The History and Discovery of Sleep

Kenneth Miller

Author of *Mapping the Darkness: The Visionary Scientists Who Unlocked the Mysteries of Sleep*

18th Annual Sleep Medicine CME Course

Conflict of Interest Disclosures for Speakers

Kenneth Miller has no relevant relationships with ineligible companies to disclose.

Learning Objectives

- Upon completion of this course, attendees should be able to:
  - Update 1: Understand how sleep science has evolved since the mid-19th century, when researchers first began exploring the basic questions of why we sleep.
  - Update 2: Understand how sleep medicine emerged in the 1960s and ‘70s, and how it has evolved since then.
  - Update 3: Understand the impact that sleep science and sleep medicine have had on society at large.

1925

NOW Science Proposes to Abolish SLEEP

The Gentle Slumber in Which We Spend Almost One-Third of Our Lives Probably a Useless Habit, Says Psychologist.

"Our night-roving ancestors were gradually eliminated by lurking foes or by accidents in the darkness. The sleepy ones survived and transmitted the useless habit to us of today."

DR. H. L. HOLLINGWORTH, professor of psychology at Columbia University.

By CARL SWOUP.

WHEN you crawl into bed tonight and sink into that stupor we call sleep, you do not think you are wasting time. Yet science has never discovered any real purpose for which we thus spend one-third of our lives in unconsciousness. Do we sleep to replenish our nervous energy—to give our tired bodies and minds a necessary rest? That is only a theory—pure guesswork, and, as Dr. H. L. Hollingworth, professor of psychology at Columbia University, points out, it is a theory which is in direct conflict with certain known facts. Dr. Hollingworth takes a different view of this mystery—for such it is.

Sleep, he says, is probably nothing but a useless habit. Just as the appendix is a useless organ that has survived from the days when it had a duty to perform, so sleep has survived from long ages ago when it, too, had a use.

It may very well be, he adds, that we can entirely eliminate sleep in the future by scaling it down gradually and getting accustomed to going without it.

This would mean that a "sleepless" race would virtually have its span of life increased by one-half; and as for a man's leisure time—it would be doubled!

Dr. Hollingworth's theory is a simple one. It takes us back to those remote days when our ancestors—whoever they may have been—were hemmed in by absolute darkness when night fell. They had no lanterns or electric lights by which they might make traveling safe.

"According to this theory," Dr. Hollingworth explains, "those who insisted on prowling about both day and night failed to survive as long as the others did, because in the darkness of those primitive unelectric days they were so easily destroyed by lurking foes and wild animals. Again, perhaps they would lose their way during the night in the desert, forest or swamp; or they might slip and fall over unseen precipices. So they left practically no descendants to imitate their sleepless example.

"Thus our genuine ancestors were those cautious savages who went abroad in daylight, when their way was clear before them, but hid in utter silence and quiet when the dangerous night came on. Now, this was probably rather difficult for a healthy man to do—to coop himself up all through the long hours of darkness; so the individuals best fitted for survival were those who had, as an accidental variation, a tendency to while away that period by falling into a stupor. In this way arose sleep—a hereditary, instinctive adaptation to darkness.

"We, today, still inherit that instinct, despite its uselessness. It is 'useless,' according to this theory, because now we can turn night into day by merely pressing a button; we need no longer 'be afraid of the dark' as were our ancestors. But the fact remains that we do inherit this disastrous habit, just as we inherit our annoying appendix, our eyebrows, our useless tonsils, our dangerous wisdom teeth, the degenerate muscles that wiggle our ears, and a number of other vestigial traces of our lowly origin.

"Some may argue that since sleep seems to be a natural response with newly born infants, it is therefore a necessity. That is poor reasoning, for the 'grasping reflex' is a natural response with newly born infants, yet it certainly is not a necessity. By 'grasping reflex' I mean this: If you touch the palm of the infant's hand with a stick it will immediately grip it firmly—so firmly that it can support its own weight by that grasp. This is not a reasoning act—it is an automatic reflex, such as we experience when we jerk away after touching a hot iron, and, likewise, when we sleep. But this automatic reflex is trained out of the child, because it would be dangerous for it to grab tightly on to anything its hand might touch—a red-hot poker, for instance. If one automatic reflex can be trained out, why not another? So far as we know, it is not at all impossible to eliminate sleep by gradually cutting it down and getting used to going without it. I shall explain that more in detail later.

"So much for this biological theory of sleep. At least there are no known facts to contradict it; while all the other reasons and guesses that have been advanced are quite clearly inconsistent with certain things that we know. Most of these other explanations of sleep are based on supposed accumulation of poisons in the system, or congestion or anemia of the nervous system, or a dulling of the senses as the day progresses. Let us see why these are all inadequate to explain sleep.

"In the first place, when we sleep we do not sleep 'all over.' The heart and the diaphragm keep on working steadily. Many of the simple reflexes (for example, the one I mentioned before, jerking away when a hot substance touches the body) are in constant readiness to function. Even some of the voluntary muscles, such as those maintaining the posture of the body, may remain in contraction; so that we can sleep in a sitting position, or even, if the reports are true, standing or riding on horseback.

"Certainly no theories based upon the action of poisons in the system, congestion or anemia of the nervous tissues, mechanical shrinking of the neurons (nerve cells), or progressive dulling of the senses are reconcilable with these facts.

"And since such important parts of the system as we have mentioned never sleep, it is certainly not obvious why the rest of the system must pass into a stupor."

SINCE so many theories have been advanced to account for sleep, what, it may be asked, has been done to find out whether or not this time wasted is really necessary?

Nothing at all, says Dr. Hollingworth. There have been plenty of experiments to show what happened to people when their regular routine was suddenly interrupted and they were kept awake for 140 hours or so. But there have been no scientifically controlled experiments to show show what would happen if, over a long period of years, we cut down gradually on our sleep.

"We spend great sums of money to exterminate the mosquito, the house fly and diseases such as cancer and tuberculosis," declares Dr. Hollingworth, "but the greatest scourge of mankind is allowed to rage unmolested. There has been no large endowment available for investigating sleep scientifically over a long period of time."

Would it be possible to carry out scientific experiments as to the possibility of a "sleepless race"?

Dr. Hollingworth believes it could be done.

"But it would be a very expensive proceeding," he says. "It would be necessary to have a large number of people living under a strict routine for 10 or perhaps 20 years.

"The amount of sleep could be reduced so gradually that the body would have a chance to become adjusted to the new conditions.

"We could see, then, if sleep is really as necessary as we all seem to assume it is."

HERE is a simple problem in mathematics: If you reduce your sleep by five minutes every two months—surely not a very abrupt change—how many years would you have to keep that up before your sleeping period would be reduced to zero?

Sixteen years is the answer (provided you start at eight hours per night).

In 16 years the stupor of sleep would be banished—if it could be. Dr. Hollingworth was asked if he advised against anyone trying that experiment.

"No," he said. "I think it would be quite a sensible thing to do. If the individual found that it was really wearing him down, he could easily stop.

"We should give the same consideration to this tragedy that we do to other human ills. At any rate, it's going to be done some time—the era of big investigation is not far off."

Already departments of psychology of other universities are following the lead of Dr. Kleitman of Chicago in trying to determine just how the human mind and body function after two days or more of wakefulness. Recently the experiment was repeated at George Washington University, Washington, D. C., seven students remaining awake for 60 hours.

KLEITMAN'S EXPERIMENTAL STUDIES OF INSOMNIA

One of the most thorough attempts to throw light on the mystery of sleep was that conducted recently by Dr. Nathaniel Kleitman in the department of psychology of the University of Chicago. He kept record of six university students who voluntarily remained awake for 115 hours—almost five days and nights. In the course of this grueling experiment it was found:

The students could keep awake if they could keep their muscles contracted, as in exercise. As soon as they relaxed at all they went off to sleep.

The longer they stayed awake, the less able they were to control their muscles. After the first two days of sleeplessness, they could not write legibly. After scrawling a few words their pens would trail off into meaningless lines.

They could still identify colors, if the test was a short one; but they became inaccurate if required to focus their attention for long.

Dreams and hallucinations occurred during the enforced waking state. One student, on the the morning of the fifth day of "insomnia," recited logarithms correctly to the instructor, but said later that he thought he was having a heated argument on labor unions all during the recitation.

Mental power, when applied to a definite problem, was not affected by the sleeplessness so far as could be determined.

This test was to determine what would occur as the result of a radical smashing of the sleep habit, and so, of course, gave little idea of what would happen in a slow, gradual elimination of sleep, as proposed by Dr. Hollingworth.

Page Four. Sunday Magazine—St. Louis Post-Dispatch—August 30, 1925.

