there are no large equilibrium reservoirs of beryllium to "dampen" out effects due to rapid fluctuations in the production rate.

As has been emphasized by Somayajulu (*11*), the search for effects of the type described above necessitates an independent method of determining the accumulation rates for the reservoirs in which the ^{10}Be is measured. It also requires the analysis of a fairly large number of samples and, depending on the magnitude of the variations being sought, probably requires an accuracy of the order of 20 percent. This requirement suggests the desirability of certain modifications in our technique. Probably the most important of these would be some method of rapidly changing samples, without changing any parameters of the accelerator. Not only would such a modification permit a much shorter measurement time per sample, but it also might permit one to bypass the acceleration of the ^{9}Be completely and simply compare ^{10}Be intensities between the sample and a known standard. On the basis of our replicate determinations of the same sample, we expect that such a procedure would improve the accuracy of the measurements considerably. Fortunately, the Grenoble cyclotron is equipped with an external ion source, and it may be possible to use this ion source to solve this problem.

G. M. RAISBECK, F. YIOU
Laboratoire René Bernas
du Centre de Spectrométrie Nucléaire
et de Spectrométrie de Masse,
91406 Orsay, France
M. FRUNEAU, J. M. LOISEAUX
Institut des Sciences Nucléaires,
53 Avenue des Martyres,
38026 Grenoble, France

References and Notes

1. R. A. Muller, *Science* **196**, 489 (1977).
2. D. E. Nelson, R. G. Korteling, W. R. Stott, *ibid.* **198**, 507 (1977); C. L. Bennett, R. P. Beukens, M. R. Clover, H. E. Gove, R. B. Liebert, A. E. Litherland, K. H. Purser, W. E. Sondheim, *ibid.*, p. 508.
3. E. J. Stephenson, D. J. Clark, R. A. Gough, W. R. Holley, A. Jain, *Nucl. Instrum. Methods* **152**, 477 (1978).
4. F. Yiou and G. M. Raisbeck, *Phys. Rev. Lett.* **29**, 372 (1972).
5. F. Yiou, M. Baril, J. Dufaure de Citres, P. Fontes, E. Gradsztajn, R. Bernas, *Phys. Rev.* **166**, 968 (1968); P. Fontes, C. Perron, J. Lestringuez, F. Yiou, R. Bernas, *Nucl. Phys. A* **165**, 405 (1971).
6. The ^{10}Be was made by the ^{13}C(n,α)^{10}Be reaction [D. R. Goosman, *Nucl. Instrum. Methods* **116**, 445 (1974)] and was provided to G.M.R. and F.Y. by D. Goosman several years ago for an analysis of the ^{10}Be/^{9}Be ratio. We determined the absolute ^{10}Be concentration by isotope dilution, using a mass spectrometer (G. M. Raisbeck, J. Lestringuez, F. Yiou, unpublished results).
7. E. D. Hudson, M. L. Mallory, R. S. Lord, *IEEE Trans. Nucl. Sci.* **NS-23**, 1065 (1976).
8. G. M. Raisbeck, F. Yiou, M. Fruneau, J. M. Loiseaux, in preparation.
9. In the present experiment there was, in fact, some ambiguity in the absolute ^{10}Be/^{9}Be values. The results derived based on the use of the ^{9}Be current obtained by Rutherford scattering were within 15 percent of the normalized values given in Fig. 2, whereas those obtained based on the use of the ^{9}Be from Faraday cup measurements were lower by almost a factor of 5. Although we originally attributed this difference to an incorrectly calibrated Faraday cup, more recent experiments suggest that the low ratio may result from our procedure of using ^{20}Ne^{4+} to tune the beam line. Apparently even the small ($\sim 10^{-3}$) mass difference between ^{20}Ne^{4+} and ^{10}Be^{2+} is sufficient to affect the beam line transmission. This difficulty could be avoided if ^{10}B^{2+} instead of ^{20}Ne^{4+} were used to tune the beam line. The discrepancy between the ^{9}Be from the Rutherford scattering and from the Faraday cup would, of course, still remain unexplained. What is important to us is that the ratio of these two measurements remained constant throughout the experiment, thus giving us confidence that our relative isotope ratios are reliable.
10. S. Tanaka, T. Inoue, and M. Imamura [*Earth Planet. Sci. Lett.* **37**, 55 (1977)] have recently extended the ^{10}Be counting technique to essentially its natural limit. These workers have been able to construct a beta counter having a background of eight counts per day. Taking typical values for chemical yield (50 percent) and counter efficiency (40 percent), this corresponds to the count rate of a sample containing $\sim 3 \times 10^{10}$ atoms of ^{10}Be. For an activity equal to this background, it is necessary to count for 1 week in order to have 1-standard-deviation statistics of 20 percent. Even if the background could be eliminated completely, this limit would not change appreciably.
11. B. L. K. Somayajulu, *Geochim. Cosmochim. Acta* **41**, 909 (1977).
12. D. Lal and B. Peters, in *Handbuch der Physik*, K. Sitte, Ed. (Springer, Berlin, 1967), vol. 46/2, p. 551.
13. J. C. Higdon and R. E. Lingenfelter, *Nature (London)* **246**, 403 (1973).
14. N. J. Shackleton, *Philos. Trans. R. Soc. London Ser. B* **280**, 169 (1977).
15. S. G. Johnsen, W. Dansgaard, H. B. Clausen, C. C. Langway, Jr., *Nature (London)* **235**, 429 (1972).
16. J. A. Eddy, *Science* **192**, 1189 (1976).

