lease in response to exogenous GnRH (*14*). These results suggested the possibility that the inhibitory effects of GnRH analog were mediated by down-regulation of pituitary GnRH receptors. This hypothesis was tested by measuring GnRH receptor number and affinity before and after administration of GnRH analog. Receptors for GnRH were measured by a radioreceptor assay (*14*), modified as suggested by Clayton *et al.* (*15*). For this method, ^{125}I-labeled [D-Leu^{6}]des-Gly^{10}-GnRH ethylamide is used as radiolabel together with a membrane-containing fraction of anterior pituitary homogenates sedimented at 10,800*g*. Protein content of the membrane fraction was measured by the method of Lowry *et al.* (*16*). Equilibrium association constants (K_a) and apparent number of binding sites per milligram of protein (R_0) were calculated by Scatchard analysis (*17*) for pooled fractions from each treatment group (Table 2).

Small decreases in GnRH receptor affinity were offset by increases in receptor number after analog treatment. These small changes in pituitary GnRH receptor binding characteristics make it likely that analog-mediated suppression of pituitary gonadotropin secretion occurs via postreceptor mechanisms in the pituitary gonadotropin-secreting cells rather than by exerting a primary down-regulatory effect at the receptor level.

These data demonstrating synergistic effects of a superactive GnRH analog and testosterone in suppressing gonadotropin secretion coupled with data in humans (*8–10*) linking inhibition of gonadotropin secretion with suppression of spermatogenesis suggest that a combination of superactive GnRH and testosterone in various doses might be useful for male contraception. Recent studies (*18, 19*) have suggested that GnRH analogs may also have direct inhibitory effects at a testicular level not related to inhibition of pituitary gonadotropin secretion. The combined use of testosterone and GnRH analogs to inhibit pituitary gonadotropin secretion and testicular function may provide enhanced suppression of male reproductive function with decreased risk of breakthrough sperm production. Since GnRH superactive analogs have consistently suppressed serum testosterone levels, concomitant androgen treatment has the added advantage of preventing symptoms related to analog-induced androgen deficiency.

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Primate Memory: Retention of Serial List Items by a Rhesus Monkey

Abstract. *A rhesus monkey correctly recognized 86 and 81 percent of 10- and 20-item lists, respectively. Its serial position curve was similar in form to a human's curve, revealing prominent primacy and recency effects. The key to these findings was in minimizing proactive interference through the use of a large pool of 211 color photographs.*

Studies of short-term (recent) memory in animals are frequently concerned with retention of only single items (*1*). Many memory phenomena, however, such as the serial position curve (*2*) and memory scanning rates (*3*), figure prominently in our current understanding of human memory and can be explored only with multiple-item retention tasks.

Multiple-item memory tasks used with animals are either so different from those used with humans [for example, spatial memory tasks for rats (*4*)] that their results find no direct counterpart in the human memory literature, or they yield poor performance (*5*). There may be one exception (*6*): a dolphin achieved a modest 70 percent correct performance with six-item lists in a procedure analogous to the human serial probe recognition (SPR) task (*7*). To our knowledge, other animals have not heretofore performed so well. We have now conducted a series of SPR experiments with a rhesus monkey, which far surpassed the dolphin's performance.

We report performance of 86 percent correct by a rhesus monkey in an SPR task with a ten-item list and compare its serial position curve to a human curve for the same task. We also provide a novel demonstration of a primacy effect in an animal in a task analogous to those used with humans. Our success with the monkey was due to a procedure that minimized proactive interference (memory of earlier items adversely affecting performance on later ones).

