SEXUAL MEDICINE HISTORY

Sleep-Related Erections Throughout the Ages

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ABSTRACT

Introduction. The occurrence of sleep-related erections (SREs) has been known since antiquity.
Aim. To highlight historical, theological, and sexual medicine-related aspects of SREs throughout the ages.
Methods. Review of old medical books on male sexual functioning and review of scientific medical and theological articles on SREs from about 1900 on.
Results. The cyclic character of SREs was first noted by German researchers in the forties of the 20th century. However, already before the beginning of the Christian era, one knew that men had erections and ejaculations during sleep. In the Middle Ages, SREs were generally considered to be rebellious manifestations of the male body, while it seemed to disobey its owner and showed up its perverted and sinful side. From the fifteenth to the end of the 17th century, severe erectile dysfunction (ED) was ground for divorce. The ecclesiastical court records show that if necessary, the members of the jury sat at the defendant's bedside at night to be able to judge any SREs occurring. Since the 17th century, SREs were considered to be part of masturbation, which could cause many ailments and diseases. Psychoanalyst Stekel acknowledged in 1920 that a morning erection, the last SRE, is a naturally occurring phenomenon in healthy men from infancy to old age. Today, some scientists assume that SREs protect the integrity of the penile cavernous bodies.
Conclusions. Throughout the ages, philosophers, theologians, physicians, members of ecclesial law courts, psychoanalysts, psychiatrists, sexologists, physiologists, and urologists have shown interest in SREs. Obviously, the observations and testing of SREs have a long history, from antiquity to modern sleep labs, in men and in women, in newborns and old adults, by penis rings with sharp spikes to fancy strain gauge devices. Despite all these efforts, the mechanisms leading to SREs and its function are however not yet completely understood. **van Driel MF. Sleep-related erections throughout the ages. J Sex Med 2014;11:1867–1875.**

Key Words. Sleep-Related Erections; Historical and Theological Aspects; Nocturnal Penile Tumescence; Rapid Eye Movement Sleep

Introduction

Penile and clitoral erections occur in several contexts, some of which have nothing to do with sexuality, for example the nocturnal ones. There is no well-developed evolutionary theory or a proposed adaptive function of these sleep-related erections (SREs), but it is well-known that they are significantly related to rapid eye movement (REM) sleep and that they decline with age. During a normal night of sleep, humans usually have about four or five periods of REM sleep attended by dreams and penile or clitoral erections. SRE is at its peak during puberty, constituting just over 30% of sleep in 13- to 15-year-old boys and decreasing to 20% in men between ages 60–69 [1–4]. This means that the duration and intensity of SREs is a function of age. Interestingly, individual peak T levels occur near the transitions from non-REM to REM sleep [5].

Long-term monitoring of erections, already in the late thirties of the 20th century, on nine 3- to 20-week-old completely undressed male infants with diapers spread out smoothly beneath their

buttocks, in a single large room, showed that when SREs occurred, "they frequently awakened the infant" [6]. In relation to this observation, it is interesting to realize that newborn babies spend about 16 hours each day sleeping, and about half of this is in REM sleep. So, one may expect long-lasting SREs, particularly while after birth, a 3-month lasting period of relatively high T levels begins, the so-called "mini-puberty." Probably because of ethical reasons, this has never been investigated. In adults, T has a key role in the modulation of SREs, but the accurate T plasma level threshold remains to be established, while in hypogonadal men, SREs may persist within the normal ranges [7,8].

Earlier, SRE was widely known as nocturnal penile tumescence (NPT), an abbreviation introduced by the psychiatrist Ismet Karacan (1927–2009) who was one of the pioneers in monitoring nocturnal erections in a sleep laboratory. In the mid-1960s, he found that NPT was not per se accompanied by erotic dream content [9]. Other investigators confirmed that dream contents at SREs are rarely erotic [10–12]. By the work of Karacan, NPT became a widely accepted abbreviation, which is still used by some sexual medicine specialists and urologists, but in the interest of linguistic accuracy, the International Classification of Sleep Disorders advises the term SREs instead of NPT.

Nearly 10 years ago, sleep medicine experts extensively reviewed SREs with regard to clinical perspectives and neural mechanisms [13]. The aim of this article is to highlight historical, theological, and sexual medicine-related aspects of SREs.

