Synaptic Lamellae of the Photoreceptors of
Pearl and Wild-Type Mice

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The retina of the pearl mutant mouse, C57BL/6J pe/pe, exhibits reduced light sensitivity in the dark-adapted condition (Balkema and Pinto, J Neurophysiol 48:968, 1982). The authors searched for an anatomic correlate in the retina which could relate to the functional deficit. Electron microscopic mosaics of the outer plexiform layer of light- and dark-adapted pearl and wild-type mice were analyzed. The numerical density and length of the photoreceptor synaptic lamellae showed these parameters to be indistinguishable in wild-type and pearl retinas under conditions of both light- and dark-adaptation. Light-adapted pearl retinas exhibited some rod spherules that contained structurally modified synaptic lamellae with bulbous thickenings and adjacent electron-dense bodies. These lamellar modifications were neither apparent in the light-adapted, wild-type retinas, nor in the dark-adapted retinas of either genotype. Pronase application to ultrathin sections hydrolyzed synaptic lamellae, bulbous thickenings and electron dense bodies. Invest Ophthalmol Vis Sci 26:992-1001, 1985

The retina of the mutant mouse pearl (C57BL/6J pe/pe) exhibits reduced light sensitivity in the dark-adapted condition. Light-microscopic examination of the retinas from pearl and wild-type mice revealed no differences in the layering of the retina, density of the cells, or morphology of cells comprising the neural retina. We have, therefore, searched for an anatomic correlate of the reduced light sensitivity of the mutant mouse pearl using electron microscopy. In this study, we have focused on the outer plexiform layer (OPL) of light- and dark-adapted retinas from pearl and wild-type mice.

Initial examination of the OPLs showed the rod and cone terminals to be comparable in pearl and wild-type mice, except for one modification. Some of the synaptic lamellae in the rod spherules of pearl terminated in bulbous thickenings or swellings. In contrast, the synaptic lamellae of the wild-type rod spherules did not exhibit this alteration of lamellar structure. This initial finding prompted a more detailed and quantitative comparison of the synaptic lamellae of pearl and wild-type retinas, which is the topic of this study.

Materials and Methods

Experimental Animals

The mice used in these experiments were of the C57BL/6J inbred strain. Wild-type mice (C57BL/6J +/+ ) were compared with cogenic pearl mice (C57BL/6J pe/pe). Electron microscopic mosaics of the outer plexiform layer of 12 light-adapted (7 +/+ ; 5 pe/pe) and eight dark-adapted (3 +/+ ; 5 pe/pe) mice were examined for the number and anatomic characteristics of synaptic lamellae. Mice were kept in a standard laboratory environment under a 12-hr light/12-hr dark cycle with the light period beginning at 0700. All perfusions were carried out between 1100 and 1500, a range of time when known circadian effects are minimal. The mice were from 4 to 9 mo of age. All procedures involving mice were performed in concordance with the ARVO Resolution on the Use of Animals in Research.

Morphologic Preparation

Light-adapted retinas were fixed in situ according to techniques described by LaVail and Battelle.3 Mice were anesthetized with ether and perfused with half-strength Karnovsky's fixative for 10 min, after which time the corneas were slit and the severed heads stored for 20 hr in fixature at 4°C. The eyes were removed, bisected along the vertical meridian, and postfixed with agitation in 2% osmium tetroxide in 0.1 M phosphate buffer, pH 7.4, containing 5% sucrose, for 30 min at 20°C and 30 min at 0°C. Retinas were stained en bloc in 2% uranyl acetate in 0.05 M
maleate buffer at 0°C prior to dehydration in ethanol and propylene oxide. The hemiretinas were embedded in a mixture of epon and araldite.

To study the effects of illumination in the isolated retina of the pearl mutant, the retina from one of the eyes of a dark-adapted pearl mouse was removed and placed in a perfusion chamber filled with Ringer's solution that was equilibrated with 95% O₂ and 5% CO₂ at 37°C. The Ringer's solution also contained 5% fetal calf serum (Dr. Ramon Dacheaux suggested adding the calf serum in order to maintain the structural integrity of the isolated retina). The preparatory manipulations were carried out under infrared illumination. Then the retina was illuminated for 30 min with fluorescent light of the same luminance as existed during the in situ illumination experiments. Following illumination, the retina was placed in fixative and prepared for examination in the electron microscope as described above.