An Eye-Opening Transformation

Then:

- Few scientists thought sleep worth much attention
- Many thought it could be minimized or eliminated

Now:

- Sleep research centers at every major university
- Sleep medicine a well-established subspecialty
- 2,500+ sleep clinics across U.S., 4,000+ in other countries
- Global sleep-health market worth $200+ billion

Miller, *Mapping the Darkness*, 2023

Antiquity to 1850s: The Pre-History of Sleep Science

Sleeper, ancient Egypt

- Pre-modern cultures: Ideas about sleep were based on traditional belief systems.
- Plant- or animal-based substances were used to induce slumber.
- Ancient Greeks were first to theorize on sleep's physiological mechanisms.
- Alcmaeon: Sleep results from blood withdrawing from body's surface to internal vessels, congesting brain.
- Aristotle: Sleep results from vapors traveling from stomach to heart.

Chokroverty & Billiard, 2015. Illustration: Glencairn Museum News, 2018

Mid-19th Century: Sleep Science Takes Its First Steps

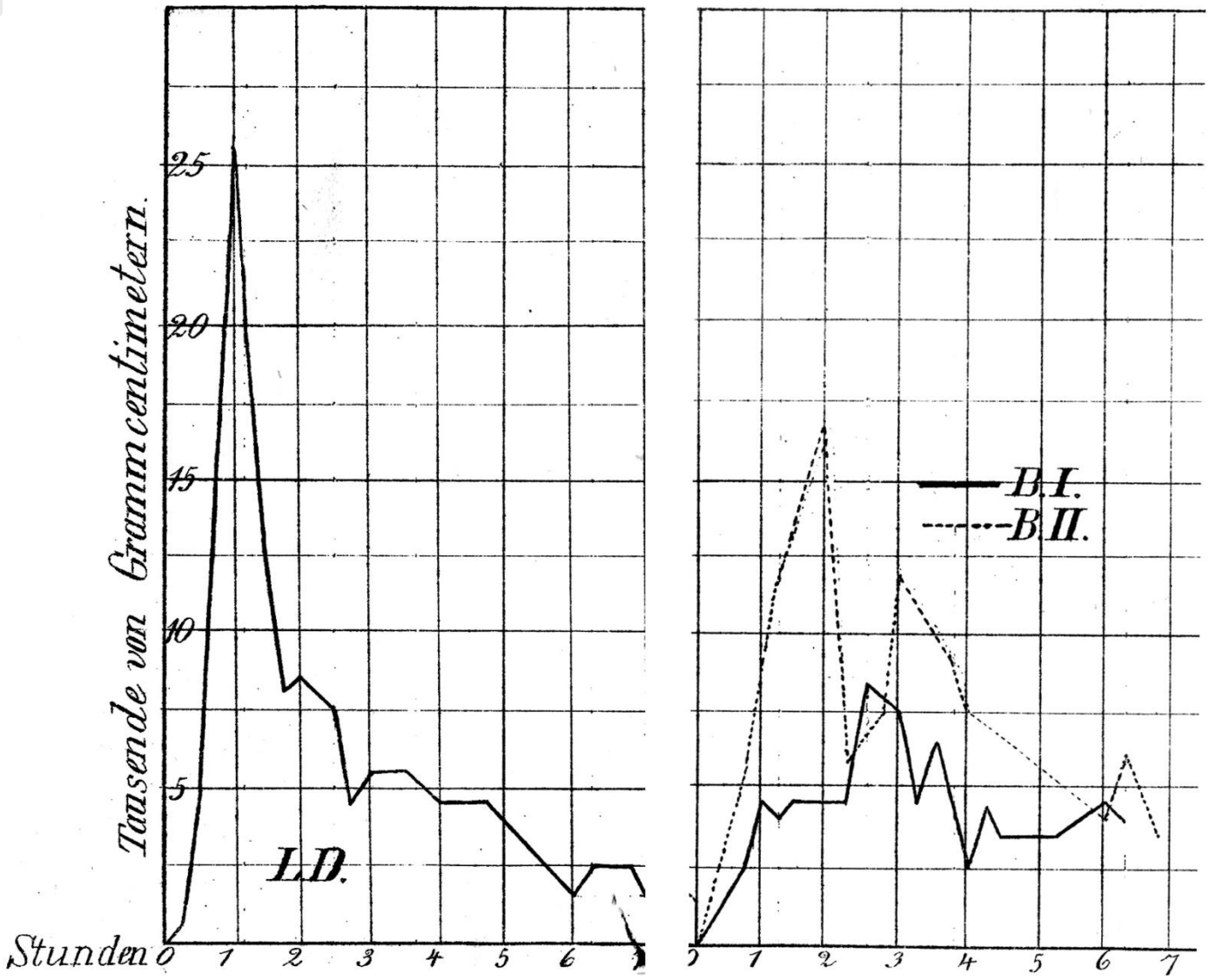
- Rise of sleep science begins during Industrial Revolution.
- Impetus #1: Drive for labor efficiency.
- Impetus #2: Rise of insomnia, associated with cheap/plentiful artificial lighting.
- Early theory: Sleep results from diminished cerebral blood flow.
- Question: What initiates that process?
- “Chemical” theories posit that buildup of waste products trigger sleep.

Kroker, 2007

19th Century: Decoding Sleep Depth

- Question #1: Are fluctuations cyclical?
- Question #2: If cyclical, what is their pattern?
- 1862: Kohlschütter is first researcher to measure sleep depth—but fudges data, gets it wrong.
- 1889: Michelson finds that sleep depth fluctuates rhythmically, diminishing throughout night.
- **New question: Why?**

Michelson's sleep-depth chart



Becker et al, 2016

19th Century: Does a Brain Center Control Sleep?

- Prevailing wisdom: Sleep is passive shutdown of entire brain.
- 1890: Mauthner's theory: Sleep is controlled by a nerve center in the midbrain.
- Clue #1: Symptoms of sleeping sickness include somnolence, paralyzed eye muscles.
- Clue #2: Patients show lesions in brain region known to control eye muscles.
- Ergo: This region probably controls sleep/waking, too.
- Problem: No way to test theory at the time.

Moruzzi, 1964; Lebensohn, 1941

Ludwig Mauthner (1840-1894)

19th Century: Exploring Forced Insomnia

- **Question: How important is sleep, really?**
- Investigative method: Forced insomnia.
- Manaseina: Puppies die after 4-5 days.
- Patrick and Gilbert: Humans experience hallucinations, slowed reflexes, diminished grip strength, weight gain.
- Piéron's theory: Sleep deprivation is harmful due to buildup of "hypnotoxins."
- Finding: Injecting fluids from sleep-deprived animals induces sleep in normal animals.
- **New question: Why?**

Manacéïne, 1894; Bentivoglio & Grassi-Zucconi, 1997; White & Gilbert, 1896; Kroker, 2007

Maria Manaseina, AKA Marie de Manacéïne (1841-1903)

Early 1900s: A Founder's Journey

Nathaniel Kleitman (1895-1999), founder of modern sleep science.

- 1903: Survives Kishinev pogrom
- 1914: Escapes Russia on eve of World War I.
- Becomes POW while attending med school in Beirut.
- 1915: Emigrates to U.S.
- Scraps his way to PhD program in physiology at U of Chicago.
- 1922: Focuses on sleep research after reading Piéron's *Le Problème Physiologique du Sommeil*.

Kleitman with his mother, Pesea, 1912

Miller. 2023

1920s: A Landmark Study of Sleep Deprivation

STUDIES ON THE PHYSIOLOGY OF SLEEP

I. THE EFFECTS OF PROLONGED SLEEPLESSNESS ON MAN

NATHANIEL KLEITMAN

From the Hull Physiological Laboratory of the University of Chicago

Received for publication May 28, 1923

Most investigators of the physiology of sleep, in reporting their findings, remind their readers, by way of apology, of the tremendous importance of the subject for the advancement of our knowledge of physiology as a science, as well as for the rational treatment of insomnia. They also like to record the fact that the average individual spends more than a third of his life in sleep, has been doing this from time immemorial, and raise the question whether eight hours or more of sleep a day really constitutes the minimum penalty for keeping awake the rest of the time. It seems reasonable to suspect that as in the case of protein consumption, there is a large "factor of safety" in the amount of sleep we are getting, and that it could be considerably reduced without impairment of health or loss of efficiency. This and other questions related to industrial physiology, especially physiology of fatigue, can be answered only by a thorough systematic study of the subject. But curiously enough, there are scarcely a dozen investigators engaged at any one time in the study of this great physiological mystery, and most of these workers are psychologists. It seems that because animals are not very well adapted for this work and the human beings that are available cannot be dissected, physiologists have allowed the psychologists to tackle this problem as best they could. Present day textbooks of physiology contain but a few short references to the subject, usually antiquated, and some texts (Starling's, for example) ignore the subject entirely. Luciani's four-volume work is the only textbook that treats the subject adequately, but unfortunately it is not in general use as a manual. Thus most medical students first encounter sleep in their study of pharmacology, and there they learn several easy ways of putting a person "to sleep." In this manner the "practical" aspect of the problem for them at least is solved. If we recall that textbook writers generally do not peruse psychological literature in bringing out their new editions, it will be readily understood why the work of many able investigators has not been brought to the attention of our students.