A 5-year-old male rhesus monkey with prior training in related tasks (*8*) sat in a primate chair located in a chamber with sound and light attenuation. The subject viewed a panel containing two rectangular rear projection screens (12 cm high by 19 cm wide) arranged vertically (16 cm from center to center) and subtending visual angles of 12° vertically and 20° horizontally. Visual stimuli consisted of 211 distinctly different items familiar and unfamiliar to the monkey (for example, fruits, flowers, animals, people, and objects). Photographs of the stimuli (35-mm slides) were projected onto the screens by projectors (Kodak Carousel). The monkey held a response lever that could be manipulated in three directions (down, left, or right). A downward press of the lever during a "ready" tone (2000 Hz) initiated a trial. The ready tone was terminated with this response, and 1 second later, list items appeared on the top projection screen. Each item of the list was presented for 1 second, with successive items separated by a 0.8-second delay. One second after presentation of the last item of the list, a probe item appeared on the bottom screen. A movement of the lever to the right indicated

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that the probe was a list member ("same"). A movement of the lever to the left indicated that the probe item was not a list member ("different"). The probe remained in full view until the monkey made a choice or until 2 seconds had elapsed. Correct choices were followed by a 0.25-second, 4000-Hz tone and by either a small squirt of orange juice, a banana pellet, or a small amount of apple sauce. A 2-second intertrial interval separated trials. Errors or failure to make a choice response turned on the chamber light for a 10-second time-out period. Typically, two sessions of 140 ten-item lists were conducted daily with equal numbers of "same" and "different" trials in random sequence. The scheduling of experimental events and data acquisition were accomplished by a specially designed transistor-transistor logic circuit.

A 22-year-old human female subject participated in the same experiments. She sat in a chair just behind the normal position of the monkey chair and held the response lever in her hand. The stimuli from this position subtended visual angles of 6° vertically and 10° horizontally. Correct responses were followed only by the 4000-Hz tone. Other experimental conditions were identical.

The results are shown in Fig. 1. Each point on the serial position curve represents 840 observations by the monkey and 70 by the human. Overall accuracy for the monkey with lists of this length was 86 percent, considerably higher than that previously found for monkeys (*5*). The two serial position functions are of identical form, although the human subject was more accurate than the monkey. Accuracy was greatest for the initial and terminal items in the list (*9*). These primacy and recency effects figure prominently in theoretical models of human memory (*10–12*); if valid, they must also figure prominently in nonhuman primate memory. The primacy effect has been hypothesized to result from differential rehearsal strategies (*13*), differential retrieval cues (*14*), or a lack of proactive inhibition on the initial list items (*15*). The recency effect has been hypothesized to represent a short-term memory buffer of limited capacity (*10*), differential retrieval cues (*16*), or a lack of retroactive inhibition on terminal list items (*15*). The medial items, in the trough of the serial position curve, are not well remembered and occurred at item 3 for both the human and the monkey, a striking correspondence we believe to be further evidence for similar mechanisms of primate memory systems. Thus, our procedure may allow us to model the human memory system with the rhesus monkey.

The performance of the rhesus monkey on a list of ten items led us to double the list length; performance was 81 percent correct overall, a drop of only 5 percent. (The human subject's performance was 92 percent correct overall with 20-item lists, a drop of only 1 percent.) We have recently obtained primacy and recency effects with 20-item lists as we did with the 10-item lists.

Our methodology differed from that of previous studies of SPR performance in monkeys (*5*) in the use of a large rather than a small pool for list construction. We hypothesized that the poorer performance obtained with small pools (*5*) was the result of proactive interference caused by the necessity of reusing the same items from list to list. An item seen during a previous list may be remembered when that same item is displayed as a probe item in a later list. This memory from earlier lists may cause the subject to err and respond "same," indicating that he thought it was contained in the list just presented. To test this hypothesis, we constructed three-item lists from a pool of the six items best discriminated in our 211-item pool. The procedure in other respects was identical to that of our earlier experiments. Both human and monkey subjects were less accurate with lists constructed from the six-item pool than from the 211-item pool (Fig. 2). The drop in overall accuracy for the monkey was substantial: from 93 to 70 percent correct (*17*). This level of performance replicates those of previous investigators (*5*) who used pools of similar sizes. This study lends further support to our hypothesis that eliminating proactive interference from previous items is necessary to achieve high accuracy with long list lengths in the SPR task.

The dolphin experiment (*6*) also made use of a large item pool—600 distinct sounds. Thus, it seems that a large pool should be used in SPR tasks so that items are not repeated during a session, eliminating or at least minimizing proactive interference from list to list. The resulting good performance permits explorations of similarities and differences between human and animal memory, furthering our understanding of both.