To study the effects of dark adaptation, two groups of mice were used. Retinas were obtained from one group of mice (2+/+; 3 pe/pe) placed into a darkened room at 0800 for 3–4.5 hr prior to perfusion with fixative. The other group of mice (1+/+; 2 pe/pe) were kept in the dark for 18–19.5 hr, from 1900 the previous evening until 1330 to 1415 the next day, at which time they were perfused. The heads of the dark-adapted animals were covered with a black cloth during the perfusion. Illumination was obtained from a 25 watt light covered with a long wavelength filter which provided incident light of wavelength >850 nm. Two television cameras equipped with videcons that have sensitivity to infrared illumination (RCA 4332 A/U, RCA; Lancaster, PA), allowed the dissection and perfusion to be viewed at full size and at a magnification of about three times as measured at the screen of the monitor. The monitors were shielded from the work area and were covered with red (λ > 630 nm) filters. Manipulations immediately following the dark perfusions were also performed under long wavelength (λ > 630 nm) illumination. Severed heads were kept in the fixative in the dark overnight, after which time the retinas were processed in the same manner as the light-adapted retinas fixed in situ.

Sections of retinas were taken in a plane parallel to the vertical meridian, medial, or lateral to the optic nerve. Sections 1-μm thick were stained with 1% toluidine blue for light microscopic examination. Ultrathin sections, 80–100 nm thick, were sequentially stained in alcoholic uranyl acetate and lead citrate prior to examination in a Philips 300 electron microscope (N.V. Philips GloeilampenFabrieken; Eindhoven, The Netherlands).

Quantification of Synaptic Lamellae

Mosaics of cross-sectional areas of 1645–6637 μm² of the outer plexiform layer of the posterior retina, covering areas approximately 250–750 μm from the optic nerve, were photographed at a magnification of 10,000. Magnification was calibrated after each photography session using a grating replica (Fullam No. 1002, Ernest F. Fullham; Latham, NY). Quantitative analysis was performed upon coded mosaics, printed at a magnification of 27,000. Synaptic lamellae were identified and the lengths of their profiles were measured on the mosaics. Counts of synaptic lamellae and dense bodies were corrected for section thickness by the Abercrombie correction. We rejected the use of a correction for tangential (noncentered) sections (see Coupland) through the synaptic lamellae for two reasons: (1) the distribution of lamellar sizes was not significantly different for wild-type and pearl mutant and, thus, the populations can be compared without correction (Fig. 5); and (2) the lamella shape differs from a sphere and, thus, no simple function can be used to predict corrected size distributions. The analysis provided the following information: (1) the numerical density of lamellae, ie, the number of synaptic lamellae per unit volume (1000 μm³) of outer plexiform layer; and (2) the distribution of the lamellar sizes. The above information was obtained both for lamellae with and without attached bulbous thickenings.

Enzymatic Digestion

In order to hydrolyze synaptic lamellae from thin sections of embedded retinas, procedures of Monneron and Bernhard and Bunt were utilized. Ultrathin sections were collected on copper grids coated with Formvar (Ernest F. Fullham). The grids were floated on a solution of 5% hydrogen peroxide for 15 min at room temperature, rinsed with distilled water, and subsequently floated on an aqueous solution of 0.5% pronase (Streptomyces griseus protease, Calbiochem-Behring; Los Angeles, CA) at pH 7.4 for 90 min at 37°C. Control sections were oxidized with hydrogen peroxide for 15 min, rinsed, and incubated for 90 min at 37°C in distilled water brought to pH 7.4 with dilute sodium hydroxide. After rinsing, all grids were stained as described above.

Results

Light-Adapted Retinas

Survey electron micrographs of the outer plexiform layer of light-adapted retinas fixed in situ revealed morphologically similar photoreceptor terminals and
Fig. 1. Survey electron micrographs of the outer plexiform layer (OPL) from pearl (A) and wild-type (B) retinas. The outer layer of the OPL is comprised of many rod spherules (RS) and a few cone pedicles. In both animals, rod synaptic terminals are flanked by invaginating postsynaptic processes (arrowheads) (bar = 1 μm; ×12,400).
postsynaptic processes in wild-type and pearl retinas (Fig. 1). However, at somewhat higher magnification, a portion of the synaptic lamellae of rod terminals in the pearl retinas exhibited distinct bulbous thickenings at the end distal to the arcuate density (Fig. 2).

