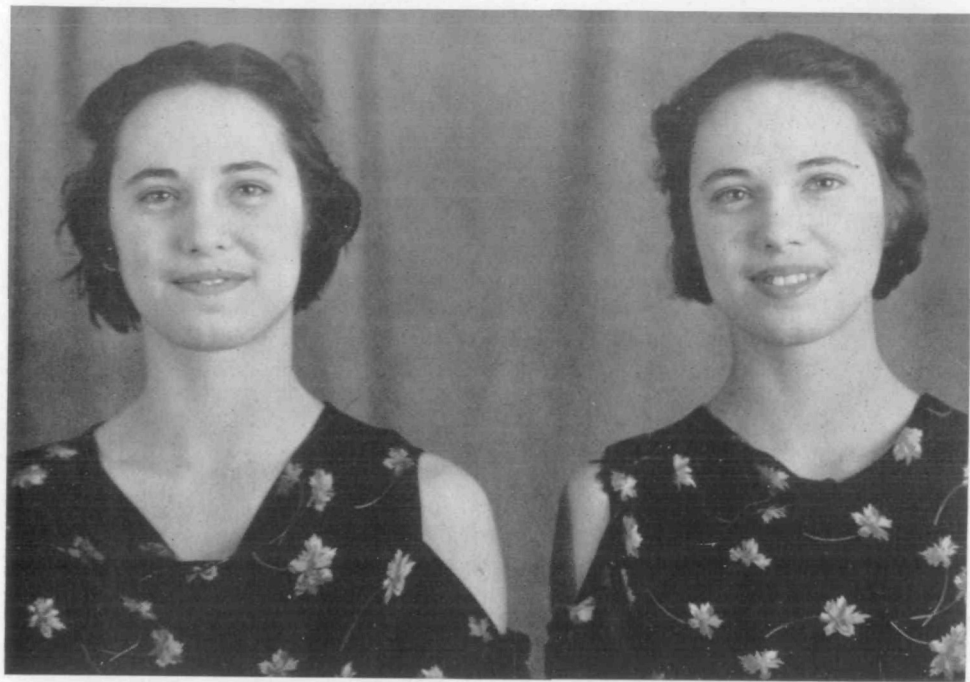


GENETIC STUDIES OF MONOZYGOTIC TWINS

III. Mirror-Imaging*

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MIRROR IMAGING IN EYE DOMINANCE

Figure 9

These twins are strikingly similar in mental and physical traits. Except in eye dominance they show no symmetry reversal. Eye dominance was the characteristic studied which most frequently showed a mirror-image relation. This is probably to be accounted for by the fact that the development of the eye is initiated at an early stage of embryonic development.

MIRROR-IMAGING in regard to direction of head-hair whorl and handedness is among the most interesting phenomena encountered in studies of monozygotic twins. In our investigations of twenty pairs of monozygotic twins, we have determined, whenever possible, the direction of head-hair whorl, handedness in both unimanual and bimanual operations, and eye dominance.

In Table I we have used the symbols *cl* to represent a clockwise, and *cc* to represent a counter-clockwise direction

of head-hair whorl. A double crown would be represented by *cc cc*, *cc cl*, or *cl cl*, according to the individual.

The observations of J. M. Rife⁶, later confirmed by Downey's² statistical survey of about fifteen hundred individuals, show impressively the value of studying both unimanual and bimanual performances, when investigating handedness. According to this classification, a person's dextrality type is shown by his handedness in respect to each of the following kinds of performances: Group 1—unimanual op-

*Prepared at the Genetics Laboratories of Ohio State University, under the supervision of Prof. L. H. Snyder.

erations; Group 2—bimanual operations in the following order: bat, golf club and ax; Group 3—spade, pitchfork, shovel and broom. Individuals who are right-handed in respect to all three types of performances are classified as *RRR*, if righthanded for Groups 1 and 2, and left-handed for Group 3, they are *RRL*, and if right-handed for unimanual operations and left-handed for all bimanual operations they are classed as *RLL*. Similarly, we find corresponding types of left-handed individuals: thus any individual may be classified under one of the following types of dextrality:

Right-handed	Left-handed
RRR	LLL
RRL	LLR
RLL	LRR
RLR	LRL

Most right-handed individuals are *RRL*. *RRL* and *LRL* individuals are extremely rare. In Table I, we have used the above system in classification of handedness.

The Parson Manoptoscope was used in the determination of eye dominance or eye preference (the eye used for sighting, looking through a microscope, etc., is not necessarily the stronger). In Table I, *R* represents right-eye dominance, *L* left-eye dominance, *RL* and *LR* no distinct dominance.

Symmetry reversal was most often encountered in eye dominance, fifteen out of twenty cases showing partial or complete reversal. Eight out of twenty cases showed partial or complete reversal in handedness, while six out of fifteen showed reversal in the direction of head-hair whorl. (We could not determine the direction with certainty in five cases.) In all cases showing any reversal in handedness, reversal of eye dominance is also shown. Reversal in the direction of hair whorl occurs with or without reversal in both eye dominance and handedness.