SREs in Antiquity and Middle Ages

The occurrence of SREs has been known since antiquity. Plato (427–347 BC) maintained that "in males the nature of the genital organs is disobedient and self-willed, like a creature that is deaf to reason, and it attempts to dominate all because of its frenzied lusts." [14] With this statement, the ancient Greek philosopher putted forward an idea characteristic of medieval theologians: The penis possesses his own will and to keep him under control is a complex and skilful exercise in which not everybody will succeed. Some years ago, Dirk Schultheiss gave an example of the description of SREs out of the Roman period [15]. It concerned the poet Horace (65–8 BC) who described a situation when he was waiting in his rest room for a very nice young female servant, who did not reach him; therefore, he wrote: "there I—what a stupid!—wait an untruthful girl till midnight: then I fall sound asleep with my penis completely erected, and my dreams stain my night-short and my supine belly with obscene images" [Satyrs, I, V, vv. 82–85].

Claudius Galenus (129-c.200/c.216), better known as Galen of Pergamon, was a prominent Greek-speaking Roman philosopher, surgeon, and personal physician of emperor Marcus Aurelius. He was the first to describe the bulbospongiosal and ischiocavernosal muscles. Galen considered dreams with their SREs as textbook examples of the category dreams that reflected an individual's physical state: "Men full of sperm will imagine that they are having sexual intercourse." [16,17] So, in his view, SREs and nocturnal ejaculations were simply the consequence of a males' physical condition. He was also an "early believer" that sexual abstinence could cause madness.

As concerns the earlier Middle Ages, most of what is known about sexuality relies on John Cassian (c. 360–435) [18]. He was a prominent ascetic and prolific writer on monastic life active in the Middle East and southern Gaul and one of those responsible for bringing eastern hermetic-style monasticism into Western Europe. In his Institutes, he gives advice with regard to coping with morning erections [19]:

"Firstly, lest the jealous fiend through some dream defile the purity which was gained in the psalms and prayers of the night, angered by out chastity to which he is ever most opposed. Once we have obtained pardon for your ignorant transgressions, and forgiveness begged with tears in confession, he is determined to corrupt us if he finds a moment's chance, and is most anxious to weaken or destroy our confidence when he sees us devoutly turning to God in purity of prayer. Thus he attempts during the short space of this hour after vigils to bring down those whom he failed to defeat all night long."

So, for Christian monks, SREs and nocturnal ejaculations became the battlefield to preserve their purity. They blamed irresistible female demons, who tempted and tantalized them with their beautiful naked bodies, especially when they were asleep and vulnerable to "attacks." They even tied metal crucifixes to their genitals before going to bed to combat these temptations. However, church father St. Augustine (354–430) sustained that in dreams, men were not responsible for their acts, even though they might feel sorry for what happened to them. He stated that "if the nocturnal

emission originates in an erotic dream, this should not be seen as sinful since the dreamer cannot control the images that appear in his dreams." [14] Another famous theologian, Thomas Aquinas (1224–1274), wrote "that is clear that a nocturnal orgasm is never a sin in itself. Though sometimes it is the result of a preceding sin." [14] Augustine also stated that in sexual relations, there should always be the hope of fertilization. In those days, that was only possible with an erect penis, normal testicles, and a fertile female. "Be fruitful and multiply," as it says in Genesis [20]. Well, men with erectile dysfunction (ED) were incapable of that and hence were violating the sacrament of marriage—it was as simple as that.

The 14th–19th Century

Following Augustine, ecclesiastical law considered it more or less a mortal sin if men with ED and hence infertile turned out to have entered into marriage. To the end of the 17th century, ED was an even ground for divorce. In an extensive study, the historian Pierre Darmon describes the manner in which those suffering from ED were treated in those days, especially in France [21]. During the trials of the ecclesiastical courts, the defendants in any case had to prove that they possessed normal external genitals, and a jury composed of theologians, doctors, and midwives had to assess it. The court records show that, if necessary, the members of the jury sat at the defendant's bedside at night to be able to judge any SREs occurring. The pompous rituals surrounding these trials indirectly confirmed the power of the Catholic Church. Initially, there was some degree of discretion, but in the course of the 16th century, the church authorities shifted sharply from spiritual voyeurism to actual voyeurism. By this time, they not only required a demonstration of the rigid erection but also of its "elasticity and natural movement." Sometimes, the jury also insisted on having a demonstration of ejaculation. Naturally, as time went by, this was not enough either, and the married couple had to have sexual intercourse in the presence of the jury, the so-called "congress." It was not until 1677 that the Catholic Church dispensed with impotence trials. In the last chapter of his book, Darmon wonders how it could have ever come to impotence trials. Possibly, the initiative came from inquisitive doctors and lawyers who could not believe that a man with a normal-looking genitals could have ED. Their occupational misconduct was not corrected in any manner at all. The church was more than willing to participate because it formed a means of displaying power, while at first the public found the proceedings highly amusing. Undoubtedly, the obsessive discussions about ED and other sexual abnormalities served as an outlet for suppressed sexual feelings.