In addition to the thickenings of rod lamellae, round, electron-dense bodies were observed in rod terminals of the light-adapted pearl retinas at an uncorrected numerical density that was 10 times greater than the density of similar dense bodies in the rod terminals of wild-type (ie, for pearl, 37 dense bodies observed in 5885 μm² of OPL; for wild-type, 4 dense bodies observed in 6637 μm² of OPL). In the individual sections from which the mosaics were photographed, the electron-dense bodies were interpreted as individual entities separate from the synaptic lamellae, since they were found at distances of 0.05–0.5 μm from the lamellae. In a few cases, the bodies were found in sections of rod spherules which did not include lamellae. In order to determine whether the dense bodies were actually attached to the lamellae, serial sections of pearl retinas were examined. Serial sections through 27 rod terminals that displayed synaptic lamellae showed five of the terminals to contain from one to three round, electron-dense bodies. Of the total of 12 bodies observed, the individual sections showed two attached to synaptic lamellae and 10 not attached. In the latter group, four of the bodies also would have appeared as attached if the plane of the sections were altered. Therefore, the round, dense bodies were either continuous with a lamella (Fig. 3) or unattached to a lamella. The dense bodies lacked a limiting membrane irrespective of their position within the rod terminal, ie, adjacent or distal to the synaptic cleft (Fig. 4). Reconstructions of individual dense bodies from as many as three serial sections demonstrated them to be cylinders of approximately 0.25–0.35 μm length and 0.10–0.15 μm diameter.

In the pearl mutant, the numerical density of the lamellar thickenings and adjacent dense bodies was 13.5% of the numerical density of the synaptic lamellae, while in the wild-type, the numerical density of the thickenings and adjacent dense bodies was only 1.0% of the numerical density of the synaptic lamellae (a total of 1136 lamellae were measured, see Table 1). However, the numerical density of the synaptic lamellae did not differ between mutant and wild-type. The mean diameter of the lamellar thickenings and dense bodies was 0.12 μm (±0.04 SE). These modifications of lamellar structure were not observed in cone terminals.

In light-adapted retinas, the outer plexiform layer of the pearl mutant exhibited a numerical density of synaptic lamellae (260 ± 17 SE per 1000 μm³) indistinguishable from that of the wild-type retinas (240 ± 19 SE per 1000 μm³, Table 2). The distribution of the lengths of synaptic lamellar profiles was also similar in both genotypes (Fig. 5).

Photoreceptor synaptic lamellae are susceptible to treatment with proteolytic enzymes. We tested the susceptibility of the bulbous thickenings and electron-dense bodies to proteolytic digestion to determine if the lamellae and adjacent electron-dense structures have a protein component. Alternate sections of a sequence of serial sections were treated with the proteolytic enzyme pronase. Such treatment hydrolyzed normal-appearing synaptic lamellae as well as those that exhibited thickenings or swellings upon their terminals. The unattached electron-dense bodies...
Fig. 3. Electron micrographs of serial sections of the pearlf, light-adapted retina. One rod spherule contains two electron-dense bodies (B). One of the bodies (arrow in B) is contiguous with the synaptic lamella. The other body (empty arrow, B-D) appears unattached to the lamella although a rotation of the plane of section would perhaps reveal an attachment. No electron-dense spheres are associated with the synaptic lamella (sl) in the adjacent rod terminal (A-F) (bar = 1 μm; ×18,000).
were also enzymatically extracted, whereas all other structural elements of the rod terminals remained intact (Fig. 6B). The alternate sections that were not treated with pronase in the sequence of serial sections enabled the positive identification of the structures which were extracted (Figs. 6A, C). No lamellae, dense bodies, or other structures were extracted following the necessary prerequisites for effective hydrolysis: hydrogen peroxide pretreatment and subsequent incubation in distilled water.

**Table 1. Synaptic lamellae with bulbous thickenings and adjacent dense bodies**

<table>
<thead>
<tr>
<th></th>
<th>Light-adapted retinas</th>
<th>Dark-adapted retinas</th>
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<tbody>
<tr>
<td>C57BL/6J +/+</td>
<td>601</td>
<td>535</td>
</tr>
<tr>
<td>C57BL/6J pe/pe</td>
<td>535</td>
<td>72</td>
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<td></td>
<td>6 (1.0%)</td>
<td>72 (13.5%)</td>
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* Corrected for section thickness.

