

Since the ratio of S-[<sup>14</sup>C]ABA to M-2 is constant between the fifth and twelfth hour, the latter compound would be a good candidate for such a role. However, purified M-2, obtained from axes fed RS-[<sup>14</sup>C]ABA, although taken up by the tissues did not change the growth inhibition by RS-ABA when added to axes at six times the concentration of RS-ABA (10).

Participation of a racemase has not been ruled out. However, the fact that ABA asymmetry affects growth inhibition and metabolism to different extents decreases the probability that racemization is involved.

From our results it is seen that, depending on the assay system, either the overall effectiveness of the two ABA enantiomorphs is the same, or the R isomer is less active. Up to now the largest physiological differences were in the inhibition of root-related growth phenomena. It can also be concluded that certain other structural features, such as a *trans*, *trans* side chain (1), the absence of a free carboxylic acid or a 4'-keto group (12), are more deactivating than a change from the S configuration. We conclude that at the degree of resolution achieved here, a change in asymmetry has a more pronounced effect on the metabolic than on the hormonal reactivity of ABA.

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tions of the binocular portion of the visual field are in register, and the lines of projection thus pass perpendicular to the laminae (Fig. 1). In this way, the parts of the nucleus that receive afferents from homonymous points of the two retinae lie adjacent to each other, and significant binocular interaction can occur within the nucleus (4).

One might expect that in any species with binocular overlap and a laminated lateral geniculate nucleus the lines of projection would pass perpendicular to the laminae. Any other arrangement would suggest a patchy representation of the visual field in the nucleus and could not easily produce the known orderly representation of the visual field upon the cerebral cortex (5). However, as shown in Fig. 2, there is some evidence that in rats and rabbits the terminations of ipsilateral retinogeniculate axons form laminae parallel to the lines of projection. This is a puzzling situation. It appears to suggest either that some of the original observations are wrong or that the central visual pathways in these two species are arranged in an unusual and at present quite incomprehensible manner. The evidence summarized below suggests a third interpretation.

Lund (6) and Giolli and Guthrie (7) have shown that certain strains of albino rats and rabbits have significantly fewer ipsilateral retinogeniculate axons than do other, normally pigmented strains. However, the manner in which the reduced ipsilateral projection is organized has not been determined, so that it is not known whether the line of decussation lies further temporally in the retina or whether the reduction is produced in some other way. Siamese cats also have a reduced ipsilateral projection (8) and the pattern of this projection has been determined (2). In these cats there is a patch in the middle of the temporal hemiretina, and ganglion cells within this patch send their axons contralaterally instead of ipsilaterally as in normal cats. As a result of this chiasmatic misrouting of a limited group of axons, the laminae that receive an ipsilateral input are disrupted, and one sees discontinuous ipsilateral terminal zones in the place of a single continuous, normal lamina (Fig. 3).

We suggest that the reduced ipsilateral projection seen in some rats and rabbits is produced exactly as in

## Mutants with Abnormal Visual Pathways: An Explanation of Anomalous Geniculate Laminae

**Abstract.** *Rats with geniculate laminae that run perpendicular to the lines of projection are described. Earlier reports of laminae parallel to the lines of projection were based on mammalian mutants that may be relatively common. In these mutants, the chiasmatic course of axons arising in a patch of retinal ganglion cells is wrongly specified.*

The dorsal lateral geniculate nucleus in mammals receives an orderly projection from the retina (1, 2) and this projection is organized so that single points in the visual field can be represented as lines, the "lines of projection" (3), which pass more or less parallel to each other through the nucleus. In

species that have a well-defined binocular part of the visual field, such as cat or macaque, the lateral geniculate nucleus is laminated and one set of laminae receives afferents from the ipsilateral eye, the other from the contralateral eye (1, 2). The laminae are arranged so that the two representa-

the Siamese cats. That is, a patch of the normally ipsilateral lamina is innervated by the contralateral eye, and the ipsilateral axon degeneration that follows removal of one eye consequently forms the discontinuous patches shown by Hayhow *et al.* (9), by Giolli and Guthrie (7), and in Fig. 2. If the ipsilateral "laminae" shown in Fig. 2 are formed in this way, then the orientation of the normal, complete lamina would be in the expected plane, roughly perpendicular to the lines of projection.

