A Twin-Family Study of Susceptibility to Poliomyelitis

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THE question of genetically controlled constitutional susceptibility to acute poliomyelitis has been discussed by several authors, notably by Aycock (1942). Although it has been proved beyond question that acute poliomyelitis occurs only with invasion of the host by the specific virus, it is equally clear that only a small proportion of the individuals exposed to the virus develop clinical signs of the disease. Aycock has reviewed a fairly large volume of data relating to the familial aggregation of cases, evaluating this in relation to the known facts concerning the epidemiology of the disease and comparing it to similar information concerning measles, scarlet fever, diphtheria and diabetes. He states that all observations are consistent with the theory that hereditary susceptibility may determine the occurrence of paralysis in a selected few of the many exposed to the virus. Several pedigrees demonstrating heavy familial aggregation of paralytic poliomyelitis, not only within a given sibship, but in related sibships widely separated geographically and in different generations, have been published by Aycock (1934, 1942). Similar pedigrees have also been published in Europe, one of the most recent accounts being that of Czickeli (1948), who cites previous similar studies. The point could be raised that such pedigrees were especially selected because they present large familial aggregations of cases, and perhaps could be expected to occur by chance alone. Although a rigorous estimate of the probability of occurrence of such extreme instances by chance alone cannot readily be obtained, it would seem rather unlikely that chance could be responsible for so many well substantiated pedigrees showing cases in different sibships so separated in time and space that contagion between sibships becomes impossible. Aycock recognizes that such pedigrees cannot be considered proof of the operation of hereditary factors, but they do present evidence which should be taken into consideration.

A somewhat different approach to the problem was used by Addair and Snyder (1942). They collected all cases of paralytic poliomyelitis with residual paralysis that occurred in an isolated section of McDowell County, West Virginia, over a period of 50 years. All 29 cases so found were shown to be related to each other, and are all listed in one large pedigree. This pedigree

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is interpreted as suggesting the existence of an autosomal recessive gene for susceptibility to paralytic poliomyelitis with about 70 percent penetrance.

In such a situation it would be expected that twin studies might provide additional evidence, probably of a more critical kind. The largest twin study found in the literature is that of Borgström (1939). Among 1592 cases of poliomyelitis occurring in Finland from 1930 to 1936, he located 17 pairs of twins, of whom at least one member of each pair had poliomyelitis while the other twin was living. Four of the twin pairs were diagnosed as monozygous and 13 as dizygous. There was concordance regarding paralysis in only 1 pair, monozygous. In six pairs (5 dizygous, 1 monozygous) there was a simultaneous illness in the second twin which might be considered "abortive" or non-paralytic poliomyelitis. In ten of the pairs (8 dizygous, 2 monozygous) the second twin had no symptoms. Borgström also summarized the case reports of twins with poliomyelitis found in the literature, citing 14 authors who collectively reported 14 monozygous pairs of whom 5 were concordant, two discordant dizygous pairs, and 6 pairs in which zygosity could not be definitely determined, of whom 4 were concordant and 2 discordant.

Aycock's (1942) data include 7 pairs of twins where zygosity is diagnosed; of 2 monozygous pairs, one is concordant regarding paralysis, and of 5 dizygous pairs, one pair is concordant and 4 discordant. Again, the available information regarding twin studies is insufficient to permit definite conclusions to be drawn with confidence.

MATERIALS AND METHODS

In the hope that a numerically more extensive study of twin pairs might give further evidence concerning the possible existence of genetically determined factors of susceptibility to paralysis in poliomyelitis, efforts were made to collect an unselected series of suitable families for study. A major problem was that of avoiding bias in selection of the pairs. Previous experience with hospital and physicians' records has convinced us that the fact that a given patient is a twin is much more likely to be recorded if both twins are ill than if only one is known to be ill. Therefore such records were not consulted in obtaining the original study group, but were sought out only after a family had entered the record from another source.

Our primary source of records was the infectious disease report card required by law to be filed with the Division of Epidemiology of the North Carolina State Board of Health by the attending physician in each case where poliomyelitis is diagnosed. Through the kind co-operation of the officials of the State Board of Health, it was possible to obtain photostatic copies of all such report cards filed during the years 1940 through 1948, totaling 4,213 cards. An attempt was then made to definitely classify as many as possible of these individuals as having been single-born or twins. Inquiry was first made

of the family physician, if still practicing in the community, regarding all cases that apparently were originally reported by him. Lists were prepared giving the name, address, age, sex, and date of illness for all patients reported by a given physician, and this list, together with a letter requesting the desired information, was mailed to the physician. The physician was requested to classify the patients on the list as twins, non-twins or unknown, and was especially requested to list individuals as unknown unless reliable personal knowledge of the family was available. Such lists were classified and returned by 786 North Carolina physicians. Additional sources of information were utilized where applicable, and inquiry was made of public health nurses, welfare workers, clinic personnel and others who might have first hand knowledge of the cases in question. Birth certificates were consulted in the records of the State Board of Health for a small proportion of the cases. Data gathered from all sources gave definite information concerning single or multiple birth for 3890 of the original 4213 cases.

By this method, 59 cases were reported to us as being members of a set of twins or triplets. Further personal investigation was then made of the 59 families so reported. Our criteria for including a family in the final group of studied cases required that (1) one or more members of the twin set should have had proved paralytic poliomyelitis, and (2) both twins should be living in the same household at the time of onset of acute symptoms, and therefore both presumably equally exposed to infection. Of the original 59 cases reported as twins, 46 families met the above criteria, while 13 families were excluded from further consideration after adequate investigation. The bases for exclusion of the 13 rejected families were as follows:

1. Twin partner deceased prior to onset of poliomyelitis in surviving twin	5 cases
2. Family moved out of North Carolina before time of survey	2 cases
3. Double report on same individual under different names	1 case
4. Incorrect report, patient with paralytic poliomyelitis had twin sibs who were not affected or had only abortive form of disease	2 cases
5. Diagnosis not acceptable:	
Non-paralytic poliomyelitis	2 cases
Other diagnosis established	1 case
Total rejected	13 cases

As will be seen from the above table, 3 of the 59 reported cases (items 3 and 4) were excluded because they were not twins. Of the 56 confirmed multiple birth cases, 55 were members of a twin pair and one was a member of a triplet set. Thus there is an observed incidence of multiple births among the 3890 classified cases of 1 in 69.46 or 1.440 ± 0.191 per cent.

The 46 families remaining who met the criteria for inclusion in this study were visited in their homes. The geographic distribution of cases is indicated on the map (fig. 1). The geographic distribution of cases of poliomyelitis in

twins corresponds very well with the distribution maps of total cases observed during the 1944 and 1948 epidemics as prepared by the North Carolina State Board of Health (Stevick, 1945, 1950). In each family an attempt was made to examine each member of the sibship including the twins and both parents. Sibs of index twins were followed and examined if possible, even though they had left the original family circle either before or after the occurrence of acute poliomyelitis in the twins. The following information was collected for all available members of the 46 families studied:

1. Pedigree, including collateral relatives closer than second cousins and direct ancestors for all generations where reliable information was available.

2. Clinical data regarding poliomyelitis, including description of any symptoms occurring at or near time of exposure to known cases of poliomyelitis, and all available hospital, clinic or physician's records pertaining to any diag-

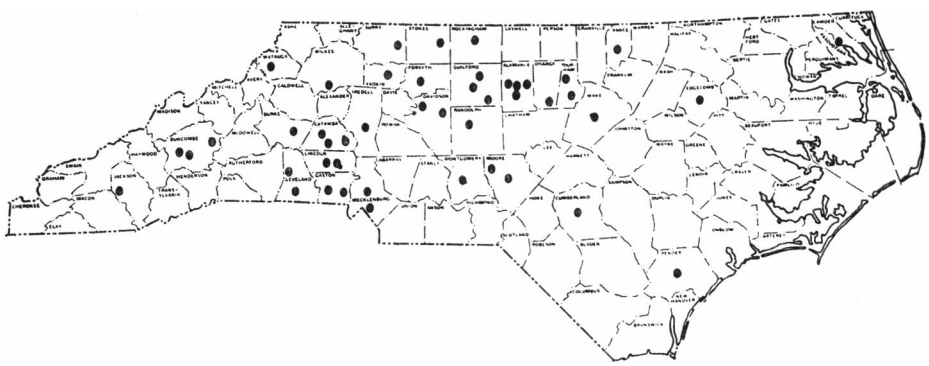

FIGURE 1. North Carolina. Geographic distribution of 46 families each containing a set of twins, one or both having had paralytic poliomyelitis.

nosed or suspicious illnesses. Information was obtained directly from each individual or his parents within the sibship of the affected twins, but information concerning poliomyelitis in more distant relatives was usually based on history alone.

3. Blood specimen for determination of ABO blood group, MN blood type, and Rh factor.

4. Saliva specimen for determination of secretor factor.

5. Taste testing with phenyl-thiocarbamide.

6. Palm prints and finger prints.

7. Photographs of twins.

8. Other information gathered but not used in the following analysis included data regarding sanitary facilities and living conditions of families; presence of other known cases of poliomyelitis in the community at time of acute infection in studied family; type of ear lobe and digital hair classification of twins.

For ABO blood grouping reactions, anti-A and anti-B serum prepared by the Blood Bank of Dade County, Miami, Florida, and distributed by the American Hospital Supply Corporation was used. For subdivision of group A bloods into groups A_1 and A_2, anti-A_1 (absorbed B) serum obtained from the Wiener Serum Laboratory, Brooklyn, New York, was used. Serum from the Wiener Serum Laboratory was also used for MN and Rh classification, using anti-M, anti-N, anti-C (anti-Rh′), anti-D (anti-Rh_0) and anti-E (anti-Rh″) sera. A saline suspension of washed cells obtained from the finger-tip was used for all blood determinations, following standard methods of procedure (see Wiener, 1946). The ABO and MN reactions were done in well slides at room temperature and the Rh reactions were done by the test tube method, with incubation for one hour in a water bath at 37°C. The enzymes in the saliva specimens were inactivated promptly after collection by immersing the tubes in a boiling water bath. The salivas were later tested for presence of A or B antigen by incubation with suitably titrated anti-A or anti-B serum, followed by addition of known test cells of the proper blood group. With this technique a secretor classification of persons of blood group O cannot be obtained. Palm and finger prints were obtained by a contact printing method, using sensitized paper obtained from the Faurot Protective Identification System and lightly wiping the hands of the subject with a solution containing tincture of ferric chloride 40%, 80% alcohol 10%, and glycerine 50%. The print develops immediately upon contact of this solution with the sensitized paper.

RESULTS

The information collected from the 46 families studied is summarized below. The case reports abstract information obtained from all sources concerning the illness of the index twin and also any other members of the family with proved or suspected poliomyelitis, whether paralytic or non-paralytic. It will be noted that a definite diagnosis can be made for all index cases and many of the secondary cases, but that all cases that did not present evidence of definite muscle involvement are listed as "abortive poliomyelitis." In some of the latter group a definite diagnosis cannot be made, and the symptoms were such that poliomyelitis would not have been suspected had they not occurred during a poliomyelitis epidemic or in the household of a known case of this disease.

The trait tabulation (table 1) presents data regarding clinical classification and test factors for all members of each family. These data are presented *in extenso* so that further analysis may be undertaken by others if this proves to be desirable. The zygosity diagnosis of the majority of twin pairs may be checked from this table, and further analysis for linkage relations, possible effects of maternal age or birth order could also be made. Because of limitations of space, data on palm and finger prints cannot be published at this time. Dermatoglyphic classification was one of the chief factors in zygosity classification in 19 out of 47 twin pairs. Palm and finger prints are being placed on permanent file in this department, and may be made available for examination on request.