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- 1923: Kleitman publishes debut paper, "The Effects of Prolonged Sleeplessness On Man."
- Paper becomes model for later studies of cognitive, metabolic and other processes in sleep-deprived humans.
- Experiment: Keeps participants awake for 40-115 hours, recording physiological, behavioral, and cognitive effects.
- Kleitman questions Pavlov's theory of sleep as a whole-brain inhibition due to repetitive stimuli.
- Offers his own early theories of why we sleep and dream.

Kleitman, 1923; Kroker, 2007; Miller, 2023

1920s: The First Full-Time Sleep Scientist

- 1925: Kleitman launches world's first dedicated sleep lab.
- Becomes first full-time sleep scientist.
- Attacks mechanisms of sleep from all available angles: behavioral, biochemical, cardiopulmonary, neurological.
- Gathers data on body temperature, motility, blood pressure, respiration, and other measures during sleep.
- Monitors patterns of alertness, coordination during waking.
- Studies correlations between wide range of variables—e.g., how alertness changes with body temperature and varying amounts of sleep.

Kroker, 2007; Miller, 2023

1920s-30s:
All In the Family

Kleitman measures the sleep of daughters, Esther and Hortense, throughout their childhood.

Miller, 2023

1920s-30s: Sleeping Sickness Reveals Crucial Clues

- 1920s: *Encephalitis lethargica* becomes global epidemic.
- 1926: Von Economo reports excessive sleepiness in patients with lesions in posterior hypothalamus, and severe insomnia in those with lesions in anterior hypothalamus.
- His theory: Posterior hypothalamus contains a center controlling sleep, anterior hypothalamus contains a center controlling waking.
- Corollary theory: Sleep involves coordination between both centers.
- 1931: Hess induces sleep in cats by stimulating posterior hypothalamus and agitation by stimulating anterior hypothalamus.
- Later researchers would confirm hypothalamus plays complex roles in sleep, waking, and circadian rhythms.

Triathou, 2006; Hess, 2008

Constantin von Economo (1876-1931)

1920s-30s: Uncovering the Biological Clock

- 1927: Observing biological rhythms in rats, Richter theorizes existence of a “biological clock.”
- Kleitman’s hypothesis: Humans aren’t governed by one.
- 1930s: Kleitman experiments with non-24-hour sleep-wake cycles in humans.
- Finds body temperature curve (proxy for adjustment) doesn’t adapt to extreme changes in sleep-wake rhythms.
- Some subjects adjust to smaller changes (21- or 28-hour cycles), but Kleitman doesn’t.
- **Question: Is he less adaptable, or more sensitive to environmental time cues?**

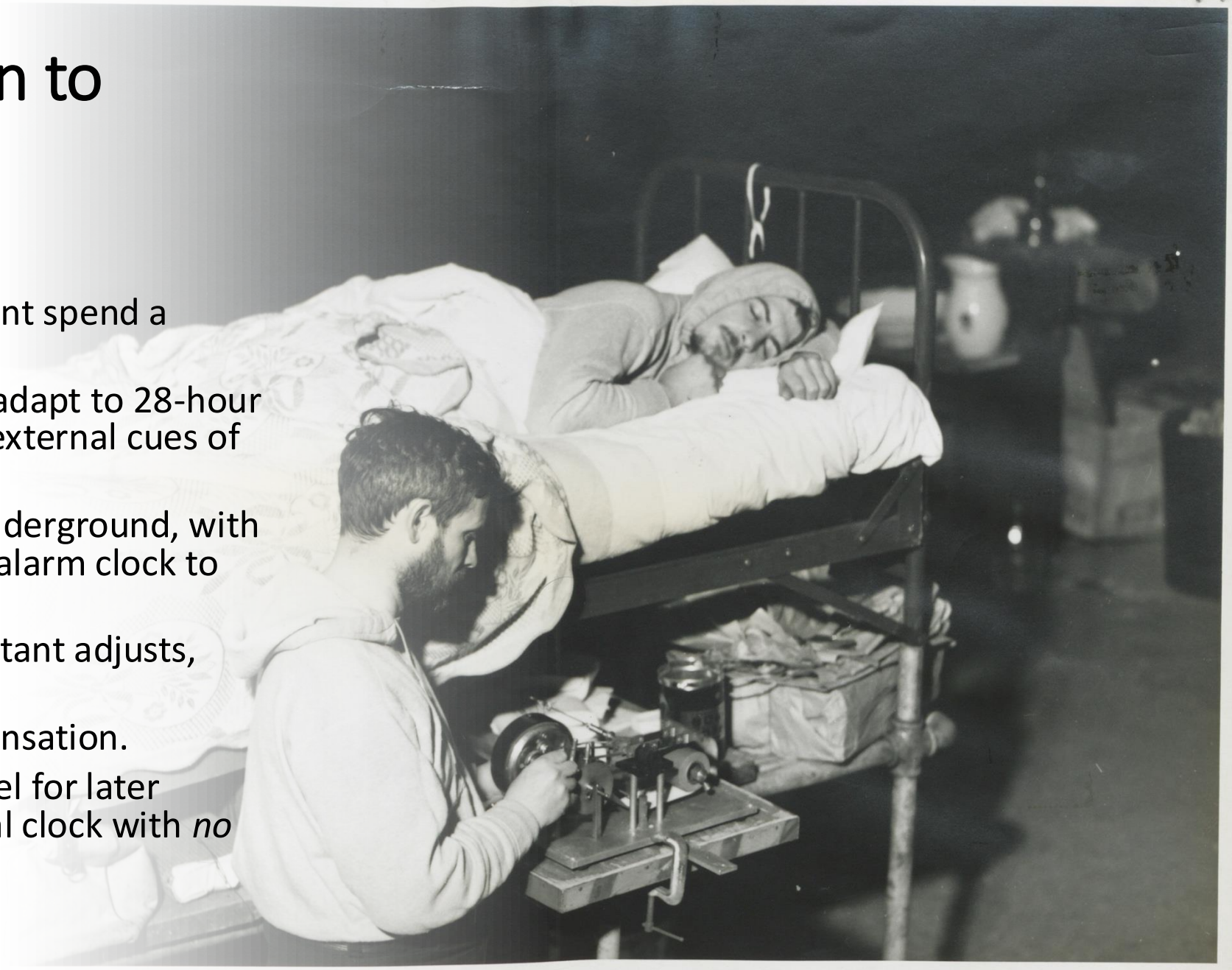
Stevens, 1988; Kleitman, 1939; Miller, 2023

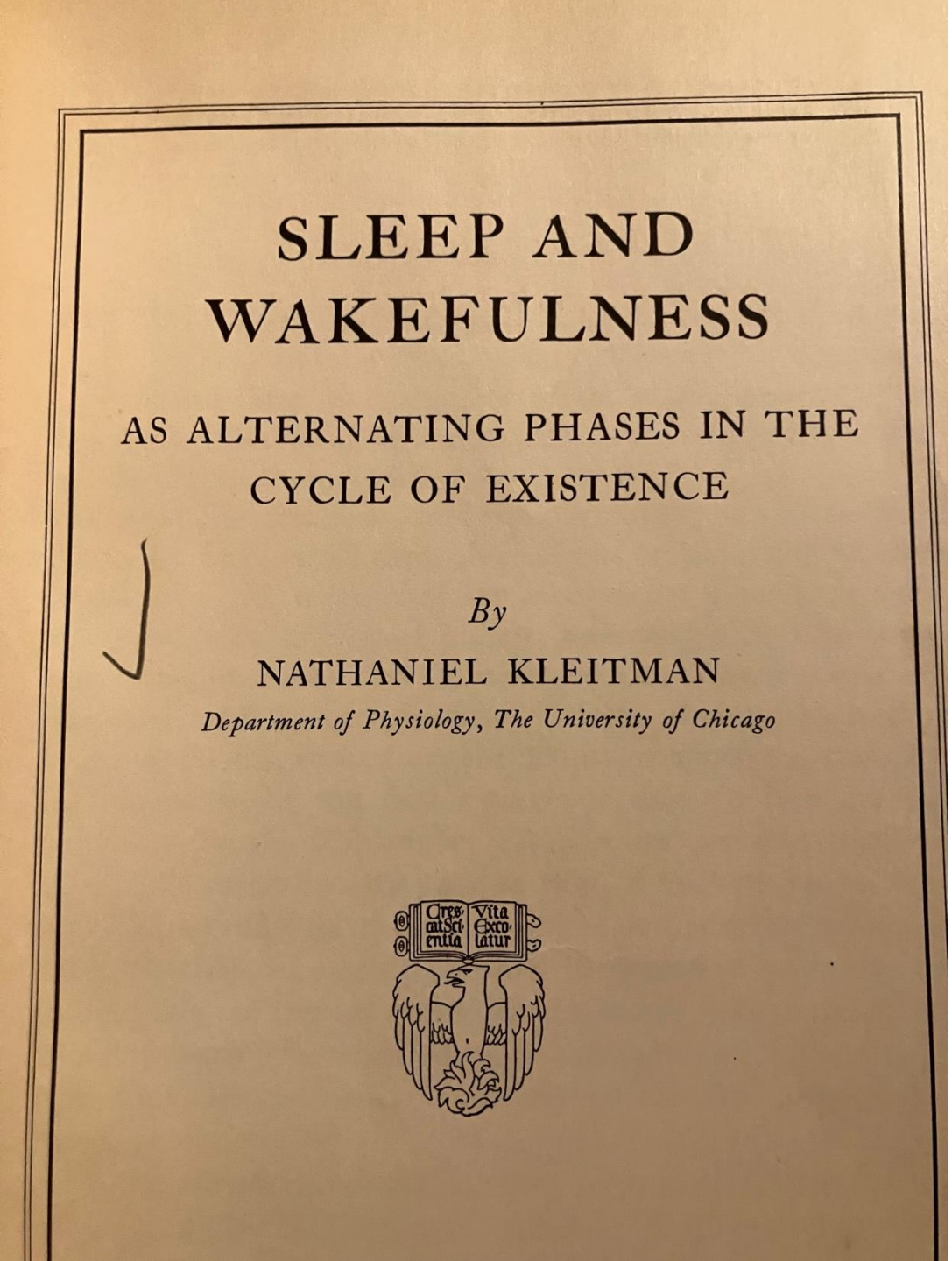
Curt Richter (1894-1988)