We have studied five rats of the C-line (10) strain and four albino rats (Holtzman). One retina from

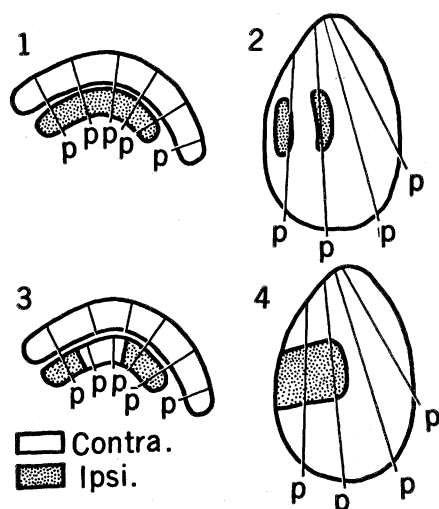


Fig. 1. Schematic representation of the dorsal lateral geniculate nucleus in mammals with a large binocular visual field. The ipsilateral (Ipsi.) and contralateral (Contra.) retinogeniculate axons end in distinct laminae, and these are aligned so that the lines of projection (P), which represent single points in the visual field, pass roughly perpendicular to the laminae. Only one pair of laminae is shown. Fig. 2. Composite diagram showing the ipsilateral "laminae" demonstrated by Hayhow *et al.* (9) and by Giolli and Guthrie (7) and the lines of projection (P) in rat and rabbit as they would appear in a horizontal section. The lines of projection are defined directly by the work of Montero *et al.* (15), who used electrophysiological recording methods, and indirectly by Rose and Malis (16), Lashley (17), and Montero and Guillery (18), who studied the segments of retrograde degeneration that occur after small lesions of the visual cortex. The borders of these segments must run along the lines of projection, since there is an ordered representation of the visual field upon the cerebral cortex (5). Fig. 3. Diagram showing the abnormal structure of the lateral geniculate nucleus in a Siamese cat (2). A part of the ventral lamina receives contralateral afferents instead of ipsilateral afferents as in a normal animal. Fig. 4. Diagram showing the single ipsilateral lamina found in rats of the C-line strain in the present study.

each rat was removed under ether anesthesia and with aseptic precautions. After survival periods of 4, 7, or 11 days, the animals were perfused with formol-saline, and frozen sections were stained by the Nauta-Gygax (11) or Fink-Heimer (12) methods. In each of the C-line animals the ipsilateral projection formed a single relatively large zone of degeneration in the medial parts of the nucleus (Fig. 4). This zone included the "laminae" described by Hayhow *et al.* (9) and also included the area between them. In the albino rats the pattern of the degeneration was rather variable, but they all showed patches of degeneration oriented like Hayhow's laminae.

We conclude that there are rats in which a single ipsilateral lamina can be defined and that this lamina has approximately the orientation that theoretical considerations would predict. Creel (13) has recently pointed out that Siamese cats, which carry an albinic allele, resemble albino rats and rabbits in having a reduced ipsilateral pathway. Our results suggest that for the cat and rat the resemblance goes further. The ipsilateral laminae are disrupted in the same manner, and it appears that in the albino rat, as in the Siamese cat, ganglion cell axons from a limited patch of retina are wrongly specified for the chiasmatic part of their course. It remains to be determined whether a single lamina can also be defined in some rabbits. Giolli and Guthrie (7) reported no difference in laminar structure between the albino and pigmented rabbits that they used. Further observations are necessary to show whether the abnormality can occur in nonalbino varieties and also whether albino varieties of other species have a similar abnormality (14).

The observations that are available are of interest because they suggest that a misrouting of retinogeniculate axons may occur relatively commonly in mammals, perhaps including man, and because the abnormality can be expected to produce strabismus whenever it interferes with binocular fusion over a significant portion of the visual field. Further, if the abnormality occurs in several mammalian lines, one has a useful choice of experimental animals for studies of these interesting visual mutants. Development and inheritance may, initially, be easier to investigate in small mammals, while

the neural interconnections are more readily studied in animals such as the cat. Finally, it may prove that a single allelic series that plays a relatively well defined role in the control of coat color is also concerned in the specification of some central axonal pathways. Since the retinal ganglion cells that are wrongly specified lie in an easily identified part of the retina, this abnormality may prove useful for study of genetic controls of axonal growth.

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