**Table 2. Numerical density of synaptic lamellae**

<table>
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<tr>
<th></th>
<th>Light-adapted retinas</th>
<th>Dark-adapted retinas</th>
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<tbody>
<tr>
<td>C57BL/6J +/+</td>
<td>240 ± 19 SEM</td>
<td>250 ± 25 SEM</td>
</tr>
<tr>
<td>C57BL/6J pe/pe</td>
<td>260 ± 17 SEM</td>
<td>220 ± 21 SEM</td>
</tr>
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Mean number of synaptic lamella/1000 μm²

Numerical density of synaptic lamella from light- and dark-adapted retinas of wild-type (+/+ ) and pearl (pe/pe) mice. No significant difference is apparent between the groups.

The lamellar modifications observed in *pearl* photoreceptors occurred in light-adapted eyes fixed in situ. However, in the *pearl* mutant, the sensitivity of the retinal ganglion cells is reduced only in the intact, anesthetized mouse, but not in the isolated, superfused retina from which the pigment epithelium is removed. For this reason we also examined photoreceptor synaptic lamellae in one isolated, light-adapted retina of the *pearl* mutant. The use of fetal calf serum in the superfusate provided excellent preservation of the retina. Examination of 152 synaptic lamellae from the isolated retina showed only two lamellar modifications: one lamella with a bulbous thickening, and...
percent occurrence observed in the wild-type retina fixed in situ.

Dark-Adapted Retinas

In dark-adapted retinas fixed in situ, the numerical density of synaptic lamellae of the outer plexiform layer of the *pearl* mutant was nearly equal to the numerical density observed in the wild-type mouse, 220 (±21 SE) per 1000 μm$^3$ and 250 (±29 SE) per 1000 μm$^3$, respectively (Table 2). Furthermore, no differences in numerical density of synaptic lamellae between the dark-adapted and light-adapted retinas were evident in either genotype. The distribution of synaptic lamellar length was similar in both genotypes (Fig. 5).

Morphologically similar photoreceptor terminals and postsynaptic processes were evident in dark-adapted mice of mutant and wild-type. However, dark adaptation did produce one notable difference in the *pearl* retina. The rod spherules of the mutant contained extremely few synaptic lamellae with bulbous thickenings or electron-dense bodies. The numerical density of the thickenings and adjacent dense bodies was 0.4% of the numerical density of the synaptic lamellae in the mutant, while no synaptic lamellae were found to have thickenings in the wild-type mouse (a total of 435 lamellae was measured) (Table 1).

![Fig. 6. Electron micrographs of serial sections of the *pearl* retina. The central section (B), was treated with pronase and the flanking sections (A and C) were not treated. The undigested rod terminals exhibit synaptic lamellae (sl), an electron-dense body (arrow) and an arcuate density (arrowhead). Pronase application substantially diminished the electron density of the sphere (empty arrow) and the synaptic lamellae but not the arcuate density (bar = 1 μm; ×26,700).](http://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/933123/)

Discussion

The synaptic lamellae of over 13% of *pearl* rod terminals exhibit bulbous thickenings and adjacent electron-dense bodies following in situ fixation during the light-adapted condition. These lamellar modifications occur in the *pearl* retina at a frequency 13.5 times greater than in the wild-type retina in the light-adapted condition. In the dark-adapted condition, however, no lamellar modifications have been identified in the rod terminals of both genotypes. Morphometric analyses of the synaptic lamellae in the outer plexiform layer of the retina reveal that numerical density and length are indistinguishable in the *pearl* mutant and wild-type mouse in the light-adapted and dark-adapted conditions. These results are in concordance with a recent morphometric analysis of photoreceptor synaptic lamellae of the guinea pig that showed no change in number of lamellae per terminal or lamellae length through a 24-hr cycle of 12 hr light/12 hr dark.