29 March 1978; revised 14 June 1978

Apparent Saturation of Blue-Sensitive Cones Occurs at a Color-Opponent Stage

Abstract. *Response saturation of blue-sensitive cone pathways was studied by measuring increment thresholds for violet test flashes on flashed violet fields in the presence of a steady yellow "auxiliary" field of constant radiance. Adding intense yellow field flashes to the violet field flash could eliminate or reduce response saturation (greatly reduce threshold), whereas "negative" yellow field flashes drove the mechanism to further saturation. The response saturation is thus not, in general, controlled exclusively by independent blue-sensitive cones but by spectrally opponent mechanisms that receive opposite-signed signals from blue-sensitive cones and from green- or red-sensitive cones. These results add to a growing number of studies that demonstrate that detection of signals from blue-sensitive cones is largely through a color-opponent pathway.*

The human visual system has limited dynamic response and will saturate when sufficiently stimulated. The rod monochromat who possesses only rod photoreceptors, for example, cannot see patterns on a field more intense than about 1000 scotopic trolands (*1*) because the rod pathways saturate and therefore cannot signal intensity variations. Aguilar and Stiles (*2*) demonstrated saturation of the "rod mechanism" in normal observers with a steady red adapting field and green test flashes presented on the peripheral retina. The intensity of the test flash was measured as a function of field intensity. The resultant increment threshold curve became very steep at field intensities of ~2000 to 5000 scotopic trolands, demonstrating saturation. Electrophysiological studies on rat (*3*) and *Necturus* (*4*) show saturation of the photocurrent of rod receptors. It is thus plausible that saturation of human rod pathways occurs at a very early stage of the visual system—in the rods themselves.

Saturation of human cone pathways has also been shown by increment threshold curves obtained with a flashed test spot on a flashed field (*5*). At sufficient intensity of the flashed field, the test flash becomes invisible even when much more intense than the field. This saturation is typically not observed when the field is presented continuously; the threshold simply rises to a high level in proportion to the adapting field intensity (*6*). Mollon and Polden (*7*), however, have shown that the blue-sensitive cone pathways do saturate with steady violet adapting fields.

Our results show that the saturation of the blue-sensitive cone pathways does not, in general, occur within independently acting blue-sensitive cones. Response saturation is studied with flashed fields. According to the principle of univariance (*8*), the response of independent photoreceptors would be controlled by the rate of quantum absorption and not by the wavelength of light. Thus if the response saturation were to occur directly in such independent photoreceptors, flashes of any color would simply drive the mechanisms into further saturation. Our results are in the opposite direction: positive yellow field flashes may undo the saturation produced with violet field flashes, and negative yellow flashes may promote this saturation. This re-

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veals interactions of mechanisms, possibly cones.

