Table 2. Effects of bombesin (BBS), vasoactive intestinal peptide (VIP) and neurotensin (NT) on TRH-induced body-shaking response

Peptide	Dose (μg)	No. of rats	No. of shakes during 30 min
TRH	1.6	14	90 ± 5.8
TRH (1.6 μg) plus			
BBS	0.1	8	85 ± 6.8
	0.2	9	53 ± 4.4**
	0.5	9	34 ± 5.2**
	1	11	27 ± 3.3**
	2	10	24 ± 4.3**
VIP	1	9	82 ± 6.1
	2	15	64 ± 6.7**
	5	15	54 ± 1.5**
	10	10	17 ± 4.5**
NT	2	8	78 ± 4.8
	5	8	63 ± 3.6**
	10	9	68 ± 3.4**
	20	8	55 ± 5.5**
	40	10	59 ± 4.5**

** $p < 0.01$ vs TRH alone (Dunnett's test). Means ± SEM.

were suppressed by BBS, VIP and NT may indicate that these neuropeptides affect the dopamine turnover induced by TRH in the brain. In this regard, NT has been reported to inhibit the dopaminergic system[13,14], but this is controversial in view of other observations[15,16]. The effects of BBS and VIP on catecholamine metabolism have not yet been clarified. Different mechanisms have been proposed for the shaking behavior, since activation of central serotonergic system[5,17] and i.c.v. administration of carbachol chloride[18] can also produce a body-shaking response in the rat. In this regard, we showed that VIP did not affect the dopaminergic system, but reduced serotonin-induced symptoms and that NT caused a pronounced decrease in serotonergic activities (unpublished data). It is possible that the stimulatory effects of TRH could be modified by these neuropeptides through their effects on the serotonergic system and probably other neurotransmitter systems in the brain are involved. It should be noted that even neuropeptides which are not effective alone could modify the effects of others in a strong positive or negative manner.

1 Acknowledgment. The authors wish to thank Professor S. Hsiao, University of Arizona, U.S.A., for his cordial criticism and Mrs Y. Maeda for her skillful technical assistance.
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Night shift paralysis[1]

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Summary. 12% of night nurses surveyed claimed to have suffered from a totally incapacitating paralysis that may be related to sleep paralysis, and contribute to impaired levels of safety on the night shift. The incidence of this paralysis is shown to be age-related, largely confined to the early hours of the morning, and to increase over consecutive night shifts.

Reduced levels of safety on the night shift[2-5] have usually been attributed to the nightworkers' low level of performance efficiency due to the combined effects of disrupted circadian rhythms[6-10] and partial sleep deprivation[11,12]. However, during the course of our investigations into the disruption of night nurses' circadian rhythms[5], we learned of a previously uninvestigated paralysis (known in the profession as 'night nurse paralysis') that may prevent nightworkers from performing their job for several minutes and might thus contribute to this problem of safety. We were told that this paralysis normally occurs when the nurse is performing a sedentary task in the early hours of the morning, and is then required to make a gross motor movement. This suggested that it may be a form of sleep paralysis which usually occurs during the transition between wakefulness and sleep[13] and is more common in young adults and adolescents[14].

Method and sample. We conducted a questionnaire survey of 434 nurses with experience of night work to determine the nature of this paralysis, its extent, and its dependence on age, time of day, and the number of consecutive nights the nurse had worked. This sample was drawn from 9 General Hospitals located in 4 different areas of England. The age range of the sample was 19–61 years, but was highly skewed with a median of only 31 years. Similarly, the nurses' experience of night duty ranged from less than 15 months to about 12 years, with a median of between 45 and 60 months. Only 24 (5.5%) of the sample were male, reflecting a similar bias in the population as a whole.

Results. General incidence and descriptive. 52 (12%) of the nurses surveyed claimed to have experienced the paralysis. There was no significant variation in this incidence across the 4 regions surveyed ($\chi^2 = 6.08$, df = 3, $p > 0.10$). The percentage of 'sufferers' was slightly higher in males (17%) than in females (12%), although this difference may well reflect an inadequate male sample size. Most sufferers (83%) claimed to have experienced the paralysis only once or twice, while only a small minority (4%) claimed to have experienced it 5 or more times. Estimates of the duration of the occurrence ranged from a few seconds up to 30 min with a mode of about 4 min and the majority (84%) estimating it to be greater than 2 min.