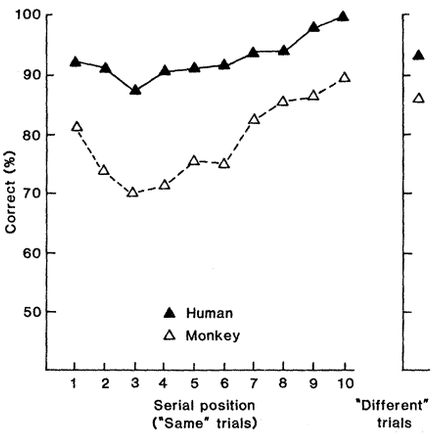

Fig. 1. Serial position curves for "same" probe trials and percentage correct on "different" probe trials for human and monkey subjects with ten-item lists.

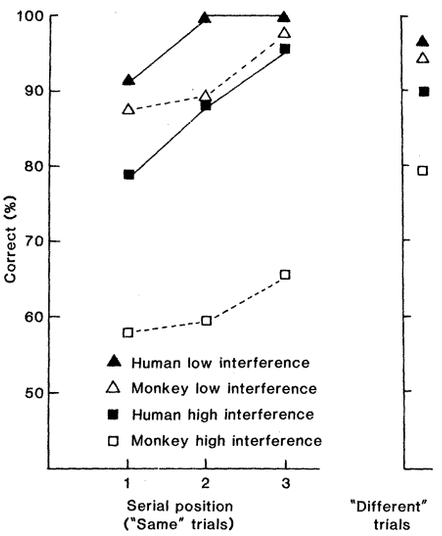

Fig. 2. Serial position curves for "same" probe trials and percentage correct on "different" probe trials for human and monkey with three-item lists under conditions of high proactive interference (six-item pool) and low proactive interference (211-item pool).

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8. The monkey was trained to respond accurately

in the SPR task by transferring simultaneous (pairs of pictures simultaneously present) same-different performance to a delayed same-different task and then to the SPR discrimination. Approximately 28,000 trials were necessary to train the monkey in the simultaneous procedure, whereas only 10,000 trials were necessary to train the monkey in the delayed and SPR tasks.
9. We identified serial position effects by testing post hoc contrasts across the sample means for the ten serial positions. Variance ratios for each contrast were compared with new critical F values [R. S. Rodger, *Br. J. Math. Statist. Psychol.* **28**, 71 (1975)] in order to control type I errors on a per decision basis. For the monkey, accuracy at serial position 1 (primacy effect) and at serial position 10 (recency effect) was higher than at medial positions 2, 3, and 4 [primacy: $F(9, 300) = 2.05$, $P < .05$; recency: $F(9, 300) = 5.37$, $P < .05$]. For the human subject, similar effects were evident but less pronounced because of a ceiling effect and fewer observations. A recency effect was indicated by higher accuracies at serial positions 9 and 10 than at positions 2 to 6 [$F(9, 90) = 1.44$, $P < .05$]. A primacy effect was also indicated since performance at serial position 1 (and at positions 7 and 8) was intermediate between these extremes [$F(9, 90) = .03$, $P > .05$].
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17. Analysis of the errors committed in the high-interference condition revealed that most incorrect responses were initially "same" responses to probe items not in the current list.
18. We would like to thank Judy Cornish for her technical assistance and Drs. M. R. D'Amato, E. Hearst, W. K. Honig, S. H. Hulse, and P. J. Urcuioli for critical comments on the manuscript. This work was partially supported by NIH grant EY01256-05 and NSF grant BNS 78-07253 to A.A.W.
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Calicivirus Pathogenic for Swine: A New Serotype Isolated from Opaleye *Girella nigricans*, an Ocean Fish

Abstract. *A new calicivirus, designated San Miguel sea lion virus type 7 (SMSV-7), was isolated from fish and produced a disease condition identical to vesicular exanthema in experimentally infected swine. Serotype SMSV-7 was also isolated from four elephant seals and one sea lion trematode, whereas a second calicivirus serotype isolated from fish proved to be SMSV-6.*

We have isolated from the opaleye fish (*Girella nigricans*) a new calicivirus we have designated San Miguel sea lion virus type 7 (SMSV-7) and have experimentally infected swine with this agent. Another calicivirus SMSV-6 (*1*) has also been isolated from the opaleye.

