Jackson Laboratory, Bar Harbor, Maine. Although these two sublines have been separated since 1957, female-female and male-male skin transplants exchanged between them are uniformly accepted, and females of both sublines behave similarly toward male skin grafts. Nevertheless, in all cases females were challenged with male skin from the same subline.

Viable cell suspensions were prepared from the axillary, brachial, cervical, and mesenteric nodes of adult rats and mice as described (*5*). The cells were administered intraperitoneally in a standard volume of 1 ml of Hanks balanced salt solution.

Skin grafting entailed the transfer of a full-thickness disk of nonactive trunk skin, about 1.0 to 1.2 cm in diameter, to the right side of the host's chest. The operative technique and method of appraisal of the well-being of the grafts have been described (*6*). In several experiments, grafts were scored without knowledge of the recipient's treatment.

Median survival times (MST's) of grafts were estimated by Litchfield's nomographic method (*7*). Statistical significance was determined by the Mann-Whitney U test (*8*).

The results are summarized in Table 1. Male cells from four (LE, FI, BH, and AUG) of the nine strains assayed succeeded in sensitizing C57BL/6 females against subsequent C57BL/6 male skin grafts. On the other hand, all female cells, as well as male cells from WF, BN, DA, ACI, and BUF donors, proved ineffective in sensitizing their female mouse recipients against male skin grafts. The results with BN cells are in accord with our previous findings (*3*).

It is undoubtedly significant that the rat cells most successful in inducing immunity to the mouse H-Y antigen all stemmed from *Ag-B*^{1}/*Ag-B*^{1} males. Indeed, the level of immunity induced by these cells, as indicated by the MST's of male skin grafts on their recipients, compared favorably with that observed after the inoculation of similar numbers of allogeneic CBA male lymphocytes.

The capacity of male cells from only some strains of rats to sensitize female C57BL/6 mice to the Y antigen could be due to differences in their survival in the host species. Thus, LE, FI, and BH cells may have survived significantly longer in the C57BL/6 hosts than did cells of other *Ag-B* genotypes; the latter, in most cases, might have been rejected before they were able to induce any immunity at all to the relatively weak H-Y antigen. Indeed, the fact that not all recipients of *Ag-B*^{1}/*Ag-B*^{1} male cells gave a demonstrable immune response when challenged with a male skin graft suggests that even these cells may not have persisted long enough in some animals to induce immunity. If the survival of rat cells in mice is a function of their *Ag-B* genotype, this would certainly not be surprising, since there is ample evidence of serologic cross-reactivity between the histocompatibility antigens of different species (*9*). Most pertinent is the report by Sachs *et al.* (*10*) that mice challenged with rat xenografts produce antibodies that can detect the major histocompatibility alloantigens of the donor rats with remarkable specificity. Direct evidence for the longer survival of *Ag-B*^{1}/*Ag-B*^{1} cells, as opposed to those of other genotypes, could be obtained by establishing the fate of isotopically labeled rat cells, derived from various strains, in C57BL/6 recipients.

Alternatively, it might be argued that the better results obtained with LE, FI, and BH male cells stems from the fact that their Y antigen is more closely related to the Y factor of C57BL/6 mice than is the male antigen of other rat strains. This possibility is, however, ruled out by the fact that BN/FI (*Ag-B*^{3}/*Ag-B*^{1}) F$_1$ hybrid cells—that is, cells derived from an animal whose Y chromosome was of FI origin—were ineffective in inducing sensitization to H-Y in mice. Indeed, the fact that these cells behaved like BN cells lends further support to the thesis that the results obtained reflect differences in the capacity of rat cells of different *Ag-B* genotypes to survive in a mouse milieu. Evidence that allelic differences at the *H-Y* locus were not responsible for the results obtained is also derived from previous grafting experiments that, with one exception (*11*), indicate that the Y factor is identical in male rats of all strains (*3, 12*).

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Seasonal Changes in the Learning and Activity Patterns of Goldfish

Abstract. Goldfish exhibit cyclic changes with an annual rhythm in their learning and activity patterns. Maximum learning ability and active behavior occurred during the months of January, February, and March. Poor learning was obtained in the summer months, after the onset of the spawning season. The results indicate that the annual periodic changes of the hormonal levels which govern spawning may also influence learning and activity patterns.

In studies of the biochemical changes that occur in the brain during learning, the ability of goldfish to learn new swimming skills was found to vary with the season of the year (*1*). The animals learned well during the winter and very poorly in the summer months. A systematic study of this behavior showed that not only the learning but also the general activity patterns of the animals followed an annual cycle, which suggested that these may be produced by rhythmic changes in the hormonal and the biogenic amine levels in the brain. The results of three consecutive years of studies of these behavior patterns are summarized in this report.

