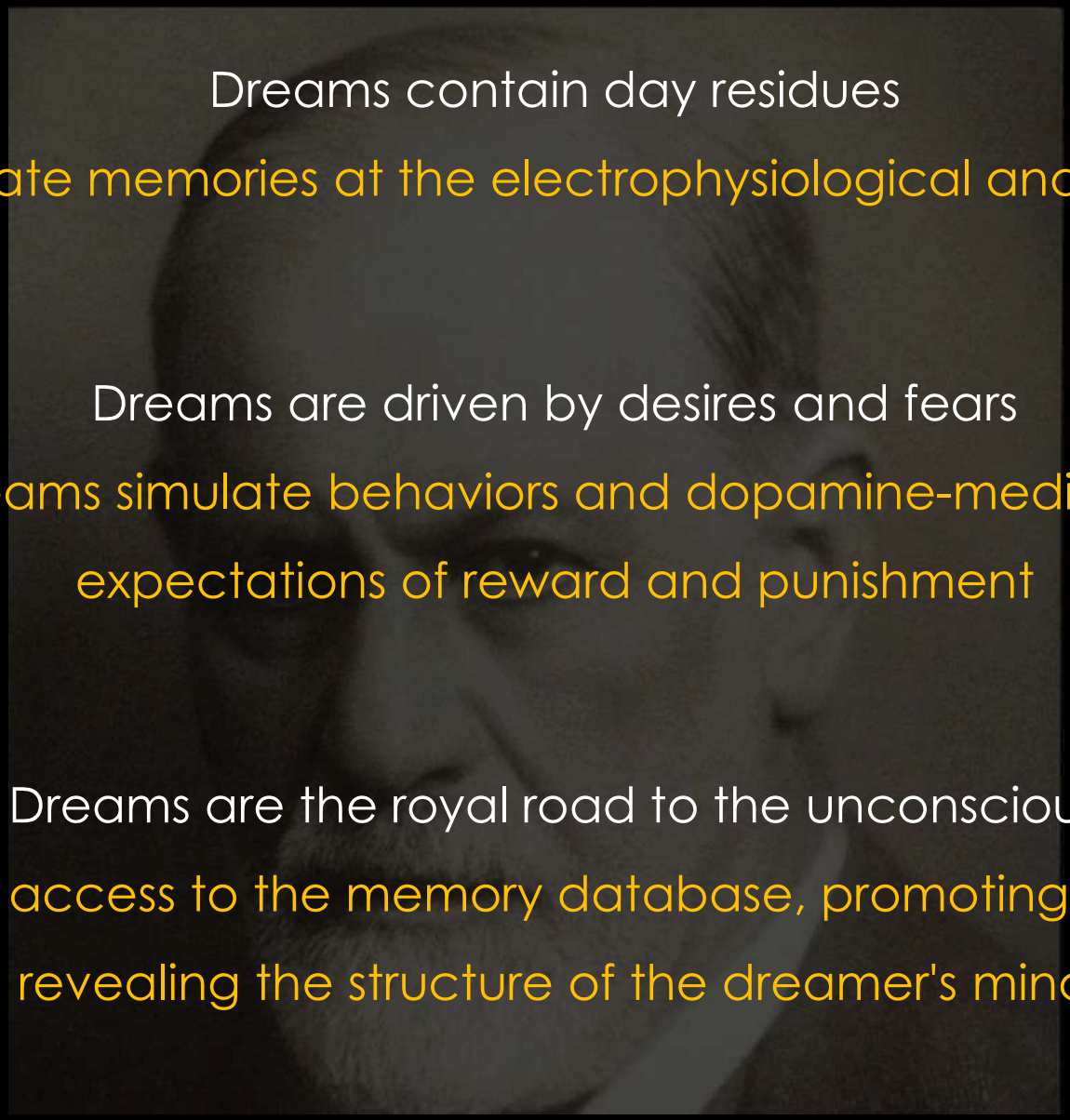


Dreams contain day residues

Dreams reactivate memories at the electrophysiological and molecular levels

Dreams are driven by desires and fears

Dreams simulate behaviors and dopamine-mediated expectations of reward and punishment



Dreams contain day residues

Dreams reactivate memories at the electrophysiological and molecular levels

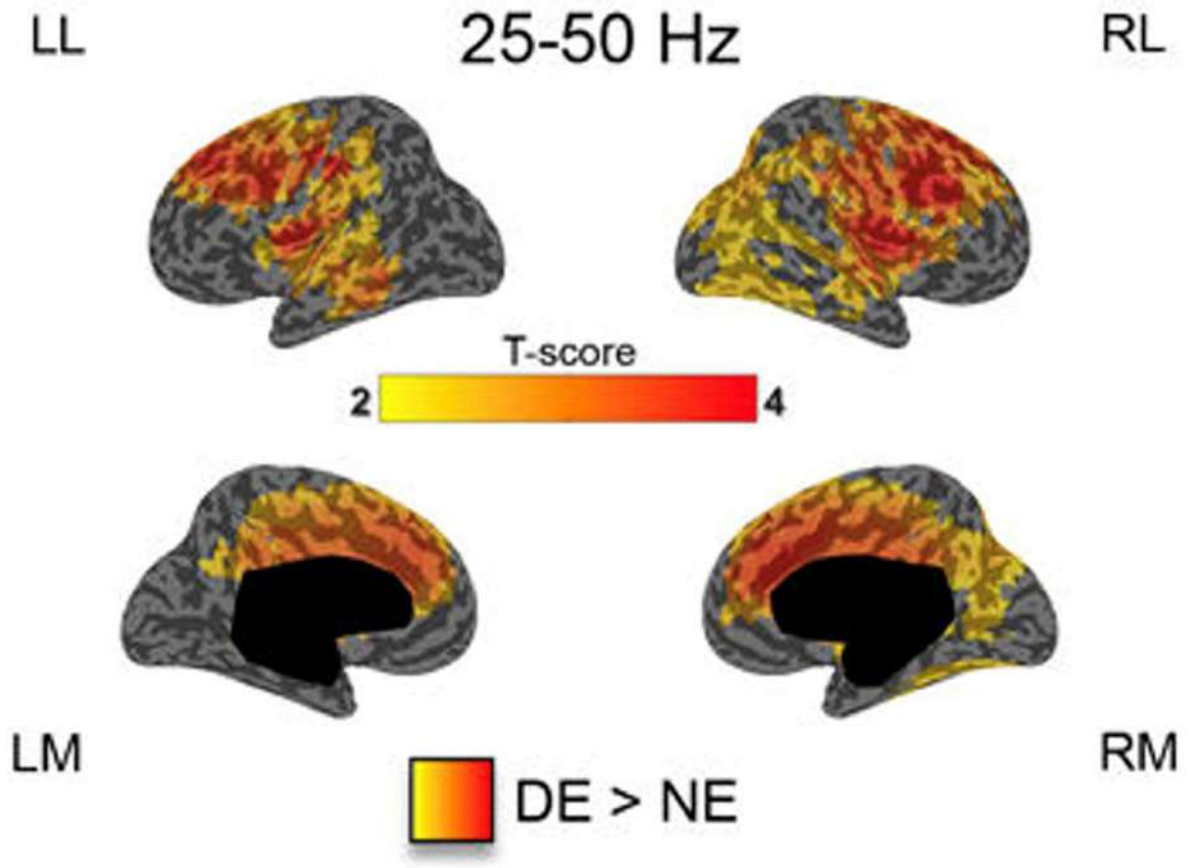
Dreams are driven by desires and fears

Dreams simulate behaviors and dopamine-mediated expectations of reward and punishment