98% of the sufferers were sitting performing a task such as reading or writing, and 90% were sure they were awake, immediately prior to the onset of the paralysis. In 92% of cases the paralysis was 'triggered' by some external event, such as a patient calling, requiring them to make a gross motor movement, rather than by their own desire to move. 96% of sufferers claimed they were unable to make any movement at all during the paralysis, but in only 1 case (2%) was there evidence of a loss of muscular tonus. 98% of sufferers said their vision was unaffected and that they were aware of what was happening in their surroundings. A little over a half of the sufferers (58%) admitted to feeling sleepier than normal for the time of day prior to the paralysis, and 25% of them spontaneously reported being frightened by it. Hallucinations, unusual physical sensation (e.g. cold or numbness) and the feeling that their limbs 'were heavy' were reported by about 10% of sufferers. In only 4 of the sufferers (8%) was there any evidence that the paralysis occurred on awakening from a sleep.

Factors affecting the incidence. The incidence of the paralysis failed to show the linear increase with the amount of exposure to night work that would be expected by chance ($\chi^2 = 17.76$, df = 4, $p < 0.01$). Over about 5 years' night work experience, additional experience had virtually no effect on the percentage of nurses claiming to have suffered from the paralysis (fig. 1). This appears to be due to a marked, and approximately linear, decrease in the incidence with increasing age (fig. 2). This reliable effect of age ($\chi^2 = 13.06$, df = 4, $p < 0.01$) is similar to that observed for sleep paralysis[12].

The reported occurrences of paralysis were entirely confined to the night shift, despite the fact that care had been taken in compiling the questionnaire to indicate that it could occur at any time of day or night. Indeed, they showed a very pronounced trend (fig. 3) over the course of the normal (20.00–08.00) night shift ($\chi^2 = 138.99$, df = 11, $p < 0.001$). This trend showed a clear peak at about 04.00 h when the circadian rhythms in nightworkers' rated alertness, body temperature, and many other psychological and physiological functions are normally at a low ebb[5,7,9–11]. Finally, the incidence of paralysis built up in an approximately exponential manner over consecutive night shifts ($\chi^2 = 16.94$, df = 3, $p < 0.001$). It was about 4 times more likely to occur on the seventh or subsequent night shift than on the first or second (fig. 4).

Discussion. The fact that this paralysis was largely confined to nurses below the age of 30 is consistent with the view that it may be related to sleep paralysis. Indeed, although nearly all the sufferers were sure they were awake at the time, many of them admitted to feeling sleepier than normal, while the trend in the incidence over the night shift was very similar to the changes normally found in night nurses' subjective ratings of alertness or drowsiness[5]. Further, the increase over consecutive night shifts could reflect a cumulative effect of partial sleep deprivation due to the reduced duration of nightworkers' day sleeps[11]. Thus the paralysis seemed to occur when the nurses managed to maintain a state of wakefulness, despite considerable pressures to sleep. In this context, it is of interest to note that it has been suggested that sleep paralysis may actually occur during the minutes preceding the onset of sleep, rather than during the sleep itself[15].

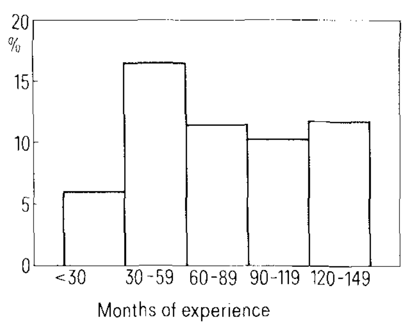

Figure 1. The incidence of paralysis as a function of experience of night work.

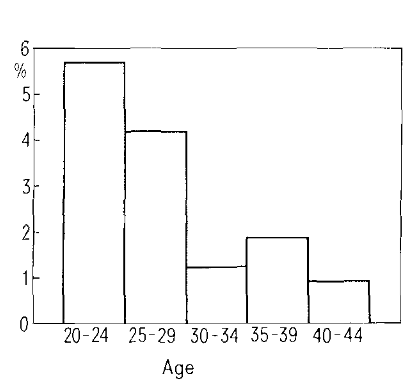

Figure 2. The incidence of paralysis at a given age, expressed as a percentage of the number of nurses in the total sample who could have experienced it at that age.

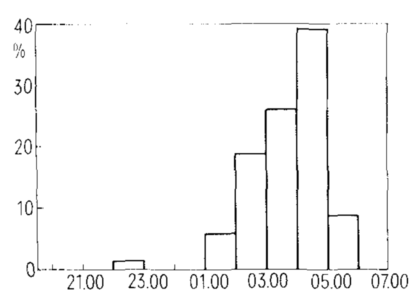

Figure 3. The incidence of paralysis at different times of night expressed as a percentage of the total number of occurrences reported.