Bernstein¹ has presented evidence which indicates that ordinarily the direction of the occipital hair whorl is determined by a pair of unit factors, a clockwise direction being dominant to a

counter-clockwise direction. Left-handedness occurs much more frequently in some family strains than in others. There are numerous records of naturally left-handed individuals who have become stammerers when forced to learn to write with their right hand. These facts indicate that handedness is at least partially determined by heredity, although the extent and manner of its transmission is unknown. How can monozygotic twins, having the same genetic makeup, show intra-pair differ-

TABLE I.—Classification of Handedness

			Handedness	Eye dominance	Hair-whorl
Case I	Twin	A	RLL	L	?
		B	RLL	R	?
Case II	"	A	RRL	L	cl
		B	RRL	R	cl
Case III	"	A	RRR	R	cc
		B	RRR	R	cc
Case IV	"	A	RRL	R	cl
		B	RRL	R	cc
Case V	"	A	RRL	R	cl
		B	RRL	R	cl
Case VI	"	A	RRR	R	cl
		B	RRR	L	cl
Case VII	"	A	RRL	R	cc
		B	RRL	R	cc
Case VIII	"	A	RRL	L	cc
		B	RRL	R	cl
Case IX	"	A	RRR	L	cc
		B	RRL	R	cl
Case X	"	A	RRL	R	cc
		B	RRR	L	cl
Case XI	"	A	RRL	RL	cl
		B	RLL	RL	cl
Case XII	"	A	RLL	L	?
		B	RLL	R	?
Case XIII	"	A	RRR	R	cl
		B	RRL	L	cc
Case XIV	"	A	RRL	L	cl cl
		B	RRL	R	cl cl
Case XV	"	A	RRL	L	?
		B	RRR	RL	?
Case XVI	"	A	LRL	L	?
		B	RLL	R	?
Case XVII	"	A	RLL	L	?
		B	RRL	R	?
Case XVIII	"	A	RRL	L	cl
		B	RRL	R	cl
Case XIX	"	A	RRL	L	cc
		B	RRL	R	cl
Case XX	"	A	RLL	R	cc
		B	LRR	LR	cc



HANDEDNESS REVERSED

Figure 10

These girls are complete mirror-images in regard to handedness. Each has a counter-clockwise hair whorl, and they show partial reversal in eye dominance. Mirror-imaging appeared to have little relation to the degree of resemblance in the twins.

ences in respect to traits ordinarily determined by heredity?

Diver³, in an investigation of the inheritance of inverse symmetry in the snail (*Linnaea peregra*), made the following observations, which may have some bearing on the principles involved in mirror imaging in monozygotic twins.

The final symmetry of an individual snail is apparently determined by the combined action of the chromosomes involved and the germinal structure, which action has a delayed effect. To be specific: factors determining and influencing the final result are resident in the chromosomes; these factors are distributed during gametogenesis in the now generally accepted manner; the determination of the final result is brought about by the combined action of the pair or pairs

of chromosomes involved, and the germinal structure of the cell as a whole; the effect of the combined action is to delay the appearance of the nuclear pattern until the next generation. . . . The determination of an individual rests upon the interaction of the parental nuclear forces (which segregate in a normal manner), and the existing modification imposed on the germinal structure of the parent by the nuclear forces of the preceding generation.

It is a well established fact that the sex of an individual is determined, normally, at the time of fertilization; it has also been shown, especially with certain plants, that by changing certain environmental conditions, the normal expression of sex may be changed, so that either an unusually large propor-

tion of males or of females may develop. Sex is quantitative, and the type expressed seems probably due to genes affecting metabolic rate, most of which are located in the X-chromosome. Outside factors affecting metabolic rate might possibly change the normal sex expression. Analogous processes may cause the mirror-imaging sometimes found in monozygotic twins. The environment of monozygotic twins is different from that of other individuals after cleavage of the embryo occurs, and may, like the germinal structure of the parent in *Linnaea peregra*, modify the expression of certain genetic traits. Traits which show mirror-imaging, although hereditary, may, like sex, be the end products of a series of processes controlled by the types of genes present, rather than being due to direct genic action; thus unusual conditions may alter the expression of such traits. Newman⁴ states:

The difference between the two sides may be reduced to terms of rate of fundamental vital activity, probably measurable in terms of rate of oxidation. One side develops more rapidly than the other, inhibiting more or less completely the growth of equivalent structures on the slower growing side. When twinning occurs, the two severed halves undergo complete regulation. Equilibrium at separation must be extremely delicate and minor factors may decide whether mirror-imaging will occur or not.

When we consider that in embryonic development the eye appears earlier than the appendage buds, it is not surprising that we should find mirror-imaging in eye dominance occurring more frequently than in handedness. The fact that all twins who showed any mirror-imaging in handedness, also showed reversal in eye dominance, should be expected, in view of the

theory that an individual's dexterity depends upon which side of the brain is superior.

Contrary to the findings of Newman⁵, mirror-imaging was observed as frequently in twins showing the greatest intra-pair physical and mental similarities, as in those showing the greatest intra-pair differences. Case XX, our only pair showing complete mirror-imaging in handedness, is among the most similar pairs in physical and mental traits, while no mirror-imaging was observed in Case III, which shows more than average intra-pair mental and physical differences. It is of interest to note that in Case XX, which showed complete mirror-imaging in handedness, the father is left-handed, also the maternal grandmother, and two maternal uncles. Case XIII, which shows partial mirror-imaging in handedness, has an *LLL* sib. I venture to suggest that possibly in families where both left- and right-handed individuals occur frequently, the chances of a set of monozygotic twins showing partial or complete mirror-imaging in this respect is greater than in families which are very predominantly right-handed or left-handed, because in ambidextrous individuals the two sides of the body are more evenly balanced, and therefore unusual conditions during embryonic development would be more likely to change the normal expression of dexterity than in natural strongly biased individuals.

Whatever may be the causes for mirror-imaging of certain traits in some pairs of monozygotic twins, such a phenomenon in itself does not disprove the fact that the traits, under normal conditions, have certain definite modes of inheritance.

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