Dreams are the royal road to the unconscious

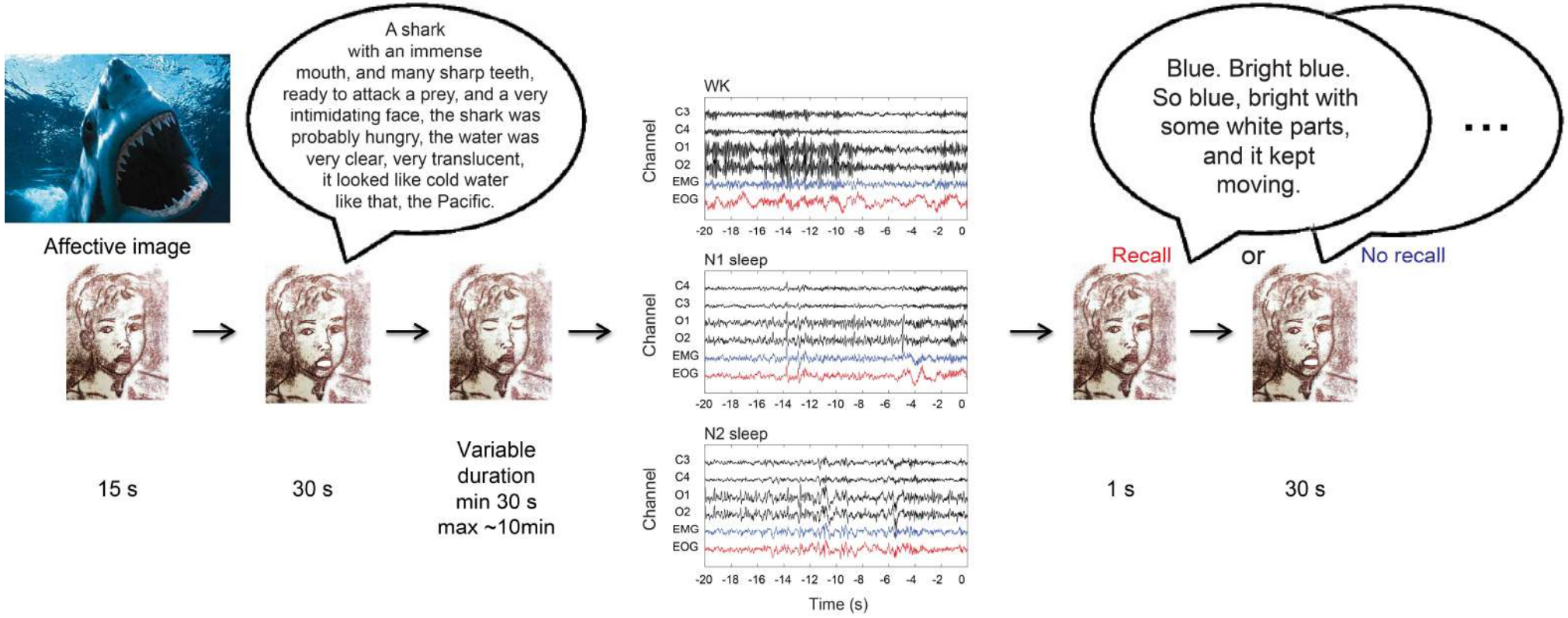
Dreams give access to the memory database, promoting creativity and revealing the structure of the dreamer's mind

Dreaming is associated with **high-frequency** activity in posterior cortical regions



Siclari F, Baird B, Perogamvros L, Bernardi G, LaRocque JJ, Riedner B, Boly M, Postle BR, Tononi G. **The neural correlates of dreaming.** Nat Neurosci. 2017 Jun;20(6):872-878.

A multiple awakenings protocol to investigate **hypnagogic dreaming**



Participant awake | *Sleep onset* | *Participant awake* | x 36 trials

Visual stimulus with eyes open

"What did you see?" Image report (x)

"How do you rate the affect?" Image valence (x)

"*Please sleep*" Eyes closed

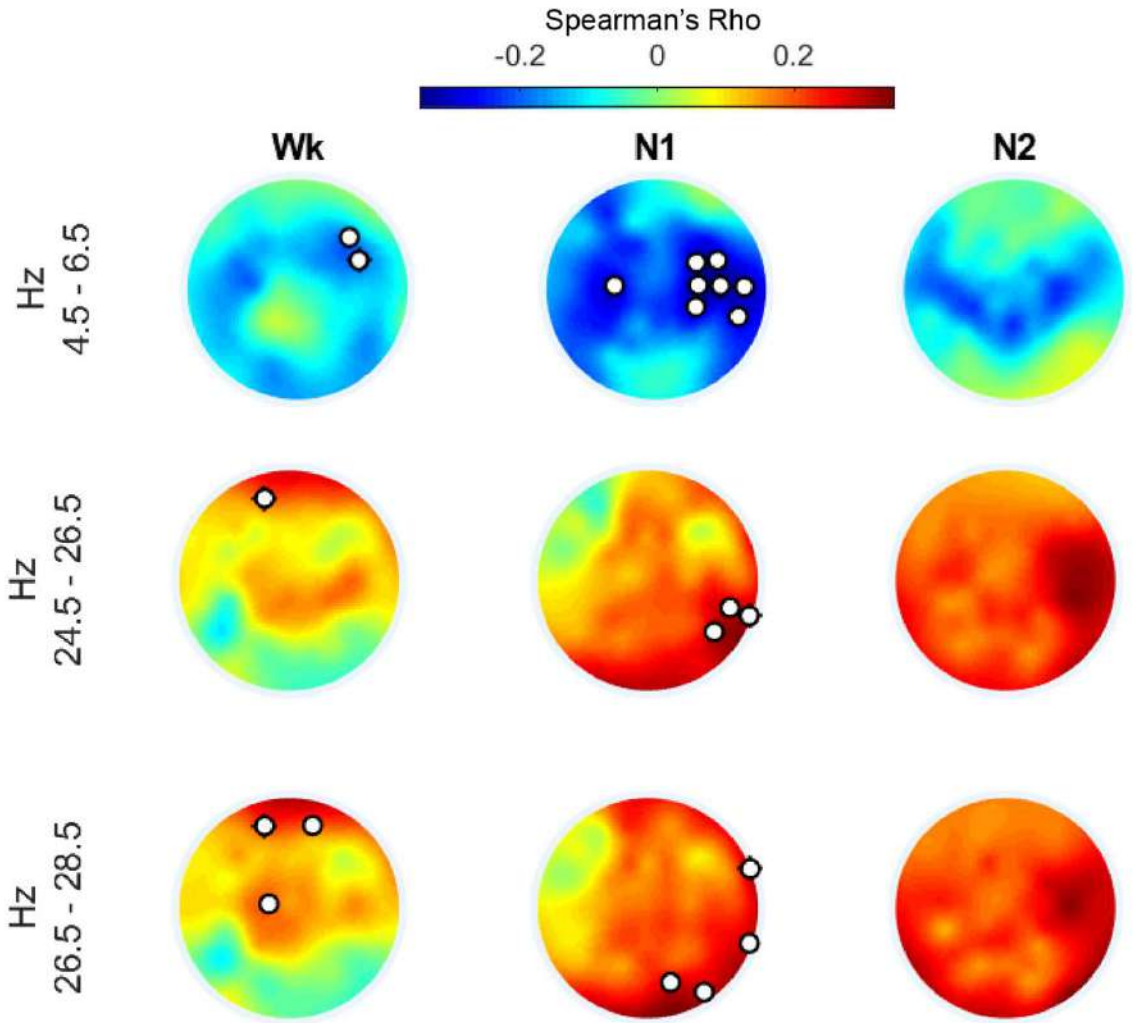
EEG recording until criterion for target state