TABLE 1. POLIOMYELITIS STATUS AND TEST FACTOR DATA FOR 47 PAIRS OF TWINS AND THEIR PARENTS AND SIBS

The table gives the classification of index twin cases and their parents and sibs with regard to presence of poliomyelitis, test factors and zygosity diagnosis. Details of the illness of any patient classified as paralytic poliomyelitis (P) or non-paralytic poliomyelitis (p) are given in the case reports. The diagnosis must be regarded as questionable in many of the non-paralytic cases, as the symptoms were frequently such that a diagnosis of poliomyelitis would probably not have been seriously considered had there not been a paralytic case in the family at the same time. Only cases listed as paralytic (P) are considered as "affected" in further analysis of these data. Palm and finger prints were carefully considered in addition to the traits listed in arriving at a diagnosis of zygosity of the twin pairs.

Symbols: P = paralytic poliomyelitis
p = non-paralytic poliomyelitis
n = normal
S = secretor
s = non-secretor
T = taster of PTC
t = non-taster of PTC
— = unknown datum
★ = propositus
d-x = died at x years

A_1, A_2, B, A_1B, A_2B, O = blood group
M, N, MN = blood type
CDE, CDe, etc. = Rh reactions (C, D, E indicate positive reactions to sera anti-C, anti-D, anti-E; c, d, e indicate negative reactions to the same three sera)

FAMILY 1. ★ DZ TWINS

Father	50	n	A_1	M	CDe	s	t
Mother	50	n	O	MN	CDe	—	T
Sister	30	n	O	MN	CDe	—	T
Brother	25	n	O	MN	CDe	—	t
Sister	18	n	O	MN	CDe	—	T
★ Twin (♂)	13	P	O	MN	CDe	—	T
Twin (♀)	13	n	A_1	M	CDe	s	T

FAMILY 2. ★ DZ TWINS

Father	—	n	O	M	CDE	—	T
Mother	—	n	A_1	MN	CDe	—	T
Brother	33	n	O	MN	CDE	—	T
Brother	31	n	O	M	CDE	—	T
Sister	29	n	O	MN	CDe	—	T
Sister	27	n	A_1	M	CDE	S	T
Sister	25	n	A_1	MN	CDe	S	T
[1] Sister	23	n	—	—	—	—	—
Brother	20	n	A_1	MN	CDe	S	T
Sister	17	n	O	M	CDe	—	T
Sister	15	n	A_1	MN	CDe	S	T
★ Twin (♀)	11	P	O	MN	CDE	—	T
Twin (♀)	11	n	A_1	MN	CDE	S	T
Sister	4	n	O	M	CDE	—	T

[1] Not examined.

FAMILY 3. ★ MZ TWINS

Father	35	n	A_1	M	cDE	s	T
Mother	29	n	B	—	Cde	S	T
Brother	12	p	O	—	cde	—	T
Sister	9	n	O	—	cde	—	T
★ Twin (♀)	7	P	O	—	cde	—	T
★ Twin (♀)	7	P	O	—	cde	—	T
Sister	4	n	A_1	—	Cde	S	T

FAMILY 4. ★ DZ TWINS

[1] Father	*d*-47	n	—	—	—	—	—
Mother	44	n	O	MN	cDE	—	T
Brother	26	n	A_1	MN	cde	S	T
Brother	23	n	A_1	N	cDE	S	T
Brother	20	n	A_1	N	cDE	S	T
Sister	17	n	O	MN	cde	—	T
★ Twin (♀)	14	P	O	M	CDe	—	T
Twin (♀)	14	n	A_1	MN	cde	—	T
Sister	11	n	A_1	N	CDE	—	T
[2] Brother	9	n	—	—	—	—	—

[1] Deceased April 23, 1949.
[2] Not examined.

TABLE 1.—*Continued*

FAMILY 5. ★ DZ TWINS

Father	29	n	A_1	MN	CDe	S	t
Mother	29	n	A_1	MN	CDe	S	T
Brother	6	n	O	N	CDe	—	T
★[1]Triplet (♂)	2	P	A_1	MN	CDe	S	T
Triplet (♀)	2	n	A_1	MN	CDe	S	T
Triplet (♀)	2	n	A_1	MN	CDe	S	T

[1] Two-ovum triplets, classed as two dizygous twin pairs.

FAMILY 6. ★ DZ TWINS

Father	36	n	O	M	cDe	—	T
Mother	29	n	O	M	cde	—	T
Sister	10	n	O	M	cde	—	T
★ Twin (♂)	8	P	O	M	cDe	—	T
Twin (♂)	8	p	O	M	cDe	—	T

FAMILY 7. ★ MZ TWINS

Father	30	n	A_1	M	CDe	S	T
Mother	28	n	B	M	CDe	S	T
Sister	11	n	B	M	CDe	S	T
Brother	9	n	A_1B	M	CDe	—	T
★ Twin (♂)	8	P	A_1	M	CDe	S	T
Twin (♂)	8	n	A_1	M	CDe	S	T
[1] Brother	2	n	A_1B	M	cde	—	—

[1] Born since onset polio in twins.

FAMILY 8. ★ DZ TWINS

Father	30	n	O	N	CDe	—	t
Mother	29	n	A_2	N	cdE	S	T
[1] Brother	10	n	—	—	—	—	—
★ Twin (♀)	7	P	A_2	N	cde	S	t
Twin (♂)	7	n	A_2	N	CDE	S	t
Brother	5	n	A_2	N	cde	s	?
[2] Brother	1	n	O	N	CDe	—	?

[1] Not examined.
[2] Age 6 weeks when sister had polio.

FAMILY 9. ★ DZ TWINS

Father	37	n	A_1	MN	cDE	s	t
Mother	39	n	A	N	CDe	S	t
★ Twin (♂)	6	P	A_1	N	CDe	s	?
★ Twin (♀)	6	P	A_1	N	cDE	s	t
Brother	8	p	O	N	cde	—	t

FAMILY 10. ★ DZ TWINS

Father	36	n	O	M	CDe	—	T
Mother	33	n	O	N	Cde	—	T
★ Twin (♂)	9	P	O	MN	Cde	—	T
Twin (♂)	9	n	O	MN	Cde	—	T
Half-brother	15	n	A_1	MN	cde	S	T
[1] Half-sister	13	n	A_1	N	cde	S	T

[1] Not living with family.

FAMILY 11. ★ DZ TWINS

Father	28	n	A_1	MN	CDe	—	—
Mother	27	n	A_2	MN	CDe	—	—
[1] Sister	9	n	—	—	—	—	—
[2] Brother	7	P	A_1	MN	CDe	—	—
[3] Brother	5	P	O	MN	CDe	—	—
[1] Sister	4	n	—	—	—	—	—
[2] Twin (♂)	2	P	A_1	MN	CDe	—	—
Twin (♀)	2	n	O	M	CDe	—	—

[1] Blood specimen not obtained.
[2] 1948 epidemic.
[3] 1944 epidemic.

FAMILY 12. ★ MZ TWINS

Father	42	n	A_1	MN	CDe	S	T
Mother	40	n	O	M	cde	—	T
★ Twin (♂)	8	P	A_1	MN	cde	S	T
Twin (♂)	8	n	A_1	MN	cde	S	T
Sister	3	n	A_1	M	cde	S	T

FAMILY 13. ★ DZ TWINS

Father	26	n	O	N	CDe	—	T
Mother	24	n	A_1	M	CDE	S	T
Sister	3	n	A_1	MN	cDE	S	t
★ Twin (♂)	2	P	A_1	MN	cDE	s	?
Twin (♀)	2	n	A_1	MN	CDe	s	?

FAMILY 14. ★ MZ TWINS

Father	32	n	O	MN	cde	—	t
Mother	28	n	O	MN	cDE	—	T
★ Twin (♀)	9	P	O	N	cDE	—	T
Twin (♀)	9	p	O	N	cDE	—	T
[1] Twin (♀)	6	n	O	N	cDE	—	T
[1] Twin (♀)	6	n	O	N	cDE	—	T

[1] Born since polio attack in 1st set of twins.

TABLE 1.—*Continued*

FAMILY 15. ★ MZ TWINS

[1] Father	*d*-43	n	—	—	—	—	—
Mother	46	n	O	MN	cDE	—	t
★ Twin (♂)	9	P	O	MN	CDE	—	t
★ Twin (♂)	9	P	O	MN	CDE	—	t

[1] Deceased.

FAMILY 16. ★ DZ TWINS

Father	31	n	A_1	M	CDe	S	T
Mother	35	n	O	MN	cde	—	T
Sister	9	p	O	M	cde	—	—
Brother	8	p	O	M	CDe	—	T
Sister	7	n	A_1	M	cde	S	T
★ Twin (♀)	5	P	A_1	MN	CDe	S	t
Twin (♀)	5	n	A_1	MN	CDe	S	t
Sister	4	n	O	M	cde	—	t
[1] Brother	1	n	O	MN	cde	—	?

[1] Born since polio in siblings.

FAMILY 17. ★ DZ TWINS

Father	53	n	O	MN	Cde	—	T
Mother	47	n	A_1	MN	CDe	s	t
Brother	17	n	A_1	MN	CDe	S	t
Sister	14	n	A_1	M	CDe	S	t
★ Twin (♂)	10	P	O	MN	CDe	—	t
Twin (♀)	10	n	A_1	N	Cde	s	t

FAMILY 18. ★ DZ TWINS

Father	40	n	O	MN	CDe	—	t
Mother	40	n	A_1	MN	CDe	s	T
Sister	11	n	A_1	M	CDe	S	T
Sister	9	P	O	MN	cde	—	T
★ Twin (♂)	4	P	O	N	CDe	—	t
Twin (♀)	4	n	A_1	MN	CDe	s	T

FAMILY 19. ★ DZ TWINS

Father	59	n	O	N	cdE	—	T
Mother	56	n	O	M	CDE	—	T
[1] Sister	*d*-32	n	—	—	—	—	—
Sister	36	n	O	MN	CDE	—	T
Sister	33	n	O	MN	CDE	—	T
Brother	31	n	O	MN	cDE	—	T
Brother	28	n	O	MN	CDE	—	t
Sister	25	n	O	MN	cDE	—	T
Brother	22	n	O	MN	CDE	—	T
★ Twin (♂)	19	P	O	MN	CDe	—	T
Twin (♀)	19	n	O	MN	CDe	—	T
Twin (♂)	16	n	O	MN	CDe	—	T
Twin (♂)	16	n	O	MN	CDE	—	t

[1] Deceased prior to 1948.

FAMILY 20. ★ MZ TWINS

Father	54	n	A_1	MN	CDe	s	T
Mother	52	n	A_1	MN	CDe	S	T
[1] Sister	*d*-3	—	—	—	—	—	—
Brother	31	n	A_1	N	CDe	S	T
Sister	28	n	A_1	MN	CDe	S	T
★ Twin (♂)	18	P	A_1	M	CDe	S	T
★ Twin (♂)	18	P	A_1	M	CDe	S	T

[1] Died of diphtheria.

FAMILY 21. ★ MZ TWINS

Father	50	n	O	N	cde	—	T
Mother	48	n	O	N	cde	—	T
Brother	29	n	O	N	cde	—	T
Sister	28	n	O	N	cde	—	T
Brother	25	n	O	N	cde	—	T
★ Twin (♂)	23	P	O	N	cde	—	T
Twin (♂)	23	n	O	N	cde	—	T
Sister	18	n	O	N	cde	—	T
Sister	14	n	O	N	cde	—	T

FAMILY 22. ★ DZ TWINS

Father	31	n	O	MN	cde	—	T
Mother	25	n	O	M	CDe	—	T
Sister	10	n	O	MN	cde	—	T
Brother	8	n	O	M	cde	—	T
Brother	5	n	O	MN	cde	—	T
★ Twin (♂)	3	P	O	MN	cde	—	T
Twin (♂)	3	n	O	MN	CDe	—	T
Brother	2	P	O	MN	cde	—	?

