latencies. Despite the long prior wakefulness before the first day sleep, *Foret and Benoit* [17] noted a decreased amount of REM sleep which is confirmed by our data. The slow wave sleep rebound at the first day sleep could be expected because of the long prior wakefulness. However, the data of *Foret and Benoit* [17] are not in agreement with this expectation and our results.

The striking change from night sleep to day sleep in the distribution of the amount of REM within the sleep period has already been observed several times [17, 23, 39, 42].

Summing up, our data show differences between day and night sleep but no essential differences of quality between morning and afternoon sleep during experimental shiftwork studies. Therefore, it is not possible to recommend a special strategy concerning the position of day sleep between night shifts.

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(Karger, Basel 1981)

Comparison of Long and Short Sleep Durations in Free-Running Sleep-Wake Cycles[5]

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Introduction

A consistent result in shift-work studies is the reduction in sleep duration during day sleep. It has been shown that this reduction is mainly due to the shift in the placement of sleep relative to the time of day [10]. Recent studies have shown that in the absence of external time cues, the duration of sleep, as well as the sleep stage structure, depends on the phase position of sleep in the circadian temperature cycle [13, 47, 48].

Another approach to this problem involves the study of sleep duration as a habitual factor in subjects who are short and long sleepers. By comparing the sleep stage structure of these two groups, long sleepers have, in ab-

[5] For references see compound list on page 208.

solute values, more stage REM, stage 1, stage 2 and the same amount of stage 3 + 4 as short sleepers. In relative values stage REM, stage 1, and stage 2 are the same or slightly higher and stage 3 + 4 is lower in long sleepers compared to short sleepers [36].

The question is whether these differences between long and short sleepers can also be seen in spontaneously long or short sleep episodes of a subject, who has normally a medium sleep duration.

Method

In this experiment 4 subjects (21–28 years old) spent 21–30 days individually in an underground room. Throughout the experimental period, the subject had no information about local time and a self-selected regime of lights on and off, bedrest-activity and meal-times. Body temperature was measured continuously by a rectal probe. Thus, the experimental conditions were the same as in the standard experiments for circadian research by *Aschoff and Wever* [6]. Additionally all bedrest episodes were polygraphically recorded. For the comparison of short and long sleep episodes of a subject, the 6 shortest and 6 longest sleep episodes of each subject were compared separately (fig. 6). These criteria were taken because of the different distributions of the sleep duration between the subjects. From the course of body temperature, the maxima and minima were scored by inspection, and for every sleep episode the distances from these values computed.

Results and Discussion

Sleep Duration. In isolation, all the subjects developed free-running circadian rhythms of body temperature and sleep-wake cycle with periods longer than 24 h [for further details see 46]. The distribution of the shortest and longest sleep episodes of each subject are shown in figure 6, where the sleep episodes are divided into three groups (indicated by different patterns of shading), according to the different phase position of the temperature minimum during sleep. On the right side of the figure, the positions of sleep in relation to the minima of body temperature are shown for two groups. Short sleep episodes always have an early temperature minimum (1.0 ± 0.93 h after sleep onset), while long sleep episodes have a late minimum (8.6 ± 3.1 h after sleep onset).

This difference in the course of body temperature is in accordance with the finding that the phase position of sleep onset in the circadian temperature cycle is related to the duration of sleep [48]. In those studies it was shown that the beginning of short sleep episodes is at the time of the cir-

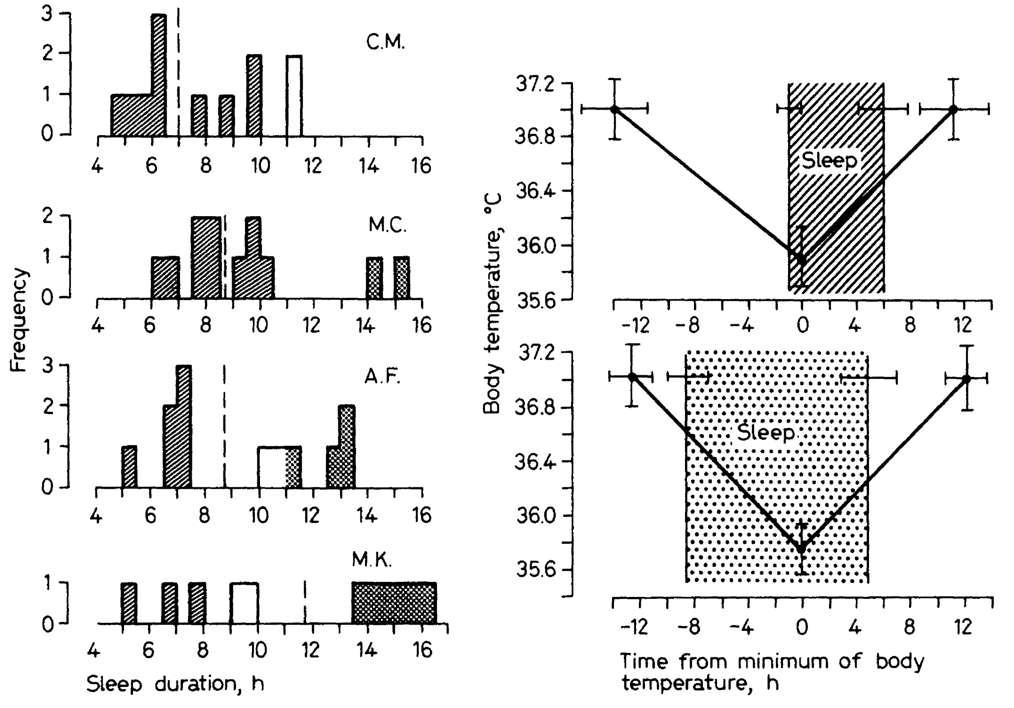

Fig. 6. Frequency distributions of the duration of the 6 shortest and 6 longest sleep episodes of the 4 subjects (left side). Additionally the phase position of the circadian temperature minimum is shown by different patterns of shading. Lined histograms represent sleep episodes where the temperature minimum occurred in the first half of sleep and hatched where it occurred in the second half. The non-shaded histograms represent sleep episodes where no definable minimum was found. On the right side for the groups with an early minimum and with a late minimum, the means and standard-deviation are given.

