tities must involve the capillary constant. In the capillary rise method the abscissa might conveniently be y_0/x which is dimensionless, and the ordinate y_0x whose analogue involves the capillary constant a^2 and so the surface tension. This curve is independent of any determination of surface tension and is applicable to all liquids. By means of these three steps the Laplace equation is now expressed in a form suitable for application to the measurement of the surface tension of an unknown liquid. In the capillary height method this fourth step is the determination of one pair of corresponding values of the radius, r, of a capillary tube and the height, h, of the liquid in it. From these the ratio h/r may be calculated which is the analogue of and equal to y_0/x. From this value of h/r and from the curve, the corresponding value of y_0x is read off. This must now be expressed in terms of similar quantities which are not dimensionless and which involve the characteristics of the particular liquid we are working with; that is, we must put back the capillary constant in the Laplace equation. This is the equivalent of saying that the y_0x read from the curve is equal, in the case of a particular liquid, to hr/a^2. Thus, knowing the value of y_0x from the curve and the values of h and of r from the experiment, the value of a^2 can be calculated.

For a detailed description of this procedure reference may be made to our application of it to the ring method for the determination of surface tension.[1] The scheme may be applied rigorously to all methods involving only stable liquid surfaces of revolution. We have indicated its application to the capillary height, bubble pressure and sessile drop methods, which involve meniscus profiles; to the pull on a disk and a sphere, which involve disk profiles; to the ring method, which involves both meniscus and disk profiles, and to various drop shape methods which involve drop profiles. The convenient and precise drop weight method, involving as it does a dynamic condition, does not come under this scheme.[2] Thus a single theory for all those methods of determining surface tension using stable liquid surfaces of revolution has been developed. Wherever the calculations based on the theory have been compared with the results of experiment, agreement has been observed within the limits of precision of the particular experiment. All these methods, we think, may therefore be considered absolute ones.

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[1] SCIENCE, 71: 345, 1930; *Jour. Am. Chem. Soc.*, 52: 1772, 1930.
[2] *Jour. Phys. Chem.*, 33: 1217, 1929.

"RIGHT-HANDEDNESS" IN WHITE RATS[1]

THIS report[2] is concerned with the problem of left- and right-handedness. The problem is one of biological, pathological and psychological interest. Biologically, we are interested in the origin, evolution and heredity of bilateral asymmetry which is expressed functionally in hand preference. Pathologically, the problem is often related to speech defect, facial paralysis, epilepsy and feeble-mindedness. Psychologically, we are interested in the acquisition, retention and modification of hand preference.

Statistical studies show that in human beings there are about 95 per cent. who are right-handed, whereas only 5 per cent. prefer to use the left hand. The question immediately arises as to why it is that the great majority of people are right-handed. Up to the present time there have been about five hundred articles published by various scientists to answer the question, but the solution of the problem still remains a mystery. We know very little as to why some people are left-handed while others are right-handed —as little as we know why some of the stars in the sky rotate on their axes from left to right while others rotate in the opposite direction.

However, various theories have been advanced to account for the phenomenon of hand preference. One theory says it is entirely a matter of habit. Now if it were entirely a matter of habit, we should expect that chances are fifty-fifty. We know that habit is formed through repetition. Repetition of what? Repetition of the initial accidental chance fixation. Now we have two hands. And if handedness were entirely a matter of habit, without any organic, environmental or social influence, then it is statistically logical that chances are fifty-fifty. To illustrate, Tsai has studied the ways people clasp their hands. Each person has his habitual way of clasping the hands. Some people clasp their hands with the left thumb uppermost, while others clasp with the right thumb on top. He found that this has nothing to do with handedness, but that the results turned out to be fifty-fifty. This can be very well explained by the theory of habit, which does not seem to account for the fact that 95 per cent. of people are right-handed.

The next theory says it is a matter of social tradition. When we are young, we are ambidextrous—and experiments show that it is true up to the age of about six months. Then society steps in and says, "Thou shalt use thy right-hand!" So we were trained by our parents to be right-handed in handling the fork or the chop-sticks, as the case may be, in shaking hands and in doing a thousand other things. But why

[1] Read before the Midwestern Psychological Association, May 23, 1930.
[2] From the Otho S. A. Sprague Memorial Institute and the departments of pathology and psychology of the University of Chicago.

is it that our parents train us to be right-handed? Well, it is because they are right-handed. Why is it that they are right-handed? It is because their parents were right-handed. So the question is pushed back to the primitive people. Archeologists, by studying the direction of the grooves produced by the flaking of stone implements, have come to the conclusion that the great majority of the prehistoric men were right-handed. The question is, "Why?"

The theory of primitive warfare maintains that prehistoric man was essentially a fighting creature. And in fighting he used his right hand for attack, because the left hand was reserved for holding the shield to protect the heart which he thought to be on the left side of the body. This sounds very interesting. But why is it that there are 5 per cent. left-handed people who can never be trained to be right-handed? Is it because their hearts are on the right side of the body?

Perhaps the best-known theory seems to be that we are right-handed because we are left-brained. It has been pointed out, though not experimentally proved, that when a person is right-handed he is also, in a less marked degree, right-footed, right-eyed and right-eared. In other words, he is right-sided. Now, the movements of the right side of the body are controlled by the left side of the brain. So this theory holds that for the majority of people the left hemisphere of the brain is more highly developed. Now more highly developed in what sense? Is it anatomical, physiological or chemical? The relative size and weight of the two hemispheres have been compared, the microscopic structures of the brains have been examined, the normal arching of the aorta artery has been reversed, but no definite results have been obtained. So the problem is still unsettled. In this connection, we may mention that we have been doing some work in comparing the relative distribution of water in the two hemispheres. Although the preliminary data seem to correspond very closely to the percentage of handedness, we are not ready to draw any conclusion pending the further results of our investigation.