From 1932 through 1955 the calicivirus that causes vesicular exanthema of swine (VESV) was repeatedly introduced into domestic swine in California fed on raw garbage contaminated with the virus; the garbage component carrying the virus remained unknown (*2-4*). In 1972, caliciviruses were isolated from California sea lions (*Zalophus californianus*) and this species was thought to be the reservoir for VESV (*5*). Later, northern fur seals (*Callorhinus ursinus*) and northern elephant seals (*Mirounga agustirostris*) were also shown to shed caliciviruses (*6, 7*).

There are 25 serotypes of calicivirus including the one serotype of feline calicivirus; 22 of these serotypes have been isolated in southern California (*8, 9*). This suggests that California is a possible focus for calicivirus activity, and we have argued that fish are a logical calicivirus reservoir (*4*). One fish, the opaleye, is the intermediate host for the sea lion lung worm (*Parafilaroides decorus*) and thus has a well-established relationship with the California sea lion (*10*).

Fish (*G. nigricans*) were collected from tidal pools on San Nicholas Island (off the southern California coast) and examined for virus. Tidal pools estimated to contain 200 to 1000 liters of water were seeded with up to 500 ml of quinaldine (*11*) diluted 1:10 with isopropyl alcohol. Within minutes the fish could be caught by hand or dip net and transferred to untreated seawater where they quickly regained their coordination.

Each fish (10 to 15 cm long) was eviscerated and the whole viscera were placed into individual Whirl-Pac plastic bags (*12*), frozen on dry ice, transported to the laboratory, and stored at −70°C. Thirty fish were processed in this way and an additional 15 were processed as follows. The major organs (liver, spleen, kidney, gut, muscle, and gills) were sampled individually from each fish and placed in separate 2-dram vials containing 2 ml of cell culture media with 10 percent fetal bovine serum. These were sealed and frozen on dry ice. Later all tissue samples were ground in a mortar with sterile sand and cell culture media,

Table 1. Serotyping of marine calicivirus isolates by means of virus neutralization test. In each test 100 $TCID_{50}$ of virus were reacted against 20 antibody units of typing serum. Symbols: +, neutralization occurred; −, unneutralized virus leading to a cytopathic effect in the cell monolayers at 72 hours. All typing serums were of rabbit origin.

Virus	Antiserums										
	SMSV-1	SMSV-2	SMSV-4	SMSV-5	SMSV-6	57-T	Gn-14	Gn-26	2837	2839	Fluke
SMSV-1	+	−	−	−	−	−	−	−	−	−	−
SMSV-2	−	+	−	−	−	−	−	−	−	−	−
SMSV-4	−	−	+	−	−	−	−	−	−	−	−
SMSV-5	−	−	−	+	−	−	−	−	−	−	−
SMSV-6	−	−	−	−	+	+	+	−	−	−	−
57-T*	−	−	−	−	+	+	+	−	−	−	−
Gn-14†	−	−	−	−	+	+	+	−	−	−	−
Gn-21‡	−	−	−	−	−	−	−	+	+	+	+
Gn-26‡	−	−	−	−	−	−	−	+	+	+	+
2816§	−	−	−	−	−	−	−	+	+	+	+
2837§	−	−	−	−	−	−	−	+	+	+	+
2839§	−	−	−	−	−	−	−	+	+	+	+
2844§	−	−	−	−	−	−	−	+	+	+	+
Fluke¶	−	−	−	−	−	−	−	+	+	+	+

*Throat swab of a 4-month-old northern fur seal pup bearing tag No. 57 sampled on San Miguel Island in October 1977. †Isolated from the spleen of *G. nigricans* No. 14 taken on San Nicholas Island, California, in February 1977. ‡Isolated from whole viscera homogenate of opaleye Nos. 21 and 26 taken on San Nicholas Island, California, in February 1976. §Tag numbers of northern elephant seal pups sampled on San Miguel Island in February 1976. ¶Trematode of the genus *Zalophatrema* from a sea lion dying of verminous pneumonia (*23*).

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