extraction of the remaining nucleic acids was completed with normal perchloric acid at 70°C. Of the total amount of recovered radioactivity, 11 percent was present in the alcohol extract, and a negligible amount in the ether fraction. In the respective samples, ribonuclease digestion released 76 percent, and the water extraction, 32 percent, the balance in each case being located in the perchloric acid extract. This result suggests that the bulk of the radioactivity bound in these leaves was present in the ribonucleic acid fraction.

Various analogues of naturally occurring purines and pyrimidines have recently been shown to have inhibitory effects on development and cellular differentiation in higher plants. Thus 5-fluorouracil partly annuls the effects of short-day induction in *Xanthium pennsylvanicum* (*2*), and 2-thiouracil similarly blocks flowering in *Streptocarpus wendlandii* (*3*). A remarkable case of the blockage of a developmental step on a cellular level has been reported for *Dryopteris erythrosa* (*4*), in which the transition from one- to two-dimensional growth in the gametophyte is blocked by 8-azaguanine. In all these cases, the implication is that the analogue functions by interfering with nucleic acid metabolism.

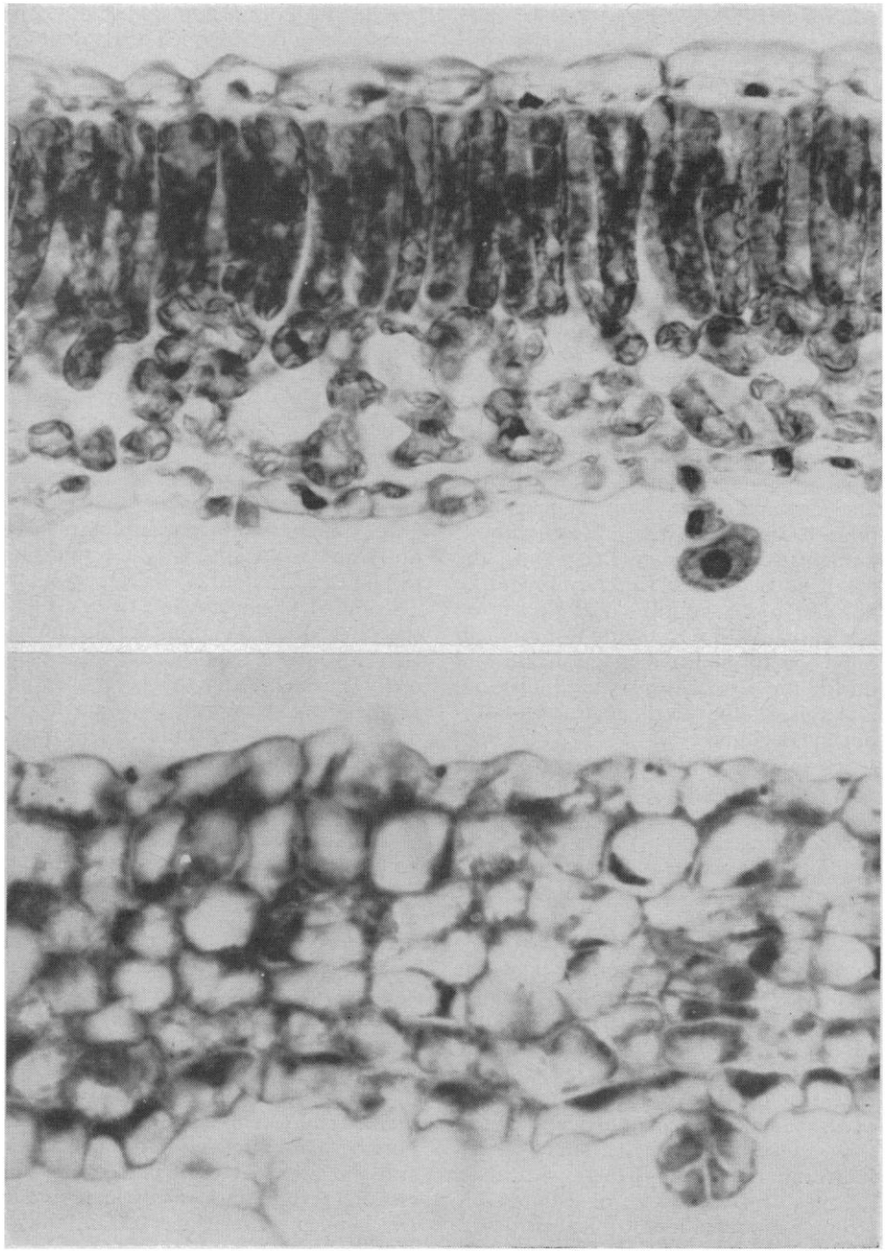

Fig. 1. (Top), Transverse section of the lamina of a normal hemp leaf, showing the characteristic differentiation of the mesophyll tissues. (Bottom), Section of a leaf of hemp developed in the presence of 2-thiouracil. The lamina is composed of a plate of undifferentiated parenchyma (about × 820).

Salisbury and Bonner (*2*) suggest that, in the inhibition of flowering in *Xanthium*, 5-fluorouracil affects the synthesis or effectiveness of the products of the inductive dark period. However, it seems to me that the response is more likely to be due to a loss of capacity of apical meristematic tissues to react to leaf-generated stimuli. Viewed in terms of gene action, it may well be that the loci, quiescent during vegetative growth, which are activated following photoperiodic induction, are unable to produce their characteristic proteins in the presence of factors modifying intermediate stages of ribonucleic acid synthesis, so that the new developmental pathway, namely flowering, cannot be entered. The concomitant effects of 2-thiouracil on cellular differentiation described above could be taken to support such a hypothesis (*5*).

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15 August 1960

Learned Behavior of Rhesus Monkeys following Neonatal Bilateral Prefrontal Lobotomy