Morphologic Nature of Synaptic Lamellae

Although Ripps suspected a synaptic defect in retinas which exhibit stationary night blindness, an animal model of this condition, the Appaloosa horse,
failed to show synaptic lamellar modifications in either photoreceptor or bipolar terminals. However, structural modifications of photoreceptor synaptic lamellae, similar to those that we observed in the light-adapted *pearl* retina, have been detected in retinas of the mature albino rat. In one study, covering a period of 12 hr of moderate light and 12 hr of dark, synaptic lamellae occasionally appeared as discrete, round bodies, or with bulbous thickenings at their ends. Unfortunately, it was not stated whether these modifications were present under conditions of light and/or dark adaptation. In a second study, after 6 hr exposure to 500 foot candles of fluorescent light, rat photoreceptor terminals also exhibited synaptic lamellae with bulbous thickenings. In this case, however, rod spherules appeared to be in the initial stages of degeneration, as judged by structural modifications of their mitochondria and cytoplasmic inclusions of membranous sacules. Such degenerative alterations were not apparent in our study of light-adapted mouse retinas fixed in situ. A more extreme case of synaptic lamellae modification has been observed in the turtle. After 11 hr of light, the multiple synaptic lamellae in each turtle rod appear fragmented. Two hours later (after 1 hr in the dark), discrete round and oval synaptic lamellae were observed. These changes were not considered to be a direct response to light but rather a response of the endogenous circadian rhythm of the turtle.

Ribbon lamellae are not exclusive structural components of photoreceptor synaptic terminals. They are also present in the inner plexiform layer of the retina where they are unique components of the presynaptic junction of bipolar cells. However, our qualitative electron microscopic surveys of the inner plexiform layer revealed no structural modification of the synaptic lamellae of bipolar cells in light-adapted retinas. Although synaptic ribbons are predominantly plate-like structures, round lamellae have been detected in various nonvisual sensory cells (see Sobkowicz et al.). In the organ of Corti of the immature mouse, the lamellae are round. But this form does not persist, for the adolescent mouse exhibits plate-like lamellae. Small, round or bulbous structures have also been observed in immature photoreceptors of frogs, fish, and mice. These structures grow into ribbon-like structures as the animals mature. The electron-dense bodies in *pearl* photoreceptor terminals also may represent a modified form of synaptic lamellae comparable to lamellae in immature photoreceptors.

**Effect of Light Adaptation upon Synaptic Lamellae**

Our results show that synaptic lamellae are morphologically dynamic structures capable of photic modification. In the groups of eyes fixed in situ, the electron-dense bodies and lamellae with bulbous thickenings were only apparent in significant numbers in the retina of the *pearl* mouse in the light-adapted condition. The modified lamellae may represent the accumulation of lamellar macromolecules not yet aligned along the lamellar plate. A similar interpretation could be made of the observations of lamellae in immature photoreceptors. However, the kinetics of lamellar synthesis and/or turnover may differ in the two mouse genotypes, +/+, and *pe/pe*, since modified lamellae were rarely observed in the retina of the wild-type mouse. The difference in synaptic lamellae structure between *pearl* and wild-type is not attributed to circadian differences as observed in turtle rods since both strains of mice were perfused at similar times of day. In eight other pigmentation mutants congenic with the C57B1/6J strain, we also observed that light-adapted retinas have some rod terminals that contain synaptic lamellae with bulbous thickenings (unpublished observations). It has been called to our attention that the photoreceptor terminals of light-adapted albino mice, *Balb/c*, also exhibit many electron-dense bodies and synaptic lamellae with bulbous thickenings (unpublished observations of M. LaVail).

In contrast to the elevated proportion (13.5%) of lamellar modifications detected in the light-adapted mutant retina fixed in situ, only 1.3% of the synaptic lamellae of *pearl* appeared modified following in vitro light exposure. Thus, the structural integrity of synaptic lamellae is maintained in the isolated retina of *pearl* during light exposure. This result is consistent with the interpretation that a diffusible component, present in the intact, light-adapted eye, is capable of modifying the structural integrity of rod synaptic lamellae in the *pearl* mutant. The action of a diffusible component which normally is transported by the pigment epithelium and/or retinal circulation may also be responsible for the sensitivity deficit of *pearl* mutants. But the lamellar modifications, per se, cannot be the cause of the sensitivity deficit, for the deficit is greatest during dark adaptation, the period during which synaptic lamellae appear normal.

