tuitary (*16*). In the present study, the pituitary was the only structure that showed differences in the content of endogenous opiate substances. We assume that the potent effect of naloxone in the abolition of overeating in obese mice and rats is mediated by the antagonism of this material released from the pituitary. If release of excess amounts of β-endorphin from the pituitary is involved in chronic overeating in the obese rodents, a logical target for this action is the opiate receptors in the gastrointestinal tract. Opiate receptors in the ileum, which have been characterized extensively both pharmacologically (*17*) and biochemically (*18*), mediate the pharmacological effects of opiates in suppressing gastrointestinal motility. However, very little is known of their normal role in the gut (*19*).

Our studies suggest that a physiological role may exist for the gastrointestinal opiate receptors in the control of feeding behavior. We cannot rule out the possibility that central opiate receptor sites also participate in the naloxone-induced abolition of overeating. We have shown that a relationship between β-endorphin and obesity occurs in at least two different species and may thus have considerable generality.

β-Endorphin acts on the pancreas to stimulate the release of insulin (*20*). These results are compatible with our findings. Thus, excess pituitary β-endorphin may cause another major physiological system, the endocrine pancreas, to contribute to the overeating and obesity syndrome.

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Conservation of Liquid and Solid Quantity by the Chimpanzee

Abstract. *Sarah, an adult "language"-trained chimpanzee, made accurate same-different judgments on quantities of liquid and solid matter and conserved both types of quantity despite a transformation in an irrelevant property (shape). Control tests showed that she judged on the basis of inference rather than perceptual evaluation of the quantities. She failed to make accurate same-different judgments on the basis of number, and she was not tested for conservation of this type of quantity.*

Piaget's classic tests of conservation (*1*) provide dramatic evidence for a developmental change in human cognition. In perhaps the best-known version of the test, the subject is presented with two identical containers filled with equal amounts of liquid and asked to judge the relation between the two quantities. Even the very young child can judge accurately that they are "the same" or "equal." However, transforming an irrelevant property of one quantity (for example, by pouring the contents of one container into another of different proportions, thereby changing the shape of the liquid) reveals a change with age in the subject's response. The young child reports incorrectly that the two containers hold different amounts: one container (typically, the one with the tallest column of fluid) has "more" than the other. The older child continues to judge accurately that the two amounts remain equal—he "conserves" liquid quantity despite a transformation in a vivid, though irrelevant, property.

According to one major theory, the ability to conserve marks the passage from one level of human intelligence (the preoperational stage) to a qualitatively different, more sophisticated level (the concrete operational stage). Conservation demands that the child not be misled by appearance: accurate judgments depend on knowledge or inference. Consequently, much research has been concerned with the conceptual and inferential processes underlying conservation and with finding ways to accelerate the developmental change from one level of intelligence to the next (*2*). However, the limits of the phenomenon remain largely unexplored. Are humans the only animals that ultimately conserve? Evidence for conservation in a nonhuman species could have important implications for our understanding of the cognitive prerequisites for conservation judgments, as well as for comparative theories of intelligence. We report here the results of conservation tests on liquid and solid quantity administered to a nonhuman primate, a chimpanzee.

The subject was Sarah, an African-born female chimpanzee (*Pan troglodytes*), approximately 14 years old. She was obtained by the laboratory when less than 1 year old and taught a simplified language between the ages of 4 years 6 months and 6 years 5 months.

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Table 1. Number of correct "same" and "different" judgments per total trials of each type in tests with liquid and solid quantity and with number. Probabilities were computed with the normal approximation to the binomial distribution.

Test	Liquid		Solid		Number	
	Equal ("same")	Unequal ("different")	Equal ("same")	Unequal ("different")	Equal ("same")	Unequal ("different")
Prestest	19/24†	22/24‡	20/24†	18/24*	10/24	12/24
Conservation A	21/24‡	17/24*	20/24†	19/24†		
Control	9/24	16/24	10/24	15/24		
Conservation B	19/24†	21/24‡	18/24*	17/24*		

*$P < .05$. †$P < .01$. ‡$P < .001$.

For the past 10 years she has been given five lessons per week on a variety of cognitive tasks (3). The present tests were based on her knowledge of two plastic "words" from her original vocabulary, "same" and "different" (4). By using same-different judgments, our test for the ape subject was made analogous to that employed with the human child. Judgments of "equal" (or here, "same") versus "more than" or "less than" (or here, "different") are the primary data from which conservation is inferred. However, the human test also employs further verbal interrogation of the subject (5), in order to ensure that responses are based on inferential reasoning rather than on alternate response strategies. Our test for the ape was necessarily nonverbal throughout and was designed with several control features of a different kind.