cadian minimum, while longer sleep episodes begin relatively earlier, with the minimum in the later part of sleep.

Sleep Stage Structure. The comparison of the absolute amounts of the different sleep stage structure showed more stage REM, stage 1, and stage 2 in long sleep episodes than in short sleep episodes while stage 3+4 was the same in most of the subjects (fig. 7). In relative amounts, stage REM and stage 1 were the same in short and long sleep episodes, while for stage 2 in long sleep episodes the amount was slightly higher. The relative amount of stage 3+4 was lower in long sleep episodes, compared with short sleep episodes in all the subjects. These results are in agreement with findings in habitually short and long sleepers [36]. Thus, the differences in the sleep stage structure, which were reported for the inter-individual comparison between long and short sleepers, are similar to those which are found in the

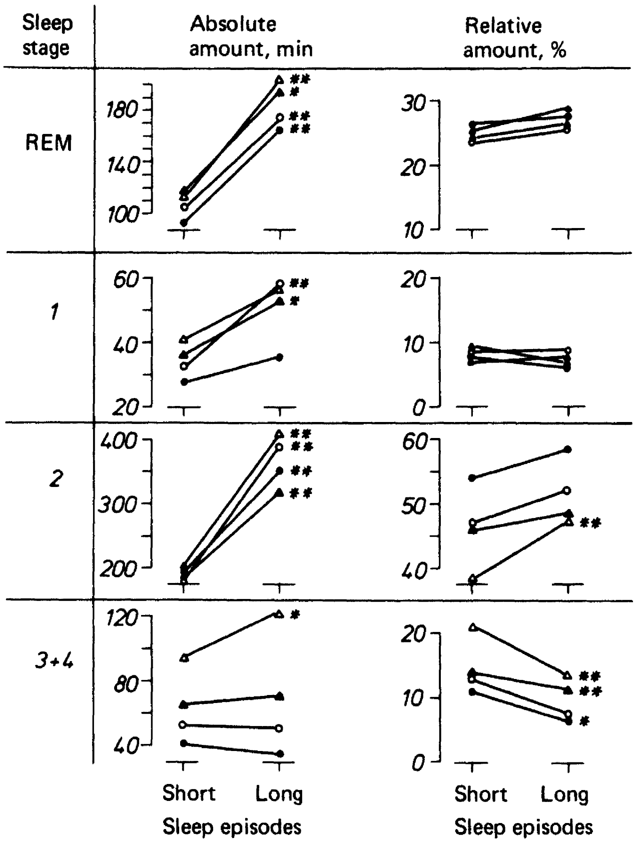

Fig. 7. Differences in the mean amount of various sleep stages between short and long sleep episodes for each subject. Asterisks denote statistical significance (t-test): $^*p<0.05$; $^{**}p<0.01$. Subjects: ● = CM; ▲ = MC; ○ = AF; △ = MK.

present study intra-individually between long and short sleep episodes of the same subject. A further analysis was done with regard to the relationship between the amount of REM sleep and the circadian temperature cycle cited above. Because of different phase positions in long and short sleep episodes in the temperature cycle, different distributions of REM sleep were expected. For this analysis, all the sleep episodes of the subjects were divided into those with an early temperature minimum and those with a late minimum as in figure 6. By comparing these two groups, sleep episodes with an early minimum have significantly more REM sleep in the first 3 h of sleep (56.67 ± 14.90 min) than the sleep episodes with a late minimum (42.75 ± 7.82 min).

This result agrees with the findings in studies of the relationship between REM sleep and the circadian temperature cycle [13, 41, 47]. By comparing sleep episodes with different durations, it has to be considered that these sleep episodes can be located at different phase positions in the temperature cycle, which results in a different distribution of REM sleep in the sleep episode.

In summary, the differences in the sleep stage structure of long and short sleep episodes in the same subject are comparable with those found in habitually long and short sleepers. In accordance with the finding that sleep duration is controlled by the temperature cycle, the long and short sleep episodes of an individual subject begin at different phases in the temperature cycle. From this it can be hypothesized that habitually long and short sleepers have different phase positions of sleep onset in the temperature cycle.

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(Karger, Basel 1981)

Concluding Remarks[6]

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These four presentations underline the complexity of the biological aspects of shiftwork in relation to the adjustment of the sleep-wake system. They illustrate the role played by factors such as age, individual characteristics of the sleep-wake system, phase relationship between sleep period and body temperature, or time of sleep.

In most available studies, individual characteristics and body temperature have not been analyzed and in some cases not even mentioned. One may suppose that the subjects were heterogeneous at least in so far as these characteristics were concerned which might explain the great variability of the results as well as the lack of significant data concerning sleep after a schedule inversion.

Age appears to be a major factor, with the 40s as a critical period for

[6] For references see compound list on page 208.