In books from the 17th to the 19th century, it is nearly impossible to distinguish SREs and ejaculations (so-called "pollutions"). Since the late 17th century both were considered to be part of masturbation, which could cause many ailments and diseases. Looking at the devices used at that time to prevent masturbation and SREs, one can find among other penis rings with sharp spikes [22]. With the current knowledge about the cyclic character of SREs, one can only imagine what excruciating pain the young victims must have endured. In 1818, a French surgeon named Jalade-Lafond even designed a corset for the penis, which reached from the shoulders to the knees. This was followed by many other devices, including a metal tube that dangled from a leather jerkin, a brainchild of the German Johann Fleck [23]. In 1849, a doctor Demeaux made an urgent request to the French Ministry of Education, requiring among other things that dormitories in boarding schools should be so designed that beds were divided into a foot end, which took up two-thirds of the bed, and a head end [24]. The two parts should be divided by a partition, and in this way, the foot end of up to a hundred beds could be monitored at night for "suspicious" movements and the head end could be blacked out by the partition. In some way, this method reminds us of the aforementioned impotence trials in the 17th century and "scientific" long-term SREs monitoring of erections in the late thirties of the 20th century on completely undressed male newborns [6].

Early Scientific SRE Research

As many laymen today, Richard Freiherr von Krafft-Ebing (1840–1902), one of the most influential figures in the scientific history of human sexuality, was erroneously convinced that morning erections are induced by a full urinary bladder. Another founder of sexology, Henry Havelock Ellis (1859–1939), really feared SREs and nocturnal ejaculations because in the Victorian Age, every child was taught that they would increase in frequency and lead to death. Ellis went to Australia to become a teacher, but there, he started a career as sex researcher by keeping a meticulous log of his

own nocturnal ejaculations [25]. After 8 years, he concluded that the frequency of ejaculations did not increase with age as claimed by others, and about his SREs, he notified the following:

> It has been said that urinating will relieve the pressure and quiet the erection. I gave this a fair trial for a long period and found no difference in the net result, though sometimes an emission might be thereby postponed a day or so. Getting out of bed and walking up and down to allay erection was of similarly temporary effect.

Ellis returned to England to qualify as a physician, and after that, he developed psychological concepts of autoerotism and narcissism. Both were later extended by Sigmund Freud (1856–1939). These two scientists revolutionized the study of dreams with regard to male sexual functioning declaring that everything that 19th century doctors had targeted as the cause of ED—masturbation, sexual excesses, addiction to drugs, alcohol and tobacco, and even the lessening of libido due to aging—were only symptoms of deep-seated psychological traumas [26]. One of Freud's earliest followers, the Austrian psychiatrist Wilhelm Stekel (1868–1940), acknowledged in 1920 that SREs are a naturally occurring phenomenon in all normal healthy men from infancy to old age and that the presence of morning erections, the last SREs, is a significant sign of psychogenic ED including a good prognosis of psychotherapy [27]. He also stated that the absence of morning erections surely is not a significant sign of nonpsychogenic ED.

