The phenomenon of repression is an intriguing one, but it does not appear to be involved in the restoration of normal behavior in cross-innervated goldfish extraocular muscles. Repression may be implicated in other systems, but it must be physiologically demonstrated before it can be accepted.

Note added in proof: Recent experiments testing the hypothesis that behavioral repression is the result of rearrangement of synapses in the central nervous system demonstrate that after behavioral repression NIII still fires in the head-down position, which indicates that no central reorganization occurs.

SHERYL A. SCOTT
Department of Biology, Yale University, New Haven, Connecticut 06520

References and Notes

1. L. Guth and J. J. Bernstein, *Exp. Neurol.* **4**, 59 (1961); R. Elul, R. Miledi, E. Stephani, *Acta Physiol. Lat. Am.* **20**, 194 (1970); D. T. Cass, T. J. Sutton, R. F. Mark, *Nature (Lond.)* **243**, 201 (1973); R. F. Fangboner and J. W. Vanable, Jr., *J. Comp. Neurol.* **157**, 391 (1974).
2. R. W. Sperry and H. L. Arora, *J. Embryol. Exp. Morphol.* **14**, 307 (1965); L. R. Marotte and R. F. Mark, *Brain Res.* **19**, 41 (1970).
3. L. R. Marotte and R. F. Mark, *Brain Res.* **19**, 53 (1970); R. F. Mark, L. R. Marotte, P. E. Mart, *ibid.* **46**, 149 (1972).
4. R. F. Mark, *Exp. Neurol.* **12**, 292 (1965); ——— and L. R. Marotte, *Brain Res.* **46**, 131 (1972).
5. H. A. Howe, S. S. Tower, A. B. Duel, *Arch. Neurol. Psychiat.* **38**, 1190 (1937); J. J. Bernstein and L. Guth, *Exp. Neurol.* **4**, 262 (1961).
6. R. F. Mark, *Brain Res.* **14**, 245 (1969); *Br. Med. Bull.* **30**, 122 (1974).
7. P. A. Redfern, *J. Physiol. (Lond.)* **209**, 701 (1970); J. Bagust, D. M. Lewis, R. A. Westerman, *ibid.* **229**, 241 (1973); M. R. Bennett and A. G. Pettigrew, *ibid.* **241**, 515 (1974).
8. R. F. Mark, *Nature (Lond.)* **225**, 178 (1970); *Memory and Nerve Cell Connections* (Clarendon, Oxford, 1974).
9. R. Miledi, *Nature (Lond.)* **199**, 1191 (1963).
10. E. Frank, J. K. S. Jansen, T. Lømo, R. H. Westgaard, *J. Physiol. (Lond.)* **240**, 24P (1974); D. A. Tonge, *ibid.* **239**, 96P (1974).
11. L. Guth, *Exp. Neurol.* **6**, 129 (1962); J. K. S. Jansen, T. Lømo, K. Nicolaysen, R. H. Westgaard, *Science* **181**, 559 (1973).
12. E. Frank, J. K. S. Jansen, T. Lømo, R. Westgaard, *Nature (Lond.)* **247**, 375 (1974).
13. M. R. Bennett, A. G. Pettigrew, R. S. Taylor, *J. Physiol. (Lond.)* **230**, 331 (1973).
14. I thank Lynn Landmesser for helpful advice and comments. This work was supported by grant NS 10666 from National Institutes of Health to L. Landmesser, NIH training grant NS 05768, and a predoctoral fellowship from the National Science Foundation.

31 January 1975

Anomalous Myopias and the Intermediate Dark Focus of Accommodation

Abstract. *The dark focus of accommodation for an individual observer correlates highly with the magnitude of night, empty field, and instrument myopia. These anomalous myopias are interpreted as resulting from the passive return of accommodation to an individually determined intermediate dark focus when the stimulus for accommodation is degraded or absent, or when the need for accommodation is eliminated.*

Accommodation represents one of the initial responses of the visual system, the objective of which is to maintain a clearly focused image on the retina. The accuracy of this process determines how much information is extractable from visual stimulation and is therefore essential to virtually every visual task. Under most viewing conditions, the accommodation reflex results in a rapid and accurate adjustment of the refractive power of the lens. In view of this normally adaptive closed loop feedback system, the manifestation of sustained and inappropriate myopia under certain stimulus conditions represents an anomaly.