1930s: Expedition to Mammoth Cave

- 1938: Kleitman and assistant spend a month in Mammoth Cave.
- Aim: Learn if it's easier to adapt to 28-hour sleep-wake cycle without external cues of night/ day.
- Method: Camping deep underground, with only lanterns for light and alarm clock to keep track of time.
- Results: Inconclusive (assistant adjusts, Kleitman doesn't).
- Corollary results: Media sensation.
- Experiment becomes model for later studies of human biological clock with *no* time cues.

Kleitman, 1939; Miller, 2023

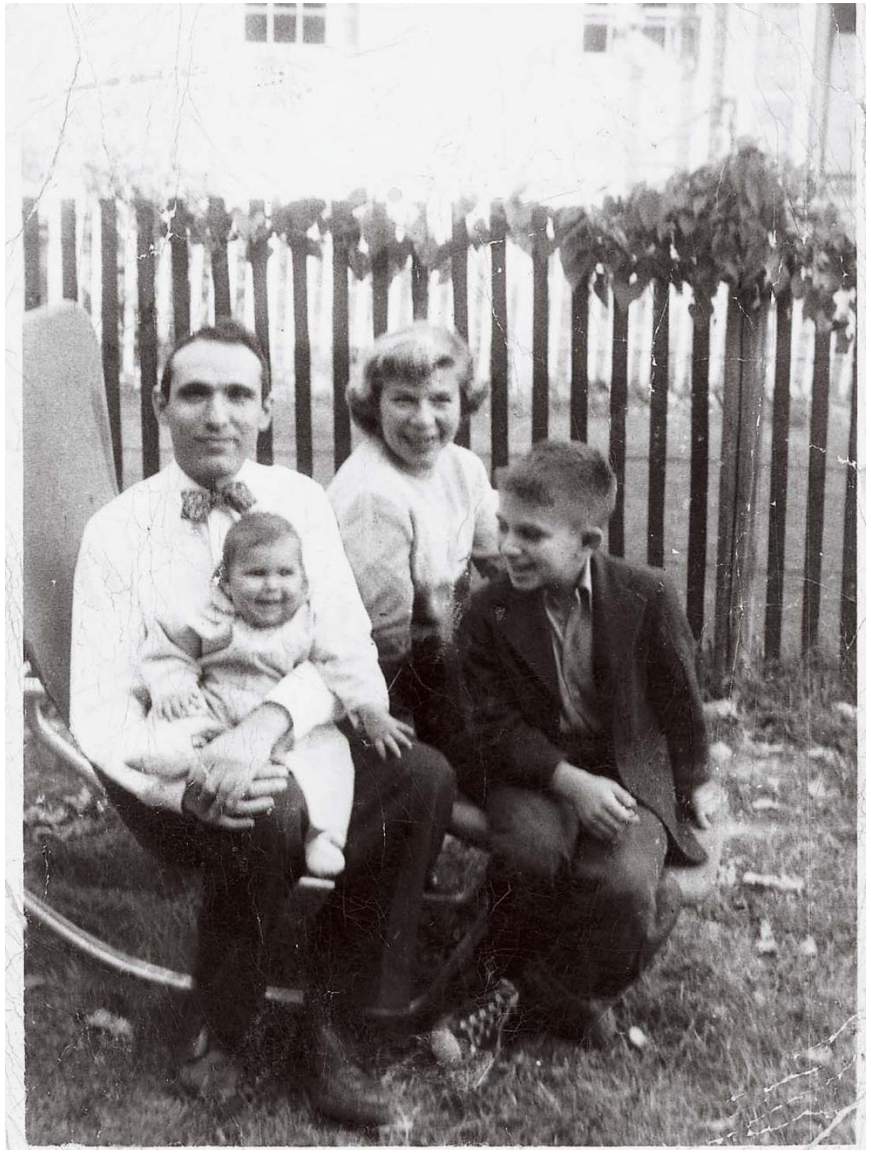




1930s: Kleitman's Magnum Opus

- 1939: Kleitman publishes the first sleep textbook, *Sleep and Wakefulness.*
- A critical digest of every important sleep study since the late 19th century.
- The bible of sleep science for decades (with an expanded edition in 1963).

Kleitman, 1939; Kroker, 2007



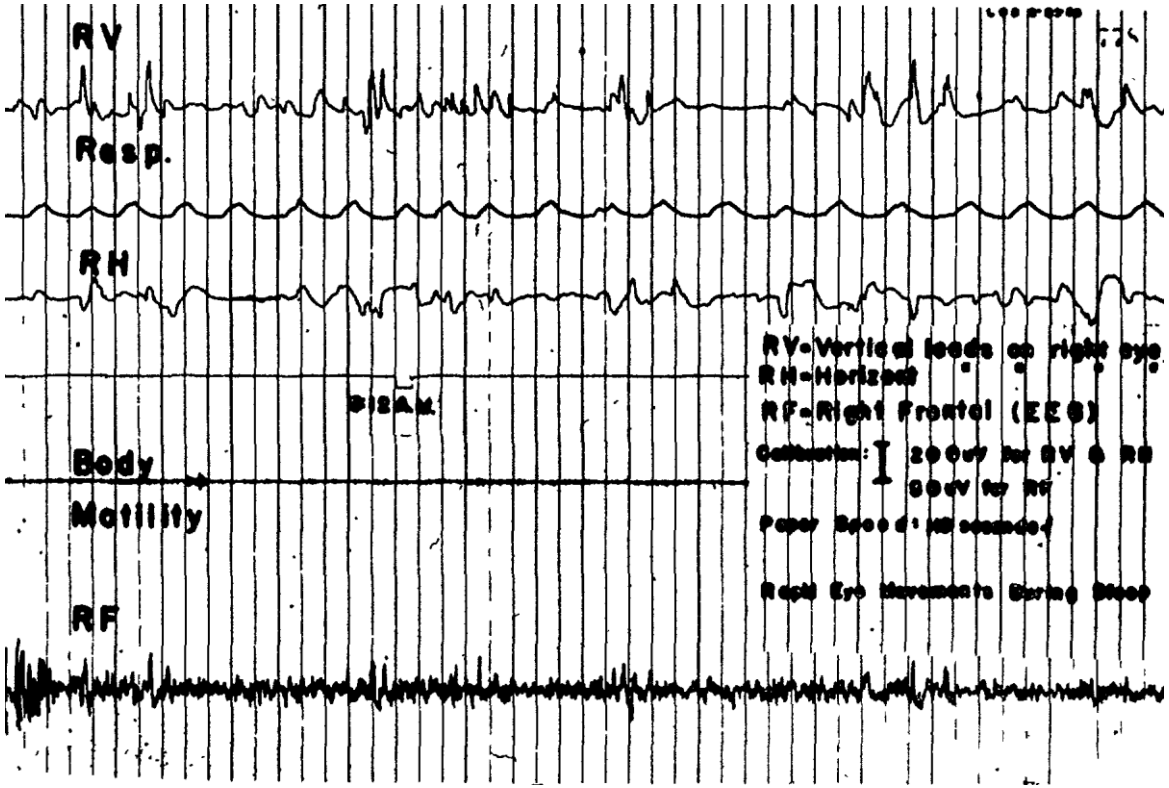
Eugene Aserinsky and family, 1953

1950s: Discovering REM Sleep

- 1930s: Kleitman and Loomis use EEG to chart brainwaves during sleep, but don't pursue the technology further.
- 1949: Aserinsky (1921-1998) becomes Kleitman's PhD student.
- 1951: Aserinsky is first to monitor sleepers' eye movements (EOG) along with EEG throughout night.
- Periodically, subjects' eyes jerk back and forth, while EEGs show patterns resembling waking.
- Aserinsky names this the "rapid eye movement" period.
- Subjects awakened during REM report they've been dreaming more often than in other sleep periods.