FAMILY 23. ★ DZ TWINS

[1] Father	39	n	—	—	—	—	—
Mother	37	n	—	—	—	—	—
Brother	16	n	—	—	—	—	—
Brother	14	n	—	—	—	—	—
Sister	5	n	—	—	—	—	—
★ Twin (♂)	*d*-2	P	—	—	—	—	—
Twin (♂)	2	p	—	—	—	—	—

[1] No test factors obtained. Affected twin died of bulbar polio. Parents report children did not look alike, no other information regarding zygosity available.

TABLE 1.—*Continued*

FAMILY 24. ★ DZ TWINS

Father	58	n	O	MN	cDe	—	T
Mother	49	n	A_1	MN	cde	S	T
Brother	25	n	A_1	M	cDe	S	T
★ Twin (♂)	23	P	A_1	MN	cde	S	T
Twin (♀)	23	n	A_1	M	cDe	S	T
Brother	20	n	O	N	cde	—	T

FAMILY 25. ★ MZ TWINS

[1] Father	42	n	—	—	—	—	—
Mother	43	n	—	—	—	—	—
Sister	21	n	—	—	—	—	—
★ Twin (♂)	*d*-10	P	—	—	—	—	—
★ Twin (♂)	*d*-10	P	—	—	—	—	—

[1] No test factors obtained, both twins died of bulbar polio. Said by parents and neighbors to have been indistinguishable. One was left-handed, other right-handed. Photos examined, appear identical.

FAMILY 26. ★ DZ TWINS

[1] Father	—	—	—	—	—	—	—
Mother	47	n	O	N	CDe	—	T
Twin (♂)	19	P	O	MN	cDE	—	T
Twin (♀)	19	n	O	MN	CDE	—	T

[1] Not examined.

FAMILY 27. ★ DZ TWINS

Father	49	n	A_1	N	CDe	S	T
Mother	45	n	O	MN	CDe	—	T
[1] Brother	*d*-23	n	—	—	—	—	—
Sister	26	n	A_1	N	CDe	s	T
[2] Sister	*d*-5	—	—	—	—	—	—
Brother	23	n	A_1	MN	CDe	s	T
Sister	20	n	A_1	N	CDe	s	T
Brother	18	n	O	MN	Cde	—	T
Brother	11	n	O	MN	Cde	—	T
Sister	9	n	A_1	N	Cde	s	T
Sister	8	n	O	MN	Cde	—	T
Brother	6	n	O	MN	Cde	—	T
Sister	5	n	O	N	Cde	—	T
Sister	4	n	O	N	Cde	—	?
★ Twin (♀)	2	P	A_1	N	Cde	s	?
Twin (♂)	2	n	A_1	N	Cde	S	?

[1] Killed in action, U. S. Army.
[2] Died of pneumonia.

FAMILY 28. ★ DZ TWINS

Father	51	n	A_1	MN	CDe	S	T
Mother	46	n	O	MN	cdE	—	T
[1] Sister	*d*-inf.	—	—	—	—	—	—
[2] Brother	28	n	—	—	—	—	—
Sister	26	n	O	MN	cde	—	T
★ Twin (♂)	23	P	A_1	M	cdE	—	T
Twin (♂)	23	n	A_1	MN	CDe	—	T
Brother	19	n	O	N	cdE	—	T
Twin (♂)	17	n	O	N	cdE	—	T
[3] Twin (♂)	*d*-inf.	—	—	—	—	—	—
[3] Sister	*d*-inf.	—	—	—	—	—	—
Sister	15	n	O	MN	CDe	—	T
Sister	12	n	O	M	cdE	—	T
Sister	10	n	O	M	cdE	—	T
Brother	8	n	O	MN	cde	—	T

[1] Died, age 5 days.
[2] Not examined, in U. S. Army.
[3] Died of "colitis" in infancy.

FAMILY 29. ★ MZ TWINS

Father	35	n	A_1	MN	?	s	T
Mother	24	n	O	MN	Cde	—	T
Brother	8	p	A_1	N	CDe	s	T
★ Twin (♀)	6	P	A_1	MN	CDe	s	T
Twin (♀)	6	n	A_1	MN	CDe	s	T
Sister	4	p	A_2	M	CDe	s	?

FAMILY 30. ★ MZ TWINS

Father	38	n	O	MN	cde	—	T
Mother	29	n	A_1	M	CDe	S	t
Sister	10	n	O	MN	CDe	—	T
Sister	8	n	O	M	CDe	—	T
Brother	5	n	A_1	M	CDe	S	T
★ Twin (♀)	3	P	O	MN	cde	—	T
Twin (♀)	3	n	O	MN	cde	—	T

FAMILY 31. ★ MZ TWINS

Father	50	n	O	N	CDe	—	T
Mother	40	n	O	M	CDe	—	T
Brother	19	n	O	MN	CDe	—	T
Sister	17	n	O	MN	CDe	—	T
Brother	14	n	O	MN	CDe	—	T
[1] Sister	12	P	O	MN	CDe	—	T
★[1] Twin (♀)	10	P	O	MN	CDe	—	T
Twin (♀)	10	n	O	MN	CDe	—	T
Brother	7	n	O	MN	CDe	—	T
[2] Sister	5	P	O	MN	CDe	—	T
Brother	3	n	O	MN	CDe	—	T
Brother	2	n	O	MN	CDe	—	?

[1] 1944 epidemic.
[2] 1948 epidemic.

TABLE 1.—*Continued*

FAMILY 32. ★ DZ TWINS

[1] Father	*d*-62	—	—	—	—	—	—
Mother	60	n	B	M	cDe	S	T
Brother	35	n	A_1B	MN	cDe	S	T
Brother	32	n	B	MN	CDe	S	T
Brother	27	n	B	M	cde	S	T
[2] Brother	25	n	—	—	—	—	—
Sister	21	n	B	MN	CDe	S	T
Brother	17	n	A_1	M	cDe	S	T
Brother	15	n	O	MN	cde	—	T
Twin (♂)	12	P	A_1B	MN	CDe	S	T
Twin (♂)	12	p	A_1	MN	CDe	S	T

[1] Deceased 1938.
[2] Not examined.

FAMILY 33. ★ MZ TWINS

Father	36	n	O	MN	CDe	—	t
Mother	33	n	O	MN	cde	—	T
Sister	13	n	O	MN	cDe	—	T
Brother	12	n	O	MN	cDe	—	T
Sister	8	n	O	MN	cde	—	T
★ Twin (♂)	7	P	O	MN	cDe	—	t
Twin (♂)	7	n	O	MN	cDe	—	t

FAMILY 34. ★ DZ TWINS

Father	50	n	A_1	M	CDe	S	T
Mother	43	n	O	MN	cDE	—	T
[1] Sister	25	n	—	—	—	—	—
Brother	24	n	A_2	MN	cDe	S	t
[1] Sister	22	n	—	—	—	—	—
Brother	21	n	A_2	M	cDE	S	t
Sister	19	n	A_2	MN	CDE	S	T
Brother	17	n	A_1	M	cDE	S	T
Brother	15	n	A_1	M	cDE	S	T
Brother	13	p	A_1	M	cDE	S	T
Sister	11	n	A_1	M	cDE	S	T
★ Twin (♂)	8	P	A_1	MN	cDE	S	t
Twin (♂)	8	p	A_1	MN	CDe	S	T
Sister	2	n	A_1	M	cDe	S	?

[1] Not examined.

FAMILY 35. ★ DZ TWINS

Father	43	n	O	N	Cde	—	T
Mother	40	n	O	MN	Cde	—	T
[1] Brother	23	n	—	—	—	—	—
[2] Brother	*d*-11	—	—	—	—	—	—
[1] Brother	21	n	—	—	—	—	—
Sister	19	p	O	MN	Cde	—	T
Brother	15	n	O	N	Cde	—	T
Sister	11	n	O	N	Cde	—	T
Brother	9	n	O	MN	Cde	—	T
Brother	5	n	O	N	Cde	—	T
★ Twin (♂)	2	P	O	MN	Cde	—	T
Twin (♂)	2	n	O	N	Cde	—	T

[1] Not examined.
[2] Deceased "heart trouble."

FAMILY 36. ★ DZ TWINS

Father	45	n	O	M	CDE	—	T
Mother	40	n	A_1	MN	CDE	S	T
[1] Brother		—	—	—	—	—	—
Sister	9	n	A_1	MN	CDE	S	T
★ Twin (♀)	8	P	O	M	CDE	—	T
Twin (♀)	8	n	A_1	MN	CDE	S	T
[1] Sister		—	—	—	—	—	—
Brother	6	n	O	MN	CDE	—	T
Sister	4	n	A_1	MN	CDE	S	T
Sister	2	n	A_1	M	CDE	S	?
[1] Twin (♂)		—	—	—	—	—	—
[1] Twin (♂)		—	—	—	—	—	—

[1] Stillborn.

FAMILY 37. ★ DZ TWINS

Father	48	n	A_1	MN	cDE	S	t
Mother	44	n	A_2	MN	CDe	s	T
Brother	24	n	A_1	M	CDE	S	t
Brother	23	n	A_1	N	cdE	S	—
Sister	20	n	A_2	MN	CDE	S	T
[1] Brother	18	n	—	—	—	—	—
[2] Brother	*d*-2	—	—	—	—	—	—
Twin (♂)	11	P	A_1	MN	CDE	S	t
Twin (♂)	11	n	A_1	MN	CDE	S	t

[1] Not examined.
[2] Deceased, cause unknown.

FAMILY 38. ★ DZ TWINS

Father	39	n	B	MN	CDe	S	T
Mother	29	n	O	N	CDe	—	t
Brother	6	n	O	MN	CDe	—	t
★ Twin (♀)	4	P	B	N	Cde	S	t
Twin (♀)	4	n	B	N	CDe	S	t

FAMILY 39. ★ DZ TWINS

Father	51	n	O	N	cDE	—	T
Mother	47	n	A_2	MN	cDE	S	T
Sister	22	n	A_2	N	cDE	S	T
Brother	20	n	A_2	MN	cDE	S	T
Sister	17	n	A_2	MN	cDE	S	T
★ Twin (♂)	15	P	A_2	N	cDE	S	T
Twin (♂)	15	n	A_2	MN	cde	S	T
Brother	10	n	A_2	MN	cde	s	t

TABLE 1.—*Continued*

FAMILY 40. ★ DZ TWINS

Father	35	n	A_1B	MN	cde	S	T
Mother	35	n	O	M	cDe	—	T
Brother	10	n	A_1	MN	cde	S	T
Sister	8	n	A_1	M	cde	S	T
Brother	5	n	B	M	cde	s	T
★ Twin (♀)	3	P	B	M	cDe	S	T
Twin (♂)	3	n	B	M	cde	s	T

FAMILY 41. ★ MZ TWINS

Father	39	n	O	M	cde	—	T
Mother	37	n	O	MN	cDe	—	T
Brother	17	n	O	MN	cde	—	T
[1] Brother	*d*-2	—	—	—	—	—	—
Sister	14	n	O	MN	cde	—	T
Sister	10	n	O	MN	cde	—	T
★ Twin (♂)	5	P	O	M	cde	—	t
Twin (♂)	5	n	O	M	cde	—	t

[1] Deceased of whooping cough and pneumonia.

FAMILY 42. ★ DZ TWINS

Father	35	n	O	N	cde	—	t
Mother	29	n	O	N	CDE	—	T
Half-brother	13	n	B	MN	cDE	s	T
Half-sister	10	n	O	MN	cDE	—	T
★ Twin (♀)	2	P	O	N	Cde	—	?
Twin (♀)	2	n	O	N	cDE	—	?
[1] Twin (♀)	1	—	O	N	cDE	—	?
Twin (♂)	1	—	O	N	cDe	—	?

[1] Born since onset of polio in index case.