As to the evolution of handedness, nobody has ever published anything beyond the primates. Practically all the work has been done on human beings with a very few exceptions on higher apes and monkeys. The conclusions thus far have been that infra-human animals are all ambidextrous and that handedness is the outgrowth of human intelligence. To quote Parson, in his book, "Lefthandedness," the first sentence of Chapter VI runs, "Since no authentic traces of handedness have been found among animals, even among the Quadrumana, we are forced to the conclusion that whatever the immediate anatomical or physiological cause may be, handedness itself is probably in some way the outgrowth of man's intellectual development." Now we find that even such a low animal as the white rat exhibits definite hand preference. The discovery was made by Tsai early in February, 1929, and a technique was soon developed by him for this particular investigation. The animal was put in a wire cage with a small glass bottle of wheat embryo inserted through the wire bottom. The opening of the bottle was so small (¾ inch in diameter) that it permitted the rat to use only one hand at a time for grasping food out of the container. Since both the cage and the opening of the bottle were circular, there existed apparently no environmental situation tending to favor the use of either hand. Two hundred and fifty observations were made on each animal. They were distributed evenly over five days, with five series in a day. After each series, which consisted of the observation of ten consecutive hand movements, the animal was temporarily removed while the bottle was again filled up to the original level about half an inch from the brim. The criterion of handedness is that any rat using the left hand (or the right hand) from 75 to 100 per cent. of the total 250 attempts is considered to be left-handed (or right-handed as the case may be), while any rat using either hand from 50 to 74 per cent. of the total attempts is classified as ambidextrous. One hundred and fifty-nine rats have been thus studied. Among them, 105 were normal rats, while 54 were vitamin B depleted rats who suffered through the depletion of their mothers during the nursing period. The results for the normal rats are presented in Tables I and II.

TABLE I

HANDEDNESS IN NORMAL RATS

Handedness	Relative frequency in percentage	
	59 males	47 females
Right	59	43
Left	26	37
Ambidextrous	15	20

TABLE II

HANDEDNESS IN NORMAL RATS EXCLUDING AMBIDEXTERITY

Handedness	Relative frequency in percentage	
	Males	Females
Right	69	54
Left	31	46

The results show that the majority of normal rats of either sex are right-handed. This discovery throws light on the phylogenetic evolution of handedness and at the same time overthrows the theory of outgrowth of human intelligence, the theory of primitive warfare and the theory of social tradition.

As to the heredity of handedness, the results in the literature are conflicting. Most investigators maintain that if handedness is hereditary at all, it does not seem to follow the Mendelian ratio. In order to study ten generations of human beings, a few hundred years are required. But with our discovery, we can attack the very same problem with better control in a short time.

As to the pathological significance of the problem, let us cite the following investigations. L. G. Smith found that among 2,055 school children, 4.5 per cent. of the girls and 5.5 per cent. of the boys were left-handed. Out of 500 delinquent, 6 per cent. of the girls and 11 per cent. of the boys; out of 200 feeble-minded, 11 per cent. of the girls and 8.5 per cent. of the boys were found to be left-handed. R. Ganter also reports that 21.9 per cent. of the epileptics and 18.7 per cent. of the feeble-minded are left-handed. In an earlier investigation, we found that normal rats are far superior in maze learning to those which have been depleted of vitamin B complex through their mothers' diet during the nursing period. It is therefore of interest to find out the distribution of handedness among the vitamin B depleted rats. The results for the depleted animals are presented in Tables III and IV.

TABLE III

HANDEDNESS IN VITAMIN B DEPLETED RATS

Handedness	Relative frequency in percentage	
	27 males	27 females
Right	48	33
Left	48	45
Ambidextrous	4	22

TABLE IV

HANDEDNESS IN VITAMIN B DEPLETED RATS EXCLUDING AMBIDEXTERITY

Handedness	Relative frequency in percentage	
	Males	Females
Right	50	43
Left	50	57

Comparison of the results indicates that the percentage of left-handedness is higher in the vitamin B depleted animals whose maze-learning ability was found to be much inferior to that of the normal rats. These results do not necessitate the conclusion that the left-handed are mentally inferior. They merely indicate that the percentage of left-handedness is higher among the poor learners, and that's all. Perhaps when we study a group of geniuses, we may find that the percentage of left-handedness is also higher. Professor McCollum, of the Johns Hopkins University, suggested that we study the members of the National Academy of Sciences or the "Who's Who in America." Of course the left-handed person may or may not be a genius, but he has certainly proved to be a great star in the baseball game.

As to the psychological aspects of the problem, Tsai has studied the time required by the animal to change from the direct method of eating with mouth to the indirect method of eating "from-hand-to-mouth." Also he has studied the amount of time required by each animal for making fifty consecutive attempts of hand movements a day. Both results, when plotted against five successive days, represent the abrupt curves of negative acceleration. As to the retention of hand-preference, he found that rats practically use the same hand after a month's interval. As to the modification of hand preference, we have not done anything. However, the experiment can be very easily performed. First put a rat in the cage and find out whether he is left- or right-handed. If he is left-handed, the next time he uses his left hand again give him a mild electric shock. See how much training is required and how long he will continue to use the modified hand. Besides, modification may also be achieved by paralyzing the preferred hand either with drug or operation, and the changes be studied during and after recovery.

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