Kroker, 2007; Aserinsky & Kleitman, 1953; Aserinsky, 1996

1950s: The Astounding Activity of the Sleeping Brain



The first published REM chart. (From Aserinsky & Kleitman, "Regularly Occurring Periods of Eye Motility, and Concomitant Phenomena, During Sleep.")

- 1953: Aserinsky and Kleitman report discovery of REM.
- Paper presents first evidence that dreaming brain is as active as waking brain.
- Before it's published, Aserinsky leaves U of Chicago and sleep science.
- Dement becomes first researcher to recognize REM's revolutionary potential.

Aserinsky & Kleitman, 1953; Kroker 2007

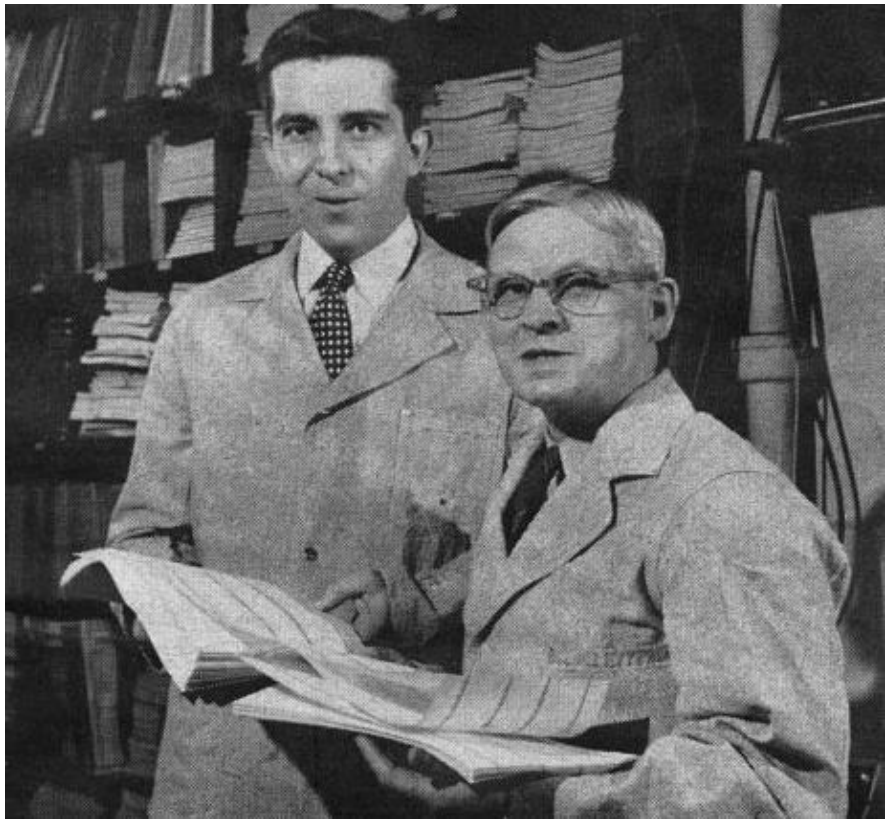
1950s: Chasing Dreams

William Dement (1928-2020) on bass, 1940s

- 1951: Dement starts medical school at U of Chicago.
- 1952: Falls in love with sleep science during lecture by Kleitman.
- Kleitman assigns him to assist Aserinsky with REM experiments.
- As a Freudian, Dement is thrilled that REM offers insights into dreaming.
- When Aserinsky quits, Dement begins running REM studies of his own.

Dement & Vaughan, 1999

1950s: Probing the Mysteries of REM Sleep



Dement and Kleitman, c. 1955

- 1955-57: Dement publishes series of studies with Kleitman, revealing new details about REM sleep.
- Findings: REM begins after sleep passes through four stages of increasing depth.
- REM occurs every 90 minutes, on average.
- Theory: REM's function is to prevent psychosis.
- 1957: Dement launches REM deprivation studies.
- Initial findings: REM rebounds after deprivation, occurs in cats, may occur immediately after sleep onset in people with narcolepsy.

Gottesmann, 2013; Dement, 1992, 1999

1950s-60s: The Puzzle of "Paradoxical Sleep"

- Dement's REM studies spur growing excitement about sleep among researchers.
- 1959: Jouvet begins publishing series of papers on REM in cats, calling it "paradoxical sleep" (as it became known in Europe).
- Reports that during REM sleep, cats experience muscle atonia to prevent them from acting out dreams.
- Finds that REM is controlled by the pons, while non-REM sleep is controlled by higher brain regions.
- 1960: Vogel publishes first report of sleep-onset REM in a narcolepsy patient.

Jouvet, 1959, 2004; Vogel, 1960

Michel Jouvet (1925-2017), c. 1964

1960s: Sleep Science Takes Off

- Polygraph-equipped sleep labs pop up across U.S., France, Italy, and U.K.
- Rechtschaffen takes over U of Chicago sleep lab, leading important studies and nurturing new generation of researchers.
- 1961: Rechtschaffen and Dement launch APSS, first professional organization for sleep scientists.
- Advances in neuroscience and chronobiology help deepen understanding of sleep.
- REM research continues to break new ground.

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Allan Rechtschaffen (1927-2021)

1960s: Dement Launches His Lab

- 1963: Dement joins Stanford faculty, starts own sleep lab.
- Continues REM studies, but switches mostly to cats.
- Finding: REM deprivation boosts cats' appetites, aggressiveness.
- Theory: REM's function is to regulate basic survival drives.
- Finding: REM accounts for ~50% of sleep in human infants.
- Theory: REM plays role in neurodevelopment.

Dement, 1999

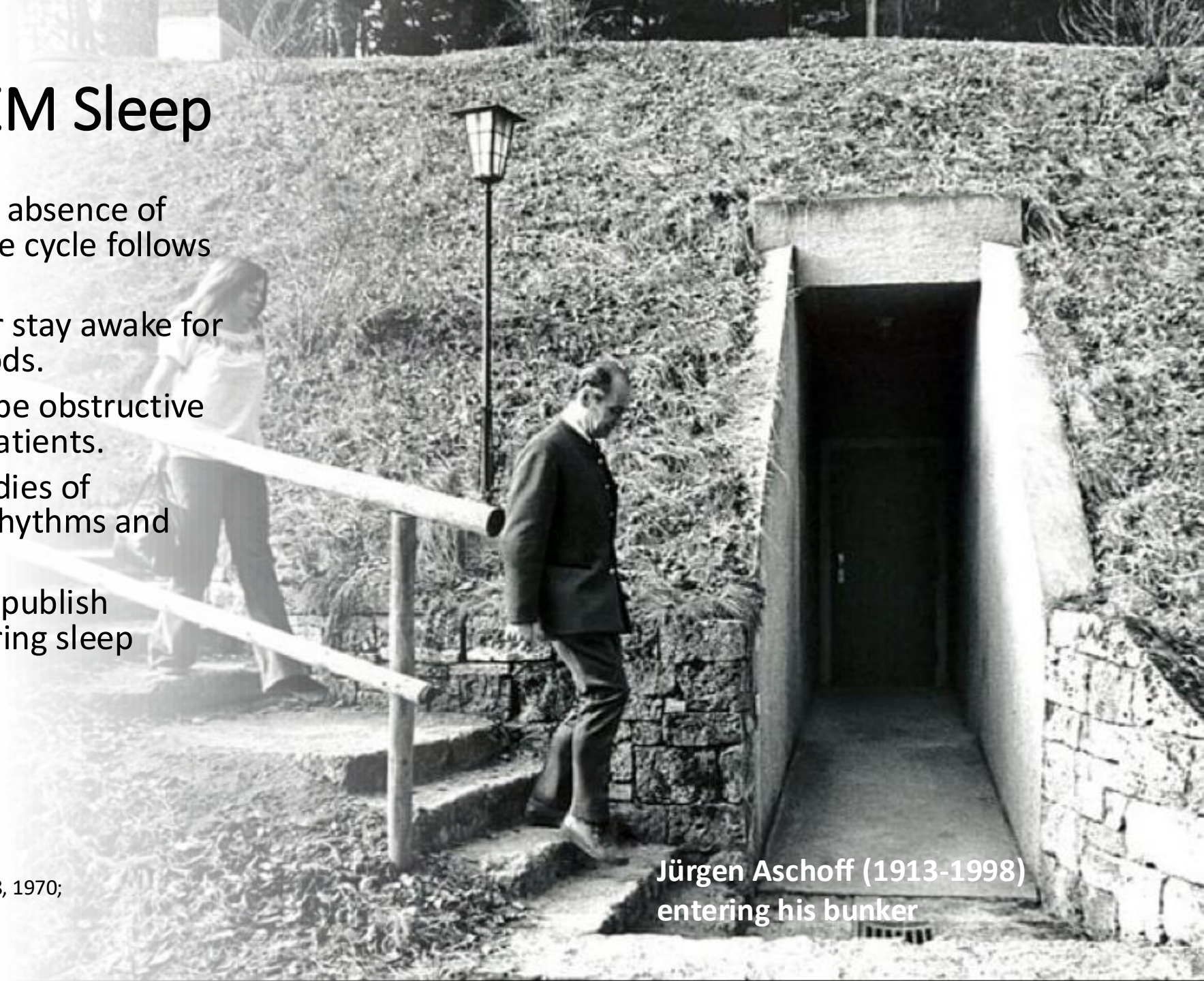
1960s: Shining a Light on Narcolepsy

- Narcolepsy: Identified in 1880 by Gélineau, but cause remained unknown and treatment options inadequate.
- 1963: Dement publishes paper with Rechtschaffen showing sleep-onset REM periods and REM-like daytime sleep attacks in group of patients with narcolepsy.
- Theory: Narcolepsy is a disorder in which aspects of REM erupt at random.
- Corollary theory: It involves dysfunction of pons or other nodes in brain's REM-regulating network.
- Dement recruits 100+ patients with narcolepsy symptoms for ongoing study.
- 1964: Launches short-lived narcolepsy clinic at Stanford—his first experience of treating sleep disorders.