Results are shown for one observer (C.F.S.); they are not shown for the other observer since they were quantitatively similar (*9*). Stimuli were seen in Maxwellian view. A violet (441.6 nm), 100-msec test flash 1° in diameter was presented foveally in the center of a yellow (575 nm, ~ 10-nm bandwidth) field 9.5° in diameter and $10^{10.85}$ quanta deg^{-2} sec^{-1} (50,000 trolands) that was presented continuously to suppress the green- and red-sensitive cone pathways and thus isolate the blue-sensitive pathways. This steady yellow field was always used. Every 6 seconds a violet field (440 nm, 15-nm bandwidth) covered the whole yellow field for 700 msec; the violet 100-msec test flash was presented 100 msec after the onset of this violet field. This timing was used throughout. The open circles in Fig. 1 show the threshold (*9*) of the violet test flash as a function of the intensity of the violet field flash. The curve ascends steeply beyond field flash intensities of about $10^{8.3}$ quanta deg^{-2} sec^{-1} (showing the saturation effect) and then becomes flat as a result of intervention of the green-sensitive mechanism. The closed circles show thresholds when a very intense yellow field flash (575 nm, ~10-nm bandwidth) of $10^{11.85}$ quanta deg^{-2} sec^{-1} is presented simultaneously with the violet field flash; this yellow flash cancels the saturation and delays its onset until much more intense violet flashed fields are used. The closed and open squares show thresholds when yellow light of $10^{11.55}$ and $10^{12.04}$ quanta deg^{-2} sec^{-1}, respectively, is added continuously to the original steady yellow field rather than being flashed with the violet field flash (*10*). These added steady yellow fields only slightly change the intensity of the violet field flash at which saturation occurs. They do raise the level at which the green-sensitive mechanism (upper, flat branch) intrudes, in good agreement with Weber's law. Clearly the flashing of the yellow field is essential to canceling the violet flash saturation.

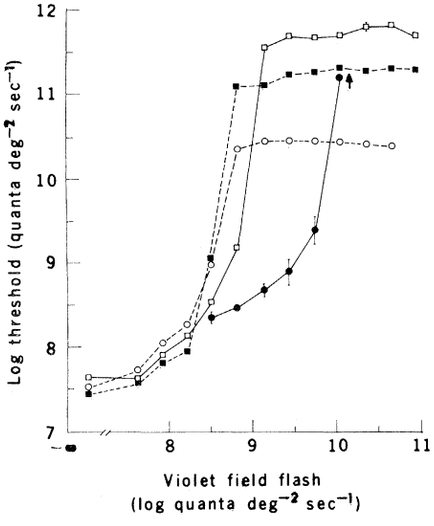

Fig. 1. Increment threshold (mean, ± 2 standard errors; error bars are not shown in Figs. 1 through 3 if they are smaller than the symbol size) for a violet (441.6 nm) test flash as a function of the intensity of a violet (440 nm) field flash. A steady yellow (575 nm) "auxiliary" field of $10^{10.85}$ quanta deg^{-2} sec^{-1} was always present. Open circles, thresholds on these fields alone. Closed circles, thresholds on these fields when a yellow field flash of $10^{11.85}$ quanta deg^{-2} sec^{-1} was presented simultaneously with the violet field flash. The arrow beside the top closed circle indicates that a test flash of this intensity was invisible. Closed and open squares indicate the thresholds when steady yellow fields of $10^{11.55}$ and $10^{12.04}$ quanta deg^{-2} sec^{-1}, respectively, were added continuously to the original steady yellow field.