With lowered illumination level, the refractive power of the eye typically increases for distant objects. This phenomenon, which was first reported by Lord Maskelyne in the late 18th century and is referred to as twilight or night myopia, might be considered maladaptive since it degrades the quality of the retinal image (*1*). Moreover, night myopia is only one of a series of potentially maladaptive manifestations of the refractive system which are here referred to as the anomalous myopias. Another example is the nearsightedness reported when viewing an unstructured field (*Ganzfeld*) such as a clear sky, or during a snow storm or fog. This phenomenon, known as space, sky, or empty field myopia, should be considered maladaptive since the focus of the eye corresponds to relatively close distances in spite of the fact that the objects of interest are ordinarily located at a distance (*2*). Similarly, nearsightedness is frequently observed when viewing through optical instruments, particularly microscopes, and is known as instrument myopia (*3, 4*).

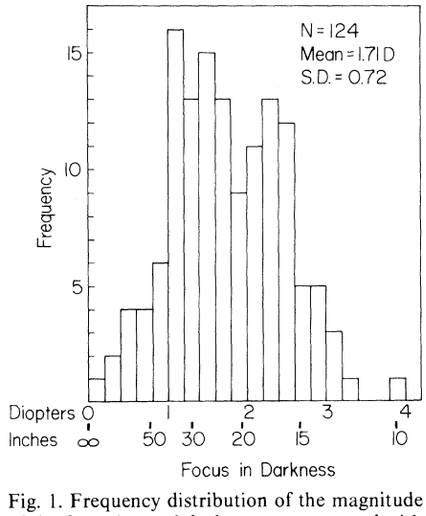

Fig. 1. Frequency distribution of the magnitude of the focus in total darkness, as measured with the laser optometer, for 124 college-age observers.

The theoretical treatment of these phenomena, in particular of night myopia, has been both extensive and varied (*5*). A critical issue in any analysis of these anomalous myopias is the state of accommodation under the conditions producing anomalous myopia. The classic assumption is that in the absence of visual stimulation or a stimulus for accommodation, the ciliary body relaxes and, assuming no refractive error, the eye is focused to correspond to optical infinity (*6*). This has been the prevailing interpretation in the literature and is implicit in ophthalmological and optometric clinical practice and the design of optical instruments such as microscopes, dissecting microscopes, and stereoscopes. However, an alternative point of view, which has appeared sporadically in the literature, is that the focus in the absence of stimulation is not to infinity but rather to some intermediate distance. This neutral focus has been estimated to be of the order of 1 diopter of accommodation, corresponding to a distance of 1 m. According to some investigators (*7, 8*), no accommodative effort is involved at this neutral focus, which has been referred to as the *Akkommodationsruhelage*, or resting state of accommodation. With adequate stimulation, the refractive power is then actively increased or decreased to correspond to the distance of the stimulus.

The intermediate focus hypothesis is particularly heuristic in relation to the anomalous myopias. In the classical context of the "resting" focus at infinity, any increase in refractive power is considered to be an active process. However, it is difficult to explain inappropriate accommodation in a system that is normally highly adaptive. On the other hand, if the resting focus is assumed to be at some intermediate value, the anomalous myopias may be simply considered as passive return of the lens to this neutral or equilibrium state.

A major methodological difficulty in the literature dealing with these problems has been the previous unavailability of a convenient technique for measuring accommodation which did not, in itself, influence the results. Although there are several precise clinical and experimental methods to assess accommodation, many do not per-

mit an unbiased quantitative measurement under the conditions that produce the anomalous myopias. Fortunately, with the availability of the laser optometer, it is now feasible to evaluate accommodation under the precise conditions for which the anomalous myopias are typically observed. The technique involves the intermittent superimposition of a diverged beam from a low-energy laser into the subjects' visual field, has no effect on accommodation, and permits measurements under a wide variety of laboratory and field conditions including total darkness (*9*).

We have carried out a series of experiments, utilizing the laser optometer, to investigate the relationship between the anomalous myopias and the focus assumed by the eye in the absence of light stimulation. The latter condition was achieved by measuring the accommodative response in total darkness. These measures are therefore referred to as the dark focus of accommodation.