Abstract. Bilateral ablation of dorsolateral frontal cortex in the newborn animal failed to produce the frontal lobe syndrome typical of the adolescent and adult stages. The crucial tests (delayed response, string tests, and discrimination learning) were performed 3 to 4 months postoperatively. At this time, no significant differences between normal animals and animals with prefrontal lesions were found.

The classical work of Jacobsen (*1*) demonstrated that adolescent and adult rhesus monkeys with bilateral lesions in the prefrontal areas show a severe deficit on the delayed-response problem and no appreciable loss in discrimination learning. This finding has been confirmed by many independent investigators, including Harlow *et al.* (*2*) and Pribram *et al.* (*3*). Furthermore, research workers in the area agree that there is no spontaneous remission of this syndrome with time. Recent researches reported by Harlow (*4*) demonstrate that the solution of delayed response by monkeys is a function of age and that this capability appears at about 125 days. The purpose of the study re-

ported here was to determine the effect of bilateral prefrontal lesions produced at an early age on learning performance, especially delayed response.

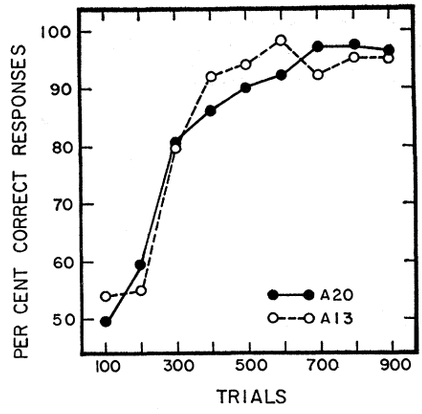
Two 5-day-old rhesus monkeys, Nos. A-13 and A-20, were subjected to bilateral ablation of the dorsolateral prefrontal areas, with complete aspiration of the cortex of the sulcus principalis. Areas 6 and 8 were spared, so that the lesions would be identical to those in the study of French (*5*). The surgery was performed under general anesthesia, from a mixture of ether and oxygen. These animals were then adapted to the Wisconsin general test apparatus, and formal testing began at 132 and 164 days of age for A-20 and A-13, respectively.

The test battery replicated the early learning tests described by Harlow (*4*) and consisted of a single discrimination problem run at the rate of 25 trials a day for 20 days, a battery of delayed-response problems (0- and 5-second delay intervals) presented at the rate of ten trials per day on each problem for 90 days, and a series of two patterned-strings tests, each of which was presented at the rate of 20 trials per day for 20 days. The parallel pattern was presented first for 20 days and was followed by presentation of the two-crossing-strings pattern for the same length of time. All three types of problems of this basic battery of tests were run concurrently until completion. After the basic delayed-response testing, the subjects were given 60 days' additional testing on a battery of delayed response tests (5-, 10-, 20-, and 40-second delay intervals) at a rate of eight trials per day for each delay interval. Upon completion of the single discrimination problem the monkeys were trained on a discrimination learning set, with a series of 600 discrimination problems, each six trials in length, presented at the rate of four problems per day.