FAMILY 43. ★ MZ TWINS

Father	36	n	A_2	MN	CDe	S	t
Mother	30	n	B	MN	cde	s	T
Sister	15	n	A_2	N	CDe	S	t
Sister	13	n	B	N	CDe	s	t
Brother	8	n	O	M	cde	—	T
Sister	5	n	O	M	cde	—	t
★ Twin (♀)	3	P	O	MN	cde	—	?
★ Twin (♀)	3	P	O	MN	cde	—	?

FAMILY 44. ★ DZ TWINS

Father	27	n	A_1	N	CDe	S	T
Mother	25	n	A_1	N	CDe	s	T
Sister	6	n	O	N	CDe	—	t
★ Twin (♀)	2	P	O	N	CDe	—	?
Twin (♀)	2	n	A_1	N	CDe	s	?

FAMILY 45. ★ DZ TWINS

Father	29	n	O	MN	cDe	—	t
Mother	29	n	O	MN	CDe	—	T
Brother	10	P	O	MN	CDe	—	T
Sister	8	n	O	MN	CDe	—	T
★ Twin (♂)	6	P	O	MN	CDe	—	T
★ Twin (♂)	6	P	O	MN	CDe	—	?

FAMILY 46. ★ DZ TWINS

[1] Twin (♂)	3	P	O	MN	CDe	—	?
Twin (♂)	3	p	A_1	MN	CDe	S	?

[1] Twins adopted, parents unknown.

CASE REPORTS

FAMILY 1. Twin, white male, born Oct. 17, 1946, On Sept. 11, 1947, a "boil" appeared on the patient's neck. During home treatment there was moderate fever, mild frontal headache and pain at the site of infection. On Sept. 18 severe pain appeared involving the left arm and shoulder with radiation into the neck, although the "boil" appeared to be healing. Paralysis of the left upper extremity appeared within 24 hours. On admission to the N. C. Baptist Hosp., Winston-Salem, N. C. on Sept. 29, he presented flaccid paralysis of the left deltoid and the extensor and rotator muscles of the left shoulder, with some muscle atrophy in this region, and moderate weakness of the left hand. Although the spinal fluid was within normal limits, a diagnosis of sequelae of poliomyelitis was made and he was treated with hot packs and physiotherapy. He was discharged on Oct. 8 and physiotherapy continued. Weakness gradually improved, and full function of the affected muscles was regained within a few months.

FAMILY 2. Twin, white female, born Apr. 29, 1948. On July 15, 1948 she was stung on the lip by a hornet. Within an hour she complained of pain and stiffness of the legs and back.

On the following day there was weakness of the legs, rapidly progressive until she was unable to stand. She was admitted to the Biltmore Orthopedic Home, Asheville, N. C. on July 17. There was moderate pharyngitis, stiffness and spasm of the neck and back, and flaccid paralysis of the lower extremities. The temperature rose to 104° and the white count on July 19 was 17,300. Lumbar puncture was not done. She received physiotherapy until discharged on Oct. 5 with bilateral leg braces, with almost complete paralysis of both lower extremities. She was readmitted from Nov. 26, 1948 until July 10, 1949 for further physiotherapy, and was able to walk with leg braces and crutches on discharge.

FAMILY 3. *Case A.* Twin, white female, born March 2, 1942. On July 2, 1948 she complained of severe headache. Sore throat and fever appeared that evening and she was quite restless for several days. On July 7 she did not want to stand up. On July 8 she began vomiting and complained of pain in the right leg and paralysis of this leg appeared. A lumbar puncture was reported as "typical of poliomyelitis" but the original data are not available. She was referred to the Emergency Poliomyelitis Hosp., Greensboro, N. C. where weakness of the neck muscles and paralysis of the right leg were noted. After four weeks treatment she was transferred to a convalescent center for three months. On May 17, 1949 there was marked residual weakness of the right leg and she walked with a limp.

Case B. Twin, white female, born March 2, 1942. On July 10, 1948 there was sore throat and moderate fever. On the following day pain and aching of both legs appeared, with marked weakness and inability to walk. The family physician made a diagnosis of "acute poliomyelitis", but no laboratory work was done. She was treated at home and regained use of her lower extremities within 10 days, with no residua demonstrable.

Case C. Brother, white male, born Feb. 28, 1947. On July 17, 1948 he complained of headache and pain in the legs, and had mild fever. He was improved on the following day and made an uneventful recovery.

FAMILY 4. Twin, white female, born March 31, 1935. During March 1947 she developed a sore throat and mild fever and was thought to have tonsillitis. Fever lasted about one week, then pain and spasm of the back muscles and left shoulder and arm appeared. The family physician made a diagnosis of "neuritis and tonsillitis." Muscle pain continued for about two weeks, somewhat relieved by local heat. Drooping of the left shoulder was noted. On recovery from the acute attack it was found that scoliosis had appeared, and she was admitted to the N. C. Orthopedic Hosp., Gastonia, N. C. on July 13, 1948 where a diagnosis of post-paralytic severe scoliosis, resulting from poliomyelitis, was made. Treatment designed to straighten the spine was administered, including a turnbuckle correction cast, physiotherapy and Risser jacket. Spinal fusion operations were done in Sept. and Oct. 1948. She was discharged Dec. 5, 1948. In Sept., 1949 she was still wearing a body jacket and the spinal correction was holding in a satisfactory manner.

FAMILY 5. Triplet, white male, born Dec. 31, 1946. On Sept. 9, 1948 he became ill with fever and vomiting, and was very drowsy and irritable. A lumbar puncture done at the Catawba General Hosp., Newton, N. C. showed a bloody tap, but the centrifuged supernatant fluid gave a positive Pandy reaction. On Sept. 11 he was referred to the N. C. Orthopedic Hosp., where he was found to have a stiff neck, pharyngitis, weakness of the left leg and abdominal muscles, and spasm of shoulder muscles. Recovery was uneventful and he was discharged Sept. 17. No residual paralysis was demonstrable on a clinic visit on Sept. 28, 1948 and he was healthy when examined on July 15, 1949.

FAMILY 6. *Case A.* Twin, white male, born Apr. 6, 1941. On about Sept. 1, 1948 he developed a "cold and sore throat" and had fever of 102°F. The family physician made a diagnosis of tonsillitis and a sulfa drug was administered for several days. On Sept. 5 he fell down several times while playing. That night he complained of pain in the back of the neck. On Sept. 6 he was unable to sit up because of pain and headache. Penicillin was given for 3 days with reduction of fever. On Sept. 12 there was severe pain in both lower extremities and weakness of the right upper and lower extremities. On admission to the James Walker Memorial Hosp., Wilmington, N. C. on Sept. 15, 1948 there was stiffness of the neck and back, spasm of the right hamstring muscles, and weakness of the right arm and leg. Spinal fluid showed a cell count of 30 and positive Pandy. He was treated with hot packs and muscle reeducation. On Sept. 21 there was still generalized weakness of the right upper extremity. There was only slight weakness when discharged on Sept. 29, and muscle power was gradually regained. When examined on July 5, 1949 there was no evidence of residual paralysis.

Case B. Twin, white male, born April 6, 1941. During Sept., 1948 at the time of illness of his twin, this child also developed a "cold and sore throat" and had fever. He was given a sulfa drug and symptoms subsided after about 3 days. He had recovered by the time paralysis appeared in his twin.

FAMILY 7. Twin, white male, born July 4, 1941. On Aug. 10, 1943 there was fever and restlessness, and he would cry when lifted or moved. On Aug. 13 there was stiffness of the neck and he was unable to stand alone. He was admitted to Duke University Hosp., Durham, N. C. on Aug. 14 presenting flaccid paralysis of the entire left lower extremity, with tenderness and pain on motion. The spinal fluid contained 86 cells (81 mononuclear and 5 polymorphonuclear), Pandy negative, culture negative and sugar normal. A diagnosis of acute anterior poliomyelitis was made and he was treated with prostigmine, warm packs and physiotherapy, with slight improvement of muscle function. He was transferred to the N. C. Orthopedic Hosp. on Sept. 14 presenting almost complete flaccid paralysis of the entire left lower extremity and mild involvement of the right thigh and abdominal muscles. Treatment continued with gradual improvement and he was discharged on March 12, 1944, able to walk with a single leg brace. He was followed in a clinic at intervals and was relatively unchanged on Sept. 6, 1949 when he presented marked muscle atrophy of the left lower extremity with a flail foot.

FAMILY 8. Twin, white female, born July 9, 1942. On May 24, 1948 she staggered in walking and seemed to have weakness of the legs. On May 25 she was unable to stand and there was mild fever. Lumbar puncture done at Pittman Hosp., Fayetteville, N. C. was reported as "positive." She was referred to the N. C. Orthopedic Hosp. on May 27 and had become rapidly worse, being semi-comatose and unable to speak or swallow. The gag reflex was absent. Respiration seemed adequate but only the lower intercostals were functioning. Both lower extremities and the left upper extremity were paralyzed. A diagnosis of acute bulbar poliomyelitis was made, and supportive treatment included oxygen and pharyngeal suction. By May 29 she could speak clearly and she became able to swallow on the following day. By June 4 no paralysis could be detected, and she was discharged June 7 and followed in the clinic. On July 7, 1949 there was no evidence of residual paralysis.

FAMILY 9. *Case A*, Twin, white male, born Aug. 14, 1943. On July 3, 1948 there was fever of 103°F. and headache. Temperature returned to normal July 5, but fever recurred July 7

and weakness of both left extremities appeared. On admission to Charlotte Memorial Hosp. on July 8 there was marked weakness of the abdominal and left thigh muscles, and moderate weakness of muscles about the right hip. Spinal fluid contained 450 cells. He was treated with hot packs and exercise in the Hubbard tank. Fever subsided by July 12 and muscle function showed gradual improvement. He was discharged Oct. 10, still showing weakness of the left hip and back, and using a brace and crutches. Physiotherapy was continued, and crutches were discarded Jan. 25, 1949. On May 10, 1949 there was still definite weakness of the muscles about the left hip and left shoulder and the abdominal muscles.

Case B. Twin, white female, born Aug. 14, 1943. On July 3, 1948 this child also developed fever and headache. Fever subsided July 6 but recurred for one day July 10. On July 13 she again had fever, sore throat, stiff neck and pain in the legs. On admission to Charlotte Memorial Hosp. on July 14 the spinal fluid showed "cells present" and positive Pandy. There was rigidity and tenderness of the neck and spasm of the hamstring muscles. She was treated with hot packs and was discharged July 22 with slight residual weakness of the right thigh, but the weakness was not detectable two weeks later. On May 10, 1949 no residual signs were found.

Case C. Brother, born Feb. 3, 1941. This child developed fever on the day following onset of illness in the twins. Low grade fever persisted several days and there was headache and questionable stiffness of the neck. No muscle weakness was detected, and lumbar puncture was not done. He recovered completely within three weeks.

FAMILY 10. Twin, white male, born Nov. 6, 1940. During Sept., 1948 he had fever and headache for two or three days, then seemed well for four or five days. On Sept. 20 he complained of headache and severe pain in the shoulders and neck, and had fever. He was admitted to the City Memorial Hosp., Winston-Salem, N. C. on Sept. 21 presenting stiff neck and weakness about the shoulder girdle. Spinal fluid: cell count 276, polymorphonuclears 43%, lymphocytes 57%; sugar 80 mgms.; chlorides 470 mgms.; Pandy trace. He was treated with hot packs and fever subsided in 4 days. Weakness of the neck and shoulders disappeared by Sept. 30. He was discharged Oct. 8 with no residual signs. On June 8, 1949 no muscle weakness was demonstrated, but the mother stated that he tired more easily than other children.