Modern SRE Research in Men

In 1944, German researchers working in Tübingen published an SRE study in five young subjects [28]. They had used a simple electromechanical transducer that provided a binary signal of the presence or absence of an erection. The first author, Peter Ohlmeyer, a young physiologist, did not mention why he got the brilliant idea to register SREs continuously over the night. The investigators found a nocturnal erection cycle with a mean duration of 85.4 minutes and a mean active phase of 25.3 minutes. Individual mean periods varied from 79.7 to 102.2 minutes. In addition, the authors showed that spontaneous awakening from sleep, on which subjects made notes, were significantly associated with the erection cycle. The second part was published in 1947 when Pflügers Archiv was reactivated after a 3-year lasting break because of World War II [29]. This part showed that the erection cycle was not restricted to night time sleep but continued during daytime sleep without change in periodicity. The long-term recordings, ranging from 11 to 26 consecutive nights, showed that SREs were part of an ongoing biological rhythm continuous during sleep and wakefulness. The SREs in consecutive nights did not occur at the same clock time but shifted from night to night by a mean value of 11.6 minutes.

Approximately 10 years later, the observations by Aserinsky of periodic REM movements in sleeping infants led to the discovery of what is now well-known as REM sleep cyclicity [30]. The close correspondence between SREs and REM sleep was noted by Aserinsky and Kleitman in 1955 and in 1965 demonstrated experimentally by the brain physiologist Charles Fisher and coworkers in the Mount Sinai Hospital, New York [31,32]. Probably not knowing details of the German history of modern medicine including the Teutonic thoroughness, Fisher qualified the work of Ohlmeyer and coworkers as follows: "About 20 years ago, there appeared two obscure (. . .) articles by several German investigators describing a cycle of erection during sleep."

Compared with their German colleagues, the Americans had a more intuitive approach. For their first attempt to record SREs, Fisher and coworkers devised a polyvinyl tube with the size and shape of a donut. This tube was filled with water, fitted around the base of the penis, and, when pressure was exerted on its inner surface during erection, a rise in the water level of a smaller tube attached to it could be observed. One of his subjects inquired whether it was supposed to be an artificial vagina. His second method involved the measurement of changes of the penile skin temperature during SREs. The belonging device consisted out of a thin resistance wire of a special alloy which had the property of varying its resistance as a function of temperature. It was applied directly to the surface of the penis. For his third method, Fisher used a mercury strain gauge applied to the penis, which consisted of an elastic silicon plastic tube filled with mercury and sealed at both ends with platinum electrodes to form a loop. An increase of two to three centimeter was found to represent an SRE. However, as in his first and second method, it was possible that this device itself would stimulate the penis. So, Fisher and coworkers decided to direct observations on completely naked sleeping subjects, who did not have any apparatus attached to their penis. Their sub-

jects slept covered by a thin transparent plastic sheet and were observed during the whole night through a small window into the sleeping room or by entering the room and observing at close quarters. Periodically, notations were made of the degree of erection on a 0–4 scale. In order to maintain the subjects' cooperation and to avoid "sexualization," the researchers tried to behave as objective "physicians," in fact again comparable with the aforementioned method by the ecclesial sex experts in the 17th century [21].

Ismet Karacan

Ismet Karacan and his coworkers found in the middle 1970s that during life, SRE episodes become fewer and shorter and begin later in the sleep cycle, and the small amount of SREs associated with non-REM sleep increases with aging [33–35]. Others confirmed that presleep sexual activity or viewing a sexually arousing film before bedtime did not affect subsequent SREs [36]. Already in 1970, Karacan also suggested that SRE testing could be used to differentiate ED as either psychogenic or organic in origin. Many articles on this topic followed over the years, and in 1978, he published a section in a standard textbook on sleep disorders entitled "The role of the sleep laboratory in diagnosis and treatment of impotence" [37]. In the '80s, attempts to economize led to a search for less expensive, less time-intensive, nonlaboratory alternatives for SREs testing [38–46]. Encircling the penis with postage-type stamps at bedtime was one of the most popularized methods [39]. The "stamps" were manufactured in the local medical school printing shop in Portland, Oregon. However, initial promising validation studies soon were followed by disappointing results. Today, urologists sometimes use the RigiScan device (Dacomed Corporation, Minneapolis, MN, USA) which continuously monitors penile circumference and rigidity, and although SRE monitoring especially outside a sleep laboratory is not the ideal test to assess erectile function, it is currently the best available diagnostic method in common urologic practice [47]. However, already since the extensive but not well-recognized studies by Uros Jovanovic from the University of Würzburg, Germany, in the late sixties, it is clear that SREs can be adversely affected by psychological factors as sleep deprivation, fatigue, anxiety, and depression [48]. The influence of these factors suggests that the central neurophysiologic substrates of affect and sexual motivation are involved in the modulation of SREs. This means that "psychogenic" ED may have its roots in "organic" central nervous system pathophysiology.

