Table 1. Reactivity of saline extract of *Saxidomus giganteus* with the red blood cells of 27 randomly selected donors.

Phenotype of donors	Samples tested with clam extract (No.)		
	Total	Positive	Negative
A_1	8	8	0
A_1B	2	2	0
A_2	3	0	3
B	4	0	4
O	10	0	10

Table 2. Absorption studies with saline extracts of the butter clam *Saxidomus giganteus* and red cells of various blood groups. Test cells were of blood group A_1.

Absorption at various dilutions of extract				
1:1	1:2	1:4	1:8	1:16
		Unabsorbed		
4	4	4	1	–
		Group A_1		
–	–	–	–	–
		Group A_1B		
–	–	–	–	–
		Group A_2		
4	–	–	–	–
		Group B		
4	4	4	1	–
		Group O		
4	4	4	–	–

the clam extract on all five occasions. The agglutinin appears specific, therefore, for a blood factor associated with the A_1 agglutinogen.

Absorption studies were carried out to elucidate the specificity of the agglutination. One volume of packed, washed red cells was mixed with three volumes of undiluted clam extract in 10 by 75 mm tubes and incubated at room temperature for 30 minutes. The supernatant obtained by centrifugation of the absorbed clam extract at 2500 rev/min for 10 minutes was tested against A_1 cells. Results from absorptions with cells of phenotypes A_1, A_1B, A_2, B, and O are presented in Table 2. Cells of groups A_1 and A_1B completely absorbed the agglutinin, while under the same conditions A_2 cells partially absorbed the agglutinin. Cells of blood groups B and O had no effect on the agglutinin. The absorptions support the data in Table 1. The partial absorption of the clam agglutinin by A_2 cells suggests, however, a structural similarity of the clam receptor on A_1 cells, with some chemical grouping on A_2 cells, even though A_2 cells were not clumped by the agglutinin.

In an effort to ascertain something of the chemical nature of the receptor for the clam agglutinin, inhibitions with various saccharides were carried out. The following saccharides were tested in 2000-μg amounts, contained in 0.1 ml, against 0.1 ml of undiluted clam extract; *d*-glucose, *d*-fructose, *d*-mannitol, dulcitol, maltose, *d*-melibiose, *d*-lactose, α-methyl-*d*-glucose, *1*-rhamnose, sucrose, *d*-xylose, raffinose, trehalose, salicin, *d*-galactose, *d*-mannose, *1*-arabinose, *d*-galactoseamine, *d*-glucoseamine, *N*-acetyl-*d*-galactoseamine, and *N*-acetyl-*d*-glucoseamine. Only *N*-acetyl-*d*-galactoseamine and *N*-acetyl-*d*-glucoseamine inhibited the agglutination of A_1 cells by the saline extract of the clam, which suggests that these sugars are associated with the receptor for the clam agglutinin.

The clam agglutinin was nondialyzable and is thus probably a large molecule. The agglutinin was inactivated when the clam extract was heated at 70°C in a water bath for 20 minutes and may, therefore, be a protein.

Preliminary studies on the anatomical location of the agglutinin have indicated that it is present in saline extracts of siphons of *Saxidomus giganteus* at about the same titer as in the whole clam extract. This observation suggests that the agglutinin is not partially digested residual food materials of the clam gut. In addition, since the clams were collected from unpolluted waters and were washed and frozen immediately after harvesting and kept frozen until examined, the possibility that the agglutinin results from microbial growth or microbial degradation of clam tissues appears unlikely. Certainly another potential source of agglutinins for red cell isoantigens has been demonstrated.

HOWARD M. JOHNSON
Milk and Food Research,
Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

References and Notes

1. W. C. Boyd, *Vox Sanguines* **8**, 1 (1963).
2. J. E. Cushing, N. L. Calaprice, G. Trump, *Biol. Bull.* **125**, 69 (1963).
3. R. T. Abbott, *American Seashells* (Van Nostrand, Princeton, N.J., 1964), p. 417.
4. The clams in this study were being used in the study of the haptenic properties of paralytic shellfish poison, a potent toxin produced by the dinoflagellate, *Gonyaulax catenella*, and concentrated in certain bivalves that use *Gonyaulax* as a food source. The clams used were not contaminated with the toxin.
5. The clams were sent by Dr. A. K. Sparks, University of Washington, Seattle, to Earl McFarren, of the Robert A. Taft Sanitary Engineering Center. I obtained them from McFarren.
6. Blood supplied by the Blood Bank, Cincinnati General Hospital.