Beep Eyes open

"What did you see?" Imagery report (y)

"How do you rate the affect?" Imagery valence (y)

Correlations between **Image Residue** and EEG power

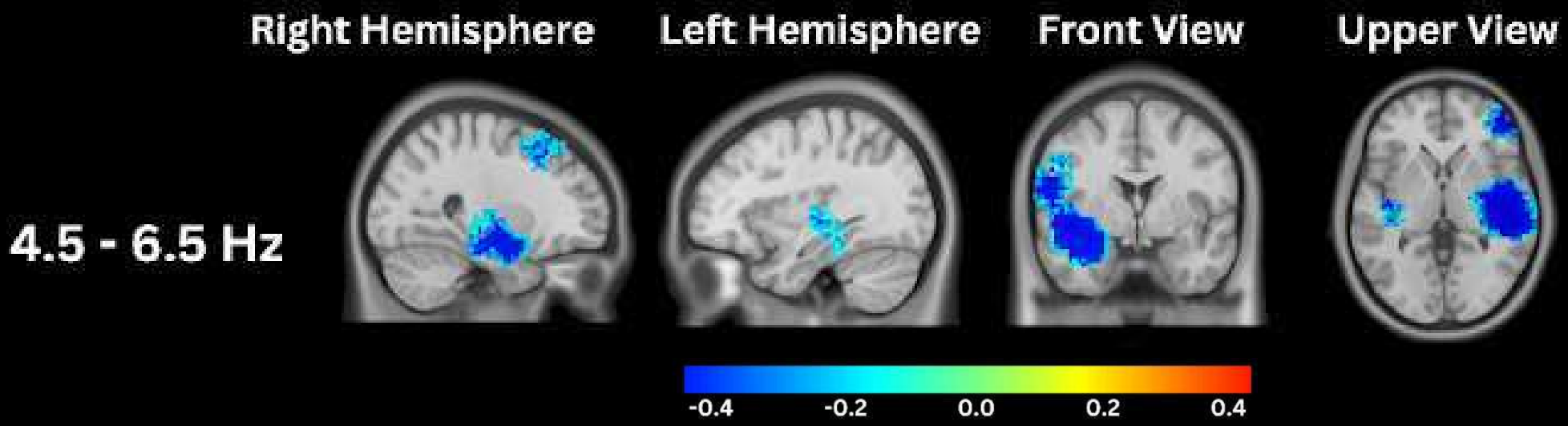


- Increased **theta** power correlates with **decreased** Image Residue.
- Increased **beta** power correlates with I**ncreased** Image residue.

Mota NB, Soares E, Altszyler E, Sánchez-Gendriz I, Muto V, Heib D, Slezak DF, Sigman M, Copelli M, Schabus M, Ribeiro S. **Imagetic and affective measures of memory reverberation diverge at sleep onset in association with theta rhythm.** Neuroimage. 2022 Dec 1;264:119690.

Could the decrease in recent Image Residue during hypnagogic sleep be caused by competition with pre-existing memories powered by theta rhythm from the **hippocampus**?

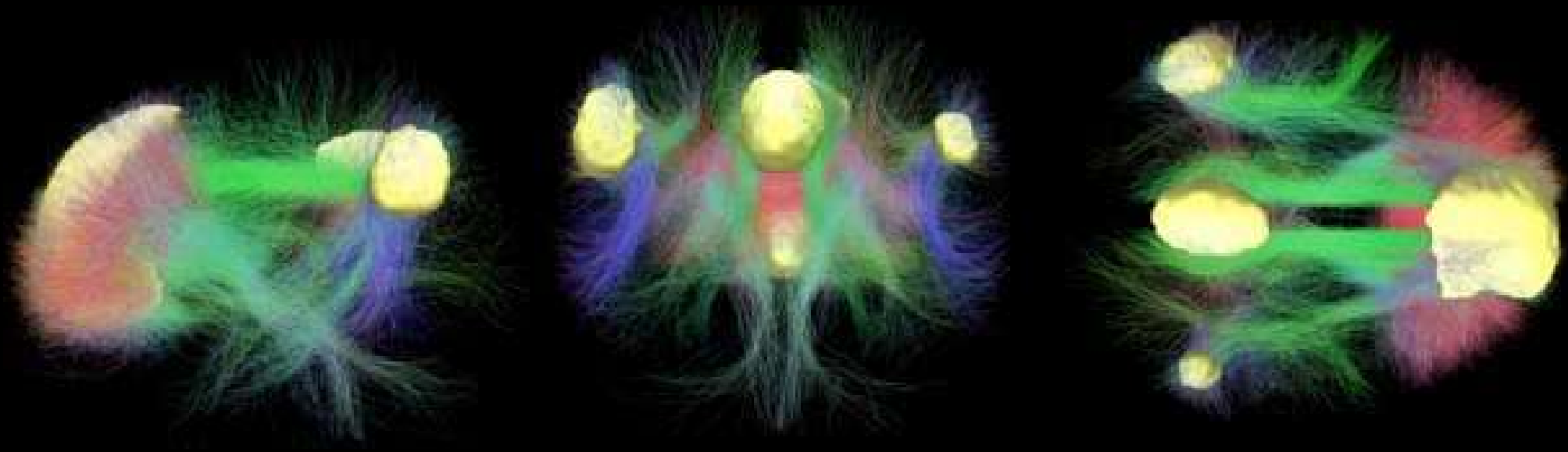
Theta power is negatively correlated with Image Residue in the **hippocampus**



The brain regions engaged during N1 sleep showed a 50% overlap with the default mode network (DMN)