FAMILY 11. *Case A.* Twin, white male, born June 19, 1947. One week before the acute illness there was an episode of mild diarrhea. His brother (see Case B) became ill with poliomyelitis July 23, 1948. On July 25 he developed fever, restlessness and vomiting. The following morning he screamed if touched and made no attempt to walk or crawl. On admission to the N. C. Baptist Hosp. July 26, temperature was 102°F. and there was stiffness of the neck. Spinal fluid: cell count 180, 20% polymorphonuclears, 80% mononuclears; protein 61 mgms.; sugar 70 mgms.; culture negative. There was weakness of both left extremities. He responded promptly to routine treatment and was discharged Aug. 5 with no evidence of residual paralysis. On return to the clinic Aug. 20 weakness of the left leg was found. On Sept. 23 he walked with a left limp and stumbled frequently. On Nov. 30 the left thigh measured $\frac{1}{2}$ inch less in diameter than the right and weakness of the quadriceps muscle was demonstrated. Improvement was noted Feb. 22, 1949 and a barely perceptible limp was present on Apr. 21.

Case B. Brother, white male, born Oct. 20, 1941. On July 23, 1948 there was fever, headache and stiffness of the neck. He was admitted to the N. C. Baptist Hosp. on July 24 presenting marked rigidity of the neck and back and weakness of muscles about the right hip and thigh. Temperature 101.6°F. Spinal fluid: cell count 215, 8% polymorphonuclears,

92% mononuclears; sugar 20 mgms.; chlorides 680 mgms.; Pandy neg.; culture neg. Moderate weakness of the right leg was present on discharge Aug. 6. Weakness had disappeared by Apr. 21, 1949.

Case C. Brother, white male, born Dec. 3, 1943. On Aug. 11, 1944 he developed fever and sore throat. Five days later spasm of the extremities and neck appeared. The family physician made a diagnosis of poliomyelitis and he was referred to the Emergency Poliomyelitis Hosp., Hickory, N. C. Record of the spinal fluid examination is not available. He remained under treatment for 8 weeks, and on discharge had partial paralysis of the right leg and was unable to walk. He was admitted to the Charlotte Memorial Hosp. from May 1, 1946 until Oct. 30, being given physiotherapy and stretching of the right Achilles tendon, and he was taught to walk with crutches. Leg braces were later added and he was soon able to discard the crutches. Braces were removed during the summer of 1948. On Apr. 21, 1949 there was still deformity of the right foot and a tendon transplant operation was recommended.

FAMILY 12. Twin, white male, born June 17, 1941. On Sept. 23, 1948 he became ill with fever and headache. On the following day there was stiffness of the neck and vomiting. He was admitted to the Biltmore Orthopedic Home on Sept. 27 presenting stiffness of the neck and leg muscles. Spinal fluid: cell count 1,080, predominantly lymphocytes, Pandy positive. Temperature was 103°F. on admission, gradually subsiding within a week. He was discharged on Oct. 8 showing weakness of the abdominal muscles. No residual signs were present on July 26, 1949.

FAMILY 13. Twin, white male, born Aug. 15, 1947. On Aug. 22, 1948 he appeared to be ill. By Aug. 24 he was unable to crawl and dragged the right leg, and temperature was 101°F. On admission to the N. C. Orthopedic Hosp. Aug. 25 there was rigidity of the neck and paralysis of muscles about the right hip. Spinal fluid: cell count 265, predominantly lymphocytes; Pandy positive. On Sept. 7 there was no function of the right toe extensors, tibial and peroneal muscles, and a cast was applied. The cast was removed Sept. 20, improvement of the peroneals was noted and a splint was applied. Orthopedic treatment was continued on an out-patient basis with gradual improvement. On Aug. 9, 1949 he was able to walk with a leg brace, but there was residual paralysis of the right quadriceps and tibial muscles and marked equinovalgus deformity of the foot.

FAMILY 14. *Case A.* Twin, white female, born Aug. 20, 1940. During July, 1941 she suddenly became ill with high fever and vomiting. Three days later the back became weak, and she was unable to sit up or use the left arm or leg. A diagnosis of acute poliomyelitis was made by the family physician and she was treated at home. Upon recovery from the acute phase, she was referred to the N. C. Orthopedic Hosp., being seen in clinic Aug. 26, 1941. The deltoid muscles bilaterally were severely affected and there was flexion contracture of the left knee. With physiotherapy and braces, gradual improvement occurred. By Feb. 8, 1944 abduction of the left arm was practically normal and the brace was discontinued. On July 31, 1945 it was noted that a full range of voluntary motion was possible at both shoulders, but there was severe atrophy of muscles about the shoulders, especially the supraspinatus and infraspinatus. On Aug. 1, 1949 there was definite weakness of the left arm and moderate atrophy about the shoulder girdle.

Case B. Twin, white female, born Aug. 20, 1940. Two days after onset of poliomyelitis in her twin, she had high fever for two or three days, then recovered. No muscle paralysis was noted.

FAMILY 15. *Case A.* Twin, white male, born Nov. 21, 1941. On July 24, 1948 there was headache and fever of 101°F. Fever subsided for two days, then recurred July 27 associated with sore throat and irregular breathing. He was referred to the Central Carolina Convalescent Hosp., Greensboro, N. C. on July 28 presenting pharyngitis, moderate stiffness of the neck, and tightness of the back and hamstring muscles. Spinal fluid: cell count 215, 70% lymphocytes, Pandy positive. He became stuporous, bulbar signs appeared and a tracheotomy was done July 29. He improved gradually and the tracheotomy tube was removed Aug. 25. Convalescence was complicated by aspiration pneumonia beginning Aug. 31, but responding quickly to treatment. When discharged on Nov. 17 he presented weakness of the anterior neck muscles, mild facial involvement, and mild weakness of muscles of the pelvic girdle.

Case B. Twin, white male, born Nov. 21, 1941. On July 31, 1948 he developed fever and vomiting began on the following day. On Aug. 2 there was pain and weakness of the neck, difficulty in swallowing appeared that night, and he was admitted to the Central Carolina Convalescent Hosp. on Aug. 3. Temperature was 103.6°F.; there was weakness of the right facial muscles and the left side of the palate, and marked tightness of the neck, back and hamstring muscles. Lumbar puncture was not done. He was unable to swallow on Aug. 4 and was fed by gavage and intravenously until Aug. 16 when he became able to swallow liquids. When discharged on Nov. 17 he presented weakness and slight atrophy of the left quadriceps muscle.

FAMILY 16. *Case A.* Twin, white female, born Feb. 5, 1944. On July 21, 1948 she became fretful, complained of pain in the neck and headache and would not attempt to walk. There seemed to be generalized muscle pain, as she complained of tenderness wherever touched. On the following day there was nausea and vomiting and the neck was "drawn over" to the right side. A lumbar puncture was done and the fluid was reported to be "positive for poliomyelitis," but details are not available. She was referred to Rex Hosp., Raleigh, N. C. on July 23 presenting stiffness and weakness of the neck muscles and both thighs. She improved rapidly and was discharged without residua on Aug. 6.

Case B. Brother, born Aug. 1, 1941. This child developed high fever and headache two days before onset of poliomyelitis in Case A, but recovered spontaneously within a week with no paralysis being noted.

Case C. Sister, born Apr. 30, 1940. On the day after onset of poliomyelitis in Case A she developed fever, sore throat, headache and severe pain in the legs. Although the parents report that there was weakness of the legs for about 4 days, reliable medical observation are not available. She recovered on home treatment in about one week with no evidence of residua. Classed as non-paralytic.

FAMILY 17. Twin, white male, born June 29, 1939. On July 14, 1948 he developed severe headache and fever, and became delirious that night. The family physician found a stiff neck and spasm of the left arm and both legs. He was admitted to Watts Hosp., Durham, N. C. on July 15 presenting in addition weakness of the flexor muscles of the left hand. Spinal fluid: cell count 16 lymphocytes. Temperature returned to normal July 22 and he was discharged. No residual signs were noted Aug. 25, 1949.

FAMILY 18. *Case A.* Twin, white male born Apr. 7, 1945. On June 21, 1948 he developed fever and nuccal pain. On admission to the N. C. Orthopedic Hosp. June 24 there was rigidity of the neck and tightness of the hamstring muscles. Spinal fluid: cell count 120, all lymphocytes, Pandy positive. Weakness of the left arm and leg and the right shoulder girdle

appeared. When discharged on Aug. 9 there was weakness of the shoulder girdle and he walked with a limp. On Aug. 1, 1949 he presented slight weakness of the left leg and the abdominal muscles and walked with a noticeable limp.

Case B. Sister, born Dec. 23, 1940. This child left home to visit her grandmother on June 19, 1948, two days before onset of symptoms in Case A. On June 23 she developed headache and fever, and weakness of one arm appeared the following day. She returned home June 25 with weakness of all four extremities. She was admitted to the N. C. Orthopedic Hosp. June 29 with fever, drowsiness, stiff neck and back, and weakness of all extremities. Response to treatment was slow. She was discharged Aug. 25, 1948 with a right leg brace and bilateral abductor splints. She was followed in clinic, receiving physiotherapy and orthopedic treatment, with gradual improvement noted. She was still under treatment on Aug. 1, 1949, having fairly severe residual involvement of both upper extremities, back and right lower extremity.

FAMILY 19. Twin, white male, born June 16, 1930. On Apr. 13, 1948 he noticed numbness, tingling and weakness of the left arm and leg. On the following day all extremities were weak, he was unable to walk, and fever appeared. On admission to the Central Carolina Convalescent Hosp. on Apr. 15 temperature was 102°F., tendon reflexes were hypoactive bilaterally, and there was difficulty in swallowing and weakness of muscles of the neck, back and all extremities. Spinal fluid: no cells, protein 40 mgms., chlorides and sugar normal. For several days there was no improvement and on Apr. 23 involvement of the left facial nerve was noted. A few days later improvement began and was rapid thereafter. He was discharged May 18 able to walk, but with considerable weakness of all extremities and the neck. One year later there was moderate muscle atrophy in all extremities.

FAMILY 20. *Case A.* Twin, white male, born Sept. 16, 1931. During June, 1935 he began vomiting and had headache and fever. He was treated at home and recovered within two weeks. It was then noted that there was weakness and atrophy of muscles about the right shoulder and right side of the neck. On July 22, 1949 residual weakness and atrophy in this region was still apparent.

Case B. Twin, white male, born Sept. 16, 1941. 4 days after the onset of illness in Case A he also developed fever, headache and vomiting, and the tonsils were enlarged and reddened. 3 days later there was complete paralysis of the left arm and on the following day marked weakness of the right leg. He was treated at home and was unable to sit up for about 5 weeks. He was referred to the N. C. Orthopedic Hosp. Feb. 25, 1936 presenting considerable recovery of function in muscles of the left shoulder girdle, but marked weakness and moderate atrophy of the left biceps and triceps muscles and equinus deformity of the right foot. He was given physiotherapy and muscle reeducation and responded well, being discharged Apr. 24. Operations to correct the foot deformity were done in 1946 and 1947. On July 22, 1949 he still presented moderate atrophy of the left arm and the right calf was 2 in. smaller than the left.

FAMILY 21. Twin, white male, born May 24, 1926. This patient had an acute illness at age 9 months with paralysis of the left arm and leg. A diagnosis of acute poliomyelitis was made at the N. C. Baptist Hosp. and he remained in a spica cast for one year and received orthopedic treatment for 8 years. He did not learn to walk until age 3 years, and then had much atrophy and weakness of the left lower extremity. He was admitted to the N. C. Orthopedic Hosp. from Sept. 27, 1938 to Aug. 23, 1939 presenting atrophy of the left shoulder girdle, extreme scoliosis, and equinovarus deformity of the left foot. A series of opera-

tions and cast procedures corrected the deformities. By Oct., 1939 he could walk well with crutches. In May, 1940 there was one inch shortening of the left lower extremity. He improved gradually with exercise. In Sept., 1949 he presented moderate scoliosis, slight weakness and moderate atrophy of muscles of the left arm and leg, and shortening of the left lower extremity.