31 August 1964

Complex Visual Concept in the Pigeon

Abstract. *Pigeons were trained to respond to the presence or absence of human beings in photographs. The precision of their performances and the ease with which the training was accomplished suggest greater powers of conceptualization than are ordinarily attributed to animals.*

It is well known that animals can use one or a few distinguishing features to discriminate stimuli such as simple visual arrays differing in size, shape, or color. In the experiment described here, however, pigeons were trained to detect human beings in photographs, a class of visual stimuli so diverse that it precludes simple characterization.

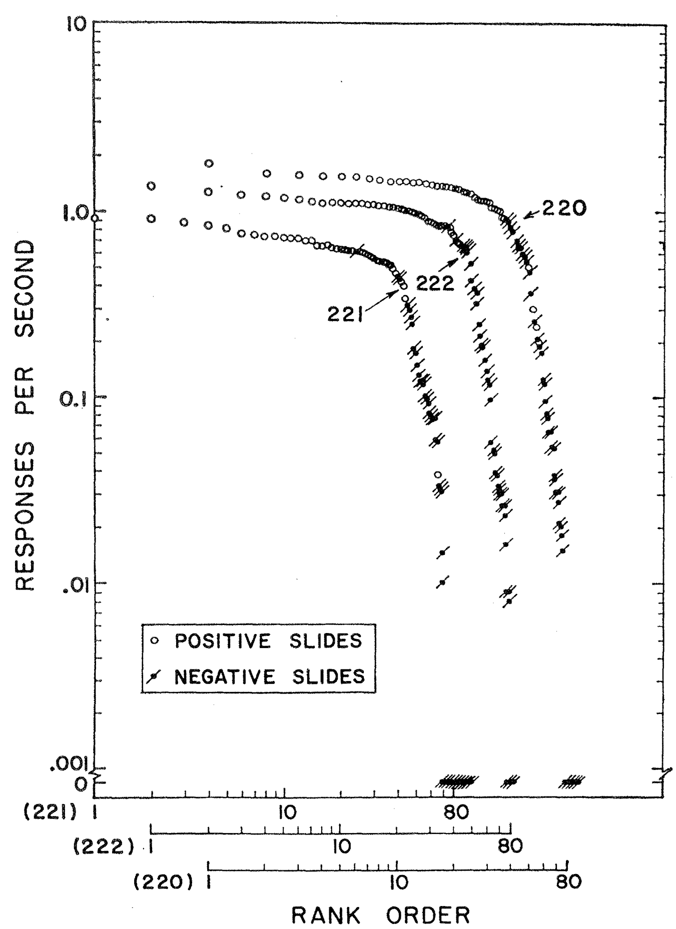
Five male racing (homing) pigeons between 1 and 2 years of age were obtained from a local breeder. Apart from the likelihood that they had been housed in outdoor coops, nothing was known about their past histories. All five were given approximately the same training and all performed similarly.

The pigeons were first fed on a minimal diet until their weights fell 20 percent. They were then fed enough food to maintain them at the reduced weights. Once a day each bird was placed in a box containing a hinged switch mounted on a wall next to a 5 cm by 5 cm translucent plate and a feeding device. During the first few sessions, the pigeons were trained to eat from the feeding device each time it was operated, when food was made available for approximately 3 seconds. Next, the pigeons were taught to peck at the hinged switch to trigger the feeder. At first, every peck at the switch operated the feeder, but, after two sessions, the procedure was changed so that pecks were effective only once a minute, on the average. An intermittent schedule of reward of this type produced relatively steady behavior, with little satiation of hunger. As a final stage in the preliminary training the pigeons were taught that only when the translucent plate next to the switch was illuminated with a uniform white light were pecks effective, but still only intermittently. When the plate was dark, pecks were entirely ineffective. The illumination changed randomly in time, averaging a change a minute, with the sole reservation that the onset of illumination could not take place within 15 seconds of the occurrence of a peck. In just a few sessions, the pigeons learned to peck when the plate was lit and not to peck when it was dark.

In the terminal procedure, the plate was illuminated throughout each session with projections of 35-mm color slides from a projector that housed 81 slides and that could be advanced by an electrical pulse. Over 1200 unselected slides obtained from private and commercial sources were available. Before each session, the projector was loaded with 80 or 81 different photographs of natural settings, including countryside, cities, expanses of water, lawn, meadow, and so on. For any one session, approximately half the photographs contained at least one human being; the remainder contained no human beings—in the experimenter's best judgment. In no other systematic way did the two sets of slides appear to differ. Many slides contained human beings partly obscured by intervening objects: trees, automobiles, window frames, and so on. The people were distributed throughout the pictures: in the center or to one side or the other, near the top or the bottom, close up or distant. Some slides contained a single person; others contained groups of various sizes. The people themselves varied in appearance: they were clothed, semi-nude, or nude; adults or children; men or women; sitting, standing, or lying; black, white, or yellow. Lighting and coloration varied: some slides were dark, others light; some had either reddish or bluish tints, and so on.