Souza GV, Mota NB, Barros, Ribeiro S (2025) **Hypnagogic Processing of Visuo-Affective Day Residues: Neural Correlates and Functional Connectivity** (under review)

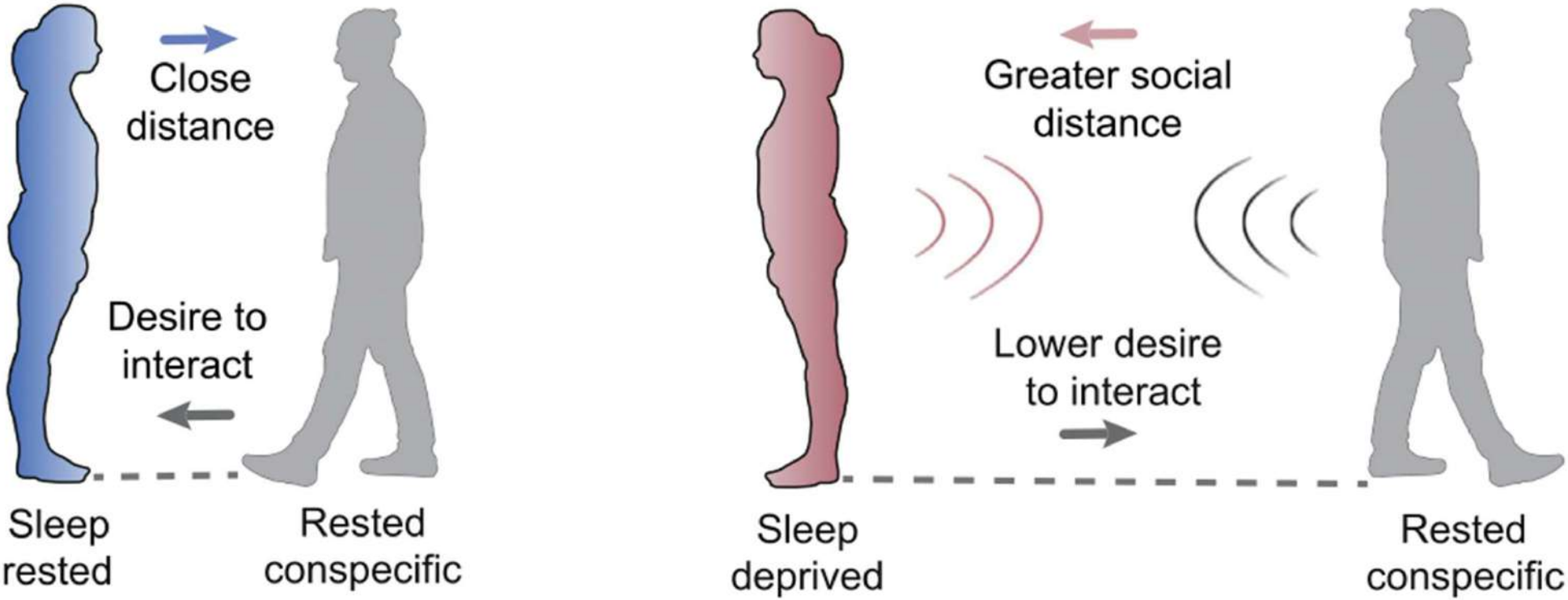
The **DMN** is activated when people dream, mindwander, produce autobiographical narratives, make action plans, and feel **empathy**.



Andrews-Hanna JR. **The brain's default network and its adaptive role in internal mentation.** Neuroscientist. 2012 Jun;18(3):251-70.

Menon V. **20 years of the default mode network: A review and synthesis.** Neuron. 2023 Aug 16;111(16):2469-2487.

Sleep loss decreases empathy and increases social distance



Guadagni V, Burles F, Ferrara M, Iaria G. **The effects of sleep deprivation on emotional empathy.** J Sleep Res. 2014 Dec;23(6):657-663

Duan H, Wang YJ, Lei X. **The effect of sleep deprivation on empathy for pain: An ERP study.** Neuropsychologia. 2021 Dec 10;163:108084.

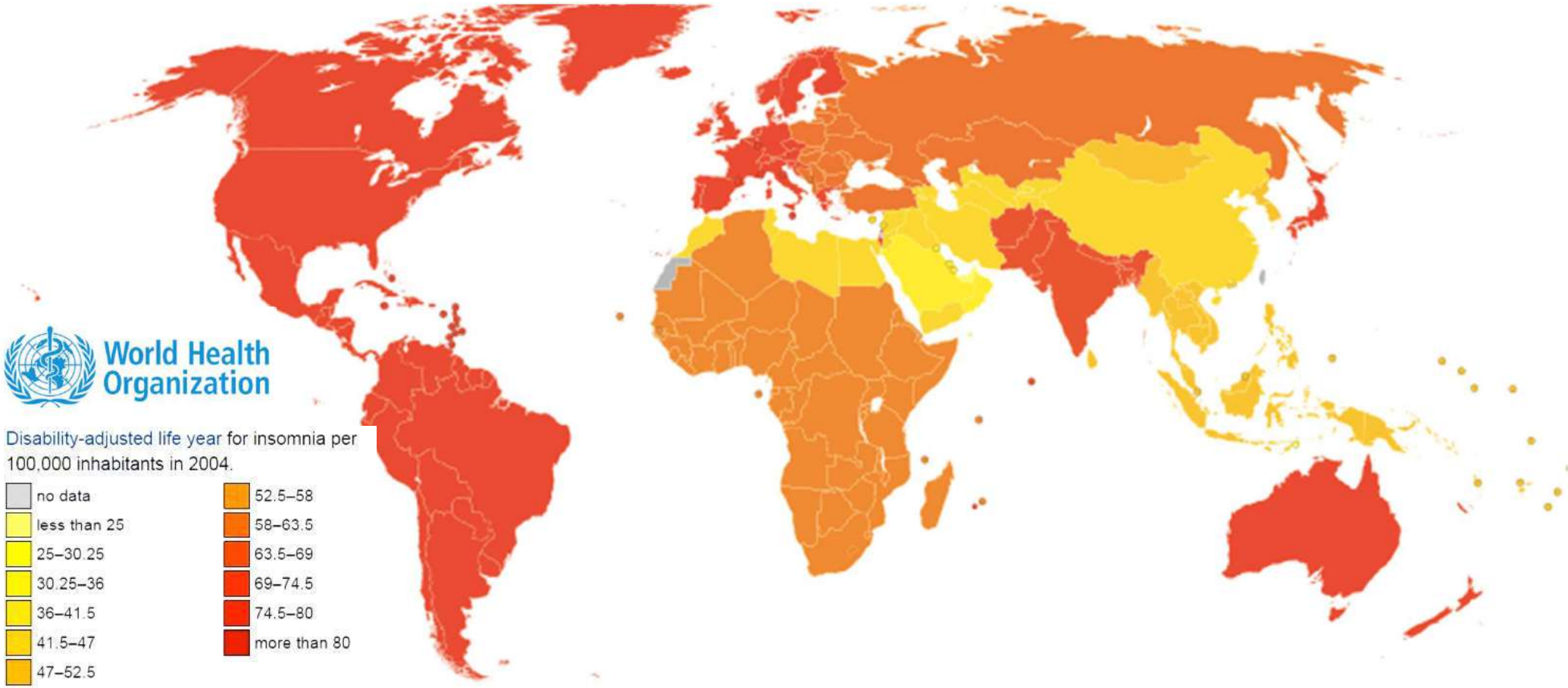
Ben Simon E, Walker MP. **Sleep loss causes social withdrawal and loneliness.** Nat Commun. 2018 Aug 14;9(1):3146.