Kroker, 2007; Rechtschaffen et al, 1963; Dement, 1999.

1960s: Beyond REM Sleep

- 1965: Aschoff reports that in absence of time cues, human sleep/wake cycle follows ~25-hour rhythm.
- BUT—some subjects sleep or stay awake for much longer or shorter periods.
- European researchers describe obstructive sleep apnea in Pickwickian patients.
- Weitzman publishes first studies of relationship between sleep rhythms and endocrine secretion.
- 1967: Rechtschaffen & Kales publish standardized manual for scoring sleep stages via polygraph.



Jürgen Aschoff (1913-1998) entering his bunker

Aschoff, 1965; Kroker, 2007; Weitzman 1966, 1968, 1970; Thorpy 2015

1970s: The First Modern Sleep Clinic

Christian Guilleminault (1938-2019)

- Late ‘60s: Dement envisions developing sleep medicine as new subspecialty.
- 1970: Launches Stanford Sleep Disorders Clinic, first specialized clinic to incorporate knowledge gained since discovery of REM.
- 1972: Guilleminault becomes medical director.
- Clinic introduces polysomnography, develops other new diagnostic and therapeutic techniques.
- Guilleminault publishes studies that help transform science’s conception of sleep apnea.
- Stanford clinic offers first CME course in sleep disorders.

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1970s: Decoding the Clockwork

- Two discoveries in early ’70s open new frontiers in sleep science.
- 1971: Caltech researchers report discovery of first “clock” gene.
- 1972: Researchers at U of Chicago and UC Berkeley report discovery of suprachiasmatic nucleus—the “master clock” in mammalian brains.
- Findings answer questions Kleitman asked decades earlier and help drive growth of sleep medicine.

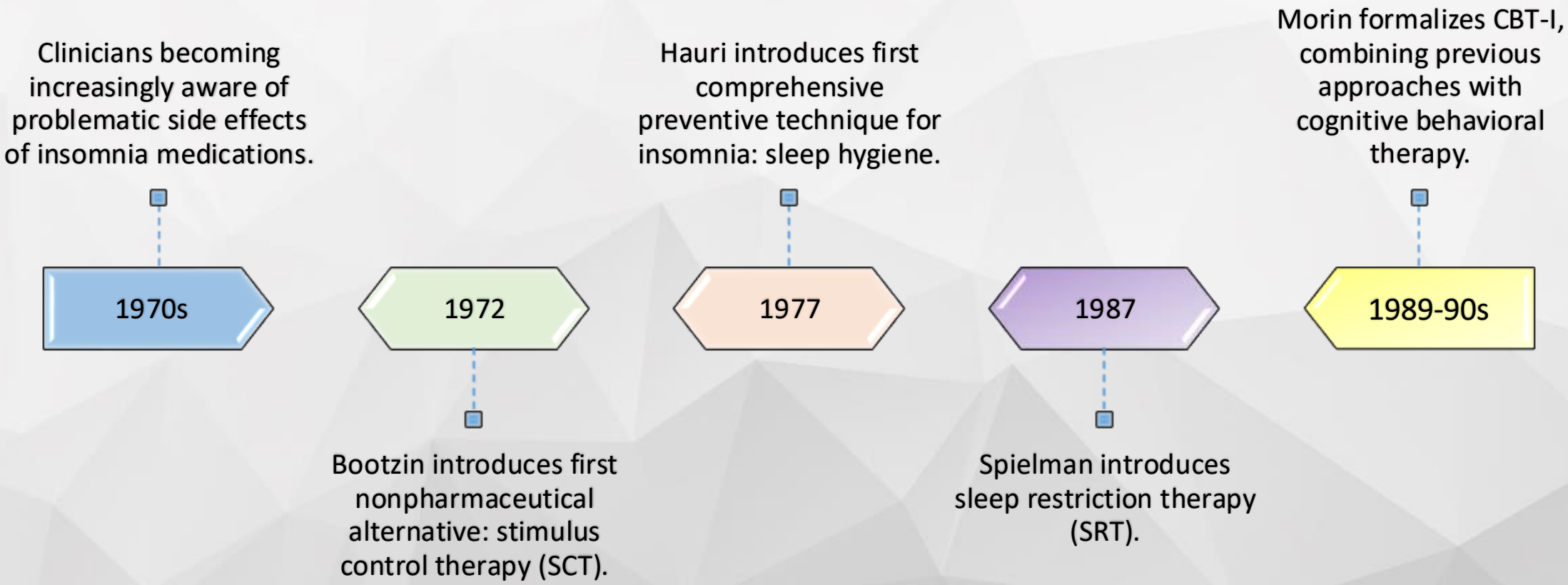
Konopka, 1971; Takahashi, 2021; Lamberg, 1994, 1997; Weaver, 1998.

1970s: Sleep Medicine Spreads Its Wings

- 1975: Dement and colleagues form Association of Sleep Disorders Centers (ASDC).
- 1976: Carskadon and Dement introduce Multiple Sleep Latency Test (MSLT).
- Czeisler identifies delayed sleep phase disorder and introduces chronotherapy.
- 1978: ASDC issues first certificates in sleep medicine.
- 1979: Diagnostic and Clinical Manual of Sleep Disorders published.

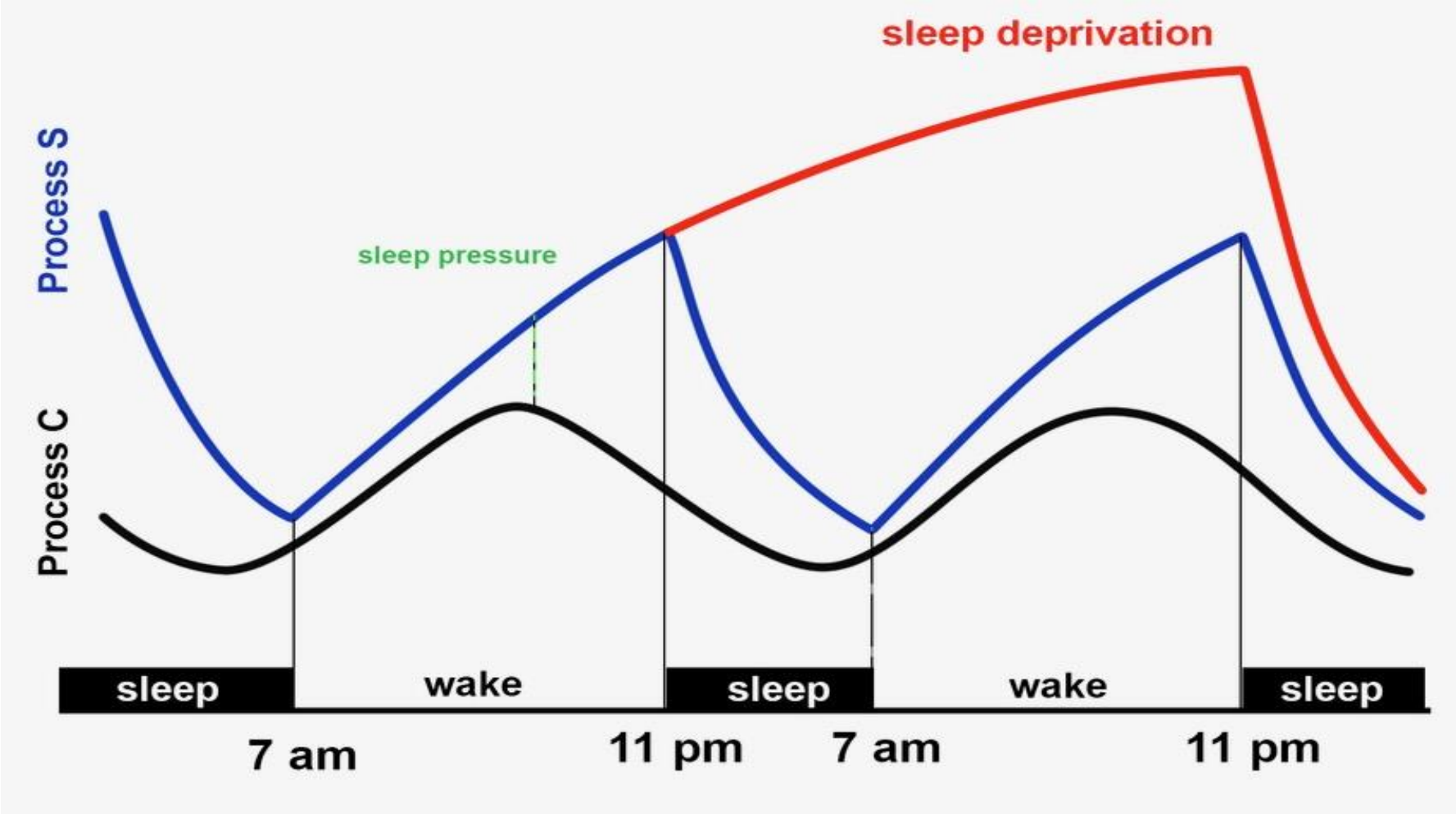
Shepard et al, 2005; Dement, 1996; Czeisler, et al, 1981; Weitzman et al, 1981.