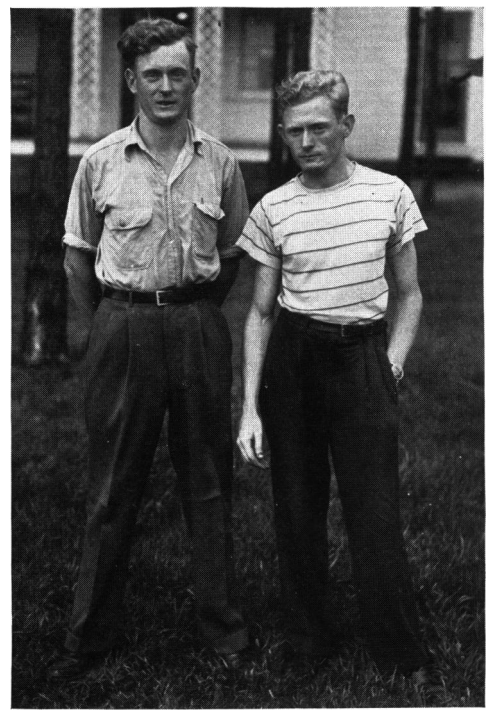

FIGURE 2. Dissimilar monozygotic twins (Family 21). The marked difference in appearance is attributed to disturbance in growth in A (on right) secondary to severe paralytic poliomyelitis at an early age.

Dermatoglyphic Formulae:

		Left					*Right*				
		5	4	3	2	1	1	2	3	4	5
Fingers:	Twin A	U	U	U	U	U	W	U	U	W	U
		0–16	0–18	0–20	0–6	0–23	30–20	18–0	19–0	23–11	17–0
	Twin B	U	Tl	W	U	W	W	U	U	W	U
		0–10	7–20	18–19	0–11	15–25	30–14	20–0	18–0	21–14	18–0

Palms:	Twin A	Left	— 7	9	4	3h	L^R/A^C	O	L	L	L			
		Right	— 7	5″	5′	3	L^R/L^R	O	O	O	L			
	Twin B	Left	— 9	X	5″	3h	L^R/A^C	O	O	O	O			
		Right	— 7	5″	9/5″	3	A^R/L^R	O	L	L	L			

Key: U = ulnar loop, W = whorl, Tl = "twin loop."

FAMILY 22. *Case A*. Twin, white male, born Apr. 20, 1946. On Feb. 18, 1949 he developed irritability and fever, and was unable to walk on the following day. He was admitted to

Watts Hosp. on Feb. 23 presenting stiffness of the neck and severe weakness of both lower extremities; left otitis media was also present. Spinal fluid: cell count 36, 95% lymphocytes. Chest x-ray showed bronchopneumonia. He responded well to hot packs and a posterior plaster shell. When discharged Apr. 19 there was much weakness of both lower extremities. There was weakness of the legs and a right foot-drop gait in Aug., 1939.

Case B. Brother, born Sept. 13, 1947. One week after onset in Case A, he seemed to have a cold with fever and lost the use of both legs. He was also admitted to Watts Hosp. where a diagnosis of acute poliomyelitis with flaccid paraplegia was made. He remained under treatment for 5 weeks, and had moderate residual weakness of the right leg on discharge. In Aug., 1949 he still walked with a right foot-drop gait.

FAMILY 23. *Case A.* Twin, white male, born Nov. 18, 1946. On July 29, 1948 he developed stiffness of the neck and fever. Because of difficulty in swallowing he was taken to Watauga Hosp., Boone, N. C. where spinal fluid examination showed 350 cells and Pandy positive. He was referred to the Biltmore Orthopedic Home on Aug. 1 presenting dehydration, a stiff neck, quadriplegia, and weakness of the intercostal muscles. The temperature was 103°F. and respiratory difficulty increased. He was placed in a respirator and given fluids with some improvement. On Aug. 6 he suddenly became cyanotic and mucous plugs were aspirated from the larynx. Bronchoscopy was done on Aug. 7 and the right vocal cord was paralyzed at that time. Fever was sustained at a high level, and the child expired on Aug. 8, 1948. Final diagnosis was acute bulbar poliomyelitis.

Case B. Twin, white male, born Nov. 18, 1946. Three days after onset of poliomyelitis in his twin, this child developed symptoms of a cold and had fever. Symptoms subsided in two or three days with no evidence of paralysis at any time.

FAMILY 24. Twin, white male, born June 17, 1926. On Sept. 6, 1941 he developed sore throat and fever followed by vomiting. One week later he developed stiffness and pain in the back of the neck and in the right leg. The right leg became paralyzed on the following day. The family physician made a diagnosis of acute poliomyelitis and he was treated at home, with recovery from acute symptoms. Weakness of the right leg persisted for about one year under treatment, and he walked with a marked limp. On July 22, 1949 there was minimal residual weakness of the right leg and a limp that appears only after exertion.

FAMILY 25. *Case A.* Twin, born Dec. 2, 1937. On Aug. 4, 1948 while on vacation at a beach in South Carolina, he developed vomiting and fever. On Aug. 6 he was unable to swallow. He was taken to a hospital in Conway, S. C. where spinal fluid examination is said to have shown a cell count of 150. By this time he was having difficulty in breathing. He was transferred to the Charlotte Memorial Hosp. by ambulance, but became rapidly worse en route, being unable to breathe and requiring artificial respiration. He was moribund on arrival at the hospital and expired 15 min. later in spite of artificial respiration, laryngeal suction and intracardiac stimulation. A diagnosis of acute bulbar poliomyelitis was made.

Case B. Twin, white male, born Dec. 2, 1937. On Aug. 8, 1948, two days after the death of his twin, he had fever of 101°F. and seemed drowsy. Spinal fluid examination that night revealed cell count 93, predominantly lymphocytes, and positive Pandy. He was admitted to the N. C. Orthopedic Hosp. on Aug. 9 presenting moderate pharyngitis, slight difficulty in swallowing, stiffness of the neck and spasm of the hamstring muscles bilaterally. On Aug. 10 he was completely unable to swallow. Treatment was vigorous, but he continued to become worse. On Aug. 12 there was evidence of severe involvement of both respiratory and cardiovascular systems, and the patient expired, death being attributed to acute myocarditis due to acute bulbar poliomyelitis.

FAMILY 26. Twin, white male, born 1930. For about one week during Aug., 1948 he complained of mild intermittent headache. On Aug. 12 headache became more severe and was associated with nausea, vomiting, fever and pain in the back of the neck. He was taken to St. Leo's Hosp., Greensboro, N. C. where a diagnosis of poliomyelitis was made, and referred to the Central Carolina Convalescent Hosp., being admitted on Aug. 13. He presented stiffness of the neck and spasm of the back and hamstring muscles. Temperature was 102.6°F. Spinal fluid: cell count 60, protein 60 mgms. He was treated with hot packs, hot tubs, and muscle stretching, with prompt response. He was discharged on Aug. 27, 1948 with no residual paralysis. No residua were found on May 25, 1949.

FAMILY 27. Twin, white female, born May 31, 1947. On Aug. 15, 1948 she developed fever and sore throat. Two days later she was unable to sit up and had flaccid paralysis of the right leg. She was admitted to Duke University Hosp. where a diagnosis of acute poliomyelitis was made. She responded rapidly to hot packs and physiotherapy and was discharged two weeks later with only moderate weakness of the right leg. One year later there was still moderate weakness and slight atrophy of the right leg.

FAMILY 28. Twin, white male, born Aug. 23, 1926. On Sept. 27, 1929 he awakened with fever and vomiting. On the following day he was unable to stand alone. The family physician made a diagnosis of poliomyelitis with paralysis of the left leg on Sept. 29, and the patient was treated at home. On recovery from the acute phase there was severe atrophy of muscles of the entire left lower extremity, and he was unable to walk. He was referred to an orthopedic surgeon and fitted with a brace and taught to walk with crutches. An operation to correct deformity was done in 1935. Since then he has been able to walk with a full leg brace with built-up shoe and cane, and has been followed in an orthopedic clinic. In 1949 he presented severe atrophy of muscles of the entire left lower extremity with shortening of nearly three inches.

FAMILY 29. *Case A.* Twin, white female, born Jan. 18, 1943. She developed pain in the back of the neck, headache and fever on Aug. 8, 1948. Pharyngitis was noted and fever persisted in spite of sulfonamides and penicillin. She was referred to the N. C. Baptist Hosp. Aug. 12 presenting marked rigidity of the neck and spasm of the back muscles. Spinal fluid: cell count 129, 10% polymorphonuclears, 90% mononuclears; sugar 70 mgms.; Pandy negative. She responded promptly and was discharged Aug. 22. No residua were noted in July, 1949.

Case B. Brother, born Feb. 1, 1941. Shortly after Case A was admitted to the hospital, this child had fever and complained of pain in the left leg for several days. This cleared spontaneously and he had no further symptoms.

Case C. Sister, born July 20, 1945. This child also had fever as high as 105°F. at the same time as Case B. No paralysis was noted and she recovered spontaneously in about 5 days.

FAMILY 30. Twin, white female, born Jan. 14, 1946. On Sept. 26, 1947 she developed fever and remained listless for 3 days. The physician then discovered paralysis of both legs, and she was referred to the N. C. Orthopedic Hosp. on Oct. 1. There was stiffness of the neck and back, weakness of the left arm and paralysis of both lower extremities with absent reflexes. Spinal fluid: cell count 16, all lymphocytes, Pandy positive. The use of a respirator was required from Oct. 2 to Oct. 15. Orthopedic treatment was begun on recovery from the acute phase, and by Mar. 28, 1948 she was able to walk with a right leg brace. She was discharged on Apr. 18 and treatment continued in the clinic. On July 5, 1949 there was severe

atrophy of the right lower extremity, mild atrophy of the left deltoid, and a leg brace was required for walking.

FAMILY 31. *Case A.* Twin, white female, born Sept. 2, 1939. This child became ill with fever, severe headache and pain in the neck about June 25, 1944. She became unable to walk 3 days later and was admitted to the N. C. Orthopedic Hosp. on July 2. There was generalized muscular tenderness, spasm of muscles along the spine and paralysis of practically all muscles of the left lower extremity. She presented whooping cough on admission and contracted measles while in the hospital. She responded fairly well to treatment and was discharged Dec. 5, 1944 with a single leg brace to the left lower extremity. She was followed in the clinic at regular intervals showing marked atrophy of the left lower extremity, findings being static for several years. A foot stabilization operation was recommended in June, 1949.

Case B. Sister, born Mar. 14, 1937. About 5 days before onset of symptoms in Case A, this child developed fever and headache. About one week later stiffness of the neck and weakness of the legs appeared. She was admitted to the N. C. Orthopedic Hosp. on July 2, 1944 presenting stiff neck and back and partial paralysis of both lower extremities. She responded well and presented only minimal atrophy of the left thigh when discharged on Dec. 5, 1944. In June, 1949 there was slight weakness of the left thigh but no demonstrable atrophy.

Case C. Sister, born July 16, 1944. On Aug. 5, 1948 she developed headache and fever. On Aug. 7 paralysis of the left leg appeared and she was admitted to the N. C. Baptist Hosp. on Aug. 8. She presented fever of 101.8°F., marked rigidity of the neck and back, flaccid paralysis of the left lower extremity, and bladder paralysis with distention reaching the umbilicus. Spinal fluid: cell count 139, 98% monocytes; Pandy positive, culture sterile. The acute phase responded well and she was transferred to a convalescent center on Aug. 19, still presenting paralysis of left lower extremity and weakness of the right. She remained at the convalescent center for 10 months and was discharged with a left leg brace.