Ben Simon E, Vallat R, Rossi A, Walker MP. **Sleep loss leads to the withdrawal of human helping across individuals, groups, and large-scale societies.** PLoS Biol. 2022 Aug 23;20(8):e3001733.

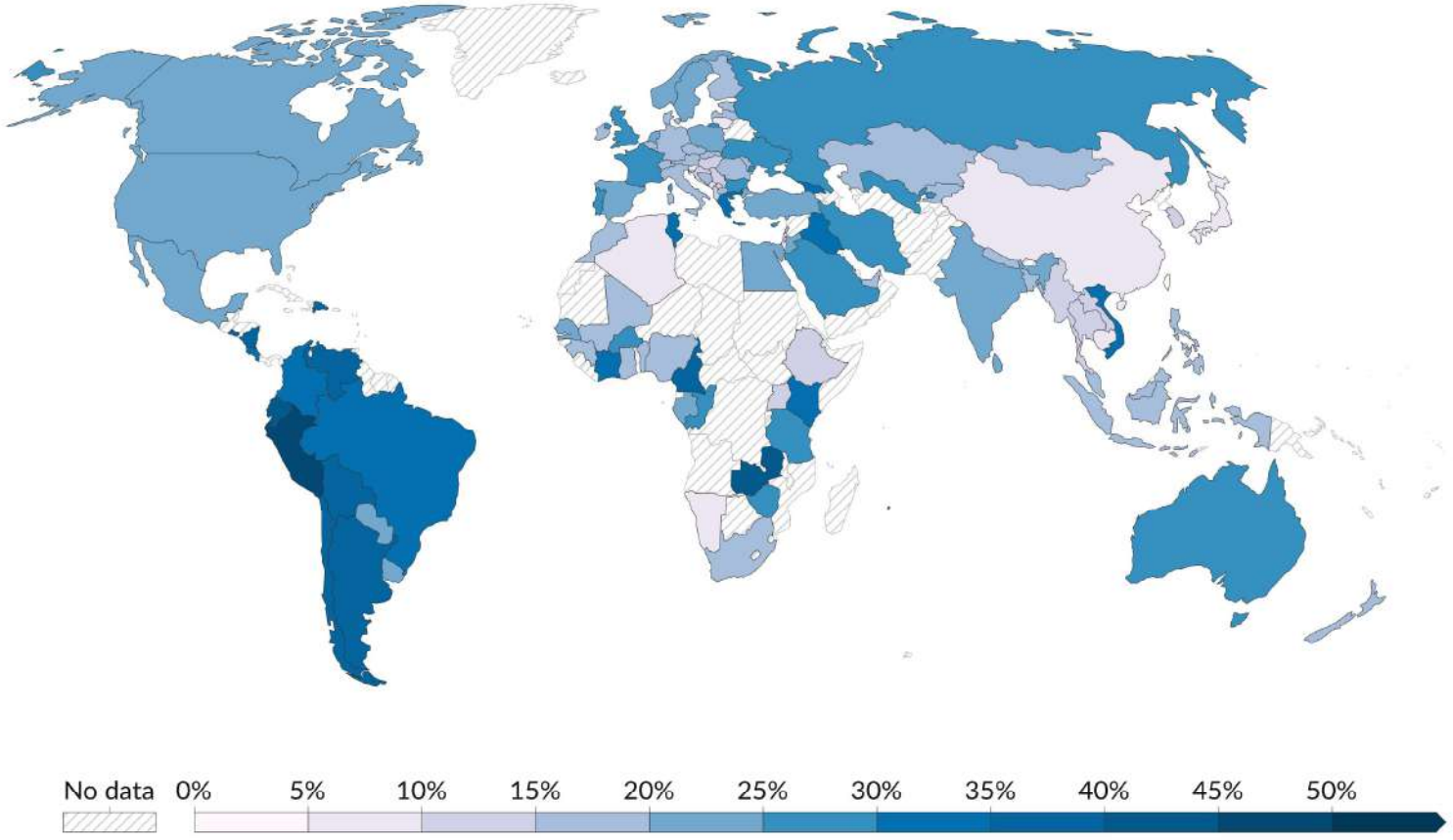
The invasion of the night by electric light, radio, television and the Internet has greatly **worsened** the quality and quantity of our sleep.

As for dreaming,
it risks becoming **extinct**.
This is detrimental to our health
both as individuals and as a society.

Poor sleep is associated with learning disorders, impaired emotional regulation, depression, diabetes, obesity, cardiovascular disease and Alzheimer's disease.



Percentage of national populations with either **anxiety** or **depression**.



Data source: Wellcome Global Monitor (2021)

OurWorldInData.org/mental-health | CC BY

Every year, around 700,000 people **suicide**,
twice as many as homicide.

The efficacy of conventional **antidepressants** is slightly greater than that of placebo.

Cipriani A, Furukawa TA, Salanti G, Chaimani A, Atkinson LZ, Ogawa Y, Leucht S, Ruhe HG, Turner EH, Higgins JPT, Egger M, Takeshima N, Hayasaka Y, Imai H, Shinohara K, Tajika A, Ioannidis JPA, Geddes JR. **Comparative efficacy and acceptability of 21 antidepressant drugs for the acute treatment of adults with major depressive disorder: a systematic review and network meta-analysis.** Lancet. 2018 Apr 7;391(10128):1357-1366.

Indigenous psychedelic medicines are powerful **antidepressants.**

Banisteriopsis caapi

Psychotria viridis

Psilocybe cubensis

Palhano-Fontes F, Barreto D, Onias H, Andrade KC, Novaes MM, Pessoa JA, Mota-Rolim SA, Osório FL, ..., Galvão-Coelho NL, Lobão-Soares B, Hallak JEC, Arcoverde E, Maia-de-Oliveira JP, Araújo DB. **Rapid antidepressant effects of the psychedelic ayahuasca in treatment-resistant depression: a randomized placebo-controlled trial.** Psychol Med. 2019 Mar;49(4):655-663.

Goodwin GM, Aaronson ST, Alvarez O, Arden PC, Baker A, Bennett JC,...., Strockis A, Tsai J, Visser L, Wahba M, Williams S, Young AH, Ywema P, Zisook S, Malievskaia E. **Single-Dose Psilocybin for a Treatment-Resistant Episode of Major Depression.** N Engl J Med. 2022 Nov 3;387(18):1637-1648. doi: 10.1056/NEJMoa2206443. PMID: 36322843.