Figure 1 presents a frequency distribution for 124 subjects of the dioptric and linear distance to which the eye is accommodated in total darkness. These observers were college students ranging in age from 17 to 26 years with an average of approximately 19.5 years. All had at least 20/25 far and near acuity, as determined by a Titmus vision tester. Normal optical corrections remained in place during the screening and determination of the dark focus (*10*). The data are consistent with the intermediate focus hypothesis. The mean value is 1.7 diopters, corresponding to a focal distance of 59 cm (23.2 inches). Although according to the classical interpretation, the focus in total darkness would be expected to correspond to optical infinity or zero diopter, the present sample included only four observers with a dark focus within 0.5 diopter of optical infinity. The marked variability in these values should be noted. The distribution is approximately normal with a standard deviation of 0.72 diopter and a range of approximately 4 diopters. Such marked intersubject variability in the intermediate focus has not, to our knowledge, been previously suggested.

The intermediate dark focus and the marked intersubject variability suggest a parsimonious explanation for the anomalous myopias. Each observer will tend to return to an individual intermediate focus when the stimulus for accommodation is degraded or when accommodation is ineffective in changing the retinal image. In the case of night myopia, low luminance levels result in decreased resolution and thus an impoverished stimulus for accommodation. In the case of empty field or space myopia, there are no contours or texture to serve as a stimulus for accommodation. Instrument myopia would be expected to result from the fact that many optical instruments, in particular light microscopes, have small exit pupils of the order of 2.0 mm or less. With such small pupils, the depth of field of the eye is expanded; this largely eliminates the need for accommodation since the stimulus is in focus over a wide range of optical distances (*4, 11*).

As a test of the hypothesis that the anomalous myopias result from a tendency for accommodation to return to an intermediate focus, data were obtained for the same observers under the three conditions that would be expected to produce anomalous myopia. If a unitary factor, return to the intermediate focus, were responsible for all three phenomena, the magnitude of the inappropriate myopia for all three conditions should be related to the individual's state of accommodation in total darkness, the dark focus. In all cases, the focus was determined by superimposing the speckle pattern from the laser optometer into the visual field. Night myopia was investigated by asking the subjects to observe monocularly a building in an urban environment at a distance of 200 m through a neutral density filter which attenuated the normal daylight ambient illuminance by a factor of 16,000 (*12*). Empty field conditions were simulated by juxtaposing a Ping-Pong ball hemisphere to the eye. A small hole in line with the visual axis permitted positioning a beam splitter for presentation of the laser speckle pattern. To ensure that the subjective appearance of the entire visual field was uniform with no visible contours nor luminance discontinuities (*Ganzfeld*), a second Ping-Pong ball hemisphere was aligned with the hole in the first. The luminance was uniform at 153 cd/m^2. Instrument myopia was evaluated by asking the subjects to focus clearly a square wave grating at a luminance of 11.0 cd/m^2 while viewing monocularly in a microscope with an exit pupil of 2.0 mm.

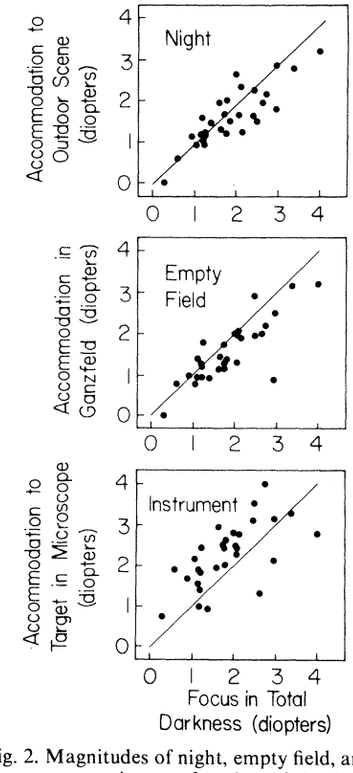

Fig. 2. Magnitudes of night, empty field, and instrument myopia as a function of the focus in the dark. Each point represents a datum for an individual observer who observed in all three situations.

Thirty subjects drawn from the same population as those in Fig. 1 were tested. The data are presented in Fig. 2 as the magnitude of anomalous myopia as a function of the dark focus of accommodation for the individual subjects. Each point represents the data for one subject. If anomalous myopia were simply a manifestation of the subject's individual dark focus, the data points would fall along the straight lines of unit slope indicated on these graphs. It will be observed that the data agree closely with this interpretation. The Pearson product moment correlations (r) for night (*13*), empty field, and instrument myopias are 0.84, 0.81, and 0.68, respectively.

