(*ww*); (iii) the LD_{50} values for females are significantly higher than for males; and (iv) genes other than those specifically investigated in this study also play a role in determining radioresistance, since differences between the two hybrid types WB × C57BL/6 and WC × C57BL/6 are conspicuous. Genes in strain WB that differ from those in strain WC increase survival at all radiation levels regardless of sex or genotype.

These findings in general fit well with the observations of other investigators, where comparisons are possible. As mentioned earlier, several groups of workers (*5*) found differences between the sexes in radiation-induced lethality, and similar strain and hybrid differences are reported by numerous other investigators (*3, 4, 10*).

Our results are also basically in accord with Doolittle's recent findings (*11*) of changes in radioresistance attributable to single gene substitutions. Doolittle studied the following genes: short ear, and its normal allele (*se* and *Se*); black and tan (a^t); non-agouti (*a*); hairless, and its normal allele (*hr* and *Hr*), chinchilla (c^{ch}); and albino (*c*). He used as his measure of radiosensitivity the number of days to death for mice exposed daily to 70 r.

Unfortunately, Doolittle's data are rather difficult to interpret in view of the fact that genetic background markedly influenced gene expression. Such variability, while confounding analysis, is not unexpected, since modification of gene action through interaction with other genes or gene products undoubtedly is the rule rather than the exception. Although his data and ours are for different genes and his method of determining radiation sensitivity was different from ours, independent investigation has led us to essentially the same conclusion—namely, that single gene substitutions may indeed affect resistance to radiation.

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16 February 1962

Amygdalectomy in the Kitten

Abstract. Kittens sustaining bilateral amygdalectomy failed to show behavioral changes seen in the adult after subjection to similar lesions. No growth deficits or hypopituitarism occurred in the kittens. A certain level of neuroendocrine maturation may be necessary for the effects of amygdalectomy to be manifested.

Removal of the amygdaloid nuclei and overlying pyriform area in the adult cat produces a number of behavioral changes. In several previous reports (*1, 2*) we have classified these changes in two distinct stages. In the early postoperative period, which may last from 1 to 3 weeks, the cats are stuporous and unresponsive to surrounding stimuli, they do not groom, and they must be fed by force. In the second stage the cats become somewhat hyperactive, are more docile, less responsive to noxious stimuli, and show an increase in oral activity and sexual behavior. With time these changes may decrease in intensity, but rudiments of this behavior may persist for several years. In the male cat, after a year or so, we have found degeneration of the spermatic tubules with maintenance of the interstitial cells (*2*). Factors which may influence the development and maintenance of this syndrome include lesions of the medial hypothalamus (*1*) and castration in the male cat (*3*). In addition, an increase in aggressive behavior may occur in the female cat, possibly as a result of an increase in gonadal hormones.

Koikegami (*4*) has reported that amygdalectomy in infant animals results in panhypopituitarism, lack of growth, early inanition and death.

My experiment compared the effects of amygdalectomy in the kitten with the syndrome in the adult and compared the development of these kittens with the development of normal and neocortically damaged kittens.

Sixteen kittens, six males and ten females, were used. All kittens were born in the laboratory from six different litters. At the time of operation the cats were 53 days old. Five kittens sustained bilateral removals of the amygdala and overlying pyriform cortex and five sustained lesions of the neocortex lateral to the rhinal sulcus. Six which were 60 days old remained unoperated. Body weights at the time of operation for the three groups were 698 ± 95 (mean ± standard deviation), 636 ± 85, and 847 ± 150 g, respectively. Lesions were made aseptically under sodium Nembutal anesthesia. Tissue was aspirated under direct exposure. This is the same procedure that was used in the previous studies of the adult cat (*1*). Figure 1 shows projection drawings through the greatest extent of the lesion for each kitten. The lesions in the amygdala included both medial and basolateral groups with the exception of kitten No. 1, in which the ventral portions of the medial and basal nuclei were spared on one side. Kitten No. 8 had unilateral neocortical injury while the remaining four in this group had bilateral damage to temporal neocortex.

After the operations, each cat was housed in an individual cage and fed a diet of raw horsemeat and milk. The cats were placed in a 4- by 8-foot room

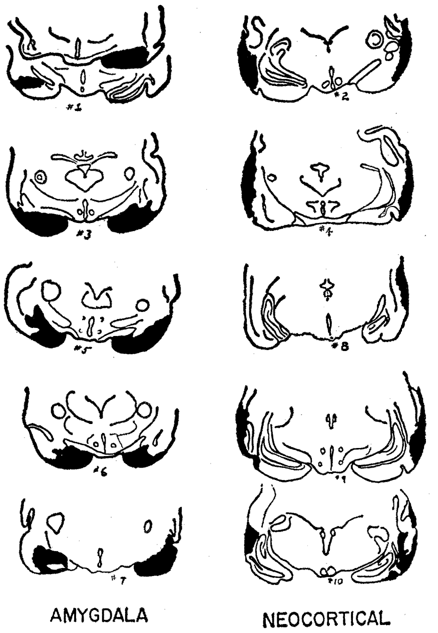

Fig. 1. Projection drawings through the greatest extent of the lesion for the amygdalectomized group (left) and the neocortical group (right).

which was enclosed by wire mesh to permit observation from outside the room. The cats were weighed and then observed for a 2-hour period each day. Special attention was paid to affective interaction between the cats, play, aggression, levels of activity, and motivation for food.