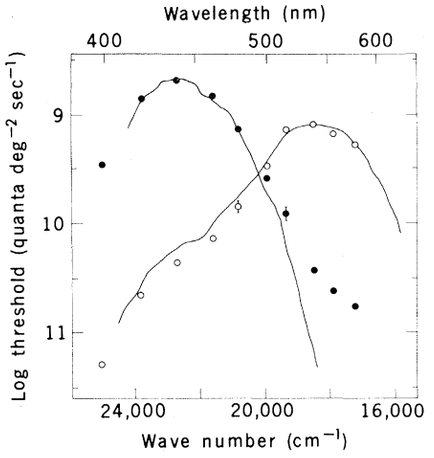

Fig. 2. Increment thresholds for test flashes of different wavelengths. Open circles, thresholds on the original steady yellow field of $10^{10.85}$ quanta deg^{-2} sec^{-1} plus violet field flash of $10^{9.40}$ quanta deg^{-2} sec^{-1}. Closed circles, thresholds on the same fields when a yellow field flash of $10^{11.85}$ quanta deg^{-2} sec^{-1} is presented simultaneously with violet field flash. Left and right curves are spectral sensitivities of Π_3 and Π_4 mechanisms of Stiles (*12*) shifted vertically.

The added yellow field flash will produce large transient responses in the red- and green-sensitive cones, whereas these cones will adapt to the steady yellow field. For the intense, steady yellow fields, a significant part of the adaptation mechanism is pigment bleaching (*11*). Presumably the strong signals in the red- and green-sensitive cones, induced by the yellow field flash, will cancel the saturation in the blue-sensitive pathways and increase their sensitivity. To demonstrate that the blue-sensitive pathways detect the test flash under the yellow field-flash condition, we measured the spectral sensitivity of the detection mechanism. Stimuli were as before, but the wavelength of the test flash was varied. The open circles in Fig. 2 show thresholds for test flashes of different wavelength (10-nm bandwidth) on the original steady yellow field plus a violet field flash of $10^{9.40}$ quanta deg^{-2} sec^{-1}, which is intense enough to saturate the blue-sensitive pathways (Fig. 1); closed circles show thresholds when a yellow field flash of $10^{11.85}$ quanta deg^{-2} sec^{-1} is added to the violet field flash. The added yellow field flash greatly increases sensitivity to blue test stimuli. The left and right curves are the spectral sensitivity functions of the blue-sensitive Π_3 and green-sensitive Π_4 mechanisms of Stiles (*12*) displaced vertically to fit the data. The intense yellow field flash greatly increases the sensitivity to short-wavelength test flashes and thereby causes a shift in the detection from the green-sensitive mechanism to the blue-sensitive mechanism.

A negative yellow field flash has the opposite effect of augmenting saturation. The steady yellow field was $10^{10.85}$ quanta deg^{-2} sec^{-1}, as before. The negative flash was produced by interposing neutral density filters in the yellow beam during the exposure of the violet field flash. The parameter beside each curve in Fig. 3 shows the size of the decrement in log units (negative sign indicates decrement). The negative yellow flashes

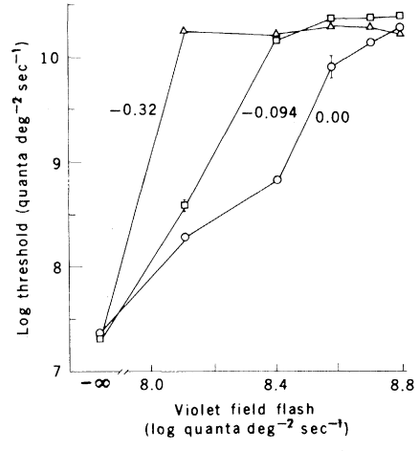

Fig. 3. Increment threshold for a violet test flash on a simultaneous positive violet field flash (abscissa) and negative yellow field flash. A negative yellow flash was produced by reducing intensity of a steady yellow field of $10^{10.85}$ quanta deg^{-2} sec^{-1}. The size of the decrement is specified in log units beside each curve (the negative sign indicates a decrement); the indicated decrements of 0.00, −0.094, and −0.32 are reductions of the radiance of the yellow field to 100, 81, and 48 percent of its original value. The abscissa has been expanded.

strongly augment the saturating effects of the positive violet flashes. The abscissa has been expanded.

The results suggest that the response saturation of the blue-sensitive pathways is largely controlled by spectrally opponent neural mechanisms that treat signals from blue-sensitive cones and those from green- or red-sensitive cones in an opposite manner (*13*). The physiological site for this opponent interaction might be the blue-sensitive cones themselves if the sensitivity of these cones is controlled by inhibitory signals originating in other classes of cones. Inhibitory interactions between different spectral classes of cones have been shown in the turtle (*14*). Our results add to the growing support of the hypothesis that the detection of signals from the blue-sensitive cones is through a color-opponent pathway (*15*).