Psychedelics induce neural **plasticity**

SCIENTIFIC REPORTS

OPEN

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ORIGINAL RESEARCH ARTICLE
Front. Mol. Neurosci., 04 September 2018 | https://doi.org/10.3389/fnmol.2018.00312

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Rafael Vitor Lima da Cruz[1*], Thiago C. Moulin[2], Lyvia Lintzmaier Petiz[1] and Richardson N. Leão[1,3*]

Psychedelics reopen the social reward learning critical period

https://doi.org/10.1038/s41586-023-06204-3
Received: 31 August 2021
Accepted: 11 May 2023

Romain Nardou[1,2], Edward Sawyer[1,2], Young Jun Song[1,2], Makenzie Wilkinson[1,2], Yasmin Padovan-Hernandez[1], Júnia Lara de Deus[1,2], Noelle Wright[1,2], Carine Lama[1,2], Sehr Faltin[1,2], Loyal A. Goff[1,3,4], Genevieve L. Stein-O'Brien[1,2,5] & Gül Dölen[1,2,5,6,7,8]

nature

Letter | Published: 03 April 2019

Oxytocin-dependent reopening of a social reward learning critical period with MDMA

Romain Nardou, Eastman M. Lewis, Rebecca Rothhaas, Ran Xu, Aimei Yang, Edward Boyden & Gül Dölen

ELSEVIER
Experimental Neurology
Volume 356, October 2022, 114148

Research paper

Nootropic effects of LSD: Behavioral, molecular and computational evidence

Isis M. Ornelas [a, 1, 2], Felipe A. Cini [b, 1, 3], Isabel Wießner [b, c, 1], Encarni Marcos [d, 1], Dráulio B. Araújo [b], Livia Goto-Silva [a], Juliana Nascimento [a, e], Sergio R.B. Silva [b], Marcelo N. Costa [a, f], Marcelo Falchi [c], Rodolfo Olivieri [c], Fernanda Palhano-Fontes [b], Eduardo Sequerra [b], Daniel Martins-de-Souza [a, e, g, h], Amanda Feilding [i], César Rennó-Costa [j], Luis Fernando Tófoli [c], Stevens K. Rehen [a, f], Sidarta Ribeiro [b]

Article | Published: 05 July 2024

Serotonergic psychedelic 5-MeO-DMT alters plasticity-related gene expression and generates anxiolytic effects in stressed mice

Margareth Nogueira, Daiane C. Ferreira Golbert, Richardson Menezes, Raíssa Nóbrega de Almeida, Nicole L. Galvão-Coelho, Andressa N. Siroky, Thiago Z. Lima, Helton Maia, Katarina E. Leão & Richardson N. Leão

Molecular Psychiatry **30**, 50–60 (2025) | Cite this article

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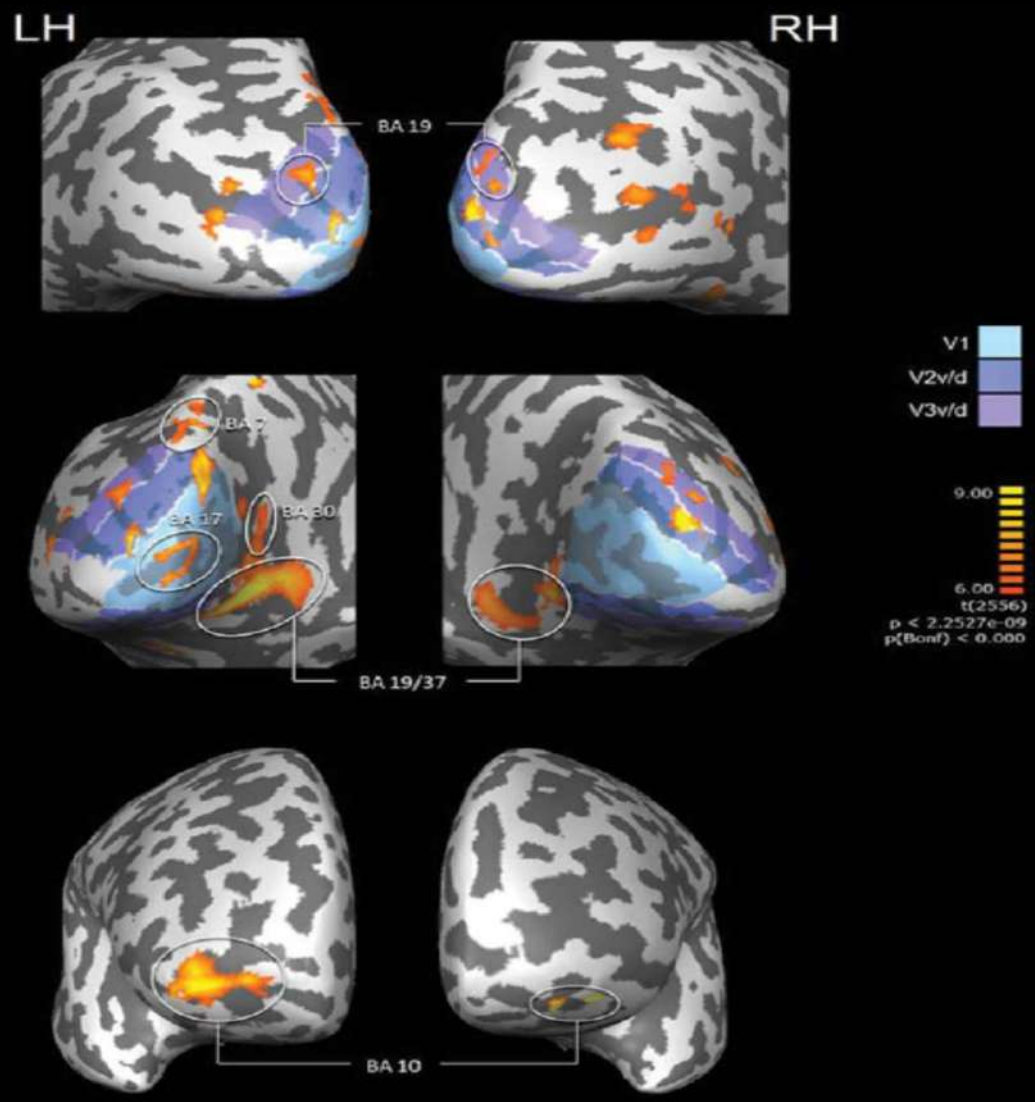
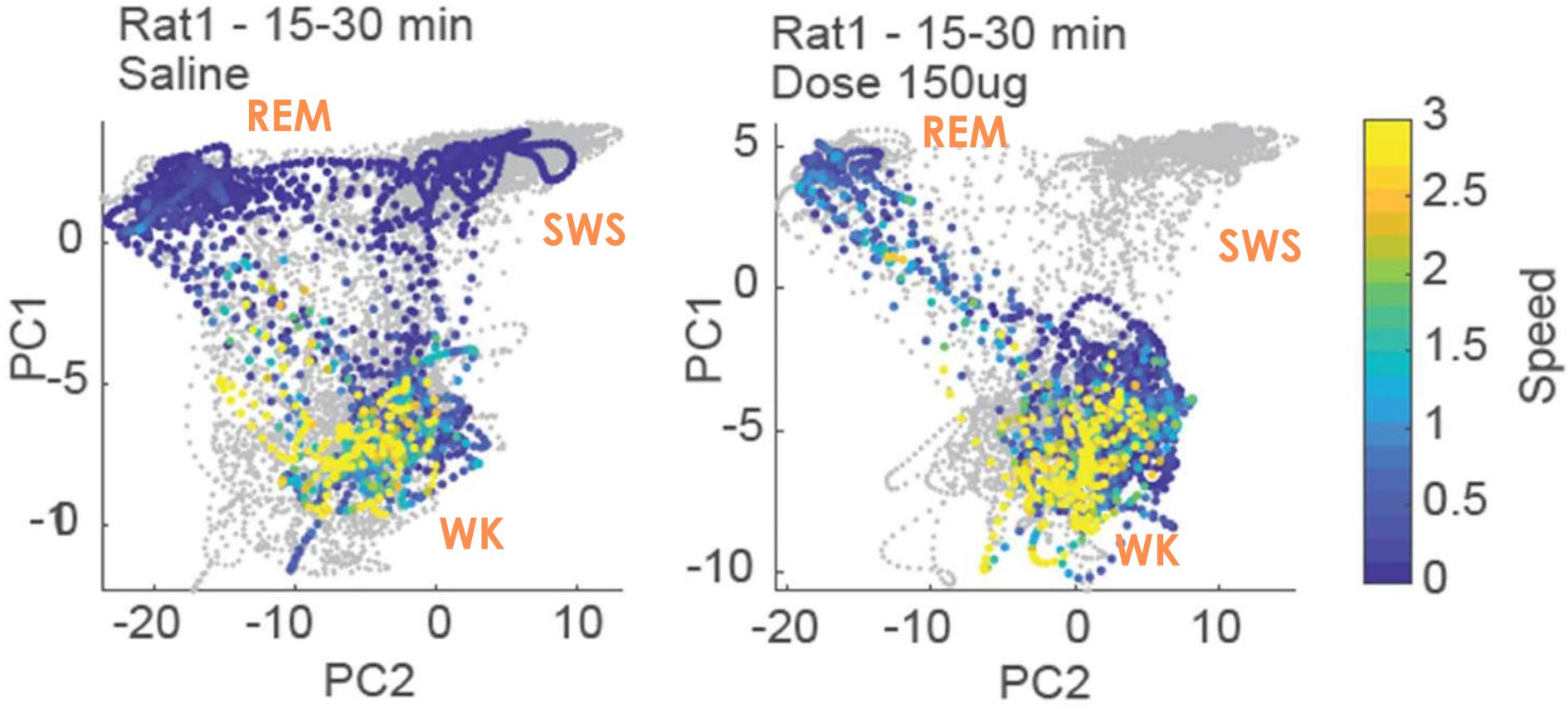
Ayahuasca produces intense visual imagery