These results support the intermediate focus hypothesis rather than the classical hypothesis that the resting focus is at infinity. The dark focus is distributed normally with a mean at approximately 59 cm and large intersubject variability. We feel that this intersubject variability is essential to understanding the anomalous myopias. The results demonstrate that the accommodation of individual subjects under conditions that either degrade or eliminate the need for accommodation is highly predictable from their individual dark focus. The lens approaches an intermediate focus when the stimulus for accommodation is eliminated by viewing in total darkness, when it is degraded (as by low luminance or an unstructured visual field), or when the need for accommodation is reduced by observing through small pupils. In this view, the three anomalous myopias are all manifestations of the passive return of the lens to the subject's individual dark focus. While these results do not rule out the influence of other factors, the strikingly high correlations over the three conditions suggest that the intermediate dark focus of accommodation represents a major factor responsible for the three anomalous myopias.

Operationally, the focus measured in the absence of visual stimulation is referred to as the dark focus. Morgan (*7*) and Schober (*8*) have presented convincing evidence that under such conditions the ciliary body is relaxed and have suggested the term resting state of accommodation. Since we have no direct measurements of the state of relaxation, it seems advisable to avoid confusion by eliminating reference to an inferred state of rest. In the present analysis, the tendency to return to an intermediate focus, determined in the absence of light stimulation, has high predictive value not only for the three anomalous myopias under discussion, but also with respect to the focus (i) assumed while viewing a diffraction pattern for which the sharpness of the image is independent of accommodation and (ii) when the depth of field is enlarged by decreasing pupil size (*11*). It also permits prediction of the maximum of the acuity-distance function for an individual observer (*14*).

With two exceptions, the ideas presented in this report have appeared previously in the literature. First, the marked variability in the intermediate dark focus has not been suggested previously, and provides a basis for explaining difficulties encountered in previous studies. For example, under the assumption that night myopia is the result of factors such as increased spherical aberration with increased pupil size, or chromatic aberrations and the Purkinje shift (*5*), one would not expect to encounter large individual differences, and such variability would be erroneously attributed to experimental error. Similarly, any attempt to ameliorate night or empty field myopia by prescribing a fixed negative correction for all observers (*15*) would be expected to produce inconclusive results. Subjects who have a far dark focus would not be helped by additional negative correction, whereas a small negative correction would not be adequate for subjects with a very near dark focus. Recognition of intersubject variability should permit a quantitative prediction of the magnitude of night myopia as well as the appropriate correction necessary to overcome its deleterious effects under low luminance observation conditions. Second, with respect to the anomalous myopias, our interpretation is unique in providing a unitary explanation for all three phenomena.

There are a number of additional implications of our data. As Morgan (*7*) and Schober (*8*) have pointed out, since the accommodation mechanism has autonomic innervation, the dark focus might represent a tonic balance between the activity of both branches of the autonomic nervous system. Thus, variations in dark focus would reflect the balance between sympathetic and parasympathetic activation. When measurements are made in total darkness, this provides a method for evaluating autonomic activity in the absence of normal light stimulation.

The intermediate dark focus might also have implications for clinical practice since objective examinations are typically made in a darkened room. Under such conditions, to the extent that the subjects return to their intermediate dark focus (*11*), refractive power would be overestimated.

Johnson (*14*) recently demonstrated that, even with high illuminance, accommodation is most accurate and visual acuity is highest when the stimulus is conjugate with the individual subject's dark focus. His data indicate that although variation in distance from the dark focus stimulates accommodation, there is a residual error of underaccommodation for nearer objects and overaccommodation for more distant objects. This accommodative error increases with distance in either direction from the dark focus, and is exaggerated by lowering the illuminance level. This implies that for optimal performance in any demanding visual task, such as photographic or x-ray interpretation, microscopy, visual inspection, driving, and flying, the optical distance of the stimulus should correspond to the dark focus of the individual observer.