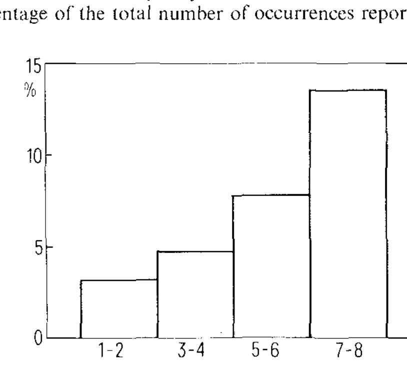

Figure 4. The incidence of paralysis as a function of the number of consecutive night shifts the nurse had worked, expressed as a percentage of the number of nurses in the total sample whose shift system involved that number of consecutive nights.

There is no reason to suppose that a similar paralysis may not occur in other groups of nightworkers. Indeed, it has been claimed that the incidence of sleep paralysis may be up to 4 times higher in males than in females[16]. Clearly, it would be of interest to study male populations, such as process controllers, pilots or air traffic controllers, who often perform an essentially sedentary task at the low ebb of many of their circadian rhythms, and under relatively sleep-deprived conditions. We are currently planning such a study. If this paralysis is found to occur in these populations, where the cost of a failure to respond can be even higher than that in nursing, it would suggest a strong need to reduce the level of sleep deprivation under which such populations commonly work, and to ensure that no single individual is ever left in sole control. However conscientiously such individuals may force themselves to stay awake, any emergency that arose could trigger a paralysis that prevented them from responding to it.

1 Acknowledgments. We wish to dedicate this paper to Professor Dr Günther Hildebrandt, Director of the Institut für Arbeitsphysiologie und Rehabilitationsforschung, University of Marburg/Lahn in honor of his 60th birthday. We also wish to thank the Nursing Officers and nurses concerned for their help in this study.
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0014-4754/84/050510-03$1.50 + 0.20/0

Adaptive respiratory variation in 4 chromosomal species of mole rats

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Summary. Oxygen and carbon dioxide pressures were measured in subcutaneous gas pockets of 4 chromosomal species of the *Spalax ehrenbergi* complex. Oxygen pressures of 11.8, 13.6, 16.9, and 17.2 torr and CO_2 pressures of 84.2, 82.9, 80.1, and 64.1 torr were measured for the chromosomal species 2n = 52, 54, 58, and 60, respectively. The differences between the 4 chromosomal species in their subcutaneous gas tension appear to reflect adaptive respiratory variation associated with geographic variation in climate. It underlies an important respiratory physiological correlate of ecological speciation in the extremely hypoxic and hypercapnic subterranean environment.

What are the respiratory physiological correlates of speciation? We explored this problem in the actively speciating complex of subterranean mole rats of the *Spalax ehrenbergi* superspecies in Israel[1,2]. The superspecies consists of 4 chromosomal species, each adapted to a different climatic regime characterized by a combination of humidity and temperature. The distribution of the chromosomal species is correlated with increasing aridity southwards (2n = 52, 54, 58, 60). Fossorial mole rats spend most of their life in the unique underground atmosphere[3] and are highly adapted to living in extreme hypoxic-hypercapnic conditions[4–8]. Consequently, the respiratory physiology of the mole rat deviates considerably from the normal mammalian pattern[5–8]. The extreme hypoxic-hypercapnic subterranean environment selects for respiratory adaptations which maintain an adequate gas exchange.

The mole rat is able to maintain resting and elevated metabolic rates at levels of hypoxia in which the comparably sized white rat cannot keep its normoxic metabolism[4]. Although the mole rat has a normal resting mammalian metabolic rate, its resting heart rate, cardiac output, and ventilation are lower than the values predicted from its body mass[5,7,8]. The reduced convection of both air and blood at rest implies increased extraction of oxygen. The high affinity of the mole rat's hemoglobin ensures oxygen loading at low alveolar P_{O_2}[5], and the low unloading pressure is compensated by short diffusion distances in the tissue[6]. Thus, the low tissue P_{O_2} and high tissue P_{CO_2} (estimated by s.c. gas pockets) of the mole rat are indicative parameters of its adaptation to the subterranean atmosphere[5].

The general respiratory adaptations characterizing the evolution of *Spalax* for its unique subterranean burrow atmosphere must also affect its speciation process. If burrow atmospheres vary geographically due to climatic and soil heterogeneity, respiratory adaptations can be expected to follow suit in the derivatives of speciation. Indeed, in Israel, precipitation is far higher and soil conductivity lower in the north (where 2n = 52 and 54 range) as compared with the central and southern regions (where 2n = 58, and particularly 2n = 60 occur). Here we present evidence supporting the hypothesis that the 4 chromosomal species of *S. ehrenbergi*