With the difference that pictures containing people now meant an opportunity to feed and that pictures without people meant no such opportunity, the procedure remained unchanged. Each day the slides themselves, and also the random sequence of positive slides (that is, containing a person) and negative slides (without people), were changed for each pigeon. Many slides were used again in later sessions, but never in the order with other slides in which they had appeared earlier. The pigeons had no opportunity, therefore, to learn groups of particular slides or sequences of positives and negatives in general.

The first test for a concept based on the image of a human being is simply whether a pigeon pecks at different rates in the presence of positive and negative slides. By this criterion, all five pigeons showed some grasp of the concept within seven to ten sessions with the pictures, but performances continued to improve with training over a period of months. Figure 1 shows a typical day's performance, with 80 or 81 totally new slides, by three pigeons after approximately 70 sessions of training. The rate of pecking in the presence of each slide was calculated. The rates were then ranked, and are plotted against their ranks on log-log coordinates. The three functions are displaced along the abscissa to facilitate inspection. Slides containing at least part of a person appear as open circles; slides without



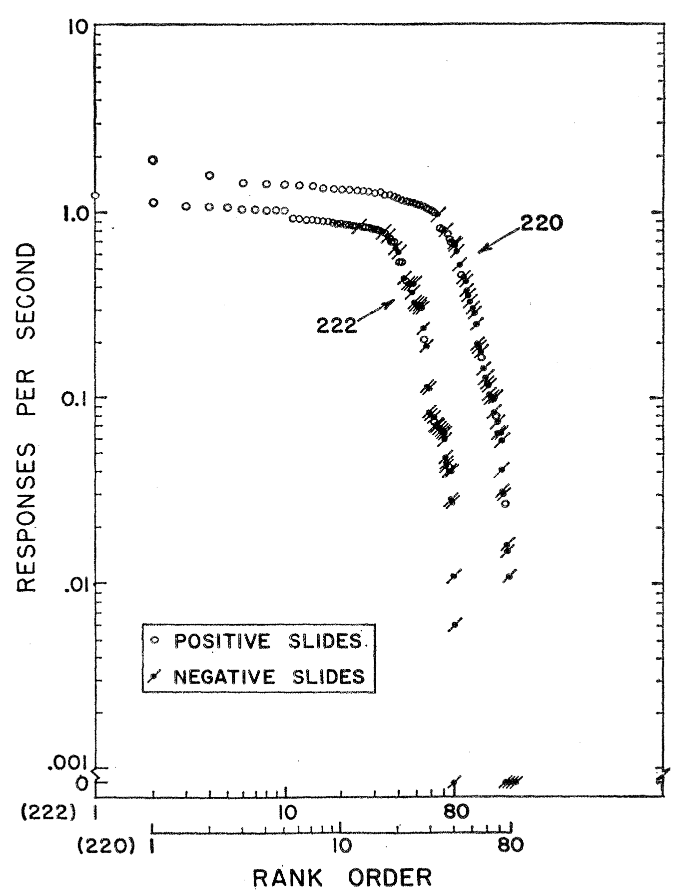


Fig. 1 (left). Rate of pecking in the presence of each picture as a function of the rank order of the rate, on logarithmic coordinates; 35-mm color transparencies were used. Open circles represent pictures containing people; closed circles pierced by a line, pictures without people. A 1-day session is shown for each of three pigeons, with the abscissas displaced as indicated. Fig. 2 (right). One-day sessions for two pigeons looking at black and white pictures.

people, as closed circles pierced by a line. The evidence for a concept is incontrovertible: the probability of obtaining by chance a set of ranks with such a degree of separation between positives and negatives is exceedingly small. The performances of the two pigeons not shown here were equally convincing.

Although the pigeons were undoubtedly responding to something closely associated with people in the pictures, it remains to be shown that it was the visual array that we would ourselves call a person. It could be that the results arose from some trivial and unsuspected visual clue in the slides, or from some nonvisual property of the procedure. To check the possibility of some correlation between the presence of a human being and color distribution in the slides, a set of slides was reproduced in black and white. Figure 2 shows the results obtained for two pigeons with black and white slides. Despite a slight deterioration in discrimination, the behavior was still unmistakably selective. To test the possibility that the pigeons were reacting to some nonvisual aspect of the procedure, a session was conducted in which half the positive slides were treated as if they were negative and half the negative slides as if they were positive. That is to say, the apparatus had a 50:50 chance of producing the wrong consequence when the pigeon pecked. Even under these contingencies, the pigeons reacted to the presence or absence of people. Numerous other simple tests have been performed, all suggesting that the pigeons were, in fact, looking for, and reacting to, images of people.