1970s-90s: Insomnia Alternatives



Turner & Asher, 1979; Hauri, 1982; Spielman, 1986; Morin, 1993; Chokroverty & Billiard, 2015

1980s-90s: The Two-Process Model



Borbély, 1982

1980s-90s: The Rise of CPAP

Early CPAP prototype

- 1981: Sullivan describes continuous positive airway pressure (CPAP) to treat obstructive sleep apnea (OSA).
- Previously, only surgical treatments were available.
- CPAP provides first effective, non-invasive alternative.
- Mid-1980s: First commercial machines are marketed.
- Mid-’90s: Sales in tens of thousands, doubling each year.
- CPAP draws cardiopulmonary specialists to sleep medicine.

Sullivan, 1981, 2018; Barnes, 2007; Kirby, 2011; Kroker, 2007

1990s: Awakening

1995: Jouvet, Dement, Kleitman, and Aserinsky reunite at Kleitman's 100th birthday celebration in Nashville.

- Mid-1980s: Dement spearheads movement to establish sleep as public health issue.
- He and allies lobby Congress to create National Commission on Sleep Disorders Research.
- Early 1990s: Commission holds public hearings nationwide.
- 1993: Congress establishes National Center on Sleep Disorders Research at NIH.
- 1995: American Medical Association recognizes sleep medicine as self-designated medical practice.
- 1999: Death of Kleitman at 104.

Miller, 2023

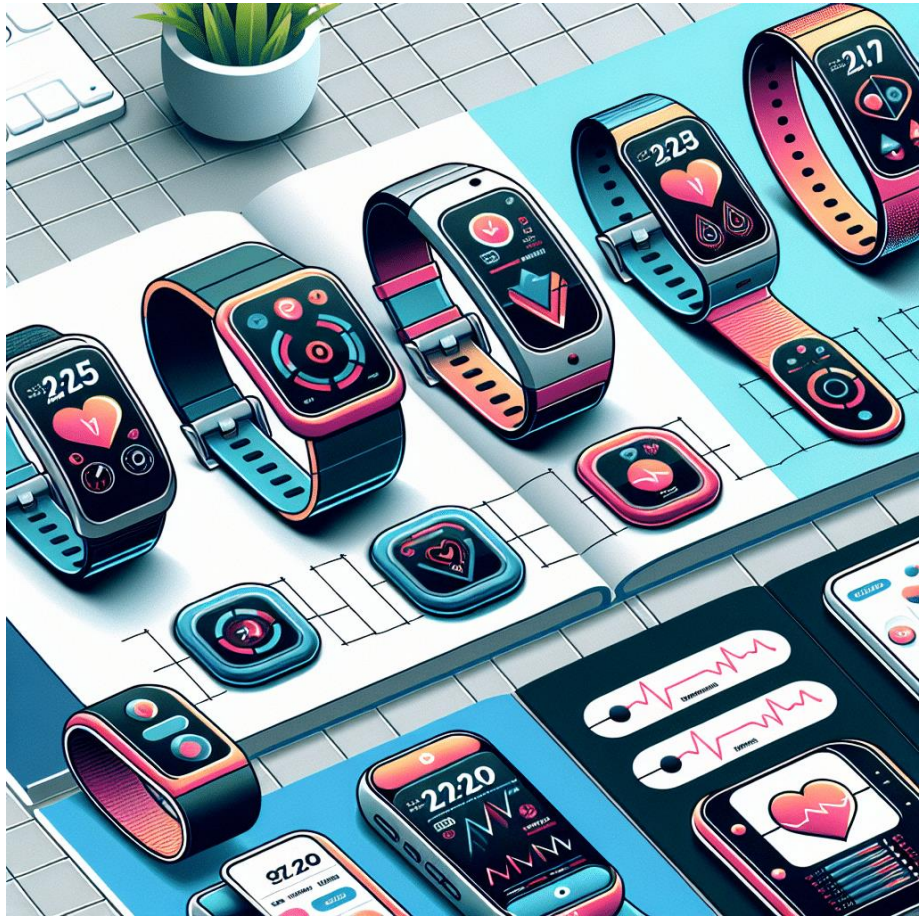
1990s: Better Sleep for Teens

Mary Carskadon (b. 1947) in her lab, 2011

- 1985: Carskadon starts lab at Brown University.
- 1990: Begins publishing studies showing unique sleep needs/impacts of sleep deprivation on adolescents.
- Helps launch global movement for later start times at middle and high schools.
- 1996: Edina, MN is first community to act on those findings, followed by growing numbers around U.S. and world.

Miller, 2023

1990s-Present: Sleep Science and Sleep Medicine Today



Notable research breakthroughs since Kleitman's centennial include:

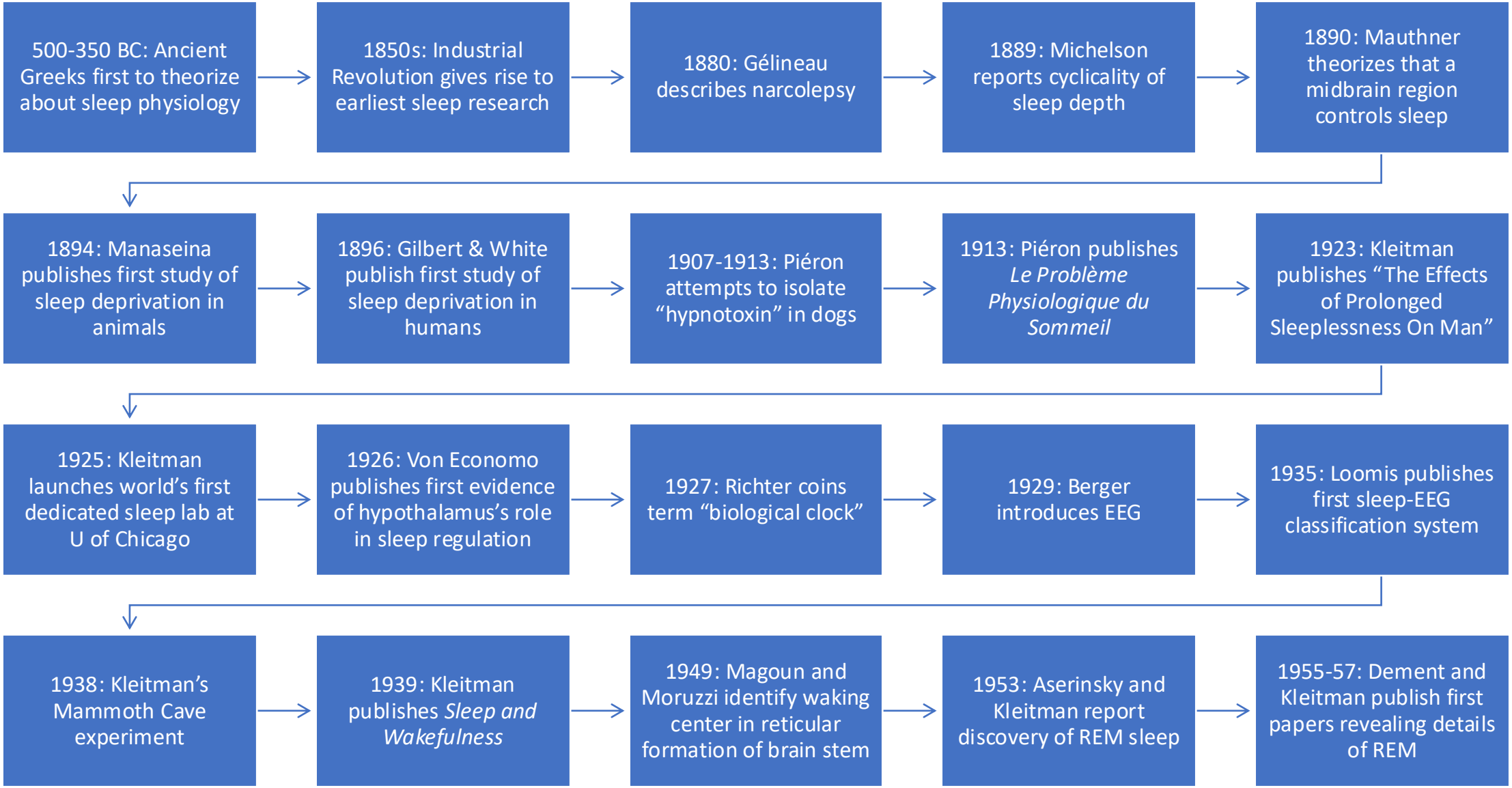
- 1998: Discovery of orexins, neurotransmitters that stabilize sleep and waking and are implicated in narcolepsy.
- 2013: Discovery that during sleep, brain washes away toxins associated with neurodegenerative diseases via glymphatic system.
- 2019: Discovery that neurons repair DNA during sleep.