First, in the human test, the quantities to be judged are usually equal, and therefore the correct answer is always "same" or "equal." In contrast we included trials with both equal and unequal quantities, such that "same" and "different" were correct equally often. This design prevented successful performance on the basis of a response bias to "same," or simply learning to respond "same" on all trials (6).

Second, the human test requires two judgments on each trial, one before and another after the transformation of one quantity. We required only one response on each trial, since judgments before and after the transformation were obtained in separate tests administered on different occasions. This procedure obviated successful performance on the basis of a simple response-repetition strategy.

Third, appropriate verbal justification for conservation judgments can assure the experimenter that the human subject's responses are not based solely on perceptual estimation of the quantities after transformation. We included a control test of the ape's ability to judge quantities after transformation, without allowing it to see the initial condition of the quantities or the transformation performed on one of them. If the subject could judge the equality of two quantities after the transformation simply by looking at them—and thus succeeded on control trials—there would be no grounds for a claim of inference. Alternatively, if the subject failed on control trials, but succeeded when shown the quantities both before and after the transformation, conservation judgments could not be made on perceptual grounds alone, but would require inference (7).

Finally, verbal prompts and questions by the experimenter can ensure that the human subject's correct conservation judgments do not result from a failure to attend to the transformation and its effects on one quantity. We included a second type of conservation test which assessed the subject's ability to discriminate a relevant from an irrelevant change in one quantity. On some trials, the transformation produced a change in shape, but not amount (the standard conservation manipulation), and on other trials, the transformation produced a change in both shape and amount (by ad-