H. W. LEIBOWITZ
D. A. OWENS
Department of Psychology,
Pennsylvania State University,
University Park 16802

References and Notes

1. J. R. Levene, *Notes Rep. R. Soc. Lond.* **20**, 100 (1965).
2. T. C. D. Whiteside, *J. Physiol. (Lond.)* **118**, 65P (1952); G. Westheimer, *J. Opt. Soc. Am.* **47**, 714 (1957).
3. H. Schober, H. Dehler, R. Kassel, *J. Opt. Soc. Am.* **60**, 103 (1970).
4. R. T. Hennessy, *ibid.*, in press.
5. G. Wald and D. R. Griffin, *ibid.* **37**, 321 (1947); J. M. Otero, *ibid.* **41**, 942 (1951); M. Kooman, R. Scolnik, R. Tousey, *ibid.*, p. 80; H. A. Knoll, *Am. J. Optom. Arch. Am. Acad. Optom.* **29**, 69 (1952).
6. H. von Helmholtz, *Physiological Optics* (Dover, New York, 1962), vol. 1, pp. 136–137; S. Duke-Elder, *The Practice of Refraction* (Mosby, St. Louis, 1969), pp. 123–131.
7. M. W. Morgan, *Am. J. Optom. Arch. Am. Acad. Optom.* **23**, 99 (1946); *ibid.* **34**, 327 (1957).
8. H. A. W. Schober, *Optik* **11**, 282 (1954).
9. For details of this technique see R. T. Hennessy and H. W. Leibowitz, *Behav. Res. Methods Instrum.* **4**, 237 (1972).
10. These subjects wore their normal corrections, if any, and no attempt was made to evaluate independently the adequacy of the individual prescriptions. Changes in individual prescriptions would not alter the correlations obtained in this study since the same corrections were worn during all phases of the experiment. They could, of course, influence the variability or magnitude of the mean dark focus.
11. H. W. Leibowitz, R. T. Hennessy, D. A. Owens, *Psychologia*, in press.
12. The resultant luminance level was within the photopic range, which eliminates the Purkinje shift as a factor.
13. In a control experiment, it was demonstrated that under full ambient daylight conditions, the mean accommodation was less than 1 diopter and with decreasing luminance systematically approached the individual subject's dark focus. Control data ruled out the dilation of the pupil as a factor. H. W. Leibowitz and D. A. Owens, *J. Opt. Soc. Am.*, in press.
14. C. A. Johnson, thesis, Pennsylvania State University (1974).
15. O. W. Richards, *Am. J. Optom. Arch. Am. Acad. Optom.* **44**, 517 (1967).
16. Supported by NIMH grant MH08061. The continuing encouragement, advice, and assistance of J. Enoch is gratefully acknowledged. We are indebted to B. Munger and J. Kobrick for their help in the preparation of the manuscript and to A. Santora for testing subjects.

21 March 1975

Prolongation of Gestation by Growth Hormone: A Confounding Factor in the Assessment of Its Prenatal Action

Abstract. *The administration of purified growth hormone to normally nourished pregnant rats prolonged gestation leading to postmaturity of the offspring. The effect explains, in part, the apparent influence of growth hormone on prenatal and early postnatal development and supports the notion that the prenatal action of exogenous growth hormone is restricted to a therapeutic one under conditions of malnutrition.*

Growth hormone (GH) administered to pregnant rats is said to enhance brain development by the time of birth (*1, 2*) or in early life (*2, 3*). Precocious behavioral development (*4*) and improvements in adult learning capability (*3–5*) are further taken to reflect the permanence of these early structural changes in the brain. However, we have been unable to demonstrate any effects of GH treatment on fetuses obtained by cesarean section near term (*6*). A resolution of this conflicting evidence may come from our observation that modern preparations of purified GH prolong the gestation period in the rat, thus raising the possibility that the apparent facilitation of development may be due to errors in estimating true postconception age when dating is made with respect to birth.

Long-Evans virgin rats (Blue Spruce Farms, Altamont, New York) were housed in a thermostatically controlled (20° to 22.5°C) room maintained on a 12-hour light-dark cycle (LD, 12 : 12) with light onset at 0800 hours. Purina laboratory chow, containing at least 23 percent protein, and water were available at all times. After 2 weeks of acclimatization, animals were mated, and insemination was verified by vaginal lavage daily (between 0900 and 1000 hours). Presence of sperm defined day 0 of pregnancy, and only females in the body-weight range 200 to 215 g on day 0 were used. On day 7 of gestation, subjects