C. F. STROMEYER III
R. E. KRONAUER, J. C. MADSEN
Division of Applied Sciences,
Harvard University,
Cambridge, Massachusetts 02138

References and Notes

1. C. B. Blakemore and W. A. H. Rushton, *J. Physiol. (London)* **181**, 612 (1965); B. Sakitt, *Science* **190**, 1318 (1975).
2. M. Aguilar and W. S. Stiles, *Opt. Acta* **1**, 59 (1954).
3. R. D. Penn and W. A. Hagins, *Biophys. J.* **12**, 1073 (1972).
4. R. A. Normann and F. S. Werblin, *J. Gen. Physiol.* **63**, 37 (1974).
5. M. Alpern, W. A. H. Rushton, S. Torii, *J. Physiol. (London)* **207**, 463 (1970); P. E. King-Smith and J. R. Webb, *Vision Res.* **14**, 421 (1974); S. K. Shevell, *ibid.* **17**, 427 (1977); D. C. Hood, T. Ilves, E. Maurer, B. Wandell, E. Buckingham, *ibid.*, in press.
6. W. S. Stiles [*An. Fis. Quim.* **57A**, 149 (1961)] showed that the increment threshold function for a 578-nm test flash on a 578-nm field followed Weber's law up to the highest field level used, $10^{5.7}$ trolands.
7. J. D. Mollon and P. G. Polden, *Nature (London)* **265**, 243 (1977).
8. K. I. Naka and W. A. H. Rushton, *J. Physiol. (London)* **185**, 536 (1966).
9. Thresholds were determined by the method of adjustment. The essential difference between results for observer C.F.S. and the other observer (J.C.M.) was that the blue-sensitive pathways of the latter saturated at violet field intensities 0.3 to 0.4 log unit lower than was required for C.F.S. This is probably because J.C.M. has considerably less macular pigment than C.F.S. (as shown by psychophysical measurements) and thus more violet light incident at the cornea reaches the receptors. The difference of macular pigmentation quantitatively accounts for the difference in the data for the two observers.
10. The steady and flashed added yellow fields are approximately the same in intensity but not identical, as the measurements were made in different experiments for purposes other than those explicitly shown here.
11. W. A. H. Rushton and G. H. Henry, *Vision Res.* **8**, 617 (1968).
12. The spectral curves shown are field sensitivities for II mechanisms [W. S. Stiles, *Coloq. Probl. Opt. Vision (Madrid)* **1**, 65 (1953); tabulated in G. Wyszecki and W. S. Stiles, *Color Science: Concepts and Methods, Quantitative Data and Formulas* (Wiley, New York, 1967)].
13. The hypothesis that the saturation is partly controlled by spectrally opponent mechanisms is also supported by several observations. J. D. Mollon and P. G. Polden (paper presented at the meeting of the Association for Research in Vision and Ophthalmology, Sarasota, Fla., 25 to 29 April 1977) observed that the increment threshold curve for a parafoveal violet (420 nm) flash on a steady blue (473 nm) field ascends slightly faster than Weber's law, thus showing partial saturation. The threshold on this steep branch could be lowered as much as 0.4 log unit by adding intense yellow light to the steady blue field to make the mixture field appear white. Both we and Mollon and Polden (paper presented to the 20th Tagung experimentell arbeitender Psychologen, Marburg, Germany, 20 to 22 March 1978) also observed that the threshold for a violet flash on a steady field composed of intense yellow light and violet light of sufficient intensity to induce saturation of the blue pathways is lowest when the fields are first viewed, and the threshold rises considerably within 30 seconds thereafter.
14. M. G. F. Fuortes, E. A. Schwartz, E. J. Simon, *J. Physiol. (London)* **234**, 199 (1973).
15. J. D. Mollon and P. G. Polden, *Philos. Trans. R. Soc. London Ser. B* **278**, 207 (1977); E. J. Augenstein and E. N. Pugh, Jr., *J. Physiol. (London)* **272**, 247 (1977).
16. Supported by NIH grant 5-R01-EY-01808-02. We thank Dr. J. D. Mollon for comments on the manuscript.