FAMILY 32. *Case A.* Twin, white male, born June 24, 1937. During June, 1948 he was lethargic and anorexic for 2 or 3 days, then developed high fever. 2 days after onset of fever he became unable to talk, and the neck was painful and stiff. He was referred to Rex Hosp. on June 19 presenting pharyngitis, left facial paralysis, stiff neck and spasm of the back and hamstring muscles. Spinal fluid: cell count 89, Pandy positive, protein 45 mgms. He was unable to speak, but was able to swallow. He responded well, fever abating by June 21, and regained some ability to speak by June 23. When discharged on July 9 he presented no residual signs. No residua were apparent in Sept., 1949.

Case B. Twin, white male, born June 24, 1937. A few days after onset of poliomyelitis in his twin, he became ill with symptoms resembling a cold. He was admitted to the Moore County Hosp. for 5 days, recovering spontaneously with no paralysis noted. He was discharged with a diagnosis of "abortive poliomyelitis," and was in good health in Sept., 1949.

FAMILY 33. Twin, white male, born Dec. 22, 1942. On Aug. 15, 1948 he developed fever and sore throat, and was thought to have tonsillitis. On Aug. 17 he was unable to stand alone, and was admitted to the N. C. Orthopedic Hosp. Aug. 18 presenting stiffness of the neck and back, complete flaccid paralysis of the left lower extremity, and severe weakness of the right hip flexors and quadriceps. Spinal fluid reported as "cells increased" and Pandy positive. He improved rapidly and on Sept. 6 was transferred to the Charlotte Memorial Hosp., and received physiotherapy there for 4 months. On discharge he was able to walk

with a left leg brace. On Aug. 11, 1949 he presented weakness and moderate atrophy of the left lower extremity and required a brace for walking.

FAMILY 34. *Case A.* Twin, white male, born May 15, 1941. On Sept. 29, 1948 he developed a "cold" with headache and fever lasting 2 days. On Oct. 2 he again had fever, with severe headache and pain in the legs. Paralysis of the legs was noted Oct. 6, and he was admitted to the Central Carolina Convalescent Hosp. on Oct. 8. He then presented paralysis of all extremities, the intercostal muscles, and the right side of the diaphragm, and there was difficulty in swallowing. A tracheotomy was done. He was critically ill for nearly a month, and began to show improvement about Nov. 20. Response to physiotherapy, muscle reeducation and orthopedic treatment was slow but definite. He was discharged on Aug. 31, 1949 able to walk with crutches and a right leg brace, but showing fairly severe residual involvement of all extremities.

Case B. Twin, born May 15, 1941. At the onset of illness in his twin, this child also had a "cold" with headache and fever. He recovered spontaneously in about 3 days and had no further symptoms.

Case C. Brother. born Mar. 30, 1936. He also developed a "cold" with sore throat, headache and fever at the same time as the twins. He recovered spontaneously in about 3 days and had no further symptoms.

FAMILY 35. *Case A.* Twin, white male, born Nov. 3, 1947. During the latter part of Aug., 1948 he suddenly developed fever and symptoms of a cold. 2 days later paralysis of the left leg appeared. On the following day a spinal tap by the family physician was reported as "positive for poliomyelitis" and he was referred to the Central Carolina Convalescent Hosp. On admission he presented a stiff neck and back and flaccid paralysis of the left lower extremity. He responded slowly to treatment and was still in the hospital on May 13, 1949 presenting moderate residual weakness and atrophy of the left lower extremity.

Case B. Sister, born Nov. 23, 1929. At the time of onset of poliomyelitis in Case A, she also developed a "cold" with fever, headache, sore throat and some stiffness of the neck. This subsided spontaneously in a few days and there were no further symptoms.

FAMILY 36. Twin, white female, born Sept. 26, 1941. On Aug. 7, 1948 she developed fever, sore throat, headache, and pain in the neck and back. She was admitted to Grace Hosp., Morganton, N. C. on Aug. 10 presenting marked neck and back rigidity and weakness of muscles of both hips, thighs and legs. Spinal fluid: cell count 110, all lymphocytes, Pandy positive. Involvement of the upper extremities appeared within a few days. She began to improve about Aug. 18 and was transferred to the Emergency Poliomyelitis Hosp., Monroe, N. C. Aug. 25. She received physiotherapy and orthopedic treatment until May 5, 1949 and made good recovery of function in the lower extremities, but still presented marked weakness of the back muscles and the left shoulder was practically flail on discharge. Improvement was noted on examination at the clinic of the N. C. Orthopedic Hosp. on June 7 and Aug. 23, 949. She still required a body support on Oct. 18, 1949.

FAMILY 37: Twin, white male, born Nov. 15, 1938. During the latter part of June, 1943 he developed fever and headache. On the third day he was unable to turn his head and could walk only with extreme difficulty. He was admitted to the Edgecombe General Hosp. and a diagnosis of poliomyelitis was made. He was transferred to Duke University Hosp. July 5, presenting fever of 103°F., stiffness of the neck and back, flaccid paralysis of the left lower extremity, weakness of the right lower extremity and bladder paralysis. Spinal fluid: cell

count 90, Pandy positive. He improved and was transferred to the N. C. Orthopedic Hosp. Aug. 17. He gradually improved under orthopedic treatment and was discharged July 8, 1944 with bilateral leg braces. He was followed in clinic and readmitted to the N. C. Orthopedic Hosp. Feb. 25, 1947. A foot stabilization operation and tendon transplant was done on Mar. 7 and he was discharged improved on May 29. In Aug., 1949 he was able to walk fairly well with a right single leg brace.

FAMILY 38. Twin, white female, born Mar. 31, 1945. On June 27, 1948 she developed a "cold" with fever of 102°F. Severe weakness of the legs appeared July 2. A lumbar puncture done July 3 at the Charlotte Memorial Hosp. showed a cell count of 182 with 82% lymphocytes, proteins 29 mgms. She was transferred to the N. C. Orthopedic Hosp. July 4 presenting complete flaccid paralysis of both lower extremities, no function of the intercostal muscles, generalized weakness of both upper extremities, weakness of the neck and facial hemiparesis. A respirator was required. The acute phase subsided, but severe paralysis remained. She was transferred back to the Charlotte Memorial Hosp. July 30, and with physiotherapy became able to stand with double leg braces. Then for 4 months there was no improvement, so she was transferred to the Warm Springs Foundation Hosp., Warm Springs, Ga. on Feb. 9, 1949. She made gradual improvement and returned home on Nov. 1, 1949. On Sept. 1, 1950 she was able to walk with a left leg brace, but was scheduled to return to Warm Springs for further treatment on Sept. 19.

FAMILY 39. Twin, white male, born Oct. 23, 1933. During the latter part of Feb., 1942 he developed weakness of both legs and fever. 2 days later there was severe weakness of both legs and moderate weakness of one arm, and a diagnosis of poliomyelitis was made, but a lumbar puncture was not done. He was treated at home and one month later presented only slight residual weakness. No residua were present on Aug. 30, 1949.

FAMILY 40. Twin, colored female, born Aug. 38, 1946. On July 27, 1948 she developed fever, malaise, weakness in walking and stiffness of the neck and back. She was admitted to the Asheville Orthopedic Home on July 28 with the above findings plus absent patellar reflexes. Spinal fluid: cell count 56, Pandy positive. Fever continued for a week, then improvement began. There was slight residual weakness of both thighs when discharged Aug. 22. On July 27, 1949 no residual weakness was apparent.

FAMILY 41. Twin, colored male, born June 23, 1944. During July, 1948 he developed pain in the back followed shortly by fever. On the following day the neck was stiff and marked weakness of both legs appeared that night. A lumbar puncture was done by the family physician and was reported to be "positive," but data are not available. He was treated at home and the house was quarantined. He remained in bed for 2 weeks, and then could walk only with great difficulty because of weakness of the right leg. There was apparent shortening of the Achilles tendon and he could not put the right heel to the floor for several months. He improved on exercise and presented only minimal weakness of the right leg on July 31, 1949.

FAMILY 42. Twin, colored female, born Feb. 24, 1947. On Aug. 18, 1948 she developed fever as high as 104°F. and was very irritable. She was admitted to the Central Carolina Convalescent Hosp. Aug. 21 presenting weakness of the flexors of the neck, stiffness of back muscles and weakness of both lower extremities with diminished reflexes. Spinal fluid: cell count 200, Pandy positive. On recovery from the acute phase there was marked weak-

ness of the lower extremities, which slowly improved. She was still in the hospital on May 24, 1949 learning to walk with a leg brace.

FAMILY 43. *Case A.* Twin, colored female, born Nov. 23, 1946. On July 19, 1948 she developed fever and headache. A few days later there was pain in the right leg, followed by difficulty in use of this extremity. She was admitted to St. Agnes Hosp., Raleigh, N. C. on July 26 presenting stiffness of the neck and partial paralysis of the right lower extremity. Spinal fluid: cell count 7 lymphocytes, Pandy negative. Paralysis of the right lower extremity became complete on the following day. Under treatment she recovered except for right foot drop. She was discharged Oct. 1 with a right spring brace. She was followed in the clinic of the Central Carolina Convalescent Hosp., receiving physiotherapy with some improvement. A brace was still required on Oct. 18, 1949.

Case B. Twin, colored female, born Nov. 23, 1946. About one week after onset of poliomyelitis in her twin, this child developed fever, sore throat and severe headache. There was stiffness of the neck and paralysis of the left leg appeared 2 days later. The acute episode subsided within 7 to 10 days, but there was residual weakness of the left leg which responded to physiotherapy. No residua were apparent on Oct. 18, 1949.

FAMILY 44. *Case A.* Twin, white female, born May 6, 1947. This child presented relatively mild congenital cerebral palsy from birth, with moderate spasticity of all four extremities. Fever and laryngitis appeared Aug. 7, 1948. Paralysis of the left leg and unusual stiffness of the neck and back were noted by the family physician on Aug. 10. She was admitted to Grace Hosp. Aug. 12. Spinal fluid: cell count 42, all lymphocytes, Pandy positive. Within a few days there was flaccid paralysis of both upper extremities and the right lower extremity, the left lower extremity remaining spastic. There was some respiratory difficulty, but a respirator was not required. She improved on treatment, and muscle power was regained by Sept. 24 and signs of spasticity reappeared. She was discharged on Oct. 2, but evaluation concerning possible residual effects was difficult because of the cerebral spastic status. On July 14, 1949 she presented obvious evidence of cerebral palsy and could neither walk nor talk.

Case B. Twin, white female, born May 6, 1947. This child had a normal developmental history. She also became ill with fever and laryngitis at about the time paralysis appeared in Case A. She recovered completely within a week with no evidence of paralysis.

FAMILY 45. *Case A.* Twin, white male, born Oct. 20, 1943. On July 19, 1948 he developed fever, severe headache and sore throat. He was admitted to Rex Hosp. July 20, and the spinal fluid is recorded as "positive," but details not available. On July 21 he presented quadriplegia, respiratory paralysis and unconsciousness, and was placed in a respirator. He was semi-comatose for two weeks and paralysis of the vocal cords was noted. He improved rapidly thereafter and was discharged Oct. 17, 1948 with only slight weakness of the lower extremities and the left arm, but almost complete paralysis of the right arm. He continued to receive physiotherapy, with good recovery of function except in the right arm. On July 22, 1949 there was practically no voluntary motion possible at the right shoulder and elbow, and flexion and extension of the right wrist and fingers was quite weak.

Case B. Twin, white male, born Oct. 20, 1943. This child presented congenital spastic paraplegia, with spacticity of both lower extremities. On July 23, 1948 (four days after onset of poliomyelitis in his twin) he also developed fever and pharyngitis. He was admitted to Rex Hosp. on July 24. In addition to the spasticity of the lower extremities previously present, he presented left facial weakness, loss of gag reflex, difficulty in swallowing, stiff

neck and weakness of the upper extremities. Spinal fluid: cell count 202, Pandy positive, culture sterile. The course was stormy and he remained semi-comatose for two days, then improved. He was discharged Aug. 7 and it was felt that there were no residua, although the status regarding spastic paraplegia was unchanged. Condition was unchanged July 22, 1949.