de Araujo DB, Ribeiro S, Cecchi GA, Carvalho FM, Sanchez TA, Pinto JP, de Martinis BS, Crippa JA, Hallak JE, Santos AC**. Seeing with the eyes shut: neural basis of enhanced imagery following Ayahuasca ingestion.** Hum Brain Mapp. 2012 Nov;33(11):2550-60.

Psychedelics prevent behavioral sleep while the brain **continues to cycle** across WK, SWS and REM

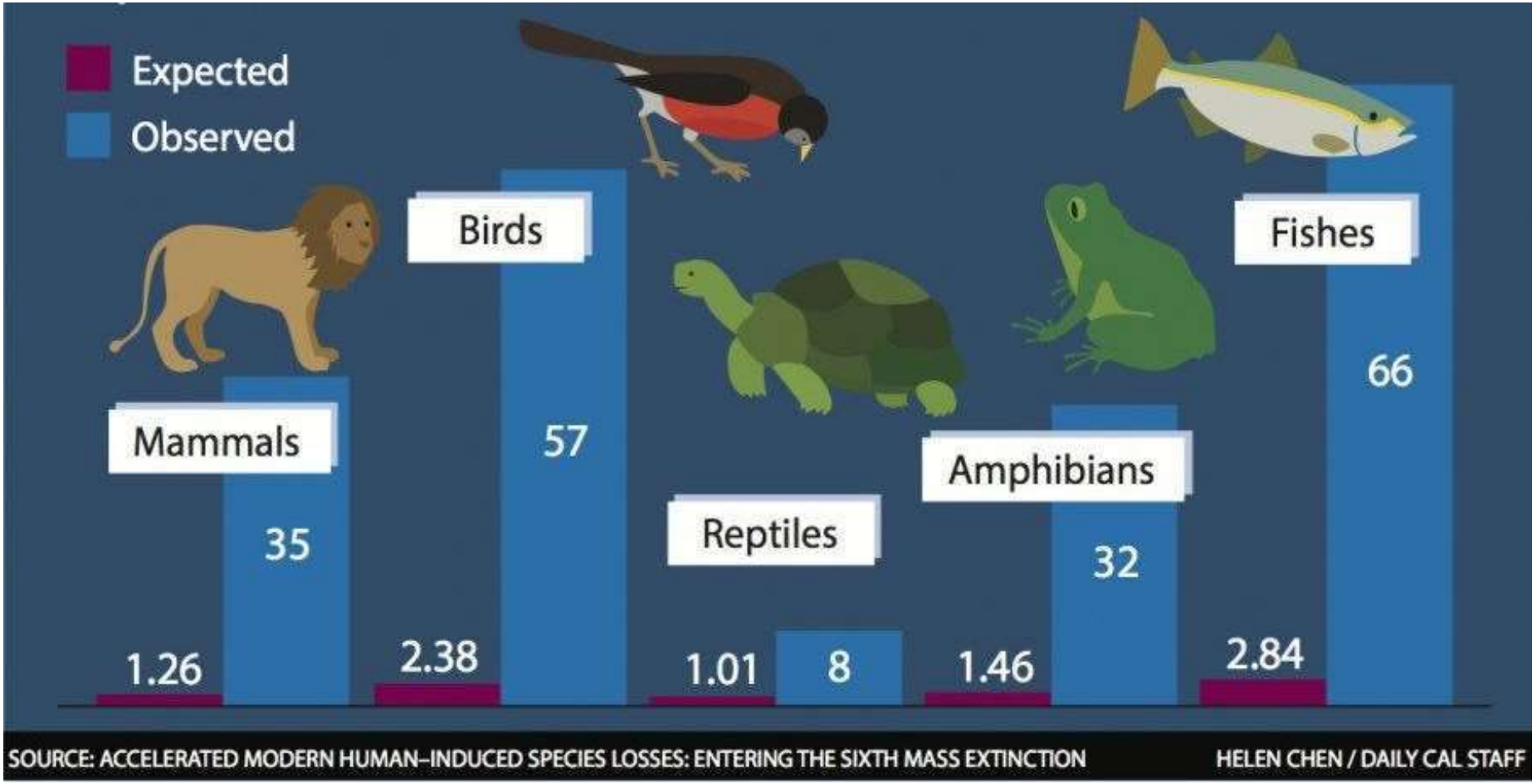


Souza AC, Souza BC, França A, Moradi M, Souza NC, Leão KE, Tort ABL, Leão RN, Lopes-Dos-Santos V, Ribeiro S. **5-MeO-DMT induces sleep-like LFP spectral signatures in the hippocampus and prefrontal cortex of awake rats.** Sci Rep. 2024 May 17;14(1):11281.