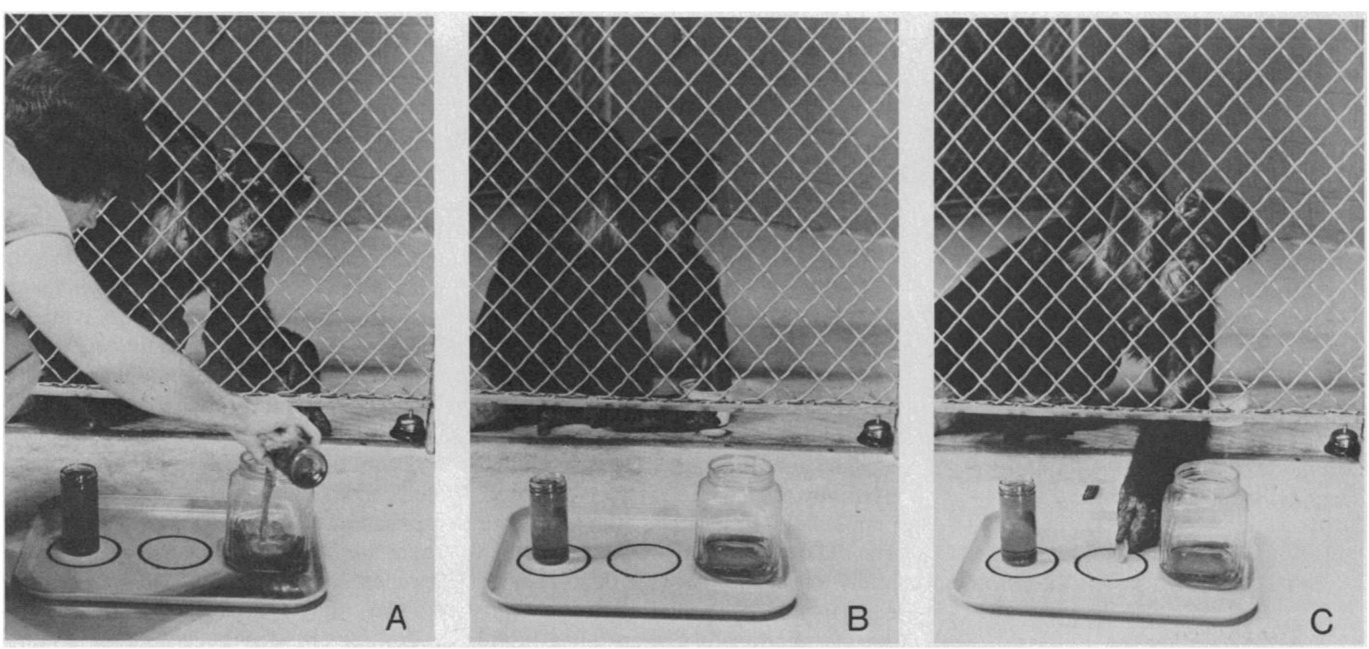

Fig. 1. The essential steps during a conservation test trial with equal liquid quantities. The trainer first showed Sarah two equal quantities of blue water in narrow jars. (A) Sarah watches the trainer pour the contents of one jar into another of different proportions. The trainer then handed Sarah the covered dish containing two plastic words ("same" and "different"), and left the room. (B) Sarah opens the dish in the absence of the trainer. (C) Sarah has removed both words from the dish, and now places the plastic word "same" in the center circle of the tray, between the exemplars. The word "different" may be seen on the floor, at a distance from the tray. In this case, Sarah's response "same" was correct. Although on this trial Sarah removed both words from the dish before choosing one of them, on other trials she removed only one of them.

dition or subtraction of material to or from one exemplar).

We arranged tests for conservation of liquid and solid quantity and number. Exemplars were cylindrical glass jars of three sizes (13 by 5.5, 15 by 8, and 17 by 14 cm) containing various amounts of blue water for tests on liquid quantity; pieces of red modeling clay formed by hand into cylindrical shapes of three sizes (2 by 2, 5 by 3, and 7 by 4 cm) for tests on mass; and rows of 2, 3, and 5 white buttons, each 1.9 cm in diameter, for tests on number. In all tests for each quantity, two of the three exemplars were presented on a 36 by 46 cm tray at the beginning of each trial. Three circles, each 11 cm in diameter, were drawn in a row on the tray. The exemplars were centered inside the left and right circles, approximately 25 cm apart. The trainer placed the tray just outside Sarah's cage on the floor and called her attention to the test material. When called for by the procedure, he then performed a transformation on one of the exemplars. Finally, the trainer handed Sarah a covered dish containing the plastic words "same" and "different," left the room, and closed the door. The subject was required to open the dish, select one word, and place it in the center circle on the tray. She then summoned the trainer by ringing a bell. The trainer entered the room at the sound of the bell, examined the tray, and said "That's good, Sarah." Thus, the subject responded in the absence of the trainer, a procedure we use routinely to control for social cues (*8*), and without differential feedback for correct or incorrect answers. At the end of each session, Sarah was given yogurt, fruit, or candy.

The experiment consisted of four cycles of testing. In the first cycle, we presented a series of three tests (pretest, conservation test A, and control test, in that order) on liquid quantity, then solid quantity, and finally number. However, the series for number was terminated after the pretest, for reasons we will discuss. The second cycle was a replication of the first. In the third cycle, we presented conservation test B on liquid and then solid quantity. The final cycle of testing was a replication of the third.

Pretest. The first test for each quantity required same-different judgments on two exemplars without transformation. For tests on solid quantity and number, the three standard exemplars appeared equally often and the position of each exemplar on the left or right of the tray was counterbalanced across trials. All possible combinations of two of the three exemplars were presented equally often in quasi-random order. For tests on liquid quantity, the two exemplars on each trial were identical glass jars containing blue water, and the three pairs of jars were presented equally often across trials. The two jars contained identical amounts of water on half the trials, and amounts differing in height by at least 5 cm on the other half of the trials. Each pretest consisted of 24 trials, 12 each with equal ("same" correct) or unequal ("different" correct) quantities, presented in quasi-random order.

Conservation test A. The second test for each quantity was identical to the first, with the following exceptions. The trainer placed two exemplars on the tray and called Sarah's attention to his subsequent actions. He manually transformed one exemplar, either by pouring the water into a jar of different proportions, or by manipulating the piece of clay. (A test for conservation of number was not administered.) His actions on half the trials of each type may be described as "compression" of one exemplar, and on the other half, "expansion." On trials with exemplars of equal quantities, the transformation produced an appearance of difference. The fluid columns differed in height and diameter, and the pieces of clay differed in length and diameter. On trials with exemplars of unequal quantities, the transformation produced an appearance of equality on one salient dimension. The fluid columns were identical in height, and the pieces of clay were equal in length. After performing the transformation and again calling Sarah's attention to the test material, the trainer handed the subject the covered dish containing answers, and trial events proceeded as before. During the course of the tests, each exemplar was compressed or expanded equally often, and the position of the changed exemplar on the left or right of the tray was counterbalanced across trials. Figure 1 shows an example of the essential steps in the procedure with liquid quantity.

