more reasonable. However, these should be specified because light sleep (or deep sleep) is a concept that can have objective meaning only in terms of the variable or variables used to describe it. One may speak of light sleep in terms of a low voltage EEG (as we have), or a low arousal threshold, or a high incidence of body movement, or a high heart rate, and so forth. Unfortunately for the concept, the various measures of lightness of sleep do not correlate well with each other. For example, the incidence of gross body movement is lower during stage 1 (dream) sleep than during adjacent periods of stage 2 (deeper) sleep. I personally feel that if depth of sleep must be measured, the most meaningful criterion is the arousal threshold. Even in this instance dreaming fails to qualify as light sleep. Current work in several laboratories seems to indicate that subjects are often more difficult to arouse while dreaming than at certain other times. The use of the EEG, or any other variable, as *the* criterion of depth of sleep is merely a matter of taste or convenience, and probably depends to some extent on how well the chosen variable fits the experimenter's personal subjective notion of this elusive characteristic.

A final point is that the eye movement potentials are not muscle potentials and hence the eye movement record is not an EMG (electromyogram). There is a more or less steady potential difference existing across the eyeball (cornea positive–retina negative). The eye movement potential is a consequence of the spatial change of the electrical field of the eyeball dipoles with reference to the fixed periorbital electrodes. Passive movement of the eyes will elicit such a potential with reference to fixed recording points, and retinal destruction will abolish it. There is no evidence of EMG potentials in the recordings that we routinely obtain, presumably because the extraocular muscles are too far from the recording electrodes.

Some of the above considerations may also apply to Ullman's comments. He refers to the dream periods as states of "partial arousal" perhaps "associated with vigilance operations during sleep." It seems to me that the term, *partial arousal*, is as ambiguous as the term *light sleep*. If by "partial arousal" is meant only the occurrence of the stage 1 EEG pattern, then the term is redundant. If the state of partial arousal is thought to have some other attribute (for example, we might logically assume it would include a lowered arousal threshold), again, we must ask, is this additional attribute in fact associated with the stage 1 EEG period and dreaming?

The periodic occurrence of a low voltage, fast EEG stage during normal sleep has also been observed in cats by myself [*Electroencephalog. and Clin. Neurophysiol.* **10**, 291 (1958)] and Jouvet *et al.* [*Compt. rend. soc. biol.* **153**, 1024 (1959)]. Since we can do no more than speculate about dreaming in cats, and since it seems unlikely that cats dream in the manner of humans, we might assume that the occurrence of a low voltage, fast EEG stage in this animal is a pure example of a vigilance operation. It might follow that during these periods the cat is more alert to various stimuli, and that the frequent occurrence of such periods during sleep greatly enhance his chances for survival. However, even here, where the issue of dreaming does not complicate the picture, the cat is, if anything, less vigilant. Jouvet reports a definite *increase* in arousal threshold during these low voltage periods as opposed to the slow wave stage of sleep, and, in a less refined study, I found that it was difficult to differentiate the two phases in terms of arousal threshold. I think that Ullman must recast his definition of vigilance with an eye to some of the more recent findings regarding the functional significance of the various EEG patterns during sleep. I think that he might also ask himself how much of the current neurophysiology of the brain stem really applies to the physiology of sleep in a more than speculative way, especially since there are still large gaps in a purely descriptive picture of sleep physiology.

WILLIAM DEMENT
Department of Psychiatry,
Mount Sinai Hospital, New York

Craftsmen and Physicists

In his paper "Dons or crooners?" [*Science* **131**, 1165 (1960)], Eric Ashby gives some examples of "craftsmanship in science" to illustrate how popularization of science for adults can be furthered. Taking the development of microscopes and microscopy as an example, he states: "Finally, in 1886 technicians succeeded in making lenses out of new sorts of glass. . . . About the same time it was discovered that if the light rays between the object and the lens do not pass through air but pass, instead, through a drop of liquid which has optical properties similar to those of glass, then larger and clearer magnifications can be obtained. These lenses were called apochromatic. . . ."

This statement contains several errors. First, it may give people the incorrect impression that apochromats were produced empirically (by craftsmen), whereas it ought to be well known that they were designed entirely mathematically by the famous professor

Ernst Abbe after he had induced the firm of Schott, in Jena, to produce the new sorts of glass which he had asked for on theoretical grounds. The grinding and mounting of the lenses is indeed craftsmanship; the design of the apochromats is not craftsmanship but applied science. Further, Ashby confuses the principle of the immersion objective with that of apochromatic correction. These are, of course, entirely independent. The principle of oil immersion objectives dates back to Amici (1784–1863), although his *Papaver* oil immersion system was not a really homogeneous immersion like Abbe's (in fact most modern oil immersion objectives are not truly homogeneous immersions either).

Later on in the article it is suggested that the detection of chromosomes was made possible by the invention of the apochromats, whereas in reality this was due entirely to improvements in microscope technique. In properly prepared sections or squash preparations chromosomes can be detected easily with objectives of considerably older design than the first apochromats.

While agreeing completely as to the need for popularization of science in the way Ashby proposes, I think it should be emphasized that the facts presented must be true.

C. VAN DUIJN
Biophysics Department, Research Institute for Animal Husbandry "Schoonoord," Utrecht, Netherlands

I am familiar with the facts van Duijn mentions, but I do not follow his reasoning when he implies that because of these facts the statement of mine which he quotes "contains several errors." Without craftsmen there would have been no apochromatic lenses. It is a matter of judgment whether the improvement of microscopes in the 19th century owed more to craftsmen than to physicists. I think it did. Van Duijn thinks otherwise. But our differences are matters of the interpretation of history. They do not justify either of us in accusing the other of error.

Similarly with homogeneous immersion lenses: I believe that the fundamental advance was made by Abbe. And as for van Duijn's assertion that the observation of chromosomes was due "entirely" to improvements in techniques for staining and mounting cells, I readily agree that these techniques were of critical importance, but I wonder whether he has tried to draw the morphology of a dividing nucleus under a pre-apochromatic microscope. I have, and I stick to my statement.

ERIC ASHBY
Clare College, Cambridge, England