Goldfish (7 to 8 g, comet variety from Ozark Fisheries, St. Louis, Missouri) were used throughout this investigation. The animals were conditioned for at least 2 days before an experiment in 30-gallon (110-liter) aquariums in water containing 5 g of NaCl per gallon; the maximum population density was three fish per 2 gallons (9 liters). The water was continuously aerated and filtered through charcoal filters. The water temperature was regulated at 21°C. Under these conditions the animals are healthy and survive well in the laboratory. The training and testing experiments were carried out in 5-gallon tanks filled with 3 gallons of water and equipped with an air bubbler and charcoal filter. Before each experiment the water was aerated for 45 minutes, and then seven animals were conditioned in each tank for an additional 45 minutes. The task used in this work was a "float training" situation (*1*) in which goldfish acquire the ability to swim with polystyrene foam floats sutured to their ventral side, 1 mm caudal to the first pair of lateral fins. The float was a 0.7-cm cube for goldfish weighing 7 to 8 g. The sequence of adaptation of the goldfish to the float was found to follow a reproducible pattern. Initially the animals were upside down. Within 1 hour they learned to swim at a 45° angle with their heads down in an upright position. After about 4 hours the animals generally swam in a horizontal position. At fixed intervals after the floats were attached to the goldfish, the swimming performance of each animal was evaluated according to the following criteria. During a 30-second observation time a performance score of 15 percent was designated to animals which failed twice to maintain a swimming posture at a 45° angle; that is, the goldfish floated to the surface in an upside down position. A score of 35 percent was assigned to a single failure to maintain the 45° swimming position during the observation time; 50 percent was assigned to constant swimming at 45°; 65 percent to swimming at an angle of about 30° to 45° to the horizontal; 85 percent to swimming at an angle of about 15° to 30°; and 100 percent to swimming in a horizontal posture.

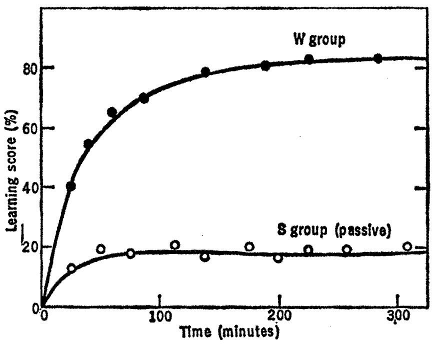

Fig. 1. Comparison of learning patterns of winter (*W*) and summer (*S*) goldfish in float training experiments. The graphs show the training scores achieved by groups of seven animals as a function of time. The observations of the group behavior were carried out at the time intervals shown. The performance of each animal was determined during a 30-second observation time according to the criteria given in the text.

The average score for a group of seven animals was then plotted as a function of training time to give a learning curve. Figure 1 shows the types of learning curves obtained for a learning winter (W) group, as compared to a nonlearning summer (S) group of animals. The winter group achieved an 80 percent group score within 150 minutes, whereas the summer group had a score of less than 20 percent in the same period. The summer group essentially did not try to learn the task and for the most part remained passive in an upside down posture at the water surface.

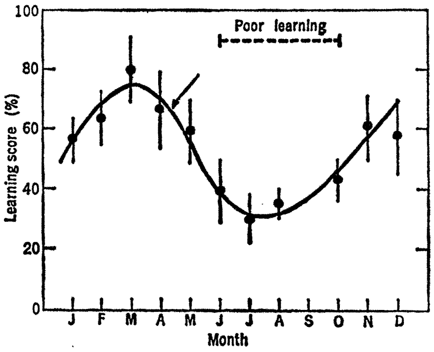

Fig. 2. Changes in the learning score achieved by goldfish in the float training experiment as a function of the time of the year. The graph shows the combined average performance scores obtained during a 3-year period from January (*J*) to December (*D*). Each point is the average score for four to seven groups of seven animals trained for 4 hours. The vertical bars depict the standard deviation of the test scores. Poor learning occurs in the summer months, and the highest scores are obtained during the winter.

Figure 2 shows the combined average test scores obtained during a 3-year period as a function of the time of the year. Each point on the curve is the average score for four to seven groups of seven animals; the standard deviation is depicted by the vertical bars. A cyclic behavior pattern with an annual rhythm is evident in the results. The learning ability of the goldfish reached a peak during February, March, and April. Poor learning occurred during June to September. A similar type of behavior has also been found for learning a conditioned avoidance response (*2*) and in maze learning (*3*). In addition, seasonal variations of nervous system functions have been reported for (i) the level of biogenic amines for the toad (*4*), (ii) the effectiveness of neural extracts on the egg-laying behavior of *Aplysia* (*5*), and (iii) the well-known seasonal changes in the properties of nerves from summer and winter frogs.