Case C. Brother, born Jan. 4, 1939. On the day following onset of illness in Case B, this child developed fever, nausea, vomiting, headache and stiff neck. He was admitted to Rex Hosp. July 25, 1948 with temperature 103°F., rigidity of the neck and back and spasm of the hamstring muscles. Spinal fluid: cell count 23, Pandy positive, culture sterile. He improved promptly, temperature subsided July 29, and he was discharged without residua on Aug. 7. No residua were found on July 22, 1949.

FAMILY 46. *Case A.* Twin, white male, born Jan. 31, 1946. On July 12, 1948 he developed fever and sore throat. On July 15 weakness of the right arm appeared and he was admitted to the Central Carolina Convalescent Hosp. He presented fever of 102°F., stiff neck and back, and partial paralysis of the right upper extremity. Spinal fluid: cell count 100, 70% lymphocytes; Pandy positive. Paralysis of the entire right upper extremity became complete, and severe weakness of the neck muscles appeared. Recovery was slow; there was still marked weakness and moderate atrophy about the right shoulder when he was discharged Feb. 9, 1949. Findings were essentially unchanged six months later.

Case B. Twin, white male, born Jan. 31, 1946. About one week before onset of poliomyelitis in his twin, this child had fever to 104°F., and sore throat for 3 days. On the day his twin was admitted to the hospital fever, vomiting and headache recurred. Mild symptoms lasted one week, but paralysis was not observed.

DISCUSSION AND CONCLUSIONS

Before analysis of the family data is attempted, it seems advisable to assess the completeness of ascertainment of the twin series. As was mentioned above, of the 3890 reported cases of poliomyelitis that were classified regarding twinning, 56 were found to be of plural birth. This gives a plural birth rate in this series of cases of 1 in 69.46 births, or 1.440 ± 0.191 per cent. One set of triplets is included in the 56 index families, and if this family is eliminated, the twin birth frequency becomes 1 in 70.71 births or 1.414 ± 0.189 per cent. The frequency of twin births in the total United States population has been determined by Strandskov (1945) as 1 in 86.13 births or 1.161 per cent, and the frequency of triplets as 1 in 8,411 births or 0.01189 per cent. The difference between the observed twin birth rate in this series and the rate determined by Strandskov is 0.253 per cent, this difference being 1.33 times its standard error and non-significant. The frequency of twins ascertained in the series of 3890 cases of poliomyelitis does not differ significantly from the corresponding frequency for the total United States population.

The proportions of twins of various types in the observed series should also give information regarding completeness of ascertainment. Strandskov and Edelen (1946) have estimated the percentage of monozygous twins among all twins in the total United States population to be 33.46 per cent, and it is generally accepted that the ratio of like-sexed to unlike-sexed pairs among

dizygous twins is approximately 1:1 as suggested by Weinberg (1902). Again eliminating the one set of triplets from consideration, the observed data include 45 pairs of twins, 14 pairs diagnosed as monozygous and 31 pairs as dizygous. The observed ratio of 14:31 is in good agreement with the expected ratio of 15.06:29.94 ($\chi^2 = 0.12$). Under the assumption of equal proportions of like-sexed and unlike-sexed dizygous pairs, the expected ratio would be 15.5:15.5 and the observed ratio 12:19, the deviation from expectancy again being non-significant ($\chi^2 = 1.58$). It therefore seems reasonable to conclude that ascertainment of twin pairs within the total series of poliomyelitis cases is practically complete, the deviation from expectancy actually being in the direction of an excess of twins, and the proportion of monozygous to dizygous pairs is in agreement with expectancy.

In all 7 cases where both members of a twin pair developed paralytic poliomyelitis both were discovered independently through their individual report cards; the family investigations brought to light no secondary cases amongst the twins themselves. This fact is indicated in table 1 by marking both members of such concordant pairs as *propositi*. This evidence is again consistent with the assumption of complete ascertainment of cases amongst twins. It could be argued, however, that two cases developed within the same family at nearly the same time would be apt to increase the likelihood of each case being reported. If such a preferential recording of concordant pairs has occurred, however, there is at least no internal evidence of the bias having been exercised differently in the two zygosity classes.

A priori, there is no reason to suspect that twins might be significantly more or less susceptible to poliomyelitis than single-born individuals. No evidence is produced by this study which would suggest any general difference in susceptibility status due to twinning *per se*, and the figures cited above might be considered as offering some evidence against such a suggestion. It is therefore assumed for purposes of this analysis that twins in general are neither more nor less susceptible to paralytic poliomyelitis than single-born individuals.

In estimating concordance rates in this material, individuals were considered as "affected" if they presented any demonstrable degree of paralysis during the acute phase of the illness, regardless of whether there was residual paralysis after recovering from the acute phase. Even though his illness may have been diagnosed as "acute non-paralytic poliomyelitis", any individual not having evidence of paralysis was classed as "unaffected." This criterion of division was adopted because of the known gradual and almost imperceptible gradation in severity of cases of proved poliomyelitis from the most severe, with bulbar paralysis, involvement of vital centers in the brain stem and rapid fatal termination (as in family 25) to the mildest "abortive" cases that may only be diagnosed with certainty by virus studies. Although severity of involvement may be clinically assigned to various categories, such as bulbar,

quadriplegic, diplegic, monoplegic, etc., such gradations are at best artificial and transitional cases exist between all grades. As the presence of paralysis in any degree is generally considered evidence of invasion of the central nervous system by the virus, it was felt that this study should be primarily concerned with paralytic cases, and in essence would investigate susceptibility of the central nervous system to viral invasion rather than any type of local respiratory or systemic involvement. Twin pairs were therefore considered as concordant only if both had evidence of muscle paralysis. The concordance table below was constructed on this basis, including data on 45 twin pairs and one set of two-egg triplets. The set of triplets (family 5) consists of an affected male and two non-affected females, the females being derived from a single ovum. This set is classed as two pairs of dizygous discordant twins in the following table:

	Concordant	*Discordant*	*Totals*
Monozygous	5	9	14
Dizygous	2	31	33
Totals	7	40	47

$\chi^2 = 6.81$, D. F. = 1

It is thus demonstrated that both members of monozygous twin pairs present paralytic poliomyelitis more often than do dizygous pairs, and that this difference is statistically significant with a probability level of less than 1 per cent ($P = 0.0091$).

TABLE 2. PERCENTAGE OF PARALYTIC POLIOMYELITIS OCCURRING AMONG COGNATES OF INDEX TWIN CASES

RELATIONSHIP	TOTAL	PARALYTIC POLIOMYELITIS	PERCENTAGE ± STANDARD ERROR
Monozygotic co-twins	14	5	35.71 ± 12.81
Dizygotic co-twins	33	2	6.06 ± 4.15
All sibs	155	7	4.51 ± 1.67
"Exposed" sibs	101	7	6.93 ± 2.53
Half-sibs	4	0	
Parents	87	0	
Uncles-aunts*	516	7	1.36 ± 0.51
Nephews-nieces*	39	1	2.56 ± 2.53
First cousins*	885	4	0.45 ± 0.22

* Information in these categories based on history rather than examination.

The incidence of paralytic poliomyelitis was also estimated for relatives as close or closer than first cousins of the twin index cases. It should be emphasized that information regarding twin partners, sibs and parents was obtained by direct examination of the individuals in question, but that information regarding uncles, aunts, nieces, nephews and first cousins is generally based on

history furnished by the parents of the twins. The same degree of reliability cannot be ascribed to the last three categories in table 2. The sibs are classified in two ways, one estimate being for all sibs, and the estimate for "exposed sibs" being based only on the number of sibs living in the same household with the affected twin at the time of onset of acute poliomyelitis, under such conditions that it may be assumed that exposure to a virulent virus occurred.

Although these data present evidence of the existence of a measurable genetic influence on susceptibility to the paralytic form of poliomyelitis, they do not permit us to reach any conclusions concerning the number or kind of genes conditioning such susceptibility. The fact that no cases of paralysis were encountered among the 87 examined parents leads one to believe that a dominant gene, even with greatly reduced penetrance, would not produce the observed results. Although the sex ratio of affected persons in this series shows a slight excess of males, in a ratio of 38:22 ($\chi^2 = 4.27$), there is no suggestion of the action of sex-linked genes in the family data. Addair and Snyder (1942) have suggested that susceptibility may be conditioned by a recessive gene with about 70 per cent penetrance. No critical evaluation of the suggestion that a recessive gene is involved is made from these data, but the concordance rate in monozygotic twins would suggest that the penetrance might be in the neighborhood of 35 per cent if this theory is correct. Using a penetrance rate of $\frac{5}{14}$ these data are at least compatible with the interpretation of Addair and Snyder, as is indicated by the non-significant differences between the observed incidence of paralysis in sibs of twin index cases and expected values calculated on this basis:

CLASS OF SIBS	PARALYTIC POLYMYELITIS AMONG SIBS		NORMAL SIBS		CHI-SQUARE (D.F. = 1)
	Observed	Expected*	Observed	Expected	
Dizygous co-twins	2	2.946	31	30.054	0.334
All sibs	7	13.839	148	141.161	3.711
"Exposed" sibs	7	9.018	94	91.982	0.496

* Expected frequency $= \frac{5}{14} \cdot \frac{1}{4} \cdot N$, where N = total number of sibs observed.

If the homozygous state of a recessive gene determines genetic susceptibility to paralysis, this gene must have a relatively high frequency in the total population, and heterozygotes must be quite numerous. Although no provisional estimate of gene frequency may be made from these data, the absence of cousin marriages among parents of the affected twins is indicative of a relatively high figure. We were unable to obtain information on this point in two families, but in 44 families we can specify that the parents are not closer kin than third cousins (coefficient of relationship = 0.0078 or less). If a rare reces-

sive gene were involved, a significant proportion of cousin marriages should have been encountered among these parents.

Another possible interpretation of these findings is that susceptibility may be due to multiple gene effects. The data are insufficient for critical evaluation of this possibility.

The observed concordance rate of 35.7 per cent for monozygous twin pairs would seem to indicate that environmental factors are of major importance in determining the reaction to exposure even in persons of identical genetic endowment. The possibility that the susceptibility status may vary from time to time in the same presumably genetically susceptible individual is suggested by the situation in families 11 and 31, where paralytic cases appeared in different children in the sibship in the 1944 and 1948 epidemics, although those being affected in 1948 were also presumably exposed in 1944. Considerable study of environmental factors which may influence the susceptibility status has been done elsewhere, and will not be reviewed here. It is to be hoped that future work in this field may recognize that the susceptibility status apparently has both a genetic and an environmental component, and that simultaneous evaluation of both components should be more productive of results than study of either one alone.

SUMMARY

1. An unselected series of 3890 reported cases of poliomyelitis was searched for twins; 46 families were located containing twins or triplets, one or more having had paralytic poliomyelitis while living with the twin partner.

2. Case histories of all paralytic, non-paralytic and suspected cases of poliomyelitis in the 46 families are presented.

3. Test factors are presented for all available members of the 46 families including ABO blood groups, MN blood types, Rh classification, secretor factor, and PTC taste test. Palmar dermatoglyphics and photographs of the twins were obtained.

4. With regard to the paralytic form of poliomyelitis, twin pair concordance was found in 35.7 per cent of 14 monozygous pairs and 6.06 per cent of dizygous pairs, this difference being statistically significant.

5. We conclude that the existence of a genetic factor controlling, at least in part, susceptibility to the paralytic form of poliomyelitis is demonstrated.

6. No conclusion concerning the genetic mechanism involved may be reached, but the data are at least compatible with the theory that susceptibility may be conditioned by the homozygous state of a recessive gene with approximately 35 per cent penetrance.

7. It is emphasized that the status of susceptibility to paralysis in poliomyelitis apparently has both a genetic and an environmental component, and

both factors should be simultaneously evaluated in studies aimed at prevention of the disease.

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