SAÍDA 200 m
Jabaquara
Imigrantes
SAÍDA 300 m
Rua Pinheiros
R. Bittencourt

Photo: Bruno Kelly

Humans are causing mass species **extinction**



Ceballos G, Ehrlich PR, Raven PH. **Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction.** Proc Natl Acad Sci U S A. 2020 Jun 16;117(24):13596-13602.

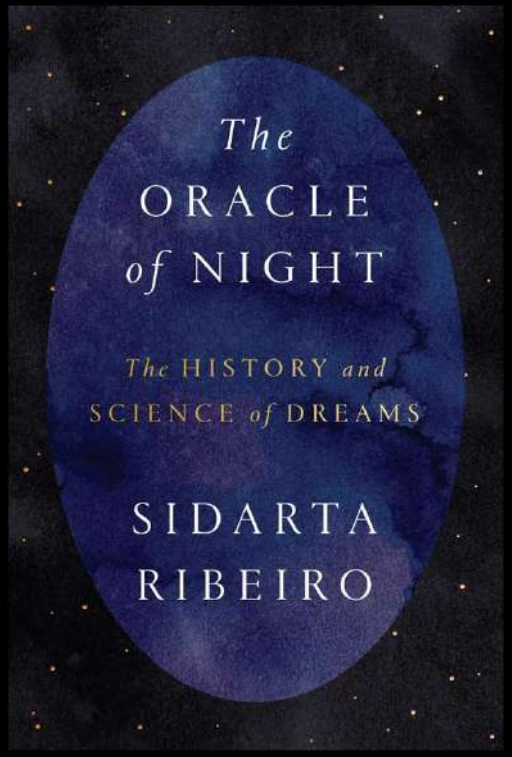
THE TERRIBLE PARADOX OF OUR TIME

Despite all our science and accumulated capital, **the future seems bleak.**

Could our lack of empathy be related to our **poor sleeping and worse dreaming**?

Could we be stuck in some sort of **delusional insomnia**, which renders us unable to find our way out of conflict, to tolerate differences and to find new solutions for old problems?

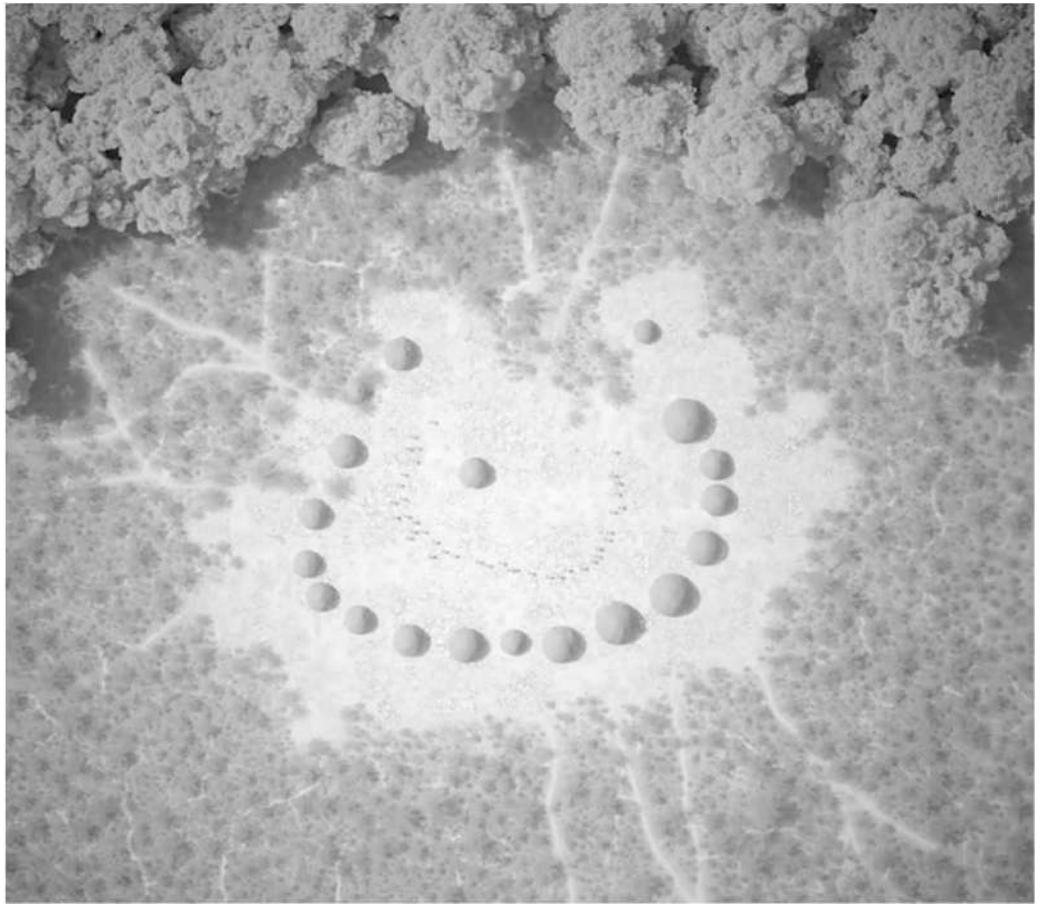
Ribeiro S. **Why We Can't Ignore Our Dreams.**
Time Magazine Oct 18, 2021.



EARLY MAMMALS (before 66 Mya)

- Dreaming likely evolved within a very narrow ecological niche as **simulations** of goal-directed behaviors subjected to reward or punishment.
- Dreams can express subliminal cues as supraliminal images of great significance for **survival**.
- Dreams as **probabilistic oracles** that test counterfactuals in a safe offline environment: given yesterday, how could tomorrow be? And most importantly: what can I do about it?

We must **rescue** the ancient art of dreaming



Xavante village
with dream circle in the center
https://memoriadaterra.org/

We need to **relearn** how to sleep well and share our dreams.

The quest of the generations now alive is to dream a future of **common good**.

Healthy sleep and dreaming may foster **bridges of empathy** across cultural boundaries.

Everybody on the planet is a neighbor, our differences enrich us, and this is a **dream worth sharing**.

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