The day following the operations both groups of lesioned animals were up, alert, moving about, and grooming. When presented with food they sniffed and licked and in general ate sparingly. By the second day, all the operated cats were more active and when allowed free access on the floor would chase each other and run about. There was always considerable neck and body biting, rolling over, and kicking with the rear legs. When food was presented all cats came to the front of the enclosure, vocalized, and pawed at the mesh. When the food was placed on the floor all gathered around and ate readily. After feeding, the kittens would lie down, lick, and groom. This general pattern was consistent throughout the observation period.

There was no growth deficit in any group. The groups with lesions in the amygdala and neocortex closely paralleled one another, and the slope of weight gain was the same as that for the slightly older normal group. Terminal body weight of the amygdalectomized group was 1172 ± 84 g, as compared with 1036 ± 151 for the neocortical group, and 1265 ± 135 for the normal group.

No hypopituitarism occurred. Adrenal weights for the amygdalectomized, neocortical, and normal groups were 0.203 ± 0.020, 0.212 ± 0.042, 0.189 ± 0.062 g, respectively. Pituitary weights were 0.024 ± 0.004, 0.023 ± 0.005, and 0.023 ± 0.002 g; testicular weights were 0.236, 0.216, and 0.340 g; thyroid weights were 0.131 ± 0.031, 0.172 ± 0.009, and 0.208 ± 0.009 g, respectively. Histological examination of the endocrine organs revealed no significant difference between groups. The testes of all males were immature, with no tubule formation or spermatogenesis.

The results indicate that the post-amygdalectomy syndrome of adult cats does not appear in kittens—at least not in kittens under 13 weeks old. There was very little difference in behavior between groups, either in the early postoperative period or after recovery. The only observable gross difference was that the amygdalectomized cats were possibly less competitive for food than the normals. However, since the normals were slightly older and larger they would be expected to be dominant.

No evidence of growth disturbance or endocrine deficiency was observed. The suggestion of precocious puberty in females is in agreement with the findings of Elwers and Critchlow (*5*), who observed precocious puberty in female rats after lesions were placed in the amygdala.

The behavioral effects of amygdalectomy in the cat may depend upon a certain level of neuroendocrine maturation.

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29 June 1962

Daily Rhythm in the Reaction of Fish to Light

Abstract. Bluegills in a 24-hour light-dark cycle were exposed briefly to light at a random time in the daily dark period. The duration of the accompanying "light-shock reaction" daily became longer at times early in the dark period and shorter at times in the later hours of darkness.

In the bluegill the light-shock reaction which immediately follows a sudden exposure to bright light after a time in darkness (or very dim light) is a sequence of peculiar movements and postures, beginning with a descent to the bottom of the aquarium. The fish may sink a short distance before halting and recovering, or it may continue to the bottom, staying there for varying periods. On the bottom it may remain immobile, fan its fins without locomotion, or move erratically backward or forward, sometimes butting into obstructions it would otherwise avoid. Eventually its movements become more organized and it rises. Fish kept in light beyond the time of recovery from the light-shock reaction and then placed in darkness fail to "react" to a second exposure during the first 5 or more minutes of darkness; the ability to react is lost with time in the light and regained with time in darkness. The duration of the light-shock reaction, or the "recovery time," is here defined as the interval that begins with the onset of bright light and ends when the fish returns to its normal attitude. The light-shock reaction, or similar reactions, in other fishes have been described elsewhere (*1, 2*). Apparently the light-shock reaction has not been extensively studied.

The light-shock reaction was of interest as a means of determining whether fish in a 24-hour light-dark cycle exhibit time-coordinated changes in behavior. The question was: Do recovery times following sudden exposure to light of a given brightness fluctuate predictably with time in the daily dark period, and does the timing of any such daily fluctuations indicate that they are regulated from within the fish by an internal rhythm which is in phase with the 24-hour light-dark cycle?

A typical experiment consisted of exposing fish for a number of minutes to a bright light (giving them a "light-shock") at a randomly determined time in the daily dark period. The light-shock was given randomly so that the influence (if any) of exposure in the dark period on one day on responses in the dark period of the next day would be randomized; thus, any regularity in the observed daily changes in recovery time would not be attributable to the timing of the light-shock. At the chosen time each day the observer illuminated the fish and actuated a stopwatch. If a fish hovered or continued to swim above the bottom, a reaction of zero duration was recorded. If a fish descended but halted before touching the bottom, a 5-second reaction was recorded. Longer reactions were measured to the nearest 5-second interval in which the fish rose from the bottom. After a number of days the daily measurements of recovery time were combined to obtain independent estimates of mean recovery time at the randomly selected points in the daily dark period (*2*).

In one experiment nine bluegills [*Lepomis m. macrochirus* (Rafin.)] were confined, in groups of three, to separate, light-tight chambers in a darkened room. A fluorescent tube