Table 2. Longest run of consecutive correct responses per total trials to the end of the run in each test with liquid and solid quantity with number. Probabilities were computed with Grant's "runs" test (*15*).

Cycle	Liquid	Solid	Number
	Pretest		
1	14/14‡	5/12	4/4
2	9/23*	7/14*	2/2
	Conservation A		
1	7/7*	13/17‡	
2	10/21†	7/15*	
	Control		
1	3/4	2/17	
2	4/19	4/16	
	Conservation B		
3	13/22‡	8/8†	
4	13/24‡	8/17*	

$^*P < .05$. †$P < .01$. ‡$P < .001$.

Control test. The third procedure was the same as that described for conservation test A, with one exception. The trainer placed the exemplars on the tray in a room adjacent to Sarah's, and performed the usual transformation out of her view. He then entered her room and tested her as before. She was required to make exactly the same judgments as in conservation test A, but without having seen either the initial condition of the exemplars or the transformation performed on one of them.

Conservation test B. The final test required that the subject discriminate a relevant from an irrelevant transformation of one quantity. All trials began with equal quantities and involved a transformation of one of the exemplars. On half the trials, the trainer performed the standard manipulation described in conservation test A; he manually changed the shape, but not amount, of liquid or clay. On the remaining trials, the trainer produced an actual change in the quantity of one exemplar. He performed the standard transformation of shape, and at the same time, added or subtracted a small amount of liquid or clay. During addition or subtraction, material was exchanged between the exemplar and a small opaque cup present in the test room. After performing the transformation on all trials, the trainer handed Sarah the covered dish containing answers, left the room with the cup, and testing proceeded as before. Thus, half the trials involved a transformation of shape, but not amount ("same" correct), and half the trials involved a transformation of both shape and amount ("different" correct). All other aspects of the procedure were the same as those described for conservation test A.

For liquid quantity, Sarah made accurate same-different judgments on both equal and unequal quantities in the pretests, and continued to make accurate judgments when one exemplar was transformed in conservation test A (Table 1). Performance exceeded chance level on both "same" and "different" trials, and thus a response bias cannot explain the results. In contrast, her accuracy fell dramatically in the control test, especially on "same" trials (*6*), and comparison of control and conservation A scores on "same" trials revealed that her accuracy was significantly greater in the conservation test ($z = 3.58$, $P < .001$). Thus, her success in the conservation test cannot be attributed to an ability to perceptually evaluate equal quantities after the transformation. Performance also exceeded chance level on both "same" and "different" trials in conservation test B (Table 1). These results show not only that the subject in fact attended to the transformation, but that she could discriminate a relevant (change in shape and amount) from an irrelevant (change in shape) transformation. Finally, the data reveal significant "runs" of correct responses during each pretest and conservation test, but not during control tests (Table 2). Taken together, these data provide strong evidence for conservation of liquid quantity on the basis of inferential reasoning (*9*).

The results for solid quantity were comparable to those for liquid quantity. Sarah made accurate same-different judgments in the pretests and both conservation tests A and B, but not during control tests (Table 1). Comparison of control and conservation A scores on "same" trials revealed that her accuracy was significantly greater in the conservation test ($z = 2.98$, $P < .01$). Finally, Sarah showed significant "runs" of correct responses in all but the first pretest and both control tests (Table 2).

Sarah's success on tests with liquid and solid quantity was not repeated on tests with number. She failed to make accurate judgments on either equal or unequal quantities in both pretests (Table 1), showed no significant "runs" of correct responses (Table 2), and was not tested further for conservation of number.

While these results show that the chimpanzee, like the human child, is capable of making inferences in conserving liquid and solid quantity, they do not identify the nature of those inferences. The child generally offers one (or more) of three types of argument (*10*) to justify his answers: (i) identity (for example, the liquid is still the same, nothing has been added or removed), (ii) reversibility (for example, pouring the liquid back into the original container will restore its original appearance), and (iii) compensation (for example, when height is increased by pouring the liquid into a narrower container, width is decreased, and the composition of the two changes leaves quantity invariant). Whether or not Sarah can reason in all of these ways would depend upon further nonverbal tests of a different kind. However, at least the primitive identity argument is needed to account for her performance here. As shown by the control tests, she failed to judge accurately when shown equal exemplars only after the transformation, but succeeded in conservation test A when shown the exemplars both before and after the transformation. In the latter case, correct judgments required that the subject discount an appearance of difference, relate the changed exemplar to its initial condition, and note that there was no actual change in quantity. Moreover, when the transformation in fact did produce a change in quantity in conservation test B, Sarah noted the change and responded "different" on appropriate occasions.