Today, there is fortunately communis opinio in sexual medicine that in most patients with ED, the Cartesian question of organic vs. psychogenic is not relevant anymore. According to Jovanovic, the quality of sleep itself is essential with regard to SREs: "Good sleepers and good dreamers have the best SREs while poor sleepers but good dreamers take the second place. Good sleepers and weak dreamers have the third place; the weakest SREs are observed in poor sleepers and poor dreamers" [48]. In fact, the aforementioned means that SRE monitoring should be done in a well-equipped sleep laboratory, especially in patients with complex, confusing histories, and in legal cases in which compensation or guilt hinges on erectile function status.

Modern SRE Research in Women

Although far fewer studies have examined females' nocturnal genitals, they also have erections (and vaginal lubrication) during REM sleep. However, the pioneering researchers could not simply hire students to wait and observe the subjects, and the average clitoris was too small for strain gauges. What one needed were some women with a congenitally enlarged clitoris and a powerful need to know. In 1970, three researchers of the University of Florida, including Ismet Karacan, put these two things together [49]. The two subjects were found to have a similar number of erections as did a control group of men, and as with the males, the SREs occurred during REM sleep. Obviously, their fancy strain gauge was not applicable to the general female population. In Würzburg, Jovanovic used two methods in 10 young women: clitorography and colpography. The first registered the increased temperature of the erect clitoris and the second vaginal muscle contractions, using a 6- to 9-cm long gummy balloon with a diameter of 0.8–2 cm connected to a pressure chamber [48]. Using a vaginal blood flow (VBF) device, Fisher and coworkers in New York studied 10 women with an average age of 30 [50]. The duration of VBF increases was equivalent to that of male SREs, but the former was distributed differently, having a greater incidence in non-REM sleep. To date, researchers have sophisticated patient-friendly devices for simultaneous measurement of pelvic floor muscle activity and VBF to

their disposal [51]. These devices are up till now not used in routine sexological or gynecological assessment.

SREs in Animals and Painful SREs

While mammals such as the rhesus monkey, the stump-tailed macaque, mouse, opossum, and rat also show erections during their REM sleep, SREs were initially considered as a general biological phenomenon in mammalians [52–54]. However, in rats carbachol-induced REM, sleep periods were not accompanied by penile erections, and Argentinean researchers found that the armadillo Chaetophractus villosus had SREs only in non-REM sleep periods [55,56]. These observations suggest that there probably are differences in sleep architecture and SREs in between mammalians. It has also been demonstrated that SREs may persist with nearly total absence of REM sleep in a human case report [57]. This man had previously shown to suffer from a highly localized traumatic pontine brain lesion, and polysomnography conducted 4 years later showed drastic reduction of REM sleep but intact SREs. In humans, uncoupling from REM sleep has also been observed as a result of drug administration and due to rebound after sleep deprivation [58,59].

As far as I know, penile pain occurring during SREs was first described in 1939 by Walker and Strauss in their book on sexual disorders in the men [60]. The authors considered painful SREs as "almost certainly due to the existence of a sexual neurosis." In 1972, Jovanovic, called the phenomenon *erectio nocturna dolorosa* [48]. Jovanovic treated his two patients successfully with sleeping pills and tranquillizers.

Overall, the histories of patients with painful SREs reveal several unsuccessful consultations with physicians, including urologists. These patients report frequent nocturnal awakenings related to unpleasant feelings of penile pressure or tension, or even unbearable pain [61]. Commonly, the intensity of pain and the duration of the associated sleep deficit increase during the second part of the night when REM sleep periods are longer. Excessive diurnal sleepiness is a consequence of REM sleep fragmentation. Various maneuvers are used to try to stop them: physical exercises, walks, ice cubes, cold showers, etc. In course of last four decades, several drugs have been tried with rather disappointing long-term results: antipsychotics, antidepressants, benzodiazepines, antiepileptics, digoxine, beta2 agonists, antiandrogens, 5-alpha-reductase inhibitors, and baclofen [61]. Up till now, predisposing factors with regard to painful SREs are not known.