Light exposure of the isolated *pearl* retina was limited to 30 min since at this time only minimal alterations were observed in the structural components of the photoreceptors, ie, very few membranous sacules in the paramitochondrial space and very few mitochondria with vesiculated cristae. Photoreceptor terminals of the intact, light-adapted mutant also showed very few structural alterations, other than the modified synaptic lamellae. The in vitro exposure did not produce the extensive synaptic terminal alterations, such as the abundant membrane proliferation and mitochondrial degradation, that became apparent.
in albino rat photoreceptors after prolonged fluorescent light exposure. The electron-dense bodies present in light-adapted *pearl* photoreceptors are not structurally comparable to the dense core vesicles that accumulate in rod terminals of frog and chicken after prolonged light exposure. The dense bodies of *pearl* lack a limiting membrane and are larger than dense core vesicles.

Continuous fibril rings located at the outer perimeter of cat cone pedicles also appear as small (100 nm in diameter), dense bodies in single sections. The length, composition, and location of these rings eliminate the possibility that the dense bodies observed in *pearl* rod spherules are similar fibrillar rings.

Other round, dense structures (60–100 nm in diameter) have been shown in rod spherules of the chick, during light- and dark-adaptation and in dark-adapted cone pedicles of goldfish. However, no direct relationship between these round, dense structures and the synaptic lamellae of photoreceptors have been suggested.

**Numerical Density of Synaptic Lamellae**

Three previous studies have compared the numbers of synaptic lamellae of photoreceptor cells in light- and dark-adapted retinas. In the goldfish, no change in the number of synaptic lamellae in rod spherules was observed between light- and dark-adapted retinas, although cone pedicles exhibited a significant decrease of lamellae after 14 hr of dark adaptation. However, in the guinea pig, the rods and cones showed no change in the number of lamellae per terminal between the light- and dark-adapted condition. Another study, using albino rats, showed the numerical density of the synaptic lamellae of photoreceptors to be greatly diminished after 7 hr of dark adaptation. In this case, the numerical density increased slowly after the lights were turned on and reached a maximum at the end of the 12-hr light period. These results do not concur with those reported for goldfish rods or guinea pig photoreceptors, nor with our observations of mouse photoreceptors. No differences were detected in the numerical density of synaptic lamellae of mouse photoreceptors in the light- and dark-adapted conditions. A possible explanation of this discrepancy is that, in the present study, mice were light-adapted for a period of 4–8 hr, which is less than the 12 hr reported to be necessary for a maximal effect in rat. Even an increase of 1.5-fold, as reported for the rat after 3.5 hr, should have been detected with our methods. These seemingly conflicting results may be attributable to some, as yet undetected difference between photoreceptors of the albino rat and the less extreme hypopigmentation mutant, the *pearl* mouse or the C57BL/6J mouse.

**Composition of Synaptic Lamellae**

Although numerous descriptive studies of synaptic lamellae have been published, very little is known about their composition or functional significance. A protein component of synaptic lamellae in amphibian photoreceptors has been elucidated by the extraction of the lamellae from ultrathin sections with proteolytic enzymes. Our results showed that pronase removes the electron-dense bodies and bulbous thickenings of synaptic lamellae, as well as the entire lamellae. These results indicate that the lamellae, dense bodies, and thickenings are comprised, at least partially, of proteins. The dense bodies and lamellar thickenings apparently are not misaligned lipid aggregates, since pronase extraction did not diminish the electron density of the membranous components of the rod terminals.

In conclusion, this study depicts a structural modification of the light-adapted *pearl* retina, ie, rod photoreceptor synaptic lamellae with bulbous thickenings and adjacent electron-dense bodies. The other parameters of the OPL that we analyzed, synaptic lamellar density and length, are indistinguishable in both the light- and dark-adapted conditions in *pearl* and wild-type retinas. The structural modifications of the synaptic lamellae may be dependent on some as yet undetermined function of the mutant retinal pigment epithelium for the modifications were not detected in the isolated retina of *pearl* following light exposure. Since the lamellar modifications are prominent only in the light-adapted condition, they cannot account for the sensitivity deficit observed in the dark-adapted condition. However, the lamellar modifications could be interpreted as an indication that *pearl* synaptic terminals are under stress during light adaptation. Recordings from second-order neurons in the eyecup preparation and in the isolated retina may help to determine the physiologic effect of the retinal pigment epithelium upon the neural retina of the mutant.

**Key words:** pearl mutant, mice, retina, synaptic lamellae

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