Additional evidence for the existence of the concept "person" lies in the nature of the errors made by the pigeons. For example, the pigeons sometimes failed to peck when the human being was severely obscured, and they occasionally pecked when the picture contained objects frequently associated with people, such as automobiles, boats, and houses. Both types of errors diminished greatly as training progressed. There were also, of course, a few errors that defied simple explanation.

The most plausible conclusion to be drawn from these results is not that the pigeons were taught the general concept "person" but that they were taught the particular features of the procedure, such as learning to eat from the feeder, learning how and when to peck at the disk, and, perhaps, learning to look at two-dimensional arrays. The speed with which their performances improved, coupled with the complexity and variety of even the first slides used, strongly suggests that they entered the experiment with the concept already formed. Whether the pigeons had learned the concept before they were subjected to the experiments, or whether they are in some way innately endowed with it, the present experiment does not reveal.

It has been the practice of most psychologists to use human beings to study conceptualization. The use of categories, which is the mark of a concept, is not only most evident in human behavior, but most easily explored in a creature that can talk. But no one would question the idea that animals can learn rules for sorting, and that they can generalize the rules to some extent, so that new objects are also sorted more or less correctly. Even in the study of instinctive behavior with animals low in the phyletic scale, there is abundant evidence for sorting and generalizing.

There has been reluctance to assume that the sorting done by human beings is of the same nature as that done by animals. Given the large difference in degree between the concepts of man and animals, a difference in kind has long seemed plausible. Man obviously sorts with pinpoint accuracy over classes involving indefinitely large membership and bewildering complexity ("even numbers," "elm trees," "grammatical sentences") and picks out new instances with ease and rapidity. Animals, on the other hand, have seemed to form concepts built on only limited critical properties ("red spot on the beak," "left turn in the maze") and have seemed hard-put to pick out new instances. The technical vocabulary itself suggests a basic difference: a human being is said to "conceptualize" or "abstract" when he sorts; an animal, to "discriminate." But, unless there is something extraordinary about the conceptual capacities of pigeons, our findings show that an animal readily forms a broad and complex concept when placed in a situation that demands one.

R. J. Herrnstein
D. H. Loveland

Psychological Laboratories, Harvard University, Cambridge, Massachusetts, and General Atronics Corporation, Arlington, Massachusetts

Note

1. Supported by a contract between the Limited War Laboratory, U.S. Army, and General Atronics Corporation, and by a NSF grant to Harvard University. We thank Dr. Max Krauss of the Limited War Laboratory for his interest and assistance.

21 July 1964

Circadian Leaf Movements in Bean Plants: Earlier Reports

Hoshizaki and Hamner (*1*), in presenting evidence for a circadian leaf movement which continues for 4 weeks in *Phaseolus* under constant conditions, say, "Nowhere in the literature is there a report of a persistent circadian leaf rhythm in higher plants." However, there are many such reports. The conditions which allow leaf movements to persist for several weeks in continuous light have been applied at Tübingen for many years, with several species of plants.

Pfeffer (*2*), who published nearly 700 pages on diurnal leaf movements between 1875 and 1915, described the persistence of leaf movements in *Phaseolus* for more than 4 weeks. Because of his special methods, elaborated over a 40-year period, he got even much clearer records. One of his figures has been reproduced more recently (*3*). Pfeffer's figures also clearly demonstrate the deviations from the exact 24-hour period, that is, the circadian nature of these persistent rhythms. Persistence of leaf movements in *Canavalia* in continuous light for several weeks was described in 1929 (*4*). Hoshizaki and Hamner measured a circadian period of about 26 hours; a period of 25.4 hours (*Phaseolus multiflorus*, continuous darkness) was measured in 1930 (*5*).

Erwin Bunning

Botanisches Institut, Universität Tübingen, Germany

References

1. T. Hoshizaki and K. C. Hamner, *Science* **144**, 1240 (1964).
2. W. Pfeffer, *Abhandl. math.-phys. Kl. K. Sächs. Ges. Wiss.* **34**, 1 (1915).
3. E. Bünning, *Handbuch der Pflanzenphysiol,* W. Ruhland, Ed. (Springer, Berlin, 1959), vol. 17, pt. 1, p. 634.
4. A. Kleinhoonte, *Arch. Nèerl. Sci. Exact. Nat.* **5**, 1 (1929).
5. E. Bünning and K. Stern, *Ber. Deut. Botcn. Ges.* **48**, 227 (1930).

13 July 1964