On the discrimination problems the two monkeys attained the criterion of ten successive correct responses after zero errors and one error, respectively. These scores are superior to those of 15 normal control monkeys of comparable age, which averaged seven errors, and the scores doubtless reflect chance preferences for the correct stimulus. Discrimination learning loss, of course, was not expected.

Subjects A-13 and A-20 made 88 percent and 95 percent correct responses during the first 100 trials on the parallel-strings test and solved the two-crossing-strings pattern after 452 and 421 trials, respectively. These scores are all well within the "normal" range, as expected.

As is shown in Fig. 1, delayed-response learning was efficient and rapid, and a level of 90 percent correct responses was attained within 500 trials.



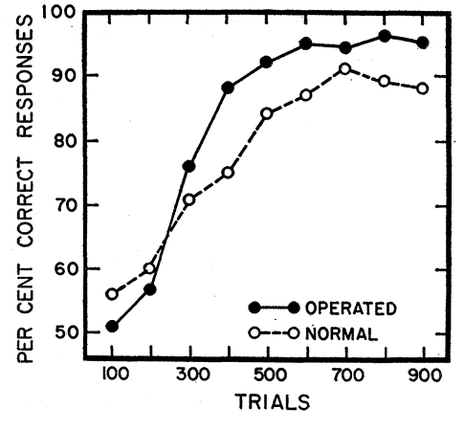
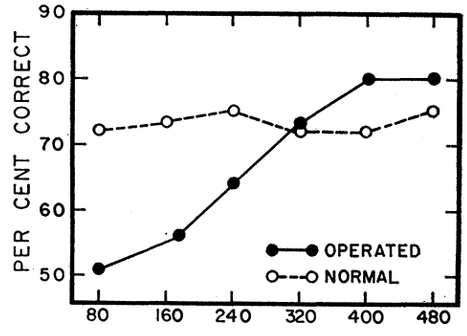


Fig. 1 (left). Individual performance curves on 5-second delayed response. Fig. 2 (right). Comparison of the performance of experimental and normal monkeys of the same age on 5-second delayed response.



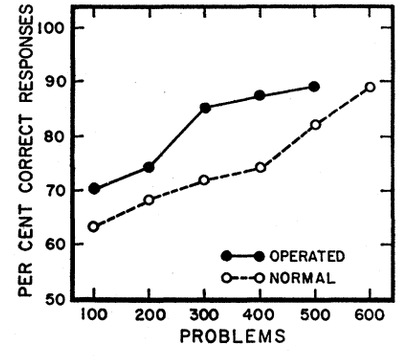


Fig. 3 (left). Comparison of the performance of experimental and normal monkeys of the same age on 40-second delayed response. Fig. 4 (right). Comparison of the performance of experimental and normal monkeys on trials Nos. 2 through 6 of a series of 600 discrimination problems.

If one compares these data with those for 15 normal monkeys tested at equivalent ages (Fig. 2), it may be seen that the performances of the two groups do not differ significantly. Actually, in absolute terms, the scores of the monkeys with prefrontal lesions were slightly superior on the subsequent delayed-response test battery, as illustrated in Fig. 3, for the 40-second delay interval. The test animals were inferior in terms of their early performance but not in terms of their terminal performance. These data may indicate some residual decrement not disclosed in the basic test battery. However, the important finding is the normal or near-normal delayed-response performance of these monkeys with neonatally induced lesions.

The performance of the experimental monkeys and of 15 control subjects on discrimination learning sets is given in Fig. 4. Although the experimental monkeys are superior to the mean of the controls, their scores do not lie outside the normal range. Loss of learning-set ability was not predicted.

The primary importance of this research is the demonstration of a degree of sparing, beyond that predicted, of delayed-response capability following neonatally induced bilateral prefrontal lesions. Indeed, there is no definitive evidence that any learning deficit resulted. These data on delayed response and other intellectual sparing are in keeping with recovery of motor functions, as previously demonstrated by Kennard (*6*), and sparing of somatic sensory functions, as reported by Benjamin and Thompson (*7*).

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