A number of factors may explain these observations. One possibility is that the stress experienced by the goldfish when they are shipped during the summer is much more severe than in the winter. This, however, was not significant, since goldfish from local hatcheries also showed poor performance in the summer and good learning ability in the winter. Another possibility is that not only learning but also other forms of behavior may follow a cyclic pattern with an annual rhythm. Thus, for example, a general decrease in the "arousal" level (*6*) of the animal could occur in the summer months. In an attempt to examine this question an activity test method was devised for evaluating the general behavior of the goldfish. In this test, groups of five animals (weighing 7 to 8 g) were conditioned in the standard manner in 5-gallon tanks filled with 3 gallons of water. A 2.5-cm cube of polystyrene foam was sutured at the ventral side of each fish 1 mm caudal from the position of the first pair of lateral fins. This float size is much too large for the animals to learn any swimming skills, and each fish remains suspended in an upside down position during the test period. In each experiment the behavior of 20 animals in four tanks (5 in each tank) was studied in a 2-hour test period. Every 5 minutes, each animal was observed for a total of 30 seconds. If a fish showed any movement during this time interval, it was scored positive. All animals with test scores of 15 and above (that is, over 60 percent) were designated as active and those with scores less than 15 were marked passive. This type of selection of the goldfish was found to correlate well with the ability of the animals to learn the float training experiment when the float size was a 0.7-cm cube. The active animals learned the task well, whereas the passive groups made little effort to master the float training task. This activity selection test was used to evaluate the seasonal behavior of the goldfish. The results (for 100 animals at each observation date) showed that in February 75 percent of the animals tested were active. This number decreased to 8 percent in June and to a low number of 2 percent in August. In October the percentage of active animals rose to 24 percent and then progressively increased to the high values of 70 to 80 percent for January, February, and March. Thus, the general activity of the goldfish follows a cyclic pattern with an annual rhythm similar to that of the learning behavior, which suggests that arousal level and not learning is the predominant factor in the behavior.

It is of interest that the periods of low activity and poor learning behavior coincide with the onset of the spawning season of goldfish (*7*). Moreover, the period of high activity and high performance scores in the learning experiments occur at about the time when there is rapid gonadal development in the animals. It is known that the spawning of fish can be regulated by the photoperiod to which the animals are exposed (*8*). Thus, animals kept at low light levels can essentially be prevented from spawning. To test this possibility one group of goldfish was placed during the month of May in an aquarium with all sides shielded and with minimum lighting (the light was provided by a 100-watt fluorescent light 3 m above the aquarium). A number of these goldfish were tested in May to establish that high training scores were obtained. The rest were kept until July and then tested in the float training experiment. Animals obtained during July, as well as animals kept under ambient light conditions from May until July, were used as controls. The experimental goldfish achieved training scores of 67 percent, compared to 15 and 25 percent for the two types of controls. The higher learning scores achieved by the May goldfish indicate that a control of the photoperiod may be useful in modifying the behavior. Additional experiments are required before any definitive correlation between the onset of spawning behavior and the decreased learning and activity patterns of the goldfish can be established. The possibility that cyclic hormonal levels as well as cyclic changes in brain biogenic amine levels (*9*) can play an important role in governing goldfish behavior is suggested by these results.

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Speed-Accuracy Trade-Off in Recognition Memory

Abstract. *In a recognition memory experiment, the time allowed for retrieval was controlled by using the offset of the probe as a signal to terminate retrieval and respond. The response latencies measured in the experiment indicate that this procedure effectively eliminated fast-guess strategies. The recognition signal-to-noise ratio,* d′, *grows at a negatively accelerated rate as the allowed retrieval time is increased from 0.5 second to 1 and 2 seconds.*

Knowledge of how the accuracy of recognition varies as a function of the time allowed for retrieval of information from the human memory may provide insights not only into recognition performance under pressure, but also into the time course of processes underlying retrieval and into the dynamics of verbal memory in general. This report describes the first investigation of recognition memory to demonstrate a speed-accuracy trade-off which, as a result of a novel experimental procedure, cannot be ascribed to a change in the proportion of fast, random guesses (*1*). The results show that recognition accuracy (as measured by *d′*, the signal-to-noise ratio) increases as the time allowed for retrieval of weakly remembered verbal material is extended from 0.5 second to 1 and 2 seconds. This gradual increase in accuracy is negatively accelerated, and when the time allowed for retrieval is further extended to 4 and 8 seconds no consistent increase is observed.

At the start of each trial the experimenter asked the three subjects (*2*) whether they were ready. If they were, three consonants (*3*) were shown on an electroluminescent display panel. After the subjects read this trigram aloud,

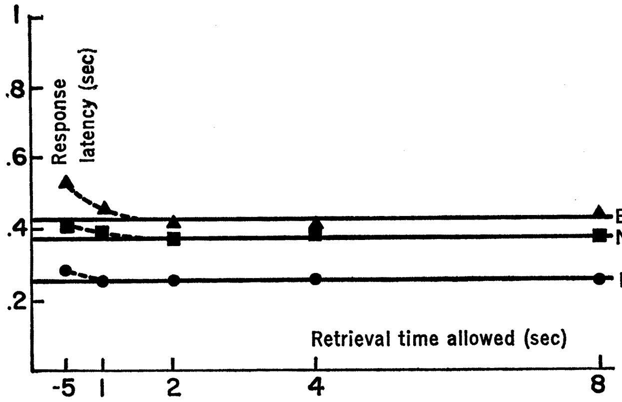

Fig. 1. Response latency after the signal to terminate retrieval and respond (probe offset), as a function of the time from the onset to the offset of the probe. Standard errors range from 2 to 8 msec.