30 March 1978; revised 21 June 1978

Physiologically Important Stabilization of DNA by a Prokaryotic Histone-like Protein

Abstract. *The thermophilic mycoplasma* Thermoplasma acidophilum *has tightly bound to its DNA a protein that closely resembles the histones of eukaryotes. DNA associated with this protein is more stable than free DNA against thermal denaturation by about 40°C, as shown in both native nucleoprotein and in hybrid nucleoprotein reconstituted in vitro with calf DNA. Since only about 20 percent of the DNA in this organism is associated with the histone-like protein, we suggest that its physiological function is to prevent complete separation of the DNA strands during brief exposures of the organism to denaturing conditions, and thus to facilitate rapid renaturation when normal environmental conditions return.*

Thermoplasma acidophilum is a nonparasitic mycoplasma that grows in extreme conditions of heat and acidity, its optimal culture conditions being 59°C and *p*H 1.0 to 2.0 (*1*). It was discovered in a spontaneously burning refuse pile, its only known natural environment (*2*).

This organism has associated with its DNA a basic protein that closely resembles eukaryotic histones (*3*). The protein is acid-soluble with a strong net positive charge at neutral *p*H and is small, composed of 89 amino acid residues of which 14 are lysine and 6 are arginine. Neither tryptophan, methionine, nor cysteine is present (*4*). The electrophoretic mobility of the protein in various conditions is similar to that of histone 4 of calf thymus. The protein is tightly bound to DNA in salt concentrations up to about 0.6*M*, which is well above the physiological range (*5*), and reconstituted nucleoprotein is relatively insoluble in 0.1 to 0.2*M* NaCl. Both native nucleoprotein and reconstituted protein–DNA complexes are partly protected from digestion by micrococcal nuclease. Also, DNA fully complexed with this protein is inactive as a template for *Escherichia coli* RNA polymerase. We now report that the protein strongly stabilizes DNA against thermal denaturation. Thus, although this protein shares several characteristics with eukaryotic histones, it does not appear to be closely homologous to any particular class of histone (*3*).

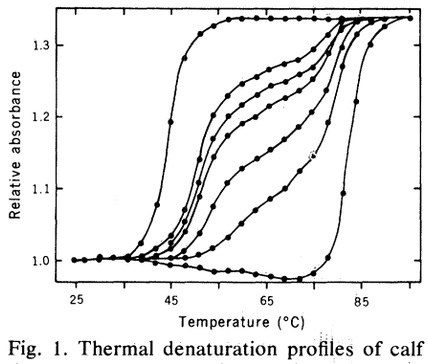

Fig. 1. Thermal denaturation profiles of calf thymus DNA reassociated with increasing amounts of the *T. acidophilum* histone-like protein. The ratio of protein to DNA by weight was (left to right) 0, 0.61, 0.80, 0.97, 1.34, 1.82, and 2.43. The hyperchromicity decreased from 1.34 to 1.29 as the protein content was increased, but in this figure has been normalized to a constant value. The DNA-protein mixtures were reconstituted by gradient dialysis (*9*) and then exhaustively dialyzed against 0.25 m*M* sodium ethylenediaminetetraacetate (EDTA), *p*H 8.0 (*7*). The samples were diluted to an absorbance at 260 nm (A_{260}) of 0.5, degassed, and centrifuged before thermal denaturation. The A_{260} was continuously recorded with a Gilford spectrophotometer as the temperature was raised 0.5 C per minute. Protein was assayed (*17*) with purified histone-like protein as a standard.

Eukaryotic histones stabilize DNA against thermal denaturation, especially under the conditions of low ionic strength that must be used in vitro to prevent precipitation (*6*). Since *T. acidophilum* exists in a high-temperature environment and has an unusually low intracellular ion concentration (*7*), one possible function of the histone-like protein might be to protect the DNA from thermal denaturation.

The protein and the purified calf

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