The Neurophysiology and Function of SREs

In his book on the "Libido Sexualis," the famous sexologists Albert Moll (1862–1939) postulated with referral to his older colleague Von Krafft-Ebing that erections may involve separate specialized higher central structures [62]. However, Moll did not discuss the origin of SREs. Until now, the neurophysiology of SREs is not yet completely understood. According to Sachs, it may be possible that several different areas of the brain contribute to the occurrence of erections in different contexts [63]. Each erection may depend on the contribution of a unique combination of several nuclei. This probably depends upon the amount of excitatory or inhibitory information that the nuclei receive from the periphery and from other central nuclei and to its hormonal environment. This means that SREs or erections by, for example, sensory input (olfactory, tactile, or visual) or erections generated from memory or fantasy may all involve separate specialized higher central structures, leading to Sachs' theory of context-specific ED.

Lesions of the lateral preoptic areas in rats eliminated SREs but left waking-state erections intact, suggesting that SREs are regulated by higher central control mechanisms involving the hypothalamus [64]. During the last two decennia, brain imaging techniques like positron emission tomography (PET) and functional magnetic resonance imaging have been used to study sleep-related brain activity changes in humans. PET scanning of humans in REM sleep showed increased activity in limbic and paralimbic regions, including the lateral hypothalamic area, amygdaloid complex, septal–ventral striatal areas, and infralimbic, prelimbic, orbitofrontal, cingulate, entorhinal, and insular cortices [65]. After reviewing the literature, Dean and Lue concluded that the mechanism that triggers REM sleep is probably located in the pontine reticular formation and that activated cholinergic neurons in the lateral pontine tegmentum combined with silent adrenergic ones in the locus ceruleus and silent serontonergic ones in the midbrain raphe are responsible for SREs [66].

In 1996, Nehra and coworkers were the first ones who postulated that SREs are physiological processes that improve cavernous smooth muscle oxygenation and contribute to maintaining a normal erectile response [67]. SREs may have a protective role on cavernous body tissues, while in the flaccid state, the blood pO2 in the sinusoidal spaces is between 20 and 40 mm Hg increasing up to 90–100 mm Hg during erection [68]. This low pO2 during the nonerect state can favor the transforming growth factor b1 synthesis in smooth muscle cells of the cavernous bodies followed by collagen and connective tissue deposition. The outcome of SRE monitoring in a healthy 37-year-old male mountain climber during a 43-day hypoxia experience in Nepal at altitudes ranging from 0 to 5,800 m above sea level supported the hypothesis that oxygen availability and delivery play an important role in the regulation of local penile erection-related mechanisms and that, as in patients with obstructive sleep apnea, decreased nitrogen oxygen synthesis due to low oxygen levels may be considered an important etiological cofactor in ED [69,70]. In this respect it is relevant to know that not only T and trazodone but also PDE5 inhibitors improve the frequency, magnitude, duration, and rigidity of SREs [13,71].

Conclusive Remarks

Throughout the ages, philosophers, theologians, midwives, physicians, members of ecclesial law courts, psychoanalysts, psychiatrists, sexologists, physiologists, and urologists have shown specific interest in SREs. Obviously, the observations and testing of SREs have a very long history, from antiquity to modern sleep labs, in men and in women, in newborns and old adults, by penis rings with sharp spikes to fancy strain gauge devices.

The studies of REM sleep and SREs have grown up together. Revelations by remarkable young researchers about one of these phenomena often led to discoveries about the other. Without any doubt, Ismet Karacan and his coworkers have been the most important pioneers with regard to modern scientific research of SREs, and his long list of publications showed that a significant number were published with a urologist as coauthor, emphasizing the importance of a multidisciplinary approach.

It has been suggested that SREs represent an intrinsic mechanism aimed at protecting the integrity of the tissues of the penile cavernous bodies, but in fact, the mechanisms leading to SREs and its function are not yet completely understood. More information about central physiological mechanisms that attend SREs will undoubtedly be relevant for a better interpretation, including the painful ones.

Generally, intact SREs only prove that the spinal cord, peripheral nerves, erectile tissues, and vascular supply at the end organ level, penis, or clitoris are intact. Though no longer routinely used clinically, SRE monitoring in a sleep laboratory remains a useful but rather expensive diagnostic method for special patients with complex, confusing sexual histories.

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