Notable technical development: Rise of wearable sleep trackers/apps.

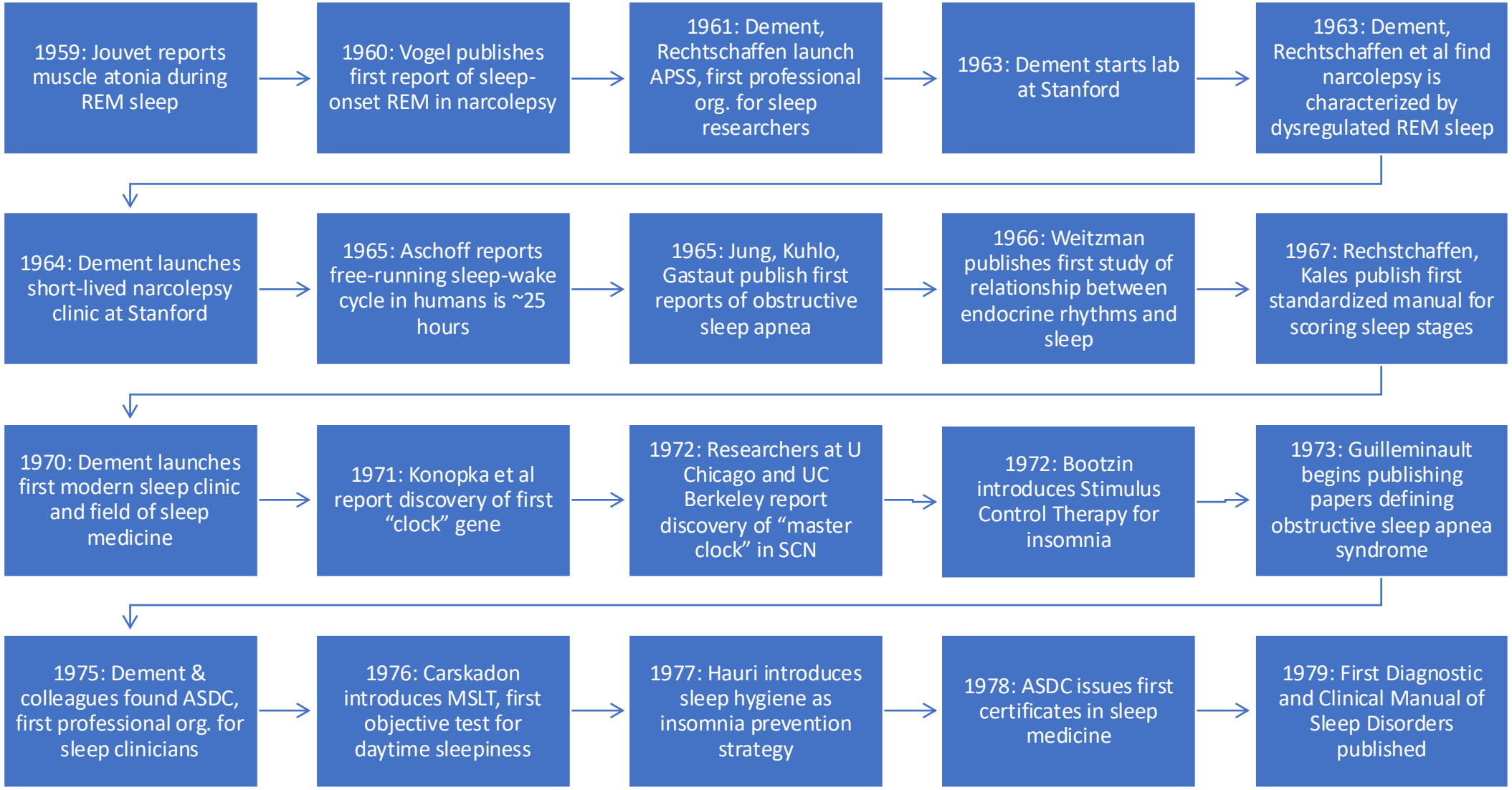
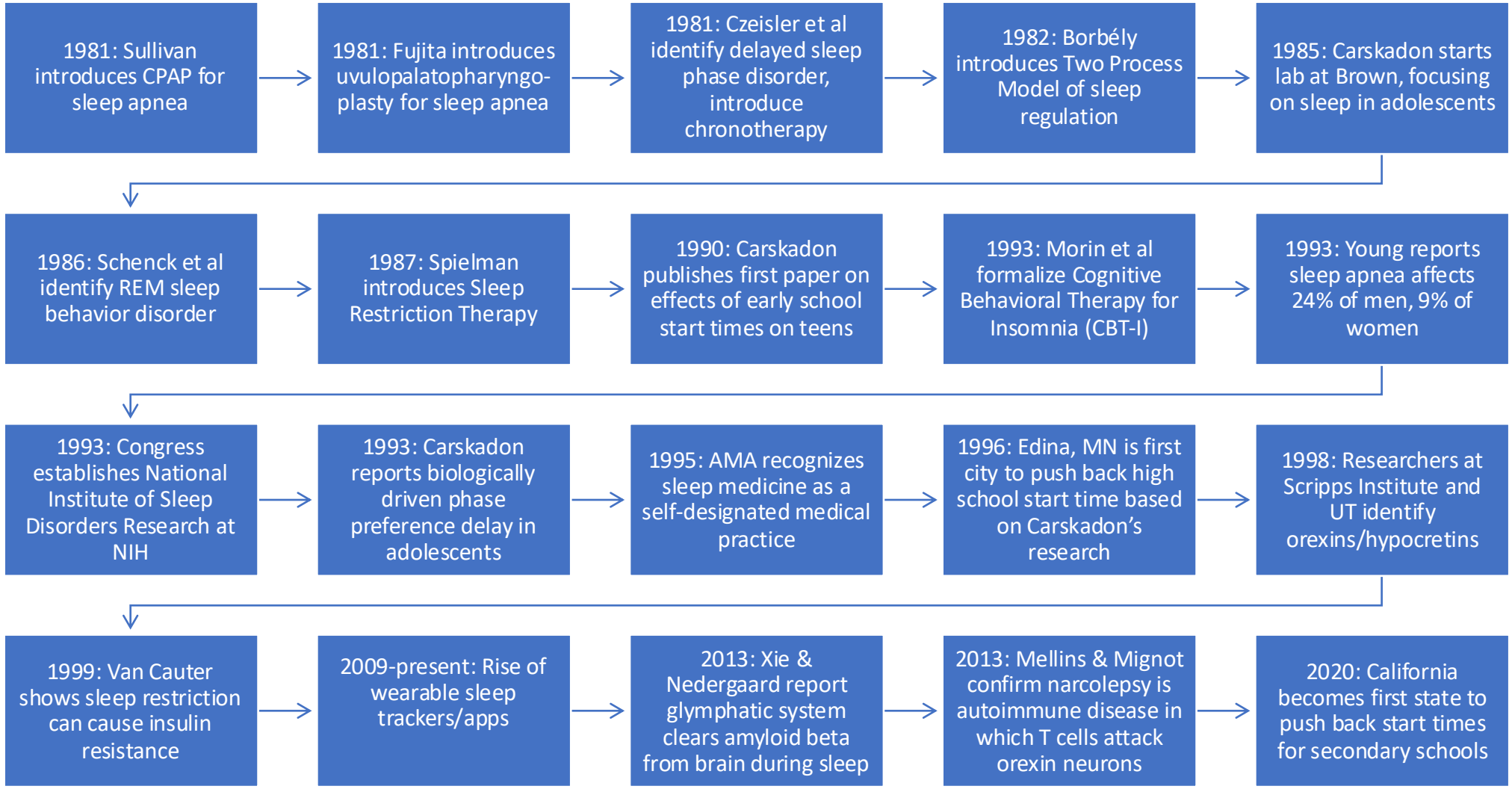
Remaining question: What is sleep's core function?

Siegel, 2001; Xie et al, 2013; Zada et al, 2019

Timeline of Sleep Science/Medicine



Timeline of Sleep Science/Medicine



Timeline of Sleep Science/Medicine