Sarah's failure to make initial same-different judgments on number is compatible with other data (*3*, *11*), which shows that number is less salient than other dimensions for the chimpanzee. In contrast, number is highly salient for the human child (*12*), and indeed, number conservation is generally acquired before conservation of the other quantities (*1*). Our results suggest that the range of quantities conserved by chimpanzee may be more restricted than that for humans, and thus the developmental course of conservation acquisitions may differ across the two species.

Although number was not salient for Sarah, liquid and solid quantity were, as shown by the pretest data for both liquid and solid quantities. Sarah's same-different judgments on equal and unequal liquids and solids were accurate from the beginning, and they were so without differential feedback or any form of pretraining. Thus, Sarah spontaneously responded to quantity of the liquids and solids, as opposed to color of the water or clay, shape of the containers, or other irrelevant properties. Of course, many species other than humans and chimpanzees readily learn to discriminate quantities of liquids and solids, such as food and water (*13*), and it may be possible to conduct further comparative research to determine the species-generality of conservation (*14*).

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4. Sarah had had extensive previous experience with same-different judgments of perceptual relations between objects and pictures, and of semantic relations (such as synonymy) between plastic-word sentences (*3*). This experiment involved her first exposure to same-different judgments on quantitative properties.
5. In a few instances, nonverbal tests have been developed for the human child. For example, P. Mounoud and T. G. R. Bower [*Cognition* **3**, 29 (1974/1975)] report evidence for conservation of weight inferred from the behavior of human infants as young as 18 months of age.
6. A claim for conservation by inferential reasoning must rest solely upon performance on trials with equal quantities, however. Two quantities that are in fact the same can be made to appear different, and a correct "same" judgment after transformation demands that the subject discount appearance (different) and rely on inference (same). For example, if two quantities of liquid are equal at the start of a trial, a transformation in shape produces a difference in both height and width; thus, a correct "same" judgment would be difficult, if not impossible, on the basis of perceptual evaluation alone. On the other hand, two quantities that are in fact different cannot be made to appear exactly the same. For example, if two quantities of liquid differ in height at the start of a trial, a transformation which equalizes height must produce a difference in width; thus, a correct "different" judgment after transformation could be made simply by perceptual evaluation of the widths of the exemplars alone.
7. Without the possibility for verbal justification of answers, this type of control is especially important for teasing apart the roles of direct perceptual judgments versus judgments based on inference in conservation tests with nonhuman subjects. Thus, R. K. Thomas and L. Peay's [*Dev. Psychol.* **12**, 349 (1976)] interesting report of conservation of length in a nonhuman primate (*Saimiri sciureus*) does not require an interpretation in terms of inferential reasoning, because their procedures lacked such controls.
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9. Although trials with unequal quantities were included in our tests principally as a control for response bias (*6*), the data from these trials proved of added interest. In the pretests, unequal quantities differed in height (liquid) or length (solid), whereas in control tests, unequal quantities differed in width. Sarah's accuracy in judging exemplars of different heights in the pretests was greater than that for exemplars of different widths in the control tests (Table 1), although the difference in her scores achieved statistical significance only for the case with liquid quantity ($z = 2.13$, $P < .05$). This aspect of the data is in keeping with results from human children, who also show a bias toward judgments based on height or length as opposed to width.
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11. Chimpanzees can judge numerosity but show limitations not seen in children. For instance, Viki, a home-reared chimpanzee, matched three to three (versus four), but was unable to repeat the number of finger taps from one to four. Sarah also matched numerosities, up to a limit of four to four (versus five), but inconsistently, succeeding in some periods, failing in others; she was not inconsistent in judging liquid or solid quantities. Similarly, Sarah learned to do generalized one-to-one correspondence, a putative precursor of counting, but only after weeks of training; 3-year-old children acquire this in one session. K. J. Hayes and C. H. Nissen, in *Behavior of Nonhuman Primates*, A. M. Schrier and F. Stollnitz, Eds. (Academic Press, New York, 1971), vol. 4, pp. 59–115.
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